Reionization to Exoplanets: Spitzer's Growing Legacy (Poster Abstracts)

1. Solar System and Exoplanets

1.1 Water in HD 209458b's atmosphere from 3.6 - 8 microns IRAC photometric observations in primary transit

Jean-Philippe Beaulieu (IAP/UCL)

The hot Jupiter HD 209458b was observed during primary transit at 3.6, 4.5, 5.8 and 8.0 μm using the Infrared Array Camera (IRAC) on the Spitzer Space Telescope. We detail here the procedures we adopted to correct for the systematic trends present in the IRAC data. The light curves were fitted including limb darkening effects and fitted using Markov Chain Monte Carlo and prayer-bead Monte Carlo techniques, finding almost identical results. The final depth measurements obtained by a combined Markov Chain Monte Carlo fit are at 3.6 μm, $1.469 \pm 0.013\%$ and $1.448 \pm 0.013\%$; at 4.5 μm, $1.478 \pm 0.017\%$; at 5.8 μm, $1.549 \pm 0.015\%$ and at 8.0 μm $1.535 \pm 0.011\%$. Our results clearly indicate the presence of water in the planetary atmosphere. Our broad band photometric measurements with IRAC prevent us from determining the additional presence of other other molecules such as CO, CO_2 and methane for which spectroscopy is needed. While water vapour with a mixing ratio of 10^{-4}-10^{-3} combined with thermal profiles retrieved from the day-side may provide a very good fit to our observations, this data set alone is unable to resolve completely the degeneracy between water abundance and atmospheric thermal profile.

1.2 Discrete Thermal Phase Curve Observations of the Eccentric Transiting Planet HD 17156b

Bryce Croll (University of Toronto)

We have observed the eccentric ($e \sim 0.67$) transiting exoplanet HD 17156b at 8 μm with Spitzer/IRAC over three pseudo-spin periods. HD 17156b experiences a 26-fold variation in stellar insolation over the course of its highly eccentric orbit. Tidal evolution should have led to pseudo-synchronization of the planet's spin, with a period of 3.8 d. Thus, at periastron, one side of this planet should be flash heated, with stellar irradiation exceeding 1000 times the solar flux at Earth. Our observations were taken at ten specifically scheduled epochs prior to and following periastron, which should allow us to to directly probe the radiative and advective timescales of the planetary atmosphere as it responds to the intense blast of stellar irradiation near periastron, and as the strongly irradiated face of the planet rotates in and out of view. Preliminary analysis will be presented.

1.3 Transit spectrophotometry of the exoplanet HD189733b with Spitzer and HST

Jean-Michel Desert (IAP)

Water, methane and carbon-monoxide are expected to be among the most abundant molecules besides molecular hydrogen in the hot atmosphere of close-in extrasolar giant planets. Atmospheric

models for these planets predict that the strongest spectrophotometric features of those molecules are located at wavelengths ranging from 1 to 10 μm making this region of particular interest. Consequently, transit observations in the infrared allow the atmospheric content of transiting planets to be determined. Primary transit observations of the hot-jupiter HD189733b, obtained in the near and mid-IR with Hubble and Spitzer Space Telescopes are presented here. The high-S/N photometric transit light curves allowed us to improve the precision of the near infrared radii of the planet. We are able to derive accurate system parameters, including planet-to-star radius ratios, impact parameter, scale of the system, and central time of the transit from fits of the transit light curves. We finally compare the results obtained here with transmission spectroscopic models and with results from various observations of this planet. In particular we show that H_2O cannot be detected by using Spitzer/IRAC observations because of Rayleigh scattering and of a large CO/H_2O ratio estimated to be between 1 and 60.

1.4 Comparison of Mass Radius Relations for Transiting ESP
Michael Lund (Cal State - Northridge)

A growing number of (over 60!) extra-solar planets (ESPs) have been discovered by transit photometry, and these systems are important because the transit strongly constrains their orbital inclination and allows accurate physical parameters for the planet to be derived, especially their radii. Their mass-radius relation allows us to probe their internal structure, and there are currently several models (e.g. Fortney et al. 2007). We present a comparison of these models to the current sample of transiting ESP. Although such models are nascent, it is important to establish trends for the current sample of ESP, which will further the understanding of their composition, formation, and evolution. Such studies have applications for future discoveries of lower mass planets.

1.5 Study of Hot-Jupiter Atmospheres using Infrared Photometry
Pavel Machalek (STScI)

We report the detection of thermal radiation from 3 unique Hot-Jupiters, discovered by the XO team, using the Infrared Array Camera (IRAC) on the Spitzer Space Telescope in order to obtain broadband spectra in the infrared to constrain the upper atmospheric temperature structure of Hot-Jupiters. The infrared spectral energy distribution of 3 Hot-Jupiters XO-1b, XO-2b and XO-3b has revealed a presence of a thermally inverted stratosphere in all 3 of them. Since the 3 XO Hot-Jupiters occupy a wide range of substellar point fluxes ($F_p \sim 0.49 - 4.2 \times 10^9$ erg cm^{-2} s^{-1}) it allows us to test whether there is a threshold bolometric substellar point flux on the planet above which the intense optical/UV light from the star is absorbed by an upper atmospheric absorber, which would drive a thermal inversion - a hot stratosphere.

1.6 AKARI survey of ices and volatiles in the solar system small bodies
Takafumi Ootsubo (ISAS/JAXA)

We present the initial result on the AKARI spectroscopic survey of ices and volatiles in the solar system small bodies, particularly for water and carbon dioxide in comet C/2007 N3 (Lulin). Near-infrared (2.5–5 μm) spectroscopy is a powerful tool to study the chemical composition of the

ice and volatiles in the solar system small bodies. Most abundant volatile molecules (especially water and carbon dioxide) are, however, difficult to measure directly from the ground because they are also present in the Earth's atmosphere. AKARI provides a near-infraed spectroscopic capability that is complementary to Spitzer near-infrared imaging observations. We have been carrying out the near-infrared spectroscopic observations of comets and asteroids with AKARI during the post-helium phase (Phase 3). Two strong vibrational bands of water at 2.66 μm and of carbon dioxide at 4.26 μm are present in the AKARI spectra of comets. In addition to these two strong band features, the carbon monoxide v(1-0) band at 4.67 μm and a broad 3.2–3.6 μm emission band of hydrocarbons can be also seen. The relative abundances of water, carbon dioxide, and carbon monoxide will be discussed.

1.7 ExploreNEOs: The Warm Spitzer NEO survey
David E Trilling (Northern Arizona University)

The majority of Near Earth Objects (NEOs) originated in collisions between bodies in the main asteroid belt and have found their way into near-Earth space via complex and little understood dynamical interactions. This transport of material from the main belt into the inner Solar System has shaped the histories of the terrestrial planets. However, despite their scientific importance, key characteristics of the NEO population — such as the size distribution, mix of albedos and mineralogies, and contributions from so-called dead or dormant comets — remain largely unexplored; some 99% of all presently known NEOs are essentially uncharacterized. We have an approved 500 hour Warm Spitzer program to derive albedos and diameters for some 700 NEOs. We will measure the size distribution of this population to understand fundamental physical processes that occur among the small bodies of our Solar System. We will measure the fraction of NEOs likely to be dead comets, with implications for the flux of organic material onto the Earth. We will measure the albedo distribution of NEOs, which indicates the compositional diversity among these small bodies. We will study properties of individual NEOs, including their surface properties and potentially their densities, and detailed properties of a subset of well-characterized objects. Our Warm Spitzer program began execution in late July, 2009, and will return on average one target per day for the next two years. We will present the first results from our program at the Spitzer Legacy meeting.

2. Star Formation

2.1 First Spectroscopic Identification of Massive Young Stellar Objects in the Galactic Center
Deokkeun An (Caltech/IPAC)

We report the detection of several molecular gas-phase and ice absorption features in three photometrically-selected young stellar object (YSO) candidates in the central 280 pc of the Milky Way. Our spectra, obtained with the Infrared Spectrograph (IRS) onboard the Spitzer Space

Telescope, reveal gas-phase absorption from CO_2 (15.0 μm), C_2H_2 (13.7 μm) and HCN (14.0 μm). We attribute this absorption to warm, dense gas in massive YSOs. We also detect strong and broad 15μm CO_2 ice absorption features, with a remarkable double-peaked structure. The prominent long-wavelength peak is due to CH_3OH-rich ice grains, and is similar to those found in other known massive YSOs. Our IRS observations demonstrate the youth of these objects, and provide the first spectroscopic identification of massive YSOs in the Galactic Center.

2.2 Disk and Envelope Structure in Class 0 Protostars
Melissa L Enoch (UC Berkeley)

We present the first results of a program to characterize the disk and envelope structure of typical Class 0 protostars in nearby low-mass star forming regions (Serpens, Perseus, and Ophiuchus). We use Spitzer IRS mid-infrared spectra, high resolution CARMA 230 GHz continuum imaging, and 2-D radiative transfer models to constrain the envelope structure, as well as the size and mass of the circum-protostellar disk, in an unbiased sample of Class 0 sources. The primary envelope parameters (centrifugal and outer radii, outflow opening angle, and inclination) are well constrained by the spectral energy distribution (SED), including IRAC and MIPS photometry, IRS spectra, and 1.1 mm Bolocam photometry. These together with excellent uv-coverage from multiple antenna configurations with CARMA allow for a robust separation of the envelope and disk. Serpens FIRS 1 serves as a test case to demonstrate the feasibility of the program. The SED is well fit by an envelope with the density profile of a rotating, collapsing spheroid with an inner (centrifugal) radius of 600 AU, and the millimeter data by a large resolved disk with $M_d \sim 1.0 M_\odot$ and $R \sim 300$ AU. Preliminary results for the rest of the Serpens sample of 7 Class 0 sources suggest that well developed disks with masses of approximately 10% of the envelope mass are common in the main accretion phase.

2.3 The Eagle Nebula: a spectral template for star forming regions
Nicolas Flagey (SSC/Caltech)

The Eagle Nebula (M16) is one of the nearest (2 kpc) massive star forming region and one of the most observed across the electromagnetic spectrum. It is a reference source for star formation and interstellar medium studies. M16 has been imaged by MSX, ISO and Spitzer (GLIMPSE and MIPSGAL surveys). A spectro-imaging observation from 5 to 15(?) μm obtained with ISO over a 3×3 arcmin field around the famous Pillars of Creation illustrates the wide diversity of mid-IR spectra on small angular scales. We present an extended spectroscopic map (25×25 arcmin) obtained with both IRS/LL and MIPS/SED of M16 to characterize both small scale structure and dust evolution within the global context of star formation. We complete this map with CFHT near-IR observations over the same extent in Brackett Gamma and H_2 to characterize several peculiar features within the Eagle Nebula.

2.4 Molecular Hydrogen Emission from the Taurus Molecular Cloud
Paul F Goldsmith (JPL/Caltech)

We report the detection of the S(0) and S(1) pure rotational transitions of H_2 in emission

from boundary layers of the Taurus Molecular Cloud. These lines were observed with the Spitzer Infrared Spectrograph (IRS), and are very weak, with maximum specific intensity 0.4 MJy/sr. The emission is strongest 8.5' (0.33 pc) outside the edge of the cloud defined by the ^{13}CO. We see H_2 emission towards the bulk of the cloud at a lower level, suggestive of limb brightening of an envelope around the purely molecular cloud. The peak column densities looking directly towards the cloud are $N(J = 3) = 1.3 \times 10^{17}$ cm^{-2}, and $N(J = 2) = 2.2 \times 10^{18}$ cm^{-2}. We discuss the cloud edge in terms of a PDR model, and discuss in particular the need for an additional heating mechanism to explain the observed quantity of warm H_2.

2.5 Nearby Star Formation Structure Dissected: A Spitzer Legacy
Robert Gutermuth (Smith College/UMass Amherst)

Spitzer's unmatched mid-infrared sensitivity has enabled near-complete large-scale surveys of forming stars with excess IR emission from disks and envelopes for over 90% of all known star forming regions within the nearest kiloparsec as well as many regions beyond. This work has greatly expanded our knowledge of the star formation process and how it varies (or doesn't!) with environment. I will present a survey of some of our recent work, from cluster shapes, sizes, and surface densities, to hierarchical structure extraction over three orders of magnitude in spatial scale, to the spectrum of star-formation efficiencies and their relationship to local natal cloud column density.

2.6 The Spitzer View of Low-Metallicity Star Formation: Fine Structure Lines, Aromatic Features, and Molecules
Leslie K Hunt (INAF-Osservatorio di Arcetri)

We present low- and high-resolution Spitzer/IRS spectra, supplemented by IRAC and MIPS measurements, of a large sample of 23 blue compact dwarf (BCD) galaxies. The BCD sample spans a wide range in oxygen abundance and hardness of the interstellar radiation field (ISRF). The IRS spectra provide us with a rich set of diagnostics to probe the physics of star and dust formation in very low-metallicity environments. We find that metal-poor BCDs have harder ionizing radiation than metal-rich galaxies; they also have a more intense ISRF, as indicated by the 71 to 160 μm flux ratio. The vast majority of our BCDs show PAH features, although the fraction of PAH emission normalized to the total infrared (IR) luminosity is considerably smaller at low metallicity than in metal-rich galaxies. We find several lines of evidence for a deficit of small PAH carriers at low metallicity, and attribute this to destruction by a hard, intense ISRF, only indirectly linked to metal abundance. Our IRS spectra reveal a variety of H_2 rotational lines, and almost half of the objects in our sample (10 BCDs) have $> 3\sigma$ detections in one or more of the four lowest-order transitions. The warm gas masses in our BCDs range from 10^6 to 10^8 $M_\odot$, and the inferred cool molecular gas content is quite significant, ranging from 2×10^7 to 2×10^9 $M_\odot$, comparable to the neutral hydrogen gas mass in some cases. Some of the lowest luminosity BCDs contain more H_2 than SINGS galaxies, relative to their total IR luminosities. Four of our BCDs also show water and OH molecular emission. For the majority of the BCDs, the extinction derived from the mid-infrared

(MIR) continuum is considerably larger than that derived from the optical Balmer decrement: the MIR radiation comes from substantially more obscured regions than the optical radiation.

