The Scientific Legacy of IRAS
A Personal Perspective

Tom Soifer

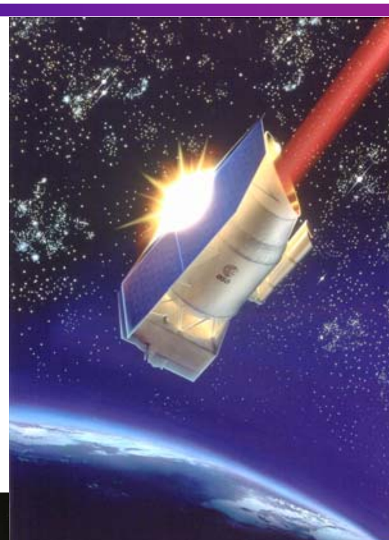
Caltech & Spitzer
Science Center

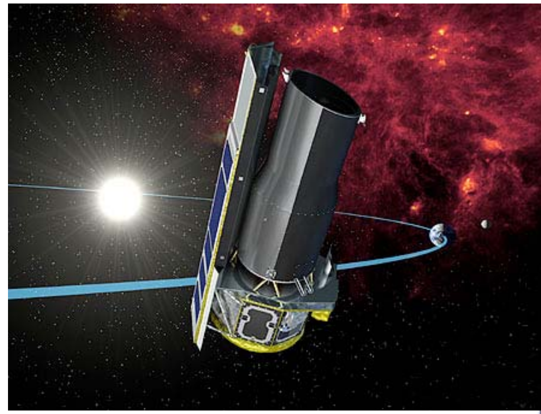
Before and After

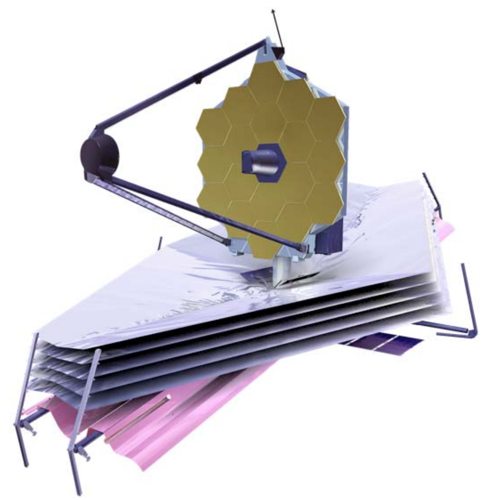
- Before –
  - *Ground – Surveys, IR Optimized Telescopes, Simple Instruments*
  - *Airborne – Lear Jet, KAO*
  - *Balloons – Surveys, Backgrounds*
  - *Sounding Rockets – Backgrounds, Surveys*
- After
  - *COBE, MSX, IRTS, ISO, SPITZER, AKARI, HERSCHEL, PLANCK, WISE, JWST*
    - Total cost - probably approaching $10B

AFTER WOULD NOT HAVE HAPPENED WITHOUT THE RESOUNDING SUCCESS OF IRAS, BOTH TECHNICALLY & SCIENTIFICALLY

The Legacy of IRAS



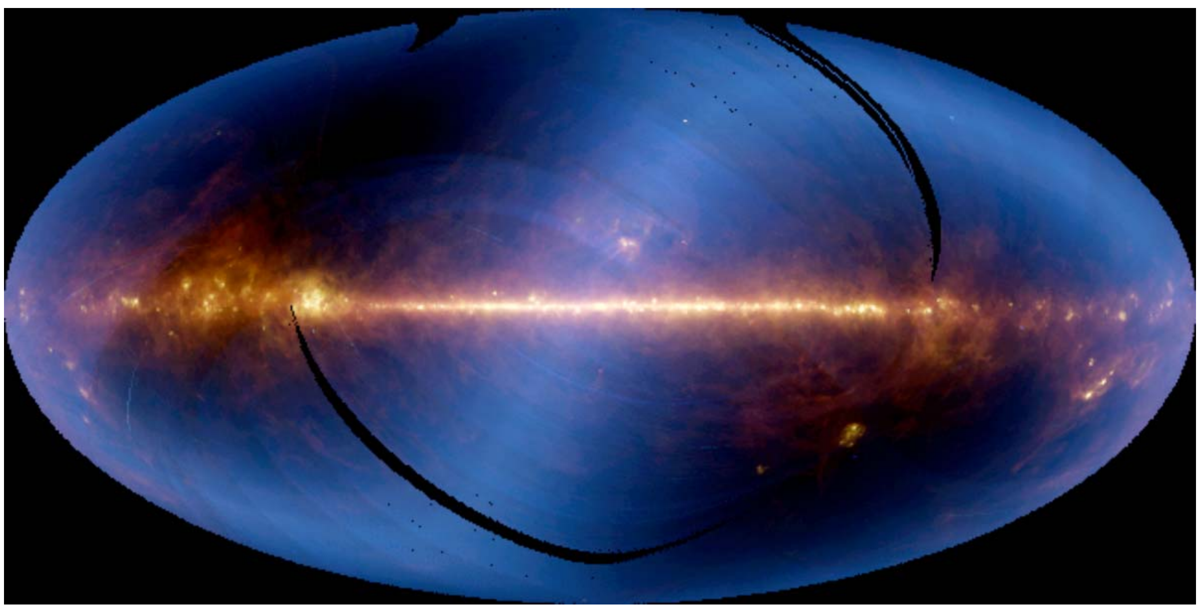




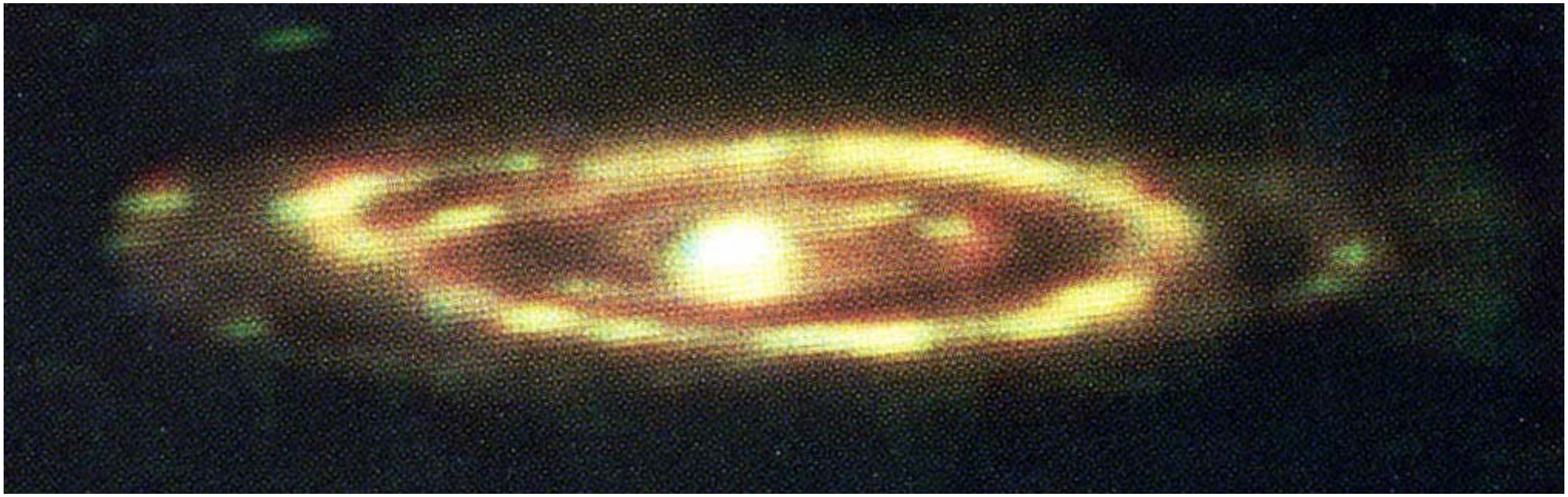
What was special about IRAS?

Wavelengths
Sensitivity
All Sky
Unbiased

Size, Quality of Catalogs, images
Rapid public release
Improved quality with reprocessing
Strong support for community usage

