Spitzer Space Telescope - General Observer Proposal #3180

Changing Seasons on Pluto: A Stellar Occultation Opportunity

Principal Investigator: Amanda Bosh
Institution: Boston University

Technical Contact: Amanda Bosh, Boston University

Science Category: planets
Observing Modes: IracMap
Hours Approved: 0.7

Abstract:
In 1989 Pluto passed perihelion and began its long swing further away from the sun. The decrease in solar insolation has led to predictions of total atmospheric collapse. However, a recent occultation observation has revealed the opposite. Continued occultation observations are crucial in this period of transition, to determine the behavior of Pluto's atmosphere as the system recedes from the sun. Due to the small angular size of the planet, occultation events are rare. Fortuitously, an occultation by Pluto of a bright star, visible from the Spitzer Space Telescope, is expected to occur in 2005. This event will provide atmospheric temperature and structure data, with a signal-to-noise ratio per scale height of 1350, the highest yet achieved.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #70

Observations of the Pluto/Charon system

Principal Investigator: Dale Cruikshank
Institution: NASA-Ames

Technical Contact: Jeffrey Van Cleve, Ball Aerospace

Science Category: planets
Observing Modes: IracMap IrsStare MipsPhot MipsSed
Hours Approved: 11.7

Abstract:
We examine the combined Pluto/Charon system using all SIRTF instruments. The IRS observations generally use the Long Lo module. When used in conjunction with IRAC and MIPS photometry observations, these observations will provide us with composition, albedo, and thermal properties information. Pluto is observed at 8 equally spaced observer sub-longitudes, and follow-up observations 1 and 2 yr after the initial lightcurve measurements are planned.

Spitzer Space Telescope - Directors Discretionary Time Proposal #467

Spitzer/IRS Observations of Uranus at Equinox

Principal Investigator: Dean Hines
Institution: Space Science Institute

Technical Contact: Dean Hines, SSI

Co-Investigators:
Martin Burgdorf, Liverpool John Moores University
Heidi Hammel, Space Science Institute
Amy Mainzer, JPL
Julianne Moses, Lunar and Planetary Institute
Glenn Orton, JPL

Science Category: planets
Observing Modes: IrsStare
Hours Approved: 9.6

Abstract:
The next apparition of the view of Uranus on the Equinox, occurs this year on UT 2007 December 7 (the last equinox was 1965; the next will be in 2049). Because of its unique (in the solar system) axis tilt with respect to its orbit, Uranus offers us a spectacular opportunity to witness the dramatic changes in a giant planetary atmosphere caused by the transition from hemispheric heating to pole-to-pole diurnal heating. Based on recent ground-based and space-based (Hubble Space Telescope) images and spectra, we know that the atmosphere has developed complex structures that change on week timescales and were not present at all during the southern hemisphere solstice in 1986! Despite this unique and exciting development, mid-IR spectra covering sufficient wavelengths to fully probe the evolution of molecular chemistry in the atmosphere are extremely rare. Many major observatories across the world and HST plan to observe Uranus at equinox. However, there are currently no plans to observe this event with Spitzer. Even though a moderate S/N spectrum taken across the entire 5-35 micron band-pass with IRS was obtained in 2005, this observation is too remote in time from the equinox for direct comparison with the flood of data to be obtained at other wavelengths within the next couple of months. Therefore, we propose to obtain IRS low- and high-resolution spectra of Uranus at its equinox. The DDT mechanism is appropriate for this proposal, since a Cycle 5 program, even if selected, could not be scheduled until mid-2008 at best. The proposed IRS spectra, contemporaneous with the other efforts, will provide a multi-wavelength picture of the state of the Uranus atmosphere at equinox. This legacy-class data set will provide a lasting contribution for comparison with historical and future observations. This opportunity will not come again for 42 years, and given the recent development of exo-solar comparative planetology, can provide crucial data for modeling the atmosphere of Uranus and its cousins in other solar systems.

Spitzer Space Telescope - General Observer Proposal #20500

The Time-Resolved Observations of the Dynamic Atmospheres of Uranus and Neptune

Principal Investigator: Glenn Orton
Institution: Jet Propulsion Laboratory/Caltech

Technical Contact: Glenn Orton, Jet Propulsion Laboratory/Caltech

Co-Investigators:
Victoria Meadows, Spitzer Science Center/Caltech
Martin Burgdorf, Spitzer Science Center/Caltech
Heidi Hammel, Space Science Institute
Sushil Atreya, University of Michigan

Science Category: planets
Observing Modes: IrsStare MipsSed
Hours Approved: 5.0

Abstract:
We propose to continue an important and efficient study of the long-term and rotational variability of the 5-25 micron spectra of Uranus and Neptune using IRS, and the 35-95 micron spectrum of Neptune using MIPS SED. The study pursues evidence in our collaborative work with GTO and our Cycle-1 GO (PID 3534) program which detected both long-term and rotational variations of the spectra of Uranus and Neptune, involving both spectroscopic "window" and stratospheric emission features. We will take advantage of Spitzer's extreme sensitivity and spectral grasp to determine whether the observed properties are the result of changes of temperature, gaseous abundance or condensate cloud thickness. The extension of Neptune's spectrum using MIPS SED will greatly improve the accuracy of the 35-95 micron spectrum of Neptune and improve the determination of Neptune's He/H2 ratio with the goal of determining whether Neptune has retained its primordial abundance of helium or whether helium separation has begun in the outer levels of the atmosphere, as is the case with Jupiter and Saturn. This study is important in order to understand the impact of extreme seasonal forcing on planetary atmospheres (Uranus), creating a paradigm for the spectral variation of small gas giant discoveries around other stars, and characterizing the reliability of Uranus and Neptune as flux calibration sources for the Herschel mission.

Spitzer Space Telescope - General Observer Proposal #3534

The Atmospheres of Uranus and Neptune: A Time-Resolved Mid-Infrared Assessment of Their Energetic Processes

Principal Investigator: Glenn Orton
Institution: Jet Propulsion Laboratory/Caltech

Technical Contact: Glenn Orton, Jet Propulsion Laboratory/Caltech

Co-Investigators:
Sushil Atreya, University of Michigan
Martin Burgdorf, IPAC
Victoria Meadows, JPL; IPAC

Science Category: planets
Observing Modes: IrsStare
Hours Approved: 9.2

Abstract:
We propose to measure variations of the 5 - 37 micron spectra of Uranus and Neptune to assess the spatial and temporal variations of temperatures, minor constituents, and cloud properties using the IRS instrument. Spatial variations will be estimated by observing each planet 3-4 times over a single rotation, providing Nyquist sampling of each hemisphere. Time variations will be determined by observing spectra several months after the GTO observations and at annual intervals thereafter through the life of the mission. Variations on time scales of months to several years will be evaluated by comparing Science Verification (SV) spectra, GTO spectra and our proposed observations. Spitzer's high sensitivity and unique spectral range will provide the best assessment of the energetics associated with radiative and dynamical forces in the atmospheres of these planets, for which there are no current or planned NASA missions for at least the next decade. This assessment, at wavelengths common to one of the proposed Terrestrial Planet Finder designs and ESA's Darwin mission design, will also be important in making comparisions with bodies of similar size in extrasolar planetary systems.

Spitzer Space Telescope - General Observer Proposal #3712

A look at the large end of the jovian ring particle size distribution

Principal Investigator: Michael Wong
Institution: UC Berkeley

Technical Contact: Michael Wong, UC Berkeley

Co-Investigators:
Imke de Pater, UC Berkeley

Science Category: planets
Observing Modes: IrsMap
Hours Approved: 3.4

Abstract:
No spectra of the thermal emission from Jupiter's ring are available to date. Spectra in the thermal infrared are crucial for interpreting numerous observations of the rings in scattered sunlight, which is primarily sensitive to particles near 1 micron in size. Only with thermal infrared ring data can we constrain fundamental properties such as the size distribution, composition, albedo, and emissivity of ring particles. The most sentitive published search for thermal emission from the rings comes from Voyager IRIS, which was only able to set upper limits. Spitzer's IRS will be able to detect any thermal emission between these upper limits and the zodiacal background. These measurements cannot be made from the ground due to strong atmospheric absorption and the faintness of the ring signal. Since thermal IR is more sensitive to the larger particles that are hidden in the reflected sunlight regime, Spitzer gives us a rare chance to study possible parent bodies of the dusty ring particles.

Spitzer Space Telescope - General Observer Proposal #3582

Determining Albedos and Sizes for Irregular Satellites of Jupiter and Saturn

Principal Investigator: Tommy Grav
Institution: Harvard-Smithsonian Center for Astrophysics

Technical Contact: Tommy Grav, Instite for Astronomy

Co-Investigators:
Mark Sykes, Planetary Science Institute
Michael Brown, California Institute of Technology

Science Category: satellites
Observing Modes: MipsPhot
Hours Approved: 18.1

Abstract:
Determining sizes and albedos for the irregular satellites of the giant planets is essential in understanding their origins and capturing processes. The Multiband Imaging Photometer (MIPS) aboard the Spitzer InfraRed Telescope Facility (SIRTF) is the only instrument available that makes photometric observation of a large number of irregular satellites in the mid-infrared possible. We propose to perform mid-infrared photometric observations of 23 Jovian and 9 Saturnian irregular satellites, over half of the known irregulars around these two planets. This sample will give us a uniqe sample of accurate sizes and albedos that will provide us with the capability to compare them with other solar system bodies in the search for their origins and processes of evolution.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #71

Observations of Outer Solar System Satellites and Planets

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Jeffrey Van Cleve, Ball Aerospace

Science Category: satellites
Observing Modes: IracMap IrsMap IrsStare MipsPhot MipsSed
Hours Approved: 21.9

Abstract:
We examine the principal satellites of outer Solar System planets, as well as Uranus, Neptune, and Pluto, using all SIRTF instruments. IRAC photometry will establish the hitherto unknown albedo of these cold objects at wavelengths between 3.5 and 8 microns, IRS will do reflectance spectrosopy at wavelengths between 5.3 and 15 um, and thermal emission spectroscopy between 10 and 40 um. Combined with MIPS photometry and SED measurements, these data willl provide compositional information, albedo, and thermal properties of these objects. All synchronous satellites are observed at leading and trailing hemispheres, while in addition the sub-Neptune hemisphere of Triton, and a series of follow-on measurements of this particularly interesting moon, are performed. The observations of Uranus and Neptune will be used to monitor atmospheric trends seen by HST and ISO, for trace composition data, and for precise straylight subtraction for observations of their innermost principal satellites. Observations of Titan will be examined for different spectral signatures of the hemisphere containing the "continent" seen in near-IR Hubble images compared to the trailing hemisphere, and interpreted in terms of surface composition and temperature.

Spitzer Space Telescope - Directors Discretionary Time Proposal #273

Spitzer Observations of the Enceladus Plume

Principal Investigator: Victoria Meadows
Institution: Caltech

Technical Contact: Carl Grillmair, Spitzer Science Center

Co-Investigators:
Yuk Young, Caltech
Diane Liang, Caltech
Bidushi Bhattacharya, SSC
Bill Reach, SSC
Jeffery Van Cleve, Ball Aerospace
Carl Grillmair, SSC
David Crisp, JPL

Science Category: Satellites
Observing Modes: IracMap IrsMap
Hours Approved: 4.7

Abstract:
During a close encounter with the Saturnian moon Enceladus on July 14, 2005, the Cassini spacecraft made one of its most unexpected discoveries to date. The recent announcements of this discovery show evidence from multiple instruments on the spacecraft for a large plume of water vapor and solid particles emanating from Enceladus' south polar region (Porco et al. 2006). The moon's weak gravitational field prevents the retention of an atmosphere on this icy body, which indicates that this gas is likely the result of some currently active venting geothermal process. This unique environment on an icy outer moon provides potential sub-surface liquid reservoirs, and a heat source, providing a hitherto unimagined potential site for life that is accessible to study via remote-sensing. However, Cassini has now left Enceladus, and will not return until 2008. Further monitoring of this unique environment must now be carried out by ground-, and space-based telescopes such as Spitzer. Here we proposed to take IRAC and IRS observations of Enceladus and its plume to characterize the Enceladus surface, and search for reflectivity and molecular spectral features from the plume. Any molecules detected may provide further clues to this environment's suitability for life.

Spitzer Space Telescope - General Observer Proposal #20446

Triton's Temperature Distribution

Principal Investigator: John Spencer
Institution: Southwest Research Institute

Technical Contact: John Spencer, Southwest Research Institute

Co-Investigators:
John Stansberry, University of Arizona
Jeff VanCleve, Ball Aerospace

Science Category: satellites
Observing Modes: IrsMap
Hours Approved: 16.3

Abstract:
We propose to obtain a 25 - 40 micron spectrum of the thermal emission from Neptune's large and complex moon Triton. The spectrum will constrain surface temperature distributions (especially in the frost-free regions), surface/atmosphere interactions, and the time variability of its surface frost distribution and atmospheric pressure. This will be the first detection of Triton's thermal emission, apart from a marginal 47 micron observation by Voyager in 1989, filling a major gap in our understanding of this fascinating body. We will use a variety of strategies to reduce and characterize scattered and diffracted thermal radiation from Neptune, including observations with identical Neptune-relative pointing with and without Triton in the slit, and will also experiment with using the end of the slit to mask out Neptune.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40842

IRS Moons and Planets, Cycle 4 extension

Principal Investigator: Jeffrey Van Cleve
Institution: Ball Aerospace & Technologies Corp.

Technical Contact: Jeffrey Van Cleve, Ball Aerospace

Science Category: satellites
Observing Modes: IracMap IrsMap MipsPhot MipsSed
Hours Approved: 6.1

Abstract:
We are continuing our observations of the principal satellites of outer Solar System planets, using all SIRTF instruments. We use IRAC photometry to measure poorly known albedos of these cold objects at wavelengths between 3.5 and 8 microns, IRS will do reflectance spectrosopy at wavelengths between 5.3 and 15 μm, and thermal emission spectroscopy between 10 and 40 μm. Combined with MIPS photometry and SED measurements, these data willl provide compositional information, albedo, and thermal properties of these objects. When the observations in this proposal are combined with those already executed in Program 71, we will have observed synchronous satellites at both leading and trailing hemispheres. We also observe eclipse of Ganymede and Callisto.

Spitzer Space Telescope - General Observer Proposal #40840

A Search for Debris From Phoebe: A New Saturnian Ring?

Principal Investigator: Anne Verbiscer
Institution: University of Virginia

Technical Contact: Anne Verbiscer, University of Virginia

Co-Investigators:
Michael Skrutskie, University of Virginia
Douglas Hamilton, University of Maryland

Science Category: satellites
Observing Modes: IracMap MipsScan
Hours Approved: 3.4

Abstract:
We request a modest amount of time to conduct a speculative program to search for an extended dust structure in the saturnian system with an origin associated with the satellite Phoebe. Under the influence of Poynting-Robertson drag and dynamical interaction, particles originating from Phoebe will uniformly populate a large toridal region around Saturn. Phoebe can be a source of such particles both through meteoric bombardment and intrinsic ''cometary'' activity. This proposal explores the likelihood that recent (within 10 million years) events on Phoebe could produce a dust structure surrounding Saturn that is detectable by Spitzer with contrast above the zodiacal background in less than 4 hours of observation.

Spitzer Space Telescope - Directors Discretionary Time Proposal #50780

Completing the Dust Census of the Saturn System

Principal Investigator: Anne Verbiscer
Institution: University of Virginia

Technical Contact: Anne Verbiscer, University of Virginia

Co-Investigators:
Michael Skrutskie, Univ. of Virginia
Douglas Hamilton, Univ. of Maryland

Science Category: satellites
Observing Modes: MipsScan
Hours Approved: 2.5

Abstract:
We request a modest amount of time to conduct a speculative program to search for extended dust structures in the saturnian system with an origin associated with Iapetus. Under the influence of Poynting-Robertson drag and dynamical interaction, particles originating from this moon will uniformly populate a large toroidal region around Saturn. Recent images obtained by the Cassini spacecraft indicate that Iapetus, like Enceladus, may endogenically modify its surface and can thus be a source of such particles through intrinsic "cometary" and/or cryovolcanic activity. This proposal follows up on Spitzer Program 40840 to search for such a dust structure associated with the satellite Phoebe. We will explore the likelihood that recent activity on Iapetus could produce dust structure surrounding Saturn that is detectable by Spitzer with contrast above the zodiacal background in less than 3 hours of observation.

Spitzer Space Telescope - General Observer Proposal #30241

Rotationally-Resolved Surface Mineralogy of an Extinct Comet

Principal Investigator: Humberto Campins
Institution: University of Central Florida

Technical Contact: Humberto Campins, University of Central Florida

Co-Investigators:
Yanga Fernandez, University of Central Florida
Joshua Emery, NASA/Ames Research Center
Javier Licandro, Instituto de Astrofisica de Canarias
Carey Lisse, JHU Applied Physics Laboratory

Science Category: asteroids
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 3.0

Abstract:
Object 944 Hidalgo is one of the asteroids most likely to be an extinct or dormant comet. Hidalgo's Tisserand invariant (T=2.07) suggests very strongly that this object originated either in the Kuiper belt or in the Oort cloud (Weissman et al. 2002). Our latest ground based results show significant rotational variability in the near-infrared spectrum of Hidalgo, but the ground based spectra are not sufficient to identify the nature of these surface variations. Spitzer observations of Hidalgo would be diagnostic of the surface mineralogy, as has been demonstrated for a number of asteroids (e.g., Emery et al. 2006). We propose to obtain 7.3 to 38 micron IRS spectra of 944 Hidalgo at 8 different rotational phases to characterize its surface composition and other properties such as thermal inertia.

Spitzer Space Telescope - General Observer Proposal #40322

Low Perihelion Near Earth Asteroids

Principal Investigator: Humberto Campins
Institution: University of Central Florida

Technical Contact: Humberto Campins, University of Central Florida

Co-Investigators:
Yan Fernandez, University of Central Florida
Michael Kelley, University of Central Florida
Javier Licandro, ING/IAC, Spain

Science Category: asteroids
Observing Modes: IrsStare
Hours Approved: 10.1

Abstract:
The primary goal of this project is to characterize the surface composition (and other properties such as radius, albedo and thermal inertia) of a sample of low perihelion Near- Earth Asteroids (NEAs), based on their 7 to 14 micron spectrum. NEAs with low perihelion distances represent a unique laboratory in which to study the effects of thermal processing on asteroid surfaces. We will study the mineral and organic composition of our targets and we will search for correlations between the mid-infrared spectral characteristics and other properties such as size, albedo, rotational properties and orbital characteristics. Understanding how asteroid surfaces change as a result of exposure to high temperatures will help constrain models of the compositional and thermal environment in the region of the protoplanetary disk where the asteroids formed. Part of the motivation to study the low perihelion NEAs comes from the results of our recent study of 3200 Phaethon (Licandro et al. 2007), where we found indications that the surface mineralogy of this low perihelion NEA may have been altered by the perihelion thermal pulse. Our total time request is 10.1 hours.

Spitzer Space Telescope - General Observer Proposal #50672

A Comparative Study of the Themis and Veritas Asteroid Families

Principal Investigator: Humberto Campins
Institution: University of Central Florida

Technical Contact: Humberto Campins, University of Central Florida

Co-Investigators:
Yan Fernandez, University of Central Florida
Michael Kelley, University of Central Florida
Javier Licandro, Institute of Astrophysics of the Canaries, Spain
Andy Rivkin, Applied Physics Laboratory/JHU
Julie Ziffer, University of Southern Maine

Science Category: asteroids
Observing Modes: IrsStare
Hours Approved: 6.4

Abstract:
Our primary goal is to characterize the surface composition (and other properties such as radius, albedo and thermal inertia) of our sample of Themis-family and Veritas-family asteroids based on their 5 to 14 micron spectra. We chose these two families for several reasons. First, they are compositionally primitive (non-igneous) so they can yield information about their physical and chemical conditions of their formation environment. Second, their parent bodies formed in the same region, yet their disruption ages are sharply different: 2.5 Gy and 8.3 My, respectively. This gives us a remarkable opportunity to understand the evolutionary processes that have affected the asteroids fragments. For example, Nesvorny et al. (2005) found clear evidence of color variations between young and old asteroids families. They identified a well defined trend among primitive asteroids, with the Themis and Veritas families at opposite ends of this color variation, which they attribute to space weathering. Finally, both families formed beyond the "frost line" and some fragments appear to have retained water-ice reservoirs for the age of the solar system; more specifically Rivkin (2007) reported the first (preliminary) detection of water ice on 24 Themis. If confirmed, this detection of water-ice opens up interesting possibilities that could transform of our understanding of these asteroids. For example, since water ice is not stable on the surface of 24 Themis over the age of the solar system what is its source? What does this imply about the interior of this asteroid and of the other members of these two families. Why does 24 Themis not show cometary activity? These are some of the questions this proposed study will address. Understanding the abundance of water-ice and hydrated minerals in this area of the solar system is particularly important, as it may be linked to the origin of Earth's water. Our total time request is 6.4 hours.

Spitzer Space Telescope - Directors Discretionary Time Proposal #481

Thermal observations of spacecraft target 1999 JU3

Principal Investigator: Humberto Campins
Institution: U. Central Florida

Technical Contact: Humberto Campins, U. Central Florida

Co-Investigators:
Joshua Emery, SETI/NASA AMES
Yanga Fernandez, U. Central Florida
Michael Kelley, U. Central Florida
Javier Licandro, IAC-Spain
Antonella Barucci, Paris Obs.-France
Elizabetta Dotto, INAF-Oss. Astro. di Roma-Italy

Science Category: asteroids
Observing Modes: IrsMap
Hours Approved: 1.4

Abstract:
We propose a 1.4 hr program to observe, with IRS, the near-Earth asteroid 161273 (1999 JU3), the primary target of two proposed spacecraft missions: the European Space Agency (ESA) MARCO POLO sample return mission and the Japanese Aerospace Exploration Agency (JAXA) Hyabusa-2 mission. These observations will provide characterization of the composition and thermophysical properties of this distinctive asteroid.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #88

Extinct Comets and Low-Albedo Asteroids

Principal Investigator: Dale Cruikshank
Institution: NASA-Ames

Technical Contact: Jeffrey Van Cleve, Ball Aerospace

Science Category: asteroids
Observing Modes: IrsMap IrsStare
Hours Approved: 15.4

Abstract:
Several objects classified as asteroids have orbits that are dynamically similar to those of comets. They are thought to be comets that have devolatilized by repeated passages through the inner solar system. Some of these objects are "near-Earth asteroids". This is a spectroscopic study of a sample of these objects. For spectroscopic comparison of the extinct comets, and for a parallel study of the compositions of low-albedo main belt and Trojan asteroids, a number of C, P, and D-type asteroids are included.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #91

Extinct Comets and Low-Albedo Asteroids-2

Principal Investigator: Dale Cruikshank
Institution: NASA-Ames

Technical Contact: Jeffrey Van Cleve, Ball Aerospace

Science Category: asteriods
Observing Modes: IrsMap IrsStare
Hours Approved: 6.1

Abstract:
Spectroscopic survey of asteroids that have dynamical characteristics indicating that they are extinct comets. the survey also includes main belt and Trojan asteroids of low albedo and classified as C, P, and D (and various subtypes).

