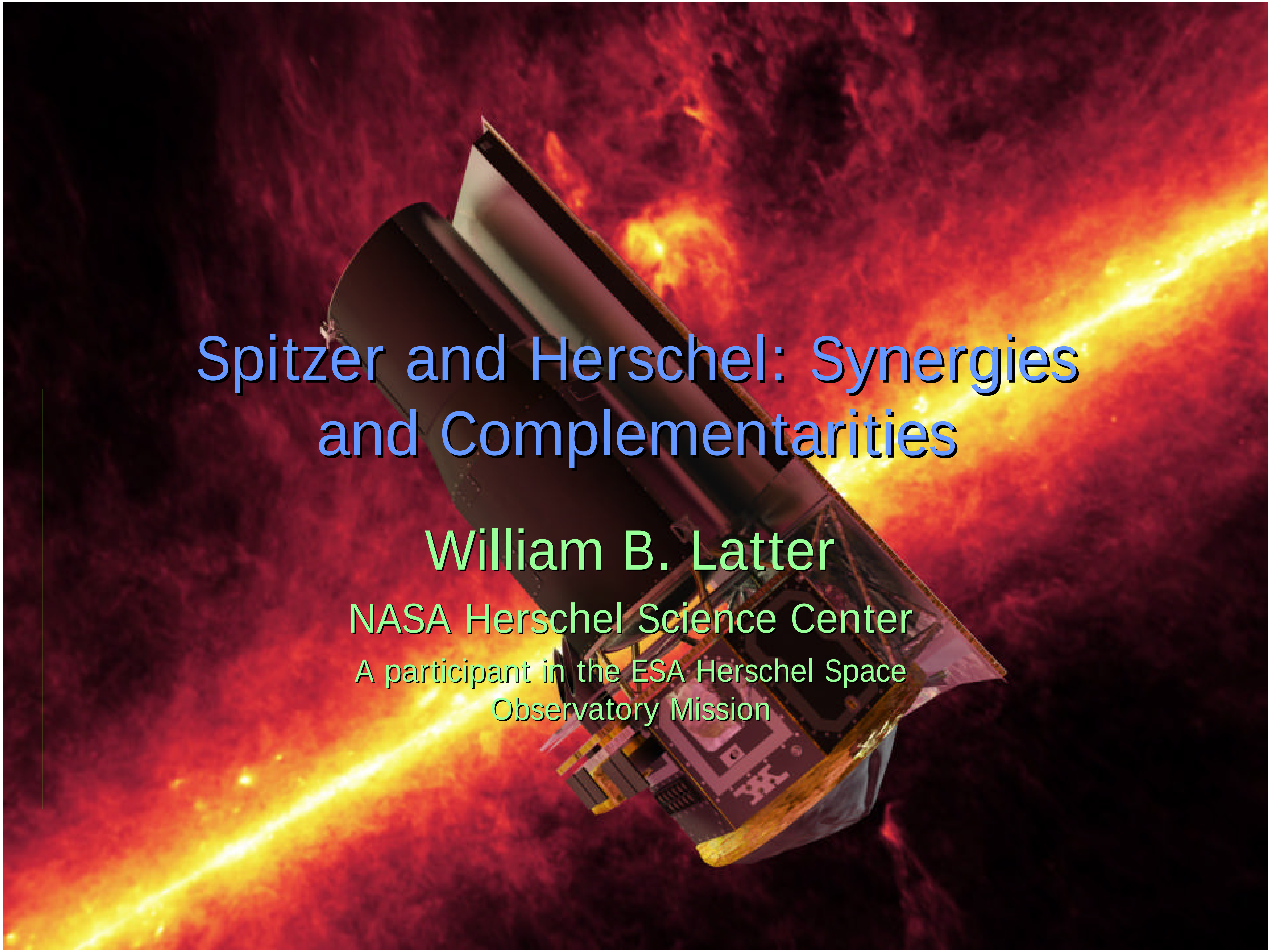
Spitzer and Herschel: Synergies and Complementarities
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Themes

- Basics and Reminders
- Large Scale Mapping
- Some Spectroscopy
- The Molecular Universe

Spitzer Overview

- Launch Date: 25 August 2003
- Launch Vehicle/Site: Delta 7920H ELV / Cape Canaveral, Florida
- Estimated Lifetime: 2.5 years (requirement); 5+ years likely
- Orbit: Earth-trailing, Heliocentric
- Wavelength Coverage: 3 - 180 microns
- Telescope: 85 cm diameter (33.5 Inches), f/12 lightweight Beryllium, cooled to less 5.5 K
- Diffraction Limit: 6.5 microns
- Science Capabilities:
  - Imaging / Photometry, 3-180 microns
  - Spectroscopy, 5-40 microns
  - Spectrophotometry, 50-100 microns
- Planetary Tracking: 1 arcsec / sec
- Cryogen / Volume: Liquid Helium / 360 liters (95 Gallons)
- Launch Mass: 950 kg (2094 lb) [Observatory: 851.5 kg, Cover: 6.0 kg, Helium: 50.4 kg, Nitrogen Propellant: 15.6 kg]