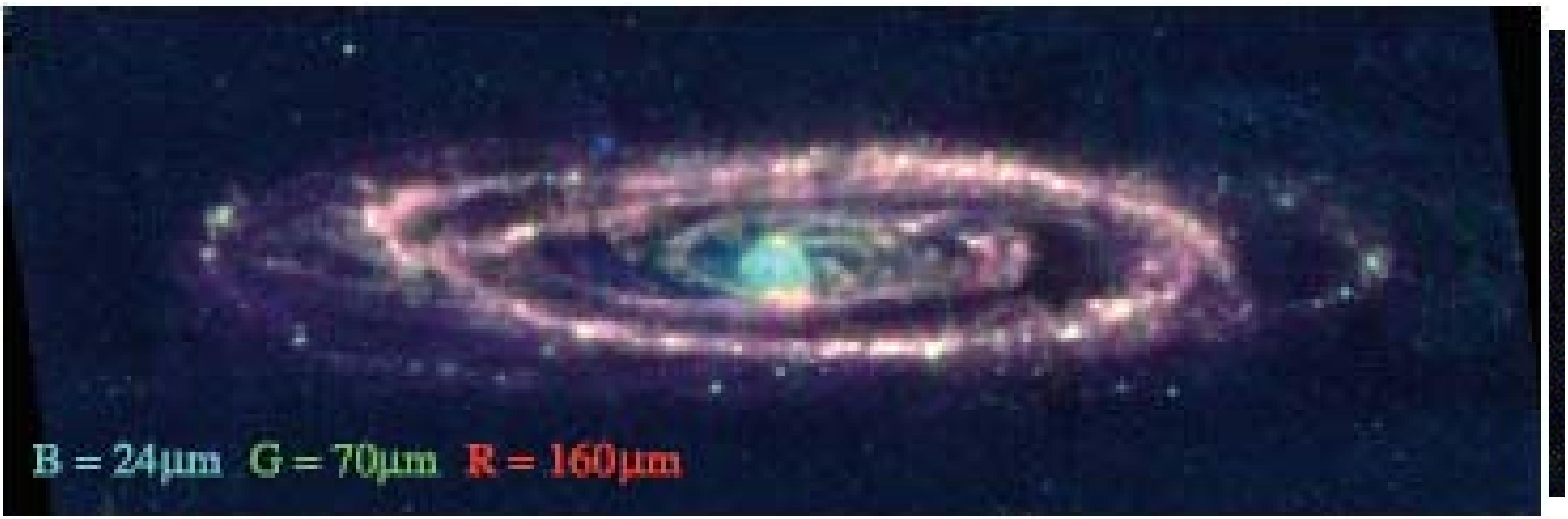


M31 in the FIR



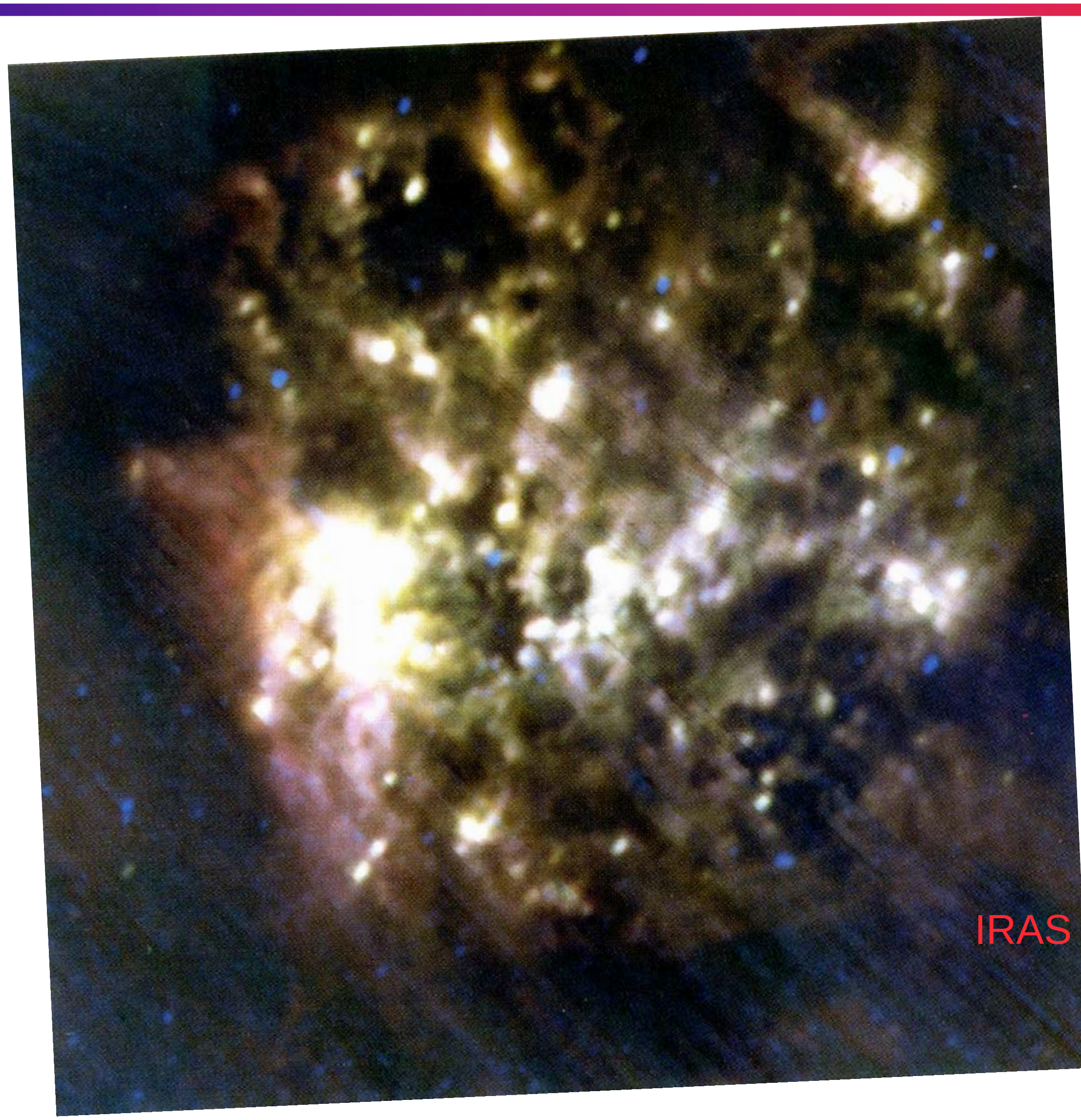
IRAS Image – Rice et al. 1988

M31 in the FIR



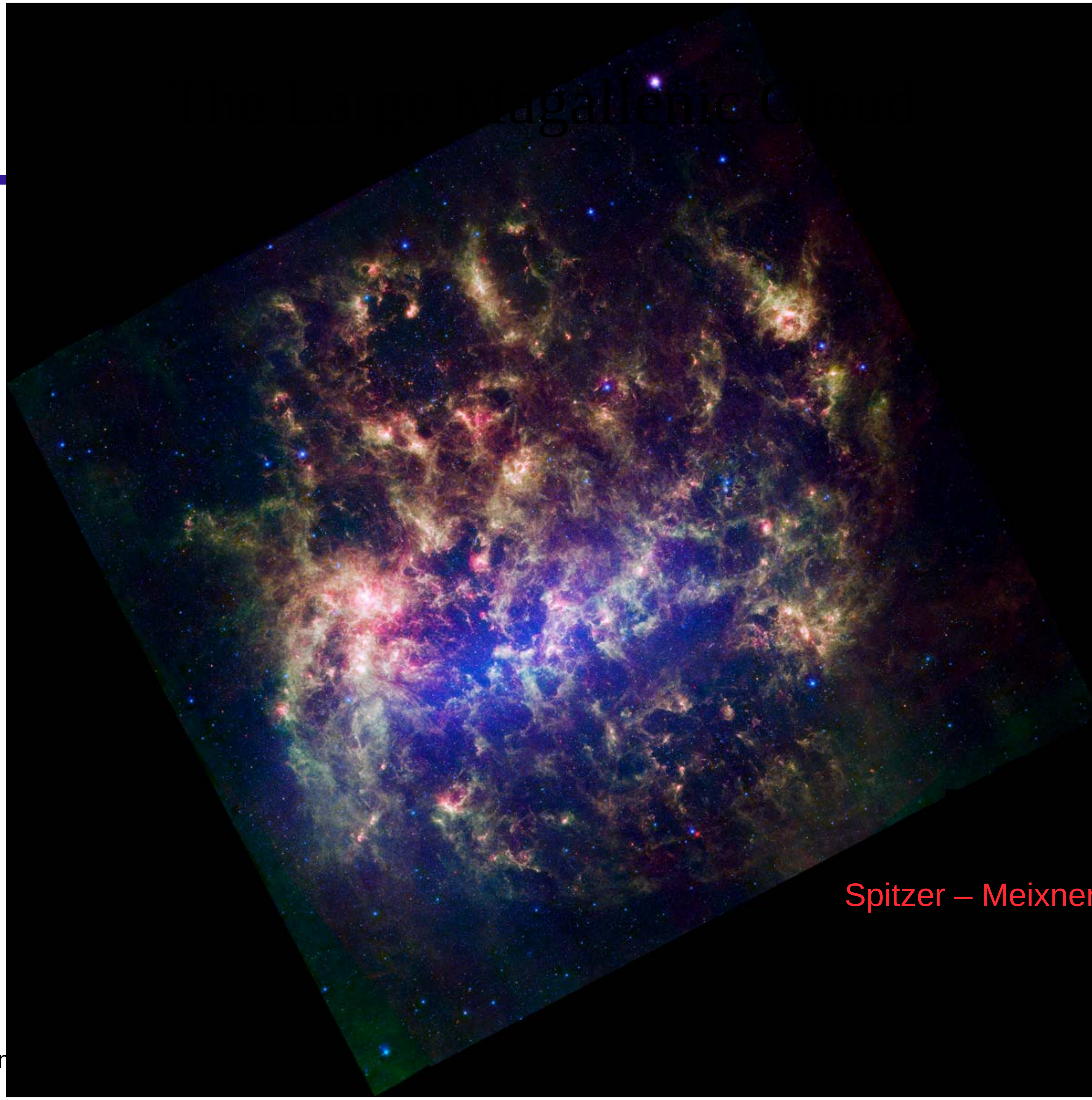
Spitzer Image – Gordon et al. 2006

The Large Magallenic Cloud



IRAS – Rice et al 1988

The Large Magallenic Cl



Spitzer – Meixner, et al. 2006

The Ubiquity of Cirrus (PAHs) in the ISM in our galaxy and normal Galaxies

Boulanger, Baud & van Albada, 1985

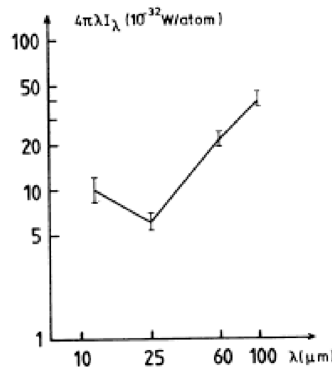
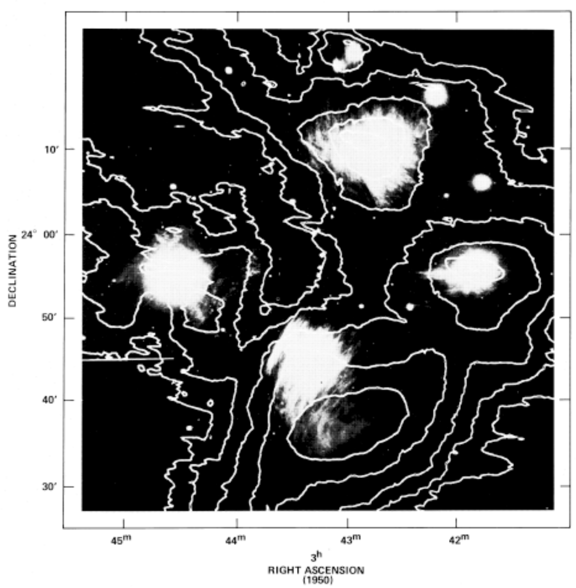
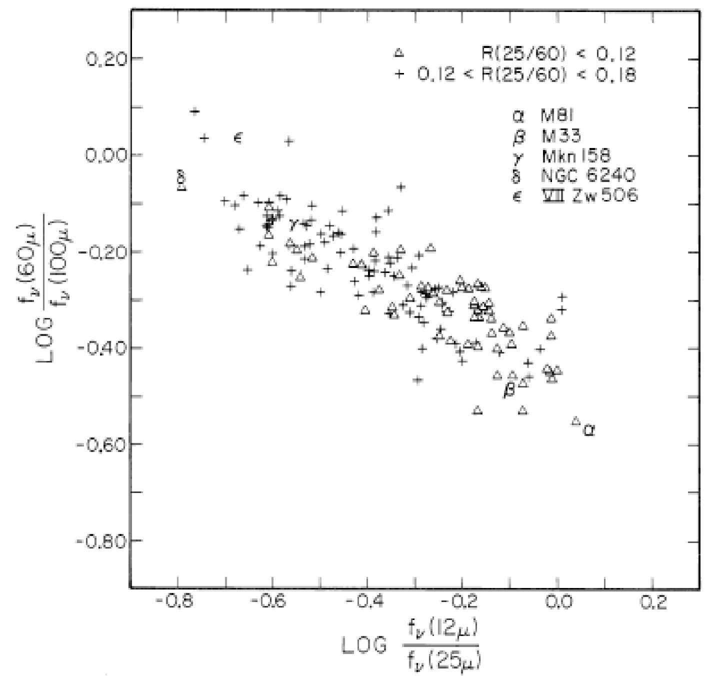


Figure 4: Infrared spectrum of the cirrus marked by a cross in figure 2. Its emission has been normalized by dividing its infrared brightness by its HI column density.