2.7 Massive Protostars around IRAS 05345+3157
Randolf Klein (UC Berkeley)

With Spitzer and CARMA, we investigated molecular cores around IRAS 05345+3157. MIPS detected two cores in a very early stage of massive star formation. The MIPS data allowed us to derive the SEDs for two cores and pinpoint the driving source for a known massive outflow, while CARMA confirmed in-fall motions. Modeling the SEDs for two cores confirm massive proto-stars. More cores were detected with CARMA showing turbulent support, but may well be seeds for future star formation.

2.8 Mid-IR variability in IC1396A
Maria Morales-Calderon (Spitzer Science Center)

We present Spitzer/IRAC photometric monitoring 3.6-8 μm data of the heavily embedded Young Stellar Objects in the IC1396A dark globule. We obtained light curves covering a 14 day timespan with a twice daily cadence for 69 YSOs, and continuous light curves with approximately 12 second cadence over 7 hours for 38 YSOs. Typical accuracies for our relative photometry were 1-2% for the long timespan data and a few mmag, corresponding to less than 0.5%, for the 7 hour continuous 'staring-mode' data. About half of the YSOs showed detectable variability, with amplitudes from ~ 0.05 mag to ~ 0.2 mag. Eighteen of the YSOs showed quasi-sinusoidal light curve shapes with apparent periods from 5-12 days and light curve amplitudes approximately independent of wavelength over the IRAC bandpasses. We have constructed models which simulate the time dependent spectral energy distributions of Class I YSOs in order to attempt to explain these light curves. Based on these models, the apparently periodic light curves are best explained by YSO models where a high latitude photospheric spot periodically heats the inner wall of the circumstellar disk, and where we view the disk at fairly large inclination angle.

2.9 The effect of mass accretion on early stellar evolution
Andrea Urban (JPL)

A high accretion rate has been proposed as an important ingredient in the formation of a massive star. We investigate the effect of high accretion rates on the early evolutionary stages of young stars. Simulations of clustered star-forming environments have shown that accretion is highly variable. In our work, we also investigate the effect of variable accretion rates on the stellar evolution of young stars.

2.10 Spitzer Observations of the Taurus Molecular Cloud: Old and New YSOs
Luisa M Rebull (SSC/IPAC/JPL)

Taurus hosts a distributed mode of low-mass star formation that has proven particularly amenable to observational and theoretical study. In 2005-7, our team mapped the central 44 square degrees of the main Taurus cloud using the IRAC and MIPS cameras on the Spitzer Space

Telescope. These images form the largest contiguous Spitzer map of a single star-forming region (and any region outside the galactic plane). The Spitzer survey is a central and crucial part of a multiwavelength study of the Taurus cloud complex that we have performed using XMM, CFHT, and the Sloan Digital Sky Survey. The photometry data points from Spitzer allow us to characterize the circumstellar environment of each object. In conjunction with the rest of the surveys (in the regions where all surveys overlap), we can construct spectral energy distributions (in the best cases) from 0.212 to 160 μm for the known population. By comparison to the color distributions of the known Taurus members, we found 148 new candidate members among the rest of the detected objects. Via spectroscopic follow-up of about half the sample, we have confirmed 24 new members, 4 probable new members, and 9 possible new members, an increase of 15-20% in Taurus members. Additional spectroscopic follow-up could confirm yet more members among our candidate member sample.

2.11 AKARI All-Sky Survey of T Tauri stars: the Taurus-Auriga region
Satoshi Takita (ISAS/JAXA)

AKARI is the first Japanese satellite dedicated to infrared astronomy, and has performed an All-Sky Survey at the mid- to far-infrared wavelengths. The mid-infrared (MIR) observations at 9 and 18 μm wavelengths with the Infrared Camera (IRC) on board AKARI have spatial resolution of about 5" and the present detection limit of about 50 mJy at 9 μm band and 120 mJy at 18 μm band, respectively. More than 90% of the entire sky was observed with the two bands. The first version of the AKARI IRC point source catalogue (PSC) will be released to the team member by around this October. We are now searching for new T Tauri stars (TTSs) over the whole sky on the basis of the AKARI IRC PSC. For this preliminary study, we have surveyed 307 TTSs around the Taurus-Auriga region, and 86 TTSs are detected with AKARI. We have newly detected 34 faint TTSs which could not be matched with the IRAS PSC. On the other hand, there are other types of sources (stars surrounded with dust) which have similar colours to those of TTSs, such as asymptotic giant branch (AGB) stars or galaxies. Based on the colour-colour and colour-magnitude diagrams made from the AKARI, 2MASS, and UCAC surveys, we could extract TTS candidates from the AKARI All-Sky data.

2.12 A MIPS View of Dense Cores and Embedded Sources in the Taurus Spitzer Legacy Survey
Susan Terebey (Cal State LA)

We analyze the 160 μm emission in the 44 sq deg Taurus Spitzer Legacy Survey to produce a mosaic of the cold dust distribution. The analysis shows there are two main emission components: the extended cold cloud at 14.2 K, and knotty filaments of cold cores at $\sim$ 10 K. The distribution of 160 μm cold cores is similar to the 2MASS extinction map, but has higher 1' spatial resolution. We further compare the distribution of cold cores with YSOs that have strong disk emission at 70 μm. In this sample 90 percent of class I sources and 55 percent of class II sources are spatially coincident with a cold core. However, most cold cores in Taurus are starless. We discuss the implications for

the relative ages of cores and young stars in the Taurus star-forming region.

2.13 Infall, outflow and protostellar accretion: "audits" of the youngest disks
Dan M Watson (University of Rochester)

If viewed along their outflow axes, the innermost regions of Class 0 protostars are visible to Spitzer: emission lines of water and OH, emitted by envelope material raining supersonically onto the embedded disk, are detected by the Infrared Spectrograph (IRS). In turn, water-line luminosity measurements yield accurate values of the envelope-disk accretion rate. Together with accurate outflow rates measured from ionic lines in the same IRS spectra, and protostellar accretion rates inferred from full Spitzer and mm-submm SEDs, these observations permit audits of the flows into and out of the disks of a large sample of Class 0 objects. Here we report preliminary results of a survey of 85 face-on Class 0 protostars with Spitzer-IRS, and an initial flow-audit of their disks. We see general correlations among infall, outflow and protostellar accretion rates, but also large dispersions about these trends. Substantial departure from uniform flow is the rule, rather than the exception, and a few objects exhibit extreme mismatches that may indicate accumulation of material in their disks. These results can therefore illuminate the physical processes behind the episodic, apparently violent nature of disk-protostar accretion during the era of envelope evolution.

3. Protoplanetary and Debris Disks

3.1 A Spitzer view of disk evolution in Orion OB1a and OB1b
Cesar Briceno (Centro de Investigaciones de Astronomia)

We present the latest results of our IRAC and MIPS observations of young stars in the 4 Myr old Orion OB1b association, and the older 8-10 Myr old OB1a region, including the 25 Ori cluster. Combined with our existing ground based optical photometric and spectroscopic data, our study provides a view of disk evolution in a numerous sample of stars within the same nearby star forming region, in the important age range 4-10 Myr.

3.2 Debris Disks in the Upper Sco OB Association
John Carpenter (Caltech)

We present MIPS 24 μm and 70 μm photometry for 205 members of the Upper Scorpius OB Association. These data are combined with published MIPS photometry for 15 additional association members to assess the frequency of circumstellar disks around 5 Myr old stars with spectral types between B0 and M5. Twelve stars have a detectable 70 μm excess, each of which also has a detectable 24 μm excess. A total of 54 stars are identified with a 24 μm excess more than 32% above the stellar photosphere. The MIPS observations reveal 19 excess sources – 8 A/F/G stars and 11 K/M stars – that were not previously identified with an 8 μm or 16 μm excess. The lack of short-wavelength emission and the weak 24 μm excess suggests that these sources are debris systems or the remnants of optically thick primordial disks with inner holes. Despite the

wide range of luminosities of the stars hosting apparent debris systems, the excess characteristics are consistent with all stars having dust at similar orbital radii after factoring in variations in the radiation blowout particle size with spectral type. The results for Upper Sco are compared to similar photometric surveys from the literature to re-evaluate the evolution of debris emission. After considering the completeness limits of published surveys and the effects of stellar evolution on the debris luminosity, we find that the magnitude of the 24 μm excess around F-type stars increases between ages of 5 and 17 Myr as found by previous studies, but at $< 2.6\sigma$ confidence. For B7-A9 and G0-K5 stars, any variations in the observed 24 μm excess emission over this age range are significant at less than 2σ confidence.

3.3 How and When Planet Formation Ends: The Lifetimes and Morphologies of Transition Disks
Thayne Currie (NASA-Goddard Space Flight Center)

We describe new results from Spitzer observations of "transition" circumstellar disks. These disks identify a pivotal intermediate stage between massive 'primordial' disks – rich in gas and dust needed to form the cores/envelopes of gas giant planets – and gas-poor/free 'debris' disks, which lack the material needed to form gas giants. Analysis of our Spitzer data yield two major findings concerning transitional disks. First, we find clear evidence for two types of transitional disks and thus two pathways for the primordial-to-debris disk transition: disks with inner holes depleting from the inside-out and disks with that are being "homologously depleted". Second, contrary to the nearly two-decades old 'canonical' results from ground-based data, we find that transitional disks are long-lived ($t \sim 1$ Myr, not 0.01–0.1 Myr). Based on these and related results, we constrain possible mechanisms responsible for transition disk morphologies and thus what processes likely shut off gas giant planet formation. Finally, we compare the transition disk populations for stars with a range of ages and masses to investigate the timescale for gas giant planet formation from M stars to A stars.

3.4 Statistics of debris disks around planet host stars
Simone Fiedler (Astrophysical Institute and University Observatory Jena)

The correlation between planets and debris disks is still not definitely established. We present our ongoing investigation of all known planet host stars for the presence of dust, which can almost undoubtedly be ascribed to populations of leftover planetesimals within a debris disk, producing detectable dust by their collisions. The aim of this project is to uncover a link, if there is one, between stars with planets on the one hand and stars with debris disks on the other hand, which is supposed to be rooted in the planet formation process and the nearly omnipresent protoplanetary disks around recently formed young stars. We identify infrared excess emission above the stellar photospheric continuum as an indicator for the presence of dust and compare infrared data from IRAS, ISO, Spitzer, JCMT and other instruments with predicted stellar continuum emission. The determination of the predicted photospheric fluxes is done using appropriate Phoenix model atmospheres fitted to the observed spectral energy distributions in the ultraviolet, optical

and near infrared spectral range. In a preliminary study we already investigated 25 multiple planetary systems and found a slightly higher disk incidence than the average for nearby solar-type stars, although more systems have to be included to reach statistically significant results. Besides, tentative conclusions about possible correlation between the presence of dust and stellar properties like metallicity or multiplicity have been drawn, and the results strongly suggest that further investigation is worthwhile. Now we are extending this study to all known planet host stars to perform a more comprehensive statistical analysis.

3.5 Detection of Silica Dust in the Debris Disk Around HD 15407
Hideaki Fujiwara (University of Tokyo)

Photometry of the F3 V main-sequence star HD 15407 with the AKARI/IRC is used to detect excess emission over the expected stellar photospheric emission between 10 and 20 μm, which is best attributed to hot circumstellar debris dust surrounding the star. We also derived mid-infrared spectra of the star with the Spitzer/IRS and detected a prominent silica emission feature centered at 9 μm in the spectra. The temperature of the debris dust is derived as $T_d \sim 500 - 700$ K, corresponding to the inner radius of the debris disk of $\sim 0.2 - 0.6$ AU. The fractional luminosity of the debris disk around HD 15407 cannot be accounted for by a simple model of the steady state evolution of a debris disk due to collisions of planetesimals, suggesting that the source of the observed silica debris dust is transient events.

3.6 Disk Dissipation at an Age of 1-2 Myr
Elise Furlan (JPL, Caltech)

We present an analysis of young (1-2 Myr old) protoplanetary disks that show signs that their disk material has already started to disperse. Their low infrared excess emission suggests that the inner disk regions are depleted in small dust grains compared to typical protoplanetary accretion disks. Using mid-infrared spectra obtained with the Spitzer Space Telescope, we characterize the infrared excess and quantify the degree of dust depletion in these systems, as well as the distribution and composition of the remaining dust. This information will be used to assess to which extent processes such as photoevaporation or planet formation play a role in clearing the inner disks.

3.7 A Spitzer Search For Disks Around Young Planetary Mass Objects
Paul M Harvey (University of Texas)

We report on a Spitzer IRAC program to obtain very deep mapping of a region in Ophiuchus containing candidate young very low mass ob jects. Our observations are aimed at detecting disks around objects down to planetary masses in a region already surveyed at higher brightness limits by Allers et al.

