A brief introduction to Infrared Astronomy

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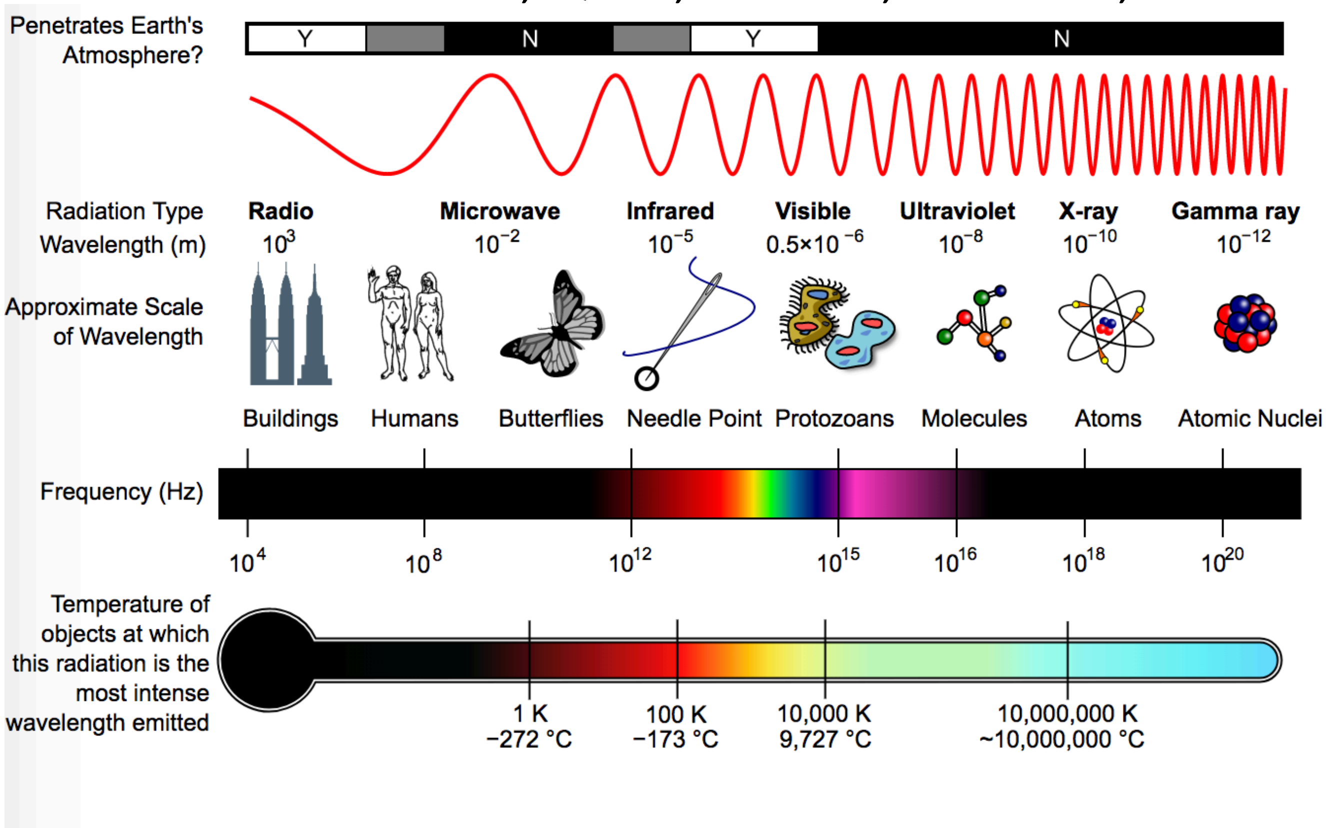
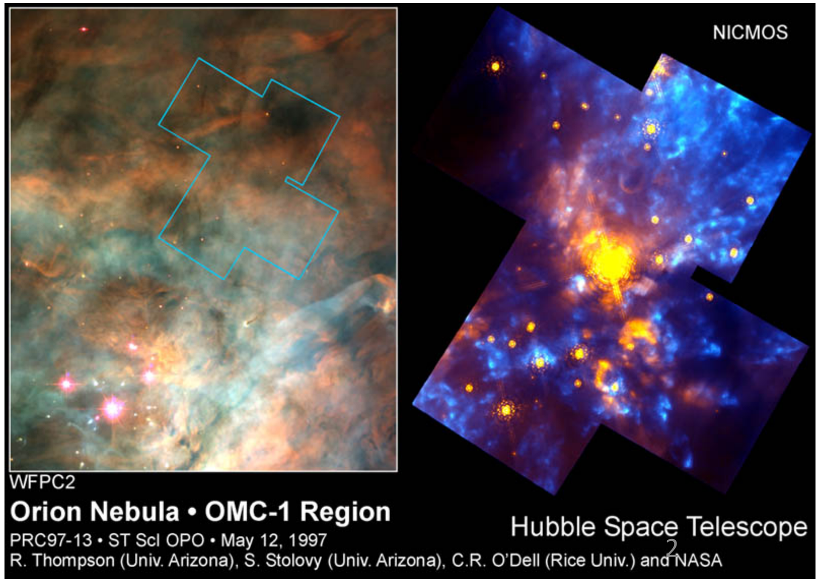
COSPAR IR School, Quito, Ecuador, Mar 5-16, 2018