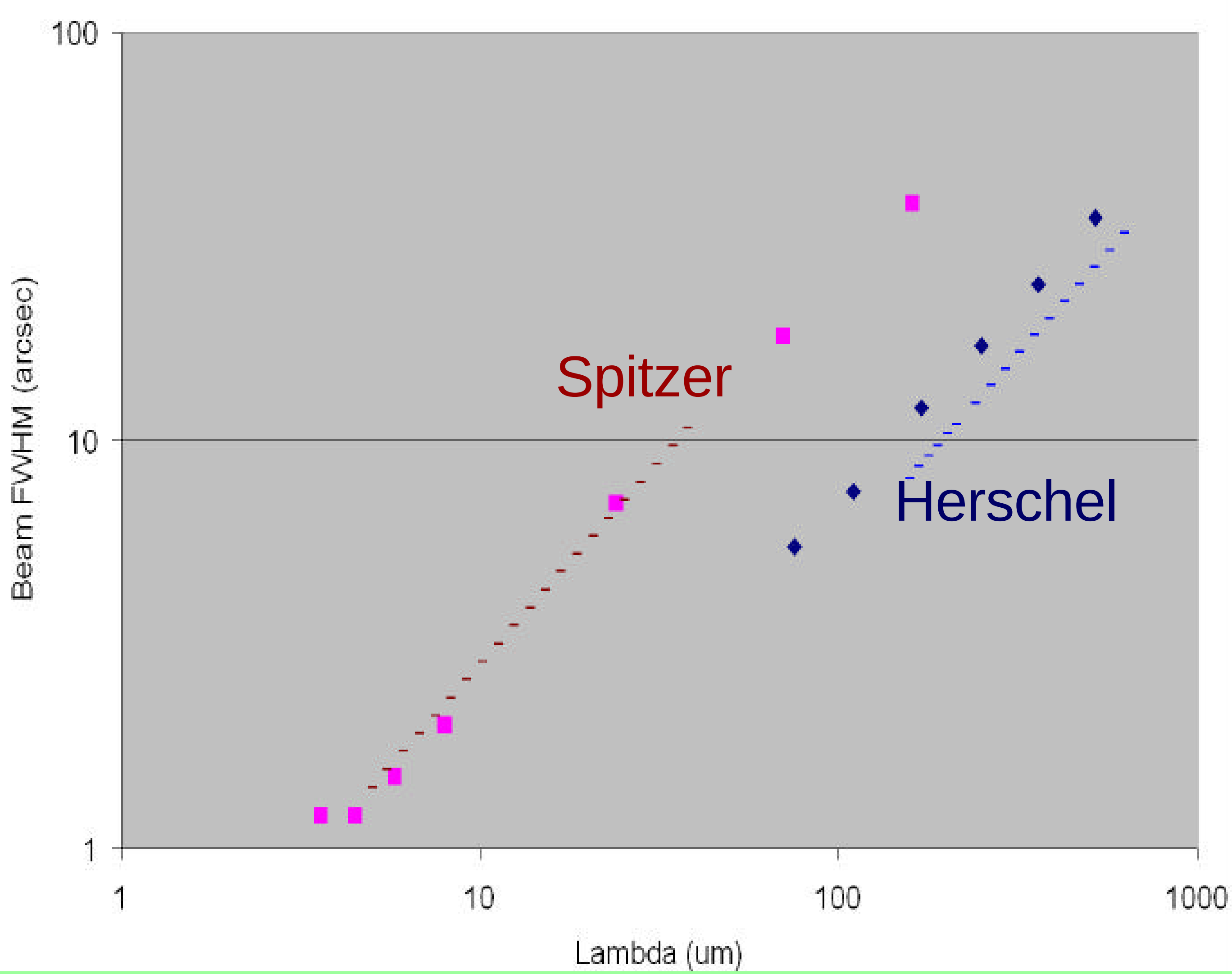
Herschel in a nutshell

- **ESA cornerstone observatory**
  - instruments 'nationally' funded, int'l - NASA, CSA, Poland – collaboration
  - ~1/3 guaranteed time, ~2/3 open time
- **FIR (57 - 670 μm) space facility**
  - large (3.5 m), low emissivity (< 4%), passively cooled (< 90 K) telescope
  - 3 focal plane science instruments
  - 3 years routine operational lifetime
  - full spectral access
  - low and stable background
- **Unique and complementary**
  - for λ < 200 μm larger aperture than cryogenically cooled telescopes (IRAS, ISO, Spitzer, Astro-F,...)
  - more observing time than balloon- and/or air-borne instruments (~1000 SOFIA flights per year)
  - larger field of view than interferometers
- **Launch in mid 2008**

Spitzer and Herschel: Basic Niche Differences

- Herschel will advance on questions that require
  - longer wavelengths
  - better spatial resolution
  - greater spectral resolution
- Herschel sensitivity to point source continuum is limited by warm telescope
  - Expected 1 hour 5s sensitivity is a few mJy for targeted point sources
    - Major improvement over confusion-limited 160μm of Spitzer
    - Still not well matched to Spitzer 24μm sensitivity for typical SEDs
- HIFI provides major advance in heterodyne capability from 157 to 625μm
  - Resolution in range 0.3 to 300 km/s

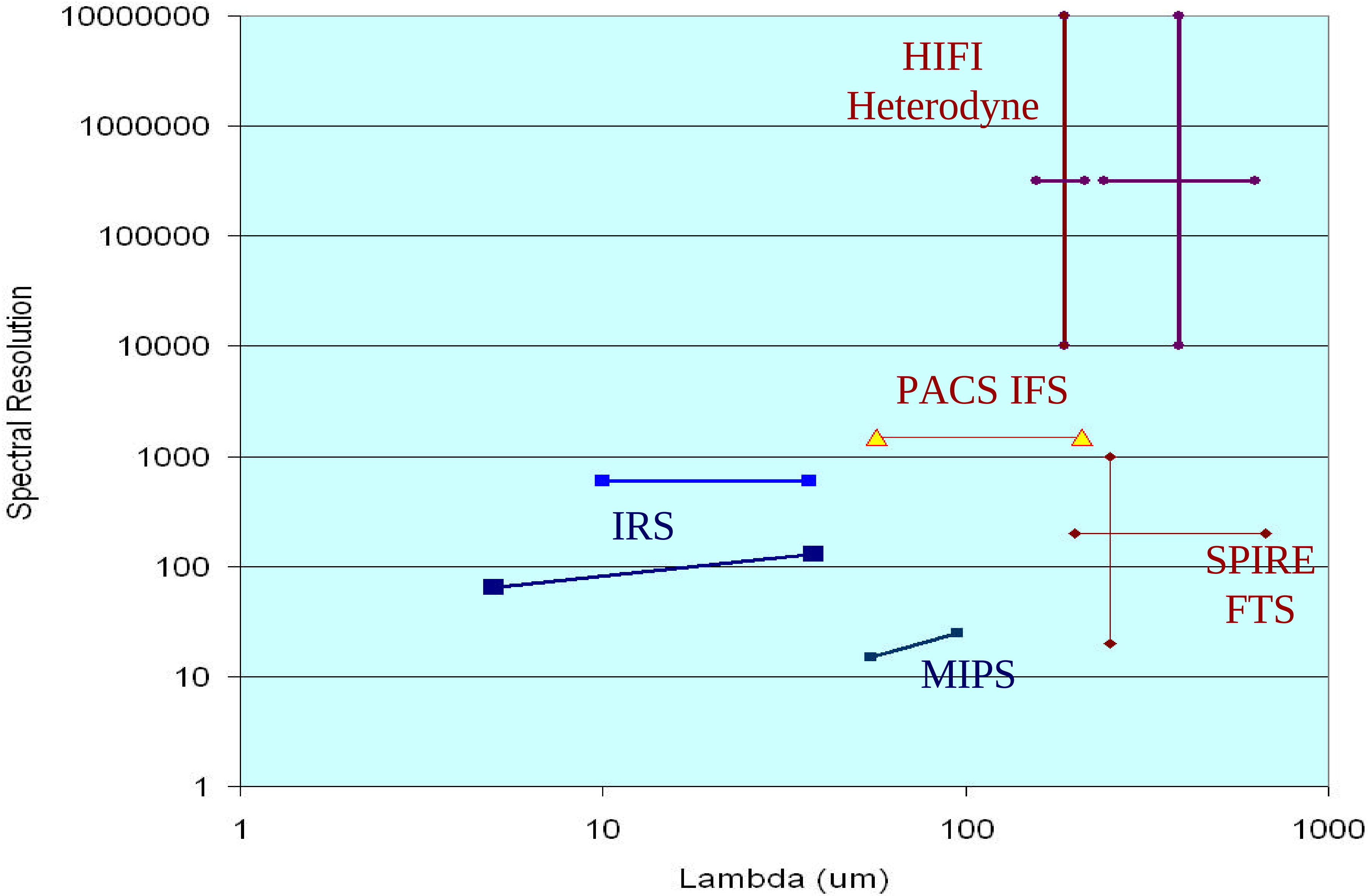
Spatial Resolution: Spitzer vs. Herschel



- Herschel offers same spatial resolution at ~4 times the wavelength
- Surface brightness sensitivity suffers proportionately

Spectral Resolution: Spitzer vs. Herschel

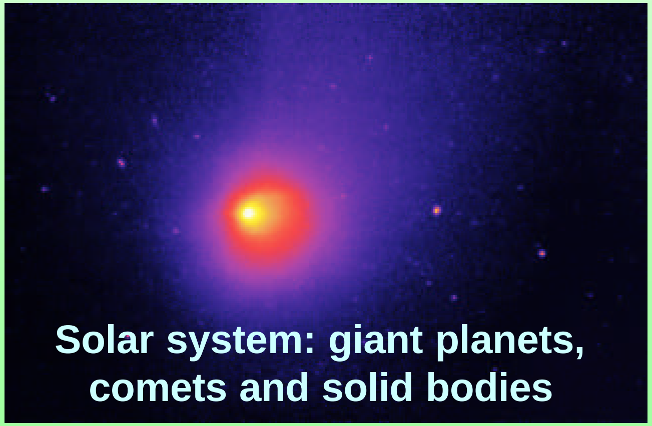
- Herschel offers comparable or greater spectral resolution