3.8 Early stages in protoplanetary disks
Jesus O Hernandez (Centro de Investigaciones de Astronomia)

Combining optical/2MASS data with IRAC/MIPS photometry, we are carrying out a systematic study to identify and characterize disk populations in star-forming regions, including the

gamma Velorum cluster, the lambda Orionis cluster, the NGC 2169 cluster, the sigma Orionis cluster, the 25 Orionis stellar aggregate and several regions located in the Orion OB1 association, covering a range in age from ~ 3 to ~ 10 Myr. Our samples are optimal for studying disk evolution; for one thing, observations and theoretical studies indicate that key processes in the evolution of protoplanetary disks take place in the 3-10 Myr age range. In addition, the samples are relatively near (< 500 pc), allowing us to probe a wide range of stellar masses, from intermediate masses down to the substellar regime. In this comparative study we address issues as the mass-dependence and age-dependence of the frequency of primordial disks. We also quantify the decrease of near infrared emission and the clearing of the inner regions of primordial disks with age, and how these interrelate to the appearance of the debris disk phenomena

3.9 Thermodynamical Structure of Protoplanetary Disks
Shigenobu Hirose (JAMSTEC)

The thermodynamical structure of protoplanetary disks around low-mass stars is studied using three-dimensional radiation magnetohydrodynamic (MHD) simulations. Local patches of disk are modeled using the shearing box approximation with vertical gravity. For simplicity, the dust and gas are well mixed and have the same temperature, and ideal MHD is assumed. The frequency-integrated radiation field is evolved using the flux-limited diffusion approximation, adopting thermally averaged opacities. The heating arises from the dissipation of the MHD turbulence driven by magnetorotational instability, and the cooling comes from radiation losses. Irradiation by the central star is treated by tuning the photospheric radiation temperature. The results indicate the heating is more concentrated in the disk atmosphere than in the classical Shakura-Sunyaev model. The single-point heating rate in the atmosphere fluctuates by orders of magnitude over time intervals comparable to the orbital period due to magnetic reconnection and shocks, while the patch of disk overall sustains dynamical and thermodynamical equilibrium over many cooling times. We show how the dust depletion inferred from Spitzer infrared colors may affect the atmospheric structure, and discuss the implications of the turbulent dissipation for the line and continuum emission.

3.10 Time-Evolution and IR Spectra of Photoevaporating, Viscous Circumstellar Disks Around Young Stars
David Hollenbach (SETI Institute)

We present the time evolution of viscously accreting disks as they are irradiated by ultraviolet and X-ray photons from a low-mass central star. Disks of initial mass 0.1 $M_\odot$ around 1 $M_\odot$ stars survive for about 4×10^6 years, assuming a viscosity parameter $\alpha = 0.01$, a time-dependent FUV luminosity that ranges from 10^{-2}-10^{-3} Lsun, and with X-ray and EUV luminosities of about 10^{-3} Lsun. We follow disk evolution around stars of different masses, and find that disk survival time is relatively independent of mass for stars with mass less than 3 $M_\odot$; for larger mass stars the disks are short-lived. We also present IR spectra from disks illuminated by the FUV, EUV, and X-rays from the central young star. EUV and X-rays heat the surfaces of disks around young,

low mass stars to thousands of degrees and ionize species with ionization potentials greater than 13.6 eV. Shocks generated by protostellar winds also heat and ionize the same species close to the star/disk system. These processes produce diagnostic IR lines, some of which have been observed by Spitzer (e.g., [Ne II] 12.8 μm), which we model as functions of key parameters (EUV luminosity and spectral shape, X-ray luminosity and spectral shape, and wind mass loss rate and shock speed). Comparing our models with observations, we conclude that either internal shocks in the winds or X-rays incident on the disk surfaces often produce the observed [Ne II], although there are cases where EUV dominates. Even if [Ne II] is mainly produced by X-rays or internal wind shocks, the neon observations typically place upper limits of $< 10^{42}$ s^{-1} on the EUV photon luminosity of these young low mass stars. This upper limit constrains EUV photoevaporation of disks.

3.11 AU Mic is Not Alone: New M Dwarf Debris Disks
Peter P Plavchan (NExScI/IPAC/Caltech)

M dwarfs constitute $\sim 70\%$ of the stars in our local neighborhood, yet we know little about the frequency and evolution of planetary systems for this diverse spectral class. Among the numerous M dwarfs sampled by Spitzer in the nearest 25pc, AU Mic remains a unique M dwarf with its debris disk, infrared excess, 12 Myr age, flaring, and X-ray activity. We present results from 24 μm and 70 μm MIPS (Multiband Imaging Photometer for Spitzer) observations of 27 X-ray saturated M dwarfs like AU Mic out to an average distance of ~ 30 pc. From these initial observations, we have discovered 3 new M dwarf debris disks identifiable from their infrared flux excess. We place our results in context with a sample of 70 A through M-type dwarfs selected with common youth indicators such as lithium abundance, moving group membership, chromospheric activity, and rapid rotation.

3.12 The Debris Disk Fraction at 24 μm
Laurie E Urban (Northern Arizona University)

We have obtained from the Spitzer archive 1445 main sequence AFGKM stars that were observed at 24 μm using the Multiband Imaging Photometer for Spitzer. These stars have been re-reduced using state-of-the-art methods (Su, et al.). We used more than 1000 of these FGKM stars to define a self-calibrated main sequence locus in (V-K, K-[24]) color-color space. The one sigma dispersion about this locus is 2-3%. With such precision, we identify more than 150 new debris disks, more than doubling the total known in this sample. We find that the overall 24 μm excess rate is significantly higher than found in previous results. We will present these new results and a detailed analysis of the excesses for G and K stars.

4.   The Galaxy

4.1 Disk and Ring Sources in the MIPSGAL Survey, and spectroscopic IRS follow-up.
Nicolas P Billot (IPAC/NHSC)

Following the discovery of hundreds of disk and ring sources in the Spitzer/MIPSGAL 24 μm survey data, we have obtained Spitzer/IRS spectroscopic observations of a sub-sample of 14 of these objects. Their spectra show significant variations in the low to high excitation gas lines ratio, as well as in the dust continuum intensity. We compare these spectroscopic data to templates of evolved stars, including PNe, SNRs and extremely rare and massive luminous blue variables to constrain their true nature.

4.2 Formation of CO_2, $HCOOH$, CH_3OH, and CH_3CH_2OH on an Icy Grain Analogue Using Fast O-atoms
Ara Chutjian (JPL/Caltech)

Carbon dioxide (CO_2), methanol (CH_3OH), ethanol (CH_3CH_2OH), and formic acid ($HCOOH$) have been formed in collisions of a superthermal, 9 eV beam of $O(3P)$ atoms with CH_4 molecules adsorbed on a gold surface at 4.8K. The products are detected using temperature programmed-desorption and quadrupole mass spectrometry. Identification of the species is carried out through use of the Metropolis random-walk algorithm as constrained by the fractionation patterns of the detected species. Relative formation yields are reported and reaction sequences given to account for possible formation routes.

4.3 AKARI FIR All Sky Imaging Survey
Yasuo Doi (University of Tokyo)

We describe the AKARI all-sky diffuse map in far-infrared (FIR) wavelengths. The AKARI FIR all-sky survey covers 50–180 μm with four bands centered at 65 μm, 90 μm, 140 μm, and 160 μm. Its spatial resolution is 43– 72", considerably better than that of IRAS or comparable to that of Spitzer. We have conducted an all-sky survey during cold phase of AKARI observation in 2006 February – 2007 August and have covered more than 94% of the whole sky. One of the important characteristics of the AKARI FIR all-sky survey is its continuous wavelength coverage that allows us to measure directly the total influx of this waveband, which virtually corresponds to the total FIR intensity or a good indicator to the star-forming activity. Additionally, we have observed both Wien side (< 100 μm) and Raileigh-Jeans side (> 100 μm) of the dust continuum to help ensure precise determination of the dust color temperature. Especially AKARI 90 μm waveband is important to evaluate FIR emission from big grains as its intensity is nearly free from the excess emission by small dust grains and complementary to Spitzer/MIPS 70 μm and 160 μm wavebands. Recently we've made a preliminary data release to the AKARI project members and plan to make a full release of the data after the careful evaluation of its calibration reliability. In this presentation, we discuss a revolutionary improvement with the AKARI FIR all-sky survey image compared to the IRAS survey as well as possible contributions to the Spitzer Legacy.

4.4 Bubbles in the Galactic Plane
Nicolas Flagey (SSC/Caltech)

We present a catalog of compact sources detected in the Spitzer/MIPSGAL 24 μm survey data. These small (< 1 arcminute) rings, bubbles, disks or shells are pervasive through the entire

Galactic plane in the mid-infrared. Over 400 such sources are detected from visual inspection of the MIPSGAL mosaic images. Their average density is found to be around 1.5 bubbles per square degree. We identify 10% of these objects by extensive cross matching with available catalogs. We find that the majority are planetary nebulae (PNe). Several supernova remnants (SNR), luminous blue variables (LBV) and one post-AGB star are also identified. The remaining 90% of the bubbles are yet unknown objects. Most of them are detected at 24 μm but neither at 8 nor 70 μm. About 10% of them exhibit a central point source at 24 microns.

4.5 The Spitzer Legacy Survey of the Cygnus-X Region
Joseph L Hora (Harvard-Smithsonian Center for Astrophysics)

We describe the first data delivery from the Spitzer Legacy Survey of the Cygnus-X region, which is a massive star formation complex containing the richest known concentration of massive protostars and the largest OB association within 2 kpc. This unbiased survey of 24 square degrees in Cygnus-X with the Spitzer IRAC and MIPS instruments has the sensitivity to detect young stars to a limit of 0.5 $M_\odot$. The data release consists of a source catalog and mosaics of the images in each band that combine all of the frames obtained in the various observation epochs. The source catalog contains the band-merged Spitzer 3.6, 4.5, 5.8, 8.0, and 24 μm photometry as well as the 2MASS J, H, and Ks bands. A preliminary source classification using this data set has yielded over 2000 deeply embedded and Class I YSO candidates, and over 12000 Class II candidate objects. Our reduction pipelines use artifact-correction methods which improve the quality of the full mosaic. The Cygnus-X survey is an important part of the Spitzer legacy in the study of star formation, and has provided a data set that will be key in future investigations carried out with the warm Spitzer, Herschel, and JWST missions, as well as ground-based observations.

4.6 Molecular Hydrogen Emission from Translucent Galactic Clouds
James Ingalls (SSC/Caltech)

Using the Spitzer IRS, we have detected emission in the S(0), S(1), and S(2) pure-rotational transitions of molecular hydrogen towards 6 positions in two translucent high Galactic latitude clouds. The detection of these S(2) lines raises important questions regarding the physical conditions inside low-extinction clouds that are far from ultraviolet radiation sources. We assert that UV pumping must not be the only source of excitation in these sources. Comparison with published models shows that collisional pumping of warm H_2 in shocked gas can produce the observed emission. The ratio between the S(2) flux and the flux from PAHs at 7.9 μm averages 0.016 for these 6 positions. This is a factor of about 9 higher than the same ratio measured towards the central regions of normal Galaxies in the SINGS survey. Thus these translucent clouds are more efficient at exciting H_2 per PAH-exciting photon than the disks of entire galaxies. We suggest that pockets of warm gas in translucent clouds integrated over the disks of galaxies may represent a major source of normal galaxy H_2 emission.

4.7 Spitzer observations of the Vela X-1 bow shock
Rosina C Iping (The Catholic University of America)

We present infrared observations of the bow shock of the high mass X-ray binary Vela X-1 obtained with the Spitzer Space Telescope. VelaX-1/HD77581 consists of a B0.5 Iab supergiant and a 283.33 sec pulsar in a nearly circular 8.96 day orbit. Vela X-1 left the OB association Vela OB1 about 2.5 million years ago, at which time the SN explosion occurred and the pulsar was born. The explosion gave the system a large space velocity through the ISM. Gas and dust were swept up, giving rise to the bow shock. Infrared images in the four IRAC bands (3.6, 4.5, 5,8,and 8.0 μm) and two MIPS bands (24 and 70 μm) are augmented by IRS spectroscopy (5-30 μm) of three positions in the bow shock. The bow shock is prominent in all IRAC and MIPS channels. The highest surface brightness occurs at 24 μm. The IR emissions from the bow shock show filamentary structures and significant geometric changes with wavelength.

4.8 A Dust Twin of Cas A: 21-μm Dust Feature in The Supernova Remnant G54.1+0.3
Jeonghee Rho (SSC/Caltech)

We present Spitzer and submm observations of a Crab-like supernova remnant, G54.1+0.3. We serendipitously discovered a dust feature peaking at 21 μm from G54.1+0.3, and the 21-μm dust is remarkably similar to that of Cas A from Rho et al. (2008). The IRS spectrum from the western shell shows the 21-μm dust feature and strong [Ar II] and weak [Ne II], [S III] and [Si II] lines. Strong correlation between 21-μm dust and Ar ejecta has been observed in Cas A. IRAC 8-μm emission mostly from Ar ejecta shows shell-like morphology and MIPS 24 and 70 μm emission from continuum also show shell-like morphology, suggesting that dust has been formed in ejecta. The shell-like ejecta distribution around pulsar wind nebula is analogy with that of the Crab Nebula. We detected submm emission from G54.1+0.3 using SHARCII (at 350 μm) and LABOCA (at 870 μm). We present dust fitting using continuous distributions of ellipsoidal (CDE) grain models. Spectral fitting requires a combination of dust composition including SiO_2, SiC, and Al_2O_3 which are responsible for 21 μm and 11 μm dust features and long-wavelength continuum, respectively. We will discuss dust properties and inferred dust mass from G54.1+0.3 and implication of supernova-dust production in early Universe.