Spitzer Space Telescope - Directors Discretionary Time Proposal #271

Size, Albedo, and Taxonomy of the Don Quijote Space Mission Target

Principal Investigator: Alan Harris
Institution: DLR Berlin

Technical Contact: Michael Mueller, DLR

Co-Investigators:
Alan Fitzsimmons, Queen's University Belfast

Science Category: Asteroids
Observing Modes: IracMap
Hours Approved: 1.2

Abstract:
Rendezvous and lander missions are a very effective but very expensive way of investigating Solar-System bodies. The planning, optimization and success of space missions depends crucially on prior remotely-sensed knowledge of target bodies. Near-Earth asteroids (NEAs), which are mainly fragments of main-belt asteroids, are seen as important goals for investigation by space missions, mainly due to the role their forebears played in planet formation and the evolution of the Solar System, but also for the pragmatic reason that these objects can collide with the Earth with potentially devastating consequences. The European Space Agency is currently planning the Don Quijote mission to a NEA, which includes a rendezvous (and perhaps a lander) spacecraft and an impactor vehicle. The aim is to study the physical properties of the target asteroid and the effects of the impact on its dynamical state, as a first step in considering realistic mitigation measures against an eventual hazardous NEA. Two potential targets have been selected for the mission, the preferred one being (10302) 1989 ML, which is energetically easier to reach and is possibly a scientifically interesting primitive asteroid. However, due to the ambiguity of available spectral data, it is currently not possible to confidently determine the taxonomic type and mineralogy of this object. Crucially, the albedo is uncertain by a factor of 10, which leads to large uncertainties in the size and mass and hence the planned near-surface operations of Don Quijote.
Thermal-infrared observations are urgently required for accurate size and albedo determination. These observations, which can only be carried out by Spitzer and would require only a modest amount of observing time, would enable an accurate diameter to be derived for the first time and the resulting albedo would remove the taxonomic ambiguity.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30252

Precision Thermal Observations of Rotational Variability in Main Belt Asteroids

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Bidushi Bhattacharya, Caltech

Co-Investigators:
Bidushi Bhattacharya, Caltech/Spitzer Science Center, USA
Thomas Mueller, Max Planck Institut for Extraterrestrial Physics,
William Reach, Caltech/Spitzer Science Center, USA
Vikki Meadows, Caltech/Spitzer Science Center, USA
Mikko Kaasalainen, Dept of Mathematics and Statistics, Univ. of Helsi

Science Category: asteroids
Observing Modes: IracMap
Hours Approved: 19.0

Abstract:
Temporal variability in optical flux from main belt asteroids is tied strongly to shape and albedo changes as these bodies rotate and also changes with illumination and observing geometry. At thermal wavelengths, surface properties are also responsible for second order effects on the light curve. As the variation with time of mid-infrared flux is not well-characterized, we propose to observe thermal variations as a function of rotation for a selected set of main belt asteroids of different taxonomic classes using Spitzer/IRAC at 8 um.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50746

The Latitudinal Distribution of Solar System Small Bodies

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Bidushi Bhattacharya, Caltech

Co-Investigators:
Victoria Meadows, University of Washington
Ed Tedesco, Planetary Science Institute
Bryan Penprase, Pomona College
Carl Grillmair, SSC
Amanda Mainzer, JPL
Marco Delbo, Observatoire de la Cote d'Azur

Science Category: asteroids
Observing Modes: MipsScan
Hours Approved: 25.6

Abstract:
Spitzer is uniquely poised to examine the remnants of primordial planetesimals in the Solar System. To date, several surveys have provided unprecedented number counts and sky plane densities of small MBAs. Observations at EcLat = 0, +5, and -9 degrees indicate that the sky plane density does not drop off quickly with distance from the plane, as previously thought. An appreciable number of smaller asteroids has been detected at higher latitudes. We propose to build upon these results by obtaining deep MIPS 24um observations down to 0.02 mJy at EcLat = 0, 17, and 25 degrees. We further work to determine radiometric diameters and albedos for the larger, known objects by obtaining near-simultaneous observations with the Pomona College 1-meter telescope at Table Mountain Observatory.

Spitzer Space Telescope - General Observer Proposal #3698

Surface History and Evolution of Small Jovian Trojans

Principal Investigator: Yanga Fernandez
Institution: Univ. of Central Florida

Technical Contact: Yanga Fernandez, Univ. of Central Florida

Co-Investigators:
David Jewitt, Univ. of Hawaii

Science Category: asteroids
Observing Modes: IrsStare MipsPhot
Hours Approved: 9.0

Abstract:
We propose to measure the albedo distribution of the Jovian Trojan asteroids that populate the small end of the known population (4 to 7 km radius). The overarching goal is to (a) understand the collisional and surficial evolution of these objects, and (b) study the connection between these relatively primitive asteroids and the similarly primitive comets. The proposed observations will let us search for differences in the physical properties between small and large Trojans that can be related to surface aging and evolution. The Trojans are thought to have formed sufficiently far from the Sun during the planetary formation era to have had a significant ice component. How much of this ice component has been depleted via sublimation is one of the main questions we wish to address. Previous work by our group, in which we measured the albedo distribution of the large Trojans (radii above 30 km), showed three significant properties: the large Trojans have a very narrow range of albedos, the albedo does not correlate with the size, and the albedo distributions of the active comets and the large Trojans are statistically consistent with being the same despite the overall disparity in sizes. The collisional history of an object is dependent on it size, and so the smaller objects should have fresher, more reflective material on the surface. We hypothesize that the small Trojans, having relatively younger surfaces, will have a higher mean albedo, a larger spread, and a correlation with size. The other question is whether the small Trojans' albedos are consistent with the idea that the Trojan swarms feed part of the ecliptic comet population. A comparison of the albedos of small Trojans, large Trojans, comets, Centaurs, and Kuiper Belt objects will give clues to the nature of small bodies' surface evolution.

Spitzer Space Telescope - General Observer Proposal #20158

A Robust Survey of the Physical Properties of the Karin Cluster Asteroids

Principal Investigator: Alan Harris
Institution: DLR Berlin, Institute of Planetary Research

Technical Contact: Michael Mueller, DLR

Co-Investigators:
Andrew Cheng, Johns Hopkins University
Alan Fitzsimmons, Queen's University Belfast
Michael Hicks, JPL
Carey Lisse, Johns Hopkins University
Stephen Lowry, Queen's University Belfast
Michael Mueller, DLR Berlin, Institute of Planetary Research
Dave Osip, OCIW, Las Campanas Observatory

Science Category: asteroids
Observing Modes: IracMap IrsPeakupImage
Hours Approved: 23.2

Abstract:
The Karin cluster is by far the youngest known family of main-belt asteroids, dating back to a collisional event only 5.8+/-0.2 Myr ago. We propose to sample the thermal continua of 17 Karin cluster asteroids of different sizes, down to the smallest members discovered so far, in order to derive accurate sizes and study the physical properties of their surfaces. Our aims include a study of trends in thermal inertia and albedo with size. The analysis will be based on sophisticated thermal models that will provide important insight into thermal inertia and regolith coverage. The widely used 'standard thermal model' leads to serious errors in thermal studies of small asteroids and is not adequate for a detailed study of the physical characteristics of Karin cluster members. The following questions are amongst those addressed by this program: 1. Are the distributions of sizes and albedos compatible with the Karin cluster being the result of a single catastrophic collision 5.8+/-0.2 Myr ago (Nesvorny et al., 2002)? 2. Are the sizes and thermal properties of the Karin-cluster members compatible with the claim of Nesvorny and Bottke (2004) that the Yarkovsky Effect is responsible for an apparent non-gravitational drift of their orbital motion? 3. Does the retention of a significant thermally insulating layer of regolith depend on asteroid size? If so, what are the consequences for modeling the Yarkovsky effect and the delivery of main-belt asteroids into near-Earth orbits? 4. Is there a correlation between albedo and size among the Karin cluster members similar to that evident for near-Earth asteroids in the same size range? If so, what are the consequences for models of age-dependent space weathering? (the Karin cluster members all have the same age).

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30228

Surface mineralogy of Trojan asteroids and extinct comets as a proxy for the outer Solar System

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Joshua Emery, SETI Institute / NASA Ames

Co-Investigators:
Joshua Emery, SETI Institute / NASA Ames
Dale Cruikshank, NASA Ames Research Center

Science Category: asteroids
Observing Modes: IrsStare
Hours Approved: 13.3

Abstract:
We propose to use IRS to observe emission spectra a suite of Trojan asteroids and extinct Jupiter family comets (JFCs). The goals of this work are to determine their surface compositions and to gain information on their surface microstructures; both factors influence the spectra of these airless bodies in the thermal infrared region covered by IRS. Trojan asteroids and extinct JFCs are thought, on dynamical grounds, to have originated in the outer Solar System, beyond Jupiter. The small bodies that accreted in the outer Solar System carry compositional information of the contents of the solar nebula in the region where silicates, organics, and ices inherited from the interstellar medium were largely preserved because of the low temperature. Because all but a very few of the objects that presently remain in the distant Solar System (the Kuiper Belt Objects) are too small and faint for mid-IR spectroscopy, the study the Trojans and JFCs is essential to characterize the compositions of a class of object that is otherwise unobservable.

Spitzer Space Telescope - General Observer Proposal #30678

Albedos of Main-Belt Comet Nuclei

Principal Investigator: Henry Hsieh
Institution: University of Hawaii

Technical Contact: Henry Hsieh, University of Hawaii

Co-Investigators:
David Jewitt, University of Hawaii
Yan Fernandez, University of Central Florida

Science Category: asteroids
Observing Modes: MipsPhot
Hours Approved: 13.8

Abstract:
Comets are icy bodies that sublimate when close to the Sun, producing distinctive unbound atmospheres (comae) and tails. The active comet population we see today mainly consists of bodies transferred via dynamical interactions with the giant planets from the outer solar system (from the Kuiper Belt or Oort Cloud) into the inner solar system. Recently, however, a new class of comets has come to light: the main-belt comets. These objects display cometary activity, yet possess no clear dynamical link to the outer solar system and thus likely formed where we see them today in the main asteroid belt. As such, they may be fundamentally compositionally distinct from classical Kuiper Belt and Oort Cloud comets. We propose to use MIPS on Spitzer in conjunction with optical facilities on Mauna Kea in Hawaii to determine albedos for these surprising objects, as well as for a number of dynamically similar but inactive comparison objects. With these Spitzer observations, we hope to better characterize the main-belt comets in the context of both other comets from the outer solar system and their inactive neighbors in the main asteroid belt.

Spitzer Space Telescope - General Observer Proposal #40819

Albedos of Small Hilda Asteroids

Principal Investigator: Henry Hsieh
Institution: University of Hawaii

Technical Contact: Henry Hsieh, University of Hawaii

Co-Investigators:
David Jewitt, University of Hawaii
Yan Fernandez, University of Central Florida

Science Category: asteroids
Observing Modes: MipsPhot
Hours Approved: 5.7

Abstract:
The Hilda asteroid group, found near the 3:2 mean motion resonance with Jupiter, is composed mostly of largely primitive D-type and P-type asteroids, with D-type asteroids dominating the small end of the Hilda size distribution and P-types comprising many of the largest Hilda asteroids. The D-type asteroids in the Hilda group are of particular interest due to their spectral similarity to cometary nuclei and the dynamical possibility that escaped Hilda asteroids may in fact contribute to the Jupiter-family comet population. We propose to use MIPS on Spitzer to obtain 24~$\\mu$m photometry of a sample of the smallest Hilda asteroids currently known, and then to combine these data with optical data obtained from telescopes on Mauna Kea to determine albedos for these poorly understood objects. The albedo distribution of this population can then be compared to those of other cometary and asteroidal groups, permitting us to relate the Hilda asteroids to objects on each side of the asteroid-comet divide.

Spitzer Space Telescope - General Observer Proposal #20796

Thermal Properties of Damocloids

Principal Investigator: David Jewitt
Institution: Univ of Hawaii

Technical Contact: David Jewitt, Univ of Hawaii

Co-Investigators:
Yanga Fernandez, Univ of Hawaii

Science Category: asteroids
Observing Modes: IrsPeakupImage MipsPhot
Hours Approved: 15.3

Abstract:
We propose to detect the thermal emission from 16 Damocloids. These are apparent asteroids on high-inclination and high-eccentricity orbits that are the dormant or extinct analogs to the Halley-Family (HF) and Long-Period (LP) comets. As such the Damocloids provide a way to study the physical properties of these cometary nuclei by proxy. Normally a HF or LP comet is active to very large heliocentric distances, thus making study of its nucleus problematic. So far we know fundamental properties of only a handful of these comets. Our primary goal is to sample the albedo and size distribution of the Damocloids by using complimentary visible-wavelength observations in concert with the proposed mid-IR program here. By sampling a large fraction of the entire known population of Damocloids, we will be able to make comparisons with the physical properties of both active and extinct Jupiter-family comets. We will look for differences that could be caused by the different evolutionary histories suffered by the two classes of comets. In addition we will search for indications of current and historical cometary activity. Deviations of the object's profile from a point source would indicate remnant low-level outgassing and dust ejection, while dust trails would suggest activity in the near past. Our program represents a first step in exploring this class of objects in the context of Solar System evolution.

Spitzer Space Telescope - General Observer Proposal #20653

Characterization of Asteroids 2867 Steins and 21 Lutetia, Targets of the Rosetta Mission

Principal Investigator: Philippe Lamy
Institution: Laboratoire d'Astronomie Spatiale, Marseille

Technical Contact: Philippe Lamy, Laboratoire d'Astronomie Spatiale

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Dale Cruikshank, NASA-Ames
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Laurent Jorda, Laboratoire d'Astronomie Spatiale
Sonia Fornasier, Padua Observatory
Olivier Groussin, Dept. of Astronomy, University of Maryland
Marcello Fulchignoni, Meudon Observatory
Jorge Carvano, Meudon Observatory
Alessandra Migliorini, Meudon Observatiry

Science Category: asteroids
Observing Modes: IrsStare
Hours Approved: 4.5

Abstract:
Asteroids 2867 Steins and 21 Lutetia are the new targets of the Rosetta mission. Our present knowledge of these two objects is still very limited. Their albedos are either unknown (Steins) or subject to question (Lutetia), with severe consequences for their sizes and their taxonomic classifications and their surface compositions are either unclear or controversial. We propose to investigate the physical properties (size, shape), the surface and thermal properties (albedo, thermal inertia, surface roughness) and surface composition of these two asteroids by taking advantage of the capabilities and performances of the Spitzer Space Telescope (SST), supplemented by ground-based observations. The SST observations consist in taking low resolution spectra with the IRS instrument over its full wavelength range 5-38 micron. Each asteroid will be observed 14 times at time intervals of 30 min for Steins and 40 mn for Lutetia in order to properly sample their light curve. The detailed knowledge of these asteroids that will result from our proposed program will be of critical importance for optimizing the flyby strategy of the Rosetta spacecraft and the operation of its instruments. They will later supplement the in-situ observations necessarily limited by the conditions of a fast flyby and contribute to their global characterization.

Spitzer Space Telescope - General Observer Proposal #40259

Characterization of Asteroid 2867 Steins, a Target of the Rosetta Mission

Principal Investigator: Philippe Lamy
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Co-Investigators:
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Laurent Jorda, Laboratoire d'Astrophysique de Marseille

Science Category: Asteroids
Observing Modes: IrsStare
Hours Approved: 1.4

Abstract:
We propose to re-observe asteroids 2867 Steins, one of the target of the Rosetta mission in order to definitevely ascertain its taxonomic classification and its surface composition. Our previous SST observations performed during cycle 2 had to assume a much bigger size than presently established, and our spectra do not have a good enough signal-over-noise ratio to clearly distinguish the exact position of the different bands. The proposed SST observations consist in taking low resolution spectra with the IRS instrument over its full wavelength range 5-38 micron so as to reach a signal-over-noise ratio larger than 200 in the 7-20 micron spectral range which is of prime interest for identification of the mineralogical features. Five individual spectra will be obtained for a total observing time of 1.4 hr. The expected results will allow identifying the mineralogical signatures so as to determine the taxonomic classification, the surface composition and possible weathering processes.

Spitzer Space Telescope - General Observer Proposal #20481

IRS Spectroscopy of M-Class Asteroids and 375 Ursula

Principal Investigator: Lucy Lim
Institution: NASA/Goddard Space Flight Center

Technical Contact: Joshua Emery, SETI Institute / NASA Ames

Co-Investigators:
Joshua Emery, SETI Institute
Timothy McConnochie, Department of Astronomy, Cornell University

Science Category: asteroids
Observing Modes: IrsMap IrsStare
Hours Approved: 13.5

Abstract:
We propose IRS 5.2--38 micron observations of the emission spectra of 27 M asteroids. Although the visible and near-IR spectra of these asteroids are nearly featureless, ten of these asteroids are now known to have hydration features at 3 micron (Rivkin et al., 2000) that are absent in the spectra of 15 others. We believe that high S/N spectroscopy of these asteroids in the mid-infrared is likely to reveal key compositional information not available in the near-infrared. In particular, it has the potential to resolve the question of whether the M-asteroid population is composed primarily of silicates, or metals, or both. This compositional information in turn is likely to lead to a better understanding of how widespread igneous differentiation was among the parent bodies of the current asteroid population.

Spitzer Space Telescope - General Observer Proposal #50259

IRS Spectra of Basaltic Asteroids: Vestoids, 1459 Magnya, and Other Non-Vestoid Basaltic Asteroids

Principal Investigator: Lucy Lim
Institution: NASA/Goddard Space Flight Center

Technical Contact: Lucy Lim, NASA/Goddard Space Flight Center

Co-Investigators:
Joshua Emery, SETI Institute / NASA Ames
Nicholas Moskovitz, University of Hawaii

Science Category: asteroids
Observing Modes: IrsStare IrsPeakupImage
Hours Approved: 19.1

Abstract:
We propose to observe the thermal emission spectra of selected small basaltic asteroids for mineralogical analysis. Our targets will include members of the dynamical family of the unique large differentiated asteroid 4 Vesta (''Vestoids''), four outer-main-belt basaltic asteroids whose orbits exclude them from originating on 4 Vesta, and a basaltic near-Earth asteroid (NEA). Our goal is to address the relationship between the population of Vesta fragments in space (Vestoids), those that have made their way to Earth (''HED'' meteorites), and basaltic fragments from differentiated parent bodies other than 4 Vesta. We plan to characterize the silicate compositions of these asteroids and in particular to achieve unambiguous detection and characterization of their plagioclase components (see below under ''Mineralogy''), which are notoriously difficult to measure in the visible and near-IR. Identifying and characterizing occurrences of differentiation in the Main Belt, as traced by basaltic asteroids, offers important insight to the thermal state of protoplanetary material. This in turn affects the initial conditions for planet formation and the efficiency with which water and other volatiles can be delivered to the nascent planets.

Spitzer Space Telescope - Directors Discretionary Time Proposal #468

Using IRAC to Measure the Yarkovsky Effect for 1862 Apollo

Principal Investigator: Amy Mainzer
Institution: JPL

Technical Contact: Amy Mainzer, JPL

Co-Investigators:
David Vokrouhlicky, Charles University
Bill Bottke, SWRI
David Nesvorny, SWRI
Russ Walker, MIRA
Steve Chesley, JPL
Ned Wright, UCLA
Peter Eisenhardt, JPL

Science Category: asteroids
Observing Modes: IracMap
Hours Approved: 4.2

Abstract:
The Yarkovsky force, first postulated in 1900, is now recognized as an extremely important mechanism for transporting small bodies throughout the Solar System. Bottke et al. (2007) recently computed that the Yarkovsky force is partially responsible for putting the D~10 km K/T impactor on a collison course with Earth. Recent, unpublished work has detected the Yarkovsky force for the asteroid (1862) Apollo. It is possible to use Spitzer to make an independent measurement of the Yarkovsky force by measuring the differences in an asteroid's thermal fluxes and colors at two epochs separated by several months, corresponding to viewing it at its local morning and evening. Apollo is an ideal candidate for validating this technique, since its spin state, shape, orbit, and Yarkovsky force are all well-established, and it is easily observed by Spitzer. If this technique can be validated on Apollo, it can be used to measure the Yarkovsky force directly for large numbers of asteroids using thermal IR data alone. This will be of considerable use to future infrared asteroid surveys. However, Apollo has only two remaining visibility windows during Spitzer's cryogenic mission, both over before Summer 2008 and the start of Cycle 5. We request time to conduct the dual epoch IRAC observations necessary to validate this valuable method of measuring the Yarkovsky force.

Spitzer Space Telescope - General Observer Proposal #30235

Eclipses and occultations on binary Trojan asteroid (617) Patroclus

Principal Investigator: Franck Marchis
Institution: UC Berkeley

Technical Contact: Michael Mueller, DLR

Co-Investigators:
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Science Category: asteroids
Observing Modes: IrsMap
Hours Approved: 3.0

Abstract:
We propose to observe a combined eclipse- and occultation event of the binary asteroid system (617) Patroclus, a member of the intriguing population of Jupiter Trojans. This will be the first thermal-IR observation of such a rare event. Patroclus, the only known Trojan binary, is a particularly well-suited target because its orbital parameters are well known (Marchis et al. 2006) and both components are of roughly equal size, which maximizes the observable effects of the eclipse event. Observing a nearly total eclipse allows the surface thermal inertia, which depends on key physical properties such as the surface porosity, to be determined in a uniquely direct way. Also, occultations allow one component to be studied without significant contamination from the other, thereby facilitating the determination of possible differences between their surface compositions. Note that the angular distance between the components does not exceed 0.15". The proposed Spitzer IRS observations will allow us to clarify the physical nature of the Patroclus system and constrain its mineralogy by providing measurements of the thermal inertia, size and albedo of each component, and the spectral silicate features around 10microns. From spatially resolved Keck imaging Marchis et al. (2006) have recently determined the orbital parameters of the Patroclus system. From these they determined the total mass of the system which, combined with a previous estimate of Patroclus' size, implies a bulk mass density of only 0.8 g cm-3, indicative of a composition dominated by water ice. This supports the idea that large Jupiter Trojans, such as Patroclus, are among the most primordial bodies in the solar system accessible to observations, and that they are basically collisionally unaltered since their formation.

