The Origin of Stars

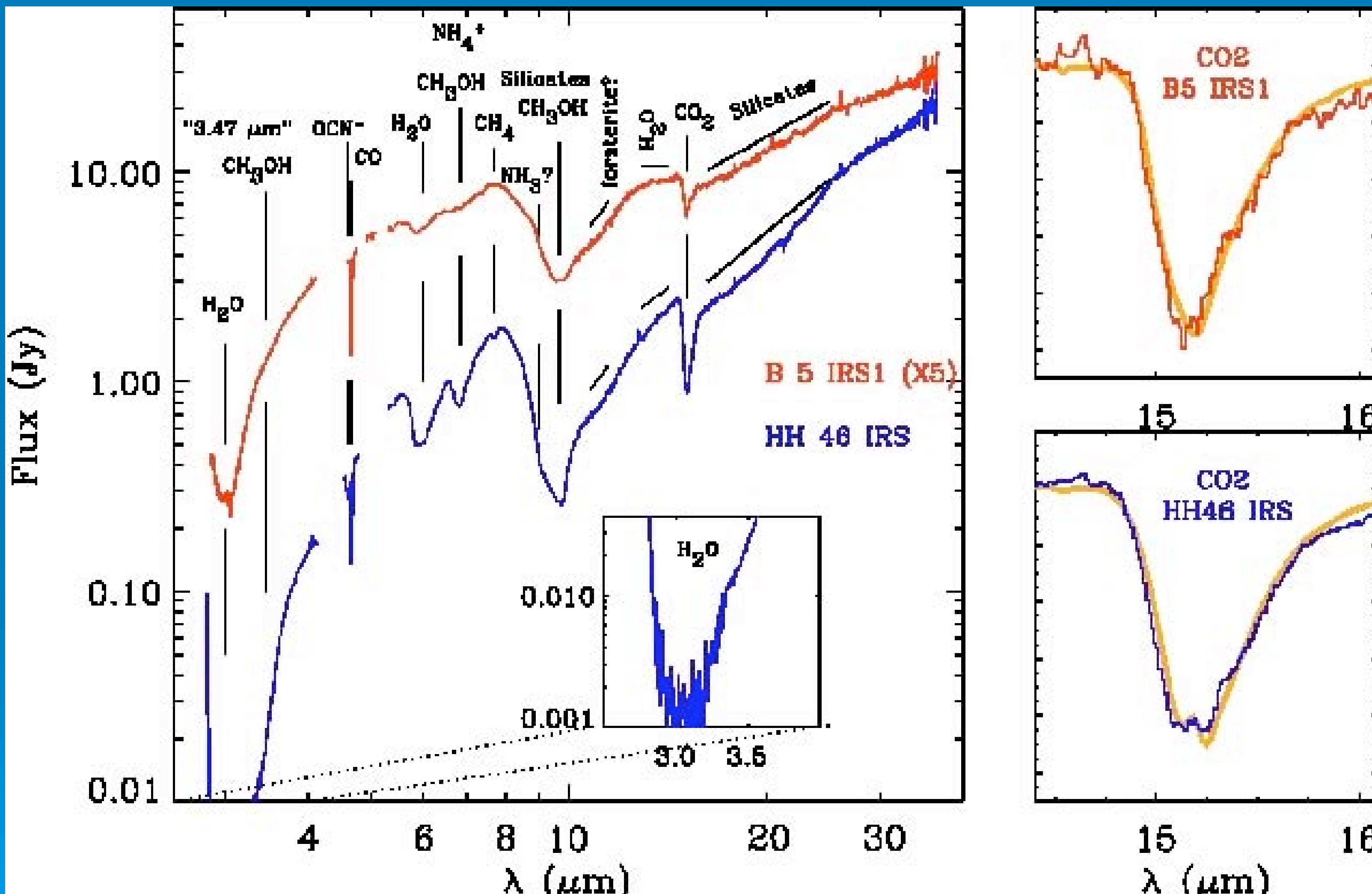
Current Star Formation

Molecular Clouds

- Composition
  - H_2 (93%), He (6%)
  - Dust and other molecules (~1%)
    - CO next most common after H_2, He
- Temperature about 10 K
- Density (particles per cubic cm)
  - ~100 cm^{-3} to 10^6 cm^{-3}
  - Air has about 10^{19} cm^{-3}
  - Water about 3×10^{22} cm^{-3}
- Size 1-300 ly
- Mass 1 to 10^6 M_{sun}

