SOFIA Basic Science FORCAST Abstracts

81_0006 Far-IR Interferometry With SOFIA: A Test of Lunar Occultation Observations

Principal Investigator: Dr. Paul M. Harvey

University of Texas at Austin

Scientific Category: ISM AND CIRCUMSTELLAR MATTER

Abstract

We propose to test the concept of observing lunar occultations in the far-IR using the FORCAST instrument at 35um. These first tests are mainly to understand the optimum observing techniques by making several test observations of the lunar limb. If an actual occultation event occurs during the Basic Science period that was easily schedulable, that of course would be even better.

81_0007 SOFIA Observations of the Gulf of Mexico Cluster

Principal Investigator: Dr. Luisa M. Rebull

Spitzer Science Center

Scientific Category: STAR FORMATION

Abstract

The relatively nearby (~550 pc) North American (NGC 7000) and Pelican (IC 5070) Nebulae is a very complex mix of bright and dark clouds thought to be likely to host more than 10,000 newly formed stars. Despite being relatively close, this region has not yet been extensively studied because it is in a region of very high star density with superimposed bright and dark nebulae, making identification of cluster members challenging in the optical. We have carried out a multi-wavelength survey of this region, revealing a spectacular cluster in the "Gulf of Mexico" region, which appears to be the most embedded, youngest, densest, and most dramatic portion of this already impressive complex. The northeastern-most 10' long portion of the Gulf of Mexico cluster has a handful of previously-identified young stellar objects (YSOs) but also contains ~50 YSO candidates that we have identified in the mid-IR, tightly clustered along a dark lane and including some that are clearly multiple but too close together for our MIPS-24 and 70 micron imaging to resolve. SOFIA observations should allow better spatial resolution and characterization of this very young, active star forming region. We propose for 5 hours of FORCAST time at 24.2 and 34.8 microns to detect and resolve the ~32 sources seen by Spitzer at 24 um at brighter than 50 mJy.

81_0013 Peering to the Heart of Massive Star Birth

Principal Investigator: Prof. Jonathan Charles Tan

University of Florida

Scientific Category: STAR FORMATION

Abstract

We propose to observe four nearby massive protostars with SOFIA-FORCAST to resolve their extended mid-infrared (MIR) emission, much of which we expect traces cavities blown by bipolar outflows. We will combine the imaging data we obtain at 11, 19, 24, 31 and 37 microns with that available at other wavelengths to construct global spectral energy distributions (SEDs) of the sources. We will examine how the MIR SED varies along the outflow axes. We will compare these observations to detailed radiative transfer calculations of massive protostars that we are developing to test massive star formation theories.

81_0015 FORCAST Imaging of Planetary Nebulae

Principal Investigator: Dr. Michael Werner

Jet Propulsion Laboratory

Scientific Category: ISM AND CIRCUMSTELLAR MATTER

Abstract

We propose to use FORCAST on SOFIA for multicolor imaging of four bright, extended planetary and protoplanetary nebulae which show intriguing morphologies in HST images. Previous measurements from IRAS, ISO and the KAO show that these are bright infrared sources showing thermal emission spectra which peak [in a nu-Fnu sense] around 25um, within the FORCAST band. These bright, ~1 arcmin size sources are ideal targets for FORCAST and we expect our images to be both scientifically informative and excellent demonstrations of SOFIA's capabilities.

81_0016 19-37 Micron Photometry of Outer Planets

Principal Investigator: Dr. Glenn Orton

Jet Propulsion Laboratory

Scientific Category: SOLAR SYSTEM

Abstract

We propose a short program of long-wavelength FORCAST photometry of Uranus and Neptune to follow up Infrared Space Observatory (ISO), Spitzer, and Herschel observations. We will also acquire imaging photometry of Jupiter to follow up 2000-2001 Cassini spectra and FORCAST first-light images. We will derive information on temperature structure and composition that is inaccessible from ground-based observatories, using filters centered at 19.7, 24.2, 31.6, 33.6, 34.8 and 37.1 micron, calibrated using a well-documented stellar standard system. This short photometric program is intended, in part, as a precursor to FORCAST spectroscopic observations of Uranus and Neptune. Thermal and compositional information on Uranus and Neptune will be used to refine atmospheric models and far-infrared through submillimeter model spectra of both planets, which form a key part of the Herschel Space Observatory flux-calibration system.