Spitzer Space Telescope - General Observer Proposal #40164

Survey of Binary Asteroids with Spitzer/IRS

Principal Investigator: Franck Marchis
Institution: University of California, Berkeley

Technical Contact: Franck Marchis, University of California, Berkeley

Co-Investigators:
Joshua Emery, NASA-Ames
Michael Mueller, DLR-Berlin (soon U. Arizona)
Jerome Berthier, IMCCE
Francois Colas, IMCCE
Pascal Descamps, IMCCE
Daniel Hestroffer, IMCCE
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Science Category: asteroids
Observing Modes: IrsMap IrsStare
Hours Approved: 19.9

Abstract:
Since the discovery of Dactyl, companion of Ida, in 1993, the number of known binary asteroids has been continuously increasing and ~120 of them are known.We propose to use the SPITZER/IRS capabilities to better estimate the fundamental properties of binary asteroid systems. Spectra between 5 and 42 microns will be recorded for 26 selected targets, allowing us to better refine their size, albedo, and eventually bulk-density. The emissivity spectra of these minor bodies will be also used to better estimate their surface composition and mineralogy. This program is of utmost importance for the broader study of binary asteroids that our group initiated a few years ago. Using various ground-based telescope observations and techniques, such as high angular resolution imaging, lightcurve photometry, and NIR spectroscopy, combined with SPITZER data, we will be able to obtain direct insights on the formation process and evolution of these systems.

Spitzer Space Telescope - General Observer Proposal #20448

Is there regolith on small asteroids?

Principal Investigator: Michael Mueller
Institution: DLR

Technical Contact: Alan Harris, DLR Berlin, Institute of Planetary Research

Co-Investigators:
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Alan Harris, DLR, Institute for Planetary Research
Michael Hicks, JPL
Mikko Kaasalainen, University of Helsinki, Ralf Nevanlinna Institute
Stephen Lowry, Queen's University Belfast

Science Category: asteroids
Observing Modes: IracMap IrsPeakupImage
Hours Approved: 0.8

Abstract:
It is generally expected that very small asteroids consist of bare rock - unlike the Moon or 'big' asteroids such as 433 Eros, which are known to be covered with thick layers of loose material (regolith). Regolith consists of captured impact ejecta; small bodies below a certain threshold size should be unable to retain this collisional debris due to their low gravity. This threshold size is as yet unknown. A study by Delbo et al. (2003), based on Keck observations of small asteroids down to a few 100 meters in diameter, found no evidence for a regolith-free asteroid amongst their targets. The presence or absence of regolith is a key parameter in the assessment of both the Yarkovsky-effect and the YORP-effect, two non-gravitational effects that strongly affect the orbits and spin states of small asteroids. We propose to observe the intriguing small asteroid 54509 2000 PH5 (diameter ~ 180m) with an ultra-fast rotation rate of only 12 minutes. We expect our target to be regolith-free since its gravity can not match the centrifugal force. On the other hand, if regolith were to be found on our target this would suggest that all asteroids as 'big' as 180m in diameter are covered with regolith.

Spitzer Space Telescope - Directors Discretionary Time Proposal #98

First Look Survey - Ecliptic Plane Component

Principal Investigator: Tom Soifer
Institution: Spitzer Science Center

Technical Contact: Victoria Meadows, Caltech

Science Category: asteroids
Observing Modes: IracMap MipsScan
Hours Approved: 14.3

Abstract:
This survey of two fields of 0.13 square degrees at ecliptic latitudes of 0 and 5 degrees characterizes the population of moving objects at 8 and 24um, and explores the smaller members of the asteroid population at diameters less than 1 km. These observations were designed to target asteroids in the main belt region between 2 and 4 AU, to determine number counts and ecliptic plane scale heights. This survey will also provide preliminary information on the zodiacal light as a function of distance from the ecliptic plane.

Spitzer Space Telescope - Directors Discretionary Time Proposal #292

Thermophysical Mapping of 25143 Itokawa

Principal Investigator: Mark Sykes
Institution: Planetary Science Institute

Technical Contact: Mark Sykes, PSI

Co-Investigators:
Robert Gaskell, Planetary Science Institute
Matthew Chamberlain, Planetary Science Institute
Paul Abell, Planetary Science Institute
William Reach, Spitzer Science Center
Faith Vilas, MMT Observatory
Susan Lederer, Cal State U. - San Bernadino
Deborah Domingue, JHU-APL

Science Category: asteroids
Observing Modes: IrsStare
Hours Approved: 3.9

Abstract:
We have a unique opportunity to map at subhemispheric resolution the thermophysical properties of the small Earth-crossing asteroid 25143 Itokawa this April/May 2007 by combining high-resolution shape and topography models, recently derived from imagery of the asteroid obtained by the Japanese Hyabusa mission, with rotationally well- sampled thermal spectra obtained with Spitzer IRS. Prior groundbased observations in the N and Q bands (limited in rotational coverage, wavelength coverage, with substantially lower signal-to-noise) provide only a single global value of thermal inertia, compared to the possible 40 surface resolution elements this program may obtain. Itokawa has a block-strewn surface combined with smooth areas with no definitive large craters and an apparent deficiency of small craters - the first clear example of a 'rubble-pile', that may be characteristic of most small NEOs. Itokawa makes its closest and best approach to the Spitzer spacecraft (0.09 AU) in April at an observational phase angle providing an excellent view of the terminator across which surface temperature changes are maximum. Significant changes in shape and spectral peak of Itokawa's SED as the asteroid rotates are simulated. The high signal-to-noise of the proposed Spitzer IRS observations will well-resolve these spectral differences. Though Itokawa is not spatially resolved by Spitzer, a priori knowledge of its detailed shape and topography from the Hyabusa mission allows us to divide its surface into subunits with independent thermal properties, and constrain them by grid search, finding those values or range of values that reproduce the numerous spectra obtained, where different combinations of surface units contribute to each spectrum as they move from evening to morning to afternoon and in and out of view (sometimes blocked by nearby units). Maximizing rotational sampling maximizes the longitudinal resolution of our thermophysical maps and the number of resolution elements covering its surface.

Spitzer Space Telescope - General Observer Proposal #20538

Albedos and Sizes of Two Small Binary Asteroids

Principal Investigator: Peter Tamblyn
Institution: Southwest Research Institute & Binary Astronomy

Technical Contact: Peter Tamblyn, Southwest Research Institute

Co-Investigators:
William Merline, Southwest Research Institute
Clark Chapman, Southwest Research Institute
Daniel Durda, Southwest Research Institute

Science Category: asteroids
Observing Modes: IracMap
Hours Approved: 1.5

Abstract:
We propose to measure the sizes of two small S-type asteroids in the main belt using Spitzer/IRAC and near-simultaneous ground-based visible photometry. These sizes will then be combined with our HST measurements of these asteroids' masses to determine the quantity of fundamental interest, their densities. Our discovery of satellites orbiting these two S-type main-belt asteroids allows us to measure orbital properties, and hence to measure remotely their masses, without spacecraft visits. Albedo and size then become the dominant uncertainties in estimates of their densities. Their albedos are currently uncertain by factors of at least 2. With thermal infrared flux measurements and near-simultaneous ground-based visible photometry, we can reduce the uncertainty in the volume by an order of magnitude, yielding densities accurate to roughly 20%. Their densities can then be compared to the 2 (much larger) S-type asteroids with measured densities (from spacecraft visits), (433) Eros and (243) Ida, and to other large S-type binary asteroids we are observing from the ground. Hence, measuring the sizes and thus the densities of these two small asteroids will allow us to test if the gross structures of S-type asteroids are similar or different across a wide range of sizes and collisional histories.

Spitzer Space Telescope - General Observer Proposal #20788

Sizes and Albedos of Young C-type Asteroids

Principal Investigator: Peter Tamblyn
Institution: Southwest Research Institute & Binary Astronomy

Technical Contact: Peter Tamblyn, Southwest Research Institute

Co-Investigators:
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Clark Chapman, Southwest Research Institute
Dan Durda, Southwest Research Institute

Science Category: asteroids
Observing Modes: IracMap
Hours Approved: 1.6

Abstract:
We propose to measure the sizes and albedos of 8 very young C-type asteroids with IRAC 8um and near-simultaneous ground-based visible photometry. Asteroid families are created from major collisions between asteroids and are identified from clustering of orbital elements. Co-I Nesvorny has recently identified an exceptionally-young family (Veritas) and precisely-dated it at only 8.3+/-0.5 Myr (just 0.2% of the age of the solar system). We will compare our results for this family with those obtained by our similar Spitzer GO-1 program where we study an even younger S-type family, Karin. C-type asteroids are composed of primitive material (as opposed to the more processed silicate-rich S-types) and comprise the majority of asteorids in the Main Belt, yet their compositions and properties remain elusive. These recent breakup events provide unparalleled opportunities to study compositions, dynamics, and collisions of asteroids. They allow tests of the rates of physical processes that happen on time scales comparable with the family age. Space weathering, for example, appears to affect C- and S-type asteroids very differently. We will test directly whether the Veritas fragments have similar albedos; we will also test if their albedos differ from those of similar asteroids with much older surfaces by study of a second C-type family, Themis. We will compare our observations with those made of larger asteroids of both families, from a companion ground-based program. We will quantify any correlation of size with albedo, a dominant uncertainty in standard size estimates. The size distribution will be used to calibrate hydrocode models of asteroid collisions. To do this will require observations at the smallest practical sizes. In addition, the measured sizes will be immediately applicable to a novel measurement of the Yarkovsky Effect. We have already demonstrated in our GO-1 program that we can make similar Spitzer observations and provide the ground-based visible support.

Spitzer Space Telescope - General Observer Proposal #3723

Sizes and Albedos of Within an Exceptionally Young Asteroid Family

Principal Investigator: Peter Tamblyn
Institution: Southwest Research Institute & Binary Astronomy

Technical Contact: Peter Tamblyn, Southwest Research Institute

Co-Investigators:
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David Nesvorny, Southwest Research Institute
Clark Chapman, Southwest Research Institute
Dan Durda, Southwest Research Institute

Science Category: asteroids
Observing Modes: IracMap
Hours Approved: 1.6

Abstract:
We propose to measure the sizes and albedos of 8 very young and 8 very old asteroids with IRAC 8um and near-simultaneous ground-based visible photometry. Such families are created from major collisions between asteroids and are identified by observed clustering of orbital elements. Co-I Nesvorny has recently identified an exceptionally-young family (Karin) and precisely-dated it at only 5.8+-0.2 Myr (just 0.2\\% of the age of the solar system). This event provides an unparalleled opportunity to study compositions, dynamics, and collisions of asteroids. It will provide insight about the nature of fragments immediately following breakup of a 25-km asteroid. In particular, it allows tests of the rates of physical processes that happen on time scales comparable to the family age. We will test directly whether the Karin fragments have similar albedos; we will also test if their albedos differ from those of similar asteroids with much older surfaces. Our sample spans the range of identified fragment brightnesses and will yield the sizes of the measured fragments. Hence, we can test for and calibrate the possible correlation of size with albedo, a dominant uncertainty in standard size estimates. Efficient visible ground-based photometry can then be used in later work to derive sizes of the rest of the family members, including those yet to be discovered. The size distribution will then be used to calibrate hydrocode models of asteroid collisions, such as the sizes, energies, and velocities imparted to fragments. In addition, the measured sizes will be immediately applicable to a novel measurement of the Yarkovsky Effect.

Spitzer Space Telescope - Archive Research Proposal #3366

Enhancing Science from the Spitzer Ecliptic Plane Survey

Principal Investigator: Edward Tedesco
Institution: Planetary Science Institute

Technical Contact: Edward Tedesco, Planetary Science Institute

Co-Investigators:
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Carol Neese, Planetary Science Institute
Gil Esquerdo, Planetary Science Institute
Rhiannon Lynne Allen, University of British Columbia, Canada
Philippe Bendjoya, Laboratoire Universitaire d'Astrophysique, France
Alberto Cellino, Osservatorio di Torino, Italy
Marco Delbo, Osservatorio di Torino, Italy
Jon Giorgini, Jet Propulsion Laboratory
Victoria Meadows, Caltech/JPL (Spitzer Science Center)
Bidushi Bhattacharya, Caltech (Spitzer Science Center)
Carl Grillmair, Caltech (Spitzer Science Center)
William Reach, Caltech (Spitzer Science Center)
Faith Vilas, Johnson Space Center
Mark Sykes, University of Arizona
Stephen Larson, University of Arizona
Edward Beshore, University of Arizona
Gareth Williams, Minor Planet Center

Science Category: asteroids
Dollars Approved: 99477.0

Abstract:
Spitzer's FLS: Ecliptic Plane Survey (EPS) was designed to "characterize the population of moving objects, at 8 and 24um, and to explore smaller members of the asteroid population (< 1 km diameter). This survey has been designed to target asteroids in the main belt between 2 and 4 AU, to determine number counts and ecliptic plane scale heights. With supporting ground-based observations at visible wavelengths we will also provide asteroid sizes and orbits to enable follow-up observations." (http://sirtf.caltech.edu/SSC/fls/eclip/). In addition, there are map regions in which all MIPS and IRAC bands overlap. These offer additional science return regarding asteroid thermophysical properties and determining the presence of water of hydration. We have used the NOAO/KPNO Mosaic CCD camera on the 4-m in Arizona, the MegaCam CCD camera on the 4-m CFHT in Hawaii, and the FORS1 CCD System in imaging mode on the 8.2-m VLT (UT1 - Antu) in Chile to obtain follow-up astrometry and visual photometry for the EPS asteroids detected by Spitzer. These data will enable us to deduce distances and preliminary orbits for the Spitzer-detected asteroids observed in our ground-based programs. These observations (to a limiting V mag of ~24 on the 4-m telescopes and to ~26 on the VLT), and the orbits deduced from them, will be placed on the Spitzer web site as soon as they are obtained and reduced - probably by mid-2004 and certainly before the end of the year. The funding requested under this proposal will allow us to use the data we have already acquired, together with Spitzer 8 and/or 24um fluxes, to compute albedos and diameters for EPS asteroids as small as several hundred meters, the first for sub-kilometer sized main-belt asteroids. Taxonomic classification and physical properties will be determined by obtaining new multi-color photometry and spectrophotometry on a subset of asteroids observed by Spitzer. These results will then be used to test and refine the most comprehensive model in existence of main-belt asteroids.

Spitzer Space Telescope - Archive Research Proposal #30213

The Spitzer Asteroid Catalog

Principal Investigator: David Trilling
Institution: University of Arizona

Technical Contact: David Trilling, University of Arizona

Co-Investigators:
Bidushi Bhattacharya, SSC
Myra Blaylock, University of Arizona
John Stansberry, University of Arizona
Mark Sykes, PSI
Lawrence Wasserman, Lowell Observatory

Science Category: asteroids
Dollars Approved: 99881.0

Abstract:
We propose to catalog fluxes and derive sizes and albedos for all asteroids with small positional uncertainties that appear serendipitously in publicly available IRAC and MIPS archive data. We will make at least 25,000 independent measurements. Our results will help extend the small end of the asteroid size frequency distribution of main belt and Jupiter Trojan asteroids; reveal compositional gradients and remove compositional degeneracies; look for common properties among asteroid families; and serve as a fundamental database of asteroid properties for the coming decades. The SSC asteroid identification tools are inadequate for this task and furthermore provide no analysis of asteroid data. We have developed and demonstrate a pilot automated pipeline capable of extracting asteroid detections from IRAC and MIPS imaging data products and generating a first order catalog of fluxes, albedos, and diameters. This pipeline will be applied to the entire publicly accessible Spitzer imaging archive. The results will be published in refereed papers and in NASA's peer-reviewed Planetary Data System.

Spitzer Space Telescope - Archive Research Proposal #40116

The Spitzer Asteroid Catalog II: 10,000 more asteroids

Principal Investigator: David Trilling
Institution: University of Arizona

Technical Contact: David Trilling, University of Arizona

Co-Investigators:
Bidushi Bhattacharya, SSC
Myra Blaylock, University of Arizona
John Stansberry, University of Arizona
Mark Sykes, PSI
Lawrence Wasserman, Lowell Observatory

Science Category: asteroids
Dollars Approved: 49935.0

Abstract:
We propose here to continue building the Spitzer Asteroid Catalog by identifying, extracting, cataloging, and analyzing serendipitous observations of asteroids in the Spitzer public archive. Under the auspices of our approved Cycle 3 Archive program, we have created a fully automated pipeline that produces catalogs of fluxes, albedos, and diameters from publicly available Spitzer images. We have recently completed Phase A of that program and catalogued 533 unique asteroid appearances, and present those results for the first time here. We propose in Cycle 4 to extend our analysis to twelve months' worth of newly available IRAC and MIPS imaging data to derive sizes and albedos from 10,000 measurements of well-known asteroids. The costs proposed here are quite low since the infrastructure for this program already exists. Our results will help reveal compositional gradients in the asteroid belt; extend the small end of the asteroid size distribution; look for common properties within asteroid families; improve existing asteroid thermal models; and serve as a fundamental database of asteroid properties for the coming decades. The products of this program will allow rich science investigations into the composition, evolution, and dynamical history of the asteroid belt and be a legacy of the Spitzer Space Telescope for decades to come. The results will be published in refereed papers and in NASA's peer-reviewed Planetary Data System.

Spitzer Space Telescope - General Observer Proposal #40964

Regoliths on small asteroids: Testing hypotheses with Spitzer

Principal Investigator: David Trilling
Institution: University of Arizona

Technical Contact: David Trilling, University of Arizona

Co-Investigators:
Andrew Rivkin, JHU/APL
John Stansberry, University of Arizona

Science Category: asteroids
Observing Modes: IrsPeakupImage
Hours Approved: 9.6

Abstract:
Two recent papers suggest, based on indirect evidence that bodies smaller than 5 km may on average be nearly devoid of regolith. If true, the physical properties of the most numerous population of objects in the Solar System (sub-km asteroids) will be revealed, and the solution to a long-standing problem in planetary science will be at hand. The Spitzer Space Telescope can be used to show conclusively whether or not these small asteroids are indeed devoid of regolith. We propose to observe 60 asteroids to test for the absence of regolith at sizes smaller than 5 km. Half of these asteroids have sizes near 10 km, and the other half have sizes near 1 km. We will use the power of Spitzer Peak-Up Imaging to derive the average thermal inertias for the two populations. If the predictions are correct, the thermal inertias should be significantly different. The results of this program will reveal a fundamental physical property of asteroids and help answer the long-outstanding ''S asteroid'' problem.

Spitzer Space Telescope - Directors Discretionary Time Proposal #465

DDT observations of five Mars Trojan asteroids

Principal Investigator: David Trilling
Institution: U. Arizona

Technical Contact: David Trilling, U. Arizona

Co-Investigators:
Andrew Rivkin, JHU/APL
John Stansberry, U. Arizona
Tim Spahr, Harvard/Smithsonian CfA
Josh Emery, NASA Ames/SETI Institute
Michael Mueller, U. Arizona

Science Category: asteroids
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 2.6

Abstract:
Mars Trojan asteroids are the only small bodies known to inhabit dynamically stable orbits in the inner Solar System. By studying these objects, we are directly studying the building blocks of terrestrial planets. We have recently completed two papers that demonstrate, surprisingly, that the compositions and formation environments of the brightest Mars Trojans are remarkably diverse. These recent results used the best available ground-based facilities, so to extend these results we must turn to Spitzer. We propose here to obtain Spitzer measurements of five Mars Trojans (of eight known). We will determine albedos -- a good proxy for composition -- for these five objects through IRS PUI imaging (in combination with new ground-based data). We will also obtain a low resolution spectrum of the brightest Mars Trojan to calibrate our thermal models and study that object's mineralogy. The total requested time is small. DD time is required because these five objects have no visibility windows during Cycle 5, but are available during Fall/Winter, 2007.

Spitzer Space Telescope - Archive Research Proposal #50274

The Spitzer Asteroid Catalog III: The Pan-STARRS 1 era

Principal Investigator: David Trilling
Institution: University of Arizona

Technical Contact: David Trilling, University of Arizona

Co-Investigators:
Mark Sykes, PSI
Lawrence Wasserman, Lowell Observatory
John Stansberry, University of Arizona
Bidushi Bhattacharya, SSC/IPAC/JPL
Timothy Spahr, SAO

Science Category: asteroids
Dollars Approved: 50000.0

Abstract:
Understanding the global properties of the asteroid population today gives us insight into the processes, compositions, and timescales of planet formation as well as the post-formation dynamical evolution that sculpted our Solar System. Asteroids appear serendipitously in a significant fraction of every Spitzer image taken. We propose to continue building the Spitzer Asteroid Catalog by identifying, extracting, cataloging, and analyzing serendipitous observations of asteroids in the Spitzer archive by extending our work into the revolutionizing Pan-STARRS 1 era. Our results to date show that the the biggest source of error by far is bad visible magnitudes. It is also clear that our catalog is limited by the sensitivity of current ground-based surveys. Data from Pan-STARRS 1 will improve orbits and photometry to such an extent that the useful size of the Spitzer Asteroid Catalog will at least double, and in time increase to ~100,000 asteroids. We will derive sizes and albedos for all of these asteroids. The resulting databases will allow rich science investigations into the composition, evolution, and dynamical history of the asteroid belt and be a legacy of the Spitzer Space Telescope for decades to come.

Spitzer Space Telescope - General Observer Proposal #30080

Worlds in Collision: Spitzer observations to improve our understanding of the collisional history and future of asteroids.

Principal Investigator: Jeffrey Van Cleve
Institution: Ball Aerospace and Technology Corporation

Technical Contact: Jeffrey Van Cleve, Ball Aerospace

Co-Investigators:
David Vokrouhlicky, Charles University/Southwest Research Institute
Harold Reitsema, Ball Aerospace & Technologies Corp.
Steve Ostro, JPL
Mike Werner, JPL
Joe Spitale, U of Arizona, LPL

Science Category: asteroids
Observing Modes: IrsMap IrsPeakupImage IrsStare
Hours Approved: 10.7

Abstract:
This proposal studies the collisional history and future of asteroids using Spitzer observations, in combination with radar and visible light curve data available from the literature or from our collaborators. There are 3 specific topics in this theme: the Yarkovsky Effect, the YORP effect, and recent collision-generated asteroid families. Understanding the formation and migration of asteroids into potentially hazardous (or useful) orbits in the Near-Earth region requires relating all three topics. The Yarkovsky Effect is the force on a small body due to asymmetric re-radiation of absorbed sunlight on the warmer 'afternoon' side of a spinning asteroid. The YORP Effect is the angular momentum complement to Yark, in which thermal radiation by a surface of an irregularly shaped object results in a torque which may secularly affect both the rotation frequency and the obliquity of the spin axis.

