

# ASTRONOMY FROM SPACE

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Imperial College London

Sept 5th 2008

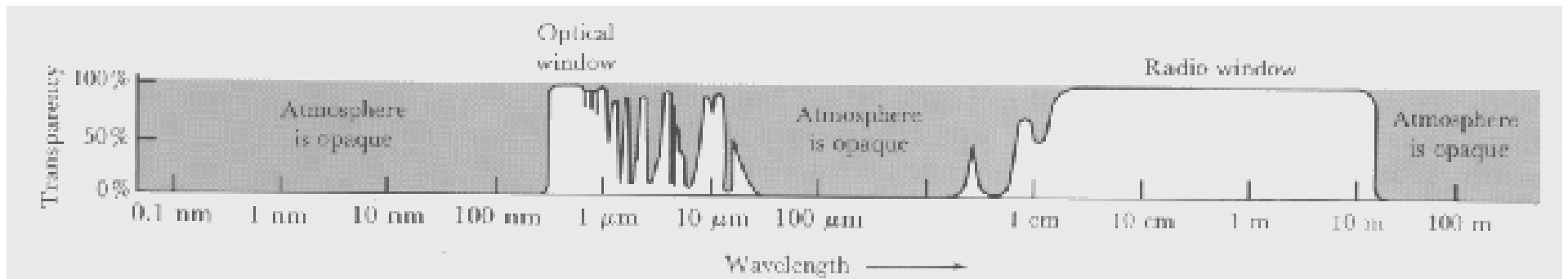
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first detection of  
electromagnetic radiation  
outside optical band

Herschel 1800

## Atmospheric transmission



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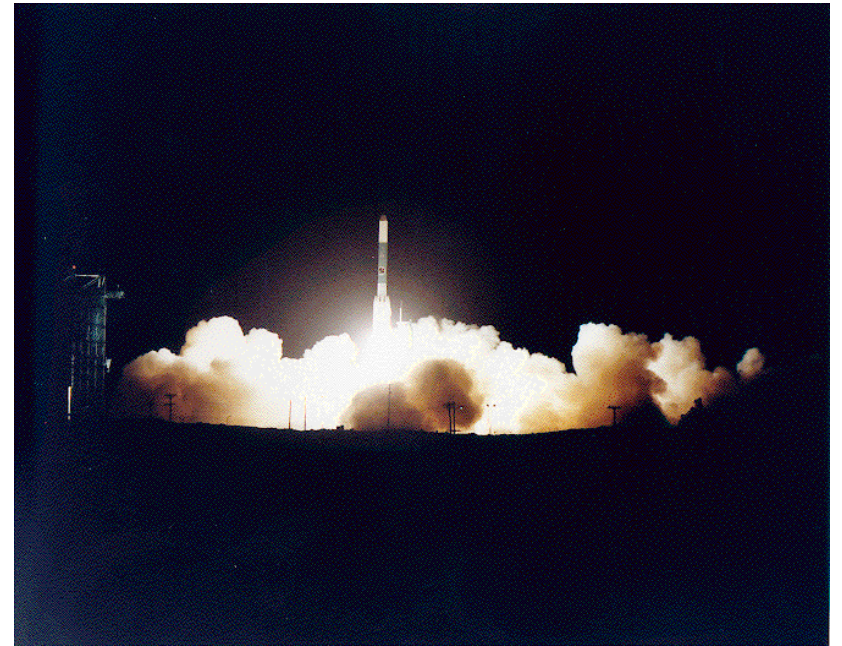
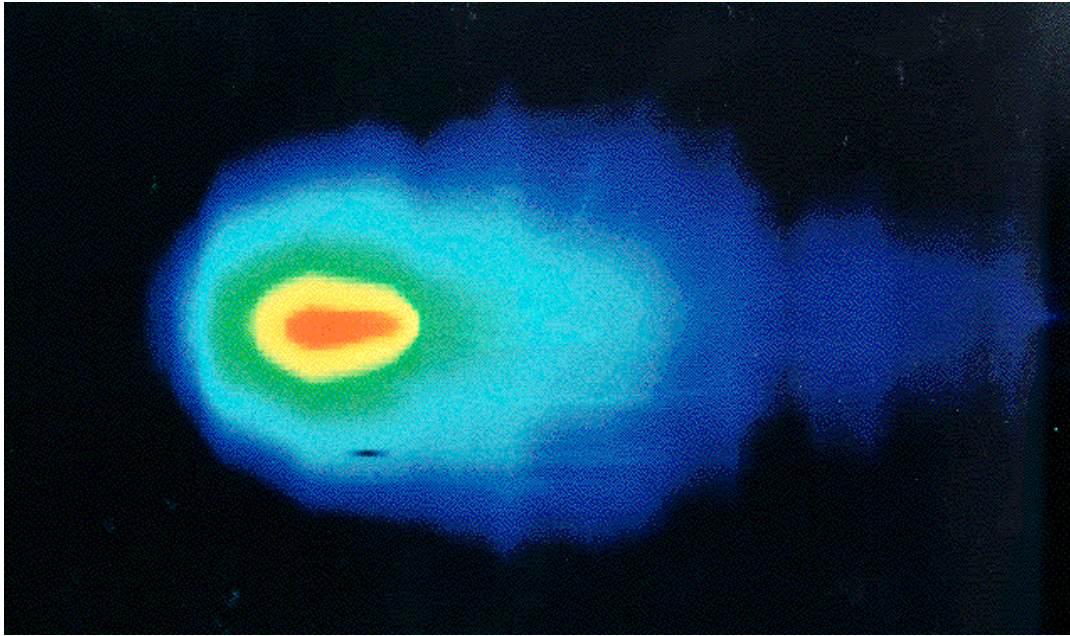
# brief history of astronomy from space

- 1946 Richard Tousey, USNRL, measures uv from sun using V2
- 1948 T.R.Burnight detects X-rays from sun using V2
- 1962 Giacconi detects Sco-X1 using Aerobee rocket
- 1963 Boyer detects Crab in X-rays (rocket)
- 1965 first extragalactic X-ray source (M87, Byram, rocket)
- 1968 Haymes, Fishman detect Crab in  $\gamma$ -rays from balloon
- 1970 Uhuru X-ray satellite maps sky at 2-20 KeV
- 1965-70 Frank Low mid-ir studies of galaxies from Lear jet
- 1972 Copernicus uv mission studies ism
- 1973  $\gamma$  -ray bursts reported by Vela N-blast monitoring satellites
- 1971-4 AFGL infrared rocket survey of sky at 4, 11, 20 microns
- 1974 launch of ANS (Dutch), Ariel V (UK)
- 1975 first ESA astronomy mission, Cos-B ( $\gamma$ -ray)
- 1970-8 balloon-borne (Jennings, Fazio) and Kuiper far-ir studies
- 1978 launch of HEAO-2 (Einstein) - imaging X-ray telescope

# history of astronomy from space (2)

- 1978 IUE (ESA-US) ultraviolet observatory launched
- 1979 launch of Hakucho (Japan) X-ray satellite
- 1983 IRAS (US-Dutch-UK) surveys sky at 12-100 microns
- 1983 launch of Exosat, first ESA X-ray mission
- 1987 launch of Ginga (Japan)
- 1989 COBE detects microwave background fluctuations
- 1990 ROSAT X-ray mission (German-US-UK), all-sky survey
- 1990 launch of Hubble Space Telescope (US-ESA)
- 1991 Compton gamma-ray observatory
- 1993 launch of ASCA (Japan)
- 1995 ISO infrared observatory (ESA)
- 1995 SOHO solar observatory (US-ESA)
- 1999 FUSE far ultraviolet explorer
- 1999 CHANDRA X-ray observatory
- 1999 XMM-Newton X-ray observatory (ESA)