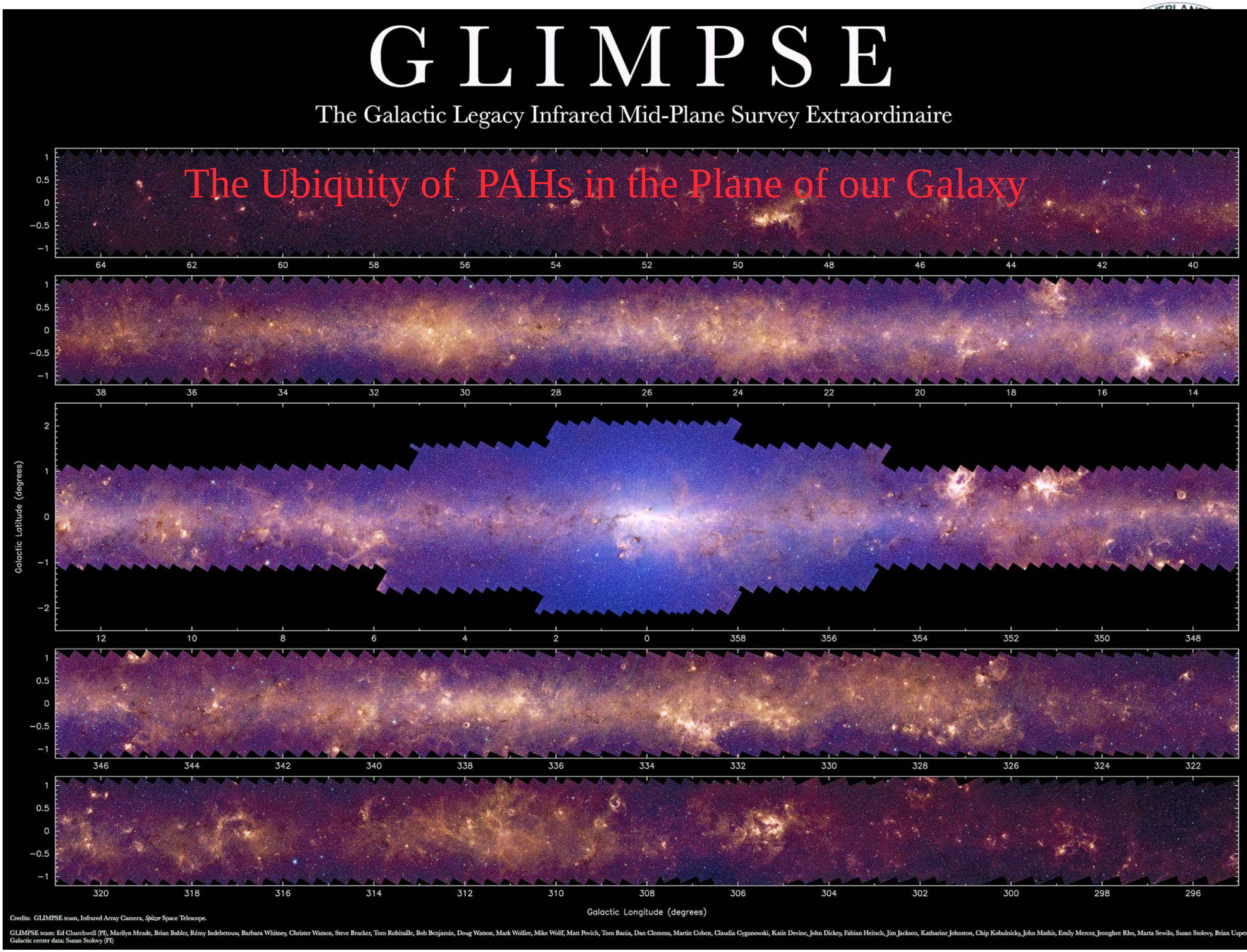
Castelaz, Sellgren & Werner 1987



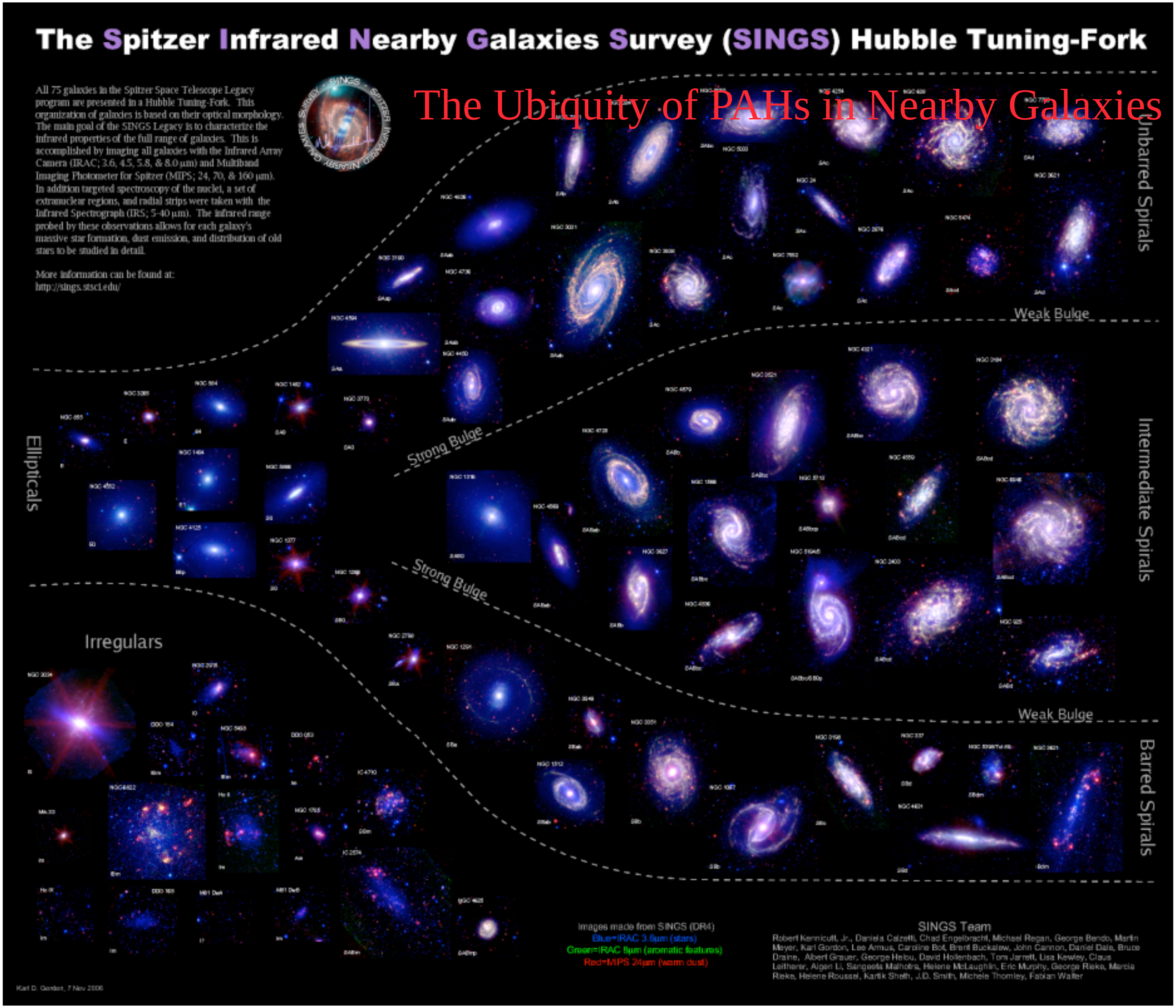
Helou 1986

IRAS Science Legacy

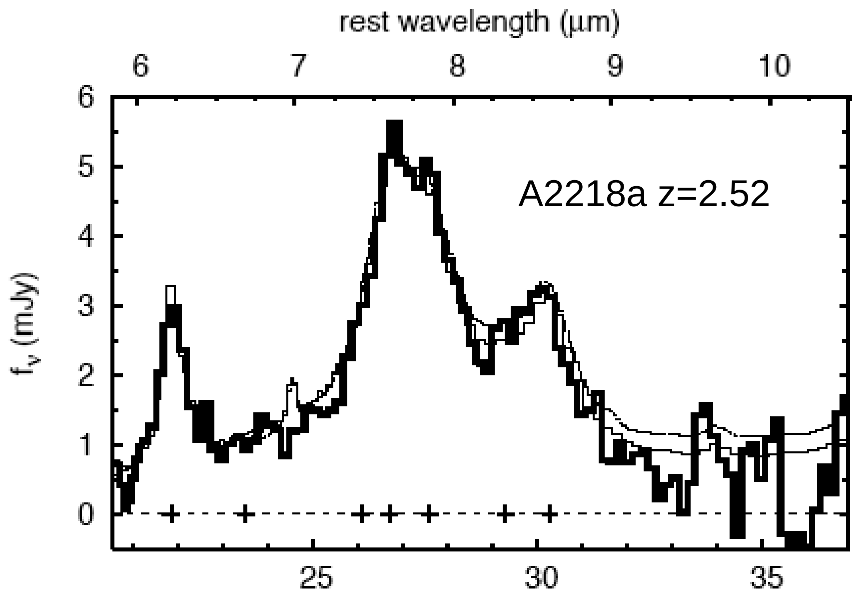
The Ubiquity of PAHs in the Plane of our Galaxy



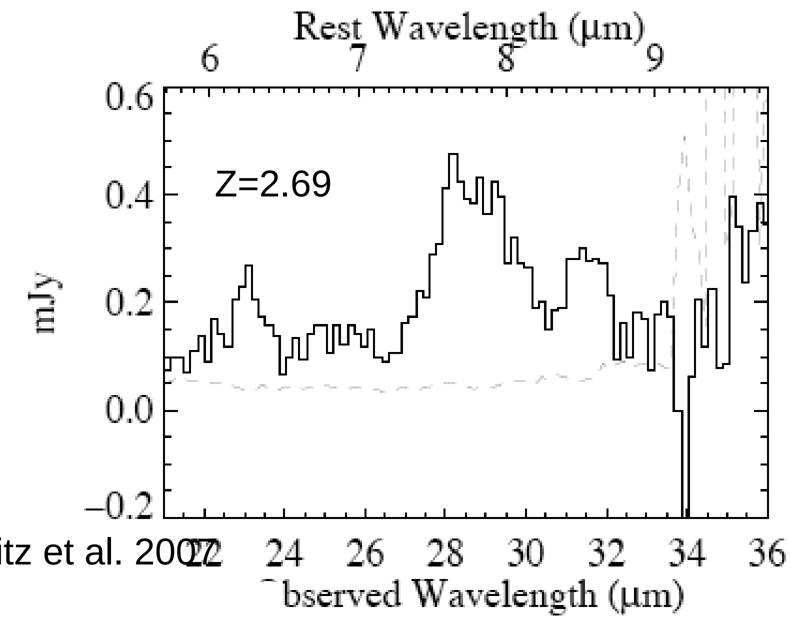
The Ubiquity of PAHs in Nearby Galaxies



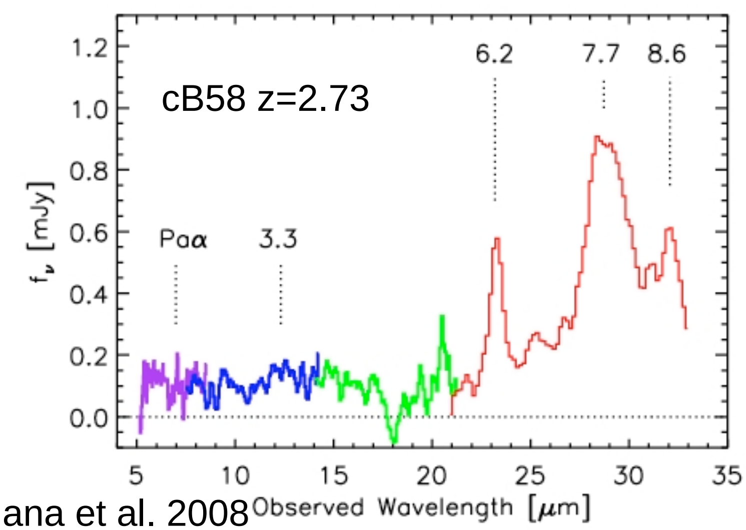
The Ubiquity of PAHs in the Universe Beyond z~2.5