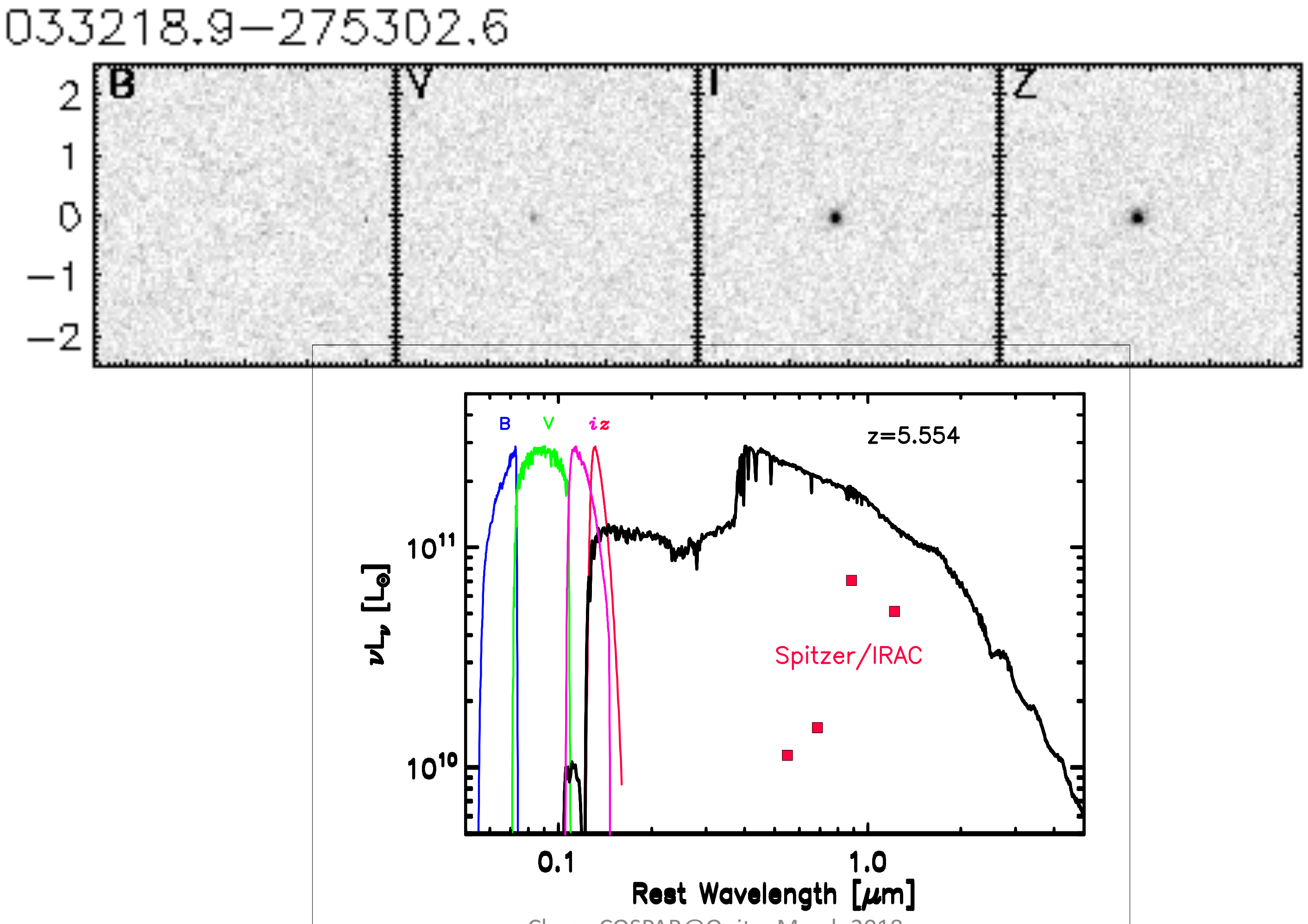


Advantages of the infrared

- Probes cooler temperatures of emission, 1000K to few K.
  - Can see dust emission
    - At early times, can probe the energy put out by stars as they form in their cocoons
  - Can see later type stars where the bulk of the stellar mass is
- Penetrates interstellar dust
  - Dust is typically of size 0.1-10 microns which obscures wavelengths of its own size
  - So can see deeper into the central regions of star-forming regions
- Redshifting of light implies can see out to the distant Universe



Detecting z>5 Galaxies/QSOs: Lyman Break Technique



The Need for Different Wavelengths

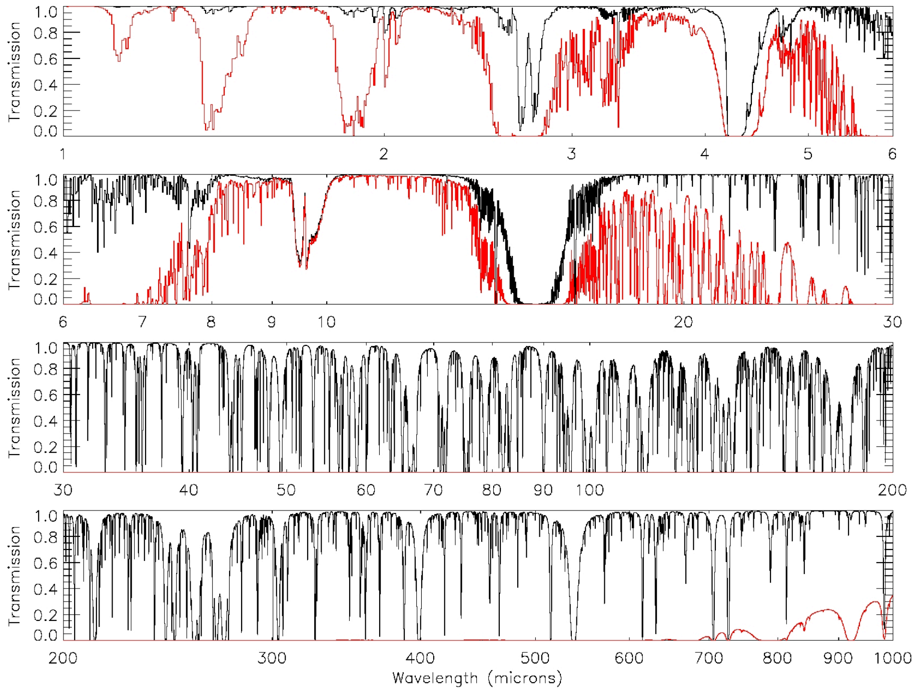
The Hubble View

The Spitzer View

The Chandra View

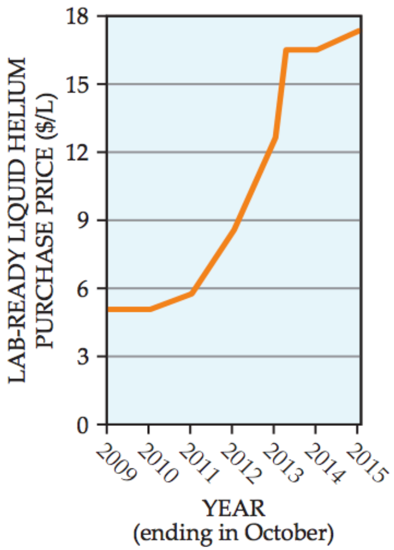
Disadvantages of the infrared

- Largely inaccessible from the ground beyond 10 microns
  - Beyond 2.5 microns, thermal emission from water vapor dramatically reduces sensitivity
  - SNR $\propto 1/\sqrt{\text{Background}}$
- Detector fabrication is highly specialized
  - HgCdTe or InSb in the near-IR (1-5 microns)
  - SiAs in the mid-IR (5-40 microns)
  - Ga:Ge or Ga:As in the far-IR (40-500 microns)
  - Bolometers in the mm/submm (>500 microns)
- Needs a cooling system since IR detectors operate at <50K
  - 0.1K for the millimeter/submm



Red line: Mauna Kea (~4000m)
Black line: 12.5km altitude

Liquid Helium is expensive; liquid N2 is $0.1/liter



THE PURCHASE PRICE for liquid helium for chemist Sophia Hayes of Washington University in St. Louis rose nearly 250% during the five years ending October 2015. (Adapted from the APS/ACS/MRS report *Responding to the U.S. Research Community's Liquid Helium Crisis.*)

Typically He4 is extracted during natural gas production.

Superfluid He3 which is produced from decay of Tritium costs >>$100/liter !