# IRAS

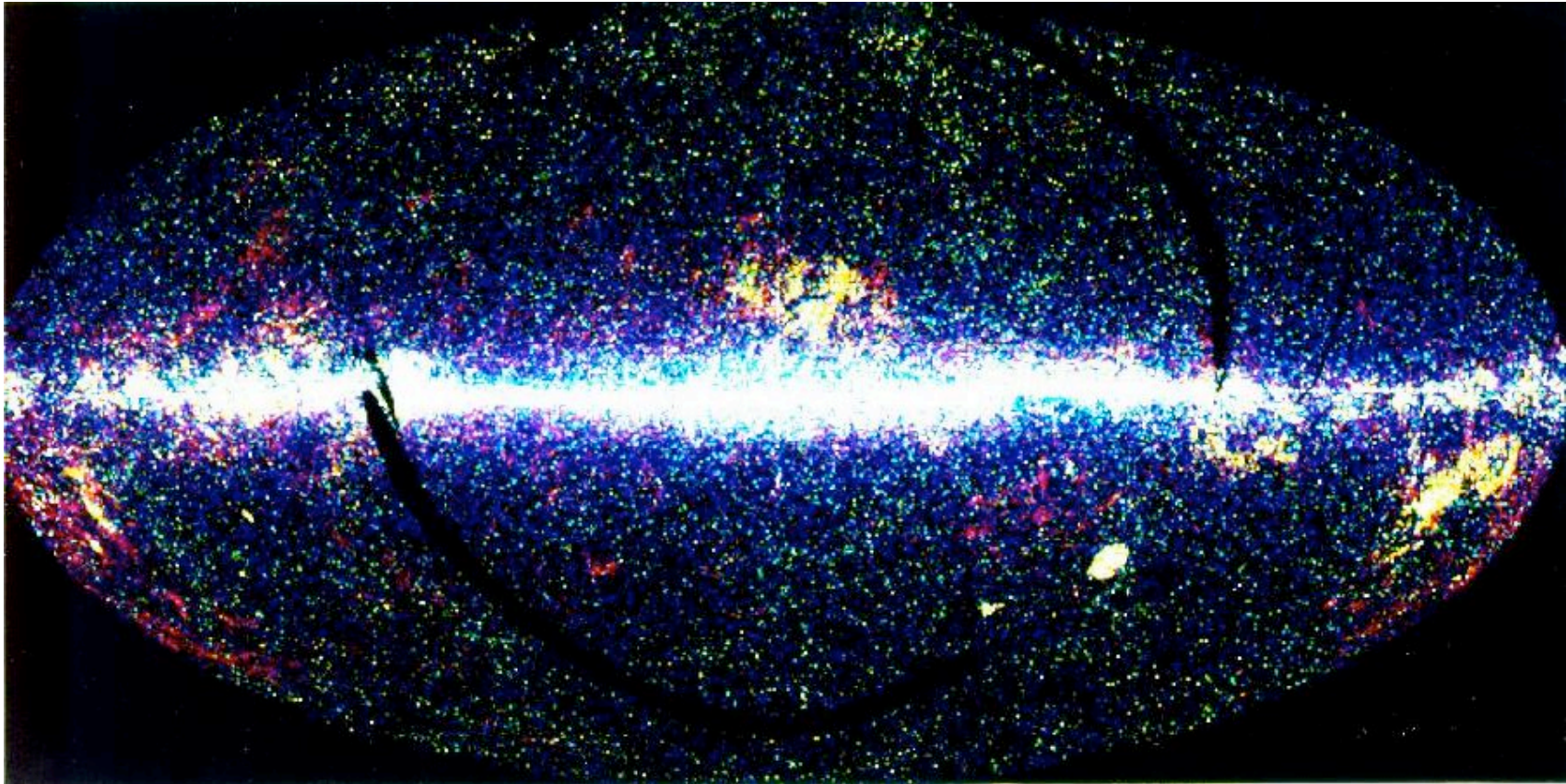


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Horsehead Nebula



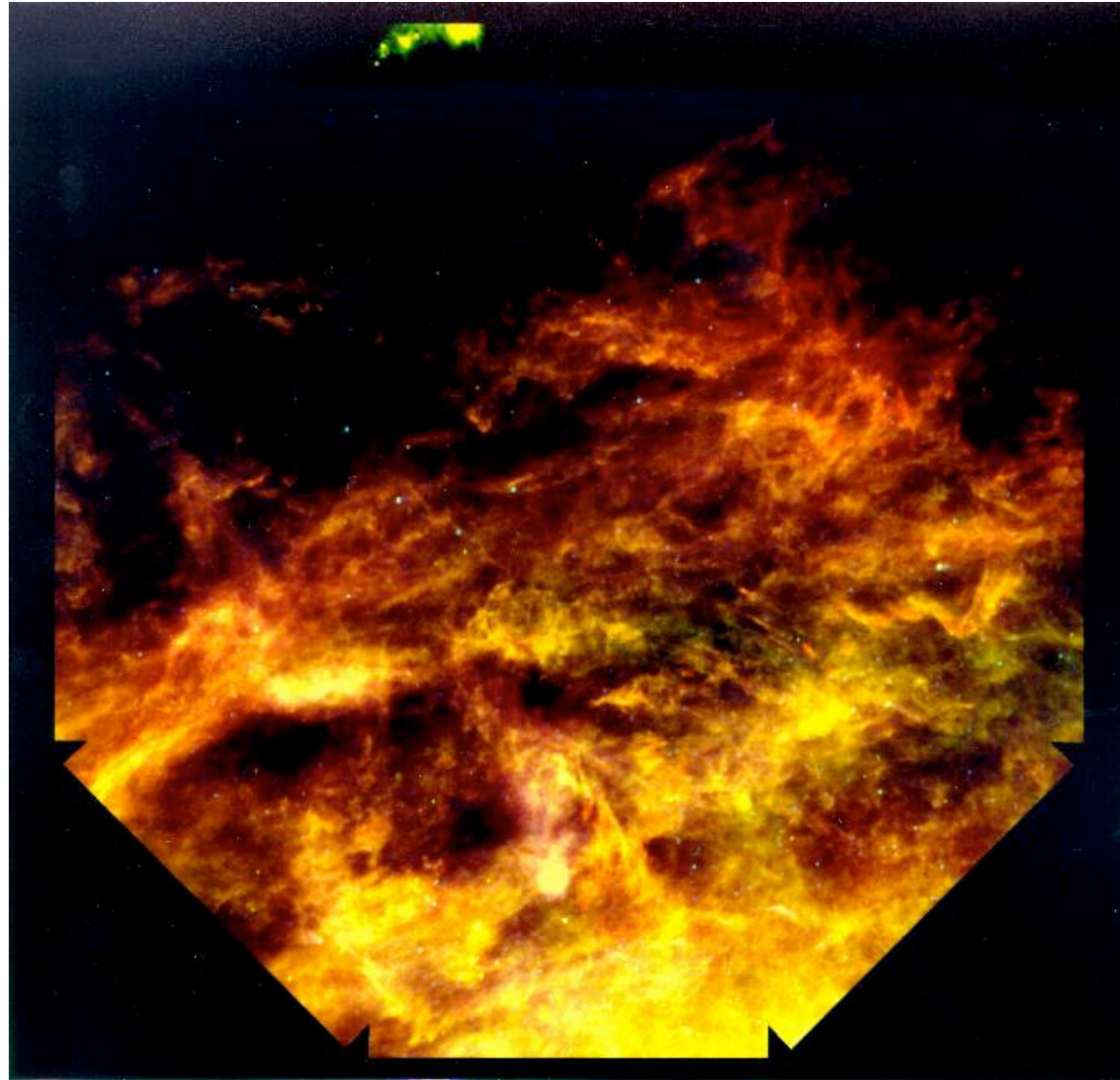
# IRAS



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# IRAS - cirrus



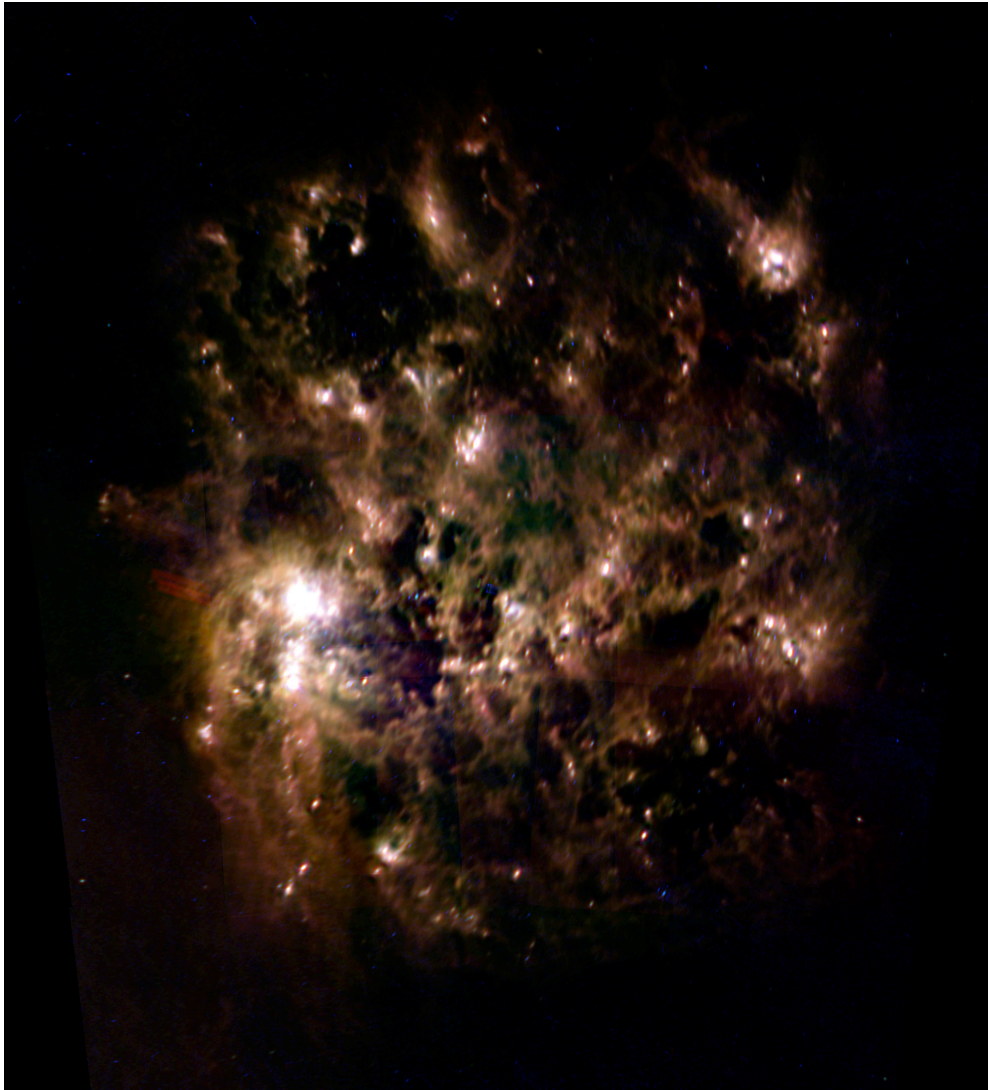
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south celestial pole



# IRAS - star forming regions



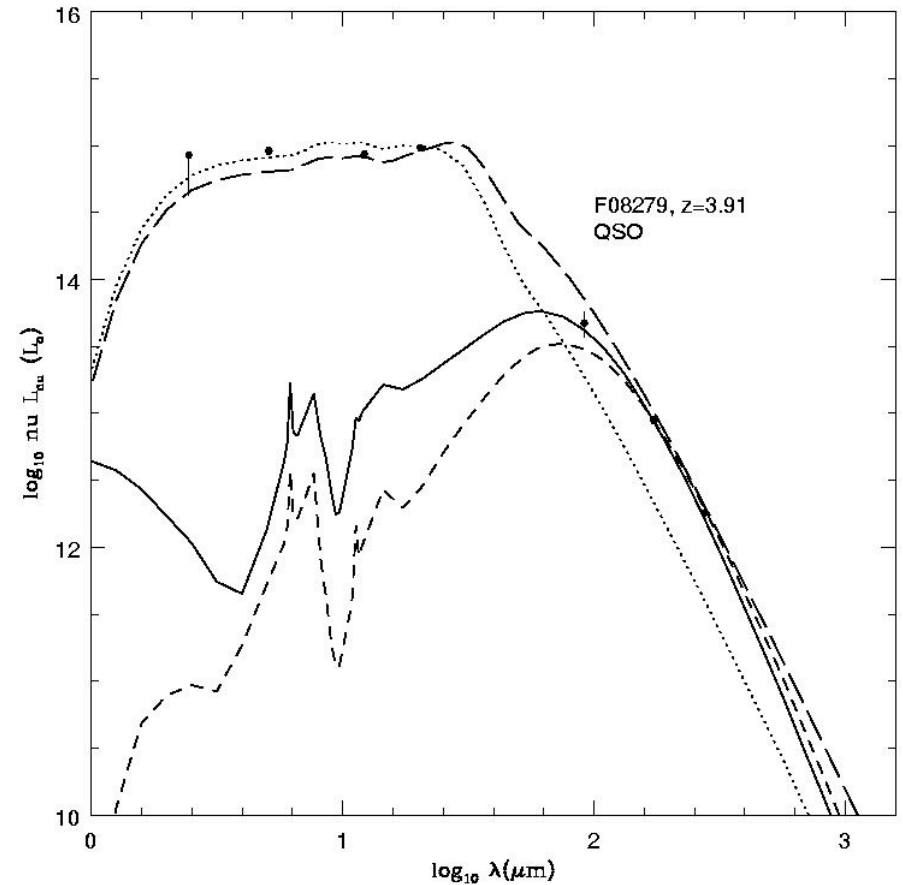
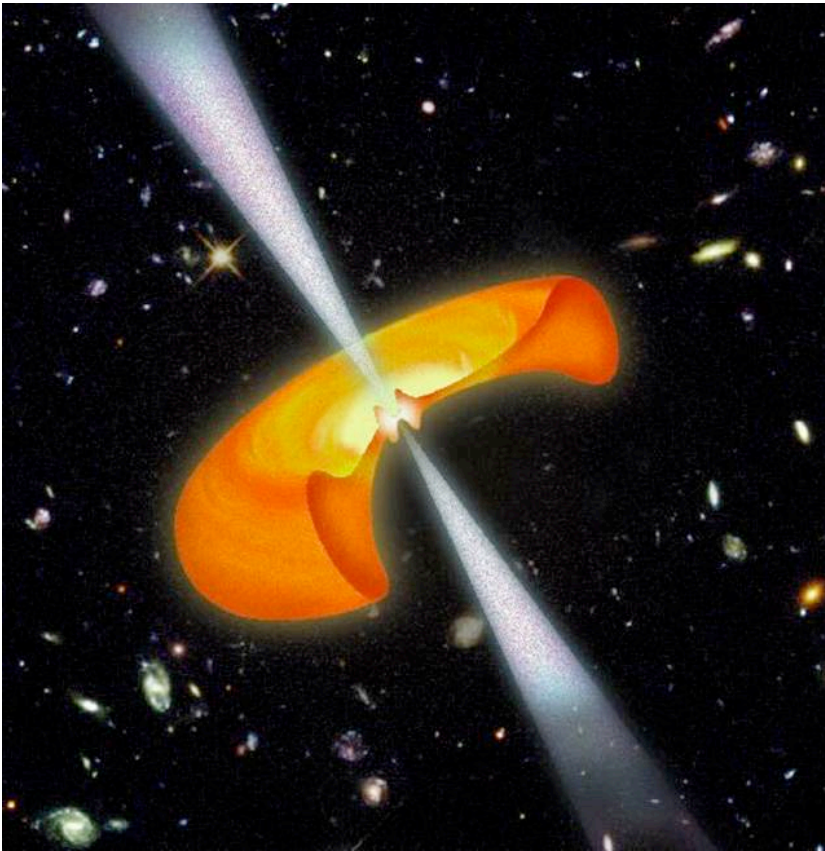
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constellation Orion