81_0022 The nature of Young High-mass (proto)stars in NGC7538

Principal Investigator: Dr. Göran Sandell

Universities Space Research Association

Scientific Category: STAR FORMATION

Abstract

We propose to do deep 11.1, 19.7 and 37.1 micron of three fields in NGC 7538. This star formation region has three sites of active on-going star formation and one of the few star forming regions which show clear evidence for accretion (through inverse P Cygni profiles) and rotating accretion disks around high-mass stars (from subarcsecond mm-array imaging). We will use 2MASS, archive Spitzer (already reduced) and Herschel data (public by next year) plus extensive CARMA line and continuum imaging to get a complete census of the young stellar population in NGC7538.

81_0024 SOFIA observations of recurrent novae

Principal Investigator: Dr. Mark Rushton

University of Central Lancashire

Scientific Category: ISM AND CIRCUMSTELLAR MATTER

Abstract

Recurrent novae are interacting binary systems containing a massive white dwarf and a low mass secondary star. They are of interest for a number of reasons, not least because they may be progenitors of type-Ia supernovae. In some recurrent novae, infrared excesses are observed due to dust in the secondary wind, which is shocked by the nova ejecta. We propose to use SOFIA/FORCAST to observe three of these recurrent novae: RS Oph, T CrB, and V407 Cyg. Our aims are to measure the spectral energy distribution of the dust emission, to determine the nature of the dust, to measure the mass-loss rates, and to monitor their long term behaviour in the infrared region.

81_0025 Spatially-Resolved Far-Infared Imaging of Bright Debris Disks: Studying the Disk Structure and the Stirring Mechanism

Principal Investigator: Dr. Carol Anne Grady

Eureka Scientific Inc.

Scientific Category: ISM AND CIRCUMSTELLAR MATTER

Abstract

Circumstellar disks are a byproduct of star formation, and are the birthplace of planetary systems. Initially gas rich and optically thick, by ~10 Myr, the majority of disks are gas-poor and contain at most a few lunar masses in dust grains. Two mechanisms have been proposed to account for spectral energy distributions where the thermal emission is at discrete temperatures, indicating that the dust is localized in belts. In the self-stirring mechanism, formation of Pluto-sized protoplanets stirs up the motion of smaller bodies, initializing a collisional cascade, which is first seen in the inner disk, and then propagates outward producing an optically thin debris disk. Collisional cascades in a planetesimal belt can also be externally excited: giant planets or stellar companions can dynamically excite the motion of planetesimals via their secular perturbation (e.g. planetary stirring). Self-stirred belts are expected to be azimuthally symmetric at all wavelengths where the belt can be detected, while belts which are excited by the planetary stirring mechanism are expected to be more symmetric at short wavelengths, and to have long-wavelength far-IR and sub-millimeter shapes which are clumpy and depart from azimuthal symmetry. We propose testing these models with SOFIA FORCAST imaging of 3 debris disks which Spitzer marginally resolved at 70 microns.

81_0029 SOFIA's Opportunity to Solve the Nebular Abundance Problem

Principal Investigator: Dr. Robert H. Rubin

NASA Ames Research Center

Scientific Category: ISM AND CIRCUMSTELLAR MATTER

Abstract

Abundance surveys of a large sample of Galactic planetary nebulae (PNe) have led to the discovery of a group of super-metal-rich nebulae whose spectra show prominent optical recombination lines (ORLs) from C, N, O, and Ne ions. The heavy element abundances derived from ORLs for several PNe are a factor >10 higher than those derived from the traditional method based on collisionally excited lines (CELs). This ratio is called the abundance discrepancy factor (adf). A promising proposition to explain the nebular abundance problem posits that these nebulae contain (at least) two distinct regions - one of "normal" electron temperature, Te (~10000 K) and chemical composition (~solar) and another of very low Te (< 1000) that is H-deficient, thus having high metal abundances relative to H. The latter component emits strong heavy element ORLs and IR fine-structure (FS) CELs but essentially no optical/UV CELs. Efforts to directly detect these inclusions in PNe have been unsuccessful to date. However, there is mounting circumstantial evidence for their existence, such as presented in our recent paper that modeled the high-adf PN NGC 6153 using a 3-D photoionization code. The models that included the low Te, H-deficient knots fit most observations far better than did those models without the clumps. Measurements have shown that the adf varies with position in a PN and is highest close to the central star. The very low Te inclusions must be cooled predominantly by FS mid-IR lines. We propose to use spectrophotometry with FORCAST on SOFIA to map mid-IR FS lines in the bright, well-characterized PN NGC 2440, which is on the largest adf list, to find if these lines peak where the adf peaks.