Rigby et al. 2008

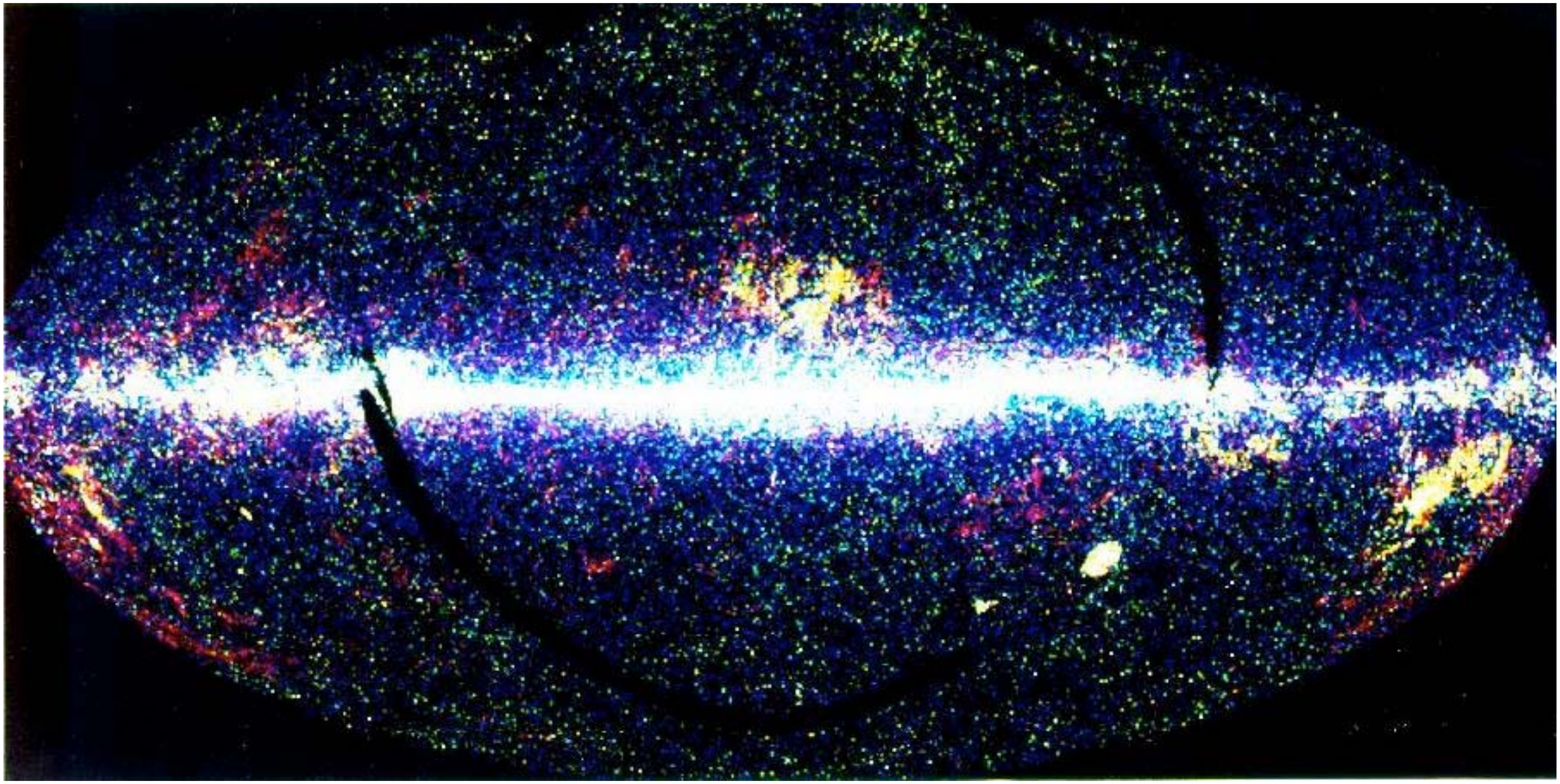


Teplitz et al. 2007

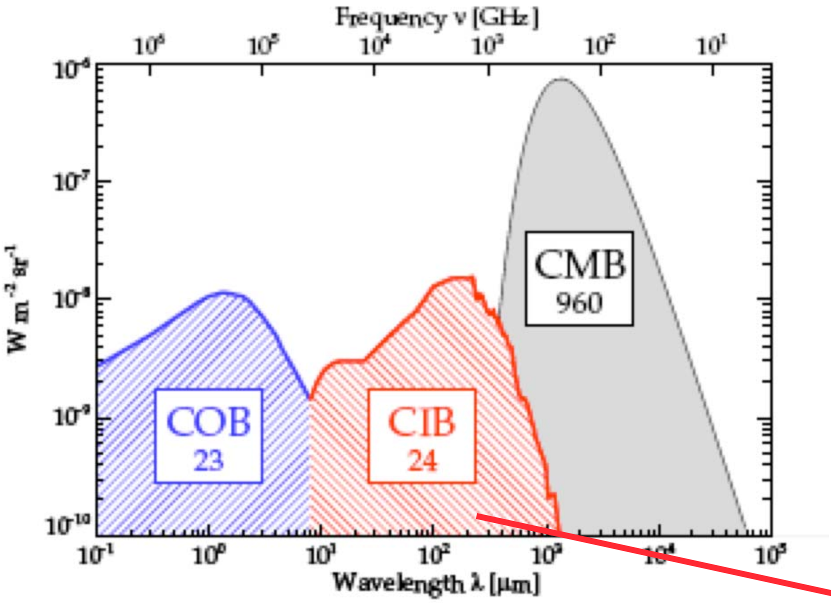


Siana et al. 2008

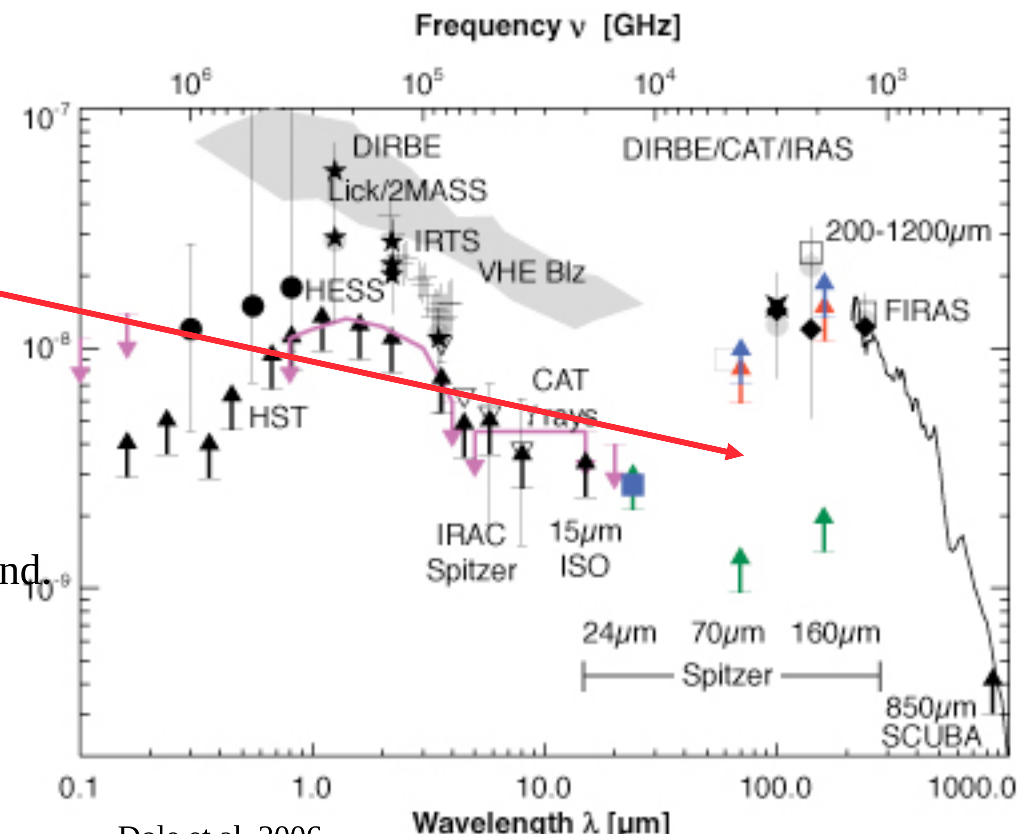
The IRAS Point Source Catalog



The Far Infrared Background is Resolved



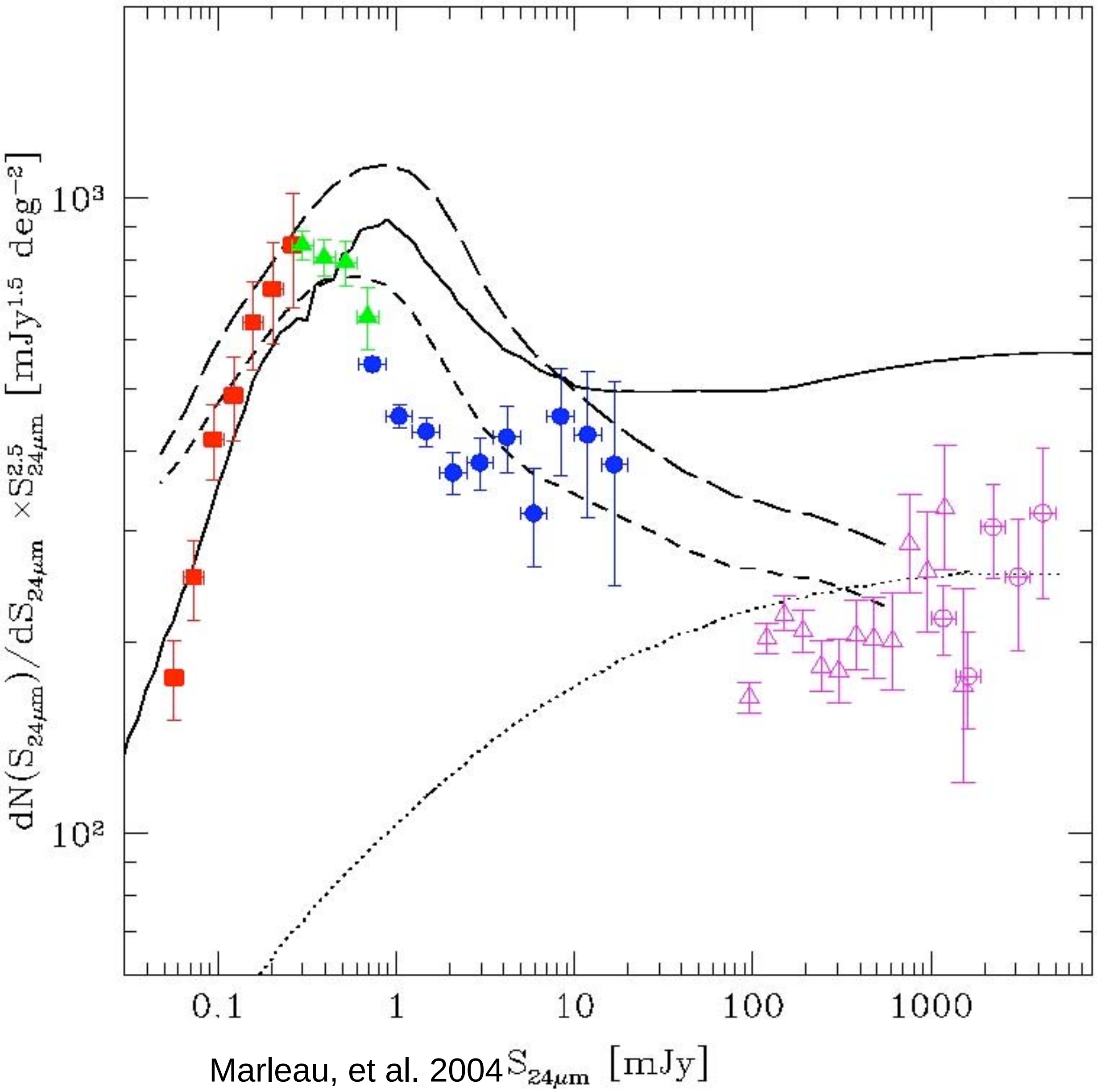
The Cosmic Infrared & Optical Backgrounds record the history of star formation and black hole growth in the Universe.



IRAS found that the FIR emission from nearby galaxies is ~25% of total luminosity. The CIB measured with COBE required strong evolution in the IR galaxy population. ISO and Spitzer have seen this evolution and resolved the FIR background.

Dole et al. 2006

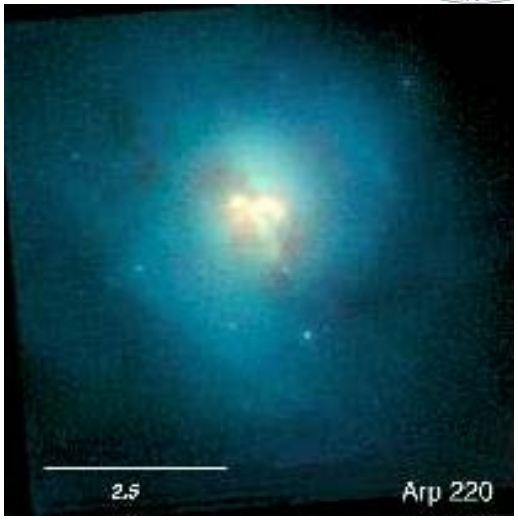
IRAS Discovered & ISO, Spitzer Confirmed That IR Luminous Galaxies Evolve Strongly



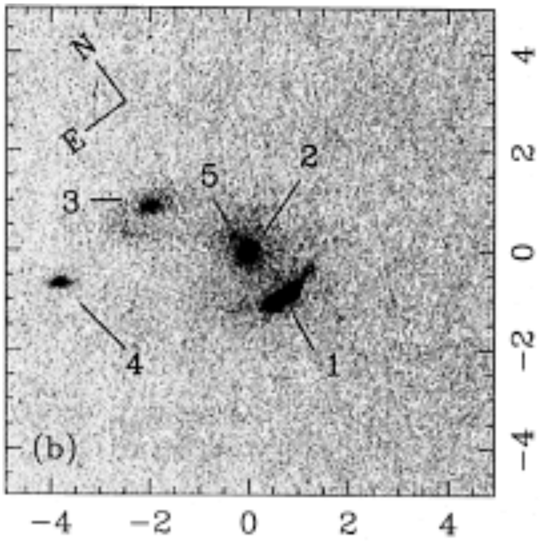
Marleau, et al. 2004

ULIRGs and HyperLIRGs

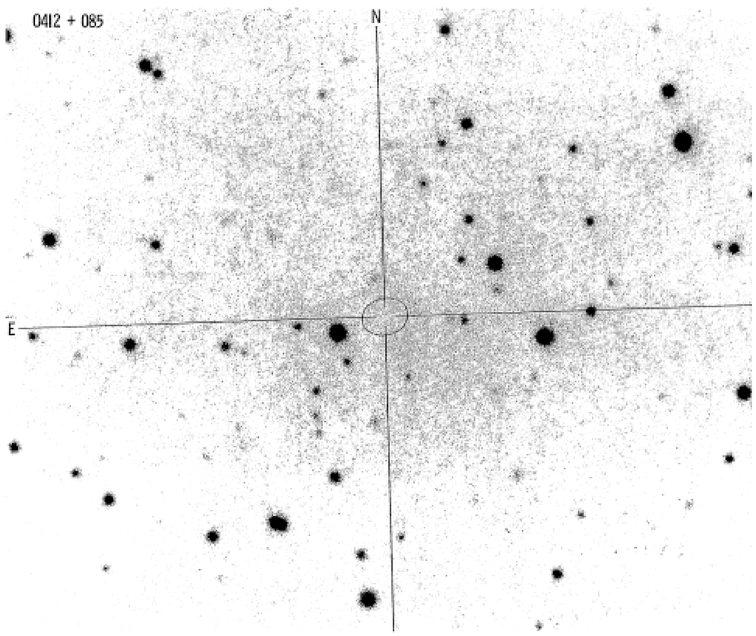
Arp 220 – The Prototype Ultra-luminous Infrared Galaxy (ULIRG)

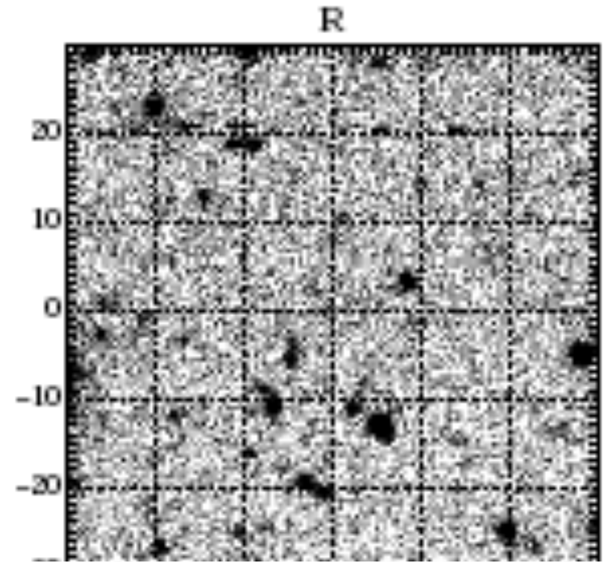


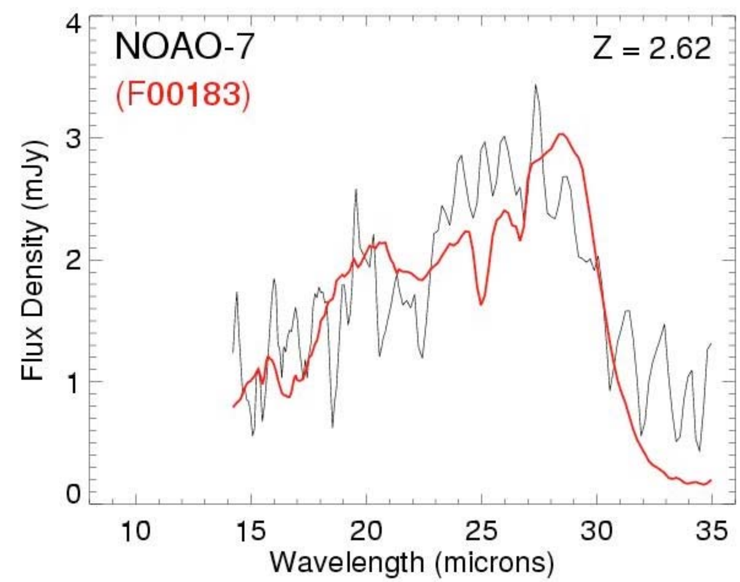
FSC10214+4724 –
The most distant IR Luminous Source seen in IRAS