Spitzer Space Telescope - General Observer Proposal #50650

The Temperatures of Large Dust Grains emitted from 67P/Churyumov-Gerasimenko

Principal Investigator: Jessica Agarwal
Institution: ESTEC, European Space Agency

Technical Contact: Jessica Agarwal, ESTEC, European Space Agency

Co-Investigators:
Eberhard Gruen, LASP, Boulder
William Reach, IPAC/SSC/Caltech
John Stansberry, Steward Observatory, Tucson
Mark Sykes, Planetary Science Institute, Tucson

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 13.5

Abstract:
We propose to observe the coma and specific sections of the dust trail of Rosetta target comet 67P/Churyumov-Gerasimenko (CG) using MIPS Photometry mode at 24 and 70 micron under two different viewing geometries (visibility windows in June/July 2008 and November 2008 to January 2009). Dust trails consist of mm-cm sized particles that trace out a portion of their parent comet's orbit and comprise a record of the continuous history of emission of these large particles. The proposed observations will extend earlier Spitzer programs on the CG dust trail (PIDs 210 and 20235) to the 70 micron range, rendering the first two-colour data of a cometary dust trail since IRAS. They will also provide the first mid-infrared images of the coma and young tail of comet CG. They will allow us to derive the temperature of the trail particles under two different insolation angles and thereby to probe if these particles are able to sustain a temperature gradient, which will provide information on their porosity and heat conductivity. The measured surface brightness of the trail as a function of distance from the nucleus and time will - together with the temperature information - allow us to refine our existing models of the emission history and dynamical properties (sensitivity to radiation pressure) of the grains. The modelling results will be used to predict the large particle environment that Rosetta will face on approach to the comet and during operations. Complementary to modelling of the dust trail, the production of large particles will be directly observable in the developing coma of the comet that during Cycle 5 approaches its perihelion in February 2009.

Spitzer Space Telescope - Directors Discretionary Time Proposal #223

The Size, Shape, and Albedo of Deep Impact Target 9P/Tempel 1

Principal Investigator: Michael A'Hearn
Institution: University of Maryland

Technical Contact: Carey Lisse, JHU-APL

Co-Investigators:
C. Lisse, Johns Hopkins University Applied Physics Lab
Y. Fernandez, IfA, University of Hawaii
M. Belton, Belton Space Exploration Initiatives
O. Groussin, University of Maryland
K. Meech, IfA, University of Hawaii
J. van Cleve, Ball Aerospace

Science Category: comets
Observing Modes: IrsStare
Hours Approved: 6.0

Abstract:
The Deep Impact mission, the eighth mission in NASA's Discovery Program, will launch on 30 Dec 2004 and will impact the nucleus of comet 9P/Tempel 1 on 4 July 2005. Delivering an impactor to a cometary nucleus and observing the results of the impact is a challenging task. Mission success depends critically on the ability of the DI spacecraft to navigate to the comet. Despite robust targeting algorithms, large uncertainties in size, shape, albedo distribution, and rotational state significantly degrade the probability that the impactor will land in a sunlit portion of the surface that is observable from the flyby. The uncertainties in the size, axial ratio, and rotational state further jeopardize the ability of the flyby spacecraft to point its High Resolution Instrument at the actual impact site with sufficient precision to ensure it is in the field of view. Current estimates of the comet's size using Keck LWS observations are uncertain by 50% [1] and they have provided no information on the distribution of albedo. Although uncertainty in the phasing of the optical lightcurve represents a large part of that error, there is also a significant uncertainty due to the combination of low SNR in the data from Keck and the limited spectral range over which data could be obtained. In order to improve our estimate of the size and shape of the nucleus of Tempel 1, we must obtain data with much higher SNR and with one-hour time resolution over a significant portion of the rotational light curve when the comet is inactive. We must determine whether or not there are large variations in albedo across the surface in order to ensure that the rotational light curve from optical data can be used to predict the convex hull of the actual shape. The observations of comet Borrelly from the Deep Space 1 have been interpreted as showing large variations in albedo but other investigators have questioned the conclusion, suggesting that the variations are primarily due to slope changes, thus leaving the question of albedo variations undecided. Tempel 1 is available in only one SIRTF viewing window before it is expected to be close enough to the sun to become active, namely the window from 27 February through 29 April 2004, before the first GO observing period, at ~3.7 AU from the Sun. The expected peak thermal flux will be ~ 10 mJy at 20 μm, easily detectable by SIRTF in a short integration time.

Spitzer Space Telescope - Directors Discretionary Time Proposal #265

Observations of the activating Centaur 2000 EC98

Principal Investigator: James Bauer
Institution: Jet Propulsion Laboratory

Technical Contact: James Bauer, Jet Propulsion Laboratory

Co-Investigators:
Youn-Jun Choi,
Paul R. Weissman,
Yan R. Fernandez,

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 2.0

Abstract:
On the next-to-last day of 2005, an amazing discovery was made. A modest member of a population of minor planets was suddenly found to be outbursting, and the object, originally classified as an astroidal body with no visible sign of coma or non-rotational photometric variation, had become a comet. 2000 EC98 is a Centaur, a class of objects which have long been suspected as the precursors to many of the comets in our Solar System, but not proven so. This previously quiescent, though fairly well studied, body has afforded the astronomy community the opportunity to observe the changes which the earliest onset of cometary activity may bring to a planetary surface, and to test the theories as to which physical characteristics may herald the potential for future activity and the existence of primordial substances, like volatiles, within the outer Solar System's asteroidal populations. We are requesting director's discretionary time on the Spitzer Space Telescope to observe t his rare event, while the Centaur is still newly active, so that we may characterize the changes taking place on the nucleus, the robustness of the activity, and the nature of the dust in the coma at this early outburst stage. Unlike the surfaces of Jupiter Family comets, which have been processed by long periods of activity, and unlike the few other active Centaurs, which have been discovered after their onset of activity, this would be the first and rare opportunity to study changes on a cometary surface as it goes from a likely long period of dormancy into strong outburst.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #210

Cometary Dust Trails

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: William Reach, Caltech

Science Category: comets
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 9.1

Abstract:
These observations search for large meteroids associated with short-period comets. We selected comets that have perihelion distance less than 3 AU and perihelion date 2002-2004. Images with MIPS or IRAC are made for a region at least 15 arcmin long along the comets' orbits. Spectra are taken, centered on the nucleus, to search for silicate features and measure dust temperature, which allows constrants to be placed on the size and composition of the recently-produced cometary particles as well as the albedo and diameter of the comet nucleus. For comet Encke, we make a spectrum or a region offset from the nucleus along the well-known debris trail. For the comet/asteroid transition object Phaethon, thought to be the parent of the Geminid meteor stream, we image a region along its orbit to see whether it is currently producing large meteoroids.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30010

Debris from Disintegrating Comets

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: William Reach, Caltech

Co-Investigators:
William Reach, SSC

Science Category: comets
Observing Modes: MipsPhot MipsScan
Hours Approved: 12.0

Abstract:
We propose to map the debris fields around 11 short-period comets, to search for meteor-sized particles and measure the mass of solid material ejected by comets. The observing program includes reobservations of the fields where large apparent debris fields (and possible multiple nuclei) of 3 comets were observed in GO1 during a survey of 30 comets. We will attempt to recover the nucleus of 104P/Kowal 2 and the debris field of 70P/Clark. We will map the 2007 apparition of comet 2P/Encke, and the 2006 close approach of comet 73P/SW3. And we will map 6 other comets making reasonable close approaches to Spitzer during the GO3 observing year.

Spitzer Space Telescope - Directors Discretionary Time Proposal #1095

Physical Evolution of Comets and Cometary Dust

Principal Investigator: Yanga Fernandez
Institution: Univ. of Central Florida

Technical Contact: Yanga Fernandez, Univ. of Central Florida

Science Category: comets
Observing Modes: IracMap IrsMap MipsPhot MipsScan MipsSed
Hours Approved: 16.0

Abstract:
Through the SIRTF Fellowship program, I will be studying the physical evolution of comets. This includes: understanding the thermal and optical properties of the surfaces of the nuclei, the behavior of the active regions, and the characteristics of the cometary dust grains. I will be observing comets from various dynamical classes: comets on their first trip from the Oort Cloud, Centaur-comets migrating in from the Kuiper Belt, highly-evolved short-period comets in the inner Solar System, and extinct-comet candidates. Since it is difficult to observe the aging of a comet in real time -- comets are active for 10^4 to 10^5 years and require 10^5 to 10^6 years to be perturbed into significantly different orbits -- understanding the life cycle of a comet is best achieved by looking at many comets from different dynamical families. The ultimate scientific goal is to place the comets in their proper context within the framework of Solar System formation and evolution.

Spitzer Space Telescope - General Observer Proposal #20697

Aphelion Behavior of Comet 2P/Encke

Principal Investigator: Yanga Fernandez
Institution: Univ. of Central Florida

Technical Contact: Yanga Fernandez, Univ. of Central Florida

Co-Investigators:
William Reach, IPAC/SSC
Carey Lisse, APL and UMd
Humberto Campins, U. Central Florida

Science Category: comets
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 5.3

Abstract:
We propose to observe comet 2P/Encke while it is near aphelion. While the comet has been studied extensively recently, understanding its mysterious photometric behavior has been difficult. The comet appears to be anomalously bright when near aphelion compared to what we know about the nucleus's size, albedo, shape, and rotation period. One solution is that the comet is active and has a variable coma, even at these large heliocentric distances. The comet however always appears as a point-source at aphelion, so any coma must remain within the seeing disk. Near aphelion the comet is too faint to study from the ground at the mid-IR wavelengths where more detailed characterizations of the dust can be measured. An active P/Encke at aphelion would require a reevaluation of its total mass loss per orbit, and by extension of the rest of the Jupiter family of comets. The phenomenon has implications for cometary evolution as well as for the source of the interplanetary dust environment. We propose to address this issue by obtaining infrared spectrophotometry and imaging of P/Encke. We will focus on the Wien-law side of the comet's spectral energy distribution over the course of an 11.1-hour rotation period. Our scientific goals are: (a) make an independent measurement of the nucleus's size, (b) determine the contribution of dust to the comet's flux, (c) monitor the dust's contribution over a whole rotation, and (d) understand the comet's aphelion mass loss rate in the context of its life history.

Spitzer Space Telescope - General Observer Proposal #30908

Survey of Ensemble Physical Properties of Cometary Nuclei

Principal Investigator: Yanga Fernandez
Institution: Univ. of Central Florida

Technical Contact: Yanga Fernandez, Univ. of Central Florida

Co-Investigators:
Carey Lisse, Johns Hopkins University Applied Physics Laborator
William Reach, Caltech/SSC
Humberto Campins, University of Central Florida
Michael A'Hearn, University of Maryland, College Park
Karen Meech, University of Hawaii
James Bauer, NASA/Jet Propulsion Laboratory
Javier Licandro, Instituto de Astrofisica de Canarias
Stephen Lowry, Queen's University Belfast
Harold Weaver, Johns Hopkins University Applied Physics Laborator
Philippe Lamy, Laboratoire d'Astrophysique de Marseille
Imre Toth, Konkoly Observatory
Olivier Groussin, University of Maryland

Science Category: comets
Observing Modes: IrsPeakupImage MipsPhot
Hours Approved: 105.4

Abstract:
We propose to make an albedo and radius survey of 100 cometary nuclei using IRS PU and MIPS imaging. We focus on Jupiter family comets (JFCs), which have dynamical and evolutionary connections to other Solar System groups: transneptunian objects (TNOs), Centaurs, Trojan asteroids, and extinct comet candidates. However, among these groups, the nuclei of JFCs remain the _only_ group not yet the subject of a detailed mid-infrared survey. Understanding the evolution of comets since formation is crucial for unlocking their secrets about the thermophysical and compositional environment of the protoplanetary disk. An important way to do this is to study comparisons and contrasts among comets, and between comets and related dynamical groups. To this end, we propose a mid-IR survey of JFCs. Our scientific goals are as follows. 1) Measure the thermal emission from the JFC nuclei to calculate their effective radii. 2) Use complementary ground-based visible-wavelength observations to derive the nuclei's geometric albedos. Note that simultaneity for these observations is not needed. 3) Compare the cometary albedo distribution with those of Centaurs, TNOs, Trojans, and extinct comet candidates to gauge the effects of surface evolution. The glaring albedo difference between TNOs and Centaurs versus other groups needs to be explained. 4) Test for correlations between cometary albedos and other properties of the nuclei, such as composition and dynamical age. 5) Resolve once and for all the long-standing question of just how safe it is to assume an albedo for a cometary nucleus. 6) Use these radii to derive a completely new and independent estimate of the current JFC size distribution that will resolve the ongoing debate between several groups. The number of targets in our sample is driven by the need to test recent indications that the size distribution is truncated at radii smaller than 2 km. In such a case, ours would be the definitive study of the JFC size distribution.

Spitzer Space Telescope - General Observer Proposal #50066

C/Hale-Bopp (1995 O1) at 27 AU

Principal Investigator: Yanga Fernandez
Institution: Univ. of Central Florida

Technical Contact: Yanga Fernandez, Univ. of Central Florida

Co-Investigators:
Laura Woodney, California State Univ., San Bernardino

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 2.9

Abstract:
Comet C/1995 O1 Hale-Bopp (hereafter HB) was one of the most active comets of all time when it passed perihelion in April 1997. During Cycle 5 it will be at a heliocentric distance (r) over 27 AU. Remarkably, the comet is still bright enough for visible and infrared study. This represents an utterly unique chance to observe a comet at extremely high heliocentric distance. Our scientific goals are to: (A) resolve the long-standing controversy of how large HB's nucleus really is, (B) measure HB's current activity level and dust production rate, and (C) use these two parameters in conjunction with earlier measurements of gas and dust production rates to understand the structure of the ice and flow of energy through the nucleus. In addition we will (D) use dynamical modeling of the dust to constrain grain sizes, grain speeds, and source regions on the nucleus. But the basic question we wish to answer is: Why is HB so active so far from the Sun? This program requests 2 AORS of MIPS photometry for a total of 2.9 hours of observing time.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #119

SIRTF Obeserbations of Comet P/Encke

Principal Investigator: Robert Gehrz
Institution: University of Minnesota

Technical Contact: Elisha Polomski, University of Minnesota

Science Category: comets
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 1.0

Abstract:
We will obtain far infrared images of coet P/Enck to determine the extent and composition of its coma.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #131

IRAc and MIPS Images of Comet P/Halley and MIPS Images of Comet P/Pons-Winnecke

Principal Investigator: Robert Gehrz
Institution: University of Minnesota

Technical Contact: Elisha Polomski, University of Minnesota

Science Category: comets
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 9.4

Abstract:
We will attempt to detect the emission from the bare nucleus of Comet P/Halley and emission from the cmoa of Comet P/Pons-Winnecke.

Spitzer Space Telescope - General Observer Proposal #40270

Measuring the physical properties of the nucleus of comet 8P/Tuttle

Principal Investigator: Olivier Groussin
Institution: Laboratoire d'Astrophysique de Marseille

Technical Contact: Olivier Groussin, Lab. d'Astrophysique de Marseille

Co-Investigators:
Philippe Lamy, Laboratoire d'Astrophysique de Marseille
Laurent Jorda, Laboratoire d'Astrophysique de Marseille
Michael Kelley, University of Central Florida
Yanga Fernandez, University of Central Florida
Imre Toth, Konkoly Observatory of Budapest
Hal Weaver, John Hopkins University

Science Category: comets
Observing Modes: IrsStare MipsPhot
Hours Approved: 0.4

Abstract:
Comet 8P/Tuttle is a returning nearly isotropic comet (NIC), i.e., an "Oort cloud comet", with an outstanding apparition in cycle 4, passing within 0.25 AU of the Earth. We propose to observe it with MIPS (photometry at 24 and 70 micron) and IRS (spectroscopy in the 5-38 micron range), to measure the physical properties of its nucleus: size, shape, rotation period, thermal inertia and mineralogy. This will provide the most detailed view of a NIC nucleus since the spacecraft flyby of 1P/Halley in 1986. The return of 8P is a rare opportunity that Spitzer should not miss. The results should yield a comprehensive picture of this NIC that can be compared to the detailed data collected on ecliptic comets (ECs) during the past 3 decades. The differences and similarities between NICs and ECs should yield valuable insights into the origin and evolution of comets.

Spitzer Space Telescope - General Observer Proposal #20235

The Large Particle Emission History of Rosetta Target 67P/Churyumov-Gerasimenko

Principal Investigator: Eberhard Gruen
Institution: University of Hawaii

Technical Contact: Eberhard Gruen, University of Hawaii

Co-Investigators:
Mark Sykes, Planetary Science Institute
William Reach, Spitzer Science Center
David Lien, Planetary Science Institute

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 11.4

Abstract:
We propose to observe the dust trail of the Rosetta target 67P/Churyumov-Gerasimenko using a series of 24 micron MIPS mapping grids at medium scan speed in order to generate a detailed dust emission model for the comet that will be used to predict the large particle environment that will be faced by Rosetta on approach and during operation. This trail was first detected by the Infrared Astronomical Satellite at far less sensitivity than is afforded by Spitzer. This observation extends the earlier Spitzer COMDUST observation (PI Fazio) of this comet in two important aspects: it quantifies the dust emission at large heliocentric distances which is indicated in the earlier observation, and it extends the characterization of large particles' emissions during previous apparitions of this comet. Dust trails consist of mm-cm size particles that trace out a portion of their parent comet's orbit and comprise a record of the continuous history of emission. We propose to map the trail from 0.2 degrees in the leading direction to 0.6 degrees in the trailing direction. This is more than a factor two larger than the previous image. The forward part of the trail is of particular interest in understanding the size-distribution and emission history of large particles. Making use of the simultaneous (though less complete) scans with the 70 micron array, we will be able to determine variations in particle properties with size. Visibility windows are available in July 2005 and March 2006.

Spitzer Space Telescope - General Observer Proposal #50335

Mediating the Controversy over Cometary PAHs and Hydrated Dust Grains Using High Signal-to-Noise 5-35 micron IRS Spectra of Five Comets

Principal Investigator: David Harker
Institution: University of California, San Diego

Technical Contact: David Harker, University of California, San Diego

Co-Investigators:
Charles Woodward, University of Minnesota
Michael Kelley, University of Central Florida
Diane Wooden, NASA Ames Research Center
Dominique Bockelee-Morvan, LESIA, Observatoire de Paris
Jacques Crovisier, LESIA, Observatoire de Paris

Science Category: comets
Observing Modes: IracMap IrsMap
Hours Approved: 15.3

Abstract:
We propose a 15.3 hr program to study the water and dust from five solar system comets during a period of active water and dust production (heliocentric distances < 3 AU) in CY5. With high signal-to-noise ratio (SNR > 100) IRS SEDs of each comet, we will be able to constrain the grain parameters of the refractory materials and model the water lines in the 5-7 micron region. Modeling the water fundamental band in the 5-7 micron region is critical for constraining at <2% the spectral signatures of carbonates and PAHs. We will also constrain phyllosilicates and crystalline silicates using the 7-35 micron SED. Species of dust such as carbonates, phyllosilicates, and PAHs have reportedly been detected in Spitzer IRS observations of comet 9P/Tempel~1 (lisse et al. 2006), however, they have not been detected in our IRS spectra of comet C/2003 K4 (LINEAR) (Woodward et al. 2007), nor in Stardust return samples (Brownlee et al. 2006). Such aqueously altered species and PAHs could be important discriminators between the dynamical comet families ecliptic comets (ECs, short-period Jupiter Family comets) and nearly isotropic comets (NICs, long period Oort cloud comets). Constraining the relative abundance of the refractory dust grains, specifically the silicate crystalline-to-amorphous ratio and placing limits on PAHs and aqueously altered species, along with the OPR of water, allows us to place strong limits on thermal processing and radial mixing in solar nebula models. Therefore, we can test the newest dynamical models on the origin of ECs and NICs. Only Spitzer's superior sensitivity and wavelength coverage can provide the data to rigorously model the water lines and fit multiple dust spectral features of major and minor dust components.

Spitzer Space Telescope - General Observer Proposal #40042

An In-depth Study of the Dust of Comet 46P/Wirtanen

Principal Investigator: Michael Kelley
Institution: University of Central Florida

Technical Contact: Michael Kelley, University of Central Florida

Co-Investigators:
David Harker, University of California, San Diego
Chick Woodward, University of Minnesota
Diane Wooden, NASA/Ames Research Center
Humberto Campins, University of Central Florida

Science Category: comets
Observing Modes: IrsStare MipsPhot
Hours Approved: 9.7

Abstract:
We propose a 9.7 hr project to study, in-depth, the dust of comet 46P/Wirtanen through Spitzer/IRS observations of its ejected grains. The relative locations of comet Wirtanen, Spitzer, and the Sun allow for a continuous visibility window 230 days in length, centered near the comet's perihelion (February 2008). The excellent capabilities of the IRS allow us to take advantage of this rare opportunity throughout the entire visibility window. We will monitor and assess the ejected dust mineralogy as insolation varies on the nucleus and the comet undergoes vigorous coma activity, giving us insight into the structure of comet Wirtanen's nucleus and the mineralogy of its formation zone in the early solar system. Our AORs are designed to attain signal-to-noise ratios large enough to detect crystalline silicates in this ecliptic comet, similar to those found in the pre-Deep Impact spectrum of comet 9P/Tempel. The proposed observations will observe the comet six times to obtain complete spectral energy distributions from 5-40 microns (9.5 hr), as comet Wirtanen travels from 1.5 AU pre-perihelion through 2.0 AU post-perihelion. The resultant data set will be, in terms of signal-to-noise and temporal coverage, analogous to the data obtained by the many mid-IR investigations of comet C/1995 O1 (Hale-Bopp). We also request one MIPS observation (0.2 hr) at 2.5 AU pre-perihelion to verify the comet's ephemeris and nucleus size, and to study the largest grains ejected during previous perihelia.

Spitzer Space Telescope - General Observer Proposal #50022

Creating Synergy Between Spitzer and Rosetta: The Coma of Comet 67P/Churyumov-Gerasimenko

Principal Investigator: Michael Kelley
Institution: University of Central Florida

Technical Contact: Michael Kelley, University of Central Florida

Co-Investigators:
Diane Wooden, NASA Ames
Charles Woodward, University of Minnesota
David Harker, UCSD / CASS
Hermann Boehnhardt, Max Planck Institute for Solar System Research
Cecilia Tubiana, Max Planck Institute for Solar System Research

Science Category: comets
Observing Modes: IracMap IrsMap
Hours Approved: 11.6

Abstract:
We propose an 11.6 hr program to complete our Spitzer mid-infrared study of comet 67P/Churyumov-Gerasimenko by obtaining observations of the comet during cycle 5 at heliocentric distances between 1.75 and 1.35 AU as it approaches perihelion. Comet 67P is the primary target of the European Space Agency's Rosetta mission. Rosetta will provide the first synoptic study of a comet, including a survey of the nucleus heterogeneities and their relation to comet activity. However, Rosetta will not be able to directly study how nuclear inhomogeneities manifest themselves as large scale coma structures or as IR spectroscopic features, and thus Rosetta alone will not provide the view needed to compare 67P with comets solely studied by remote sensing techniques. We propose IRS spectral maps and IRAC images to assess the composition of discrete active areas by investigating rotationally-variant IR spectra and imagery at four rotational phases. The synergy between Spitzer and Rosetta will demonstrate if cometary nuclear heterogeneities can be detected using IR remote sensing techniques. With Spitzer, we seek to: 1) derive the dust production rate; 2) assess the dust composition and grain size distribution; 3) assess the CO, CO2, and water contributions to the volatile gas production rates; and 4) investigate the heterogeneous dust and volatile composition of the nucleus.