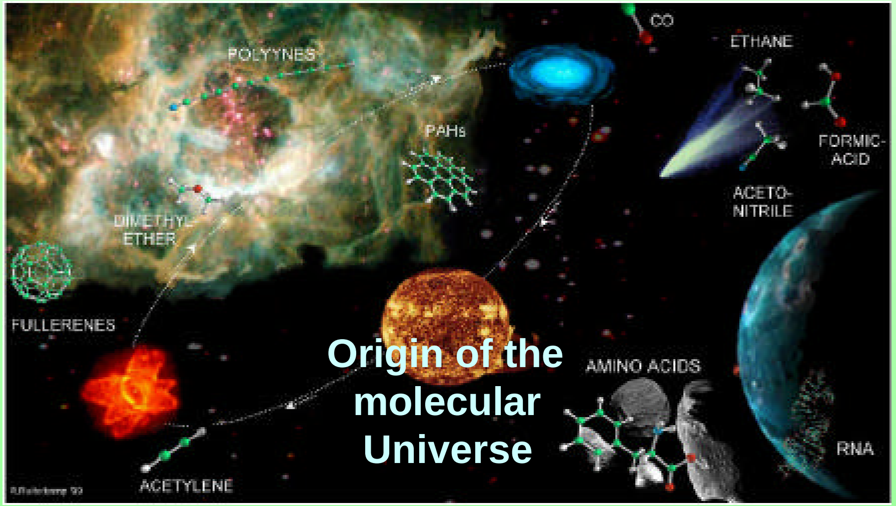


Herschel Science Goals

Statistics and physics of
early galaxy formation

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

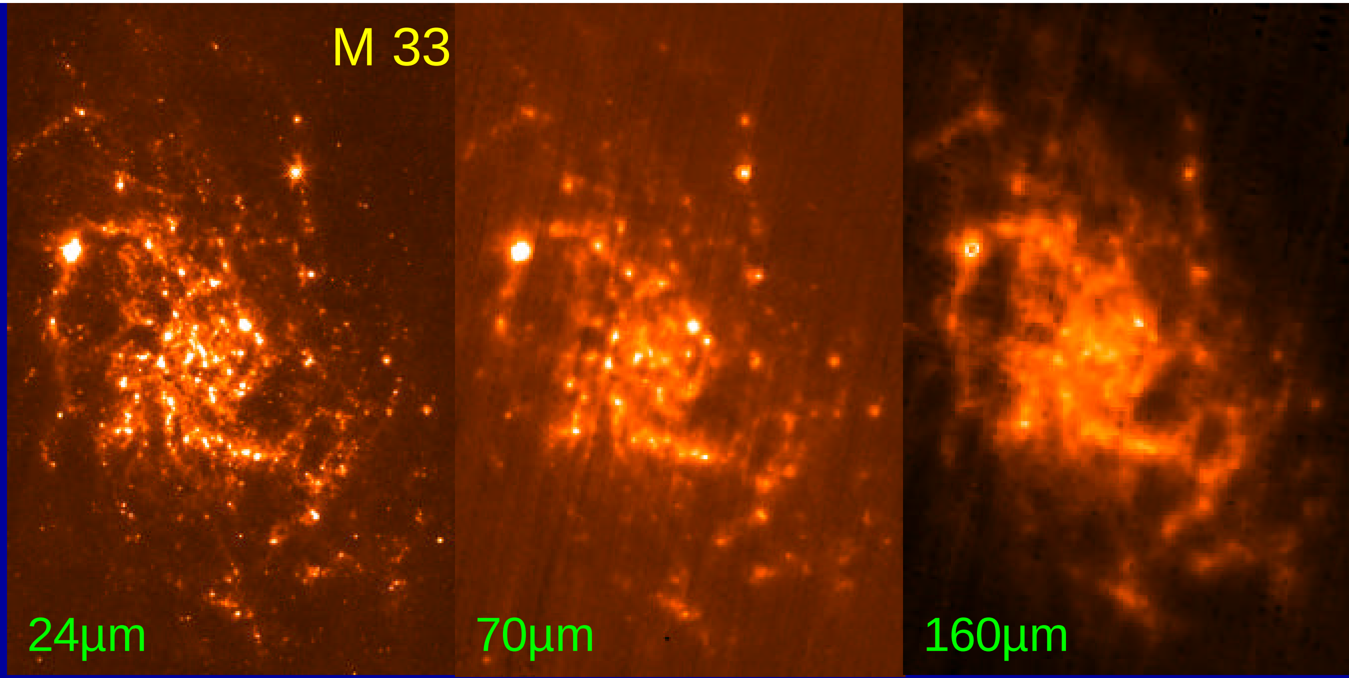


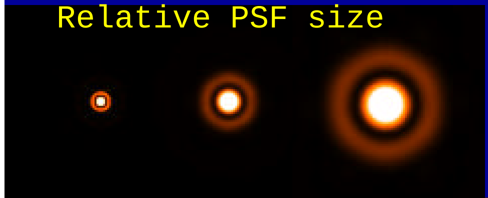


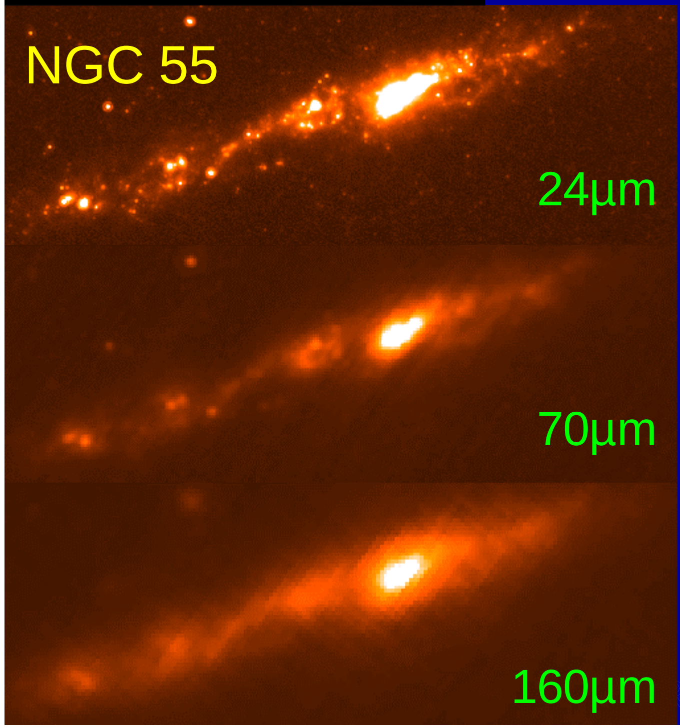
Theme: Large Scale Mapping
-- Galaxies, Nearby and Distant

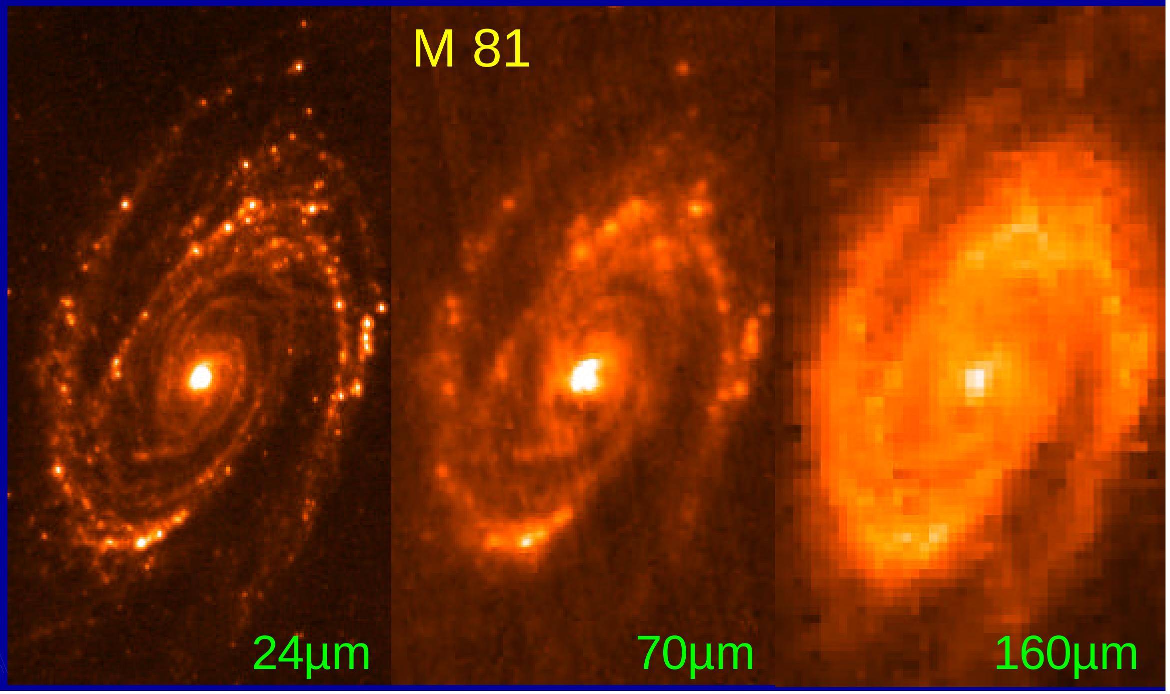
- Herschel offers best spatial resolution at the peak of the dust emission, 100-400μm, that will be available for a long time (ALMA)
- Will provide images of nearby galaxies to match 24 and 70μm maps
  - Improve our knowledge of the local SED within galaxy disks, of dust heating and distribution, cold dust distribution, etc
  - Improves total IR maps, for comparison with radio, H-alpha, etc
- Will resolve ULIRG and interacting systems at intermediate distances, approaching Spitzer imaging at 24μm
  - Improves our ability to assign SEDs to components, e.g. core and host, or interacting galaxies
- Will provide SED for objects to longer wavelengths and higher redshifts
  - Direct bolometric luminosity measures, radio-IR, etc
  - Fill in SED for SMG, address warm/cool ULIRG question: geometry? dust?
  - Possibly address extent of emission in these objects