4.9 Near- to mid-infrared spectroscopy of interstellar PAHs in the Milky Way and in the Large Magellanic Cloud based on AKARI/IRC observation
Itsuki Sakon (University of Tokyo)

We present several samples of near- to mid-infrared spectra of diffuse Galactic emission and of interstellar medium in the Large Magellanic Cloud (LMC) obtained with slit spectroscopic modes of NG(2.5-5 μm), SG1(5-8 μm) and SG2(8-13 μm) of Infrared Camera (IRC) onboard AKARI. The data are collected in the framework of AKARI Mission Program(MP)/ISMGN (P.I., H. Kaneda). The target positions in the Milky Way are settled both in the inner and outer Galactic plane and those in the LMC are selected so that they cover a wide range of the strength/hardness of radiation fields. From the datasets obtained in the LMC, relatively larger UIR band ratios of 6.2μm/11.2μm, 7.7μm/11.2μm and 8.6μm/11.2μm were found in molecular cloud associated with a young star cluster than in quiescent molecular cloud, which is consistent with the photo-ionization model of

PAHs. On the other hand, both regions exhibit almost the same UIR 3.3μm/11.2μm ratio. In this poster presentation, we examine the variations in the relative band strength of UIR features in 3-13 μm among our samples and discuss the cause of variations.

4.10 A census of young stars in NGC 2023, Horsehead & Ori I-2
Goran Sandell (SOFIA-USRA, NASA AMES RESEARCH CENTER)

We investigate the young (proto)stellar population using Spitzer IRAC and MIPS archive data, JCMT SCUBA imaging, and deep optical R and H alpha imaging (Ori I-2 only). We study the distribution of gas, dust and young stars in NGC 2023 and the L1630 molecular cloud bordering the HII region IC 434, and the cometary globule Ori I-2 inside the HII region to see where stars are forming, and whether the expansion of the HII region has triggered star formation.

4.11 Analysis of Ices Toward YSOs in Rho Ophiuchi
Kari A Wojtkowski (University of Missouri–St. Louis)

Recent technological advances have sparked an exciting study of the chemistry in star forming regions. By combining Spitzer IRS and ground based observations, a more sensitive diagnostic of the composition of the material surrounding Young Stellar Objects (YSOs) can be performed. An important correlation to consider is the ice abundances with respect to the location of the YSO. For example, Pontoppidan (2006) found that CO_2 and CO abundances were enhanced toward the center of the cold Ophiuchus-F core, and recent results for the CO_2 ice feature at 15.2 μm also imply spatial variations within regions of star formation. However, Whittet et al. (2009) found similar CO_2 profiles for background objects consisting mainly of a polar component (85%) toward three distinct dark clouds, thus providing a benchmark of unprocessed ices to which processed ices can be compared. We present a combination of ground-based and space-based results for the stretching, bending, and libration modes of H_2O ice at 3 μm, 6 μm, and 13 μm respectively, the CO ice stretching mode at 4.67 μm, and the CO_2 ice bending mode at 15.2 μm of the Rho Ophiuchi star forming region. These data were taken with the Infrared Spectrometer (IRS) on the Spitzer Space Telescope and SpeX at the Infrared Telescope Facility (IRTF) located on Mauna Kea, HI. We measured abundances and used laboratory spectra to constrain the polar/apolar composition and the thermal history of the region. The abundances and profile shapes are compared while considering their location with respect to the Ophiuchus A, B, and F cores, and their evolutionary state. In the future, additional YSOs in the Taurus and Rho Ophiuchi regions will be similarly analyzed in order to correlate variations in the volatile composition of the material surrounding YSOs due to environmental factors and evolutionary state.

4.12 Mid-Infrared Spectrum Variation of Long-Period Variables seen with IRS
Takashi Onaka (University of Tokyo)

We carried out observations of the mid-infrared (MIR) spectrum time variation of five oxygen-rich long-period variables in our Galaxy and in the Large Magellanic Cloud with the IRS short and long low-resolution modules. Two LMC stars, HV2446 and IRAS04544-6849 were observed 6 times over one variability cycle. Both stars show prominent silicate emission and their MIR

spectra vary with their variability cycle. The variation patterns are very similar to that found in the Galactic Mira variable Z Cyg (Onaka et al. 2002 A&A, 388, 573). While the 10 to 20 μm emission ratio increases at maximum and becomes low at minimum, the silicate band profiles do not change. Based on the relation between the infrared luminosity and the dust shell temperature, the emissivity of silicate grains is derived to be quite similar to each other and also to that derived for Z Cyg. The present observations suggest that silicate dust properties and the dust formation in long-period variables in the LMC are similar to those in Galactic Mira variables. Among three Mira variables monitored in our Galaxy, W Dra shows prominent silicate emission. The variability of the MIR spectrum is also similar to Z Cyg except that it suggests a presence of another dust component, possibly aluminum oxide (Onaka et al. 1989 A&A, 218, 169), and that the silicate emission feature is slightly different from the standard profile.

4.13 Spitzer Studies of Supernova Ejecta and Dust
Schuyler Van Dyk (SSC/Caltech)

Over four Cycles of the Spitzer cryogenic mission we (the Mid-Infrared Supernova Consortium) conducted mid-infrared studies of supernovae (SNe), and here we provide the highlights of our results in this poster. Our program resulted in many "firsts." We primarily have investigated the hypothesis that core-collapse SNe (CCSNe) are, or have been, major producers of cosmic dust, by looking for evidence for dust condensation in real time. Alternatively, infrared light echoes may arise from pre-existing dust in the circumstellar medium created by mass loss from the progenitor. We have used the mid-IR spectral energy distribution and evolution of SNe to deduce between the two scenarios in several cases. We therefore provided the first real evidence that dust does condense in the ejecta of typical CCSNe. We also detected the first incidence (since SN1987A) of molecular emission from SiO in a CCSN. We have achieved the first-ever mid-IR detections of type Ia SNe, and deduced that that the ejecta exhibit significant chemical structure and show signs of large deviations from spherical symmetry. We have tested explosion models for SNe by measuring the intensity and evolution of late-epoch fine-structure lines and molecular features, and have been able to test explosion-model-sensitive predictions of abundances. Our late-time measurements of stable Nickel have constrained CCSN progenitor masses and metallicities.

5. Nearby Galaxies

5.1 The Mid-IR Properties of Nearby Galaxy Groups
Lei Bai (Carnegie Observatories)

We will present the first mid-IR study of a sample of nine redshift-selected groups at $z = 0.06$. The Spitzer 24 μm data were used to determine the star formation rates in galaxies. On average, 60% of the group galaxies are forming stars at a rate $> 0.1 M_\odot$ /yr, and this fraction is at least 20% lower than the fraction in the field. The SF fractions in groups do not show strong dependence on group velocity dispersion, total stellar mass or the presence of an X-ray emitting intragroup

medium, but a weak anti-correlation is seen between star-forming (SF) fraction and projected galaxy density. However, even in the densest regions, the SF fraction in groups is only comparable to that in cluster outskirts, suggesting that preprocessing of galaxies in group environments is not sufficient to explain the much lower fraction in clusters. The typical specific star formation rates of SF galaxies in groups are lower, but not by much, from those in the field across a wide range of stellar mass. If galaxy-galaxy interactions are responsible for the smaller SF fraction in groups, then the very small starburst galaxy fraction ($< 1\%$) found in groups suggests a short timescale (~ 0.1 Gyr) for any merger-induced starburst stage.

5.2 The First UV Intracluster Plume in the Virgo Cluster
Carrie Bridge (Caltech)

We have begun a new multi-wavelength project to explore the interaction history and evolution of galaxies in clusters. As a cluster hierarchically grows, gravitational and gas dynamical effects (e.g. galaxy-galaxy interactions, harassment, ram pressure stripping, starvation) are capable of removing stars, gas, and dust from galaxies. The intracluster light (ICL) therefore holds a record of the growth history of the cluster. We intend to explore the intracluster light in the central degree of the Virgo cluster. We have recently been awarded Spitzer Warm IRAC 3.6 and 4.5 μm data to compare with the published V-band imaging of Mihos et al. 2005. In addition we have discovered the first ever detected ICL feature in the UV with GALEX. This feature is ~ 50 kpc long, ~ 40 kpc from the interacting galaxy pair NGC4438/4435, and is spatially coincident with a tidal plume detected in deep V -band and NUV imaging. The presence of this feature in the UV is extremely surpising because previous optical analyses indicate that IC stars are old, and should therefore be undetected in the FUV. Spectral energy distribution(SED) fitting of the GALEX and optical data of this plume reveal not only a population of young IC stars but also significant amounts of IC dust.

5.3 Characterizing local bar properties from the optical to the mid-IR
Cameron M Charness (Carnegie Observatories)

As photometric studies begin to probe the evolution of galactic structure with redshift, it is important to establish a baseline of structural properties in the local Universe that can later be compared to observations of high-redshift galaxies. Bars are a crucial components of galactic structure, and may play a major role in the secular evolution of galaxies. The redshift evolution of the bar fraction is an important signpost on the growth and maturity of disk galaxies and is known to evolve with redshift. The next step is to understand how the bar properties evolve with redshift. Since the observed band shifts to bluer and bluer rest-frame wavelengths, we need to calibrate how bar properties vary with wavelength. To do this, we use the Spitzer IRAC 3.6μm images and ground-based optical and near-IR observations to characterize bar properties in large, nearby, well-studied barred spirals. We study the bar length and the bar strength as a function of wavelength.

5.4 Powerful H_2 Line-Cooling in Stephan's Quintet

Michelle E Cluver (SSC/Caltech)

Stephan's Quintet is a strongly interacting compact group experiencing a group-wide shock due to the high velocity ($\sim 1000\,\mathrm{km\,s^{-1}}$) collision of an intruder galaxy with the intragroup medium. We present results from deep, mid-infrared spectral mapping of Stephans Quintet, using the *Spitzer Space Telescope*, that show for the first time the striking abundance and widespread distribution of warm H_2 within the group. In the main shock region alone, we find $2.8 \times 10^8\,M_\odot$ of warm H_2 covering $\sim 480\,\mathrm{kpc^2}$ and additionally report the discovery of a second, major shock-excited feature, likely a remnant of previous tidal interactions. This brings the total H_2 line luminosity of the group in excess of $10^{42}\,\mathrm{erg\,s^{-1}}$, exceeding the X-ray luminosity by a factor of ≥ 3, confirming the molecular hydrogen emission lines as the dominant cooling pathway in the shock. Emission line maps show evidence of dust reprocessing in the shock and a lack of star formation (as traced via nebulae lines or PAH emission) in the main shock. The concordance with a model of H_2 emission driven by turbulent energy transfer, and the prevalence of this pathway over other sources of cooling in fast galaxy-scale shocks, may have important implications for the cooling of gas in the assembly of the first massive galaxies, as well as shock physics in systems ranging from ULIRGs to supernovae remnants.

5.5 High ionization lines in a sample of Wolf-Rayet galaxies.
Michelle Devost (CFHT)

We investigate the occurrence of O IV and Ne V lines in a small but well-defined sample of Wolf-Rayet galaxies selected from their optical emission lines, starburst size, and abundances. We find no trace of Ne V emission in any of the galaxies. On the other hand, O IV is detected on many of the spectra. We present here the analysis of O IV with other mid-infrared line ratios to determine the source of the energy responsible for presence of O IV emission. Two sources of energy are explored; 1) photoionization by massive stars and 2) high velocity ionizing shocks. We find that high velocity ionizing shocks are the main source of energy for the production of the O IV line. Investigating other lines like Ne II, Ne III, S III and S IV, we find that photoionization models alone do not reproduce the data well. A mix between photoionization and shocks models is needed to explain the line ratios.

5.6 The Extended Emission of LIRGs
Tanio Diaz-Santos (University of Crete)

We present an analysis of the extended emission of a volume-limited ($d < 82.5$ Mpc) sample of luminous infrared galaxies (LIRGs) drawn from the GOALS galaxy sample. We use Spitzer IRS spectra to determine the fraction of the emission arising from the extended component in these LIRGs. In order to estimate and subtract the nuclear emission of each system, we use IRS spectrum of a standard star and scale the spatial profiles of its PSF as a function of wavelength. We find that at least $\sim 20\%$ of the emission of the LIRGs at all wavelengths stems from the extended component, which may contribute even up to $\sim 80\%$. With the IRS spectra we are also able to separate out the different emission components (dust continuum and PAH feature emission, ionized and molecular

gas) and calculate how much they are extended individually. For example, in some galaxies the PAH feature emission is clearly more extended (up to 3 times) than that of the mid-infrared continuum. Therefore these preliminary results suggest that mid-infrared emission of LIRGs is not as compact as in their more luminous counterparts (ULIRGs) but it is rather distributed across their disks. The analysis of the extension of the different components will also enable us to determine whether the high-redshift, higher-luminosity submillimeter galaxies (SMGs), which also present very extended star-formation, could be the scaled-up luminosity examples of local LIRGs.

5.7 Galaxy Spectral Energy Distributions from 20 to 180 μm
Charles W Engelbracht (Steward Observatory)

We present galaxy spectral energy distributions (SEDs) from 20 to 180 μm, using data from the Spitzer Space Telescope. Most of the targets were observed as part of the Spitzer Infrared Nearby Galaxy Survey (SINGS) program. We have divided each SED into a region of stochastic emission with a range of heating intensities and a region of equilibrium emission, characterized by a power law and a blackbody (with a frequency-dependent emissivity), respectively. We discuss the slopes of the power laws and the dependence of the wavelength of the transition between the two regimes on galaxy properties.