Key Infrared Space Missions (ESA, JAXA, NASA)

- IRAS (0.57m, 1983): 12, 25, 60 and 100 microns, 0.5’-2’ resolution
- Hubble (2.5m, 1990+): <u>operational</u>, 1-2 microns, <0.2” resolution, (NICMOS, WFC3); **S**
- ISO (0.6m, 1995-1998): 3-200 microns, (ISOCAM, ISOPHOT, LWS, SWS); **S**
- Spitzer (0.85m, 2003+): <u>operational</u>, 3.6-200 microns, (IRAC, MIPS, IRS); **S**
- Herschel (3.5m, 2009-2013): 70-500 microns, 6-30” (PACS, SPIRE, HIFI); **S**
- WISE (0.4m, 2009-2013): 3.3, 4.5, 12 and 22 microns, 6-12”
- Akari (0.68m, 2006-2011): 1.8-180 microns, <1’ resolution, (IRC and FIS); **S**
- Planck (1.6m, 2009-2013): 350 microns to 1 cm, 5’-33’ resolution, (HFI and LFI)
- SOFIA (2.7m, 2011+): <u>operational</u>, 1-750 microns, 4”-30” resolution (many instruments); **S**
- JWST (6.5m, 2019+ ?): 0.6-25 microns, <0.1” resolution (NIRI, NIRCAM, NIRSPEC and MIRI); **S**
- Euclid (1.2m, 2021+ ?): 0.5-2 microns, <0.3” (VIS and NISP); **S**
- WFIRST (2.4m, 2025+ ?): 0.5-2.2 microns, <0.2” (WFI); **S**

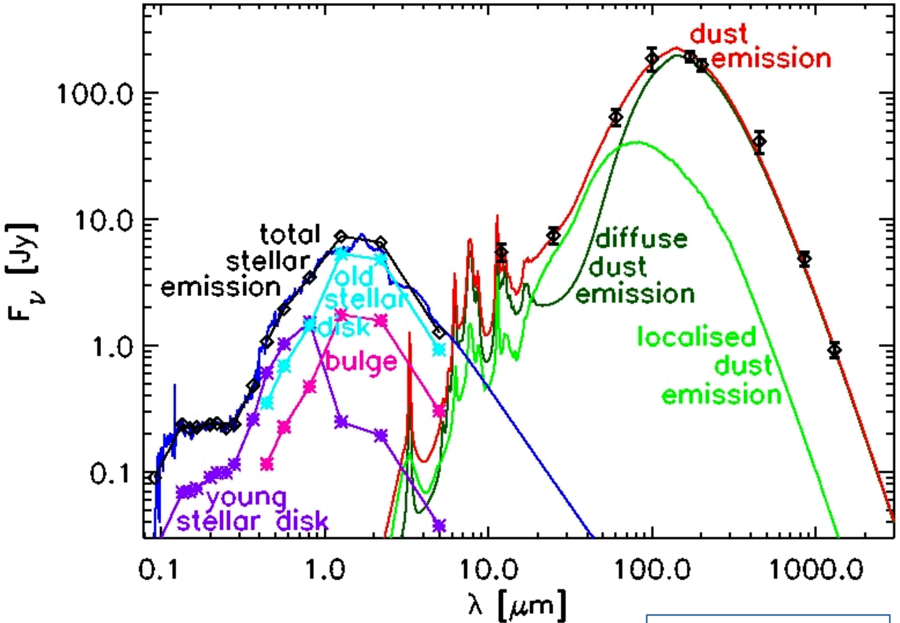
Galactic missions like SWAS and MSX are notable exclusions from this list; **S indicates spectroscopic capabilities**

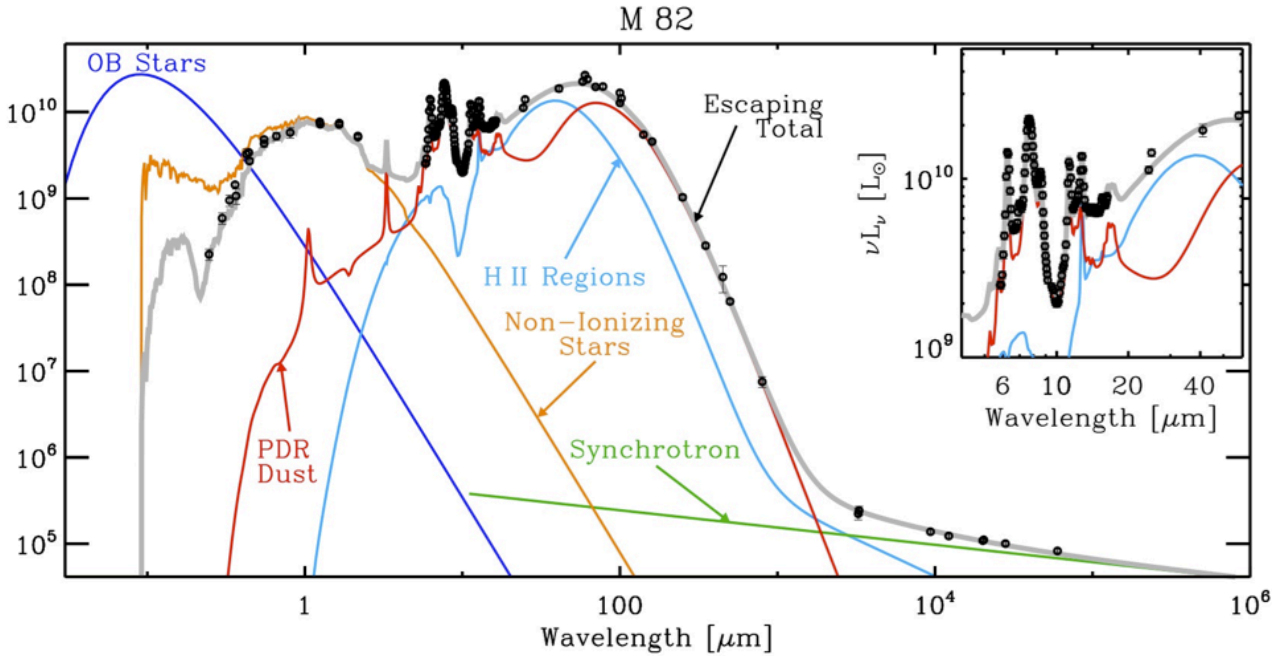
Ground-based infrared projects

- 2MASS, UKIDSS, VISTA are all in the near-infrared 1-2.2 microns with the latter two still taking data. Typically <1” resolution.

- CSO – 350-1000 microns, single dish survey instrument, 10-20” resolution
- JCMT – (SCUBA, SCUBA2), single dish survey instrument, 450 & 850 microns, 10-20” resolution
- IRAM/PdBI – <u>operational</u>, single dish and interferometer, few arcsec resolution
- Submillimeter Array – <u>operational</u>, submillimeter interferometry, <0.5” resolution
- ALMA (Chile) – <u>operational</u>, millimeter/submillimeter interferometry, 250 microns – 3 mm, <0.5” resolution
- LMT (Mexico) – <u>operational</u>, single dish survey instrument, 1-2mm, 10” resolution
- SPT and ACT – <u>operational</u>, ground-based cosmic microwave background (CMB) experiments beyond 1mm.