Galaxies in all 3 MIPS bands



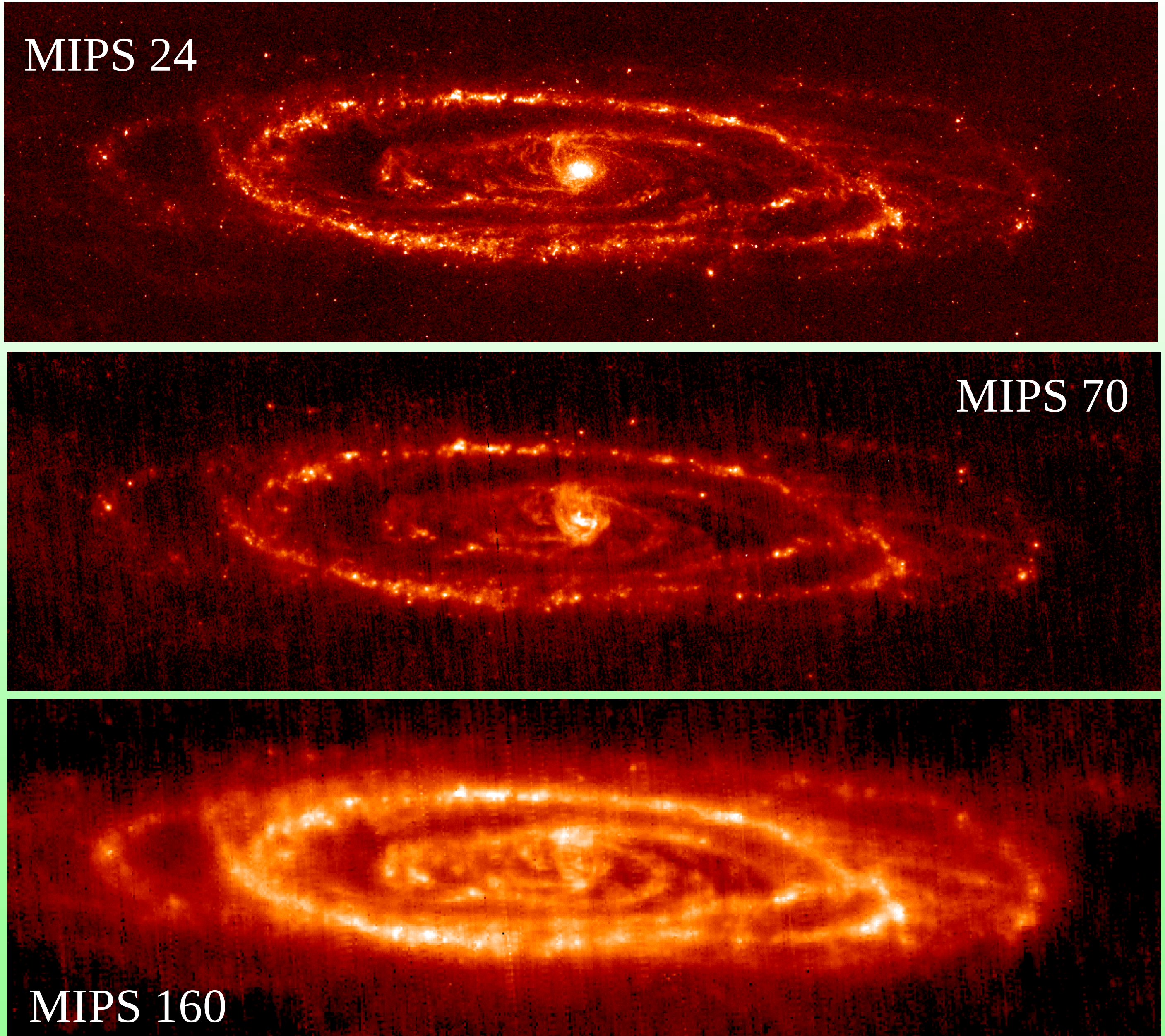




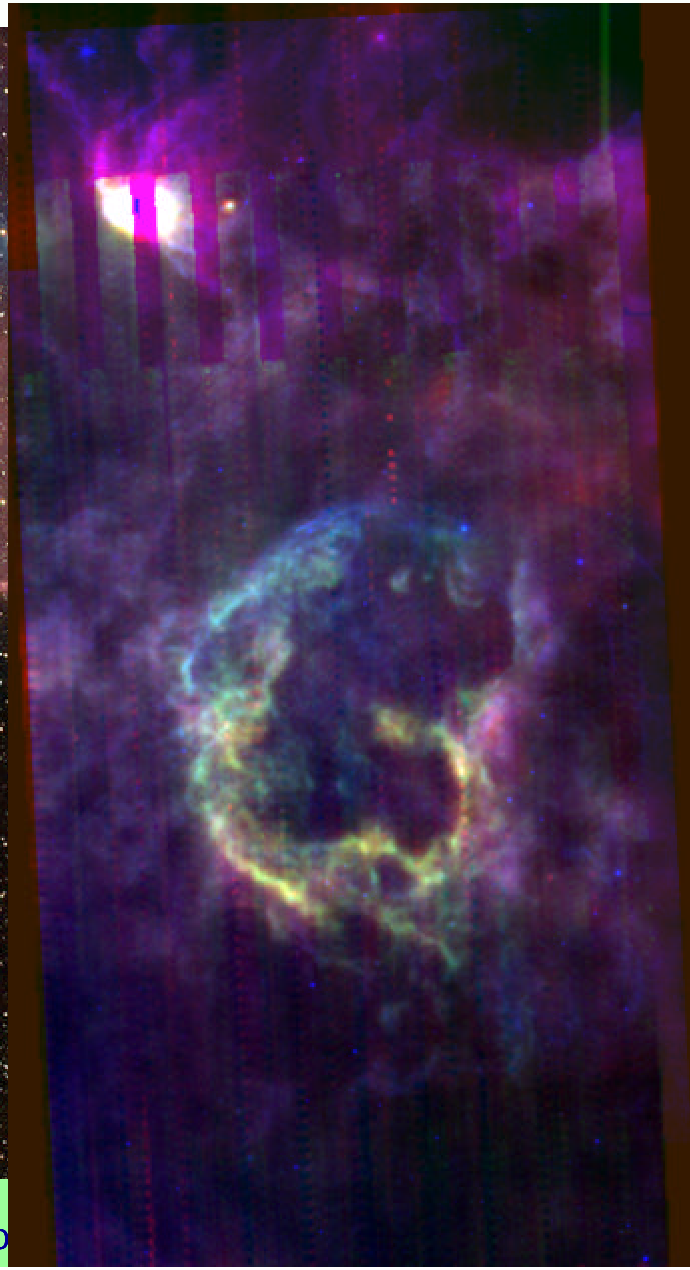


M31 - The Andromeda Galaxy

Size = 0.83 x 2.83 degrees

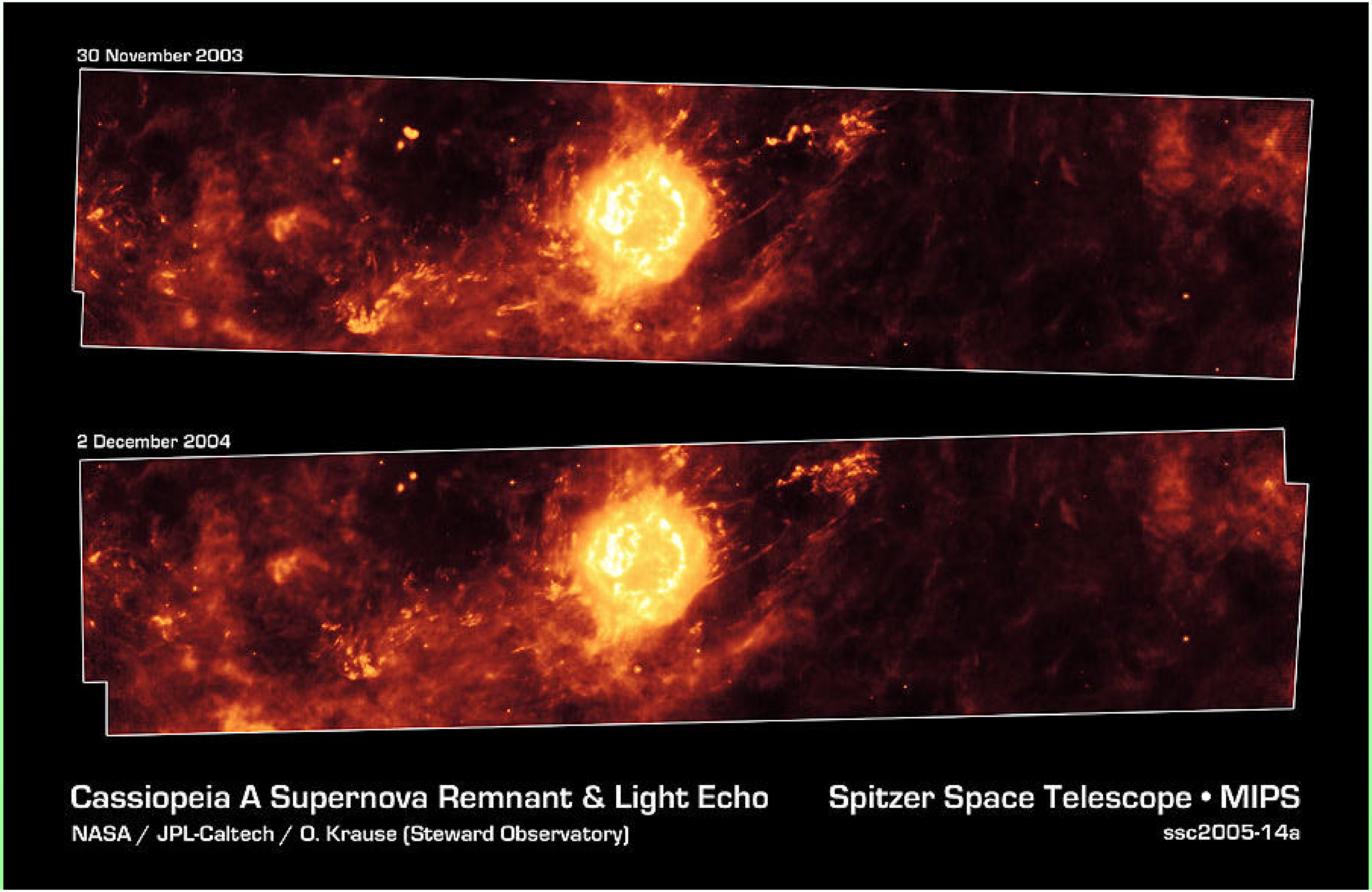


Spitzer and sources of dust: A SNR