5.8 SAGE-SMC: Surveying the Agents of Galaxy Evolution in the Tidally-Stripped, Low Metallicity Small Magellanic Cloud
Karl D Gordon (STScI)

SAGE-SMC: Surveying the Agents of Galaxy Evolution in the Tidally-Stripped, Low Metallicity Small Magellanic Cloud Abstract: SAGE-SMC is a Spitzer Legacy program (cycle 4) that has mapped the entire SMC (Bar, Wing, and Tail) with IRAC and MIPS. The SAGE-SMC observations cover ~ 30 deg^2, greatly expanding on the S3MC pathfinder survey (PI: Bolatto) which covered the inner ~ 3 deg^2 of the SMC. The main SAGE-SMC goal is to study the evolution of a single galaxy in detail. As the SMC is close ($d \sim 60$ kpc), we can study the cycle of star formation and dust by studying of injection of material into the interstellar medium (ISM) from evolved stars, the contents of the present day ISM, and how the ISM is consumed in regions of star formation. The SMC is a unique target for such studies as it is nearby, low metallicity ($1/5$ $Z_\odot$), and tidally disrupted. The comparison of the SAGE-SMC observations with similar observations of the LMC (SAGE-LMC, PI: Meixner) and the Milky Way (e.g., GLIMPSE & MIPSGAL) will provide a solid understanding of galaxy evolution over a wide range of metallicities and star formation histories.

5.9 Starbursts: Emitters or Absorbers?
Daniel J Hanish (University of Michigan)

The escape fraction of ionizing radiation is a vital parameter for understanding cosmic ionization, ISM/IGM energy budgets, and star formation rate indicators. In a previous study (Oey et al. 2007) we suggested that starburst galaxies may have a higher-than-expected escape fraction of Lyman continuum radiation. It is known that relationship between the quantity of photons absorbed by dust and the number escaping from a galaxy can depend greatly on mass, morphol-

ogy, and star formation rate. In this study, we compare thirteen local starburst galaxies to ten of their non-starburst, star-forming counterparts using infrared MIPS data from the Spitzer Space Telescope to measure the dust luminosities. We correlate these observations with ultraviolet data from GALEX, as well as ground-based Hα and R-band observations; by examining these SED's for a variety of local star-forming galaxies, we compare the escape fraction in the starburst and control samples.

5.10 The Buried Starburst in the Interacting Galaxy, II ZW 096 as Revealed by the Spitzer Space Telescope
Hanae Inami (Caltech/SSC, JAXA)

We report on our analysis of Spitzer Space Telescope, Hubble Space Telescope, Chandra X-ray Observatory, and AKARI (ASTRO-F) Infrared Astronomy Satellite data of the merging galaxy II Zw 096 at $z = 0.036$. With an infrared luminosity of $\log(L_{\mathrm{IR}}/L_\odot) = 11.9$, II Zw 096 is classified as a Luminous Infrared Galaxy (LIRG) and it was observed as part of the Great Observatories All-sky LIRG Survey (GOALS). The Spitzer data suggest that 80% of the total infrared luminosity ($L_{\mathrm{IR}} = 2.84 \times 10^{38}$ W $= 7.42 \times 10^{11} L_\odot$) comes from an extremely compact, red source not obviously associated with the nuclei of the merging galaxies. We estimate the star formation rate from this source to be approximately 100 $M_\odot$/yr from the Spitzer infrared imaging and 45 $M_\odot$/yr from the AKARI near-infrared pectroscopy. Spitzer mid-infrared spectra indicate no obvious high-ionization lines from a buried active galactic nuclei in this source, although the 6.2 μm polycyclic aromatic hydrocarbon (PAH) equivalent width is low for a pure starburst nucleus. The strong detection of 3.3 μm PAH emission feature in AKARI spectrum supports a powerful starburst in the source. We suggest that II Zw 096 is currently the most extreme example of the type of buried, off-nuclear starburst first identified in the Antennae galaxy, but with a luminosity which is larger by more than an order of magnitude. Finally, the high-resolution B, I, and H-band images show many star clusters in the interacting system. The colors of these clusters suggest at least two populations–those with ages of 1-5 Myr and those with ages of 20-200 Myr, reddened by 1-2 magnitudes of visual extinction. The masses of these clusters span a range between $10^6 - 10^8 M_\odot$.

5.11 Aromatic Emission in the Magellanic Clouds and Other Nearby Galaxies
Andrew R Marble (Steward Observatory)

We present a purely photometric methodology for measuring the strength of mid-infrared aromatic features (i.e., PAH emission) in nearby galaxies using IRAC and MIPS broadband photometry. The reliability of the technique is tested using IRS observations of SINGS galaxies, and then applied to Spitzer imaging of other nearby galaxies observed as part of the Local Volume Legacy (LVL) and Surveying the Agents of a Galaxy's Evolution (SAGE) programs.

5.12 Dual AGNs, Dust in a Superwind, Shocks, and Super Star Clusters in the LIRG Mrk 266
Joseph M Mazzarella (Caltech)

Mrk 266 (NGC 5256) is a Luminous Infrared Galaxy (LIRG, $L_{IR} = 3.6 \times 10^{11} L_\odot$) involving a

major merger with a projected nuclear separation of 10" (6 kpc). Recent imaging and spectroscopic observations from Spitzer, HST, and Chandra, mostly acquired in the Great Observatories All-sky LIRG Survey (GOALS), reveal new evidence for dual AGNs, gaseous outflows (feedback) ranging from 0.2 kpc (inside the NLR) to 20 kpc (a superwind), shock-heated X-ray emitting gas co-spatial with enhanced radio continuum emission concentrated between the colliding disks, and over 100 super star clusters. Detection of 24 μm emission with Spitzer (MIPS) in an arc extending 10-34 arcsec (6-20 kpc) from the SW nucleus that is co-spatial with Hα, radio continuum and X-ray emission suggests that $\sim 10^8 M_\odot$ of dust is being swept out of the system in the most prominent region of the superwind. Spectral mapping at 5-15 μm with Spitzer (IRS) reveals significant differences between the 9.7 μm silicate absorption strengths, PAH emission features and fine-structure lines in the two galaxies. Mid-IR diagnostics, including the [Ne v]14.32μm/[Ne II]12.81μm line ratio and 6.2 and 7.7 μm PAH equivalent widths, indicate that approximately 60% of the total infrared luminosity (dust heating) is powered by AGN radiation and the remaining 40% is from star formation. Bulge luminosities derived from decomposition of the 1.6 μm HST (NICMOS) image using GALFIT, with application of the established correlation between bulge luminosity and mass of the supermassive black hole (SMBH), indicate the presence of accreting SMBHs with masses of 1.4×10^8 and $1.9 \times 10^8 M_\odot$ in Mrk 266 SW and NE, respectively. Being one of only a few (U)LIRGs in the local universe with confirmed dual AGNs, Mrk 266 is important for understanding the origin of binary SMBHs with parsec-scale separations observed or suspected in some QSOs.

5.13 MIR Diagnostics and Warm Molecular Gas in Local Luminous Infrared Galaxies in the GOALS sample

Andreea O Petric (Spitzer Science Center)

I will present an analysis of of 248 luminous infrared galaxies (LIRGs) nuclei which comprise the Great Observatories All-sky LIRG Survey (GOALS) observed with the Infrared Spectrograph on Spitzer in the rest-frame wavelength range between 5 and 38 μm. I will present and compare several diagnostics effective at isolating the Active Galactic Nuclei (AGN) contribution to the Mid-infrared (MIR) emission using [Ne v], [O iv], [Ne ii], the 6.2 μm PAH EQW and the shape of the MIR continuum. The [Ne v] 14.322 μm and [O iv] 25.890 lines are detected in 23% and 51% of all LIRG nuclei respectively while the 6.2 μm PAH and [Ne ii] are detected in 98% and 100% of the sample. These diagnostics suggest that between 10% to 13% of local LIRGs are AGN dominated in the MIR and that AGNs contribute 12% of the total bolometric luminosity of the entire sample. I will also present observations of the pure rotational transitions of molecular hydrogen and use them to determine the mass and temperature of the warm gas. A wide range of ratios of the H$_2$ to the IR luminosities between $\sim 7 \times 10^{-5}$ and 1.7×10^{-3} with a median of 2×10^{-4} is found and there seems to be a weak correlation between the warm H$_2$ mass and IR luminosity. The derived H$_2$ temperatures seem to change with merger stage in that advanced mergers appear to have higher excitation temperatures. We compare the results obtained for the GOALS sources to similar studies of nearby galaxies and ULIRGs.

5.14 IR and Radio Properties of Obscured AGN

Andreea O Petric (Spitzer Science Center)

We present a study of the IR and radio properties of a sample of 400 MIR-selected AGN. We compare narrow and broad-line AGN in terms of the fraction of radio loud sources, location on the radio-to FIR correlation and luminosity distribution with redshift. Type-2 AGN tend to have higher FIR to radio ratios and their detection rates at longer IR wavelengths suggest that they form more stars than type 1s.

5.15 Resolved Star Formation Law in NGC 4254

Nurur Rahman (University oF Maryland)

An accurate knowledge of star formation law is crucial to make progress in understanding galaxy formation and evolution. We are studying this topic using CARMA STING (Survey Toward Infrared-bright Nearby Galaxies), an interferometric CO survey of a sample of 27 star-forming nearby galaxies with a wealth of multi-wavelength data designed to study star formation in environments throughout the blue sequence at sub-kpc scales. We present results for NGC 4254 (M99), one of our sample galaxies. We construct star formation rate surface density (SFRSD) and gas (atomic and molecular) surface density indicators using a combination of high resolution data from CARMA, KPNO, Spitzer, IRAM and VLA. We find a tight correlation between SFRSD and molecular gas surface density (MGSD), whereas the relation between atomic gas surface density and SFRSD shows very large scatter. Within the central 6 kpc (radius) where CARMA is the most sensitive the MGSD derived from CO(1-0) and CO(2-1) shows similar trend, however, in the extended disk the slope, derived from CO(2-1) data alone, gets steeper.

5.16 Spitzer/IRS Spectral Mapping of Local Luminous Infrared Galaxies

Miguel Pereira-Santaella (IEM-CSIC)

Luminous Infrared Galaxies (LIRGs, $L_{IR} = 10^{11} - 10^{12} L_{\odot}$) and Ultraluminous Infrared Galaxies (ULIRGs. $L_{IR} > 10^{12} L_{\odot}$) play an important role at cosmological distances. LIRGs and ULIRGs dominate the co-moving star formation ratio density at $z \sim 1$ and $z \sim 2$, respectively. The mid-IR spectra of distant ($z \sim 2$) ULIRGs resemble those of local LIRGs, rather than those of local ULIRGs. This may indicate that the star formation was taking place over kiloparsec scales as occurs in local LIRGs. We used all, low and high resolution, IRS modules to produce spectral maps of, at least, the central 20"×20" region, which encompass most of their IR emission, and cover the 5-40 μm spectral range. Thus we can study the spatial distribution of the spectral features as well as compare the nuclear and integrated properties. Our goals are: (1) to measure the nuclear and integrated 9.7μm silicate feature, (2) to study the physical conditions, density and ionization state, of the gas using fine structure line ratios (3) to identify the main excitation mechanism (AGN vs. H II) of the nuclei, (4) to calibrate mid-IR star formation rate indicators such as the [Ne II] 12.8 μm + [Ne III] 14.3 μm, and the PAH feature luminosities. The characterization of the mid-IR properties of local LIRGs is the first step to understanding their more distant counterparts.

5.17 The Mass Loss Return from Evolved Stars to the Large Magellanic Cloud:

Oxygen-Rich Asymptotic Giant Branch Stars
Benjamin A Sargent (STScI)

The Spitzer Space Telescope Legacy program Surveying the Agents of Galaxy Evolution (SAGE; PI: M. Meixner) has observed over 6 million stars in the Large Magellanic Cloud with both the Infrared Array Camera (IRAC) and Multiband Imaging Photometer for Spitzer (MIPS) instruments to explore the life-cycle of matter in a galaxy. Over 17000 of these stars were found to be candidate Oxygen-rich Asymptotic Giant Branch (O-rich AGB) stars. We combine photometry from Spitzer and elsewhere in constructing Spectral Energy Distributions (SEDs) for the SAGE candidate O-rich AGB stars. These SEDs are then modeled using the radiative transfer program 2Dust, with the goal of determining the O-rich AGB star candidates' mass-loss rates. Spitzer Infrared Spectrograph (IRS) spectra are available as part of the Spitzer Legacy program SAGE-Spectroscopy (PI: F. Kemper) for a number of SAGE O-rich AGB star candidates; for two of these, IRS spectra in addition to the photometry are modeled with 2Dust to determine reasonable dust grain parameters to use for the candidate O-rich AGB stars in the rest of the SAGE sample. Using these dust grain properties, a grid of radiative transfer models was computed using 2Dust, varying stellar effective temperature and luminosity, dust shell inner radius, and dust shell optical depth at 10 μm wavelength. Synthetic photometry from models and observed photometry are plotted on color-color and color-magnitude diagrams, and model SEDs are directly compared to observed SEDs. The mass-loss rates from all O-rich AGB stars, especially those with the highest mass-loss rates, in the LMC are estimated and compared to its mass budget. Dust composition is also discussed in light of the results of the model grids.