IR Loud, Optically Invisible Sources



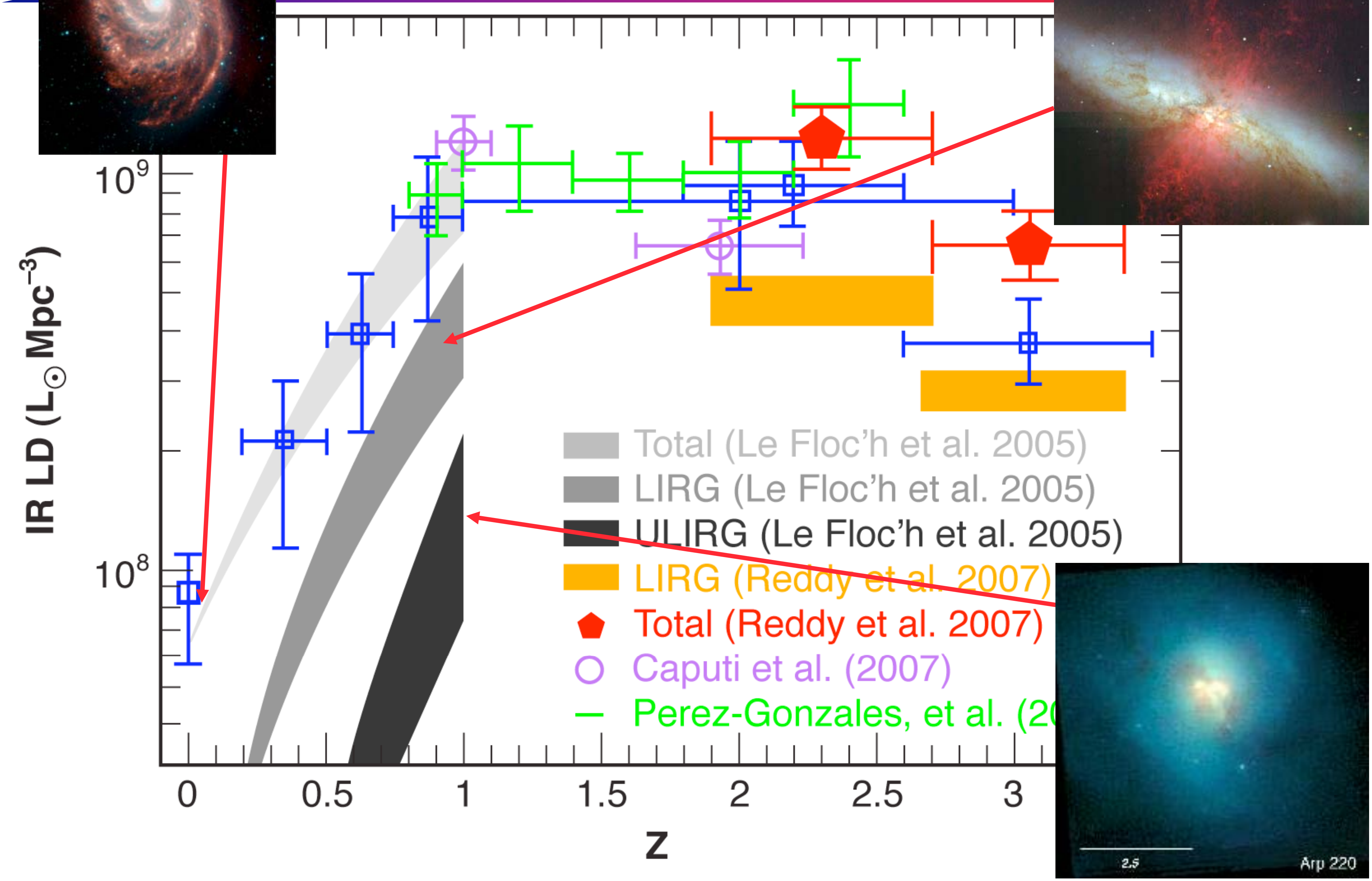




Houck et al 1984, ~0.5 Jy @ 60μm,
>20mag@ R

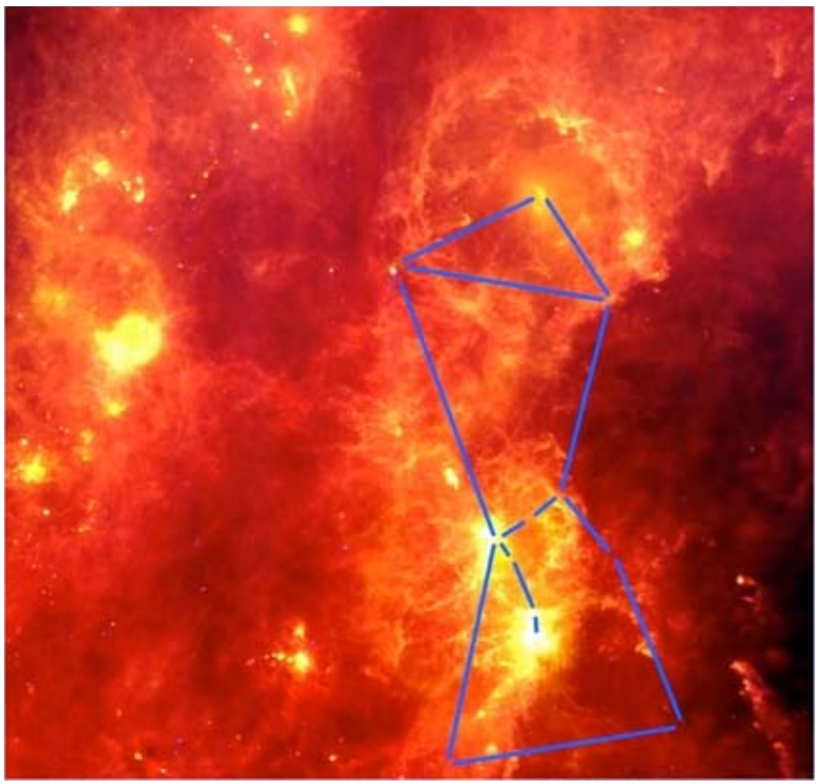
Houck et al 2005, ~1 mJy@24μm,
>25mag@R

What Kinds of Galaxies Comprise the Cosmic Infrared Background

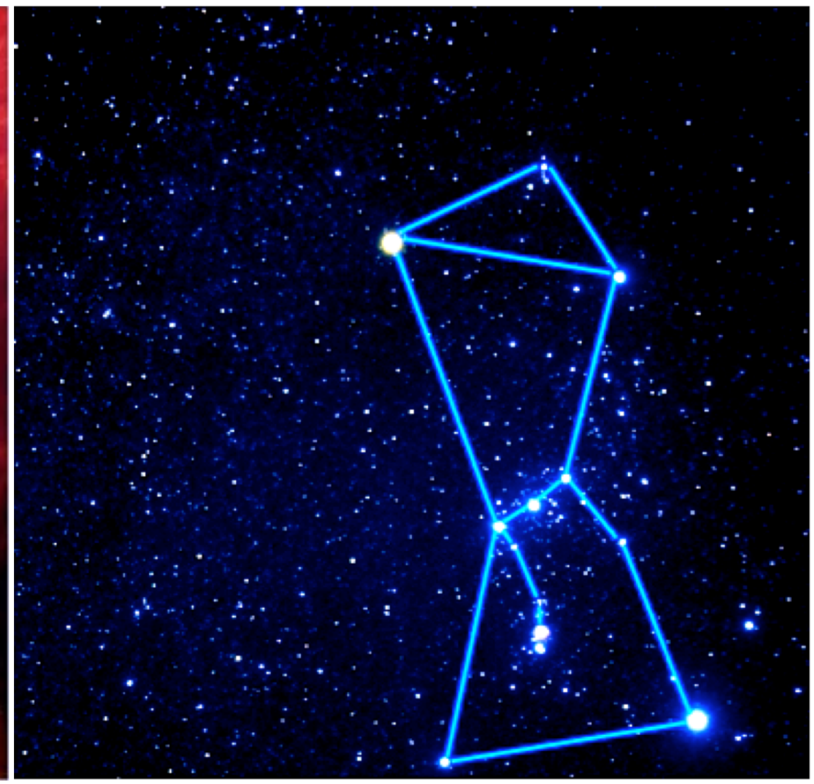


Views of Orion

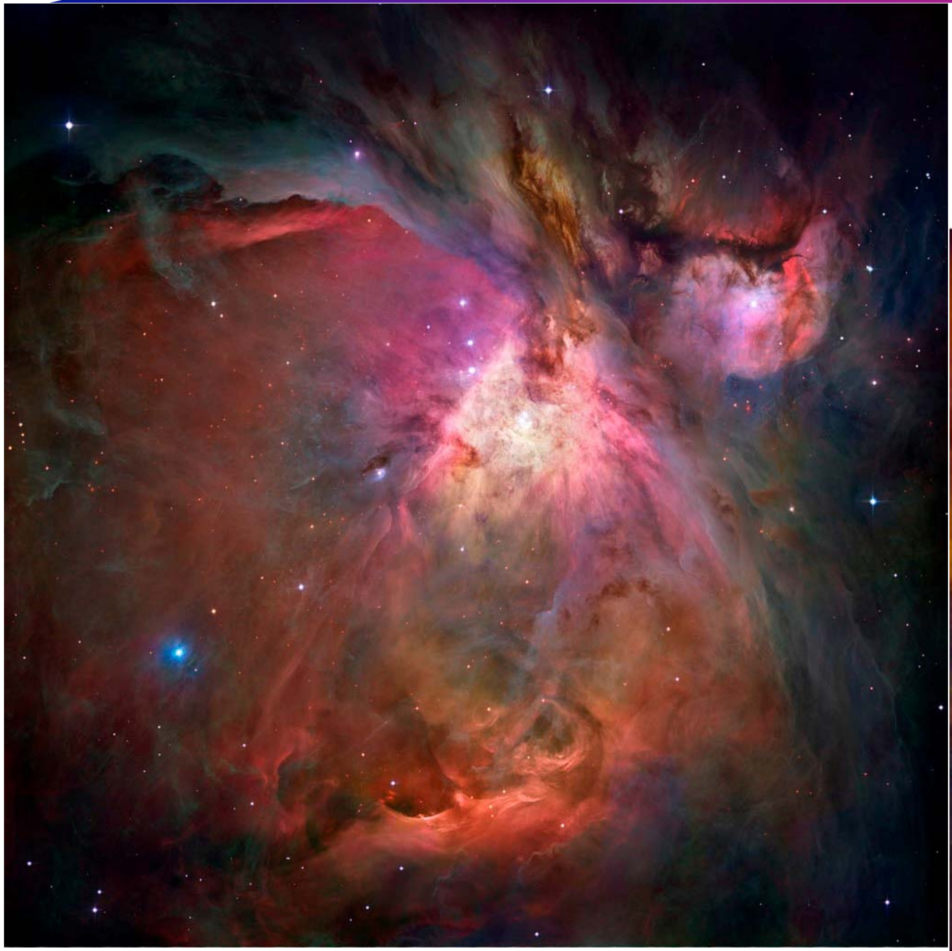
Infrared (IRAS)



Visible Light (Akira Fujii)



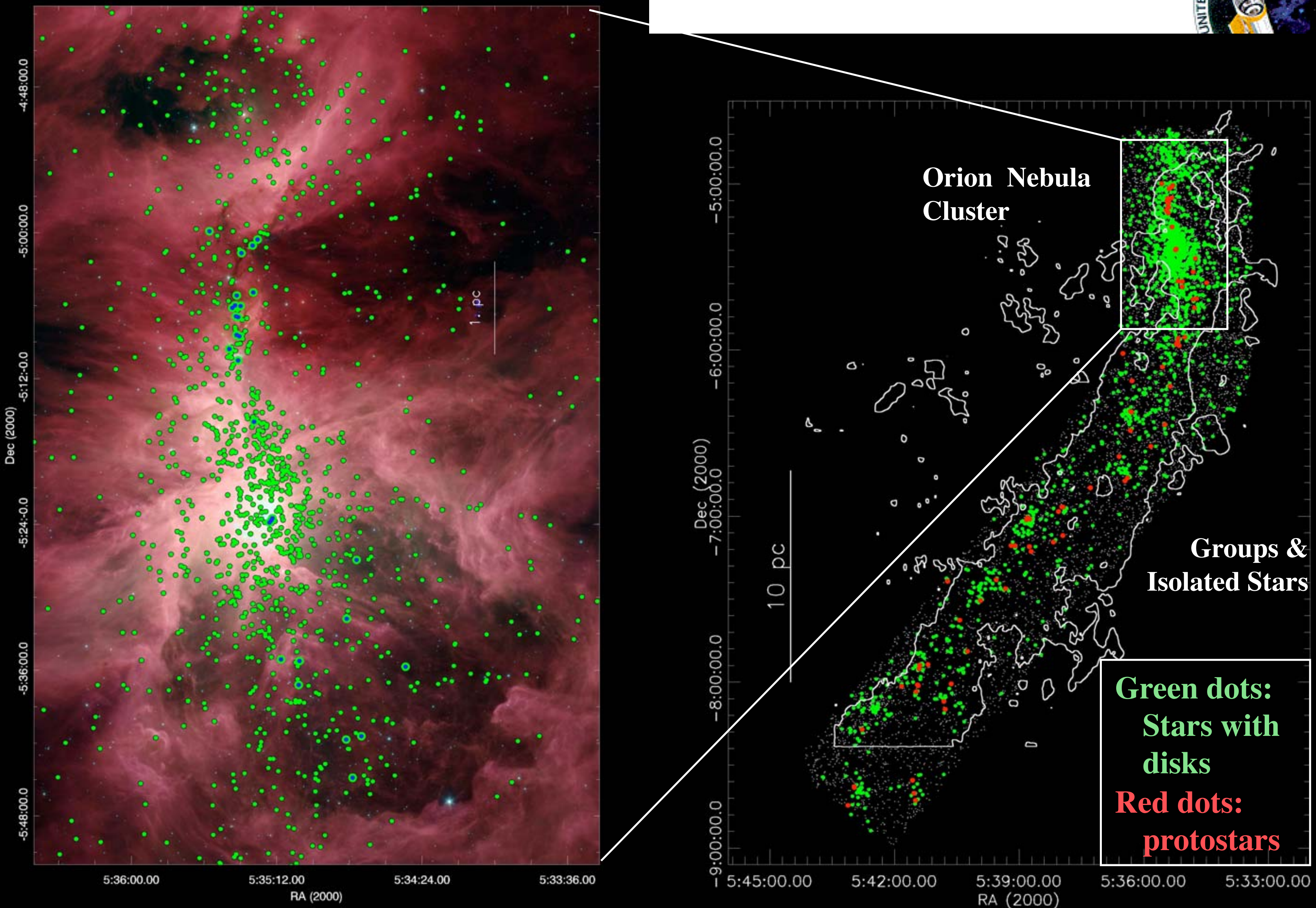
The Core of Orion – HST & Spitzer



VISIBLE LIGHT IMAGE

0.43-0.53µm
0.60-0.91µm
3.6µm 8.0µm

The Spitzer Survey of the Orion Nebula and Orion A Molecular Cloud



Megeath et al. (2005)

Contours: Bell Labs CO survey of Orion A

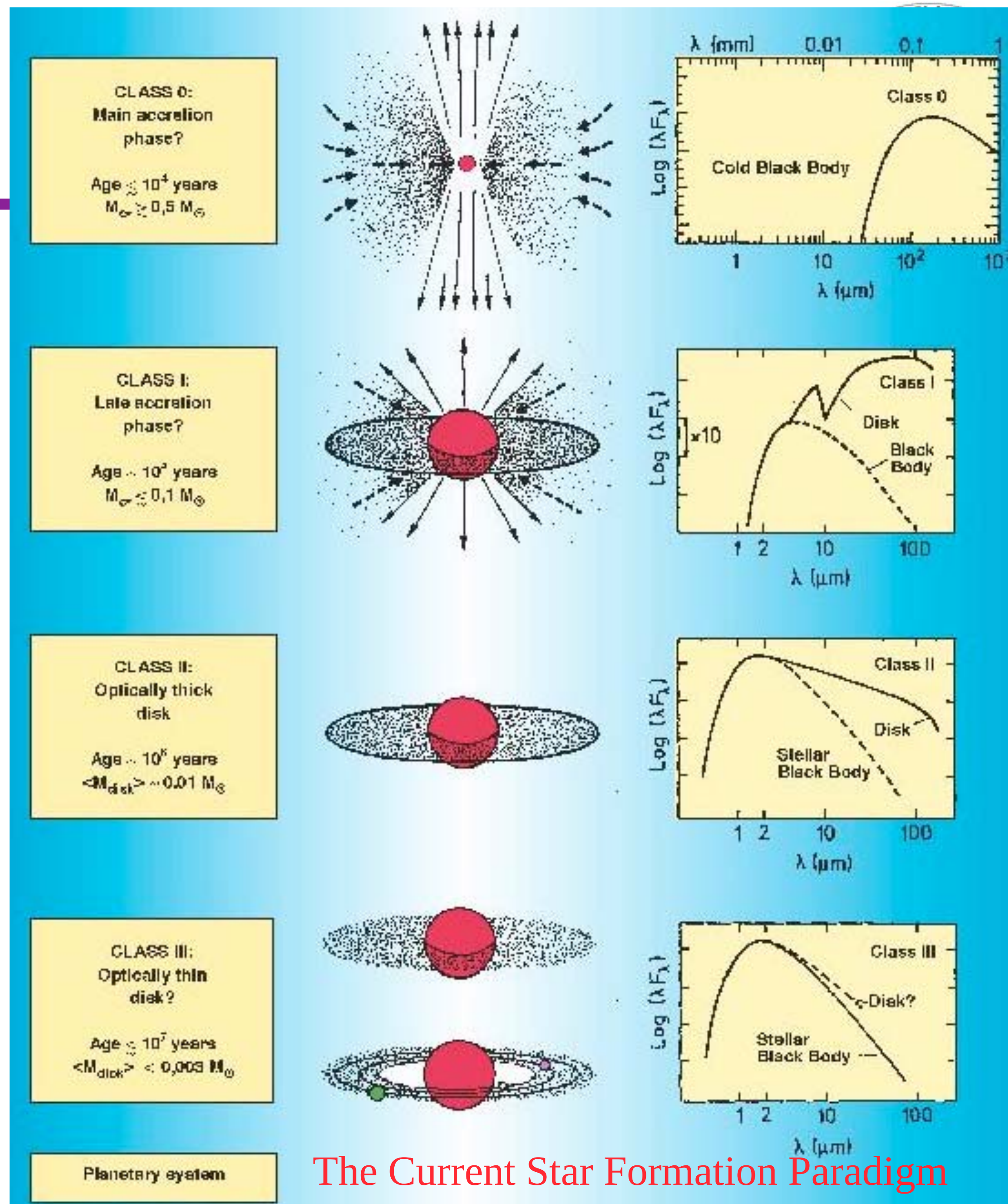
Class 0
Main accretion phase?
M_{env}>~0.5 Msun
<~10^4 years