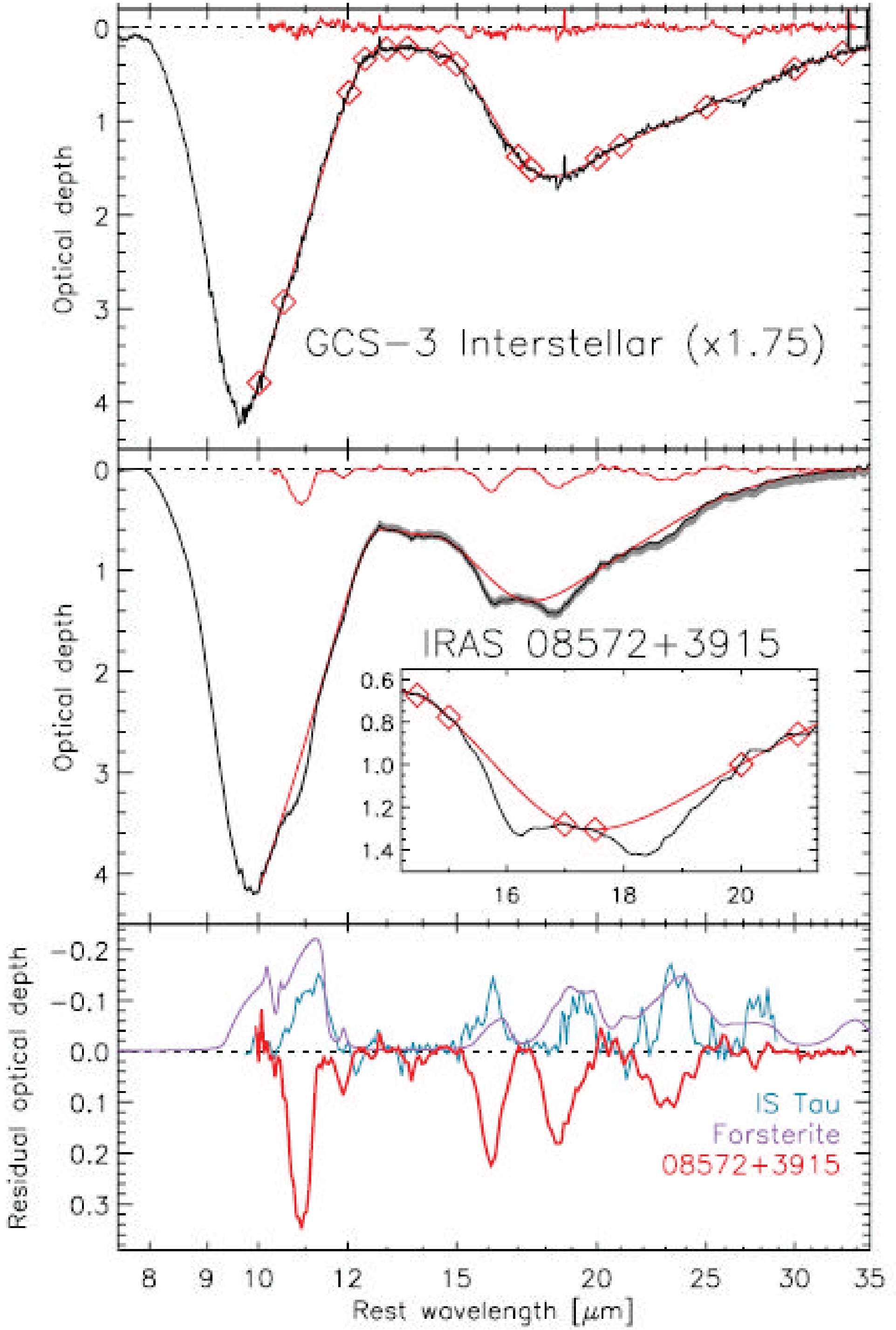
IC443 – A supernova remnant

24µm Images of Cas A Show Variations Over a Year



Theme: Some Spectroscopy

Crystalline silicates, apparently not present in the ISM of our galaxy, appear in absorption in at least a dozen Ultraluminous Infrared Galaxies