Spitzer Space Telescope - General Observer Proposal #20001

A Multiwavelength Investigation of Comet 73P/SW3-C

Principal Investigator: Philippe Lamy
Institution: Laboratoire d'Astronomie Spatiale, Marseille

Technical Contact: Philippe Lamy, Laboratoire d'Astronomie Spatiale

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 2.1

Abstract:
The nucleus of comet 73P/Schwassmann-Wachmann-3 experienced a non-tidal breakup in late 1995. The largest fragment (73P/SW3-C) survived its subsequent perihelion passage in 2001 and will return in 2006, when it will pass very close to (0.08AU) Earth. This represents an outstanding opportunity to characterize a fresh cometary nucleus, and we propose an intensive investigation using both the Hubble and Spitzer telescopes. Employing the technique that our group has developed over the past decade to characterize 31 cometary nuclei, we will use HST/ACS to photometrically resolve the nucleus of 73P/SW3-C at optical wavelengths and SST/MIPS to do the same thing at thermal infrared wavelengths, thereby allowing us to determine both the size and albedo of this fragment. We also plan to measure the lightcurve of 73P/SW3-C to obtain detailed shape information, and use HST/NICMOS to probe the composition, in particular to search for evidence of icy material on the fresh surface. Previous observations indicate that most of the remaining mass of 73P/SW3 is in the form of numerous small fragments. A few of those may have been captured by the C fragment, and the determination of their orbits would allow the first, direct measurement of the mass of a cometary nucleus. Thus, we will also perform a deep search for any possible companions to the C-fragment.

Spitzer Space Telescope - Directors Discretionary Time Proposal #222

Measuring the Size and Shape of Comet 67P/Churyumov-Gerasimenko, the Target of the Rosetta Mission

Principal Investigator: Philippe Lamy
Institution: Laboratoire d'Astronomie Spatiale, Marseille

Technical Contact: Philippe Lamy, Laboratoire d'Astronomie Spatiale

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 1.9

Abstract:
In support of the Rosetta mission, we request Director's Discretionary time to measure the size and shape of its target, the nucleus of comet 67P/Churyumov-Gerasimenko. A safe landing of the Lander package on its surface remains critically dependent upon its size which is not unambiguoulsy determined from visible photometry because of the uncertainty on its albedo. On the contrary, measurements of the thermal emission of the nucleus will allow a direct determination of its size. Observations with the Spitzer Space Telescope in late February 2004 will provide the best possible data thanks to very favourable observing conditions. We propose to use MIPS to image the nucleus at 24 microns seventeen times, over a time interval of 12.5 hr to as to cover the full light curve of the nucleus and derive both its size and shape. Complementary observations at 70 microns will help constraining its SED and the thermal model to interpret the data. By further combining with past HST observations, the rotational state of the nucleus will be better con strained and the albedo will be determined thus allowing to characterize its surface.

Spitzer Space Telescope - General Observer Proposal #3658

Comet 9P/Tempel 1 During the Deep Impact Encounter

Principal Investigator: Carey Lisse
Institution: University of Maryland

Technical Contact: Carey Lisse, U. Maryland

Co-Investigators:
Michael A'Hearn, University of Maryland
Michael Belton, Belton Space Exploration Initiatives
Yanga Fernandez, IfA, University of Hawaii
Tony Farnham, University of Maryland
Olivier Groussin, University of Maryland
Karen Meech, IfA, University of Hawaii
Peter Schultz, Brown University
Jeff Van Cleve, Ball Aerospace

Science Category: comets
Observing Modes: IRS IrsMap
Hours Approved: 17.0

Abstract:
On July 4, 2005 NASA's discovery mission Deep Impact (hereafter DI) will send a 375 kg impactor into the nucleus of comet 9P/Tempel 1 at 10.2 km/s relative velocity in order to produce a crater that will reveal sub-surface layers of the nucleus. To maximize the scientific return of the DI mission, we propose to use the Spitzer[f1] Space Telescope to observe the comet before, during, and after the impact. Using the IRS at 5 - 40 um, we will be able to study the composition of the neutral gas coma and the size and composition of the emitted dust. Any changes in the observed properties of the comet after a new equilibrium has been reached will be attributable to the removal of a section of evolved, insolated surface and the exposure of the relatively fresh sub-surface interior of the nucleus.

Spitzer Space Telescope - General Observer Proposal #3660

The Dust Environment of Comet 9P/Tempel 1

Principal Investigator: Carey Lisse
Institution: University of Maryland

Technical Contact: Carey Lisse, U. Maryland

Co-Investigators:
Michael A'Hearn, University of Maryland
Michael Belton, Belton Space Exploration Initiatives
Yanga Fernandez, IfA, University of Hawaii
Tony Farnham, University of Maryland
Olivier Groussin, University of Maryland
Karen Meech, IfA, University of Hawaii
Jeff Van Cleve, Ball Aerospace

Science Category: comets
Observing Modes: IrsMap IrsStare MipsPhot
Hours Approved: 8.7

Abstract:
On July 4, 2005 NASA's discovery mission Deep Impact will encounter comet 9P/Tempel 1. During this encounter, an impactor will be released, and will strike the nucleus, producing a crater that will be studied by a separate flyby spacecraft. In support of this mission, we propose to use Spitzer Space Telescope observations to characterize the dust environment around the nucleus, with two main goals in mind. First, these observations, in conjunction with observations from our existing ground-based database, promise to reveal fundamental information about the physical and chemical properties of the dust grains in the comet's coma, and these results can be used in comparative studies of the dust in other comets. Second, the data will be used in support of the DI mission, providing constraints on the grain properties that will be invaluable in the analysis of the encounter phase hazards.

Spitzer Space Telescope - Directors Discretionary Time Proposal #291

IRS Observations of the Primeval Dust and Nucleus Surface of the Extraordinary Comet of 2007, C/McNaught 2006 (P1)

Principal Investigator: Carey Lisse
Institution: Johns Hopkins University - APL

Technical Contact: Carey Lisse, JHU-APL

Co-Investigators:
Yanga Fernandez, University of Central Florida
G. Jones, U. College London
Michael Sitko, Space Science Institute
N. Dello Russo, JHU-APL

Science Category: comets
Observing Modes: IrsStare IrsPeakupmage
Hours Approved: 1.3

Abstract:
Comet McNaught 2006 (P1) is one of the most awe-inspiring comets of modern times, rivaling the two most spectac ular modern comets C/West 1975 and C/Hale-Bopp 1995 O1. Unremarkable and almost completely unstudied until shortly before its perihelion passage in December 2006, this comet became unexpectedly bright and active on the incoming leg of its close perihelion passage (q = 0.17 AU). McNaught is dynamically new from the Oort cloud, meaning that it has not passed through the inner solar system since its formation and ejection from the giant planet region of the Proto-Solar Nebula 4.5 Byrs ago, and its composition appears highly unusual, rich in H2O and NH3 but poor in CO and CH4. It is emitting large amounts of near-pristine PSN material easily detectable by Spitzer during an April 27 - May 18 IRS window of opportunity. Observations of this material promise to be as paradigm changing as the ISO observations of Hale-Bopp in 1996.

Spitzer Space Telescope - Directors Discretionary Time Proposal #460

Recovery and Characterization of the NASA EPOXI Mission Target Comet 85P/Boethin

Principal Investigator: Carey Lisse
Institution: Johns Hopkins U.

Technical Contact: Carey Lisse, JHU

Co-Investigators:
Michael A'Hearn, University of Maryland
Tony Farnham, University of Maryland
Yan Fernandez, University of Central Florida
Olivier Groussin, Laboratoire d'Astrophysique de Marseille
Karen Meech, University of Hawaii
William Reach, Spitzer Science Center

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 15.2

Abstract:
In July 2007 NASA selected the EPOXI mission for flight operations. This mission utilizes the Deep Impact flyby spacecraft, which survived encounter with comet 9P/Tempel unscathed after returning, in conjunction with Spitzer, a wealth of data on the primordial makeup of comets. EPOXI will rendezvous with comet 85P/Boethin (Boethin) and obtain comparable observations. However, little is known about it, and nothing definitive is known about its nucleus, not its size, rotation rate, albedo, or thermal inertia. Mission success depends critically on the ability of the EPOXI spacecraft to navigate to the comet. Despite robust targeting algorithms, large uncertainties in size, shape, albedo distribution, and rotational state significantly degrade the probability that the spacecraft will view a sunlit portion of the surface. Another critical point is the fact that the comet has not been seen in over 20 years due to unfavorable observing geometry, despite intense visible-wavelength searches by the EPOXI team over the last two years using 8-meter class telescopes (including Subaru and VLT in June-July 2007). Fortunately, the mid-1980s orbit determination is good enough to establish a long, but narrow region along the comet's orbital path where the nucleus is located. We propose here to use Spitzer?s MIPS 24 um imager to recover and characterize comet 85P/Boethin. This imager is highly sensitive to cold solar system objects, and with the stable hardware and large field of view it is actually easier to recover this comet in the mid-infrared than it is in the visible. The final decision to fly to Boethin must be made no later than 2007 Oct 1, to allow proper EPOXI trajectory corrections to be made. Our proposal calls for recovery of comet Boethin during the MIPS 44 campaign, Sept 15 - 20, 2007. The recovery involves a moving-cluster mode MIPS 24um map of a 1-degree long strip of the sky at 24 um observed over 2 days utilizing 15.2 hrs of telescope time.

Spitzer Space Telescope - General Observer Proposal #50593

Characterization of the NASA EPOXI Mission Target Comet Nucleus 103P/Hartley 2

Principal Investigator: Carey Lisse
Institution: Johns Hopkins University - Applied Physics Laborat

Technical Contact: Carey Lisse, JHU - APL

Co-Investigators:
Michael A'Hearn, University of Maryland
Tony Farnham, University of Maryland
Yanga Fernandez, University of Central Florida
Olivier Groussin, Laboratoire d'Astrophysique de Marseille
Karen Meech, Univeristy of Hawaii
William Reach, SSC/IPAC

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 2.6

Abstract:
In July 2007 NASA selected the EPOXI mission for flight operations. This mission utilizes the Deep Impact flyby spacecraft, which survived encounter with comet 9P/Tempel (T1) unscathed after returning, in conjunction with Spitzer, a wealth of data on the primordial makeup of comets. EPOXI will rendezvous with comet 103P/Hartley2 (H2) and obtain comparable remote imaging observations of the nucleus surface. However, little is known about its nucleus, not its size, rotation rate, or albedo. Mission success depends critically on the ability of the EPOXI spacecraft to navigate to the comet and make accurate, non-saturated measurements. Despite robust targeting algorithms, large uncertainties in size, shape, albedo, and rotational state significantly degrade the probability that the spacecraft will view a sunlit portion of the surface. We propose here to use Spitzer's MIPS 24 um imaging camera to characterize the nucleus of comet 103P/Hartley2. Observing the comet at 5 different epochs will allow easy detection of the moving object vs. background stellar sources, as well as providing a gross measure of the rotational variability. The derived science will add directly to the JFC nucleus survey of Fernandez et al (PID 30908), and the comet trail survey of Reach et al (PID 3119). Our proposal calls for characterization of H2 during the 11 Aug - 20 Sep 3008 observability window, the only one available during Cycle 5, when the comet will be 5.4 AU from the Sun and 5.0 AU from Spitzer, well outside the ice line and thus inactive. The characterization involves fixed- single mode, dithered MIPS maps of the region immediately surrounding the comet, performed 5 times to verify the motion of the target. The total telescope time requested is 2.64 hours.

Spitzer Space Telescope - Directors Discretionary Time Proposal #256

Ejecta from comet Tempel 1

Principal Investigator: William Reach
Institution: Caltech

Technical Contact: Mark Sykes, Planetary Science Institute

Co-Investigators:
Mark Sykes, Planetary Science Institute
David Lien, Planetary Science Institute
Carey Lisse, Johns Hopkins U.
Michael Kelley, U. Minnesota

Science Category: comets
Observing Modes: IracMap MipsPhot
Hours Approved: 11.5

Abstract:
We propose to observe comet 9P/Tempel 1 at three epochs to monitor the evolution of its debris. The observations will be combined with those already obtained in July 2005. The Deep Impact event on July 4, 2005 liberated copious small grains, but it is not known whether larger debris, which is difficult as it remains very close to the nucleas, was produced. Meteor-sized particles produced in the impact will gradually separate from the comet, with larger and larger particles becoming detectable as time goes on. In addition to Deep Impact-generated debris, we will study the evolution of the naturally-produced debris, using a single model of the dust production history to match all epochs. We will use IRAC images from Jul-Sep 2005 to search for extended CO+CO2 emission from the comet and to measure the color of the debris.

Spitzer Space Telescope - Directors Discretionary Time Proposal #274

Extended imaging of the String of Pearls from comet 73P

Principal Investigator: William Reach
Institution: Caltech

Technical Contact: William Reach, Caltech

Co-Investigators:
Michael Kelley, U. Minnesota
Mark Sykes, Planetary Science Institute
Carey Lisse, Johns Hopkins U.
Jeremie Vaubaillon, SSC

Science Category: Comets
Observing Modes: MipsScan
Hours Approved: 24.1

Abstract:
We request to make an image of the entire "String of Pearls" that is currently being created from comet 73P/Schwassmann-Wachmann 3. As part of a GO2 program (PID 20039) we imaged a field containing the two fragments (C and B) that were known at the time when the AORs were modified, a month before scheduling. The GO2 observations took place on 2006 Mar 28 (IRAC) and 2006 Apr 1 (MIPS) and worked flawlessly, perfectly framing the two main fragments and the bridge connecting them (which was the primary target of that proposal). In the meantime, 8 other fragments have been discovered and reported to the Minor Planet Center. Our GO2-observed (2006 April 1) field contains 2 other of these "known" fragments, but the remaining 6 "known" fragments lie behind the field we observed.

Spitzer Space Telescope - General Observer Proposal #3119

Survey of Cometary Debris Trails

Principal Investigator: William Reach
Institution: Caltech

Technical Contact: William Reach, Caltech

Co-Investigators:
Mark Sykes, University of Arizona
Michael Kelley, University of Minnesota
Masateru Ishiguro, University of Hawaii
David Osip, Las Campanas Observatory
Russ Walker, Monterey Institute for Research in Astronomy

Science Category: comets
Observing Modes: MipsPhot
Hours Approved: 14.1

Abstract:
We propose a MIPS 24 micron survey all short-period comets that will be bright during the 2004-5 observing season to search for large meteoroid production. The large particles will be dynamically separated from small dust particles in the wide-field images due to their different radiation pressure forces. Large particles are spread mostly behind the comet in a long, thin debris trail. The proposed survey will cover 25 comets and will help determine whether all comets produce large meteoroids. Large meteoroids are they dominant mass loss of comets, yet very little is known about them now. They are also important as potential hazards to spacecraft and are the same phenomenon as meteor showers.

Spitzer Space Telescope - Directors Discretionary Time Proposal #466

Eruption of comet 17P/Holmes

Principal Investigator: William Reach
Institution: Caltech

Technical Contact: William Reach, Caltech

Co-Investigators:
Carey Lisse, JHU/APL
Harold Weaver, JHU/APL
Jeremie Vaubaillon, Caltech

Science Category: comets
Observing Modes: IrsMap IrsPeakupImage MipsScan
Hours Approved: 12.0

Abstract:
Comet 17P/Holmes was reported to increase in brightness by 14 magnitudes on 2007 October 24. The material produced in this eruption is likely to be relatively pristine material that has not been exposed to sunlight since formation of the comet in the outer Solar System. Opportunities to measure such material are rare, and its mineralogy is of great interest. The nature of the eruption is unknown. Spitzer observations will distinguish between naturally-produced cometary dust (weak spectral features), fine ejecta from a violent event (strong dust features, as was found from Deep Impact), large meteoroids (featureless spectrum but debris trail), and fragmentation.

Spitzer Space Telescope - General Observer Proposal #20039

Disintegration of short-period comets

Principal Investigator: William Reach
Institution: Caltech

Technical Contact: William Reach, Caltech

Co-Investigators:
Mark Sykes, University of Arizona
Michael Kelley, University of Minnesota
Masateru Ishiguro, University of Hawaii
Carey Lisse, University of Maryland

Science Category: comets
Observing Modes: IracMap MipsPhot MipsScan
Hours Approved: 16.1

Abstract:
We propose to search for debris from short-period comets as they disintegrate in the inner Solar System. The debris is well-known as meteor showers for comets whose orbit intersects the Earth's, and as the dust trails discovered by IRAS. This proposal has three parts. (1) Continuation of a survey of for debris trails behind currently active short-period comets. The new observations will double the sample size from previous work, where small numbers (2-3 each) of comets had particularly unique properties, including no trail, massive trail comparable leading and trailing, and narrow trails much narrower than ever seen before. (2) Search for debris from recently-split comets in particular 73P/Schwassmann-Wachmann 3 which has an excellent viewing geometry during the GO2 period. The sum of known fragment masses appears to be much less than the original comet, meaning significant mass may be in the form of mm- to cm-sized debris similar to the IRAS trails. (3) Search for debris left behind by "dead" comets in particular 3D/Biela whose nucleus has not been recovered but which produced exceptional meteor showers in apparitions after being observed to split.

Spitzer Space Telescope - General Observer Proposal #20205

Infrared Spectroscopy of Comet 73P/Schwassmann-Wachmann 3

Principal Investigator: Michael Sitko
Institution: Space Science Institute

Technical Contact: Michael Sitko, Space Science Institute

Co-Investigators:
David Lynch, The Aerospace Corporation
Ray Russell, The Aerospace Corporation
Elisha Polomski, University of Minnesota
Barbara Whitney, Space Science Institute
Michael Wolff, Space Science Institute

Science Category: comets
Observing Modes: IrsMap IrsPeakupImage IrsStare
Hours Approved: 35.6

Abstract:
Observations of recently-fragmented short-period comets provide an opportunity to sample material in these objects which has not been subjected to hundreds or thousands of years of exposure to the effects of solar radiation. Repeated passages into the inner solar system are expected to deplete the surface layers of the smallest dust grains, the very ones responsible for producing the detailed spectral features used for mineralogical analysis. We will observe the three surviving remnants of comet 73P/Schwassmann-Wachmann 3, which fragmented in late 1995, using the Infrared Spectrograph of the Spitzer Space Telescope. We will use both "stare" and "spectral map" modes to uncover the size & mineralogy of these important remnants of the early solar nebula. The Spitzer observations will be supported by ground-based optical and infrared observations. The observed characteristics of these fragments will be compared to those of both short-period and more dynamically new comets. The spectra will be modeled using accurate radiative transfer models to be developed in the very near future.

Spitzer Space Telescope - General Observer Proposal #30066

IR Spectroscopy of Comet 73P/Schwassmann-Wachmann 3 Post-Perihelion

Principal Investigator: Michael Sitko
Institution: Space Science Institute

Technical Contact: Michael Sitko, Space Science Institute

Co-Investigators:
Barbara Whitney, Space Science Institute
Michael Wolff, Space Science Instutute
Elisha Polomski, University of Minnesota
David Lynch, The Aerospace Corporation
Ray Russell, The Aerospace Corporation
David Harker, University of California at San Diego
Carey Lisse, Johns Hopkins University Applied Physics Lab

Science Category: comets
Observing Modes: IrsMap IrsPeakupImage IrsStare
Hours Approved: 20.8

Abstract:
Observations of recently-fragmented short-period comets provide an opportunity to sample material in these objects which has not been subjected to hundreds or thousands of years of exposure to the effects of solar radiation. Repeated passages into the inner solar system are expected to deplete the surface layers of the smallest dust grains, the very ones responsible for producing the detailed spectral features used for mineralogical analysis. We will continue to observe the three surviving remnants of comet 73P/Schwassmann-Wachmann 3, using the Infrared Spectrograph of the Spitzer Space Telescope. This continues our Cycle 2 program, but follows the objects into their post-perihelion phase. The observed characteristics of these fragments will be compared to those of both short-period and more dynamically new comets, with each other, and pre- & post-perihelion phases. Two existing grain models will be used to analyze the data, and work on a third one will begin.

Spitzer Space Telescope - Archive Research Proposal #3692

A Search for Comet Debris Trails in the Spitzer FLS Fields

Principal Investigator: Russell Walker
Institution: Monterey Institute for Research in Astronomy

Technical Contact: Russell Walker, MIRA

Co-Investigators:
Mark Sykes, Steward Observatory, University of Arizona
David Lien, Oaklahoma State University

Science Category: comets
Dollars Approved: 108527.0

Abstract:
We propose to identify serendipitous detections of comet dust trails in the Spitzer First Look Survey fields. This will include debris in the orbits of known short-period comets as well as 'orphan' trails. This will allow us to determine the number density of trails, the fraction associated with known short-period comets, the extent of trails along comet orbits, whether the distribution of orphans in ecliptic latitude suggest a cometary or asteroidal origin, whether communition of trail particles would allow for comets to be a significant contributor to the broad thermal emission of the zodiacal dust complex, and whether the physical properties of trail particles vary from comet to comet (suggesting different origins). Analysis of detected trails will allow us to determine the temperature and optical depth of the grains, the emission velocities and ages of the trail particles, comet mass loss rates, and constrain comet dust-to-volatile mass ratios. The database of detected comet trails and their thermal radiance will generate important follow-on science by future Spitzer GO trail observations. Trail search techniques and software developed here will serve as a pilot study for efficient trail searches in more extensive programs such as SWIRE.

Spitzer Space Telescope - General Observer Proposal #3152

IRS Observations of a ToO Oort Cloud Comet at Four Heliocentric Distances from 7-3 AU

Principal Investigator: Diane Wooden
Institution: NASA Ames Research Center

Technical Contact: Diane Wooden, NASA Ames Research Center

Co-Investigators:
David Harker, University of California, San Diego
Charles Woodward, University of Minnesota
Humberto Campins, University of Central Florida (Orlando)
Pascale Ehrenfreund, Leiden Observatory
Nicolas Biver, Observatoire de Paris-Meudon
Dina Prialnik, Tel Aviv University
Susan Lederer, California State University San Bernardino
Catherine Delahodde, University of Central Florida (Orlando)
Mrs.Ealeal Harari, Tel Aviv University

Science Category: comets
Observing Modes: IrsMap
Hours Approved: 5.3

Abstract:
We propose a 5.3 hr non-impact ToO Spitzer (+ IRS) mapping program to observe an Oort cloud (OC) comet over a range of heliocentric distances from 7-3 AU. Based on NEAT, LINEAR, and MPEC records over the past four years, we expect in Cycle 1 the discovery of two ToO comets at heliocentric distances greater than 5 AU that also have perihelia of less than 2.5 AU. Our goal is to obtain Spitzer (+IRS) spectral energy distributions (SEDs) of the same ToO OC comet at four epochs at heliocentric distances of roughly 7, 5, 4, and 3 AU to measure the thermal emission from the coma+nucleus during the three stages of cometary activity: (7-6 AU) distant activity primarily driven by CO sublimation from the nucleus, (6-4 AU) coma onset driven by crystallization of amorphous water ice from the nucleus subsurface layers, and (4-1 AU) vigorous activity stage driven by water ice sublimation from the nucleus. In addition to these nuclear sources, (non-nuclear) distributed sources produce molecular species in the coma and are attributed to an unknown grain component(s). By fitting Spitzer (+ IRS) SEDs with dust thermal emission models, we aim to constrain and compare the dust properties in the coma during the three stages of cometary activity. In doing so, we investigate the potentially crucial roles that dust grains play in warming volatile ices and in the nature of distributed coma sources, and the role gas production plays in transporting dust grains into coma. Understanding the nature of distributed sources and investigating the co-dependence of dust properties and activity are essential to translating coma abundances into nuclear abundances. Grain properties such as the grain size distribution and the crystalline silicate fraction betray early solar nebula processes such as grain growth and radial transport. The composition of OC cometary nuclei reveals the physical conditions during planet formation.

