Things to look at before coming to SSC … but we will go through all of this once you get here.

1. General Intro to the project
2. General Intro to Spitzer
3. Star Formation
4. More concrete things like Units & Photometry

General Intro to the project

a.k.a. why are we doing this, again?

<http://coolwiki.ipac.caltech.edu/index.php/BRC_Bigger_Picture_and_Goals> has big goal, concrete goal, story arc, and rough timeline.

General Intro to the Spitzer Space Telescope

NASA’s Great Observatories

*Spitzer* infrared ~1600 – 100,000 nm

*Hubble* visible ~500 nm

*Chandra* x-ray ~2 nm

*Compton* gamma-ray now, dead

General info on infrared … <http://coolwiki.ipac.caltech.edu/index.php/What_is_infrared_light%3F>

ir photo gallery:

<http://coolcosmos.ipac.caltech.edu/image_galleries/our_ir_world_gallery.html>

Looking at other wavelengths …

<http://coolwiki.ipac.caltech.edu/index.php/How_can_I_get_data_from_other_wavelengths_to_compare_with_infrared_data_from_Spitzer%3F>

Relative sizes of light

near-infrared ~0.9 – 5 µm ~ smoke particles

mid-ir 5 – 30 µm ~ hair diameter

far-ir 30 – 350 µm ~ salt grain

Two Key Questions for *Spitzer*

* How do stars and planetary systems form and evolve?
* What did the early universe look like

Why do we need to go to space for infrared?

* Space is cold
* Earth’s atmosphere absorbs some infrared light

Instruments aboard *Spitzer*

* IRS infrared spectrograph
* MIPS multiband imaging photometer … 24 µm, 70 µm, 160 µm
* IRAC infrared array camera … 3.6 µm, 4.5 µm, 5.8 µm, 8.0 µm

The Spitzer Science Center and Program Selection

Jargon

AOT astronomical observation template

AOR astronomical observation request (completed AOT)

DCE data collection event (1 raw data frame)

BCD basic calibrated data (result of AOR)

PBCD post-basic calibrated data (mosaic)

AORs are processed individually

Anything in the plane of the solar system can be seen by *Spitzer* 2x/yr for 40 days each BUT at the pole? Seen anytime. Smooth change between 40 d window and 365 d window as a function of ecliptic latitude.

When looking at something very bright, beware that artifacts exist.

Legacy programs … no proprietary period, and products (like photometry) delivered back to SSC/IRSA

<http://ssc.spitzer.caltech.edu/spitzermission/observingprograms/legacy>

Latest Star-Formation Results from *Spitzer*

Good resources:

<http://coolcosmos.ipac.caltech.edu/resources/star_formation/>

<http://coolwiki.ipac.caltech.edu/index.php/Studying_Young_Stars>

Formation of Low-Mass Stars (AWESOME MOVIES)

1. Cloud of gas and dust with dense core (~200,000 AU diameter)
2. Zooming in on one clump, gravitational collapse onto a disk (~10,000 AU diameter) CLASS ZERO
   1. Cocoon, jets
   2. Reprocessed energy coming out
   3. Looks like cold blackbody
   4. Most embedded
   5. MENV > ~0.5 MSUN
   6. Shortest lived
3. Some amount of matter gets ejected into jets resulting in a protostar … disk ~500 AU … 10,000 to 100,000 years old CLASS ONE
   1. Late accretion phase
   2. Reprocessed radiation is coming out of cocoon
   3. MENV > ~0.1 MSUN
   4. Very dusty
4. Bi-polar flow from center … disk ~100,000 AU … Classic T-Tauri star (CTTS) … 100,000 – 3,000,000 years old CLASS TWO
   1. Optically thick disk
   2. No more outflows or cocoon
   3. Average MDISK> ~0.01 MSUN
5. Pre-Main Sequence Star … planetary debris disk forms … TPF will be designed to look for olivine in space … Weak T-Tauri star (WTTS) … 3 -50 millions years old CLASS THREE
   1. Optically thin disk
   2. Average MDISK> ~0.003 MSUN
   3. No dust
6. Young stellar system … after planets form, they start to clear out the dust … ~50,000 AU from central star to edge of system … > 50 million years old