5.18 Mid-Infrared Properties of Normal, Local Emission-Line Galaxies
Marie Treyer (Caltech)

We investigate the use of MIR polycyclic aromatic hydrocarbon (PAH) bands, continuum and emission lines as probes of star-formation and AGN activity in a sample of 100 'normal' and local ($z \sim 0.1$) emission-line galaxies. The MIR spectra were obtained with the Spitzer Infrared Spectrograph (IRS) as part of the Spitzer-SDSS-GALEX Spectroscopic Survey (SSGSS) which includes multi-wavelength photometry from the UV to the far-infrared and optical spectroscopy. The continuum and features were extracted using PAHFIT (Smith et al. 2007), a decomposition code which we find to yield PAH strengths up to $\sim$ 30 times larger than the commonly used spline methods. Despite the lack of extreme objects in our sample, we find significant variations in the PAH, continuum and emission line properties of these normal galaxies and systematic trends between their MIR properties and optically derived properties such as age, metallicity, radiation field hardness and star-formation rate. Based on the strongest of these trends, we revisit the Genzel et al. (1998) diagnostic diagram relating PAH equivalent widths and [Ne II] 12.8/[O IV] 25.9, and find it very efficient as distinguishing weak AGNs from SF galaxies in a region of the parameter space previously quite blurred when spline interpolations were used to fit the continuum. The luminosity of individual PAH components, of the continuum and of the neon emission lines, are found to be tightly correlated to the total infrared luminosity, making individual MIR components

good proxies for the total dust emission in SF galaxies. Following the approach of Kennicutt et al. (2009), we show that like the total infrared luminosity, these individual components can be used to estimate dust attenuation in the UV and in Halpha lines based on energy balance arguments. We also propose average scaling relations between these components and dust corrected, Halpha derived star-formation rates.

5.19 Spitzer Observations of Cold Dust Galaxies
Christopher N Willmer (University of Arizona)

New Spitzer observations are combined with SCUBA and 2MASS measurements to improve the estimates of cold dust in moderately star-forming galaxies. By fitting dust models typical dust masses of $10^{7.9} M_\odot$ and luminosities of $10 \times 10^{10} L_\odot$ are found, the cold dust being the main contributor to M_{dust}. These galaxies combined to the larger SINGS sample extend the diversity of local templates that can be used to interpret observations of nearby and distant galaxies until Herschel data become available.

5.20 Tidal and Shock-induced Star Formation in the Outer Disk of NGC 3077
Zhong Wang (SAO)

We report on the investigation of physical properties of a star forming region near NGC 3077, commonly known as the Garland. We estimate the rates and extent of star formation in this shell-like structure based on Spitzer's IRAC and MIPS observations, and examine their relationship to the tidal forces that are pervasive in the M81-M82-NGC3077 triplet environment. Individual clusters of star formation can be identified in the Garland, and their kinematic properties precisely measured with high resolution spectroscopy. Our data show that these clusters were ignited in a large-scale, coherent event, suggesting that they are part of the second-generation star-forming activities, likely induced by expanding shocks in the interstellar medium produced in an earlier generation. While this type of feedback mechanisms may be commonplace near the center of many interacting systems, the layout of the Garland region offers an unique perspective that illustrates the possible consequences of such a process in a dramatic fashion.

5.21 Spitzer Observations of a K-Band Selected Galaxy Pairs Sample
Cong K Xu (NHSC, IPAC)

We present Spitzer observations for a sample of close major-merger galaxy pairs (KPAIR sample), selected from a 2MASS/SDSS-DR3 cross-match. The scientific goals are (1) studying the star formation activity in these galaxies and (2) setting a local bench mark for the cosmic evolution of close major-mergers. The Spitzer KPAIR sample (27 pairs, 54 galaxies) includes all spectroscopically confirmed spiral-spiral (S+S) pairs and elliptical-spiral (E+S) pairs in a parent sample that is complete for primaries brighter than K= 12.5 mag, projected separations of $5 \leq r \leq 20h^{-1}$ kpc, and mass ratios ≤ 2.5. The Spitzer data, consisting of images in 7 bands (3.6, 4.5, 5.8, 8, 24, 70, 160 μm), show very diversified IR emission properties.

6.   AGNs/Quasars, Distant Universe

6.1 Powerful Extragalactic H_2 Emission from Shocks: From Spitzer to Herschel and Spica
Philip N Appleton (NHSC-Caltech)

I will review the growing body of data on powerful sources of molecular hydrogen from shocks, beginning with the giant extragalactic shock in Stephan's Quintet, the MOHEGs, and the prospects of detecting H_2 from high-redshift galaxies and into the era of reionization. The work rests of the legacy of data from the Infrared Spectrometer on Spitzer, and will include prospects for detecting shocked signatures with Herschel's PACS spectrometer, and the remarkable opportunities that the SPICA mission provides for extending this work to high redshifts.

6.2 Low Resolution Templates for AGNs and Galaxies from 0.03 - 30 μm
Roberto J Assef (The Ohio State University)

We present a set of low resolution empirical SED templates for AGNs and galaxies in the wavelength range from 0.03 to 30 μm based on the multi-wavelength photometric observations of the NOAO Deep-Wide Field Survey Bootes field and the spectroscopic observations of the AGN and Galaxy Evolution Survey. Our training sample is comprised of 14448 galaxies in the redshift range $0 < z < 0.8$ and 5347 likely AGNs in the range $0 < z < 5.58$. The galaxy templates correspond to the SED templates presented by Assef et al.(2008) extended into the UV and mid-IR by the addition of FUV and NUV GALEX and MIPS 24 μm data for the field. We use our templates to determine photometric redshifts for galaxies and AGNs. While they are relatively accurate for galaxies ($\sigma/(1 + z) = 0.04$, with 5% outlier rejection), their accuracies for AGNs are a strong function of the luminosity ratio between their AGN and galaxy components. Somewhat surprisingly, the relative luminosities of the AGN and its host are accurately determined even when the photometric redshift is significantly in error. We also use our templates to study the mid-IR AGN selection criteria developed by Stern et al. (2005) and Lacy et al. (2004). We find that the Stern et al. (2005) selection suffers from significant incompleteness at $z \sim 4.5$ when the broad Hα emission line is redshifted into the [3.6] band, and that the criterion of Lacy et al. (2004), while not affected by incompleteness, is strongly contaminated by low redshift star forming galaxies. We use our templates to predict the color-color distribution of sources in the upcoming WISE mission and define a color criterion to select AGNs analogous to those developed for IRAC photometry. Finally, we use our template to study the shape and evolution of mid-IR selected AGN luminosity function in the redshift range $0.17 < z < 5.85$.

6.3 The IRAC Shallow Cluster Survey
Mark Brodwin (Harvard-Smithsonian Center for Astrophysics)

We have identified 335 galaxy cluster and group candidates spanning $0 < z < 2$, using a 4.5 μm selected sample of galaxies in a 7.25 deg^2 region in the Spitzer/IRAC Shallow Survey. Using full redshift probability distributions for all galaxies, clusters were identified as 3-dimensional

overdensities using a wavelet algorithm. To date 12 clusters at $z > 1$, and nearly 100 at $z < 1$ have been spectroscopically confirmed. The mean I-[3.6] color for cluster galaxies up to $z \sim 1$ is well matched by a $z_\mathrm{f} = 3$ passively evolving model. At $z > 1$, a wider range of formation histories is needed, but higher formation redshifts (i.e. $z_\mathrm{f} \sim 4 - 5$) are favored for most clusters. The cluster autocorrelation function, measured for the first time out to $z = 1.5$, is found not to have evolved over the last 10 Gyr, in agreement with the prediction from LCDM. The average mass of the IRAC Shallow Cluster Survey sample, inferred from its clustering, is $\sim 10^{14}$ $M_\odot$.

6.4 Spitzer legacy at gamma-rays. The case of the new Fermi LAT blazar PKS 1502+106
Stefano Ciprini (University of Perugia & ASI-INAF, Italy)

The discovery of high-energy gamma-ray emission from the distant blazar PKS 1502+106 by the Large Area Telescope (LAT) onboard the Fermi Gamma-ray Space Telescope triggered one of the first Fermi multi-frequency campaigns, performed in the period August-December 2008. Following the twofold goal of obtain a more complete picture on this new high-energy source (rather unexplored before at frequencies above radio-mm bands) and the recommendation to exploit archival data and multi-mission databases (to maximize through multi-frequency analysis the science results of Fermi observations), serendipitous and unpublished Spitzer IRS data about PKS 1502+106 are analyzed. This first and unique mid-infrared detection of PKS 1502+106 obtained on August 13, 2005 by Spitzer, pointed out a rather featureless IRS spectrum consistent with synchrotron emission peaked beyond near-IR frequencies, and consistent with an intermediate-level activity. Such serendipitous observation is presented joined with a summary of the other mission/archival unpublished data and the multi-frequency Fermi campaign results on this object.

6.5 PAH Emission from Lyman Alpha Blobs
James Colbert (SSC, Caltech)

The physical origins of Lyman alpha blobs (LABs) are still unknown, with the most likely models shocks from supernova-driven winds, escaping AGN illumination, and cooling flows. LABs are an extremely energetic class of objects (10^{44} ergs/s), so far found only in high-redshift, overdense regions. Their high observed interaction/merger rate suggests these luminous sources could be high-mass mergers, like those predicted to build giant ellipticals. We present Spitzer IRS Long Low and IRAC and MIPS 24 μm imaging of all the Ultraluminous Infrared Galaxies (ULIRGs) associated with high-redshift LABs. We present detections of PAH features and estimate the relative contribution of AGN versus starburst. We also derive masses and compare 24/850 μm ratios to that of models.

6.6 The Dirt on Dry Mergers
Vandana R Desai (SSC, Caltech)

Dry merging (i.e., merging without gas) is invoked in models of hierarchical galaxy formation as an important mode of galaxy assembly, necessary to reproduce the observed fractions and luminosities of galaxies in the red sequence. In one prominent study, van Dokkum (2005), hereafter

vD05, found that 70% of nearby ($z \sim 0.1$) optically red early-type galaxies show signs of tidal interaction, and concluded that the majority of luminous field ellipticals were formed via dry mergers. We present the long wavelength Spitzer/MIPS (3.6-70 μm) SEDs of the vD05 sample. We find that a significant fraction of the dry mergers identified by vD05 are found to have mid-IR emission in excess of what would be expected from a passively evolving galaxy. Based on mid-IR colors, dusty star formation is the likely source of this mid-IR excess. The derived SFRs are large for passive galaxies, with $\sim 25\%$ of the dry merger candidates exhibiting SFRs greater than 1 $M_\odot$/yr. We will discuss the implications of these results for the relevance of dry merging in the formation of early-type galaxies, as well as the potential impact of ALMA observations on dry merger scenarios.

6.7 Spitzer/IRS Study of Dust Continua in Active Galactic Nuclei
Rajesh P Deo (Drexel University)

We present results on a Spitzer/IRS study of high- and low-redshift active galactic nuclei drawn from the Spitzer archives and our accepted programs. We compare the mid-IR properties of these AGN to their properties in the optical and ultra-violet regime to understand the nature of the dust torus. The circum-nuclear dust reprocesses the incident active nuclear continuum, however this process also obliterates any inherent differences between the intrinsic active nuclear continua. We search for correlations between optical/ultra-violet and mid-IR emission line strengths and nature of the dust continua.

6.8 Spitzer Observations of $z \sim 6$ Quasars
Linhua Jiang (University of Arizona)

We present rest-frame optical and NIR SEDs and hot dust properties of $z \sim 6$ quasars using Spitzer photometry in the four IRAC channels, the IRS PUI blue (~ 15.6 μm) band, and the MIPS 24 μm band. We show that hot dust properties in $z \sim 6$ quasars could be very different, as evidenced by the discovery of two quasars without any NIR emission from hot dust. The two quasars have the smallest black hole masses and the highest Eddington luminosity ratios in a sample of 21 $z \sim 6$ quasars. Such quasars were not found at low redshift. Furthermore, the hot dust abundance, characterized by the ratio of rest-frame NIR-to-optical emission, builds up at a similar rate as the central black hole grows at $z >= 6$; while at low redshift it is almost independent of the black hole mass. These findings clearly indicate that the two hot-dust-free quasars are the first-generation quasars born in dust-free galaxies and are in their early evolution stage with rapid mass accretion. They are too young to have formed a detectable amount of hot dust around them.

6.9 Mid-IR Sources in Redshift One Galaxy Clusters
Jessica Krick (Spitzer Science Center)

We present infrared luminosities, star formation rates (SFR), colors, morphologies, locations, and active galactic nuclei (AGNs) properties of 24 μm detected sources in photometrically detected high-redshift clusters in order to understand the impact of environment on star formation (SF) and AGN evolution in cluster galaxies. We use three $z = 1$ clusters selected from the IRAC dark field; the deepest ever mid-IR survey with accompanying, 14 band multiwavelength data. We find 90

cluster members with MIPS detections within two virial radii of the cluster centers, of which 17 appear to have spectral energy distributions dominated by AGNs and the rest dominated by SF. We find that 43% of the star -forming sample have IR luminosities $L_{\mathrm{IR}} > 10^{11} L_{\odot}$ (luminous IR galaxies). The majority of sources (81%) are spirals or irregulars. At least 25% of the sources show obvious signs of interactions. The MIPS-detected member galaxies have varied spatial distributions as compared to the MIPS-undetected members with one of the three clusters showing SF galaxies being preferentially located on the cluster outskirts, while the other two clusters show no such trend. Both the AGN fraction and the summed SFR of cluster galaxies increase from redshift zero to one, at a rate that is a few times faster in clusters than over the same redshift range in the field. Cluster environment does have an effect on the evolution of both AGN fraction and SFR from redshift one to the present, but does not affect the IR luminosities or morphologies of the MIPS sample. SF happens in the same way regardless of environment making MIPS sources look the same in the cluster and field, however the cluster environment does encourage a more rapid evolution with time as compared to the field.