Astrophysical components in the infrared





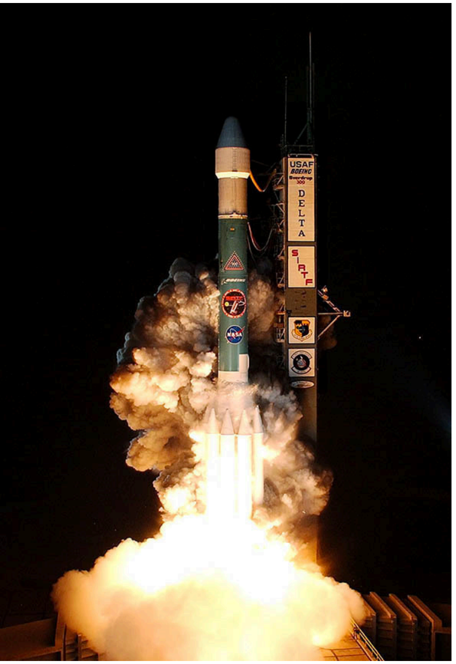
Ambient ISM

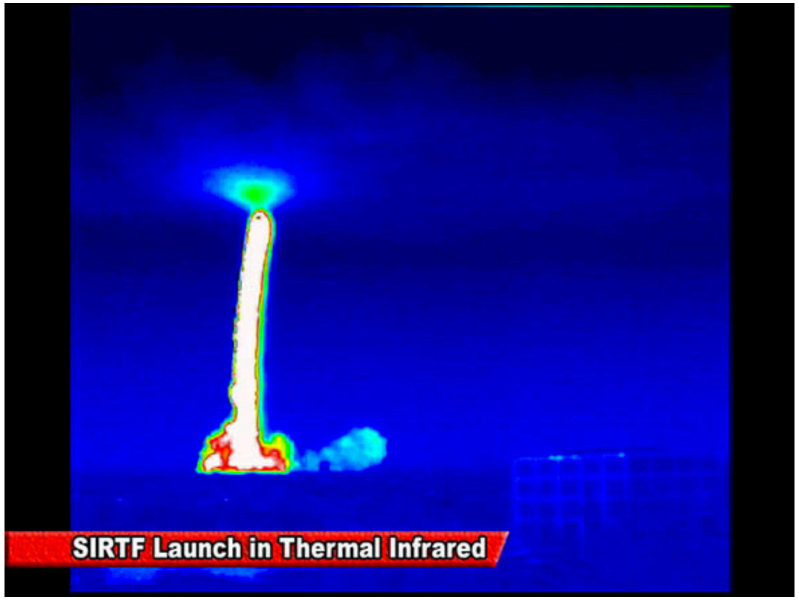
SFR

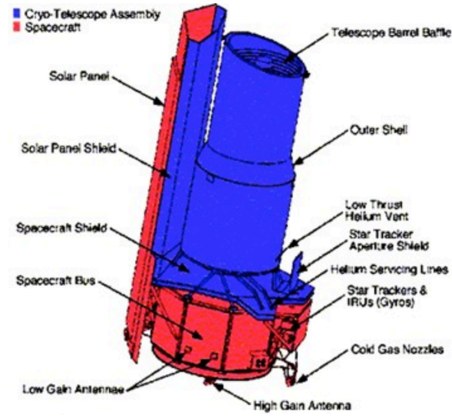
Obscured AGN
Obscured SFR

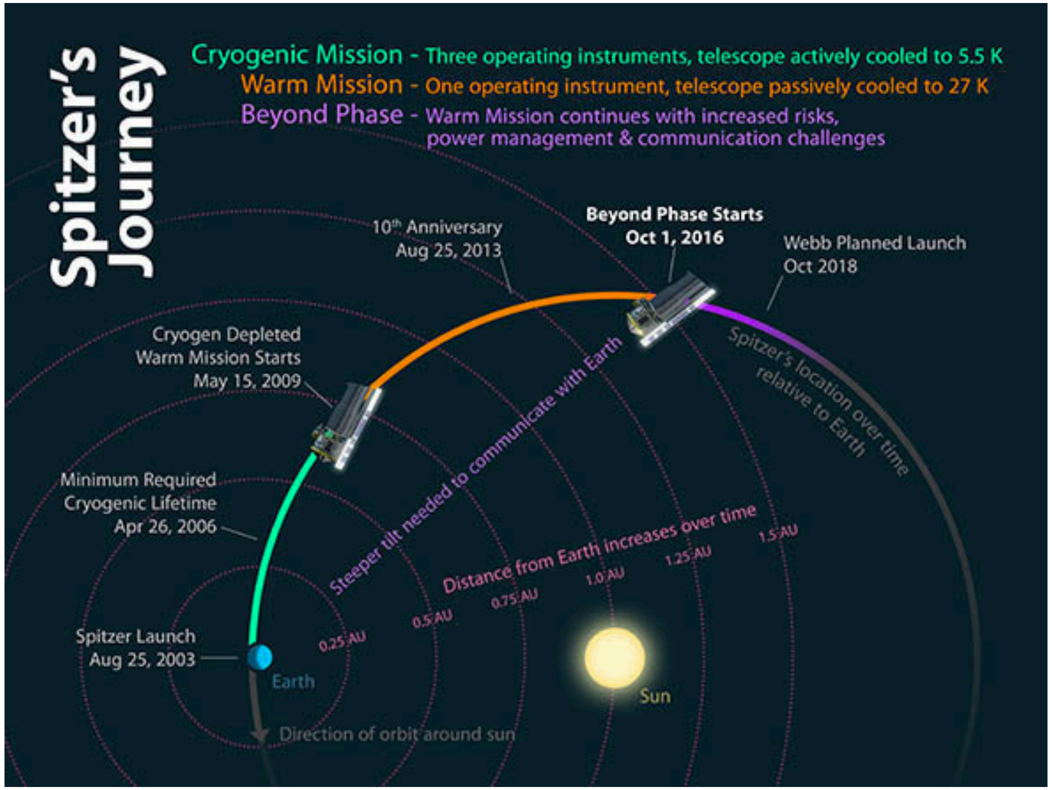
Stellar Mass

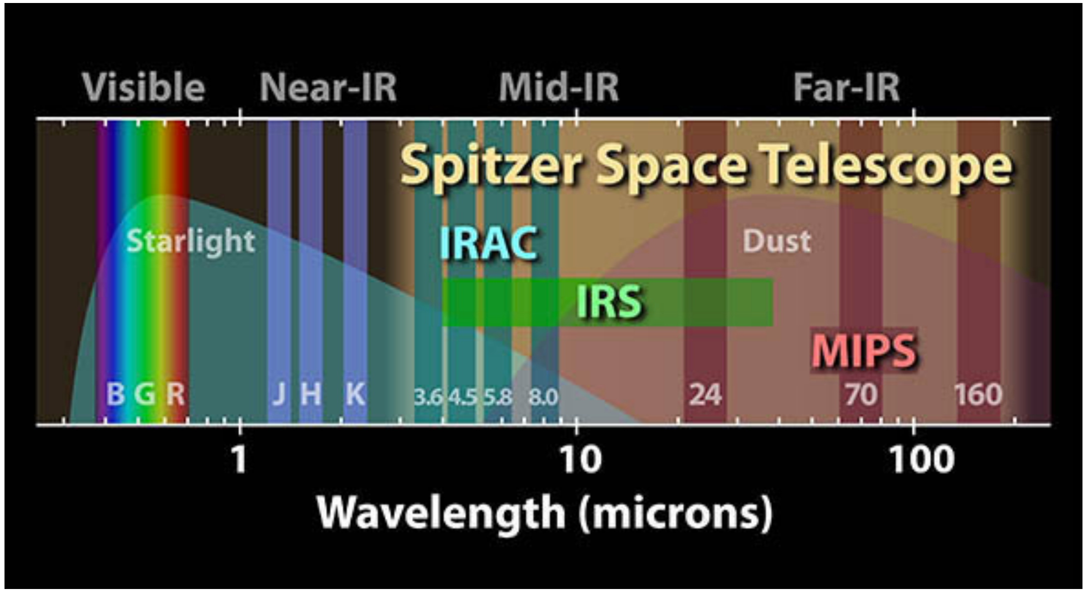
Details about Spitzer