# IRAS - AGN dust tori

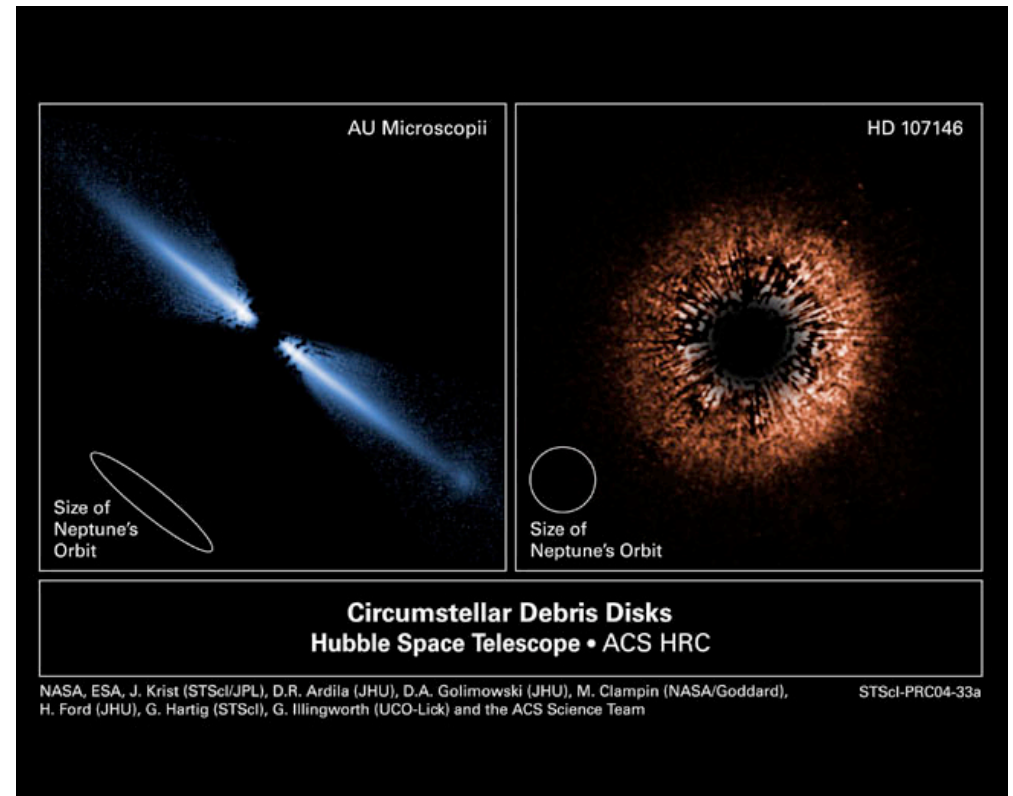
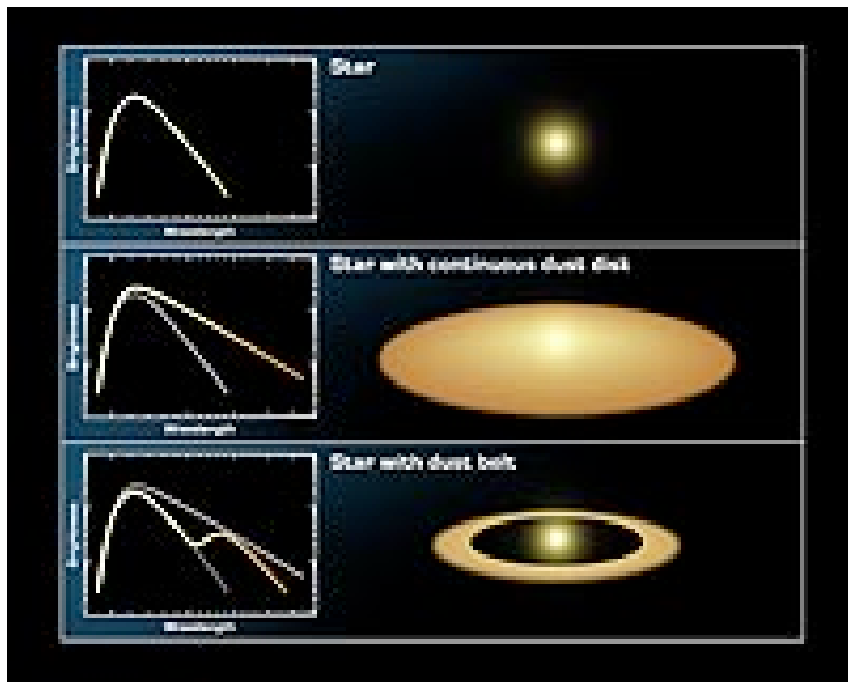
Miley et al, 1984, ApJ 278, L79:  
A 25  $\mu\text{m}$  component in 3C390.3



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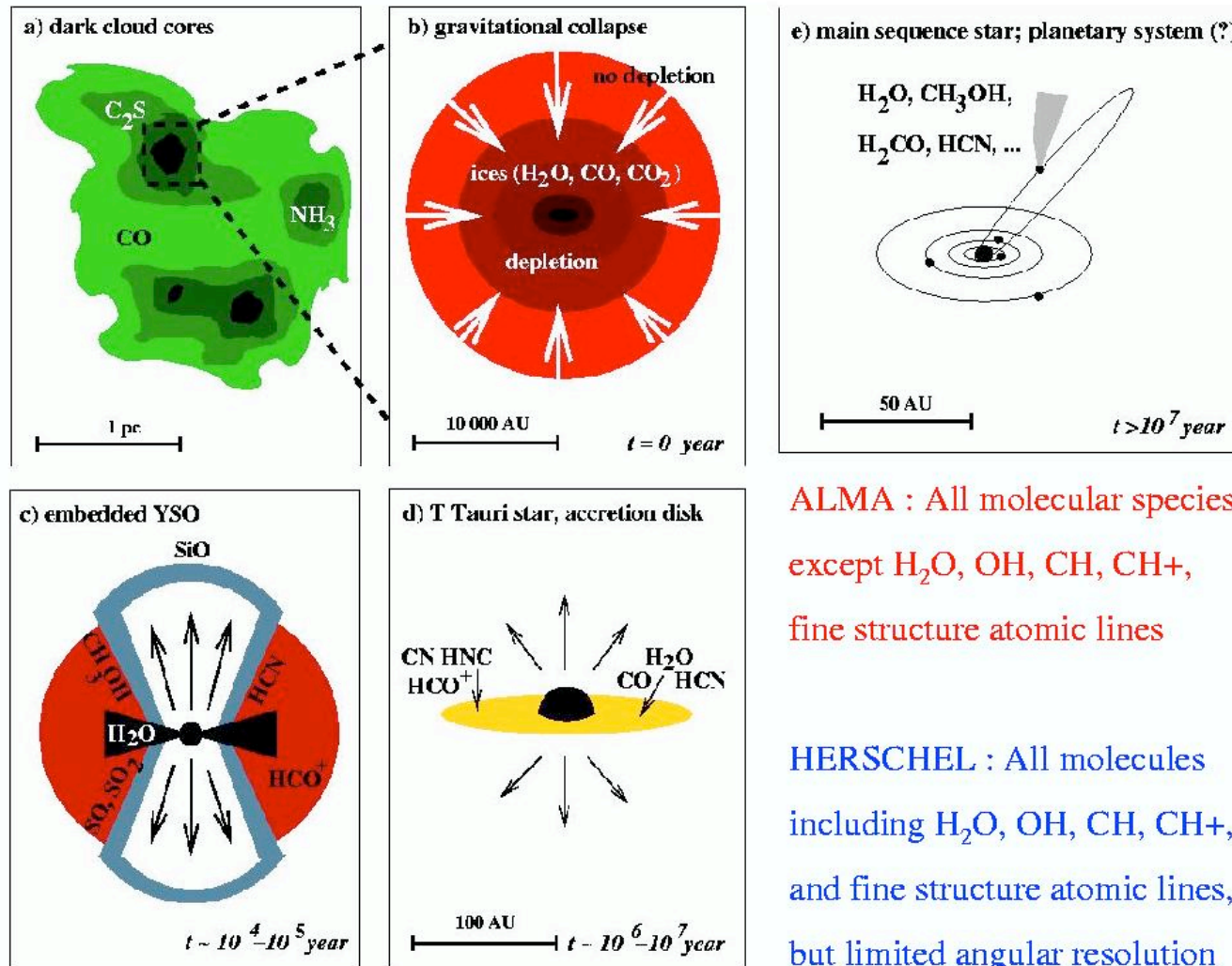
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# IRAS - dust debris disks