Spitzer Space Telescope - General Observer Proposal #20104

Spitzer Spectroscopy and Imaging of Oort Cloud Comets C/2004 B1 and C/2003 T4 During their Sojourns through the Solar System

Principal Investigator: Diane Wooden
Institution: NASA Ames Research Center

Technical Contact: Diane Wooden, NASA Ames Research Center

Co-Investigators:
David Harker, CASS/UCSD
Charles Woodward, U. Minnesota
Michael Kelley, U. Minnesota
Harold Butner, Joint Astronomy Center
Sue Lederer, Cal. State Univ. San Bernadino
Dina Prialnik, Tel Aviv Univ.
Ealeal Beer-Harari, Tel Aviv Univ./NASA Ames
Nicolas Biver, CNRS, Obs. de Paris-Meudon
Hermann Boehnhardt, MPI for Solar System Research
Pascale Ehrenfreund, Leiden Institute of Chemistry

Science Category: comets
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 26.6

Abstract:
Spitzer observations of Oort cloud (OC) comets during their sojourns through the solar system investigate the interplay between dust grain properties and activity with heliocentric distance. We propose a 26.6 hr multi-cycle program [85% IRS and 15% IRAC/MIPS] to observe two OC comets whose combined heliocentric distance-range, restricted by visibility windows, spans 2-6 AU: Comet C/2004 B1 (LINEAR) [B1] at 2.2 AU pre-, 2.0 AU post-, 2.6-3.0AU post-, and 4.8-6.0 AU post-perihelion; and comet C/2003 T4 (LINEAR) [T4] at 3.2 < r_h < 4.8AU post-perihelion. By fitting Spitzer IRS spectra plus IRAC or MIPS images with models, we aim to constrain and compare the grain properties in comae during three stages of cometary activity: 1) distant activity (>7-5 AU), 2) coma onset (6-4 AU), and 3) vigorous activity (<3-4 AU). During all three stages of activity, some molecular species (e.g., CO) have significant contributions from distributed (non-nuclear) sources, suggested to arise from an unknown grain component. Our investigation will characterize the grains that are potential carriers of the distributed sources. By modeling multi-epoch observations, we investigate the potentially crucial roles that grains play in warming volatile ices and in the nature of distributed coma sources, and the role gas production plays in transporting grains into the coma. Understanding the nature of distributed sources and investigating the co-dependence of grain properties and activity (dust production rates) are essential to translating coma abundances into nuclear abundances. The compositions of cometary nuclei reveal the physical processes and conditions in the solar nebula during icy planetismal formation.

Spitzer Space Telescope - General Observer Proposal #20105

Spitzer Observations of a ToO Bright Oort Cloud Comet at Five Heliocentric Distances from 7-2 AU

Principal Investigator: Diane Wooden
Institution: NASA Ames Research Center

Technical Contact: Diane Wooden, NASA Ames Research Center

Co-Investigators:
David Harker, CASS/UCSD
Charles Woodward, U. Minnesota
Michael Kelley, U. Minnesota
Harold Butner, Joint Astronomy Center
Sue Lederer, Cal. State Univ. San Bernadino
Dina Prialnik, Tel Aviv Univ.
Ealeal Beer-Harari, Tel Aviv Univ./NASA Ames
Nicolas Biver, CNRS, Obs. de Paris-Meudon
Hermann Boehnhardt, MPI for Solar System Research
Pascale Ehrenfreund, Leiden Institute of Chemistry

Science Category: comets
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 9.8

Abstract:
We propose to observe a bright Oort Cloud (OC) comet at five different heliocentric distances ranging from 7 to 2 AU, beginning within a year of discovery as a target of opportunity (ToO). From large to small heliocentric distances, some molecular species, e.g., CO, have significant contributions from extended (non-nuclear) sources, which are suggested to arise from an unknown grain component. We will characterize the temperatures, sizes, and mineralogies of the grains that are the potential carriers of distributed sources by chi-square fitting thermal emission models to IRS spectral energy distributions (SEDs). The activity level of a ToO bright OC comet with changing heliocentric distance will be studied by deriving dust production rates from IRS SEDs, as well as by studying coma morphology from IRAC or MIPS images. We aim to constrain and compare the dust properties in the coma during three stages of cometary activity that are sponsored by different nuclear energy sources: 1) distant activity triggered by CO sublimation (>7-5 AU), 2) coma onset fueled by the exoergic crystallization of amorphous water ice (4-6 AU), and 3) vigorous activity driven by water sublimation (<3-4AU). In doing so, we investigate the potentially crucial roles that dust grains play in warming volatile ices and in the nature of distributed coma sources, and the role gas production plays in transporting dust grains into coma. Understanding the nature of distributed sources and investigating the co-dependence of dust properties and activity are essential to translating coma abundances into nuclear abundances. Images also will yield nuclear fluxes, that when combined with our planned complementary visual and near-IR ground-based observations of the albedo by our co-investigators, will yield constraints on the size of the nucleus. The properties and compositions of cometary nuclei yield important constraints for the physical and chemical conditions in the early solar nebula during the epoch of icy planetesimal formation.

Spitzer Space Telescope - General Observer Proposal #30069

Spitzer CY3 ToO Comet Initiative

Principal Investigator: Diane Wooden
Institution: NASA Ames Research Center

Technical Contact: Charles Woodward, Univ. Minnesota

Co-Investigators:
Chick Woodward, U. Minnesota
Mike Kelley, U. Minnesota
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Harold Butner, Joint Astronomy Center
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Nicolas Biver, Obs. de Paris/LESIA
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Ealeal Beer-Harari, NASA Ames Research Ctr
Herman Boehnardt, Max Planck Inst.
Pascale Ehrenfreund, Leiden Inst. of Chemistry

Science Category: comets
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 10.3

Abstract:
We propose to observe a bright Oort Cloud (OC) comet at five different heliocentric distances (r_h) ranging from 7 to 2 AU, beginning within a year of discovery as a target of opportunity (ToO). From large to small r_h, some molecular species (e.g., CO) have significant contributions from extended (non-nuclear) sources, suggested to arise from an unknown grain component. Our investigation will characterize the dust grains that are potential carriers of the distributed sources. We will constrain the grain parameters, including their temperatures, size distributions, and relative mineral abundances by fitting thermal emission models to IRS spectral energy distributions. Coma morphologies and nuclear fluxes will be extracted from IRAC or MIPS images. We aim to constrain and compare the dust properties in the coma during three stages of cometary activity: 1) distant activity, 2) coma onset, and 3) vigorous activity. In doing so, we investigate the potentially crucial roles that dust grains play in warming volatile ices and in the nature of distributed coma sources, and the role gas production plays in transporting dust grains into coma. Understanding the nature of distributed sources and investigating the co-dependence of dust properties and activity are essential to translating coma abundances into nuclear abundances. The composition of cometary nuclei reveals their origins and physical conditions in the early solar nebula during planet formation. This ToO proposal was awarded CY2 telescope time (PID 20105), but was not triggered as no appropriate comet was discovered that met our observational and scientific criteria.

Spitzer Space Telescope - General Observer Proposal #30589

The Heliocentric-Dependence of Activity of Comet 67P: Spitzer and Rosetta

Principal Investigator: Diane Wooden
Institution: NASA Ames Research Center

Technical Contact: Diane Wooden, NASA Ames Research Center

Co-Investigators:
Hermann Boehnhardt, MPI for Solar System Research
Ealeal Harari Beer, NASA Ames Research Center, NPP Postdoctoral Fellow
Eberhard Gruen, HIGP, University of Hawaii
David Harker, University of California, San Diego, CASS
Michael Kelley, University of Minnesota
Dina Prialnik, Tel Aviv University
Charles Woodward, University of Minnesota

Science Category: comets
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 13.8

Abstract:
We propose an in-depth study of the activity profile along the orbit of JFC comet 67P/Churyumov-Gerasimenko (67P) using Spitzer MIPS+IRAC imaging and IRS spectroscopy observations. 67P is the main target of ESA's ROSETTA mission that is already on its way to the comet and will arrive in Spring 2014. Our observations will address - for the first time - several open issues on the distant activity and the dust content of this comet that, besides their relevance for cometary science, will illuminate mission critical properties of this comet as well as it will complement the global understanding of the object as a JFC studied by an in-depth spacecraft exploration. To date, no measurements of 67P have been made inbound from aphelion, i.e. pre-perihelion, at 5.5 AU > r_h > 2.7 AU, the distance range that is most interesting for ROSETTA since it includes the approach, rendezvous and early exploration phase of the comet by the spacecraft and the distance (~3 AU) when the ROSETTA lander will be dropped onto the nucleus. Mission critical key topics we will address are: determination of the dust production rates; assessment of the gas production rates through calculation of the minimum grain size lifted off the nucleus; search for the ''neckline'' feature seen in previous apparitions; measure the occurence of outbursts; and by using our thermal dust models, determine the grain size distribution, and at ~3 AU constrain mineralogy after the start of water production.

Spitzer Space Telescope - Directors Discretionary Time Proposal #294

The Nucleus Size/Albedo of Rosetta Target Comet 67P/Churymov-Gerasimenko

Principal Investigator: Diane Wooden
Institution: NASA Ames

Technical Contact: Diane Wooden, NASA Ames

Co-Investigators:
David Harker, UC San Diego
Michael Kelley, U. Central Florida
Charles Woodward, U. Minnesota
Hermann Boehnhardt, Max Planck Institute for Solar System Research
Cecilia Tubiana, Max Planck Institute for Solar System Research

Science Category: comets
Observing Modes: IracMap MipsPhot
Hours Approved: 4.8

Abstract:
The Rosetta Mission spacecraft and its lander will rendezvous with Jupiter Family comet 67P/Churymov-Gerasimenko (67P) in 2014 near 5 AU when the comet is inbound on its orbital trajectory toward perihelion. Only by obtaining Spitzer phased light curves at 8 microns and 24 microns can we tightly constrain the longitudinally-dependent projected nuclear size, because with 2 wavelengths the effects on the IR flux of color temperature and nuclear size can be separated. This proposed light curves of comet 67P are critical to the potential success of the Rosetta mission, as they enable (1) tightening of the constraints on basic nucleus properties, specifically, the nuclear size (projected onto the sky plane) versus rotational phase angle, and (2) measurement of the dust production rate and activity level of 67P within the heliocentric distance range spanned by the 2014 Rosetta encounter an R-band light curves are to be obtained through our approved ESO VLT program, which allows the first observationally constrained longitudinally-dependent albedo determinations for comet 67Ps nucleus.

Spitzer Space Telescope - Archive Research Proposal #40571

Mining the Deep Impact Spitzer Archive for Crystalline Silicates

Principal Investigator: Diane Wooden
Institution: NASA Ames Research Center

Technical Contact: Diane Wooden, NASA Ames Research Center

Co-Investigators:
David Harker, University of California, San Diego
Charles Woodward, University of Minnesota
Mike Kelley, University of Central Florida

Science Category: Comets
Dollars Approved: 86378.0

Abstract:
The Deep Impact Mission hit comet Jupiter Family 9P/Tempel 1 on 2005 July 4 and expelled surface and subsurface nuclear materials into its coma. To our surprise, the dust grains and the volatile gases were more similar in composition and abundance to Oort cloud (long-period) comet Hale-Bopp than to any previously observed Jupiter Family (short-period) comet. Crystalline silicate features are much more pronounced in the Deep Impact-induced coma compared to the normal coma. We propose to investigate whether the silicate feature and the crystalline silicate features are stronger because the grain structure is different (e.g., more porous), or whether the grains are of different composition. If the subsurface and surface grains are of different composition, this has implications for the 'aging' of Jupiter Family comets in the inner solar system or implies the nucleus is inhomogeneous on even smaller scales than suggested by the TALPS model (Belton et al. 2007). Our program will utilize the Spitzer (+IRS) archive data obtained over a 164 hr duration, as well as observations of the pre-impact coma and the coma weeks after impact. The Deep Impact Spitzer data set is of unparalleled signal-to-noise: the 10''-wide IRS slit samples the low-surface brightness pre-impact coma and reveals crystalline silicate emission features that are not discernible in 8-m class telescope spectra of the inner coma.

Spitzer Space Telescope - General Observer Proposal #40812

Dust in the Coma and Trail of Spectacular Comet C/2006 P1 (McNaught)

Principal Investigator: Diane Wooden
Institution: NASA Ames Research Center

Technical Contact: Diane Wooden, NASA Ames Research Center

Co-Investigators:
David Harker, University of California, San Diego
Charles Woodward, University of Minnesota
Mike Kelley, University of Central Florida

Science Category: comets
Observing Modes: IrsStare MipsPhot
Hours Approved: 15.6

Abstract:
We propose a 15.6 hr project to study the dust of comet C/2006 P1 (McNaught). Comet McNaught dazzled Earth observers everywhere with an impressive post-perihelion dust tail. The dust production near perihelion, estimated to be greater than that of Hale-Bopp, allows for the opportunity to detect, for the first time, a dust trail from an Oort Cloud comet, owing greatly to the timing of the comet's perihelion passage and the lifetime of the Spitzer Space Telescope. With Spitzer IRS SEDs of comet McNaught's coma, still modestly bright at 3-4 AU, we can study the relationship between dust grain properties and coma activity, as water sublimation ceases during the comet's outbound journey. The proposed observations will observe the comet to full 5-37 micron IRS spectral energy distributions (SEDs) at 3.5 and 4.1 AU, from which we can constrain the dust mineralogy. We will image the comet with MIPS at 24 microns at 3.5, 4.1, and 6.5 AU. Using a large MIPS map at 3.5 AU, we will search for the comet's dust trail, direct evidence for the ejection of grains larger than 100 microns. We augment the 24 micron images with 170 micron images at 3.5 AU to the thermal emission from the largest grains. Using the MIPS images, we will search for small nucleus fragments (of order 100 m in radius) shed during its close (0.2 AU) encounter with the Sun. The following MIPS observations at 4.1 and 6.5 AU will help us determine a nucleus size for the comet, necessary to properly interpret the dust coma in our IRS spectra. The Spitzer McNaught data set will be of similar legacy-quality to that the ISO SWS data set on comet Hale-Bopp.

Spitzer Space Telescope - General Observer Proposal #20639

CO2 Sublimation in Comets Beyond 5 AU

Principal Investigator: Laura Woodney
Institution: Cal State University, San Bernandino

Technical Contact: Laura Woodney, Cal State University, San Bernandino

Co-Investigators:
Yanga Fernandez, Univ of Hawaii

Science Category: comets
Observing Modes: IrsStare
Hours Approved: 17.1

Abstract:
While it is widely believed that CO_2 makes up a significant fraction of the total mass of Oort Cloud comets and distant comets, it has only rarely been actually measured as it is impossible to detect from the ground. The Spitzer Space Telescope offers a unique opportunity to expand our understanding of cometary CO_2 through observations of the nu_2 band near 15.0 microns. We propose to observe CO_2 in two active Centaurs and one long-period comet whose perihelia are all greater than 5 AU. These comets have likely never come close enough to the sun to warm to the temperature required for water sublimation, so their activity is thought to be completely driven by CO and CO_2. We will compare the CO_2 production rates with dust production rates obtained simultaneously from the IRS spectra. We will also compare CO_2 production with the gas production rates or upper limits from our in-hand Keck LRIS spectra of the same objects. We will begin to constrain the structure and composition of these distant objects.

Spitzer Space Telescope - General Observer Proposal #2316

The Astromineralogy of Solar System Comets

Principal Investigator: Charles Woodward
Institution: Univ. Minnesota

Technical Contact: Charles Woodward, Univ. Minnesota

Co-Investigators:
David Harker, Univ. California San Diego
Diane Wooden, NASA Ames
William Reach, Spitzer Science Center
Huberto Campins, Univ. Central Florida
Robert Gehrz, Univ. Minnesota
David Osip, Magellan Observatories
Michael Kelley, Univ. Minnesota
Sue Lederer, Cal State Univ. - San Bernardino
Martha Hanner, Univ. Massachusetts
Elisha Polomski, Univ. Minnesota

Science Category: comets
Observing Modes: IrsStare
Hours Approved: 25.0

Abstract:
A key scientific challenge in modern astrophysics is to understand conditions in early protoplanetary disks during the epoch of planetesimal formation. In our own solar system, comets are frozen archives of this early epoch. Using Spitzer (+IRS), we propose an extensive 45.9 hr study of 52 select comets (both Jupiter- and Oort-family members). We will investigate their physical properties and dust characteristics, and search for possible organic (PAH-like) signatures, creating the first comprehensive mid- and far-infrared database of these relic, nearly pristine samples of outer solar nebula materials. Our program will enable the first comprehensive survey of faint Jupiter-family comet dust properties, permit an in-depth, systematic comparison of Jupiter- and Oort-family comet dust properties and physical characteristics, facilitate assessment of the importance of crystalline silicates as a diagnostic of solar nebula evolution and turbulent mixing models, and establish critical remote-sensing data products to provide interpretive context for NASA and ESA comet rendezvous and sample return missions. Only Spitzer has the mJy sensitivity at mid- and far-infrared wavelengths to detect the significant diagnostic spectral features/resonances emitted by dust, organics, and ices, necessary to effect this survey program.

Spitzer Space Telescope - General Observer Proposal #20021

Solar System Comet Astromineralogy

Principal Investigator: Charles Woodward
Institution: Univ. Minnesota

Technical Contact: Charles Woodward, Univ. Minnesota

Co-Investigators:
Michael Kelley, Uinv. Minnesota
David Harker, Univ. California San Diego
Diane Wooden, NASA Ames
William Reach, Spitzer Science Center
David Osip, Magellan Observatories
Humberto Campins, Univ. Central Florida
Jana Pittichova, Uinv. Hawaii IfA
Sue Lederer, Cal State Univ. - San Bernardino
Robert Gehrz, Univ. Minnesota
Martha Hanner, Univ. Massachusetts

Science Category: comets
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 55.0

Abstract:
A key scientific challenge in modern astrophysics is to understand conditions in early protoplanetary disks during the epoch of planetesimal formation. In our own solar system, comets are frozen archives of this early epoch. We propose to study 14 sublimating comets (both Jupiter-family and Oort Cloud members) in a 55.0 hr (42 AORs) program to characterize the coma and nuclear spectra and to establish a statistically sample of high quality cometary spectra. We seek to: 1) study their dust characteristics; 2) search for possible organic (PAH-like) signatures; and 3) address a fundamental question -- the origins of crystalline silicates in the solar nebula. A major objective of our program is a comprehensive survey of faint Jupiter-family comet dust properties, which will permit an in-depth, systematic comparison of Jupiter-family and Oort Cloud comet dust properties and physical characteristics, facilitate assessment of the importance of crystalline silicates as a diagnostic of solar nebula evolution and turbulent mixing models, and establish critical remote-sensing data products to provide interpretive context for NASA and ESA comet rendezvous and sample return missions. Only Spitzer has the sensitivity at mid- and far-IR wavelengths to detect the significant diagnostic spectral features/resonances emitted by dust and organics necessary to effect this study.

Spitzer Space Telescope - Directors Discretionary Time Proposal #221

Measuring the Size of Objects beyond Pluto

Principal Investigator: Michael Brown
Institution: Caltech

Technical Contact: Michael Brown, Caltech

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 3.7

Abstract:
Proposal to use MIPS to determine the size of objects beyond the orbit of Pluto.

Spitzer Space Telescope - Directors Discretionary Time Proposal #245

Radiometric determination of albedos of icy bodies

Principal Investigator: Michael Brown
Institution: Caltech

Technical Contact: Michael Brown, Caltech

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 17.7

Abstract:
DDT proposal for MIPS observations of Xena/2003 UB313.

Spitzer Space Telescope - General Observer Proposal #3283

Characterization of the Icy Planetoids of the Outer Solar System

Principal Investigator: Michael Brown
Institution: Caltech

Technical Contact: Michael Brown, Caltech

Co-Investigators:
Kristina Barkume, Caltech
John Stansberry, University of Arizona
Chad Trujillo, Gemini Observatory
Bill Reach, Spitzer Science Center

Science Category: Kuiper belt objects
Observing Modes: IrsStare MipsPhot MipsSed
Hours Approved: 21.3

Abstract:
The last two years have seen an explosion in the discoveries of what is essentially a previously unknown class of solar system objects: the icy planetoids of the outer solar system. These objects -- Kuiper belt objects with diameters greater than 500 km -- bear more resemblance to Pluto and to the icy satellites of the giant planets than they do to cometary nuclei. GTO surveys have concentrated on the modest-sized Kuiper belt objects and the icy satellites. The icy planetoids -- generally unknown at the time the GTO lists were frozen --remain largely unexamined. These poorly understood bodies provide an ideal laboratory for the study of the chemical, geophysical, and accretional evolution of the outer solar system. We propose a comprehensive program designed to take advantage of the unique capabilities of Spitzer to study the size-distribution, differentiation, and chemical evolution of this unique class of icy planetoids. All 14 currently known icy planetoids have been detected in our ongoing large-scale survey of the outer solar system; we continue to discover new objects this size at the rate of approximately one every other month. Our total target list thus includes all 20 planetoids that will be known during this cycle. Critically, this sample of icy planetoids is known to be complete to 45 AU: our survey has detected all objects with an absolute magnitude less than 4.8 (9% albedo size of 500 km) out to a heliocentric distance of 45 AU within the 4000 square degrees covered (which includes most of the sky within 7 degrees of the ecliptic). Such a carefully selected sample is critical for accurate interpretation of many of the results of a survey such as this and is only possible with a sample chosen from a carefully controlled survey. With these observations and the ground-based auxiliary observations we are obtaining, we will have a comprehensive picture of these poorly studied icy planetoids which dominate the outer solar system.