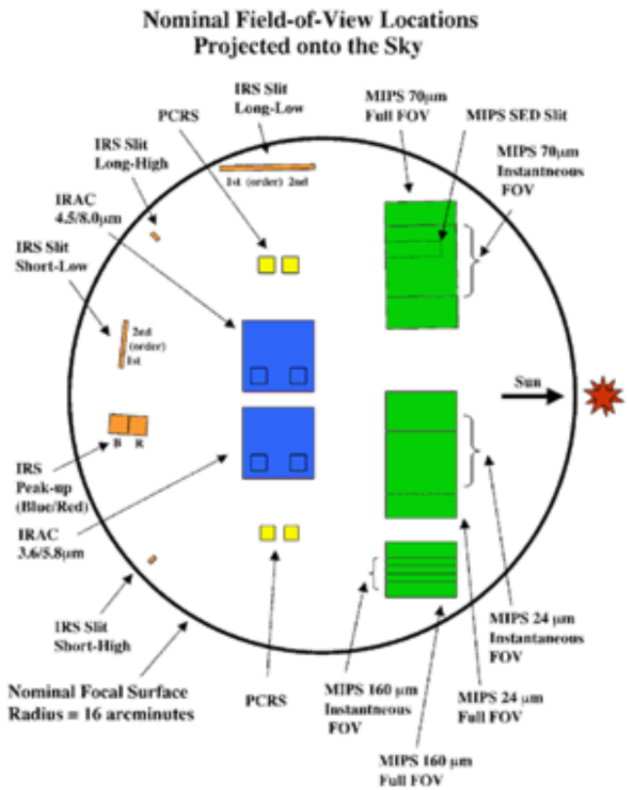




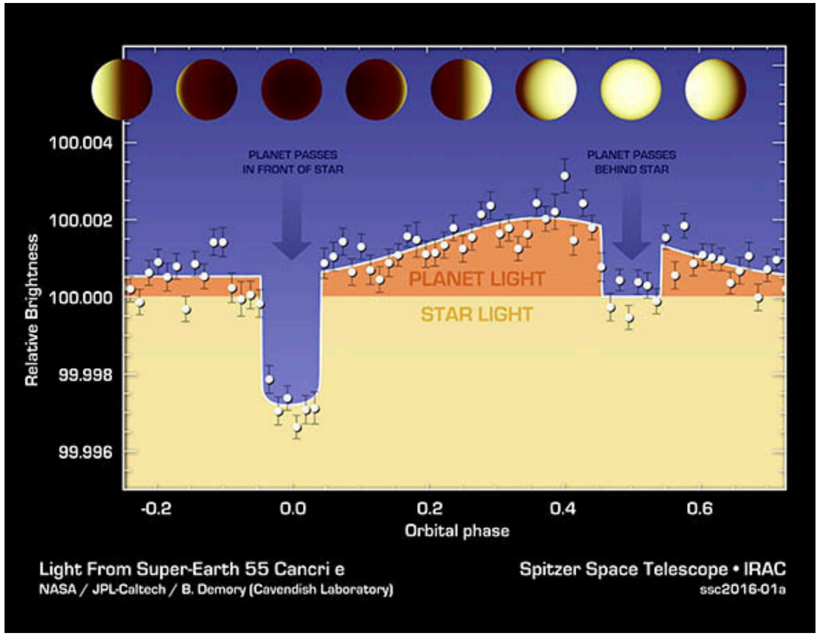


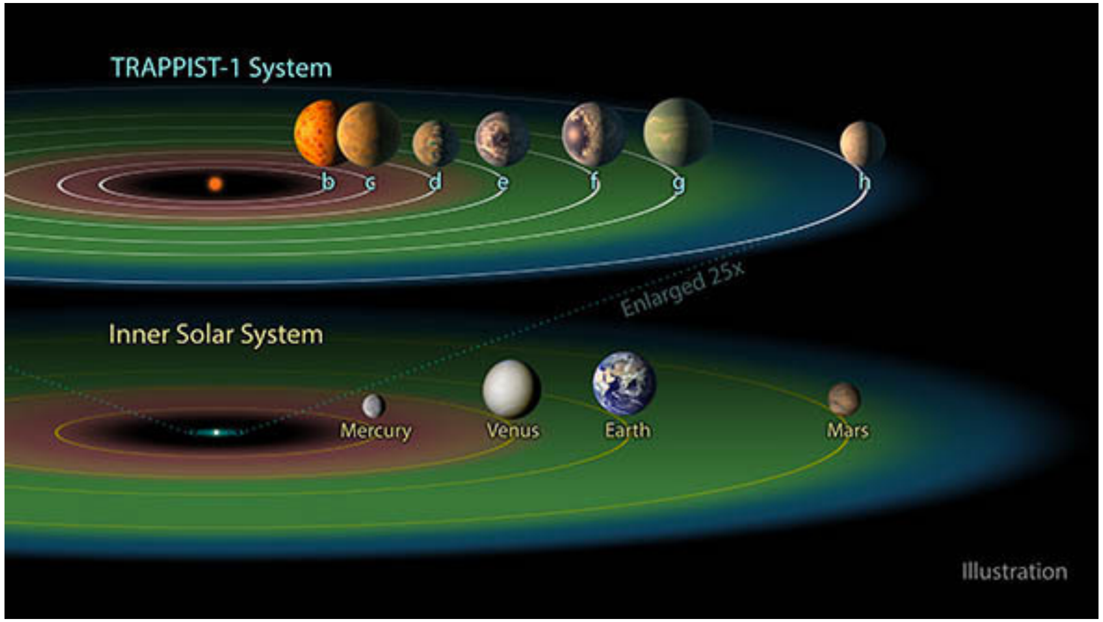
Signal to noise ratio is dominated by astrophysical background i.e. the zodiacal light from the solar system
Only IRAC 3.6 and 4.5 microns are operational now since Helium tank was emptied in 2009
Proposals due March 23!