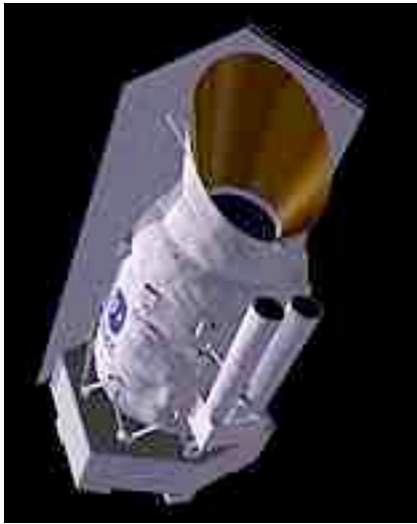


# IRAS - protostars

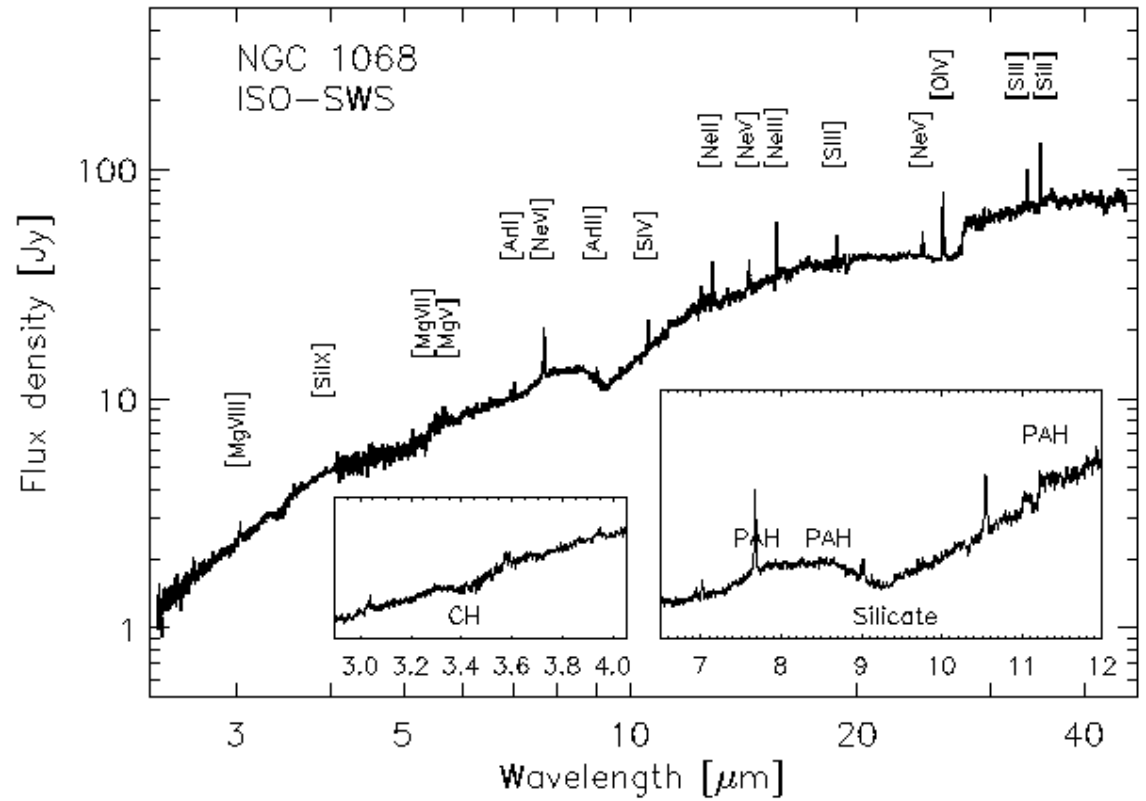
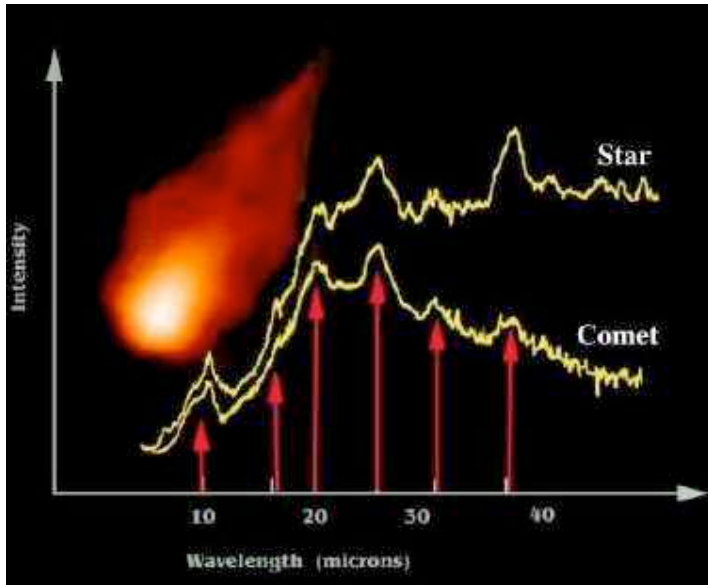
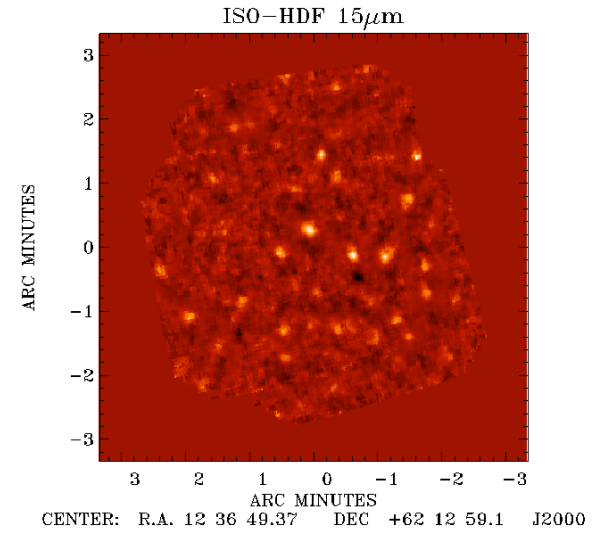


ALMA : All molecular species except  $H_2O$ ,  $OH$ ,  $CH$ ,  $CH^+$ , fine structure atomic lines

HERSCHEL : All molecules including  $H_2O$ ,  $OH$ ,  $CH$ ,  $CH^+$ , and fine structure atomic lines, but limited angular resolution



# ISO

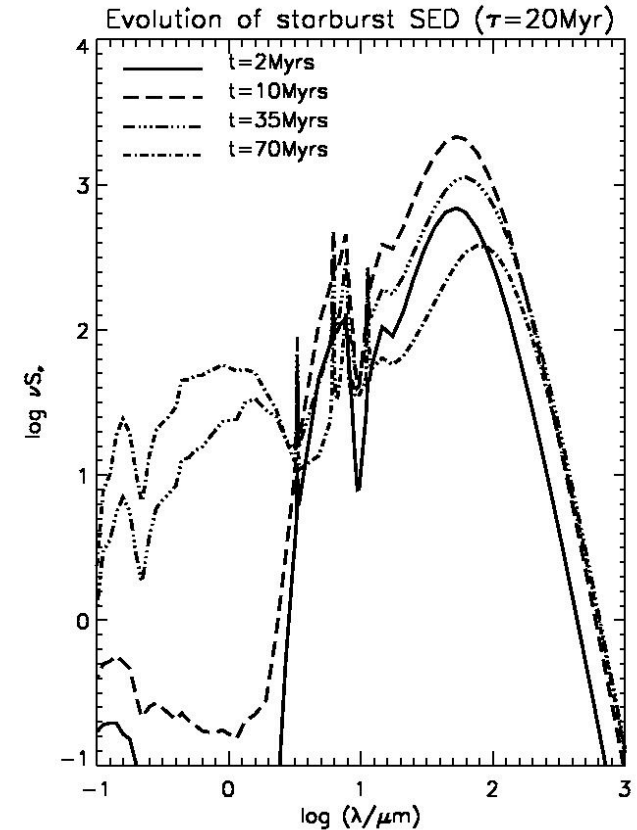
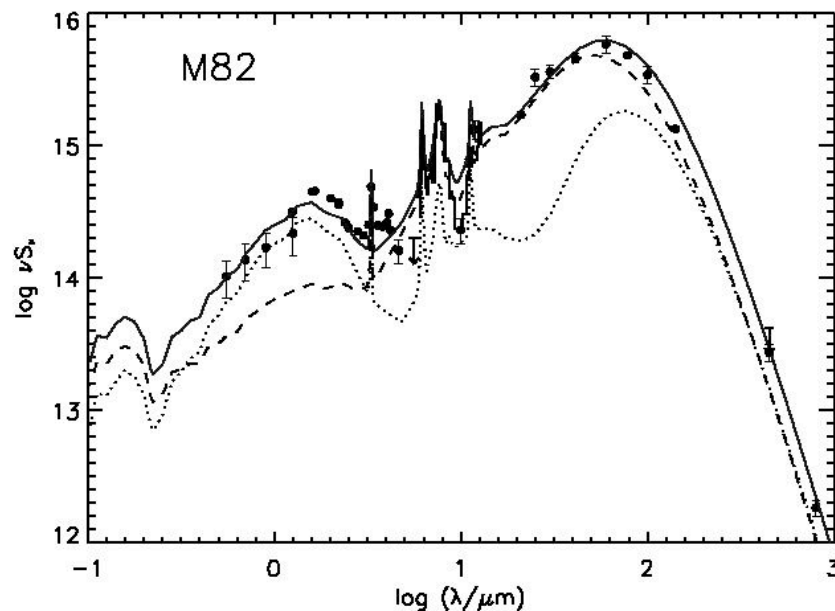


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# Models for starburst galaxies

Eftstathiou, Rowan-Robinson, Seibenmorgen,  
2000, MN 313, 734

- embedded phase,  $t < 10^7$  yrs
- expanding neutral shell,  
 $t = 10^7 - 10^8$  years
- at  $10^8$  yrs, indistinguishable from cirrus

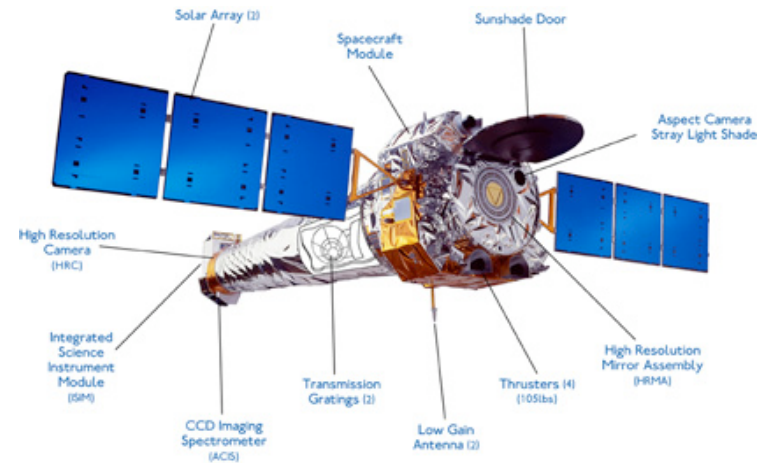


# the NASA Great Observatories



HST  
1990

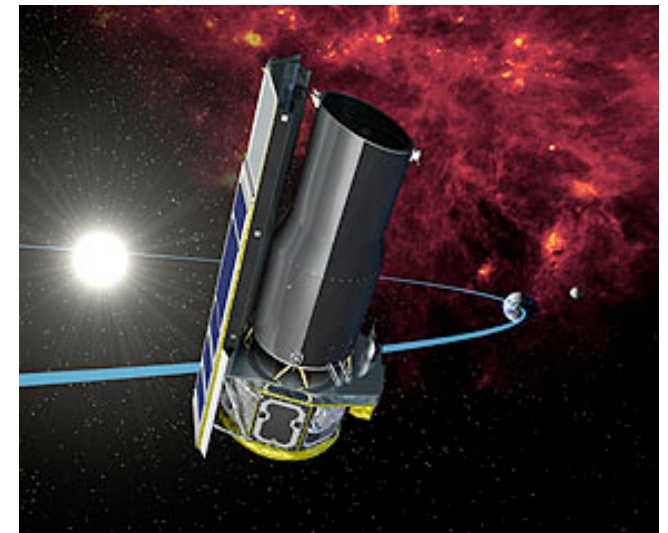
CHANDRA  
1999



COMPTON  
1991

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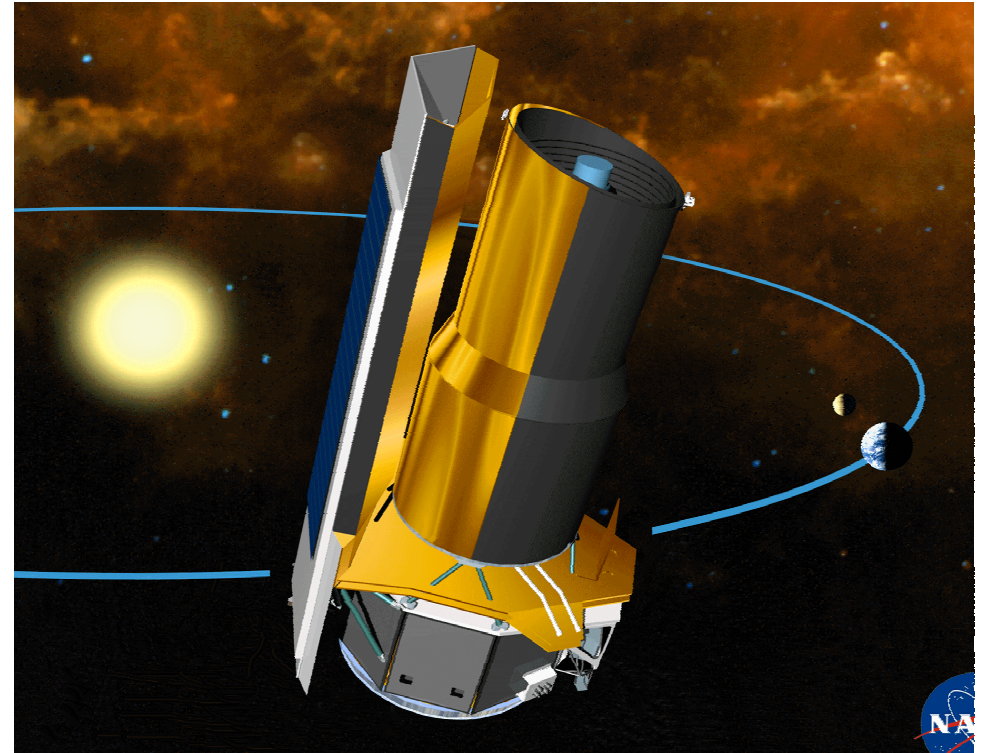
SPITZER  
2003