*-- Greene, American Scientist, July-August 2001*

Occasionally these protoplanetary objects hit each other and create a secondary dusty ring ... Then re-accretes onto the protoplanets

* Zodiacal dust comes from comets and leftovers
* Moon’s create … which arose from huge collision between Earth and a smaller planet-like body
* Oort cloud … left from cocoon (stage 3 above)
* Kuiper belt … left over from disk (stage 5 above)

Examples:

* + HD 206267
  + IC 1396
  + Eta Carinae
  + M16 “Pillars of Creation”
  + Lynds 1014
  + NGC 1333
  + Fomalhaut

Range of disk lifetimes

A stars … rocky objects smash into each other and merge to make large bodies. The violence of these collisions causes immense clouds of dust to escape and spread out. These disks are warmed by central stars and glow in the infrared. Data show there can be huge amounts of debris … up to ages of 100-200 million years. BUT even around some of the youngest stars, there is no detectable debris … a large range of properties from star to star.

Systems more like ours

* A lot of stars (20-60%) like our Sun have dusty disks

… lots of rocky planets??? *– Meyer et al 2008*

* Lots of water formed in clouds around YSOs  *-- Watson et al 2007*
* Are moons and tides rare? *--Gorlora et al 2007, Currie et al 2008*
* Planets around binaries? ­*-- Trilling et al 2007*

More Concrete Things

Chain of tasks for BRCs:

<http://coolwiki.ipac.caltech.edu/index.php/Working_with_the_BRCs>

Using the SHA

Spitzer Heritage Archive … <http://sha.ipac.caltech.edu/applications/Spitzer/SHA/>

<http://coolwiki.ipac.caltech.edu/index.php/How_do_I_download_data_from_Spitzer%3F>

1. Use SIMBAD to resolve the name … coordinates show … since we want only IRAC and MIPS, uncheck IRS
2. Investigate the footprint of each observation to determine which you want … bigger = better.
   1. AOR footprint …
3. Within this table, you can search on each column header … sort AORKEY … once you know what data you want, prepare download and download now to desktop
4. Once you have the data, you want \*maic.fits files. These are mosaic files. You don’t want mcov.fits (coverage) or munc.fits (uncertainties)

Units Fabulous explanation here on the wiki; we will return to this page again and again: <http://coolwiki.ipac.caltech.edu/index.php/Units>

* Flux … energy per unit area per unit time (J/s\*m2)
* Luminosity … energy per unit time (J/s)
* Flux density … energy per unit area per unit time “per photon” (Jy) or (W/m2\*Hz)

Spitzer images … MJy/sr

Make sure you check that the number makes sense!

Photometry

<http://coolwiki.ipac.caltech.edu/index.php/Photometry>

Using APT … <http://coolwiki.ipac.caltech.edu/index.php/Aperture_photometry_using_APT>

What to do with photometry when you have it:

Making color-magnitude and color-color diagrams

<http://coolwiki.ipac.caltech.edu/index.php/Color-Magnitude_and_Color-Color_plots>

When you make color-color, distance goes away.

Magnitudes are implicit comparisons with respect to Vega

Stars without excess (no disk) have no color

We’re talking about stars with metallicity like our Sun

*Spitzer* is so sensitive that you can easily see galaxies at the edge of the Universe, even when you are trying to just see the YSO nearby

Star formation (here or elsewhere) has the same colors

High resolution imaging at other wavelengths can help us distinguish between local objects (cluster members or field stars) and galaxies

*-Rebull et al 2010*

Analyzing SEDs

<http://coolwiki.ipac.caltech.edu/index.php/SED_plots>

Calculate slope 2-8 µm (better to use all possible data)

log 

 F 

0.3 < m class I

0.3 > m > -0.3 flat

-1.6 > m < -0.3 class II

m < -1.6 class III

*-- Wilking et al 2001, ApJ 551, 357*