Spitzer focal plane layout

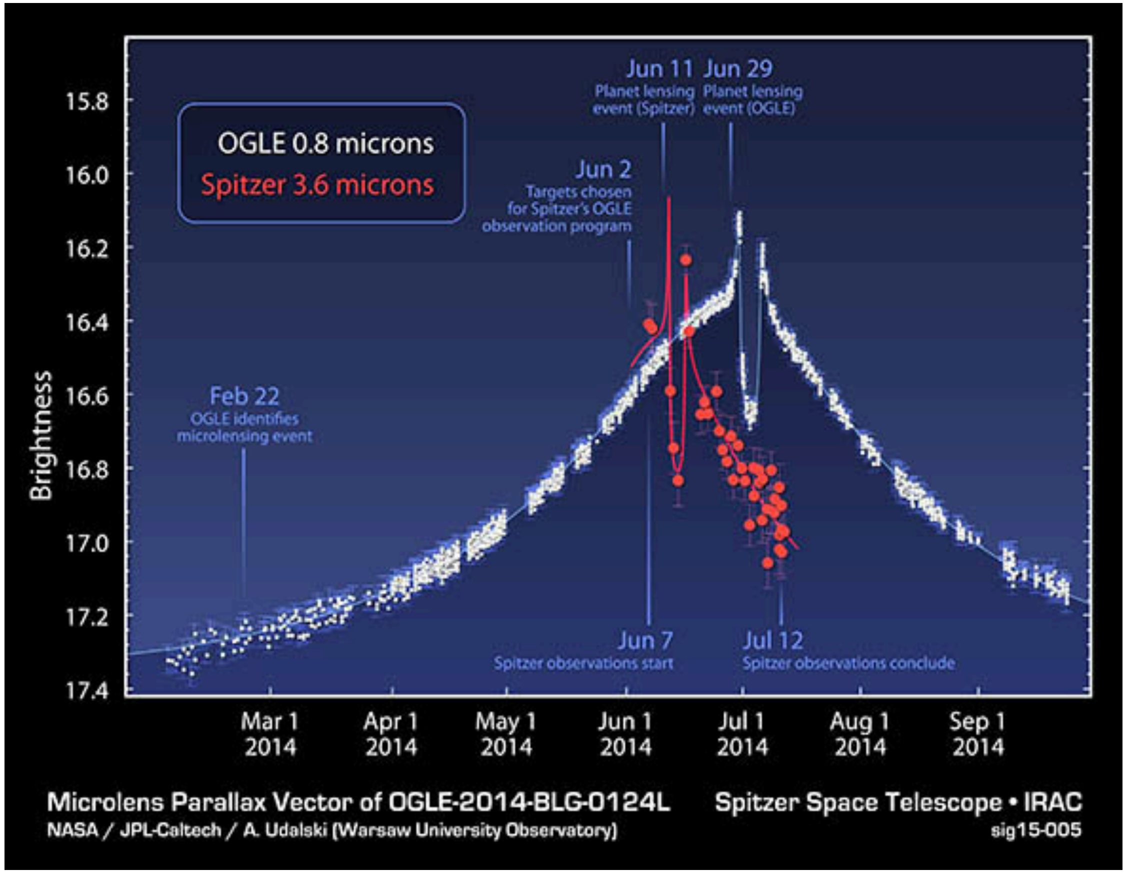


Science with Spitzer: IRAC & Exoplanets

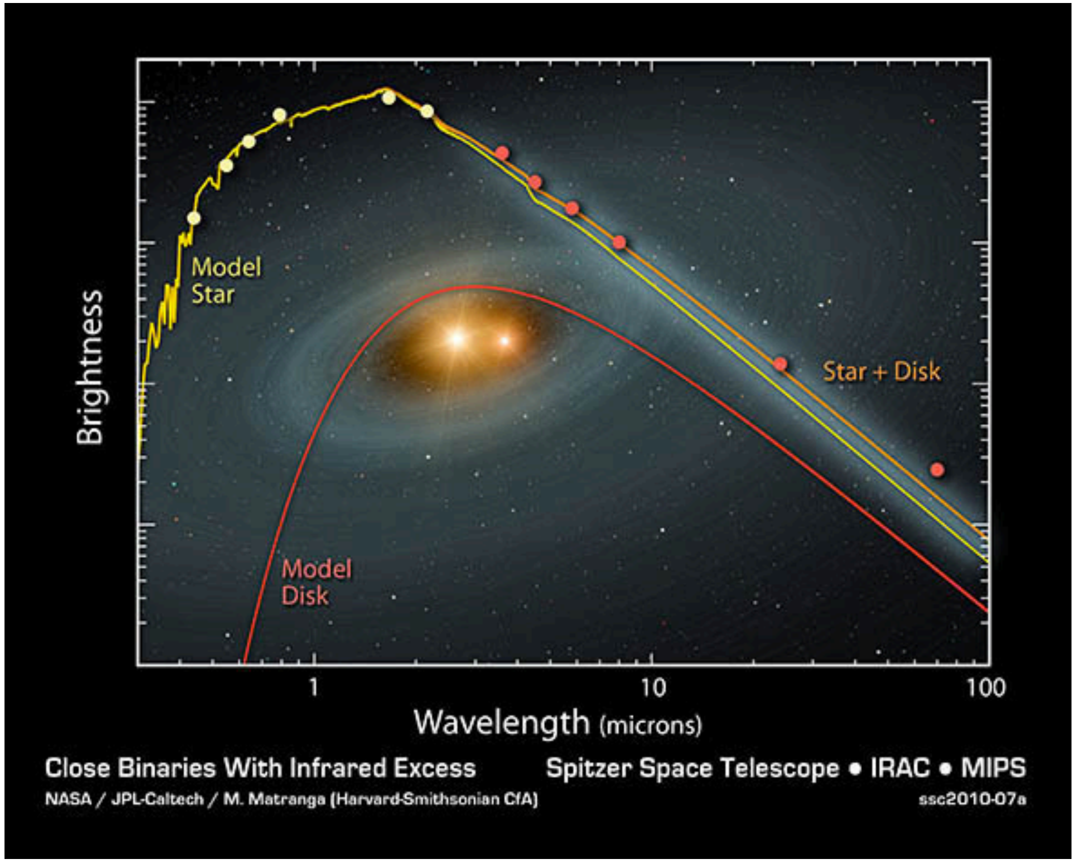




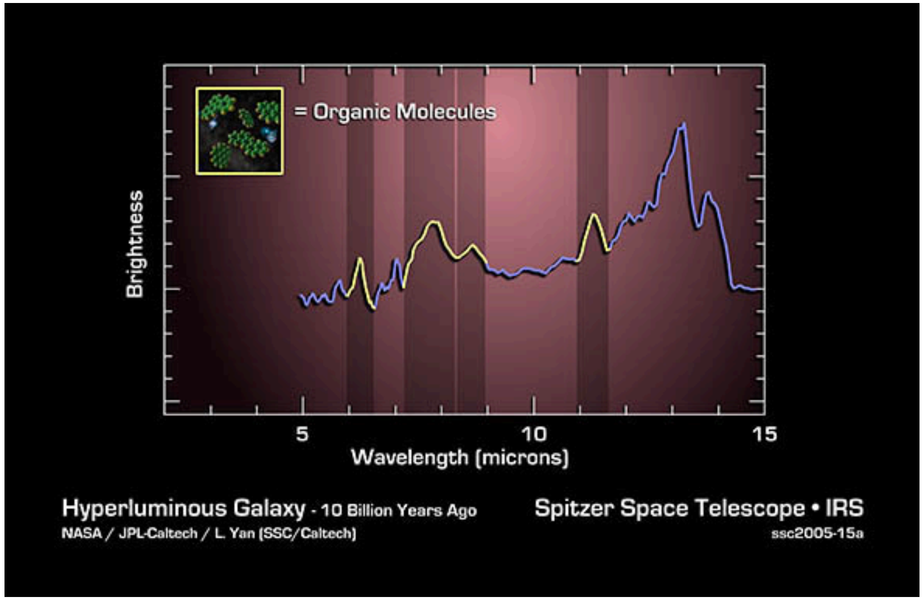
Exoplanets with microlensing