# SPITZER

M. Werner, Project Scientist: Tom Soifer, Director, SSC

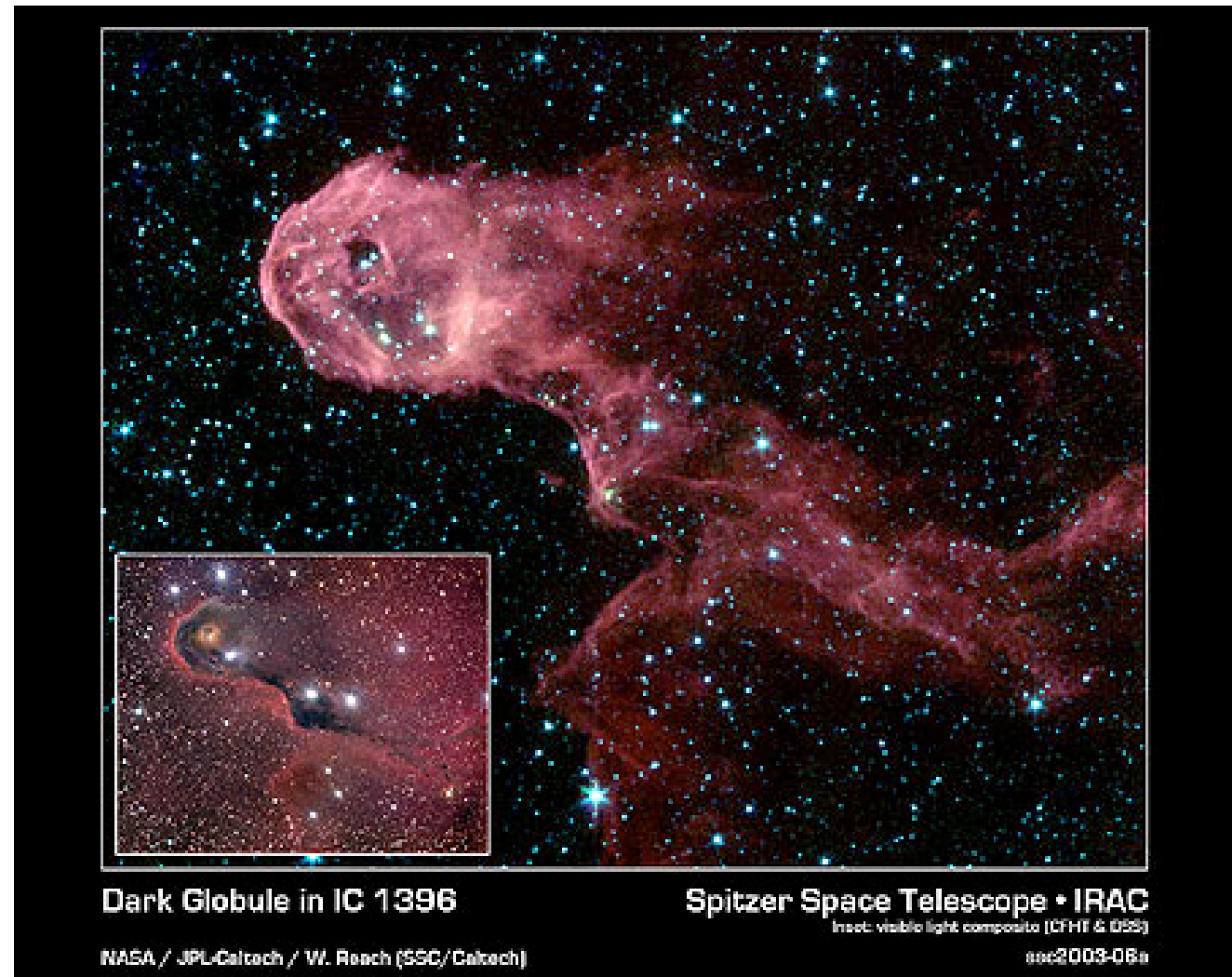
- 85 cm telescope; diffraction limited at  $6.5\mu\text{m}$
- 3 - 160  $\mu\text{m}$
- ~5 yr expected lifetime
- Delta launch: **Aug 23, 2003**
- Earth-trailing orbit: No eclipses or occultations, continuous operations.
- Six Legacy surveys performed during first year, rapid data release
- Science Center at IPAC, Caltech
- Community Time >75%



# IC1396, the Elephant's Trunk

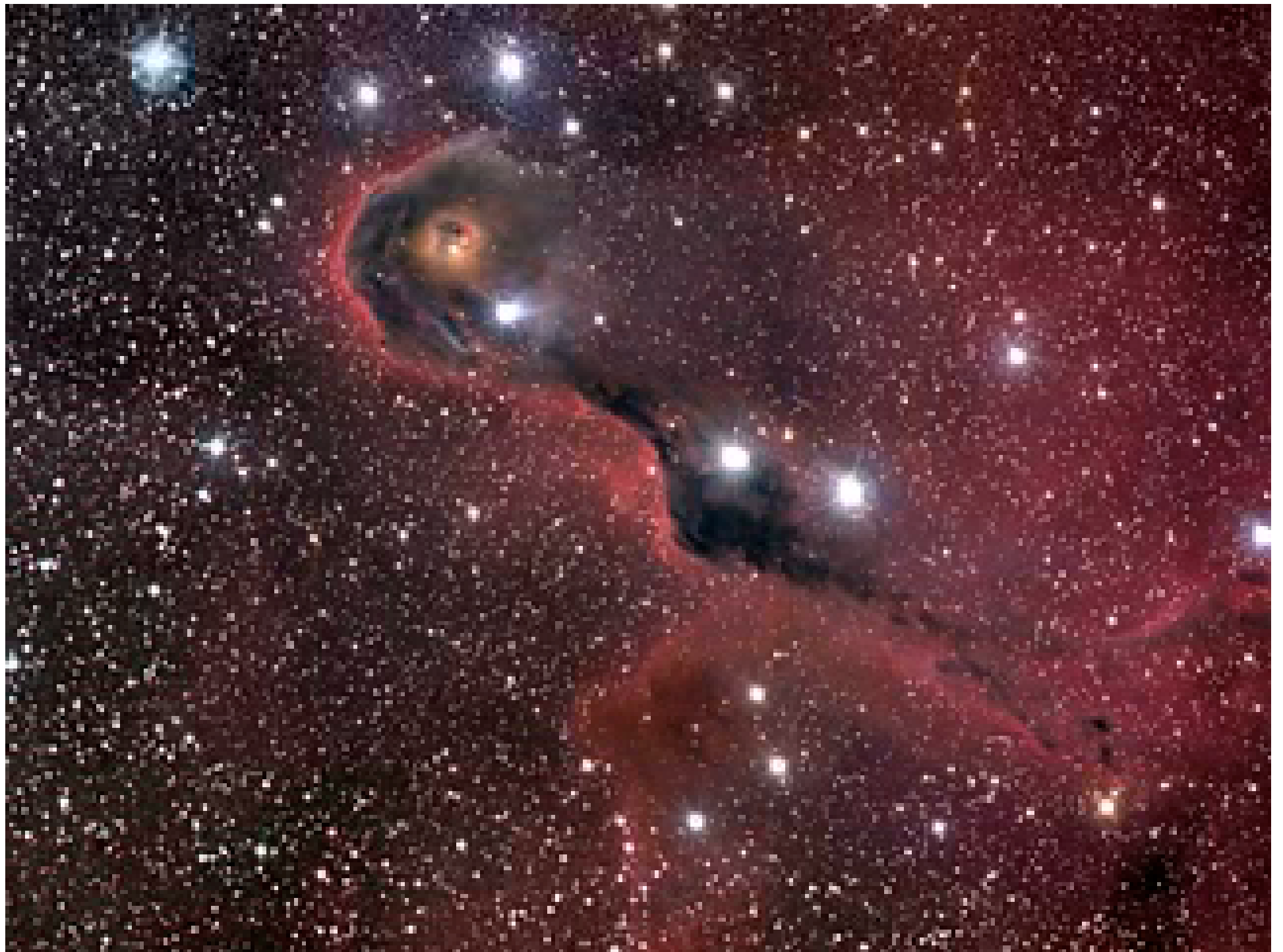
- dark globule  
inside emission  
nebula (ionizing  
star is to left of  
frame)

- pair of newly  
formed stars  
have created  
cavity



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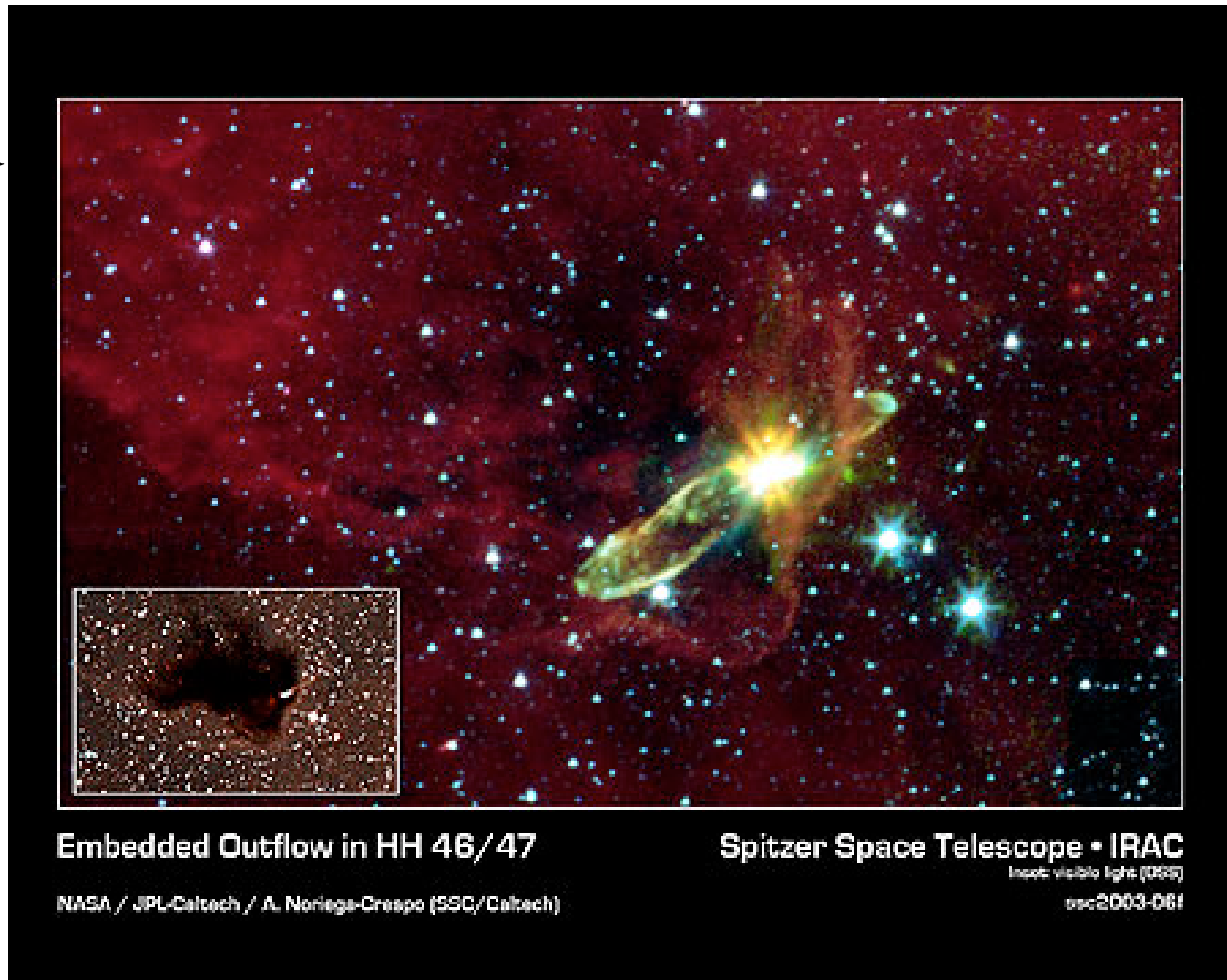


# HH46-47

- protostar with outflows, located in Bok globule,  $d \sim 350$  pc

- composite: 3.6 (blue), 4.5/5.8 (green), 8.0 (red)