81_0037 SOFIA 24 and 35um imaging of the OB young stellar objects in Cygnus-X.

Principal Investigator: Dr. Tracey Hill

Commissariat a l'Energie Atomique (CEA), Service d'Astrophysique

Scientific Category: STAR FORMATION

Abstract

Cygnus X is a well-studied region known to be forming massive stars. Within this region, the DR21 and DR21(OH) regions are particularly enticing active star forming regions to study. The proximity of Cygnus X (1.6 kpc) offers the unique opportunity to resolve intermediate/high mass protostars. We propose to image two regions within Cygnus X -- the DR21 & DR21(OH) region as well as the millimeter-identified Cyg-N3 region -- with the FORCAST continuum camera at both 35 and 24 microns. This SOFIA program is vitally needed to better understand the formation of massive OB-type stars. 35 micron observations are particularly crucial as they complete our wavelength coverage of these sources, bridging the gap between Herschel at 70 micron and Spitzer at 24 micron, at comparable resolution to Spitzer and Herschel. The 24 micron SOFIA observations provide the opportunity to image sources saturated in the Spitzer MIPS images at a higher angular resolution than MIPS. These SOFIA data will capitalise on our existing data from 1 and 3mm (PdBI) and Herschel (500,350,250,160,70 micron), as well as Spitzer 24 micron for weaker sources in the field, and will facilitate spectral energy distribution (SED) modeling. From tightly constrained SED models, we can obtain a far better constraint on key parameters such as the bolometric luminosity, temperature and envelope mass, from which we can estimate the evolutionary status of the source.

81_0039 Cool Dust and the Mass Loss Histories of Cool Hypergiants

Principal Investigator: Dr. Roberta M Humphreys

University of Minnesota - Twin Cities

Scientific Category: COOL STARS

Abstract

A few highly unstable, very massive stars lie on or near the empirical upper luminosity boundary in the HR diagram. They represent a short-lived evolutionary stage, characterized by high mass loss and

eruptive events. Many of them are strong infrared sources and powerful OH masers. Space and ground based visual and near-IR imaging has revealed evidence for asymmetric ejections and multiple high mass loss events in the circumstellar ejecta of VY CMa and IRC+10420, for example. In this proposal, we turn our attention to the cool dust which may or may not be spatially coincide with the visual ejecta. It may have formed due to the recent mass loss episodes or be a fossil record of earlier mass loss. Measuring the cold dust will provide a more complete estimate of the total mass lost and the mass loss histories of these stars. The recent measurement of extended 24 micron emission around Mu Cep, previously undetected at shorter wavelengths, is an example. We propose near-IR and mid-IR photometry with FORCAST of 8 of these hypergiants, including mid-IR imaging of four of them to resolve faint extended emission out to radii of 10'' - 20'' using a shift and add method.

81_0041 FORCAST imaging of the mini-starburst in W43

Principal Investigator: Prof. John Bally

University of Colorado at Boulder

Scientific Category: STAR FORMATION

Abstract

We propose to image the W43 'mini-starburst' region, one of the nearest giant HII region / massive star formation complexes in the Galaxy. The goals of this program are: Search for massive, embedded protostars in the Z-shaped star-burst region that contains about 50 sub-mm / mm wavelength clumps of dense gas and which are saturated in the mid-IR Spitzer images. Determine the SEDs and luminosities of these protostars. Search for clustering and companions. Investigate the structure of the warm mid-IR dust emission associated with the HII region, the surrounding PDR, and the massive protostars. Each of the 11 fields will be observed at 11.1, 19.7, 31.4, and 37.1 microns with total exposure times of 900 seconds, sufficient to detect the extended emission with high signal to noise. This program will serve to demonstrate SOFIA/FORCAST capabilities for the study of massive star and cluster forming regions.

81_0047 FORCAST Study of 21 Micron Sources

Principal Investigator: Prof. Peter J Sarre

University of Nottingham

Scientific Category: ISM AND CIRCUMSTELLAR MATTER

Abstract

Five proto-Planetary Nebulae (PPNe) are chosen to be imaged at wavelengths from 7.7 to 37.1 microns to determine their spatial distributions. Imaging at 7.7, 8.6 and 11.3 microns are to be used to try and determine any spatial correlations between PAH features and the two unidentified features at 21 and 30 microns, and to help identify chemical and physical processes behind the respective carriers.