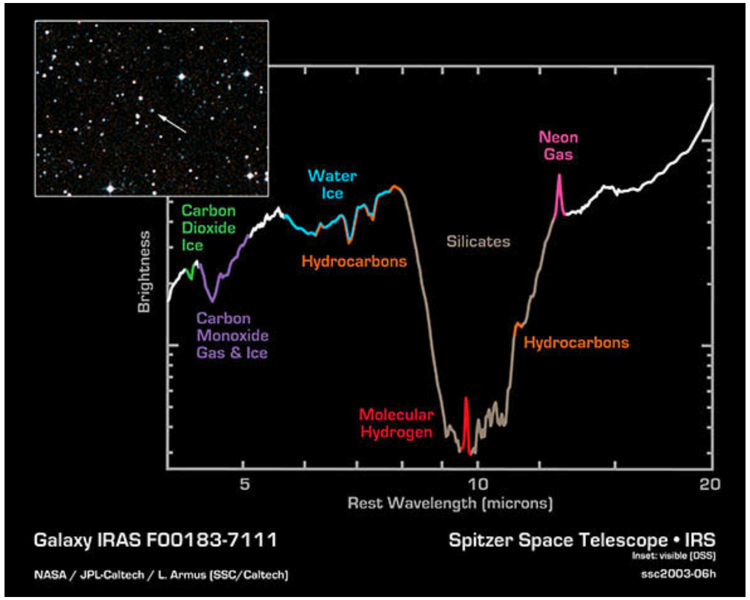


Evidence for circumstellar disks

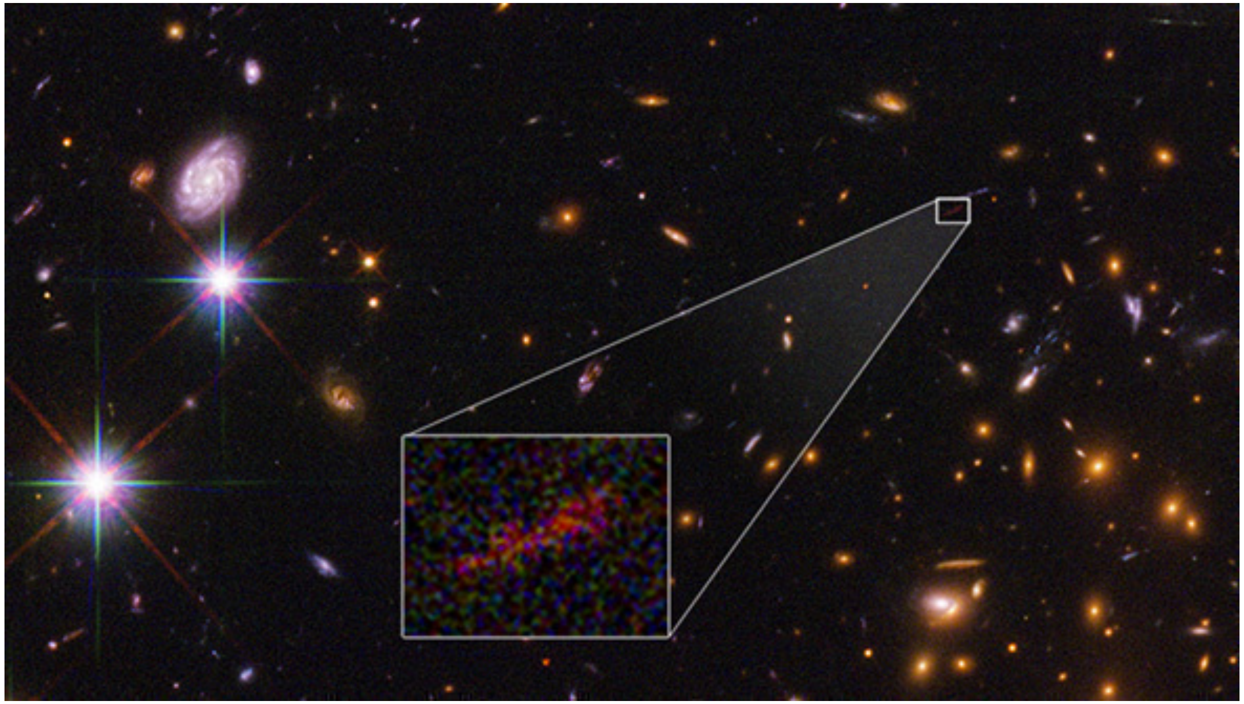


IRS and Distant Galaxies: Detecting Polycyclic aromatic hydrocarbon and molecular lines