- red glow is due to PAHs



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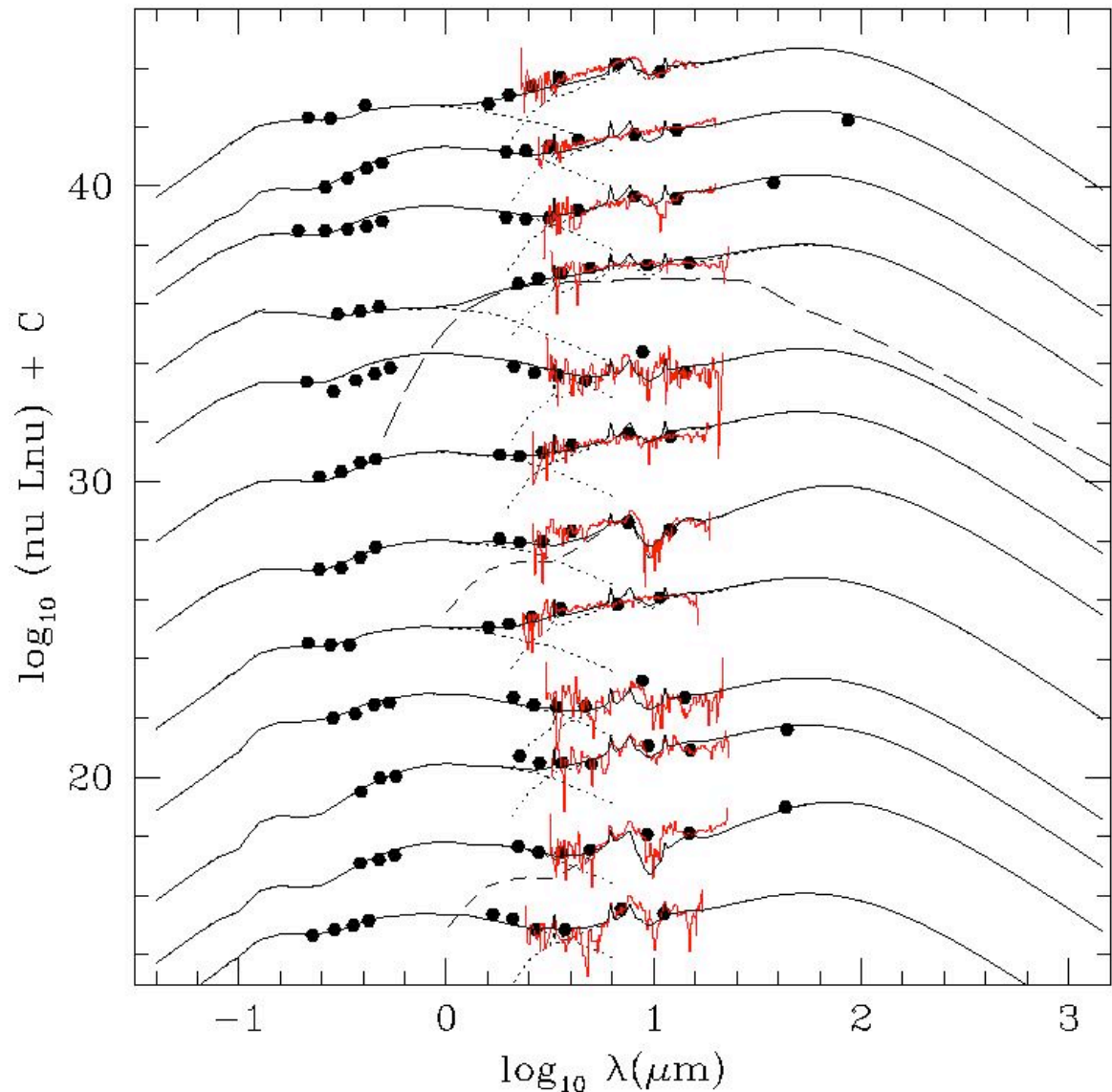
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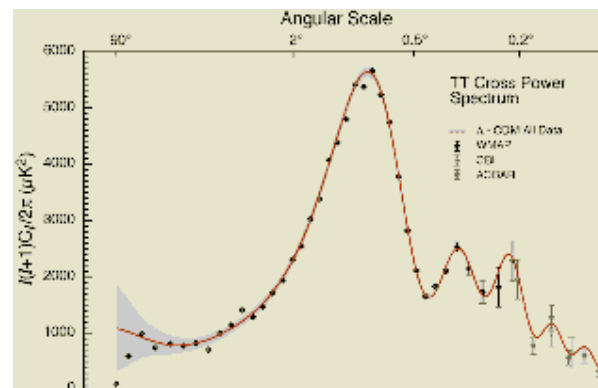
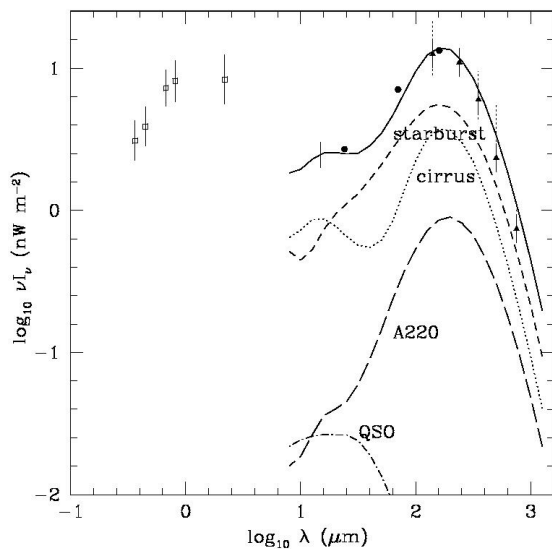
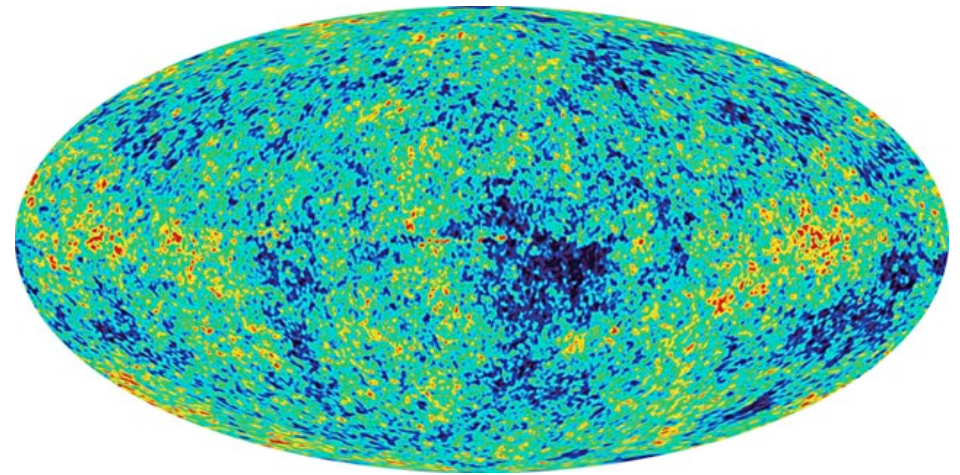
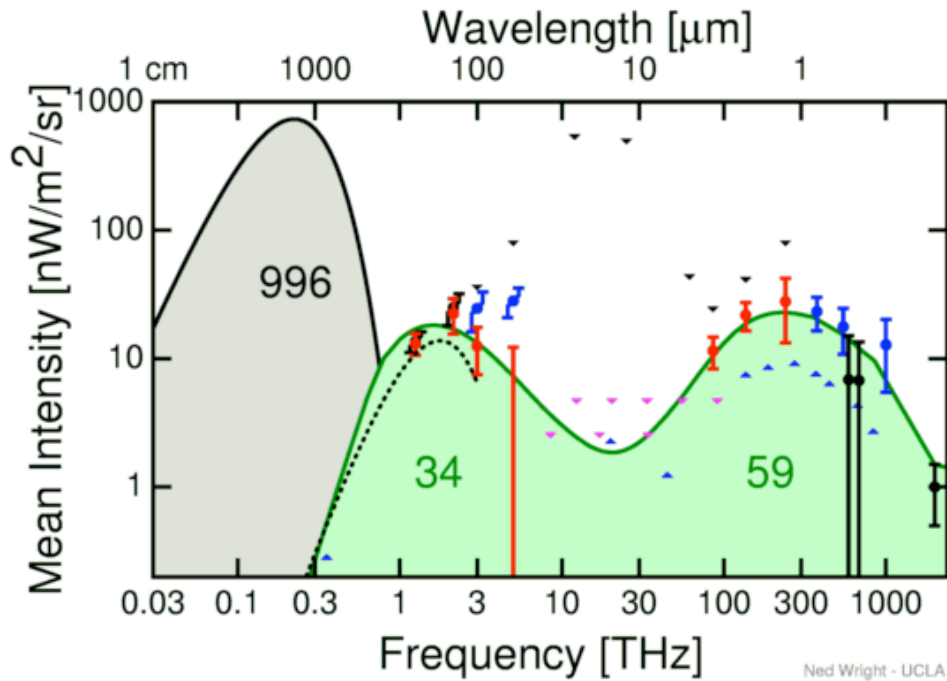
# SPITZER-IRS spectra of ELAIS sources

- IRS spectra for 70 ELAIS-N1 and -N2 sources with  $S_{15} > 1\text{mJy}$  validate the template fits
- most are ULIRGs, with  $z = 1-3$
- Filled circles: optical, ISO, SWIRE ( and MAMBO) data
- Solid curves: model SEDs
- Red curve: calibrated IRS data  
(Hernan-Caballero et al 2006, Perez-Fournon et al, 2006, in prep)

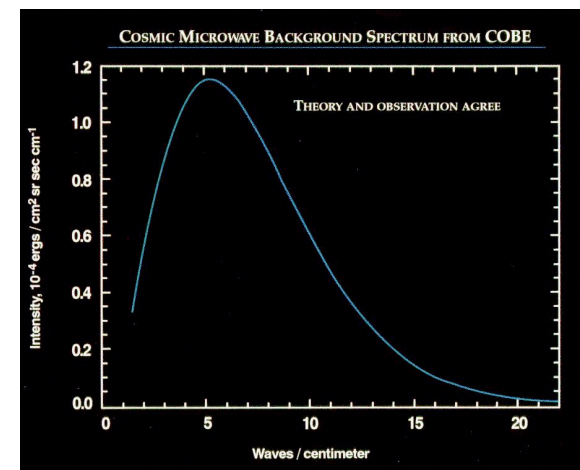


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# Optical, ir and microwave background