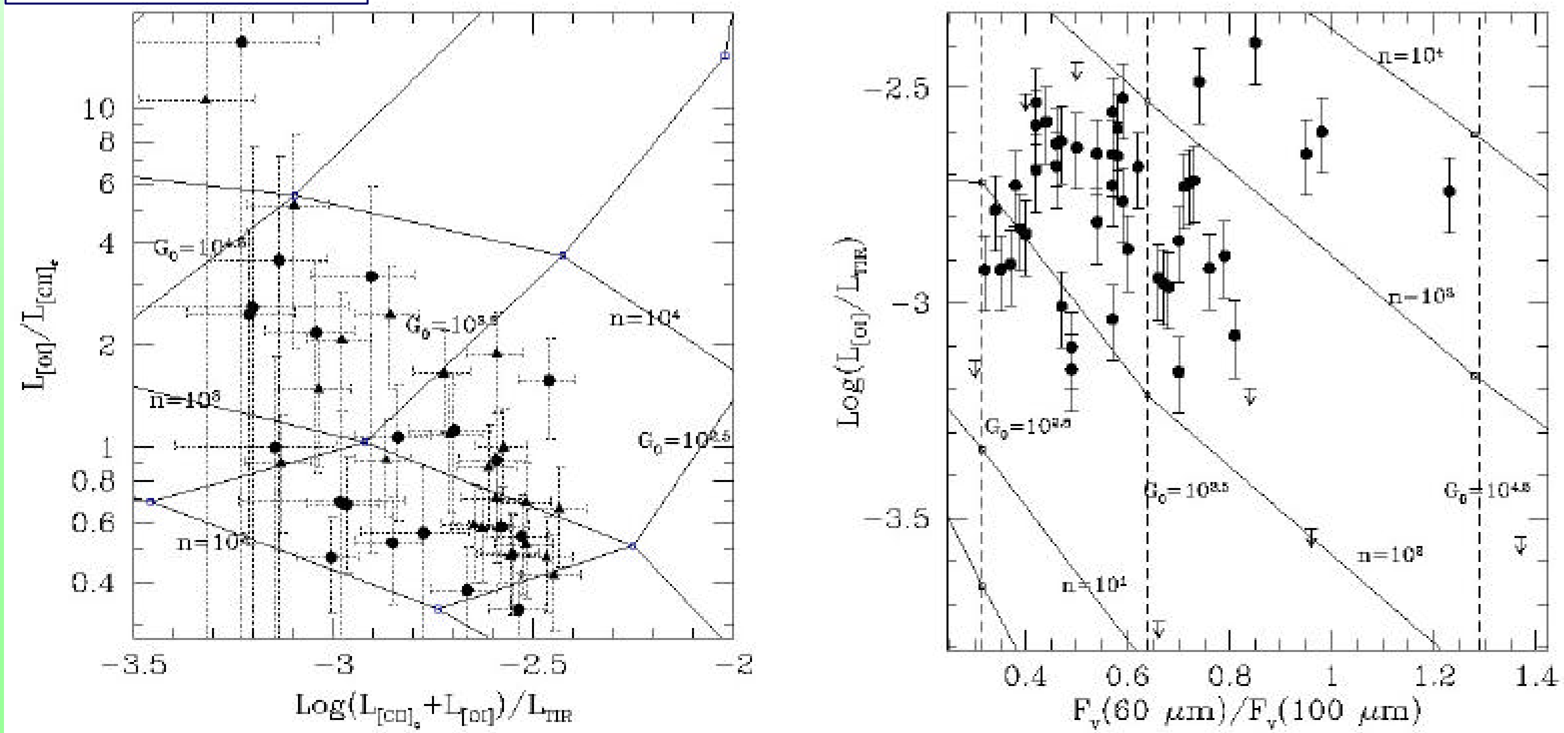


FIR Fine-Structure Lines as ISM Diagnostics

- Traditionally, IR fine-structure line studies in the Milky Way have relied on PDR modeling to deduce physical parameters (n, U, T) of PDR from data. See Hollenbach & Tielens (ARA&A 1997).
  - Unique, low extinction probes of the warm atomic and ionized regions that are assessable to Spitzer and Herschel, but not both

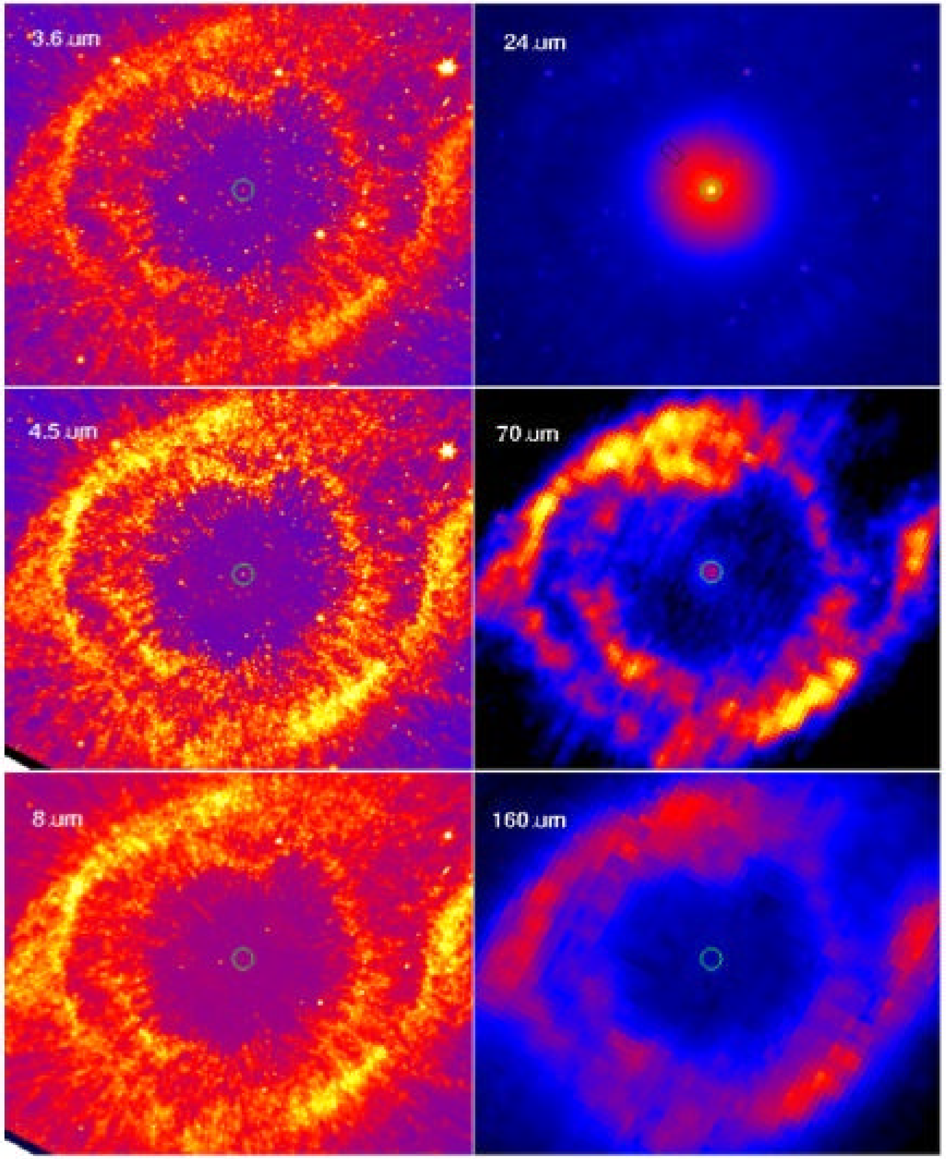
Species	λ (μm)	E.P. (eV)	I.P. (eV)	$\Delta E/k$ (K)
[C II]	157.7	11.3	24.4	91
[O I]	63.2		13.6	228
[Fe II]	35.3	7.9	16.2	407
[Si II]	34.8	8.2	16.4	413
H_2 S(0)	28.2			510
[Fe II]	26.0	7.9	16.2	554