Class I
Late accretion phase?
M_{env}<~0.1 Msun
~10^5 years

Class II
Optically thick disk
Avg M_{disk}~0.01 Msun
~10^6 years

Class III
Optically thin disk
Avg M_{disk}<~0.003 Msun
~10^7 years

IRAS Science Legacy



The Current Star Formation Paradigm
Based on IRAS observations

The Vega Phenomenon

THE ASTROPHYSICAL JOURNAL, **278**:L23–L27, 1984 March 1
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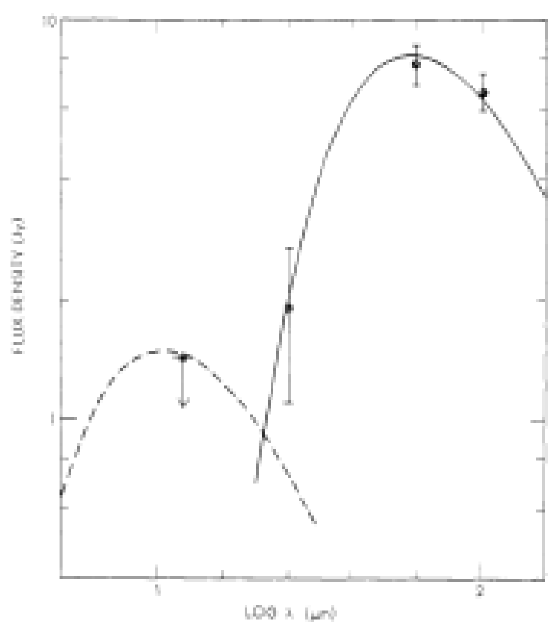
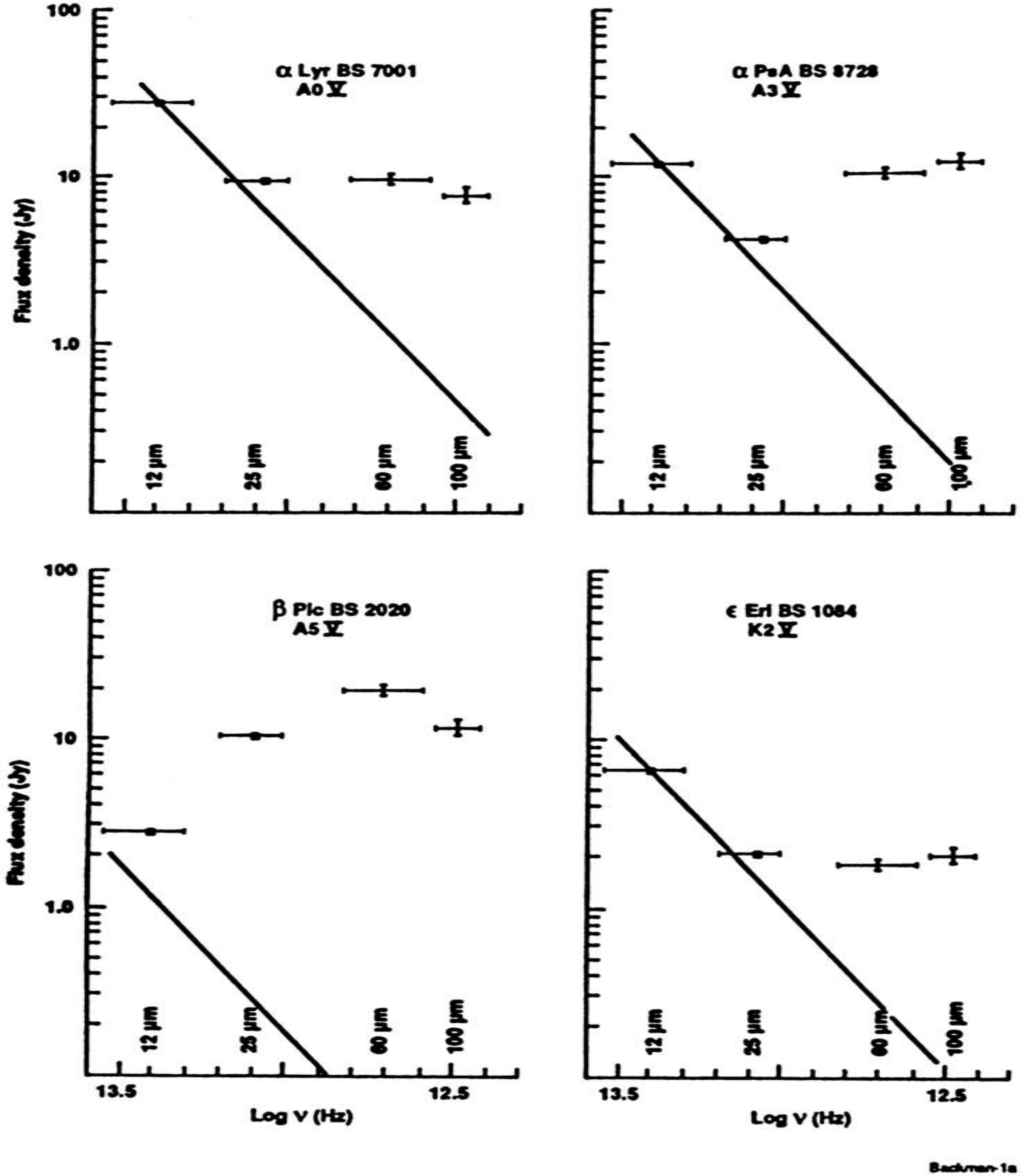
DISCOVERY OF A SHELL AROUND ALPHA LYRAE[1]

H. H. AUMANN, F. C. GILLETT, C. A. BEICHMAN, T. DE JONG, J. R. HOUCK, F. J. LOW,
G. NEUGEBAUER, R. G. WALKER, AND P. R. WESSELIUS
Received 1983 September 22; accepted 1983 November 18

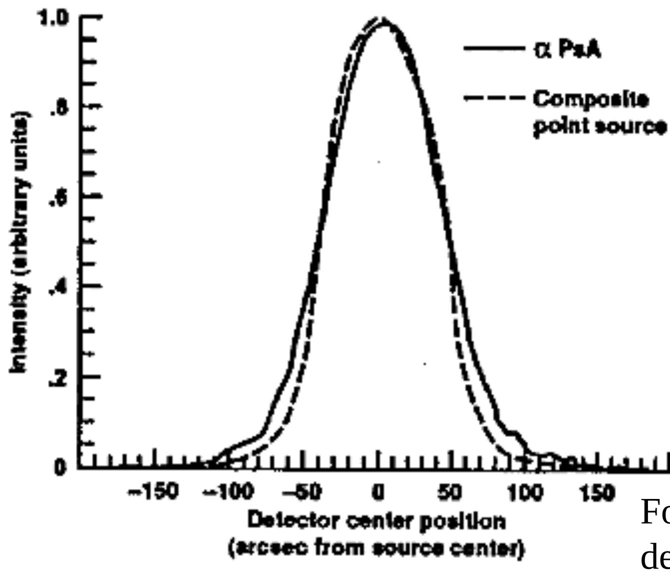




The Fabulous Four debris disk SEDs
Gillett 1984

Vega A0V
Fomalhaut A3V

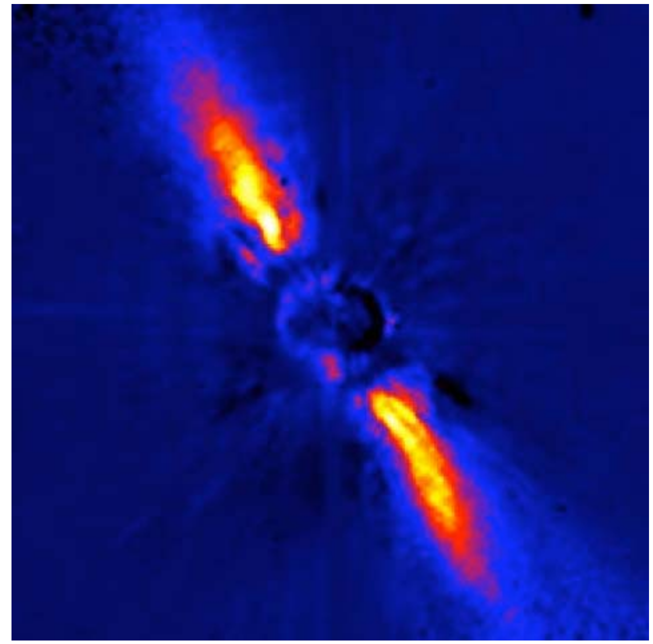
Beta Pictoris A5V
Epsilon Eridani K2V



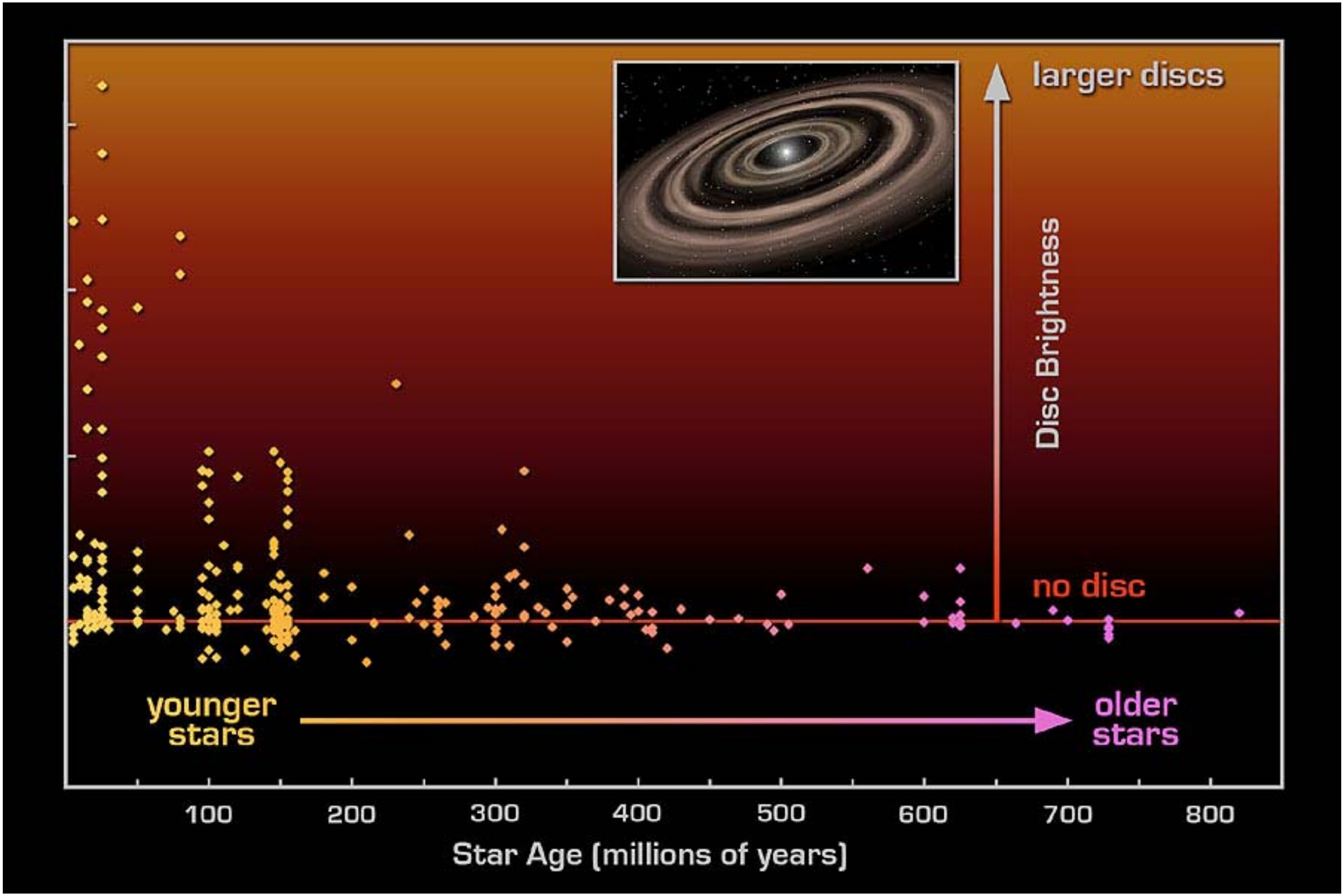
Fomalhaut debris disk scan profile, 60 microns

Backman & Paresce 1993

Figure 3.—Comparison of IRAS 60 μm scan profiles of α PsA, the most extended of the "Big 3," with a composite of several point sources. The scans were made at 1/2 the all-sky-survey scan rate with a sampling interval of 3.6 arcsec. Scan widths represent a combination of detector FOV, detector response time, telescope diffraction and intrinsic source width; the FWHM is equal to the 90 arcsec detector width parallel to the scan direction ("in-scan"). The profiles are normalized to 1 at their peaks, which makes the broader source appear narrower above the FWHM points. Irregularities in the α PsA profile wings indicate the noise level (data provided courtesy of F. Low, F. Gillett, G. Neugebauer, J. Good and H. Aumann).