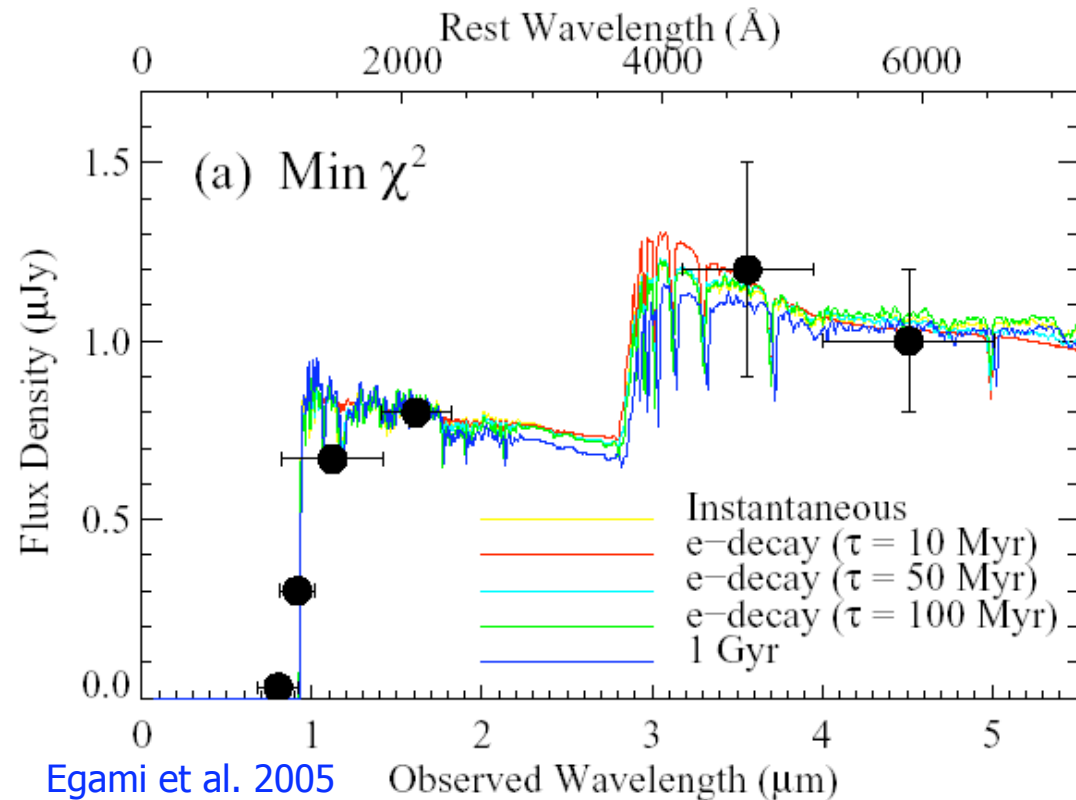


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# Spitzer detection of $z \sim 7$ galaxy

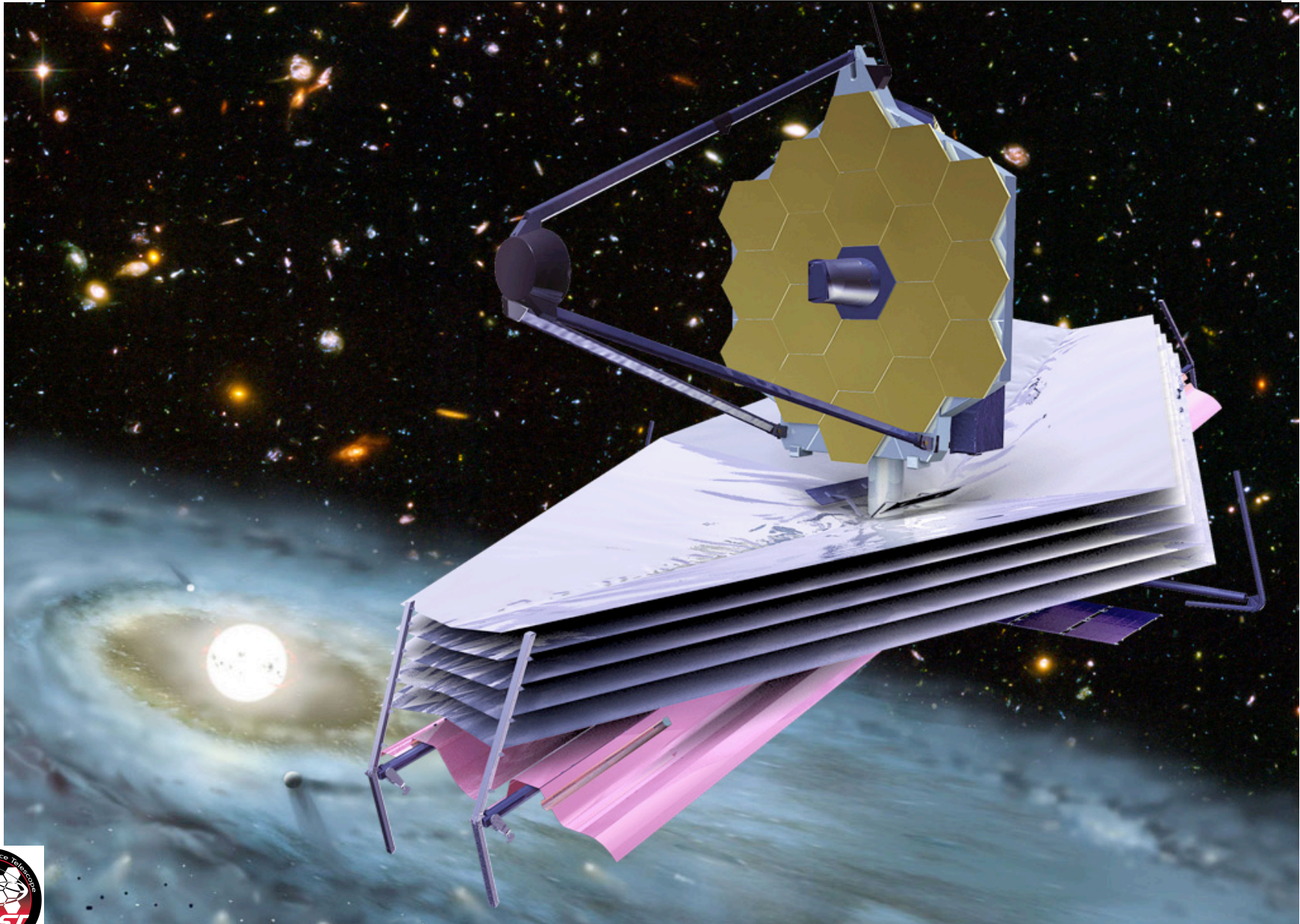
- Spitzer is showing us that galaxies at  $z \sim 7$  formed stars as much as 200-400 million years earlier (around  $z \sim 10$ )
- ➔ Epoch of first star formation now seem likely to have been around  $z \sim 10-15$  from combining Spitzer and WMAP results.





how to detect  $z = 10$  galaxies ?

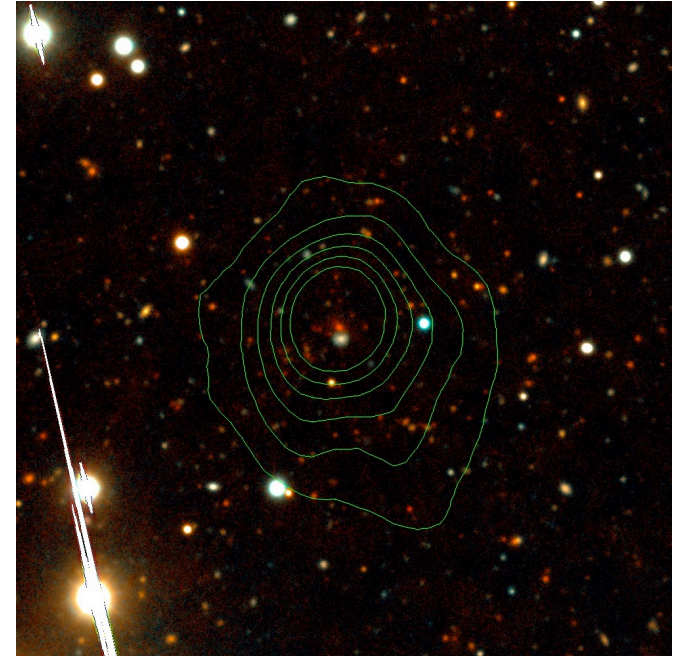
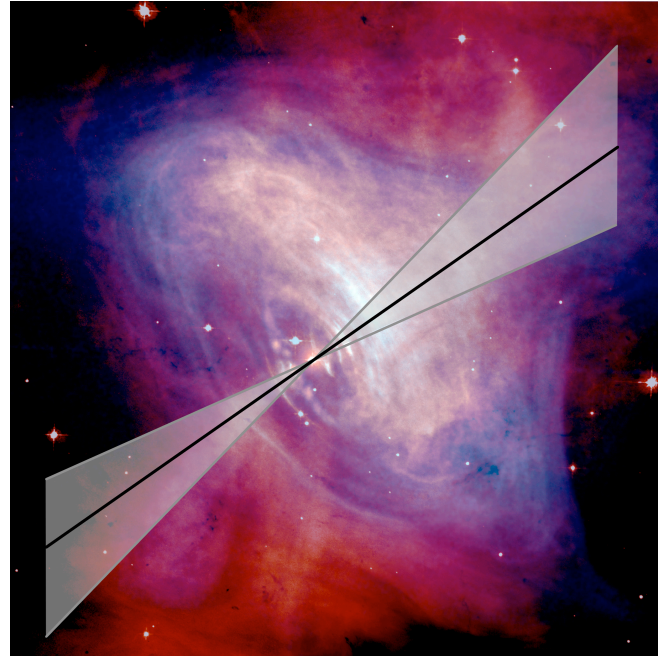
James Webb Space Telescope



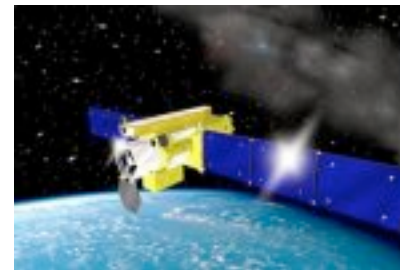
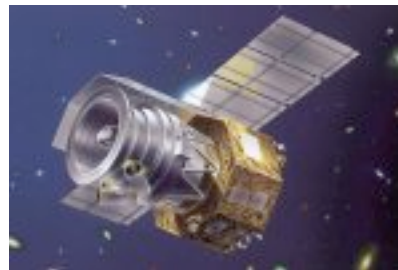


# ESA current missions

Integral  
XMM  
Rosetta  
Venus Express  
Mars Express  
Cluster  
Soho



HST (US)  
Cassini-Huygens (US)  
Double Star (China)  
Akari (J)  
Hinode (J)  
Corot (F)

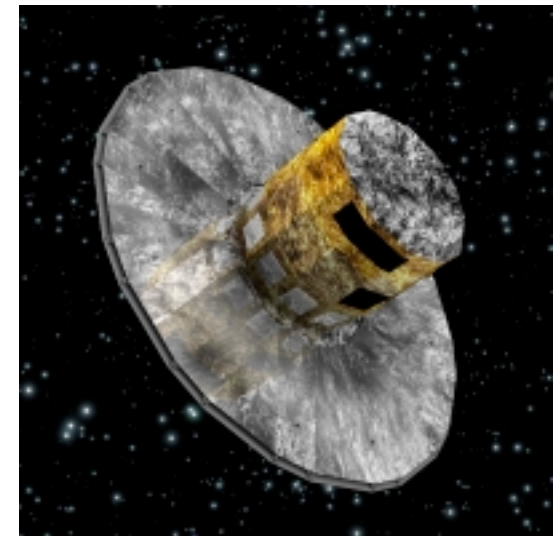
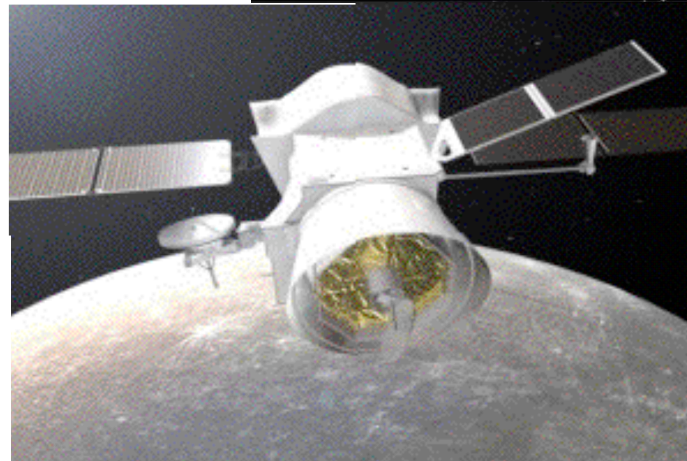
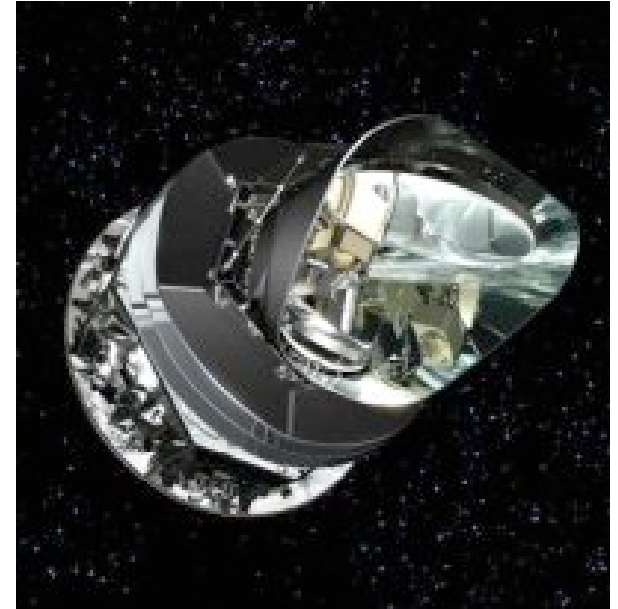