81_0048 Uncovering Buried Star Clusters in Nearby Starburst Galaxies

Principal Investigator: Dr. William D Vacca

Universities Space Research Association

Scientific Category: GALAXIES

Abstract

We propose to use FORCAST to image a small sample of starburst galaxies in order to study the earliest stages of massive stellar cluster formation and evolution. From previous radio and/or infrared observations, the galaxies in our sample are known to contain so-called Ultra-Dense HII regions, which are believed to be young, massive stellar clusters deeply embedded in large amounts of the natal dust from which they formed. Such "buried clusters" thus represent the youngest phases of stellar cluster evolution. Surprisingly, these buried clusters are often the overwhelmingly dominant contributors to the total IR flux from their host galaxies. Previous space-based IR observations of buried clusters have been hampered by poor spatial resolution. The higher spatial resolution achievable with SOFIA/FORCAST will allow the clusters to be studied individually. The resulting MIR photometry will be combined with existing radio and IR data to generate the spectral energy distributions of the clusters, and used to constrain the parameters of the physical models of these regions.

81_0051 Resolving Class 0 Binaries in the Mid-Infrared: The Result of Non-Axisymmetric Envelopes

Principal Investigator: Prof. Leslie Looney

University of Illinois at Urbana - Champaign

Scientific Category: STAR FORMATION

Abstract

In our Spitzer survey of low-mass, deeply embedded protostars, so-called Class 0 objects, the 8 micron PAH absorption (tracing column density independent of temperature) revealed complex, non-axisymmetric structures in the circumstellar envelopes around most protostars in the sample. We suggested that these non-axisymmetric envelopes drive binary star formation, while single stars result from more axisymmetric large-scale structures. Using radiative transfer modeling, we can probe the inner envelopes of these systems and compare them to the single systems to reveal the effect of the binary on the inner envelope, as well as how the non-axisymmetry impacts the binary systems.

Unfortunately, the Spitzer MIPS observations have insufficient resolution to probe binaries at the scale on which they most impact the inner envelope morphology and structure. To resolve this problem, we propose a small SOFIA survey of 9 known close binary (1000-3000 AU) systems using the FORCAST camera in 4 bands. With the resolution and sensitivity to detect the faintest components of the binary, we can reveal the emission from the inner envelope for the first time, infer the impact of the binary system on the envelope, and refine our radiative transfer models of the properties of the envelope.

81_0059 Observations of the Nearby Starburst Galaxy NGC 2146 with FORCAST on SOFIA

Principal Investigator: Dr. Lee Armus

California Institute of Technology

Scientific Category: GALAXIES

Abstract

The Great Observatories All-sky LIRG Survey (GOALS) is aimed at measuring the properties of a large, complete sample of low-redshift LIRGs across the electromagnetic spectrum. Here, we propose to image one of the nearest and brightest galaxies in the GOALS sample, the edge-on starburst NGC 2146, with FORCAST on SOFIA in the 11.3, 19.7, and 37.1 micron filters. FORCAST offers high spatial resolution imaging and a wide variety of filters to uniquely probe the mid-infrared emission in starburst galaxies. With these data we will be able to map the variation in PAH grain properties across the NGC 2146 disk, and fill in critical SED points between existing Spitzer MIPS and Herschel PACS imaging, which will allow us to model the dust opacities and temperatures in the starburst.

81_0066 FORCASTing Evolved Star Mass Loss in the Galactic Bulge

Principal Investigator: Dr. Margaret Meixner

Space Telescope Science Institute

Scientific Category: ISM AND CIRCUMSTELLAR MATTER

Abstract

We propose to obtain multi-band photometry of a well-selected sample of very dusty asymptotic giant branch (AGB) stars (including OH/IR stars) and supergiant (SG) stars in the Galactic Bulge of the Milky Way Galaxy using the FORCAST mid-infrared imaging instrument on SOFIA. The photometric bands of FORCAST are ideally placed in wavelength to identify emission from the various kinds of dust produced by AGB stars and, thus, to place significant constraints on the mass-loss rates from these stars. This is of crucial importance in determining the mass budget of dust in our Galaxy, which has implications for studies of AGB stars in the rest of our Galaxy, the interstellar medium, etc. Our goal in obtaining these observations will be accurate photometry for each band, and SOFIA-FORCAST should excel in this, even given the early stage in the characterization of the observatory and its instruments. In addition, this data will be combined with submillimeter-wavelength data from the Sub-Millimeter Array (SMA) and other data to study gas and dust mass loss as a function of metallicity. Our targets are optimal for observing during the Basic Science period of SOFIA operations. The proposed observations complement studies conducted by the proposers of evolved star dust production in the Magellanic Clouds and will enable studies of AGB dust production over a wide range of local metallicity. Such studies will be invaluable to future studies of AGB dust production using SOFIA, James Webb Space Telescope (JWST), Herschel Space Observatory, etc.