Spitzer Space Telescope - General Observer Proposal #30001

The largest Kuiper belt objects

Principal Investigator: Michael Brown
Institution: Caltech

Technical Contact: Michael Brown, Caltech

Co-Investigators:
Henry Roe, Caltech
Kristine Barkume, Caltech
Emily Schaller, Caltech

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 3.6

Abstract:
The past year has seen an explosion in the discoveries of Pluto-sized objects in the Kuiper belt. With the discoveries of the methane-covered 2003 UB313 and 2005 FY9, the multiple satellite system of 2003 EL61, and the Pluto-Charon analog system of Orcus and its satellite, it is finally apparent that Pluto is not a unique oddball at the edge of the solar system, but rather one of a family of similarly large objects in the Kuiper belt and beyond. HST observations of the past decade have been critical for understanding the interior, surface, and atmosphere of Pluto and Charon. We propose here a comprehensive series of observations designed to similarly expand our knowledge of these recently discovered Pluto-sized and near-Pluto-sized Kuiper belt objects. These observation will measure objects' sizes and densities, explore the outcome of collisions in the outer solar system, and allow the first ever look at the interior structure of a Kuiper belt object. Our wide field survey that discovered all of these objects is nearly finished, so after five years of continuous searching we are finally almost complete in our tally of these near-Pluto-sized objects. This large HST request is the culmination of this half-decade search for new planetary-sized objects. As has been demonstrated repeatedly by the approximately 100 previous orbits devoted to the study of Pluto, only HST has the resolution and sensitivity for detailed study of these distant objects. With these new Pluto-sized objects only now being discovered we have a limited window left to still use HST for these critical observations.

Spitzer Space Telescope - General Observer Proposal #30883

Thermal properties of the largest Kuiper belt objects

Principal Investigator: Michael Brown
Institution: Caltech

Technical Contact: Michael Brown, Caltech

Co-Investigators:
John Stansberry, University of Arizona
Bill Reach, SSC

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 22.5

Abstract:
The past year has seen an explosion in the discoveries of near-Pluto-sized objects in the Kuiper belt. With the discoveries of the methane-covered 2003 UB313 and 2005 FY9, the multiple satellite system of 2003 EL61, and the Pluto-Charon analog system of Orcus and its satellite, it is finally apparent that Pluto is not a unique oddball at the edge of the solar system, but rather one of a family of similarly large objects in the Kuiper belt and beyond. Thermal observations over the past decade have been critical for understanding the interior, surface, and atmosphere of Pluto and of Charon. We propose here a comprehensive series of observations designed to similarly expand our knowledge of the recently discovered Pluto-sized and near-Pluto-sized Kuiper belt objects (KBOs). These observations will measure objects' sizes and densities, explore the surface thermal properties of a Pluto twin, and search for spectral proxies for albedo in the large water-ice covered KBOs. The discovery of these largest and brightest KBOs midway through the Spitzer mission makes these observations particularly urgent. All of these observations would certainly have taken place as the very earliest solar system GTO observations had the objects been know. With the limited window left for Spitzer, thorough study of these largest objects, which will be the subjects of intensive study at all wavelengths for years to come, is critical.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #67

IRS and MIPS SED observations of Centaurs and Kuiper Belt Objects

Principal Investigator: Dale Cruikshank
Institution: NASA-Ames

Technical Contact: Jeffrey Van Cleve, Ball Aerospace

Science Category: Kuiper belt objects
Observing Modes: IrsStare
Hours Approved: 11.6

Abstract:
We examine the spectra of Centaurs and Kuiper Belt Objects using the IRS and MIPS SED, using a target list which is a subset of the MIPS photometry list developed by Stansberry. The observations generally use the Long Lo module of the IRS, but other modules are used for the brightest Centaurs. When used in conjunction with the MIPS photometry observations, hIgh S/N observations of the brightest sources will provide compositional information, while low S/N observations of fainter sources will be used to constrain the albedo, size, and thermal properties of these objects.

Spitzer Space Telescope - General Observer Proposal #20769

Surface compositions of KBOs, Centaurs, and low albedo asteroids: Constraints from IRAC reflectance measurements

Principal Investigator: Joshua Emery
Institution: SETI Institute / NASA Ames

Technical Contact: Joshua Emery, SETI Institute / NASA Ames

Co-Investigators:
Dale Cruikshank, NASA Ames Research Center
David Trilling, Univ. Arizona / Steward Observatory
John Stansberry, Univ. Arizona / Steward Observatory
Yanga Fernandez, Univ. Hawaii
Cristina Dalle Ore, SETI Institute / NASA Ames

Science Category: Kuiper belt objects
Observing Modes: IracMap
Hours Approved: 34.6

Abstract:
We propose to measure broadband fluxes of a sample of Kuiper Belt Objects (KBOs), Centaurs, and low albedo asteroids with IRAC. Ground-based spectra have been recorded from the visible to 2.5 microns for all objects in the target list, but spectral models admit a range of possible compositions. Reflectance in two or, in some cases, three bands (3.6, 4.5, and 5.8 microns) will allow discrimination between possible spectral models, thereby constraining surface compositions. For several objects, thermal emission will be detected in the 8.0-micron band. The simultaneous measurement with IRAC of both reflected and emitted flux will permit estimation of size and albedo for these objects. Compositions of these primitive bodies allow analysis of conditions in the outer solar nebula during formation, diversity in the Kuiper Belt, and possible dynamical and evolutionary links between KBOs, Centaurs, and low albedo asteroids.

Spitzer Space Telescope - General Observer Proposal #40389

IRAC reflectances of KBOs, Centaurs, and Trojan asteroids

Principal Investigator: Joshua Emery
Institution: SETI Institute / NASA Ames

Technical Contact: Joshua Emery, SETI Institute / NASA Ames

Co-Investigators:
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Cristina Dalle Ore, SETI Institute/NASA Ames
Yanga Fernandez, University of Central Florida
John Stansberry, University of Arizona
David Trilling, University of Arizona
Janusz Eluszkiewicz, Atmospheric and Environmental Research, Inc.

Science Category: Kuiper belt objects
Observing Modes: IracMap
Hours Approved: 87.1

Abstract:
We propose to measure broadband fluxes of Kuiper Belt Objects (KBOs), Centaurs, and Trojan asteroids with IRAC in order to determine surface compositions. The value of IRAC is that its measurements of reflectance will 1) provide a far more sensitive search for ices than is possible at shorter wavelengths and 2) readily distinguish between candidates for the poorly understood "dark material," which is also not possible at shorter wavelengths. These capabilities critically address several longstanding questions in planetary science: What is the nature of the dark material that is nearly ubiquitous in the outer Solar System? Is it a single material or does its composition vary on different bodies in or from different locations? and What is the distribution of volatiles? For several objects, thermal emission will be detected in the 8.0-micron band. The simultaneous measurement with IRAC of both reflected and emitted flux will permit estimation of size and albedo for these objects. Our cycle-2 program to observe an initial set of outer Solar System objects has been tremendously successful, and this proposal builds on that success.

Spitzer Space Telescope - General Observer Proposal #3542

The Dynamical History of the Classical Kuiper Belt: Radiometric Diameters and Albedos

Principal Investigator: Will Grundy
Institution: Lowell Observatory

Technical Contact: John Stansberry, The University of Arizona

Co-Investigators:
Marc Buie, Lowell Observatory
Eugene Chiang, University of California, Berkeley
Dale Cruikshank, NASA Ames Research Center
Robert Millis, Lowell Observatory
John Spencer, Southwest Research Institute
John Stansberry, Steward Observatory
Lawrence Wasserman, Lowell Observatory

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 102.4

Abstract:
We propose deep 24 and 70 micron MIPS photometry of 20 Kuiper Belt Objects (KBOs), 19 selected from the Classical belt (CKBOs) plus the one known Neptune Trojan. These observations will enable us to accurately determine their sizes and albedos, and to look for differences between dynamically hot and dynamically cold CKBO sub-populations. These two groups exhibit distinct color and absolute magnitude distributions, and we want to determine if/how these relate to their sizes and albedos. This project will for the first time enable us to investigate correlations between size, albedo, and inclination in the Classical belt. We will also investigate trends in size/albedo with heliocentric distance among the cold CKBOs, which will in turn shed light on whether they accreted in situ, or were pushed outward from their birthplaces by the migration of proto-Neptune. CKBOs are distant, small, and cold, so it takes hours of SST time to collect sufficient signal from each one. Accordingly, we used 3 MYr orbit integrations for all KBOs to enable us to precisely select the most dynamically useful targets for this investigation. We have also verified our flux models and expected background and instrument performance figures with actual MIPS data, recently returned for 3 KBOs and 3 Centaurs, as part of a thorough GTO survey of Centaurs, Resonant objects, and Scattered objects (which neglected the Classical Belt out of time considerations). Two thermal wavelengths are needed to properly constrain diameters and albedos of KBOs because of much larger uncertainties about what directions they emit their thermal radiation into, compared with the relatively simple situation for asteroids. More rigorous thermal models are needed for KBOs, and we have already developed and tested these. Essential V and R photometry of our targets will be secured by co-Is who are members of the Deep Ecliptic Survey, the discoverers of nearly half of all known KBOs.

Spitzer Space Telescope - General Observer Proposal #50540

Exploring the Boundaries of the Cold Classical Population

Principal Investigator: Will Grundy
Institution: Lowell Observatory

Technical Contact: Will Grundy, Lowell Observatory

Co-Investigators:
John Stansberry, Steward Observatory
Keith Noll, Space Telescope Science Institute
Michael Mueller, Steward Observatory
Melissa Brucker, Lowell Observatory / Univ. of Oklahoma
Steve Tegler, Northern Arizona University
David Osip, Las Campanas Observatory (OCIW), Chile
Hal Levison, Southwest Research Institute

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 22.6

Abstract:
Objects in the Cold Classical Kuiper belt exhibit distinctive physical characteristics from other members of the trans-neptunian swarm. These include higher albedos, more homogeneously red colors, smaller sizes, and higher rates of binarity. Spitzer is the premier facility for determining albedos of these distant objects, since it can detect more than one thermal wavelength, enabling otherwise crippling model uncertainties to be overcome. We propose to use Spitzer to study objects in dynamical regions near the Cold Classical belt to see if they too have high albedos, consistent with possible kinship with the Cold Classical population. Possible physical affiliations between these different dynamical classes could provide valuable constraints on dynamical models of the evolution of the outer Solar System. We request observations of five strategically selected targets. Two are part of the Inner Classical group, objects in otherwise Classical type orbits except that they are closer to the Sun than the 3:2 mean motion resonance with Neptune. Two are among the least excited occupants of the 2:1 mean motion resonance and one is among the least excited occupants of the 3:2 resonance. As Neptune migrated outward, these resonances could have transported objects outward and deposited them into the Cold Classical region. If so, we would expect their least excited members to share physical characteristics with the Cold Classical objects.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #55

Far-IR Observations of Kuiper Belt and Centaur Objects

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: John Stansberry, The University of Arizona

Science Category: Kuiper belt objects
Observing Modes: MipsPhot MipsScan MipsSed
Hours Approved: 45.9

Abstract:
We will obtain MIPS photometry for 44 KBOs and 12 Centaurs. For the KBOs we will focus on 70 microns, doing 24 micron and/or 160 micron observations for 10 to 20 objects, with S/N of 5 or better. These data will provide the first determinations of the albedos and diameters of KBOs, and the multi-wavelength data will constrain surface temperature distributions on some objects. For Centaurs we will focus on 24 microns, adding 70 micron measurements for all but 2, and 160 micron measurements for 3, and obtaining a minimum S/N of 5. While groundbased sizes/albedos already exist for 3 Centaurs, ours will be the first detections of these objects at longer wavelengths, and will provided constraints on the size, albedo, and temperature distribution for most known Centaur objects. In several cases 24 micron integration times were adjusted upward significantly from that required to obtain 5-sigma on the nuclear thermal flux in order to search for extended thermal emission. Such emission might result from the presence of comet-like dust trails in the neighborhood of the nucleus, although there is some possibility of detecting a dust coma directly."Shadow" observations are included for all targets in all bands. The shadow observations consist of a second observation of the target with the same integration time as the primary observation. The purpose of the shadow observation is two-fold. First is to obtain an additional measurement of the target flux, improving signal to noise and confirming any extended structure which may be detected. Second is to provide a resolved image of the background emission at the position the object occupied at the time of the primary observation (the primary observation then automatically provides an equivalent image for the shadow observation). The impact of confusing sources on photometry and searches for extended emission will be greatly reduced by subtraction of the background images.

Spitzer Space Telescope - General Observer Proposal #40016

Kuiper Belt Albedoes and Densities

Principal Investigator: George Rieke
Institution: U. Arizona

Technical Contact: John Stansberry, U. Arizona

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 10.7

Abstract:
Spitzer measurements of the thermal emission of Kuiper Belt Objects (KBOs) have shown that a number of them have surprisingly high albedos, and that in general the range of albedoes is very large, from a few percent to nearly 100%!. These results are important to combine with spectra of the reflected light and help determine the surface properties. Models for the collisional and chemical evolution, and the dust production in the Kuiper Belt, depend on this information. For two binary KBOs, the measurements also indicate shockingly low densities, of order 1 g/cm3. These densities push to the limit interior models for these objects, since the KBOs are too large for 'porosity' to account for the low densities: at least in their core regions, gravity should have crushed the material into a solid mass. Thus, the proportion of high density material in them must be kept relatively small to be compatible with the data. The two results indicate the potential for Spitzer thermal measurements to have a major impact on our understanding of the Kuiper Belt. We propose to consolidate these surprising findings by improving the signal to noise on three KBOs previously measured in the MIPS GTO program, but where the current data are insufficient to determine the properties of the objects well. Two of the targets (1997 CS 29 and Typhon) are binaries, and hence can test whether the small densities are fairly typical. Expanding the sample with well-determined densities from two to four can have a lot of leverage on assuring us that the low densities are not for peculiar, exceptional objects. The other one (1996 TL 66) is a case where a high-confidence albedo can be obtained with a modest additional investment of time. It is one of a small number of 'inner classical' KBOs that can be observed well with Spitzer. There are indications of systematic trends in albedo with orbital radius for KBOs and Centaurs, and increasing the size of samples in under-represented classes is important to test this result.

Spitzer Space Telescope - Directors Discretionary Time Proposal #498

Thermal Observations of the First Equal Sized Plutino Binary

Principal Investigator: Scott Sheppard
Institution: Carnegie Institution of Washington

Technical Contact: Scott Sheppard, Carnegie Institution of Washington

Co-Investigators:
Chad Trujillo, Gemini Observatory
John Stansberry, Univ. Arizona

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 5.0

Abstract:
We have recently discovered the first equal sized binary Kuiper Belt object in the 3:2 resonance with Neptune (2007 TY430). The four other binary objects known in the 3:2 resonance (including Pluto) have secondaries that are significantly smaller and closer to the primary. Our newly discovered equal sized binary indicates a different binary formation mechanism operating within the 3:2 resonance population. Equal sized binaries are common in other parts of the Kuiper Belt and are believed to have formed through some sort of collisionless interactions within a much denser Kuiper Belt. None of these other known equal sized binary objects could be efficiently observed with Spitzer because of their extreme faintness and distance. We request Spitzer time to observe this new bright binary in order to constrain the albedo and thus size of the binary components. Knowledge of these physical parameters along with the binary orbital information will allow us to determine the bulk densities of the binary. This will constrain what kind of formation mechanisms would allow such a binary to form. These results will give us insights into the collisional history and evolution of the 3:2 resonance population and Kuiper Belt and put strong constraints on when and where the 3:2 resonance population was formed.

Spitzer Space Telescope - General Observer Proposal #3229

Density and Composition of Kuiper Belt Objects, Using Binaries

Principal Investigator: John Spencer
Institution: Southwest Research Institute

Technical Contact: John Spencer, Southwest Research Institute

Co-Investigators:
Will Grundy, Lowell Observatory
Keith Noll, Space Telescope Science Institute
John Stansberry, University of Arizona
Marc Buie, Lowell Observatory
Robert Millis, Lowell Observatory

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 28.8

Abstract:
We propose to obtain the first well-constrained densities for any Kuiper Belt objects (other than Pluto and Charon), in order to better understand the composition and internal structure of these important bodies, which preserve a record of the accretional history of the outer solar system. We will accomplish this by obtaining robust radiometric diameters for five binary KBOs which have masses that can be determined from their mutual orbits. We will use MIPS to obtain S/N ~11 photometry at 24 and 70 microns, and will determine diameters from the measured fluxes at the two wavelengths using a thermal model which solves for both diameter and the degree to which the object is a "fast" or "slow" rotator. As a byproduct we will also obtain albedos for our targets, adding to the small inventory of KBO albedos and providing additional constraints on surface composition and origin of these bodies.

Spitzer Space Telescope - General Observer Proposal #20217

Density and Albedo of the KBO Binary System 1999 SM165

Principal Investigator: John Spencer
Institution: Southwest Research Institute

Technical Contact: John Spencer, Southwest Research Institute

Co-Investigators:
John Stansberry, University of Arizona
William Grundy, Lowell Observatory
Keith Noll, Space Telescope Science Institute

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 19.2

Abstract:
Densities provide our only available constraint on the internal structure and composition of Kuiper Belt objects (KBOs), and currently only two KBOs are amenable to direct density measurements. These are the two brightest binary KBOs, which have masses determined from their satellite orbits and sufficient thermal emission for Spitzer to determine a useful radiometric diameter. One of these, (47171) 1999 TC36, has already been observed by a Spitzer GTO program and has a surprisingly low density of ~0.75 g cm-3. We propose to obtain a radiometric diameter and density for the other detectable binary, (26308) 1999 SM165, to provide a first estimate of the range of densities, and thus internal structures and compositions, among Kuiper Belt Objects.

Spitzer Space Telescope - General Observer Proposal #30014

Measuring Pluto's Thermal Lightcurve and Thermal Inertia

Principal Investigator: John Stansberry
Institution: The University of Arizona

Technical Contact: John Stansberry, The University of Arizona

Co-Investigators:
Will Grundy, Lowell Observatory
John Spencer, Southwest Research Institute
Marc Buie, Lowell Observatory
Emmanuel Lellouch, Observatory of Paris, Meduon
Dale Cruikshank, NASA Ames
George Rieke, University of Arizona

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 9.0

Abstract:
Pluto is a complex, unique, and still-enigmatic object at the boundary between the major planets of the Solar System and the primitive bodies of the Kuiper Belt. Spitzer offers a unique capability for studying Pluto's thermal emission from 20 - 160 um using MIPS. We propose to repeat and improve on MIPS GTO observations of Pluto. These data will provide an accurate snapshot of Pluto's seasonally varying thermal state, against which stellar occultation and New Horizons data can be tested and compared. The data will also provide sensitive constraints on the thermal inertia of Pluto's surface, which is a critical input to seasonal models for the transport of volitile N2 and CH4 ices.

Spitzer Space Telescope - General Observer Proposal #30081

Spitzer Thermal Radiometry of Kuiper Belt Objects and Centaurs

Principal Investigator: John Stansberry
Institution: The University of Arizona

Technical Contact: John Stansberry, The University of Arizona

Co-Investigators:
Will Grundy, Lowell Observatory
John Spencer, Southwest Research Institute, Boulder
Dale Cruikshank, NASA Ames
David Trilling, University of Arizona, Astronomy
Keith Noll, Space Telescope Science Institute

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 37.6

Abstract:
About 10 Kuiper Belt Objects (KBOs) have been detected at both 24 and 70um with Spitzer at high enough signal-to-noise ratio (SNR) to allow determinations of their of their albedos and diameters. While these physical parameters can be estimated from a detection at a single thermal wavelength, they are then subject to large uncertainties stemming from the assumed model for the temperature distribution on the surface. A two-color thermal detection eliminates most of the model uncertainty, and the accuracy of the derived parameters is then limited primarily by measurement and calibration errors. An added benefit of a two-color detection is that it yields some information about the temperature distribution, and therefore about the thermal parameter (or thermal inertia, if the rotation period is known) of the surface materials. We propose to use MIPS to detect 8 KBOs and 8 Centaurs at both 24 and 70um, at SNR > 5 in both bands. We base our predictions of their thermal emission, our sensitivity estimates, and our observing strategy on our past observations of KBOs with Spitzer. Our sample size is chosen to double the sample of both KBOs and Centaurs with two-color data, significantly improving our knowledge of their physical parameters, and providing enough objects to allow us to begin to look for trends in albedo vs. size and color.

Spitzer Space Telescope - General Observer Proposal #50016

Pluto's Seasonal Variation and 160 micron Lightcurve

Principal Investigator: John Stansberry
Institution: The University of Arizona

Technical Contact: John Stansberry, The University of Arizona

Co-Investigators:
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Emmanuel Lellouch, Observatory of Paris, Meduon
Leslie Young, Southwest Research Inst., Boulder
John Spencer, Southwest Research Institute
Joshua Emery, NASA Ames/SETI Inst.
Marc Buie, Lowell Observatory
Dale Cruikshank, NASA Ames

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 11.6

Abstract:
Our MIPS observations of Pluto in 2004 and 2007 show strong evidence for secular changes in its far-IR thermal emission. These changes, particularly at 70um, are far larger than expected from the changing distance to Pluto, and are real. While our 160um data at both epochs were inadequate to provide even a robust rotationally-averaged detection, validation observations obtained using the new enhanced 160um AOT demonstrate that it is now possible to detect Pluto at high SNR (>10) in that band, and to measure the 160um lightcurve. We request new MIPS observations at two epochs in cycle 5 in order to: 1) measure the 160um lightcurve, and 2) verify and extend the temporal baseline over which we monitor Pluto's seasonally-changing thermal emission. We propose to measure the 160um lightcurve in late 2008, well within the cryogenic mission lifetime, and to attempt to extend the temporal baseline in April 2009. This second observation is just beyond the nominal cryogen lifetime in the call for proposals, but extending the baseline an extra ~6 months seems to us to be worth the risk.

Spitzer Space Telescope - General Observer Proposal #50024

Densities, Diameters and Albedos of Trans-Neptunian Binaries

Principal Investigator: John Stansberry
Institution: The University of Arizona

Technical Contact: John Stansberry, The University of Arizona

Co-Investigators:
Will Grundy, Lowell Observatory
Keith Noll, Space Telescope Science Inst.
John Spencer, Southwest Research Inst.
Michael Mueller, Univeristy of Arizona
David Trilling, Univ. of Arizona
Thomas Mueller, Max-Planck Institute, Garching
Emmanuel Lellouch, Obs. Paris, Meudon

Science Category: Kuiper belt objects
Observing Modes: MipsPhot
Hours Approved: 77.8

Abstract:
We propose to determine diameters and albedos for 8 KBOs, 4 members of the cold-classical (low inclination, low eccentricity) class, 2 on orbits resonant with Neptune's, and 2 scattered objects. All have estimated diameters less than 500 km. Of the 4 comparably-sized KBOs with known densities, none are in the classical belt: this program will provide the first diameter and albedo, and utimately density, determinations for classical KBOs. Density determinations will be made by combining our Spitzer results with those from an on-going comlementary HST program. Currently there are 7 binaries with well-determined diameters (5 based solely on Spitzer observations) and densities, three with diameters of 1000 km or larger. The program we propose will double the total sample of binaries with well-determined diameters and albedos, extend the sample to classical objects, and focus entirely on medium-sized targets. These densities will provide better understanding of the composition and internal structure of TNOs and Centaurs, which in turn provide clues regarding conditions in the outer proto-planetary disk. The densities can also be compared with those of cometary nuclei, providing clues into the mechanisms by which some TNOs are transformed into comets. Our diameters will also provide valuable constraints on models for the formation of TNO binaries, and the albedos will provide additional insight into the relationships between TNO binaries and other physical (color, composition) and dynamical classes of TNOs.