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# ESA development

Herschel Mar 2009  
Planck Mar 2009  
BepiColumbo Aug 2013  
GAIA Dec 2011  
  
JWST June 2013 (US)



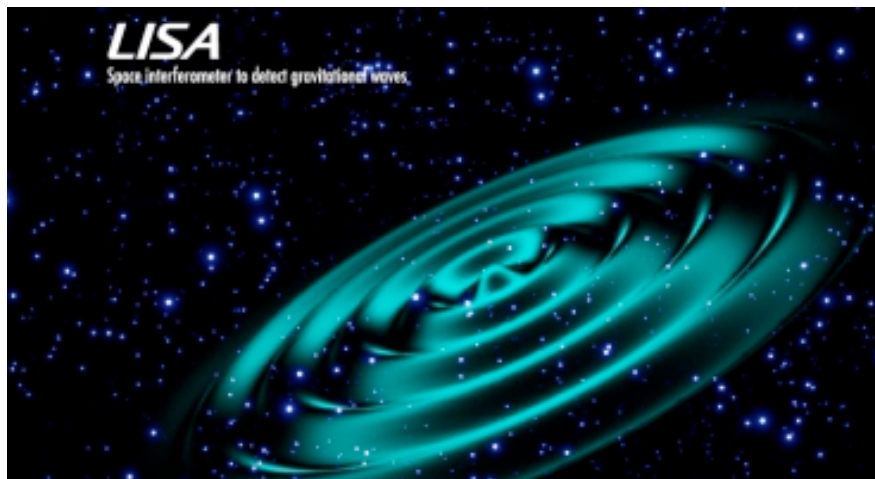
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# ESA COSMIC VISIONS

L- Laplace  
/Tandem  
LISA  
Xeus



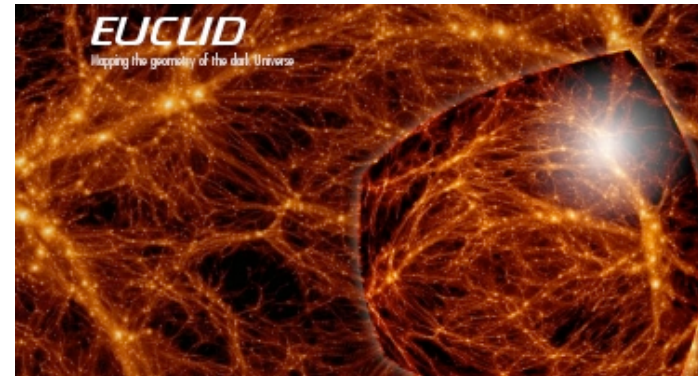
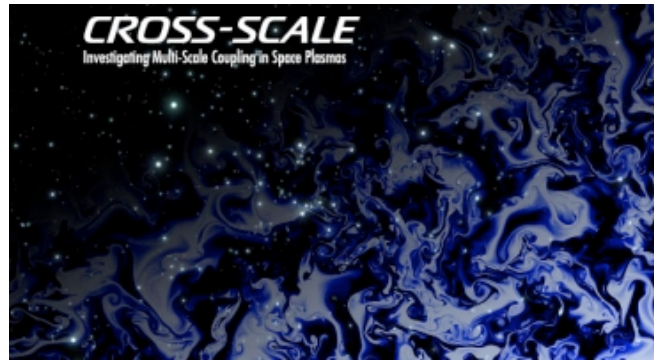
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# ESA COSMIC VISIONS

M- Euclid  
CrossScale  
MarcoPolo  
Plato



Spica (J)



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# NASA Astro current missions

Chandra

Fermi

Galex

HST

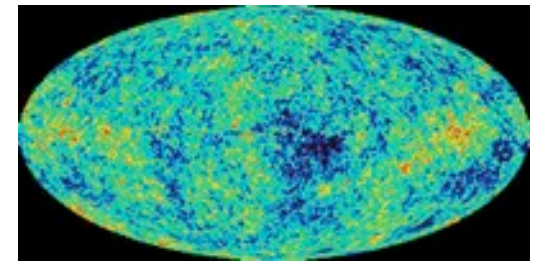
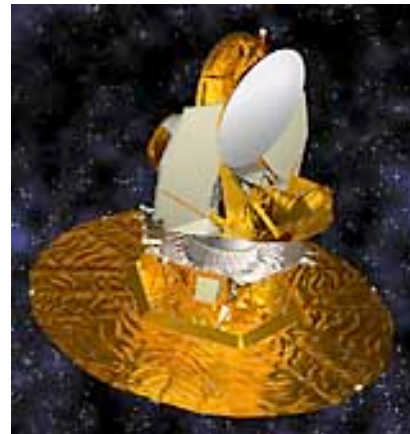
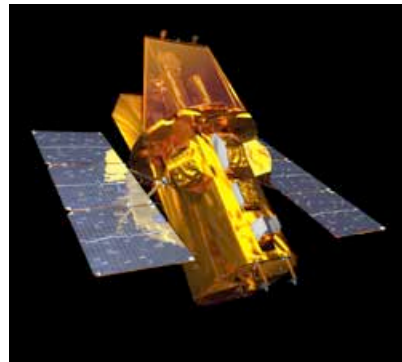
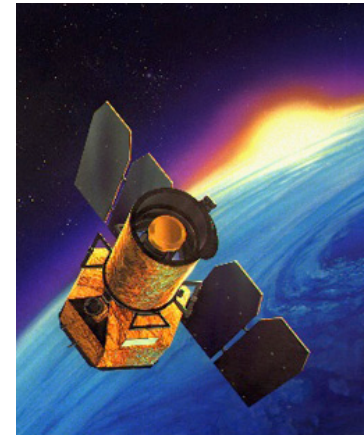
Rossi

Spitzer

Swift

WMAP

Suzaku (J)



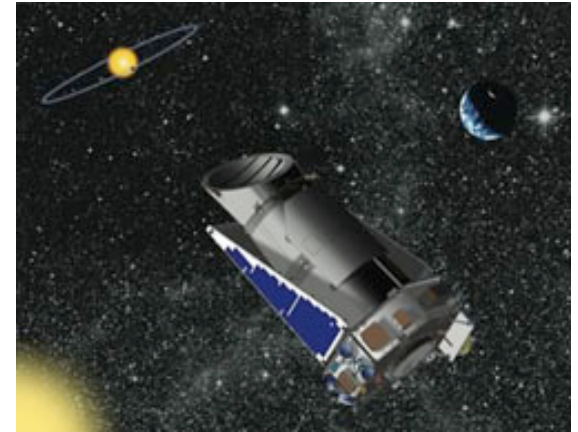
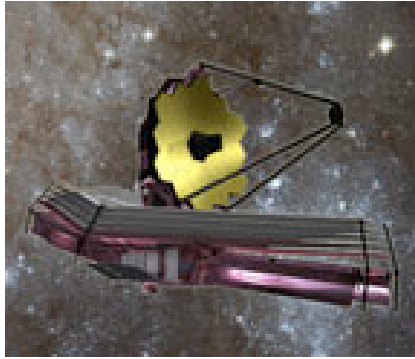
# NASA Astro development

JWST June 30, 2013

Kepler Feb 16, 2009

Sofia June 1, 2009

WISE Nov 2, 2009



Herschel Mar 2009 (ESA)

Planck Mar 2009 (ESA)



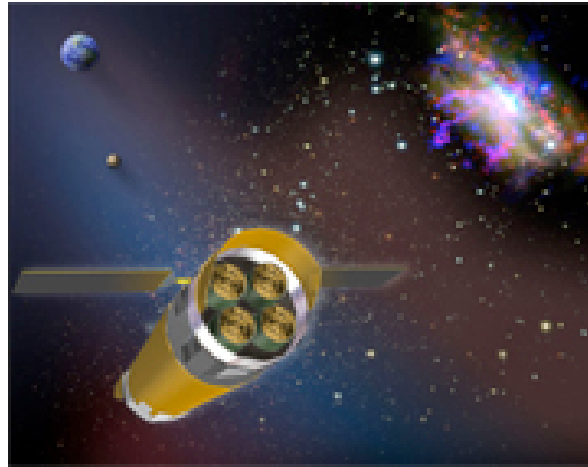
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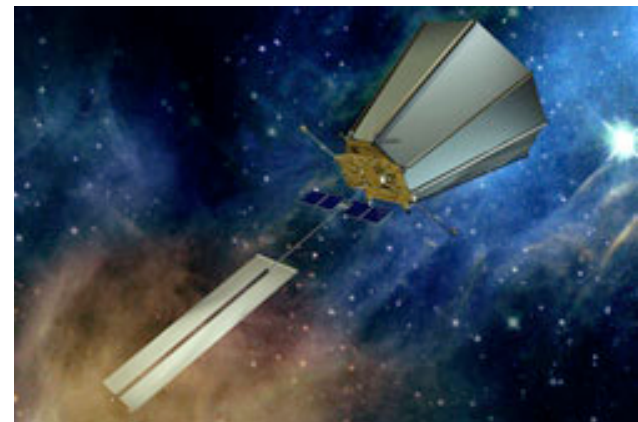
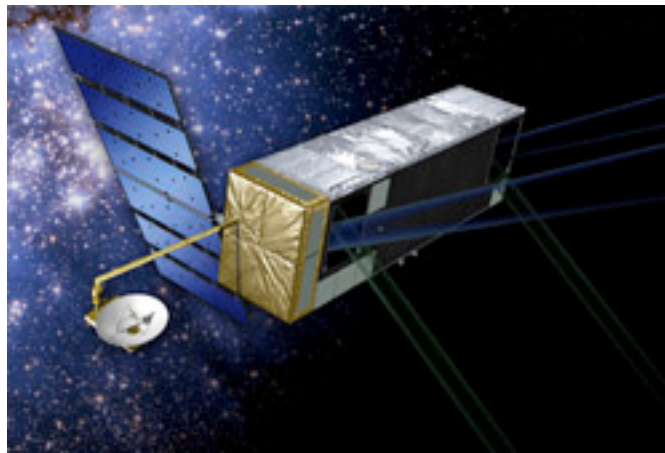


# NASA Astro study

Constellation-X  
JDEM  
NuSTAR  
SIM  
TPF



LISA (ESA)



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# ESA news

\* Invitations to tender have been issued for Cosmic Visions M-missions, for L-missions later this year

- HST Service Mission 4, due for launch Oct 8th, will instal New WFC3, Cosmic Origins Spectrograph, gyros, batteries  
- will try to fix STIS (failed Oct 04), and ACS (failed early 07)

\* Bepi Columbo mass problem, need to switch to Ariane 5 with increased cost, narrow vote not to cancel

- new Directorate of Science (mandatory) and Robotic Exploration (optional), Director David Southwood

# Further reading

NASA and ESA web pages

Google to find web page for each of these space missions

NED, IRSA, Astrogrid for links to data archives (also individual data archives for many of these missions)

*Cosmic Landscape*, M.Rowan-Robinson (OUP 1979) for popular account of early history