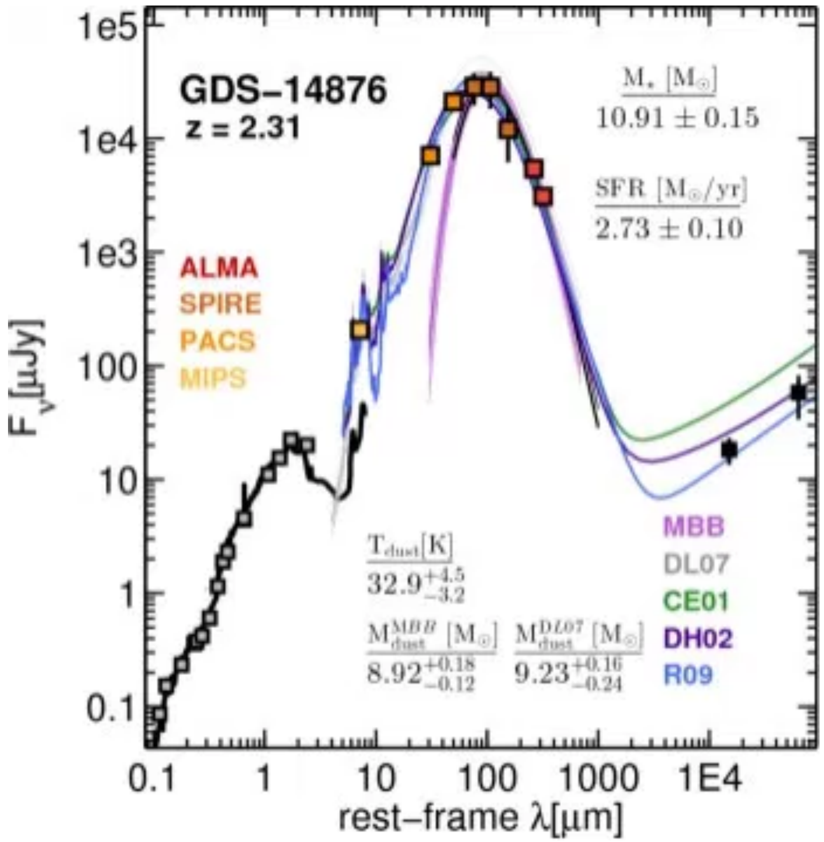




IRAC and distant galaxies: yielding stellar masses

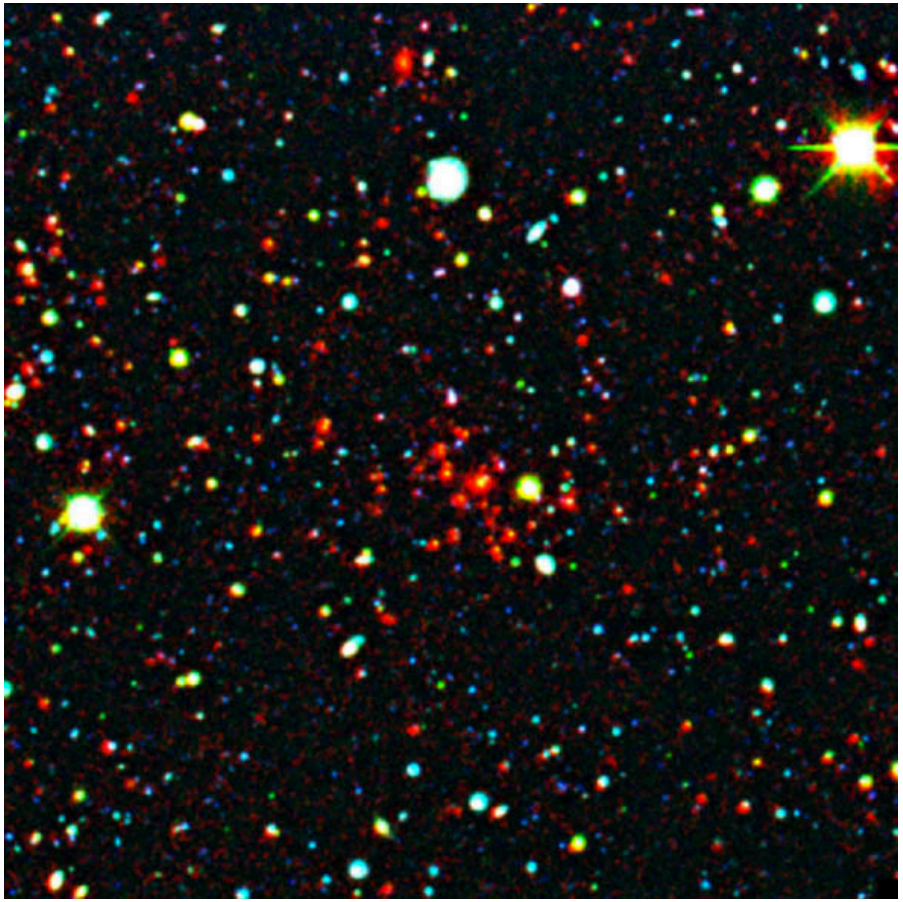


MIPS and distant galaxies: measuring SFR and AGN activity



G. Barro et al.

IRAC and galaxy clusters at z>1: Relying on k-correction



Brodwin et al.

Introduction to Akari

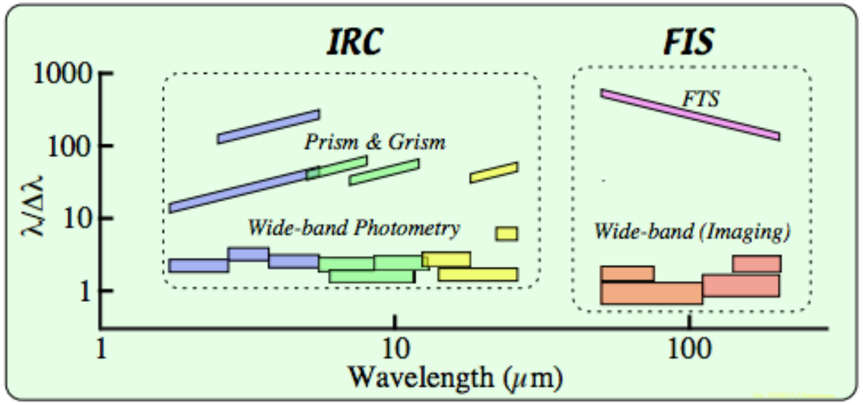
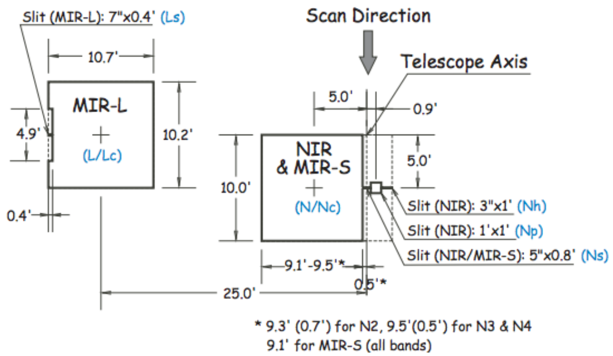


Figure 2.4.5: The wavelength coverage and resolving power of the *AKARI* instruments.

Table 4.1.1: Specifications of the Infrared Camera (IRC).

Channel	NIR	MIR-S	MIR-L
Detector	InSb(SBRC-189)	Si:As (CRC-744)	Si:As (CRC-744)
Array	512 × 412	256 × 256	256 × 256
Imaging FoV (arcmin^2)[1]	9.3 × 10.0	9.1 × 10.0	10.3 × 10.2
Imaging Area (pixel^2)[1]	391 × 412	233 × 256	246 × 256
Pixel Size (arcsec)	1.46 × 1.46	2.34 × 2.34	2.51 × 2.39
Wavelength (μm)	1.8–5.5	4.6–13.4	12.6–26.5
Filters	N2, N3, N4	S7, S9W, S11	L15, L18W, L24
Dispersion Elements	NP, NG	SG1, SG2	LG2

[1]Cross-scan × in-scan. Masked areas are excluded.



Access to Data & Documentation!

- Spitzer archive at the Infrared Science Archive (IRSA)
  - http://sha.ipac.caltech.edu/applications/Spitzer/SHA/
- IRSA also maintains Akari catalogs and Planck/SOFIA data
  - http://irsa.ipac.caltech.edu
- Akari full archive at JAXA
  - http://www.ir.isas.jaxa.jp/AKARI/Archive/

Quiz

- Which is more sensitive and why – Spitzer or a ground-based telescope?
- Can one do FIR observations from the ground?
- What is the advantage of having a FIR telescope on a 747?
- True or false – does optical brightness measure star-formation rates?
- True or false – does FIR brightness measure star-formation rates?