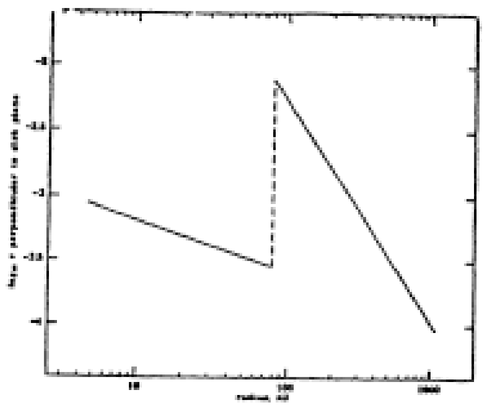


Β Pic in optical,
Smith & Terrile, 1984



Rieke et al. 2005

Understanding what disks are made of



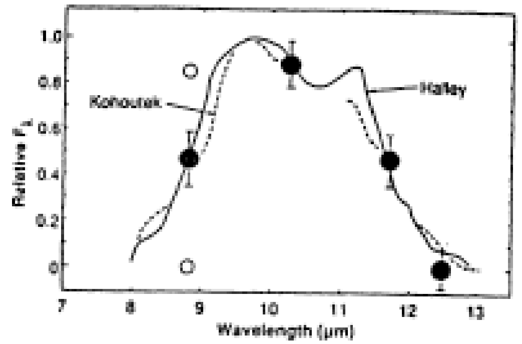
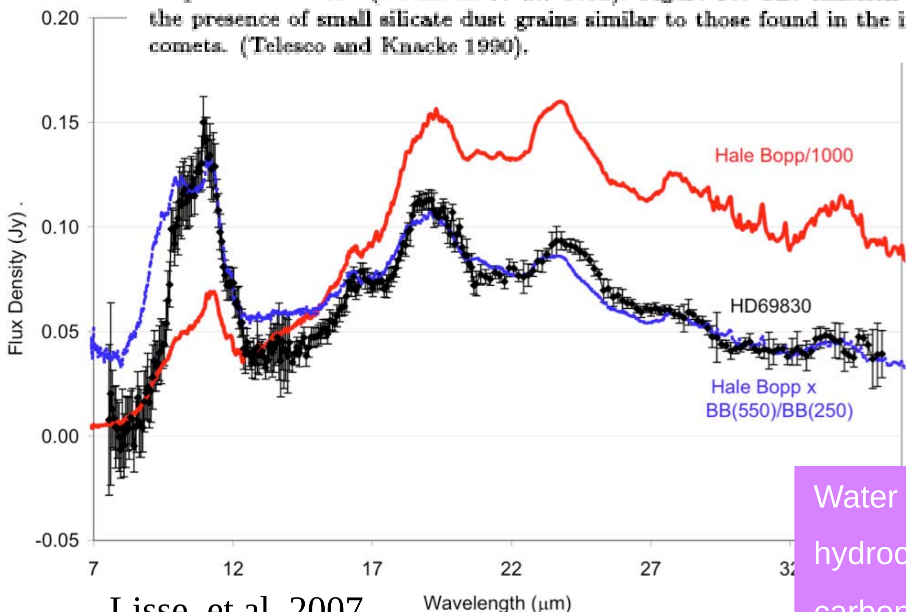
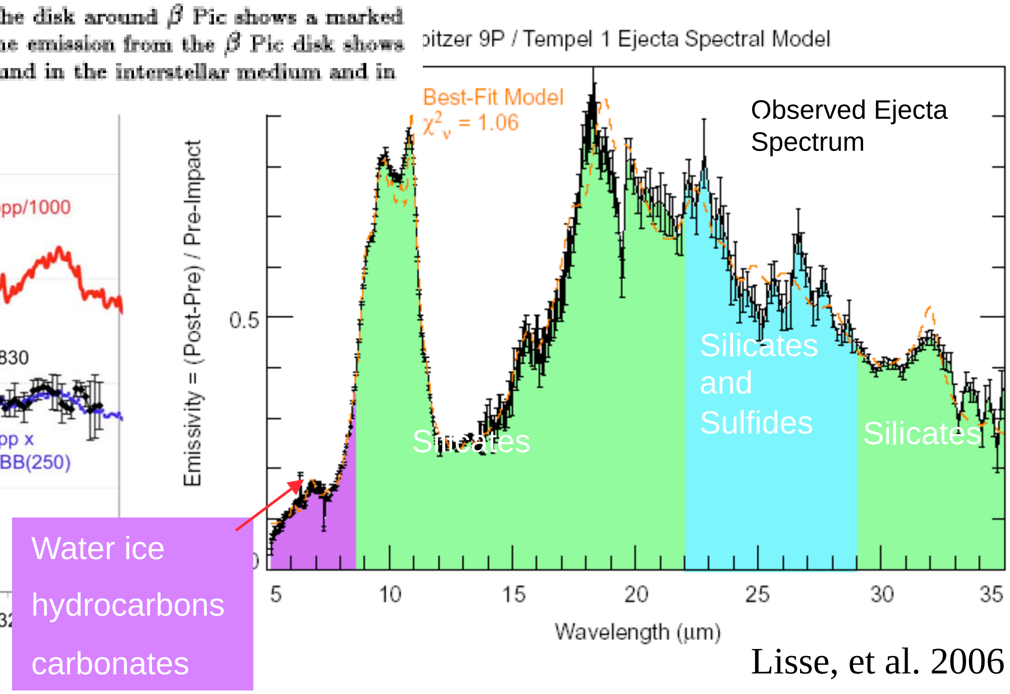


Figure 3a. The inferred density distribution of material in the disk around β Pic shows a marked drop within 100 AU (Backman *et al.* 1992). Figure 3b. The emission from the β Pic disk shows the presence of small silicate dust grains similar to those found in the interstellar medium and in comets. (Telesco and Knacke 1990).