81_0067 Mid-Infrared imaging of the W40 Star Forming Region using SOFIA-FORCAST.

Principal Investigator: Dr. Ralph Shuping

Space Science Institute

Scientific Category: STAR FORMATION

Abstract

We propose to observe the central part of the W40 star formation region using the FORCAST instrument in order to extend the mid-IR SEDs of the young stellar objects, the UCHIIs, and the Main Sequence stellar population that we have identified using near-IR spectra. The W40 region is one of just a handful of high-mass star forming regions within 1 kpc of the sun and thus provides an important laboratory for understanding the nature of star and cluster formation. We intend to model the complete SEDs for our sources in order to derive stellar luminosities, disk masses, envelope masses, and infall rates and then compare those parameters to the known spectral types we have derived from near-IR spectra that we have obtained from the IRTF. The mid-IR fluxes provided by FORCAST are critical in constraining the model parameters. In addition to studying the known IR sources in W40, we will also carry out a 9 arcmin X 9 arcmin map of the region at 38.4 microns to search for any additional embedded objects.

81_0069 Probing The AGN-Starburst Connection

Principal Investigator: Dr. Thomas J Nikola

Cornell University

Scientific Category: AGN/QUASARS

Abstract

We propose to investigate the interplay between active galactic nuclei (AGNs) and nuclear starbursts by imaging the central region of nearby AGN/starburst galaxies in the mid-IR using all 8 broadband filter between 10 and 40 micron of FORCAST. The mid-IR spectral energy distribution (SED) probes the hot dust component and measures its temperature. By imaging the nuclear region we also obtain the morphology of the dust emission in each band. Together this results in a 2D SED for the nuclear region with unprecedented spatial resolution allowing to trace the heating source and its effect on the surrounding environment.

81_0072 Intermediate-Mass Star Formation Regions: Defining a High-Latitude Sample

Principal Investigator: Dr. Henry Kobulnicky

University of Wyoming

Scientific Category: STAR FORMATION

Abstract

High-mass star formation cannot be viewed as simply a scaled-up version of the paradigm for low-mass star formation. The high-mass regime (>10 Msun) appears to require significant differences in cloud fragmentation, accretion, radiation, turbulence, and overall molecular density compared to the low-mass regime. We haveidentified, on the basis of IRAS color selection, a sample of intermediate-mass star-forming regions (IMSFRs) that straddle the boundary of these two regimes and can be used to understand the factors that govern the transition between these extremes. Most notable among these factors is the possibility of a critical cloud mass column density that appears to divide high-mass SFRs from IMSFRs. Yet, the stellar content and evolutionary stage of IMSFRs is unexplored, except for our pilot study of objects contained in Spitzer's Galactic surveys. We propose here to image a sample of nine candidate IMSFRs at 24 and 35 microns that lie at high galactic latitudes |b|>5 degrees in order to 1) confirm the IMSFR nature morphologically, 2) resolve their pre-main-sequence contents and measure the mass and the evolutionary stage of protostellar objects therein, and 3) compare the properties (mass, stellar content, size) of high-latitude IMSFRs with those found in the mid-Plane.

81_0074 Resolving Protostars in the Serpens South Protocluster

Principal Investigator: Dr. Tracy L. Huard

University of Maryland

Scientific Category: STAR FORMATION

Abstract

Recently, the Spitzer Space Telescope revealed a new young cluster, known as Serpens South, located in the Serpens-Aquila Rift. With a high ratio of protostars to young stellar objects, Serpens South is among the youngest known clusters. Present in the cluster core are at least two groups of protostars that are blended or confused in Spitzer MIPS observations; some of these protostars may share a common protostellar envelope. We propose FORCAST observations of the cluster core, taking advantage of the higher angular resolution to properly derive mid-infrared fluxes. With these fluxes, their spectral energy distributions may be characterized, which will enable constraints on their luminosities and physical structures. If indeed some of these protostars share envelopes, their relative luminosities may be suggestive of the winners and losers in the competition for matter from the same reservoir. Followup interferometric millimeter observations will provide additional details concerning these protostars and their envelopes.