6.10 Observations of a $z \sim 0.9$ Cluster of Galaxies
William A Mahoney (IPAC/Caltech)

The cluster CL1257+4738 was found by comparing a ROSAT image with red ground based images taken to determine if the red galaxies were young dusty ones or old early type galaxies. This cluster adds another to the handful of clusters with z larger than about 0.9. Each one provides new insights as to the relationship between the evolution of galaxies and the ICM. We acquired Chandra, XMM-Newton, Spitzer IRAC plus MIPS 24 μm, and ground based data to study this relationship between galaxies and the ICM. The Chandra plus Spitzer and ground based data gave us the unique opportunity to find candidate galaxies and AGNs that could be at redshifts from 3 up to as high as 10.

6.11 Highlights of AKARI Deep Extragalactic Surveys
Hideo Matsuhara (ISAS, JAXA)

Scientific highlights on the extragalactic deep surveys obtained by pointed observations with AKARI will be presented. The high-visibility regions near the ecliptic poles are selected for the surveys: North Ecliptic Pole (NEP) deep field & AKARI Deep Field South. The AKARI mid-IR imaging deep survey is unique in the continuous wavelength coverage including 8-24 μm where IRAC & MIPS imaging bands do not exist. From AKARI NEP survey, we picked-up young, PAH-lumonius starburst galaxies at $z = 0.5$ and 1, generated number counts at 11, 15, 18 μm, and then constructed the mid-IR luminosity function up to $z = 1.5$, and also studied the nature of mid-IR selected red AGN. We also performed the un-biased spectroscopic survey over 1000 square arcmin in NEP. ADF-S is 12 square degrees FIR Legacy survey field toward the low-cirrus region, "cosmological window", near the South Ecliptic Pole. Deep number counts at 90 μm as well as the spatial fluctuations of cosmic far-IR background will be presented and discussed.

6.12 Mid-Infrared Spectroscopy of Submillimeter Galaxies: Extended Star Formation

in Massive High Redshift Galaxies
Karin Menendez-Delmestre (Carnegie Observatories)

Ultra-luminous infrared galaxies (ULIRGs; $L > 10^{12} L_\odot$) are locally rare, but appear to dominate the co-moving energy density at $z > 2$. Many are optically-faint, dust-obscured galaxies that have been identified only recently by the detection of their thermal dust emission redshifted into the submillimeter wavelengths. We used Spitzer IRS to study the mid-IR properties and investigate the energetics of 24 such Submillimeter Galaxies (SMGs) in the redshift range of $z \sim 0.65 - 3.2$. We detect in $> 80\%$ of our sample prominent emission features from Polycyclic Aromatic Hydrocarbons (PAHs), which are associated to intense star-formation activity. Furthermore, the median mid-IR spectrum of SMGs is well-described by a starburst component with an additional power law continuum, likely representing a $< 32\%$ AGN contribution to the bolometric luminosity. This indicates that the colossal IR luminosities in SMGs are dominated by starburst activity, not by AGN. We also find that SMGs show weaker silicate absorption at $\sim 9.7\ \mu$m than local ULIRGs and stronger $6.2\ \mu$m PAH emission (relative to the $7.7\ \mu$m PAH feature) than local nuclear starbursts, the latter of which may be attributed to lower extinction by water ice along the line of sight to SMGs. The combination of these results suggests that the mid-IR emitting regions of SMGs are less obscured than those in local starbursts and similarly luminous low-redshift ULIRGs. We interpret this as evidence for a more extended distribution of cool and warm dust in SMGs compared to the more compact emitting regions in local ULIRGs and nuclear starbursts. This suggests that SMGs are not simple high-redshift analogs of local ULIRGs or nuclear starbursts, but instead they appear to have star formation which resembles that seen in less-extreme star-forming environments at $z \sim 0$ – suggesting their intense activity is distributed across a far larger region than the ~ 1-kpc nuclear bursts in local ULIRGs.

6.13 Balancing the Energy Budget between Star-Formation and AGN in High Redshift Infrared Luminous Galaxies
Eric J Murphy (Caltech/SSC)

We present deep *Spitzer* mid-infrared spectroscopy, along with 16, 24, 70, and $850\ \mu$m photometry, for 22 galaxies located GOODS-N. The sample spans a redshift range of $0.6 \lesssim z \lesssim 2.6$ and consists of SMGs, X-ray or optically selected AGN, and optically faint ($z_{AB} > 25$ mag) sources. We find that IR luminosities derived by fitting local SEDs with 24 μm photometry alone are well matched to those when additional mid-infrared spectroscopic and longer wavelength photometric data are used for galaxies having $z \lesssim 1.4$ and 24 μm-derived IR luminosities typically $\lesssim 3 \times 10^{12}\ L_\odot$. However, for galaxies in the redshift range between $1.4 \lesssim z \lesssim 2.6$, typically having 24 μm-derived IR luminosities $\gtrsim 3 \times 10^{12}\ L_\odot$, IR luminosities are overestimated by an average factor of ~ 5 when SED fitting with 24 μm photometry alone. This result arises partly due to the fact that high redshift galaxies exhibit aromatic feature equivalent widths that are large compared to local galaxies of similar luminosities. Through a spectral decomposition of mid-infrared spectroscopic data, we are able to isolate the fraction of IR luminosity arising from an AGN as opposed to star formation activity. On average, this fraction is only able to account for $\sim 30\%$ of the total IR luminosity

among the entire sample and $\sim35\%$ of the "excess" IR emission relative to that expected based on extinction corrected UV SFRs. This suggests that AGN are not the dominant cause of the inferred "mid-infrared excesses" in these systems. Among the sources having mid-infrared excesses, half are accounted for by using proper bolometric corrections while half show the presence of obscured AGN. The FIR-radio correlation shows no evidence for evolution over this redshift range, however SMGs have IR/radio ratios ~3 times lower, on average, than what is measured for locally.

6.14 Infrared Emission from High-z Galaxies in Cosmological SPH Simulations
Kentaro Nagamine (University of Nevada Las Vegas)

We compute the infrared emission from high-z galaxies in cosmological SPH simulations by coupling the output of the simulation with the GRASIL code by Silva et al. Based on the stellar mass, metallicity and formation time of each star particle, we estimate the full SED of each star particle from UV to far IR, and compute the luminosity function and number counts of simulated galaxies in the Spitzer wavelength bands for direct comparision to the available Spitzer observations.

6.15 Radio Jet Feedback in Molecular Hydrogen Emission Galaxies.
Patrick M Ogle (SSC–Caltech)

Spitzer has revealed a new class of galaxies (MOHEGs) with very strong molecular hydrogen emission lines. These galaxies are characterized by very large H_2/PAH and H_2/IR emission ratios. A subset of these galaxies with powerful radio jets, selected by the isotropic radio lobe flux at 178 MHz, are the focus of this poster. The AGN X-ray emission measured by Chandra is too weak to power the H_2 emission. Instead, we argue that the H_2 emission must be powered by the interaction between the radio jet and the host galaxy interstellar medium. This may be an important mechanism for suppressing star formation in massive elliptical galaxies.

6.16 Understanding the mass assembly of galaxies at $z < 4$: Spitzer's contribution and open questions
Pablo G Perez-Gonzalez (Universidad Complutense de Madrid (UCM))

We will present the main results of our research about the assembly of galaxies at $z < 4$ based on the data obtained by the deepest Spitzer surveys carried out with its two imagers (IRAC and MIPS) in the first 6 years of the mission. These data in the mid- and far-IR have allowed us to obtain unprecedentedly robust estimations of the obscured SFR and the stellar masses of distant galaxies, specially at $z > 1$. Analyzing SFR and stellar mass functions in several redshift bins at $0 < z < 4$, we have found that galaxies formed following a downsizing scenario, with the most massive systems assembling early in the lifetime of the Universe and very quick (i.e., with very high star formation efficiencies, and a significant amount of obscured starbursts), while less massive systems assembled later and/or more slowly. However, Spitzer data have left several open questions that still hamper our current understanding about the formation and evolution of galaxies. I will discuss three of these results and how future facilities such as Herschel, ALMA or JWST can lead to a more robust and detailed (with higher spatial resolution and depth) characterization of how galaxies formed in the early Universe ($z > 1$): (1) the mid-to-far IR colors of galaxies evolve with

redshift, departing considerably from the typical values observed in the local Universe, specially at $z > 1.5 - 2.0$; (2) the IMF might not be universal time, evolving to a top-heavy IMF at $z > 1.5$; (2) obscured AGN may be ubiquitous in high-z galaxies, playing a significant role in the downsizing scenario.

6.17 Type 2 QSOs: star formation at high redshifts?
Dimitra Rigopoulou (University of Oxford)

We present new mid-infrared and submillimetre observations for a sample of high redshift type-2 QSOs located in the Chandra Deep Field South. The sources are X-ray absorbed with luminosities in excess of 10^{44} erg s^{-1}. Most of the sources are detected at submm wavelengths. All sources are detected in multiple mid-infrared bands with the Spitzer Space Telescope. The multiwavelength spectral energy distributions (SEDs) of the type-2 QSOs are compared to those of two local ultraluminous galaxies (Arp220 and IR22491) in order to assess contributions from a star-forming component in various parts of the SED. We suggest that their submillimetre emission is possibly due to a starburst while a large fraction of the mid-infrared energy is likely to originate in the obscured central quasar. Using the mid-infrared and submm observations we derive infrared luminosities which are found to be in excess of L>10^{12}L$_\odot$. The submillimetre (850 μm) to X-ray (2 keV) spectral indices (α_{SX}) span a wide range. About half of the type-2 QSOs have values typical for a Compton-thick AGN with only 1 per cent of the nuclear emission seen through scattering and, the remaining with values typical of submm-bright galaxies. Combining the available observational evidence we outline a possible scenario for the early stages of evolution of these sources.

6.18 QUEST: A Comprehensive Study of Local ULIRGs with Spitzer Spectra
David Rupke (Institute for Astronomy, U. Hawaii)

The goal of the Quasar and ULIRG Evolution STudy (QUEST) is to understand the hypothesized transformation of galaxies into quasars via major mergers. Using Spitzer observations, we have traced the buried black hole activity in a large sample of late stage mergers. Infrared diagnostics consistently show that, while star formation dominates the infrared output of most of these systems, AGNs are ubiquitous. It is also clear that the history of star formation and AGN activity over the course of a merger is complex.

6.19 Cosmic Evolution of Star Formation in Type-1 Quasar Hosts Since $z = 1$
Yong Shi (IPAC, Caltech)

We present Spitzer Infrared Spectrograph observations of a complete sample of 57 Sloan Digital Sky Survey type-1 quasars at $z \sim 1$. Aromatic features at 6.2 and/or 7.7 μm are detected in about half of the sample and show profiles similar to those seen in normal galaxies at both low and high redshift, indicating a star formation origin for the features. Based on the ratio of aromatic to star formation infrared (SFIR) luminosities for normal star-forming galaxies at $z \sim 1$, we have constructed the SFIR luminosity function (LF) of $z \sim 1$ quasars. As we found earlier for low-redshift Palomar-Green (PG) quasars, these $z \sim 1$ quasars show a flatter SFIR LF than do $z \sim 1$ field galaxies, implying the quasar host galaxy population has on average a higher star formation

rate (SFR) than the field galaxies do. As measured from their SFIR LF, individual quasar hosts have on average LIRG-level SFRs, which mainly arise in the circumnuclear regions. By comparing with similar measurements of low-redshift PG quasars, we find that the comoving SFIR luminosity density in quasar hosts shows a much larger increase with redshift than that in field galaxies. The behavior is consistent with pure density evolution since the average SFR and the average SFR/BH accretion rate in quasar hosts show little evolution with redshift. For individual quasars, we have found a correlation between the aromatic-based SFR and the luminosity of the nuclear radiation, consistent with predictions of some theoretical models. We propose that type-1 quasars reside in a distinct galaxy population that shows elliptical morphology but that harbors a significant fraction of intermediate-age stars and is experiencing intense circumnuclear star formation.

6.20 Star formation and dust extinction of $z \sim 4$ galaxies in GOODS
Hyunjin Shim (SSC/Caltech)

We present rest-frame optical star formation rates of $z \sim 4$ galaxies with spectroscopic redshifts, selected over the Great Observatories Origins Deep Survey (GOODS) fields. Among galaxies that are relatively isolated and detected in Spitzer IRAC 3.6 and 4.5 μm, $\sim 50\%$ of galaxies show clear excess in 3.6 μm compared to the expected flux using stellar continuum only. We suggest that this excess in 3.6 μm is due to Hα line flux redshifted into 3.6 μm band at $3.8 < z < 5.0$. The selection of $z \sim 4$ star-forming galaxies using this photometric excess is sensitive to galaxies with strong equivalent widths, i.e., rest-frame EW> 350A. We derive the optical star formation rates of these galaxies using the estimated Hα flux. The ratio between UV-derived star formation rates and Hα-derived star formation rates should work as an independent measure of dust extinction in these galaxies, providing strong constraints on the dust properties of high-redshift star-forming galaxies.