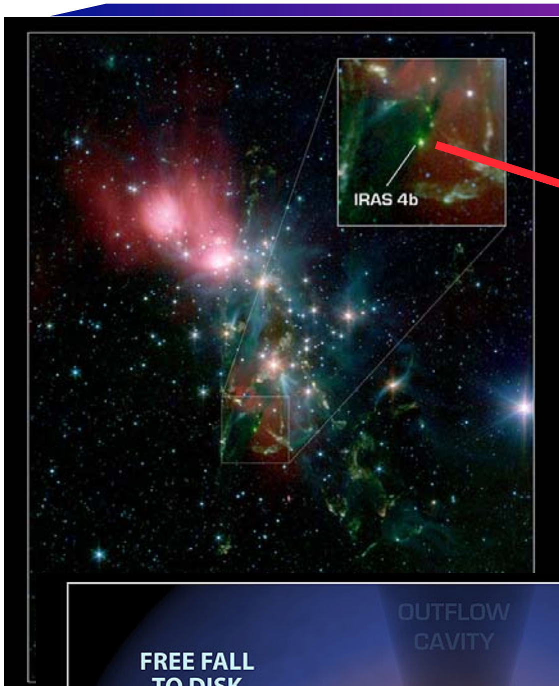


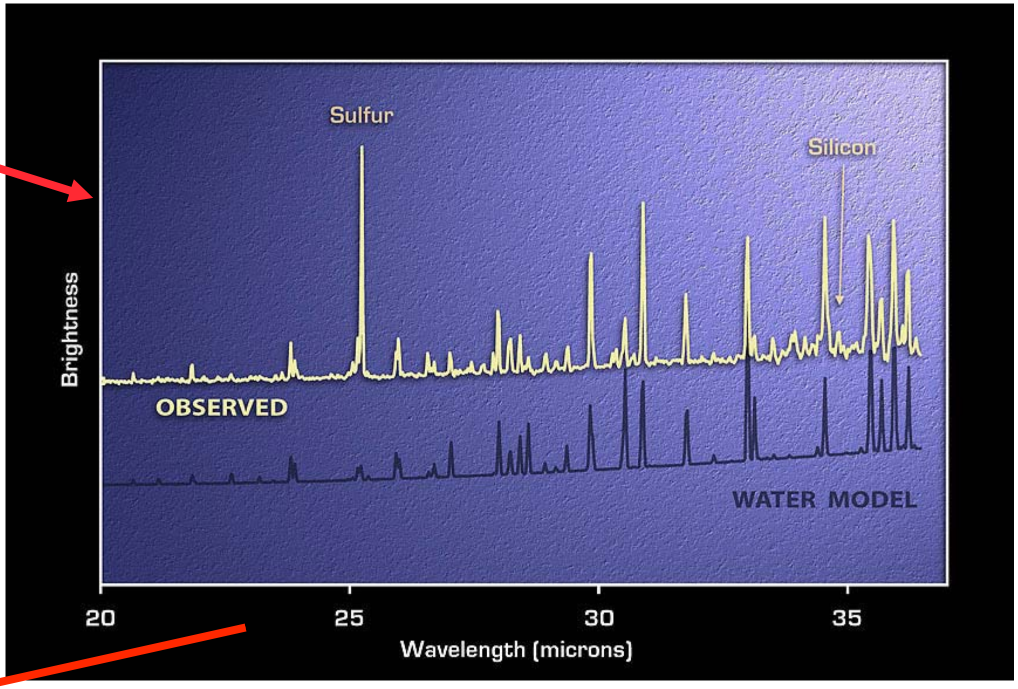
Lisse, et al. 2007

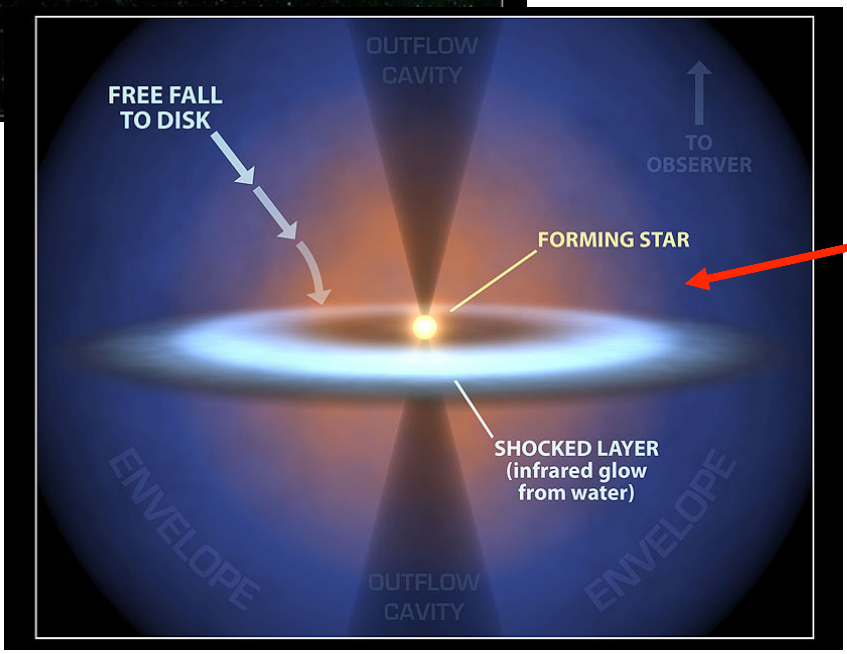


Lisse, et al. 2006

Oceans of Water in forming Planetary Systems

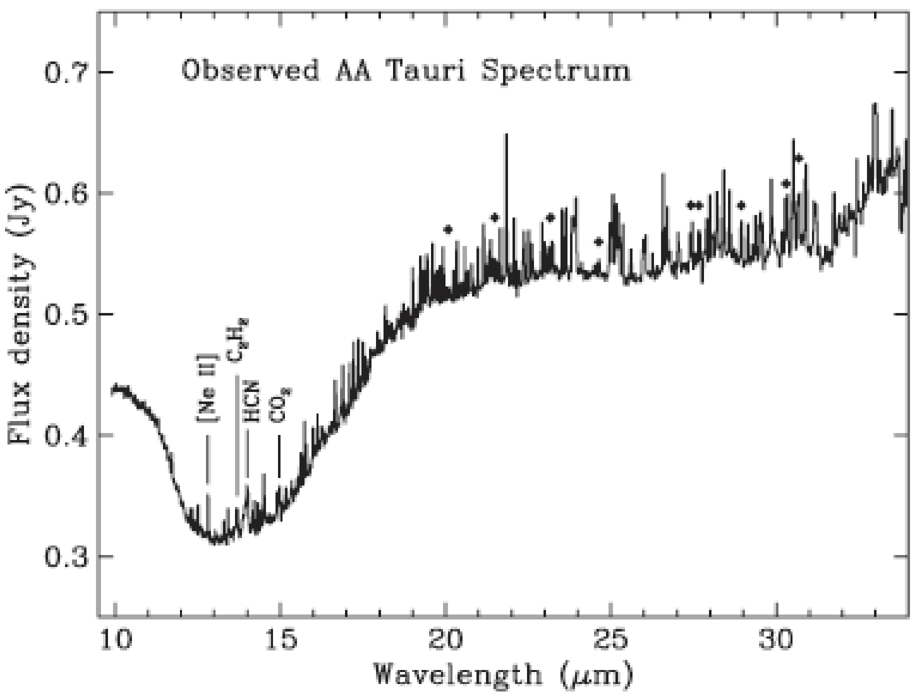


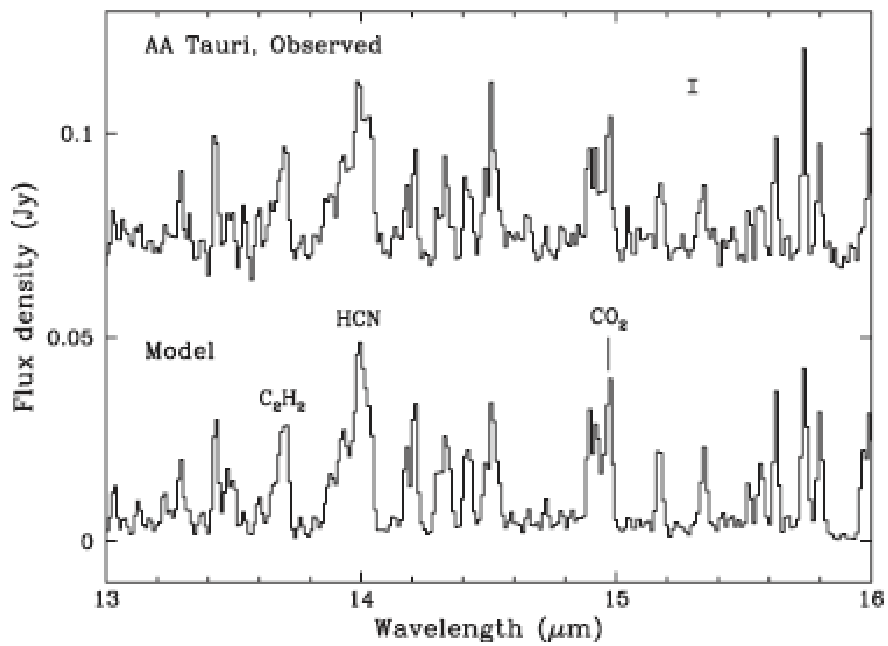




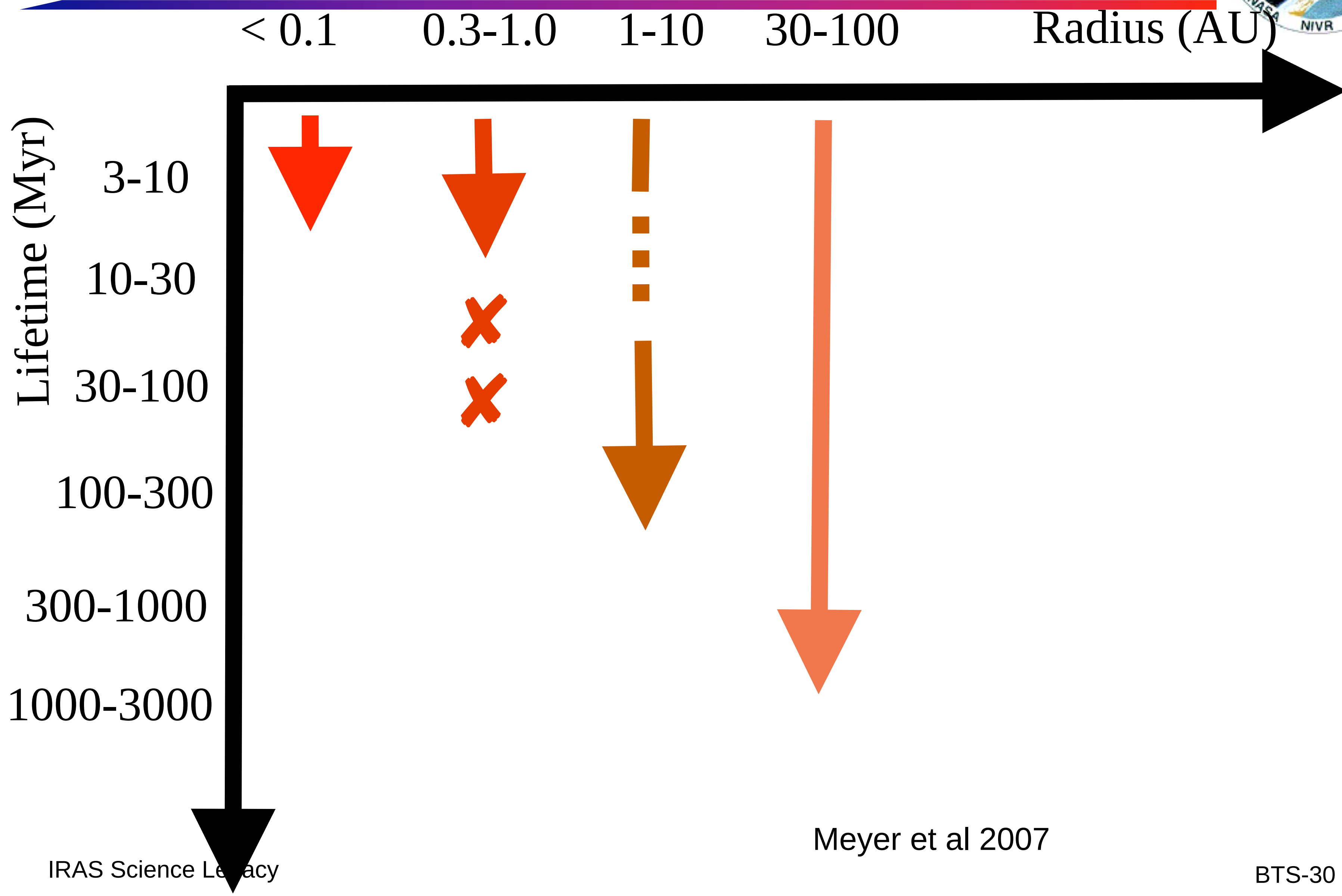
Organic Molecules and Water in the Planet Formation Region of Young Circumstellar Disks

John S. Carr[1] and Joan R. Najita[2]





FEPS *Preliminary* Results: Debris Disk Lifetimes



Meyer et al 2007

The Washington Post

No. 248 · © 1983 The Washington Post Company · WEDNESDAY, AUGUST 10, 1983

VIOLENCE IN ULSTER

Belfast youths examine remains of a truck burned late Monday. British troops shot and killed a young Catholic man during disturbances yesterday. Story, Page A10.

New Evidence of Other Worlds

Satellite Discovers Possible Second Solar System

By Thomas [illegible]

A satellite carrying an infrared telescope has discovered swarms of large particles around the star Vega, and scientists say they think the particles and the star make up a complete solar system like our sun and the nine planets and thousands of asteroids and meteorites that surround it.

If true, it is the first evidence that the universe contains a second solar system like this one.

Though scientists have speculated for years that the Earth and its eight sister planets are not alone in the cosmos, they have never had evidence that their speculations were correct.

"The discovery provides the first direct evidence that solid objects of substantial size exist around a star other than the sun," said a statement yesterday from the Jet Propulsion Laboratory in Pasadena, where the Infrared Astronomical Satellite (IRAS) pictures are analyzed.

"The material could be a solar system at a different stage of development than our own," the statement said. Vega is a young star only 1 billion years old. The Earth's sun is almost 5 billion years old.

Nevertheless, Vega is similar to the sun. Its surface temperature has been measured at 10,000 degrees, almost the same as the sun. This suggests that though it is younger, Vega and its surrounding system may be undergoing the same kind of evolution that this solar system went through 4 billion years ago. Among the bodies in evolution around Vega could be even the equivalent of a young Earth.

What the IRAS satellite has seen time after time since it left the Earth last January is that Vega has appeared "much brighter and larger in infrared light" than any other similar star the satellite has observed, strongly suggesting there were celestial bodies in orbit around Vega just as the planets in this solar system circle the sun.

Further investigation showed that the bodies [illegible] Vega had temperatures measured by the infrared telescope at about 300 degrees below zero Fahrenheit. This is far above the temperature of empty interstellar space and approximates the temperature of the inner rings of Saturn.

The telescope on IRAS has no way of counting the number of bodies in orbit around Vega or even of estimating their size. But the statement released yesterday by JPL said the particles could range "from buckshot to the size of asteroids and planets."

The statement said the material the telescope sees around Vega "could be comparable in mass to all the nine planets and other matter in our solar system, excluding our sun."

While the telescope is sensitive to heat, it cannot resolve, or "see," the mass of particles around Vega precisely enough to distinguish between them. All it sees is a ring of particles, not individual bodies. The buckshot-sized particles men-

See VEGA, A8, Col. 1

Detected material ("dust") would be destroyed on time scales much shorter than the age of Vega -- thus the material must be "2nd generation", not primordial !!

Backman

From the Vega Phenomena to ExoPlanets

The Washington Post

No. 248 WEDNESDAY, AUGUST 10, 1983

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New Evidence of Other Worlds

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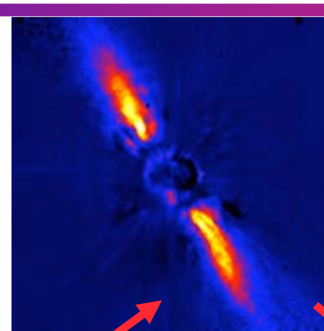

THE ASTRONOMICAL JOURNAL VOLUME 110, NUMBER 2 AUGUST 1995

ASYMMETRIES IN THE BETA PICTORIS DUST DISK

PAUL KALAS AND DAVID JEWITT

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Received 1995 January 12; revised 1995 April 18

ABSTRACT

Five types of asymmetry are identified and measured in the circumstellar dust disk of Beta Pictoris using new R band coronagraphic data. Models of axisymmetric dust disks show that the observed tilt of the midplane may result from a small inclination of the disk to our line of sight combined with a nonisotropic scattering phase function. The remaining four asymmetries indicate a nonaxisymmetric distribution of orbiting dust particles between 150 and 800 AU projected radius. The disk may have been gravitationally perturbed in the past 10^3–10^4 yr, though a perturbing agent has not been detected. The statistical probability of a stellar close-approach is very small and no field stars have been uniquely identified as having passed near Beta Pictoris recently. Planets are unlikely candidates due to the large scale of the asymmetries, while a brown dwarf search has yielded negative results. © *1995 American Astronomical Society.*

A Jupiter-mass companion to a solar-type star

Michel Mayor & Didier Queloz

Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.

A planetary system as the origin of structure in Fomalhaut's dust belt

Paul Kalas[1], James R. Graham[1] & Mark Clampin[2]

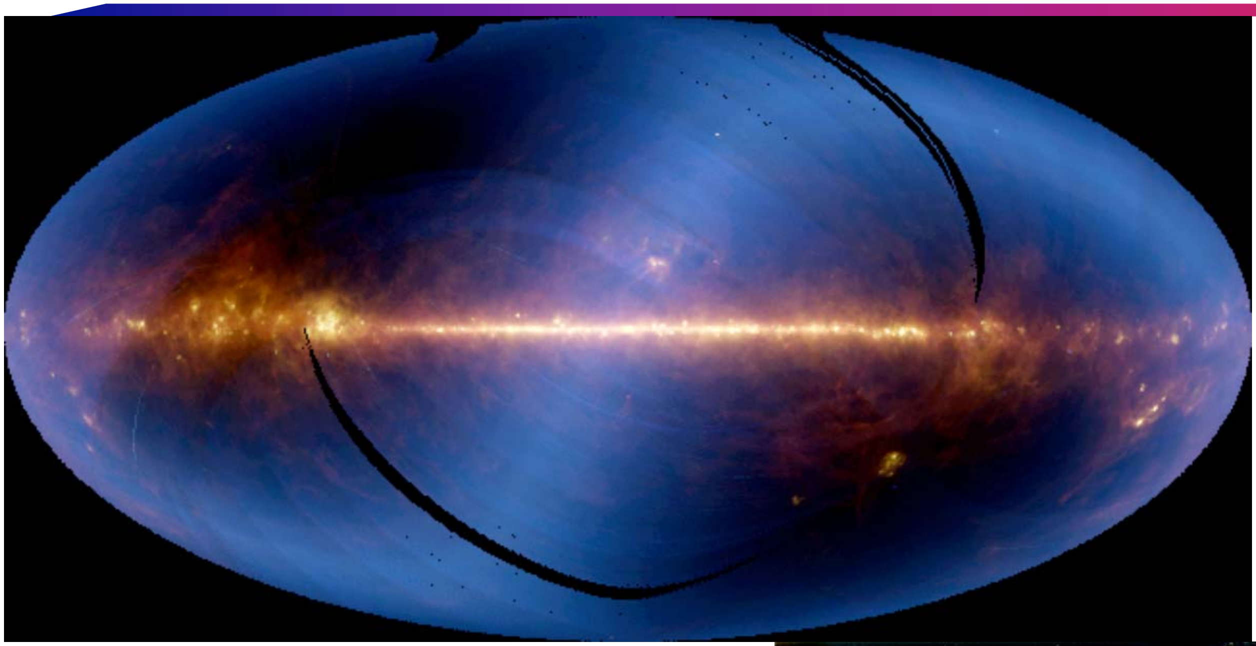
Some of the IRAS Scientists

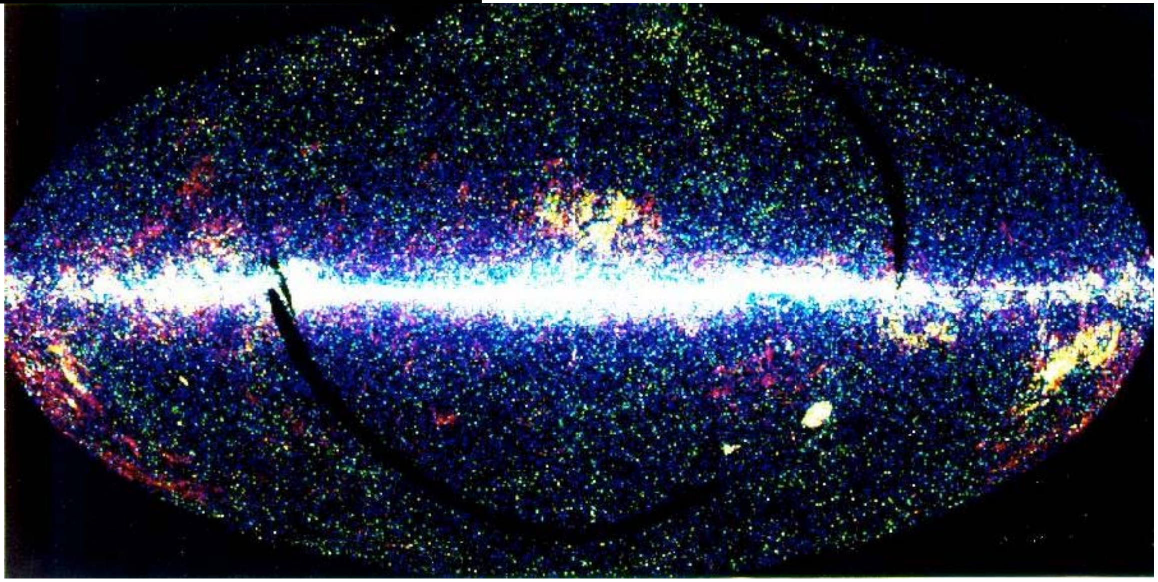
A Few of the Unsung Heroes

The IRAS Scientific Legacy

- Infrared Bright Galaxies are an important population in the local Universe
  - *>3/4 of star formation in the universe is obscured by dust and its luminosity emerges in the infrared*
- IR Cirrus is important in our galaxy and in nearby galaxies, 12μm emission is much brighter than expected
  - *PAH emission is ubiquitous in environments from the Milky Way to galaxies at z ~ 3*
- IRAS identified newly formed/forming stars
  - *The current paradigm emerged from IRAS and we are now exploring in detail how stars form*
- Planetary Debris disks found in the Fabulous 4
  - *Debris disks are shaped by the presence of planets; their composition, structure and evolution is being traced*

The Infrared Universe Viewed by IRAS





IRAS Science Legacy