Malhotra et al 2001



Herschel Prospects for Fine-Structure Lines

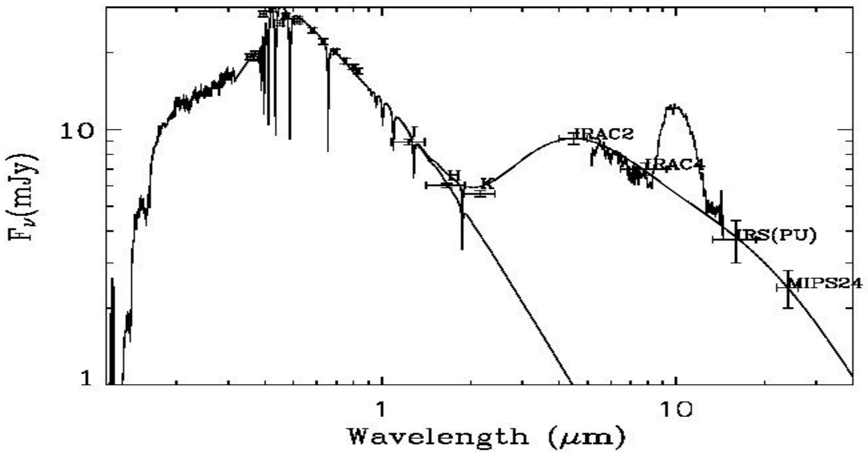
- Access to [OI], [OIII], [CII], other major cooling lines at z=0 to 2 or more
- Access to mid-IR lines [SiII], [SIII], H_2 etc at z~1 to ??
  - ISM, ISRF physical parameters: heating, density, clumping, opacity
  - PDR Evolution - Planetary Nebulae
  - Kinematics of warm, star-forming regions
  - Redshift determination similar to Aromatic Features with Spitzer