6.21 Search For Warm Molecular Hydrogen Shocks In Ram-Pressure Stripped Cluster Galaxies
Suresh Sivanandam (Steward Observatory)

We present the Spitzer IRS spectral mapping study of a small sample of galaxies in nearby clusters in which we searched for strong signatures of shocked warm molecular hydrogen, the result of ICM/ISM interactions, to study the effects of ram-pressure stripping. The sample galaxies were specifically chosen to be prime candidates that are currently experiencing strong ram-pressure stripping. We detected strong warm molecular hydrogen emission in two of the four sample galaxies. Of the two detections, we have modeled one of them, ESO 137-001, extensively. We discovered a molecular hydrogen tail that extends approximately 20 kpc away from ESO 137-001 and is coincident with the X-ray and Hα tail previously discovered. The molecular hydrogen tail consists of a warm component (140-160 K) that is the dominant portion of the tail mass and a hot component (580-680 K), which have a combined mass of 2.5×10^7 solar masses. We estimate the galaxy is losing its interstellar gas at a rate of at least 1-2 solar masses/yr. If the galaxy persists to lose mass at this estimated rate, it will exhaust its gas reservoir in a single pass through the cluster core, which will take at most 0.5-1 Gyr. Results produced from the modeling of the ram-pressure

stripping timescale are consistent with our upper limit and suggest that the effects of ram-pressure are most likely to be seen when the galaxy approaches the outskirts of the cluster core for the first time. Shocked molecular hydrogen signatures can be effective probes for understanding cluster transformative processes.

6.22 Evolved ULIRGs revealed as UL-ellipticals by Spitzer+ISO galaxy counts
Brigitte M Rocca-Volmerange (Institut d'Astrophysique de Paris)

The deepest faint galaxy counts at 24 μm (SPITZER) and 12 μm, 15 μm (ISO) show a typical differential brightness excess at $\sim$ 0.3 mJy. To choose between number density and luminosity evolution effects, we propose the interpretation by galaxy types of the mid-IR deep counts in coherency with the deepest UV-optical-NIR counts (Fioc and Rocca-Volmerange, A&A 1999, 344, 393). We use the recent version of our evolutionary code PEGASE (www.iap.fr/pegase) to predict evolution by types of the coherent dust plus stellar emissions. We find (Rocca-Volmerange et al. A&A, 2007, 475, 801) that one minor ($\sim$ 10 percent) galaxy population of ultra-luminous-infrared distant ellipticals explains the excess, respecting the other populations found in the UV-optical-NIR. The model is valid at 24 μm, 12 μm and 15 μm (ISO) without ad-hoc starbursts (no number density evolution). These ULIRGs evolve as massive ellipticals, but dusty and likely hosting AGNs. Consequences on the Cosmic Star Formation History, high-z galaxy masses and galaxy formation models are important.

6.23 S5-Spitzer SDSS Statistical Spectroscopic Survey
Ronin Wu (New York University)

We introduce the Spitzer SDSS Statistical Spectroscopic Survey (S5). This unique and unprecedented legacy survey contains 292 optically selected star–forming galaxies with available UV photometry. The sample is selected from the SDSS at a redshift range of $0.05 < z < 0.1$ with Hα fluxes $F_{H\alpha} > 3 \times 10^{-15}$erg s^{-1} cm^{-2}. One of the main goals for S5 is to determine the physical properties of star–forming galaxies, using a combination of optical (SDSS) and mid-IR (Spitzer/IRS) emission–line diagnosics. We present here the high resolution (R$\sim$600) MIR spectra of the sample. The spectroscopic properties are also examined with the galaxies categorized into groups of AGN, composite, low–metallicity star–forming, and high–metallicity star–forming galaxies based on the BPT diagram.

6.24 Witnessing the Birth of Radio Galaxies: IRS Spectroscopy of Compact Symmetric Objects
Kyle Willett (University of Colorado)

We have used the IRS to obtain spectra of ten examples of an unusual type of galaxy called "compact symmetric objects" (CSOs). CSOs are very young AGN with rapidly advancing radio lobes thought to be the predecessors of large-scale, powerful radio galaxies similar to Cygnus A. The power source for these young radio objects, however, remains unknown - optical and near-IR observations show no evidence for either a central AGN point source nor for accreting gas. IRS spectra show no evidence for the high-ionization line [Ne V] in any of our objects, suggesting that

CSOs as a class lack accreting nuclear gas. This requires a different source of energy to power the luminous, non-thermal jets such as tapping of black hole spin energy. The IRS spectra also reveal a remarkable diversity among the CSOs in the mid-IR; some resemble starbursting ULIRGs with deep dust absorption and powerful PAH features, while others resemble PG quasars with little evidence of star formation and silicate dust in emission. One target, PKS 1413+135, shows a strong continuum with no mid-IR features associated with gas in the ISM; the only visible feature is dust absorption at 10 and 18 μm. The diversity of CSOs in the mid-IR may suggest either a rapid evolution in the merger processes creating the giant elliptical hosts, or that multiple scenarios may lead to the formation of these young radio galaxies.

6.25 Exploring the Aromatic Emission in 5MUSES
Yanling Wu (Caltech/IPAC)

The 5 Milli-Jansky Unbiased Spitzer Extragalactic Survey (5MUSES) is a flux limited infrared spectroscopic sample selected from MIPS 24 μm fluxes. We present our preliminary results on studying the aromatic features in 5MUSES.

6.26 Spitzer Space Telescope Infrared Spectra of Xray Bright, Optically Normal Galaxies
Varoujan Gorjian (JPL)

In 1982 Elvis et al called attention to a pair of galaxies with AGN-like x-ray emission but no AGN features in their visible spectra [referred to here as XBONGS]. Since then, deep x-ray surveys have revealed large numbers of galaxies with these characteristics: luminous in the x-ray but without the high excitation lines, specific line ratios, or broad emission lines which characterize Type I and/or Type II AGN. Thus understanding XBONGS is an important step towards defining the accretion history of the Universe. For brevity, we continue to refer to these objects as XBONGS, while recognizing that they are not a homogeneous group, and in fact a variety of explanations have been proposed. It has been suggested that XBONGs are powered by AGN which are hidden at visible wavelengths by (i) dilution by the bright emission from the galaxy, by (ii) extinction, or by (iii) the absence of visible and ultraviolet radiation due to modifications in the character of the accretion disk which surrounds the central black hole. We tested these possibilities by taking Spitzer spectra of 4 XBONGs carefully selected from 26 XBONGs identified in the XBootes survey of the NOAO Deep Wide-Field Survey. We present the spectra and analyze the features to see which of the above three possibilities is more likely. What is most striking is that these spectra show none of the characteristic AGN features in the IR like high excitation [Ne] lines or a rising flux density towards longer wavelengths.

7.   Nuts and Bolts

7.1 Validation Testing of the MOPEX Software Using Simulations and Spitzer Data
Timothy Y Brooke (SSC/IPAC)

The MOPEX toolset was developed at the Spitzer Science Center (SSC) to make mosaics and do point-spread-function (PSF) fitting photometry of astronomical data, along with other related tasks (Makovoz, D. et al. 2006, SPIE 6274, 10). Both command-line and GUI versions are available for commonly-used platforms. MOPEX is used to make the "Post-BCD" mosaics familiar to users of the Spitzer archive. The main MOPEX functions have been validated on simulated data and with appropriate benchmarks on Spitzer data, e.g. 1) fluxes of simulated IRAC point-sources placed on individual frames are recovered by MOPEX's APEX PSF-fitting tool; 2) MIPS 24 μm aperture fluxes of galaxies obtained from a mosaic of a sub-sample of SWIRE frames agree with the deeper results. IRAC presents some challenges to PSF-fitting photometry, e.g. variable intra-pixel sensitivity and array-position-dependent responsivity. MOPEX/APEX can handle these effects, with some correction factors. With the current point response functions (PRFs) provided by the SSC and appropriate corrections, one can do photometry of IRAC point sources with systematic offsets due to PRF issues limited to $< 2\%$ on clean fields. For MIPS 24 μm PSF-fitting photometry, if enough data are available to derive a PRF from the data, one can get systematic offsets down to $< 2\%$ on clean fields.

7.2 DPHOT photometry method
David G Elliott (JPL Retired)

The DPHOT photometry method reads a set of overlapping Spitzer Basic Calibrated Data (BCD) frames and places a grid of up to 20,000 point response functions, spaced about 0.4 arcsec apart, over a data area. A simultaneous fit of the PRFs to the BCDs detects sources and returns information for deriving flux densities, positions and shapes. The poster presents examples of DPHOT photometry for IRAC data from GLIMPSE, GOODS, Galactic Center, and Einstein Cross.

7.3 Fast computation of GRASIL SED using Artificial Neural Networks
Gian Luigi E Granato (Osservatorio Astronomico di Trieste)

GRASIL is the state of the art model for the Spectral Energy Distribution of galaxies, and it has been widely used by the community. Being based on real physical computations of dust reprocessing, it is relatively slow with respect to phenomenological solutions, but allows much deeper physical understanding. To overcame this limitation, we have developed fast ways to obtain GRASIL SED exploiting the Artificial Neural Network technique. We show sample applications, in particular to semi-analytical models of galaxy formation.

7.4 FIFI LS@SOFIA: An Airborne Imaging Far-Infrared Spectrometer for You to Use
Randolf Klein (UC Berkeley)

FIFI LS is a far-infrared integral field spectrometer for the SOFIA airborne observatory. The instrument is designed to maximize the observing efficiency by simultaneous and nearly independent imaging of the field-of-view in two medium spectral resolution bands. Its unique features as the large far-infrared photoconductor detectors and its integral field concept make it ideal to study star-formation on all scales. Built as a Principal Investigator instrument, it is currently upgraded to allow general access to FIFI LS on SOFIA.

7.5 WISE: The Wide-field Infrared Survey Explorer
David Leisawitz (NASA Goddard Space Flight Center)

WISE will map the entire sky at 3.4, 4.6, 12 and 22 μm with sensitivities of 0.12, 0.16. 0.85, and 4 mJy. WISE will find the most luminous galaxies in the universe, the closest stars to the Sun, and detect most main belt asteroids larger than 3 km. WISE will be placed into a Sun-synchronous polar orbit on a Delta 7320-10 rocket, rotating at a constant rate while a scan mirror freezes the line of sight during each exposure, covering the sky in 6 months following a one month checkout. Orbit to orbit overlap provides 8 or more exposures per location. The instrument, provided by the Space Dynamics Laboratory, includes a 40 cm telescope from SSG-Tinsley, a solid hydrogen cryostat from Lockheed-Martin's Advanced Technology Center, and 1024x1024 pixel Si:As and HgCdTe arrays from DRS and Teledyne. Dichroic beamsplitters allow simultaneous images in the four bands over a 47'x47' field of view with 5" resolution to be obtained every 11 seconds. Ball Aerospace is provided the spacecraft, which includes a 500W fixed solar array, two star trackers, reaction wheels, and torque rods. The 50 GB per day of images are losslessly compressed, stored in flash memory, and downlinked at 100 Mbps four times per day using a fixed antenna and TDRSS satellites. The Infrared Processing and Analysis Center will process the data and deliver the image atlas and source catalog, with a preliminary release 6 months after the survey, and a final release 2 years after the survey. JPL manages the project for UCLA PI Ned Wright, and conducts mission operations. Education and Public Outreach is provided by UC Berkeley's Space Science Laboratory. WISE has completed assembly, integration, and testing, and is at the Vandenberg Air Force Base launch site where final preparations for the 2009 Dec. 7 launch are underway.

7.6 The Spitzer Source List
Harry I Teplitz (IRSA)

The Spitzer Science Center will produce a source list (SL) of photometry for a large subset of imaging data in the Spitzer Heritage Archive (SHA). The list will enable a large range of science projects. The primary requirement on the SL is very high reliability, even at the cost of completeness. The SHA at the NASA Infrared Science Archive (IRSA) will serve the SL as an enhanced data product. The SL will include data from the four channels of IRAC (3-8 μm) and the 24 μm channel of MIPS. The Source List will include image products (mosaics) and photometric data for Spitzer observations of about 1500 square degrees and include around 30 million sources. We describe the plans and timeline for development of the Spitzer Source List. We demonstrate the verification of the Source List pipeline using Spitzer Legacy catalogs at "truth tables". Finally, we discuss the range of use cases which will be supported.

7.7 Spitzer Heritage Archive
Xiuqin Wu (Caltech/SSC/IRSA)

Spitzer Heritage Archive will be released to the public in Februay 2010. This AJAX-based web application requires no plug-ins but contains advanced web technologies such as a true FITS viewing, spectrum plot, interactive tables, input field validation. It will allow you to search the

Spizer archive data by position, by observer, by keywords, and also by program ID, request ID (or AOR key), etc. It will let users to download the selected data products and associated ancillary and calibration data products. It has been designed and developed under collaboration of Spitzer Science Center(SSC) and NASA/IPAC InfraRed Science Archive (IRSA). It took advantage of the SSC and IRSA existing technology and knowledge base. The heritage archive system will initially contain the raw and final reprocessed cryogenic science products (will be available gradually), and will eventually incorporate the final data products from the Spitzer Warm Mission

7.8 SOFIA - The Stratospheric Observatory for Infrared Astronomy
Erick T Young (SOFIA)

The Spitzer Space Telescope, in particular with its large scale surveys like GLIMPSE, MIPS-GAL, and SWIRE, has produced a wealth of sources that demand follow-up observations. As one of the few ways to access much of the infrared to sub-millimeter parts of the spectrum, SOFIA will be an essential capability for the next two decades. SOFIA will provide instrumentation ranging from imagers to high resolution infrared spectrometers to heterodyne spectrometers. This poster presents some of the observational opportunities available for Spitzer follow-up.