Spitzer Space Telescope - General Observer Proposal #50348

The sizes, albedos, and comae of Centaurs

Principal Investigator: David Trilling
Institution: University of Arizona

Technical Contact: David Trilling, University of Arizona

Co-Investigators:
John Stansberry, University of Arizona
Michael Mueller, University of Arizona
Keith Noll, STScI

Science Category: Kuiper belt objects
Observing Modes: MipsPhot IrsPeakupImage
Hours Approved: 21.5

Abstract:
The small bodies of the Solar System retain the best information about the era of planet formation and the subsequent evolution of our planetary system. As escaped KBOs that wander close(r) to Earth and to the Sun, we have the opportunity to study KBOs with a sensitivity and resolution that is not generally available in the main Kuiper Belt. Centaurs are both dynamically transitional --- as former Kuiper Belt Objects and potentially future comets --- and physically so, as some display cometary activity that is absent in the Kuiper Belt. We propose here to observe 27 Centaurs with Spitzer to address these fundamental questions about this interesting transitional population. We will determine their physical properties --- size and albedo --- as a probe of their fundamental nature. We will carry out a coma search. This program will more than double the number of Centaurs observed with Spitzer and create a sample of nearly 50 targets in which we can look for correlations among physical properties and derive a true size distribution for Centaurs that can be compared to the best-known KBO and Jupiter family comet size distributions. If any Centaurs in our sample are observed to be binaries in a companion HST program, we will derive their densities, and compare Centaur densities to KBO densities. We will look for common properties among active Centaurs. The results will reveal the physical properties of this interesting transitional population, and help constrain the suggested link between Kuiper Belt Objects and Jupiter family comets.

Spitzer Space Telescope - General Observer Proposal #20312

Investigation of suitable targets for space missions to Near-Earth Objects

Principal Investigator: Elisabetta Dotto
Institution: INAF-Osservatorio Astronomico di Roma

Technical Contact: Elisabetta Dotto, INAF-Osservatorio Astronomico di Roma

Co-Investigators:
Maria Antonietta Barucci, LESIA-Observatoire de Paris, France
Sonia Fornasier, Astronomy Dep., Padova University, Italy
Pasquale Panuzzo, INAF Padova, Italy
Ettore Perozzi, Telespazio, Italy
Richard P. Binzel, MIT, Cambridge MA, USA
Joshua Emery, SETI Institute NASA Ames, Univ. Arizona, USA
John Robert Brucato, INAF Napoli, Italy
Marcello Fulchignoni, University of Paris VII, France
Cesare Barbieri, Astronomy Dep., Padova University, Italy
Alessandra Migliorini, Astronomy Dep., Padova University, Italy

Science Category: near-Earth objects
Observing Modes: IrsStare
Hours Approved: 24.5

Abstract:
The Near-Earth Objects (NEOs) are small bodies of the Solar System which periodically approach or intersect the Earth's orbit. The NEO population is supposed to be continuously replenished by asteroids and comets and is believed to be one of the principal sources of meteorites found on the Earth. As a consequence, the study of the physical properties of NEOs is interesting for scientific goals, to investigate the nature of the whole population of small bodies of the Solar System. It also provides essential information for technological purposes, considering the potential hazard that these objects constitute to our planet and the development of suitable mitigation strategies both on Earth and from space. In the last years, scientific and technological goals have pushed space agencies to plan and launch space missions to NEOs. In this respect, observations investigating the physical and thermal structure of NEOs are needed in support of future space missions. Due to the wide variety of the orbital characteristics of NEOs, target selection must be able to guarantee both technical feasibility and high scientific return. We therefore propose to carry out spectroscopic observations, in the infrared wavelength range 5.2-38 micron, of NEOs characterized by a high degree of accessibility for a space mission. We have selected 13 targets accessible from Earth for space missions and we ask for a total of 24.5 hours of IRS observations to obtain spectroscopic data between 5.2 and 38 micron. The aim of these observations will be the investigation of the surface composition and thermal structure and the determination of the albedo and diameter of each selected target.

Spitzer Space Telescope - Directors Discretionary Time Proposal #289

Thermal Observations of OSIRIS target 1999 RQ36

Principal Investigator: Joshua Emery
Institution: SETI Institute

Technical Contact: Joshua Emery, SETI Institute / NASA Ames

Co-Investigators:
Yanga Ferandez, University of Central Florida
Carl Hergenrother, LPL Univ. of Arizona
Dante Lauretta, LPL Univ. of Arizona
Michael Drake, LPL Univ. of Arizona

Science Category: near-Earth objects
Observing Modes: IracMap IrsStare IrsPeakupImage
Hours Approved: 5.5

Abstract:
We propose to observe the near-Earth asteroid (101955) 1999 RQ36, the target of the OSIRIS sample return mission, with IRS and IRAC. These observations will provide characterization of the composition, structure, and thermophysical properties of this distinctive asteroid. Compositionally diagnostic emissivity features measured by IRS at two longitudes will be used to constrain the surface mineralogy and structure (e.g., grain size, porosity). IRS thermal flux spectra also provide some constraint on size, albedo, and thermal inertia. IRAC and IRS peakup imaging photometry of 1999 RQ36 will be dominated by thermal emission in all six bands, and will be used to map the albedo and thermal inertia as a function of rotation, making observations at 10 different longitudes, and with higher accuracy than would be possible with only IRS spectra.

Spitzer Space Telescope - General Observer Proposal #50716

The Physical Properties of Near-Earth Asteroids Associated With Meteoroid Streams

Principal Investigator: Michael Kelley
Institution: University of Central Florida

Technical Contact: Michael Kelley, University of Central Florida

Co-Investigators:
Humberto Campins, University of Central Florida
Yan Fernandez, University of Central Florida
Peter Jenniskens, SETI Institute
William Reach, IPAC/Caltech
Jeremie Vaubaillon, IPAC/Caltech

Science Category: near-Earth objects
Observing Modes: IrsStare MipsPhot
Hours Approved: 7.5

Abstract:
The recent Near-Earth asteroid surveys have discovered a number of bodies now identified as parents of our meteor showers. We propose a 7.5 hr Spitzer program to study the physical properties and meteoroid streams of 4 near-Earth asteroids. We will assess the size, albedo, surface composition, and thermal inertia of all 4 targets with 7-14 micron IRS spectra. We also propose MIPS 24 micron maps to measure each targets' meteoroid stream and assess their recent cometary activity. We expect that NEAs associated with meteor showers are all primitive in nature, i.e., they are derived from primitive main belt asteroids, or extinct Jupiter-family comets. We will compare the physical parameters of our targets to NEAs not associated with meteor showers, and to primitive asteroids, in the Spitzer archive. It is important to study NEAs in order to: 1) determine the sources of the current NEA population, 2) characterize the sources of meteorites, meteor showers, and interplanetary dust particles accumulated by the Earth, 3) characterize the properties of Earth impact hazards, and 4) find interesting targets of future robotic and human space exploration missions (e.g., Marco Polo and OSIRIS, two proposed sample return missions). Meteor showers also have a wide public appeal and Spitzer observations of these objects are likely to attract much attention whenever a new call for meteor shower observations is issued to the public.

Spitzer Space Telescope - Directors Discretionary Time Proposal #476

Proof of Concept for Spitzer Warm Mission Observations of Near Earth Objects

Principal Investigator: David Trilling
Institution: U. Arizona

Technical Contact: David Trlling, Arizona

Co-Investigators:
Timothy Spahr, Harvard-CfA
Giovanni Fazio, Harvard-CfA
Joseph Hora, Harvard-CfA
Howard Smith, Harvard-CfA
John Stansberry, U. Arizona
Michael Mueller, U. Arizona
Steve Chesley, JPL
Amy Mainzer, JPL

Science Category: near Earth objects
Observing Modes: IracMap
Hours Approved: 1.8

Abstract:
Near Earth Objects (NEOs) are fragments of remnant primitive bodies that date from the era of Solar System formation. NEO orbits bring these primordial samples close to the Earth, and studies of the composition of the material from which the planets formed may follow. However, at present, the physical properties and origins of NEOs are poorly understood. Characterizing NEOs is important because of the potential threat of an Earth impact and because they are the closest Solar System bodies to the Earth, and therefore the most easily explored. The Spitzer Warm Mission will have the unique capability of measuring the thermal emission and temperature for ~2000 NEOs in a pointed survey of ~1300 hours. The Spitzer data, when combined with ground-based optical data, will allow us to determine the sizes and albedos of individual NEOs and to obtain for the first time a size-frequency distribution for the NEO population down to sizes smaller than 1 kilometer. We propose here to observe three NEOs in a proof of concept experiment for potential observations in the Spitzer Warm Mission. The NEOs proposed here are all smaller than one kilometer, more than an order of magnitude smaller than the smallest NEO that will be observed by WISE yet representative of an important subclass of objects. Pointing constraints make JWST much more inefficient at carrying out such a survey of NEO physical properties.

Spitzer Space Telescope - General Observer Proposal #20539

High Latitude Dust Bands in the Main Asteroid Belt: Fingerprints of Recent Breakup Events

Principal Investigator: William Bottke
Institution: Southwest Research Institute

Technical Contact: William Bottke, Southwest Research Institute

Co-Investigators:
David Nesvorny, SWRI
Daniel Durda, SWRI
Mark Sykes, Planetary Science Institute
David Lien, Planetary Science Institute
Sumita Jayaraman, Planetary Science Institute
Russell Walker, MIRA
John Stansberry, University of Arizona
William Reach, Spitzer Science Center

Science Category: zodiacal dust
Observing Modes: MipsScan
Hours Approved: 100.2

Abstract:
The present population of main belt asteroids is largely the result of many past collisions. Ideally, the fragments produced by each impact event could help us understand the collisional processes that shaped the planets during early epochs. Most known asteroid fragment families, however, are very old and thus have undergone significant collisional and dynamical evolution since their formation. This evolution masks the properties of the original collisions. To overcome this problem, our team has used numerical methods and a large database of asteroid orbits to identify several families produced by recent disruption events (<< few tens of My). Not only have these young families undergone little collisional and dynamical evolution, but several of them appear to be the source of dust bands observed by IRAS (e.g., the Karin and Veritas families, both which are < 10 My old; Nesvorny et al. 2002; 2003). Here we propose to use Spitzer observations to investigate the structure of high latitude dust bands in the main asteroid belt. Our results indicate that 2 faint dust bands identified by IRAS, the J/K band at proper inclination i = 12 deg and the M/N band at i = 15 deg, were produced by break up events associated with asteroids (4652) Iannini and (1521) Seinajoki, respectively. Numerical integration work by our team suggests the former family is < 5 My old, making it the youngest family yet discovered in the main belt. Taking advantage of the increased sensitivity of Spitzer over IRAS, we will determine the dust production rate and size distribution in the high latitude bands, relate them to the Zodiacal Cloud, and use this data to constrain main belt collisional processes.

Spitzer Space Telescope - Directors Discretionary Time Proposal #1099

Exploration of the Earth's Resonant Ring

Principal Investigator: Sumita Jayaraman
Institution: Planetary Science Institute

Technical Contact: Sumita Jayaraman, Planetary Science Institute

Science Category: zodiacal dust
Observing Modes: MIPS MipsScan MipsTp
Hours Approved: 14.3

Abstract:
The unique feature of the SIRTF is the heliocentric trailing trajectory over the course of its mission. For the first time, an infrared satellite will traverse through the zodiacal dust distribution near the Earth. The primary goal of this proposal is to utilize this golden opportunity to study the structure of the dust cloud associated with the Earth's Resonant Ring. The Resonant Ring is a dynamical structure embedded in the zodiacal cloud. SIRTF observations will provide critical constraints to the dynamical model of this feature by systematically measuring the zodiacal flux asymmetry caused by the resonant ring.

Spitzer Space Telescope - General Observer Proposal #20075

Continued Observations of Earth's Resonant Ring

Principal Investigator: Sumita Jayaraman
Institution: Planetary Science Institute

Technical Contact: Barnett Bruce, Planetary Science Institute

Co-Investigators:
Bidushi Bhattacharya, Spitzer Science Center
Keith Grogan, Jet Propulsion Laboratory
Alberto Noriega-Crespo, Spitzer Science Center
William Reach, Spitzer Science Center
John Stansberry, University of Arizona
Michael Werner, Jet Propulsion Laboratory

Science Category: Zodiacal Dust
Observing Modes: MipsScan MipsTp
Hours Approved: 23.0

Abstract:
We propose continuing observations for a multi-wavelength study of the Earth's Resonant Ring. The unique Earth trailing orbit of Spitzer traverses this Resonant Ring - a heliocentric ring of dust particles at 1 AU. The dust particles in this ring, produced by the grinding down of asteroids in the main belt, spiral into the inner Solar System due to drag forces and are trapped into resonant orbits in the vicinity of Earth. Azimuthal structures in the ring result in a dust cloud that follows the Earth in its wake. This trailing dust cloud produces a flux asymmetry - the radiation in the direction trailing the Earth's orbital motion is higher than the flux in the leading direction by approximately 1.7 MJy/Sr (2-3%). The only confirmed detection of a structure in a disk caused by a known planet, it constrains the mass and location of a planetary perturber embedded in a circumstellar disk. As Spitzer starts to penetrate the trailing dust cloud, the next 1.5 years are critical because the dynamical model predicts that the flux asymmetry will increase dramatically to >7 MJy/Sr and then start to reverse in direction. This project, started in Jan 2004, has been monitoring the ring with MIPS TPM data. We will extend it to a multi-wavelength study with MIPS and IRAC - stare mode at the poles and 10 & 12 deg scans across the ecliptic to filter the asteroidal dust bands. Since the resonant trapping of particles into the ring is a function of particle size, these observations will constrain particle size-frequency distribution using our dynamical model of the ring. The study of Earth's resonant ring will(1) measure the variations of the local zodiacal foreground over the lifetime of Spitzer; (2) constrain the size-frequency distribution, and estimate the number density, of dust in the near-Earth interplanetary environment; (3) act as a case study for the formation and structure of resonant rings in debris disks, associated with the existence of planets embedded in nearby stars.

Spitzer Space Telescope - Archive Research Proposal #20077

Creating a Spitzer Zodiacal Cloud Database

Principal Investigator: Sumita Jayaraman
Institution: Planetary Science Institute

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Co-Investigators:
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David Lien, Planetary Science Institute
William Reach, SSC/IPAC
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Mark Sykes, Planetary Science Institute
Russell Walker, MIRA

Science Category: zodiacal dust
Dollars Approved: 154558.0

Abstract:
We propose to develop the Spitzer Zodiacal Database, a sparse, high resolution map of the zodiacal emission using all relevant Legacy, and available GTO and GO, data from MIPS, IRAC as well as IRS. The final product will include a) time-tagged images and for studies of asteroids, comet trails, dust bands, b) coadded images for precise estimates of the background emission for the broader astronomical community as a whole and c) 1-D scans for the study of the large scale zodiacal background as well as fine structure. In addition, there will be a catalog of comet trails using software specifically developed for trail detection - including trails associated with comets and 'orphan' trails (with no detected source). This database will be web-accessible and searchable through the Planetary Data System's Dust Subnode. This is a unique data product giving the extended emission maps (away from the Galactic plane) that will be applicable to other areas of research beyond the Solar System. It will characterize the foreground zodiacal emission especially near the poles and give us insight into distant background emissions like the Cosmic Infrared Background.

Spitzer Space Telescope - General Observer Proposal #30667

Traversing the Trailing Dust Cloud in the Earth's Resonant Ring - Part 3

Principal Investigator: Sumita Jayaraman
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Science Category: zodiacal dust
Observing Modes: MipsScan MipsTp
Hours Approved: 28.5

Abstract:
We propose continuing observations for monitoring the Earth's Resonant Ring. The unique Earth trailing orbit of Spitzer traverses this heliocentric ring of dust particles at 1 AU. The dust particles in this ring, produced by the grinding down of asteroids in the main belt, spiral into the inner Solar System due to drag forces and are trapped into resonant orbits in the vicinity of Earth. Azimuthal structures in the ring result in a dust cloud that follows the Earth in its wake. This trailing dust cloud produces a flux asymmetry - the radiation in the direction trailing the Earth's orbital motion is higher than the flux in the leading direction by approximately 1.7 MJy/Sr (2-3%). The only confirmed detection of a structure in a disk caused by a known planet, it constrains the mass and location of a planetary perturber embedded in a circumstellar disk. As Spitzer is entering this trailing cloud, the next year is critical because the dynamical model predicts that the flux asymmetry will increase to >7 MJy/Sr, reversing direction in 2006. In Cycles 3 as in 1 & 2 we propose 3 sets of observations : TPM mode at the eclipitic, at the poles, and 12 deg scans across the ecliptic to filter the asteroidal dust bands. These will be combined with calibration observations from IRS and IRAC for a multi-wavelength study of the ring. Since the resonant trapping of particles into the ring is a function of particle size, these observations will constrain particle size-frequency distribution using our dynamical model of the ring. The study of Earth's resonant ring will(1) measure the variations of the local zodiacal foreground over the lifetime of Spitzer; (2) constrain the size-frequency distribution, and estimate the number density, of dust in the near-Earth interplanetary environment; (3) act as a case study for the formation and structure of resonant rings in debris disks, associated with the existence of planets embedded in nearby stars.

Spitzer Space Telescope - General Observer Proposal #40893

Traversing the Trailing Dust Cloud in the Earth's Resonant Ring - Part 4

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Science Category: zodiacal dust
Observing Modes: MipsScan MipsTp
Hours Approved: 26.6

Abstract:
In 4th set of continuing observations for monitoring the Earth's Resonant Ring during the Spitzer mission, the earth-trailing orbit of Spitzer traverses the solar ring of dust at 1 AU. These particles in the ring, produced by the grinding down of asteroids in the main belt, spiral into the inner Solar System due to drag forces and are trapped into Earth's mean motion resonances. Structures in this heliocentric ring result in a dust cloud that follows the Earth in its wake. producing a flux asymmetry: The radiation in the direction trailing the Earth's orbital motion is higher than the flux in the leading direction by approximately 1.7 MJy/Sr (2-3%). The only confirmed detection of a structure in a disk caused by a known planet, it constrains the mass and location of a planetary perturber embedded in a circumstellar disk. Spitzer entered the trailing cloud,at the end of 2005 and traverse pastthe center of the cloud in early 2007. After that point the flux asymmetry will slowly reverse its direction allowing us to measure the spatial extent of the dust distribution. In Cycles 4 we propose 3 sets of observations : TPM mode at the eclipitic, at the poles, and 12 deg scans across the ecliptic to filter the asteroidal dust bands. These will be combined with calibration observations IRAC for a multi-wavelength study of the ring. Since the resonant trapping of particles is a function of particle size, these observations will constrain particle size-frequency distribution using our dynamical model of the ring. The study will will(1) measure the variations of the local zodiacal foreground over the lifetime of Spitzer; (2) constrain the size-frequency distribution, and estimate the number density, of dust in the near-Earth interplanetary environment; (3) act as a case study for the formation and structure of resonant rings in debris disks, associated with the existence of planets embedded in nearby stars.

Spitzer Space Telescope - General Observer Proposal #30545

A New Source of Interplanetary Dust: Type II Dust Trails

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Science Category: zodiacal dust
Observing Modes: MipsScan
Hours Approved: 75.0

Abstract:
Studies of the circumsolar (zodiacal) cloud serve as an important baseline for interpreting observations of extrasolar debris disks. The cometary trails and asteroid dust bands, both analyzed to a great detail in the past, provide vital information on the contribution of cometary activity and large asteroid collisions to the zodiacal cloud. Now, in our Cycle 1 Spitzer program, we detected a new important source of interplanetary dust particles that have not been seen since IRAS mission more than two decades ago, the Type II trails. Unlike narrow (~1 arcminute) comet trails, Type II trails are extremely wide (0.5-2 degrees) and were found by IRAS to extend over tens of degrees. Surface brightness estimates indicate that Type II trails could be supplying more dust to the interplanetary dust complex that all short-period comets combined. Using the IRAS and Spitzer data on detected Type II, our orbital elements fitting to these observations indicate a possible asteroid origin for these structures. Here we propose observations of Type II trails to determine their origin. We propose to make a series of three scan traverses of regions on the sky near the expected locations of the trails. By combining these data with our Cycle 1 observations, we will be able to determine the orbits of Type II trails precisely and to clearly distinguish between asteroidal and cometary sources. Moreover, the determined orbits will be used to pinpoint the exact location of sources of the observed dust particles. The detail structure of trails in different scans, when properly analyzed, will provide valuable insights into the details of their underlying dust production mechanism and formation history. Taken together, the observations proposed here will substantially contribute to our understanding of the zodiacal cloud and its evolution over time.

Spitzer Space Telescope - General Observer Proposal #2317

The Production of Zodiacal Dust by Asteroids and Comets

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Science Category: zodiacal dust
Observing Modes: MipsScan
Hours Approved: 170.9

Abstract:
Dust production in the asteroid belt has been recently demonstrated to arise primarily from the stochastic catastrophic disruption of small asteroids, making previous estimates based on an equilibrium collision model no longer valid. We propose to determine the relationship between asteroids and the zodiacal dust complex by measuring and detecting dust band structures 200 times fainter than the principal bands discovered by the Infrared Astronomical Satellite. We seek to relate these dust bands to specific source regions within the asteroid belt corresponding to recent and old collision events, and put limits on their dust production when dust bands are not correlated with them. This study is necessary to gain insight into how much of the zodiacal cloud is generated by asteroid collisions and the question of zodiacal cloud variability. An additional source of zodiacal dust is large particle emissions from comets, which stretch out into a narrow trail over a portion of their orbits. The net contribution of comets to the cloud is uncertain. These observations will give us the opportunity to search for dust trails associated with both known and unknown short-period comets, to assess the completeness of the known short-period comet population, and to constrain the contribution of comets to the zodiacal dust complex, in particular that contribution from as yet undiscovered comets. Towards this end, we will use the 24 micron MIPS array to scan two sets of five parallel strips of constant ecliptic longitude, on opposite sides of the ecliptic, roughly 90 degrees away from the galactic plane. Each set of 5 longitudinal strips will be scanned at two solar elongations. Each strip is 20 degrees long, centered about the ecliptic plane in latitude. The survey is designed to characterize and remove background cirrus and to identify and distinguish among structures arising from asteroid dust bands, partial dust bands, and comet dust trails and ascertain their specific locations.