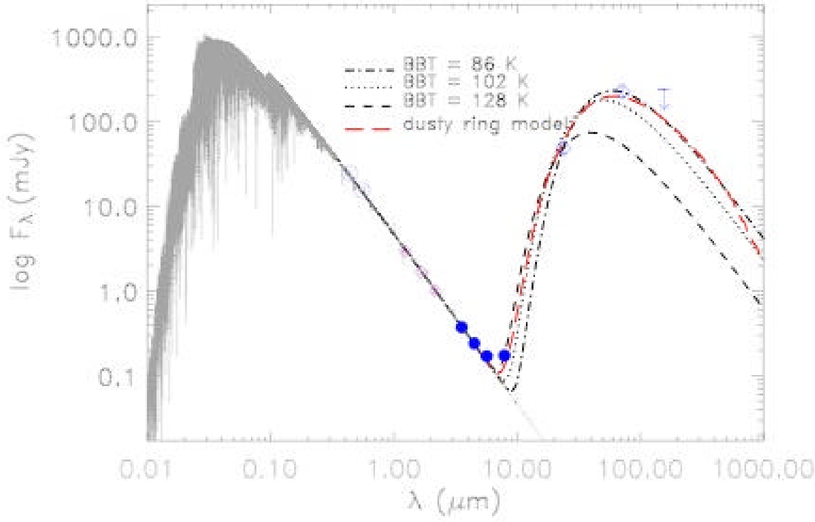
K. Su et al. ApJ, submitted

Disks Everywhere Show Similar Characteristics

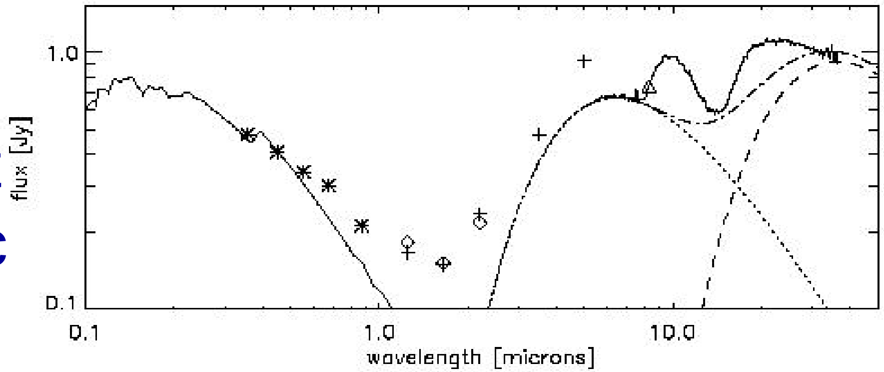
Disk Around White Dwarf



Helix Nebula Central Star



Disk Around Hypergiant Star in Large Magellanic Cloud

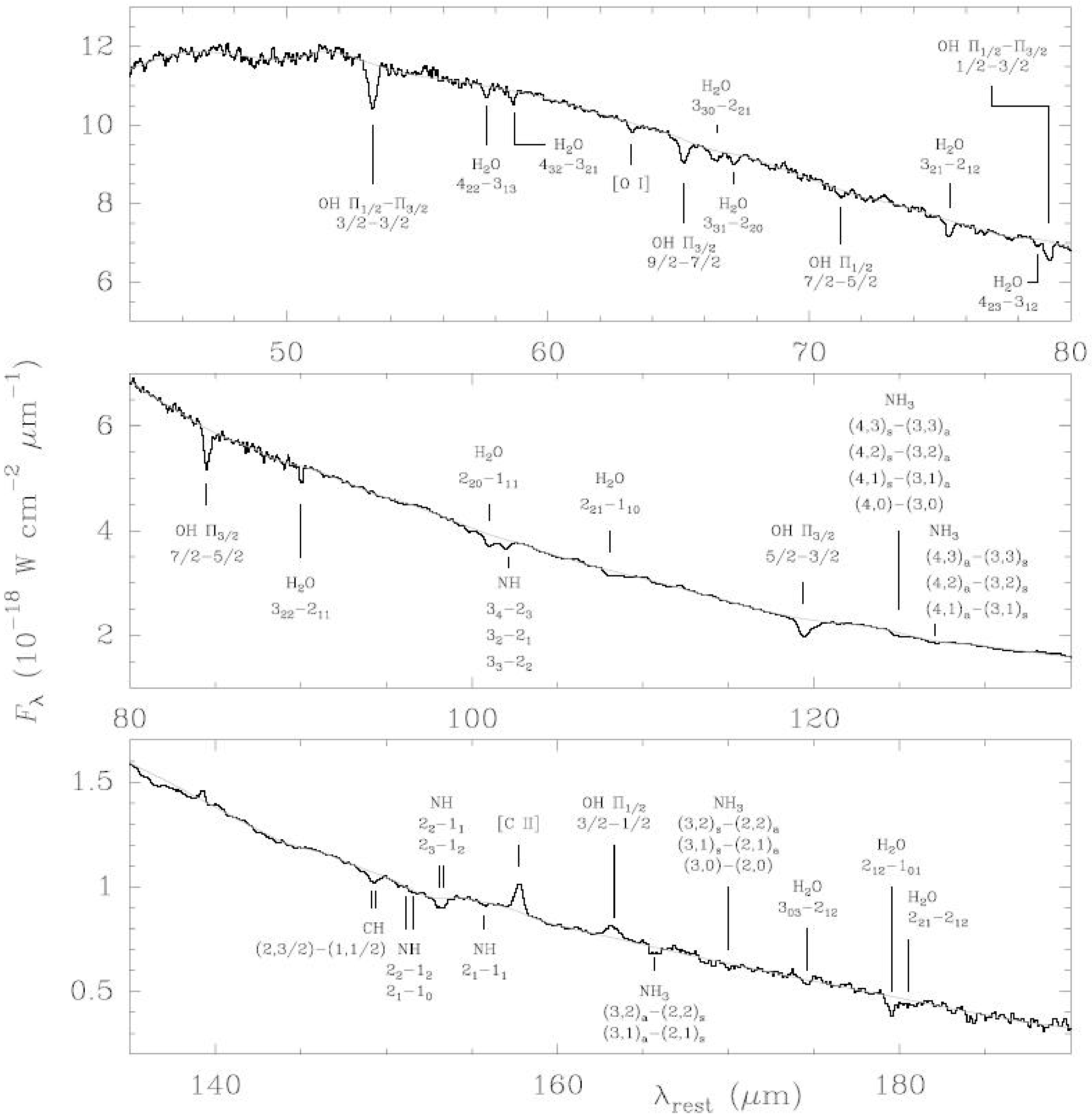


Theme: The Molecular Universe
-- High-Resolution Spectroscopy

- Heterodyne spectroscopy allows for detailed studies of:
  - Kinematics, multi-component line structure
  - Chemistry, composition
  - Physical conditions in different regions and phases of the ISM and CSEs
  - Modeling of chemistry, including metallicity estimates in neutral medium
- Only very low resolution spectra (SED) available with Spitzer over the important range of 50 - 100 microns
- Herschel high resolution studies will address both molecular and fine-structure lines unavailable to Spitzer

Arp 220 Detailed Spectra at R~ 300 (ISO)

Gonzalez-Alfonso et al 2004



Examples: Arp 220 and Sgr B2 Detailed Spectra

Gonzalez-Alfonso et al 2004

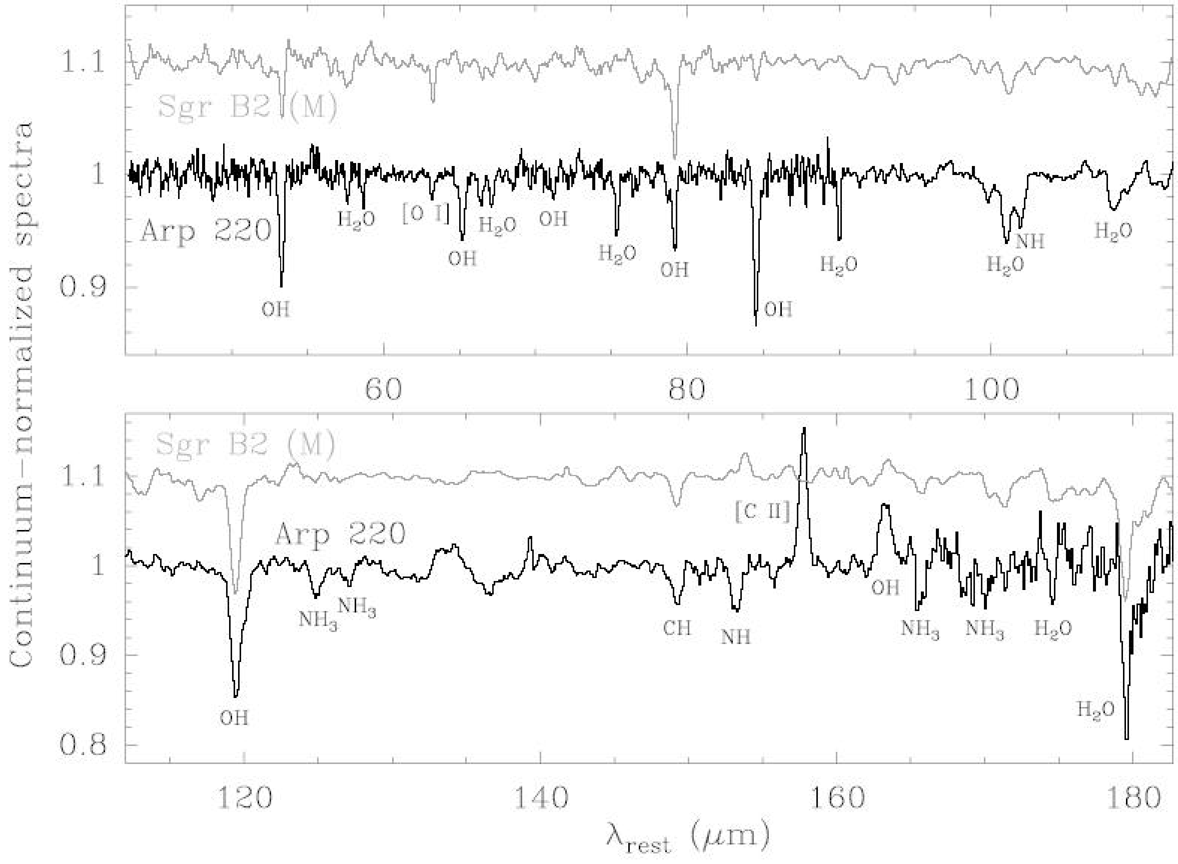


Fig. 6.— Continuum-normalized spectra of Sgr B2 (M) and Arp 220. The main carriers of some line features are indicated.

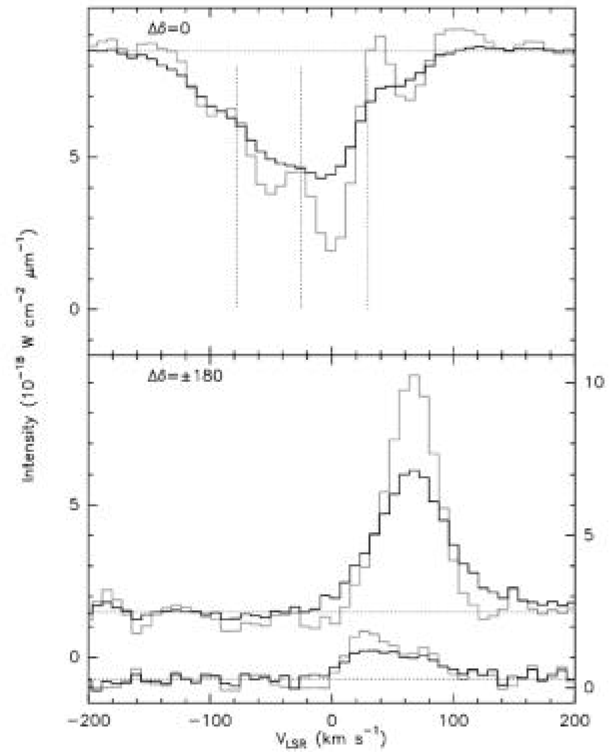


FIG. 2.—O I (63 μm) Fabry-Perot spectra toward Sgr B2(M) (*upper panel*), 180″ north, and 180″ south (*lower panel, upper and lower curves, respectively*). Black and gray lines correspond to the raw and MEM-deconvolved spectra, respectively. The lower panel vertical axes on the left and right correspond to the 180″ north and 180″ south spectra, respectively. The intensity scale is in the LWS Fabry-Perot units as given by the LWS analysis package (ISAP).

Prospects Summary - Herschel

- Spitzer will complete the picture with mid-IR Fine-Structure lines & H_2 lines
  - Most important are Si II, Fe II, H_2
- Herschel will provide high-resolution maps of nearby galaxies, PNe, and the local ISM in the FIR Fine-Structure lines
  - PDR structure and evolution
- Herschel will detect lines at 0.5% of 10^{12} L(sun) galaxies at z~1, requiring ~3 10^{-18} W/m^2
- Herschel will decipher ISM chemistry with heterodyne precision

- All of that will connect galactic and extragalactic ISM diagnostics, relate them to metallicity, age, evolutionary state, ISRF, solar system evolution, and numerous other topics limited only by the imagination of the investigators....