A Small Molecular Cloud

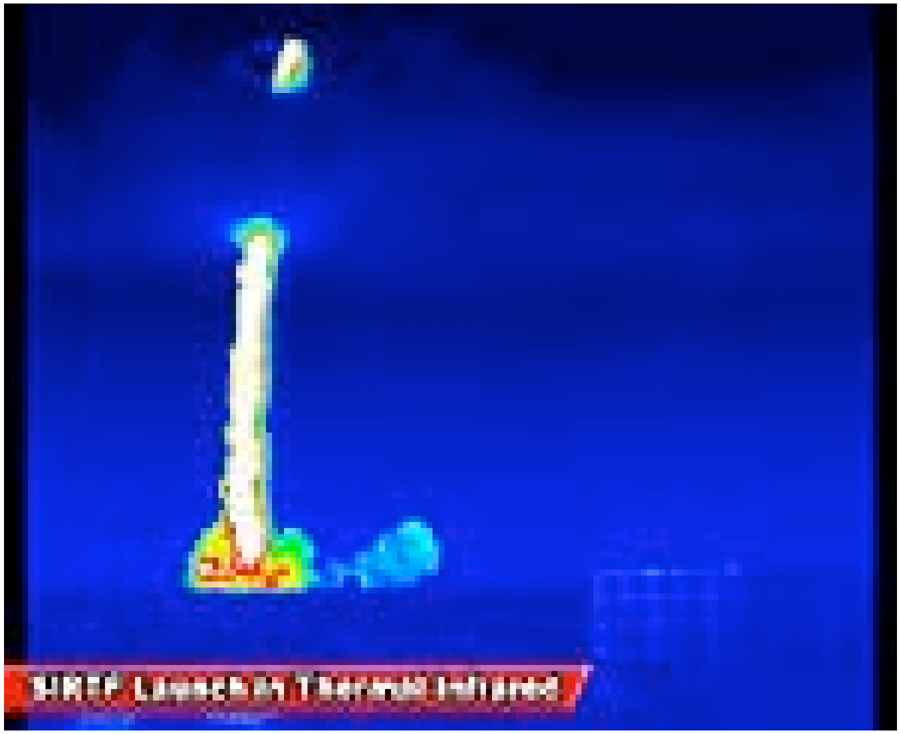
Ices on Dust Grains



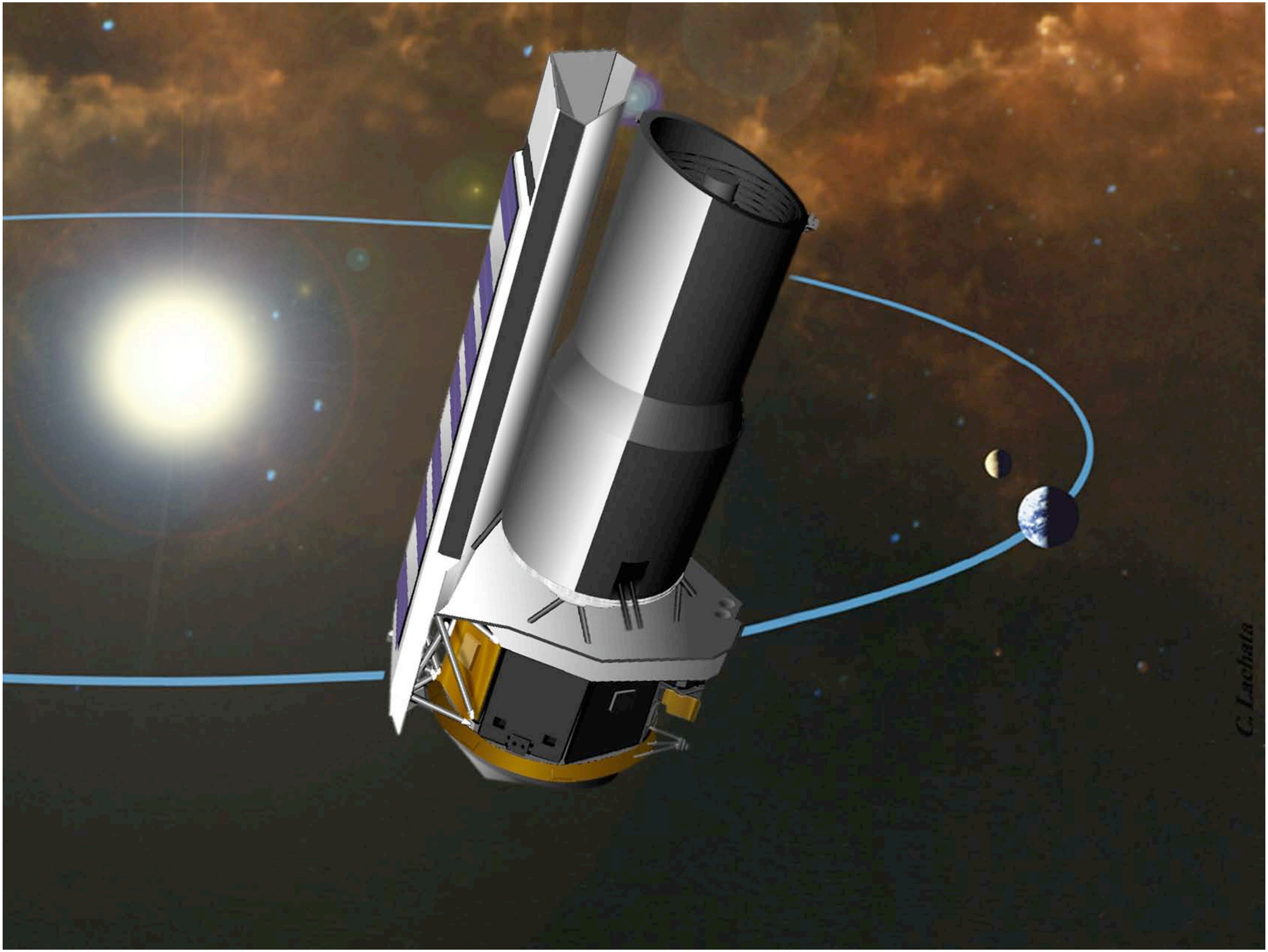
Current Star Formation

- Occurs in gas with heavy elements
  - Molecules and dust keep gas cool
  - Radiate energy released by collapse
  - Stars of lower mass can form
  - Mass needed for collapse increases with T
- Star formation is ongoing in our Galaxy
  - Massive stars are short-lived
  - Star formation observed in infrared

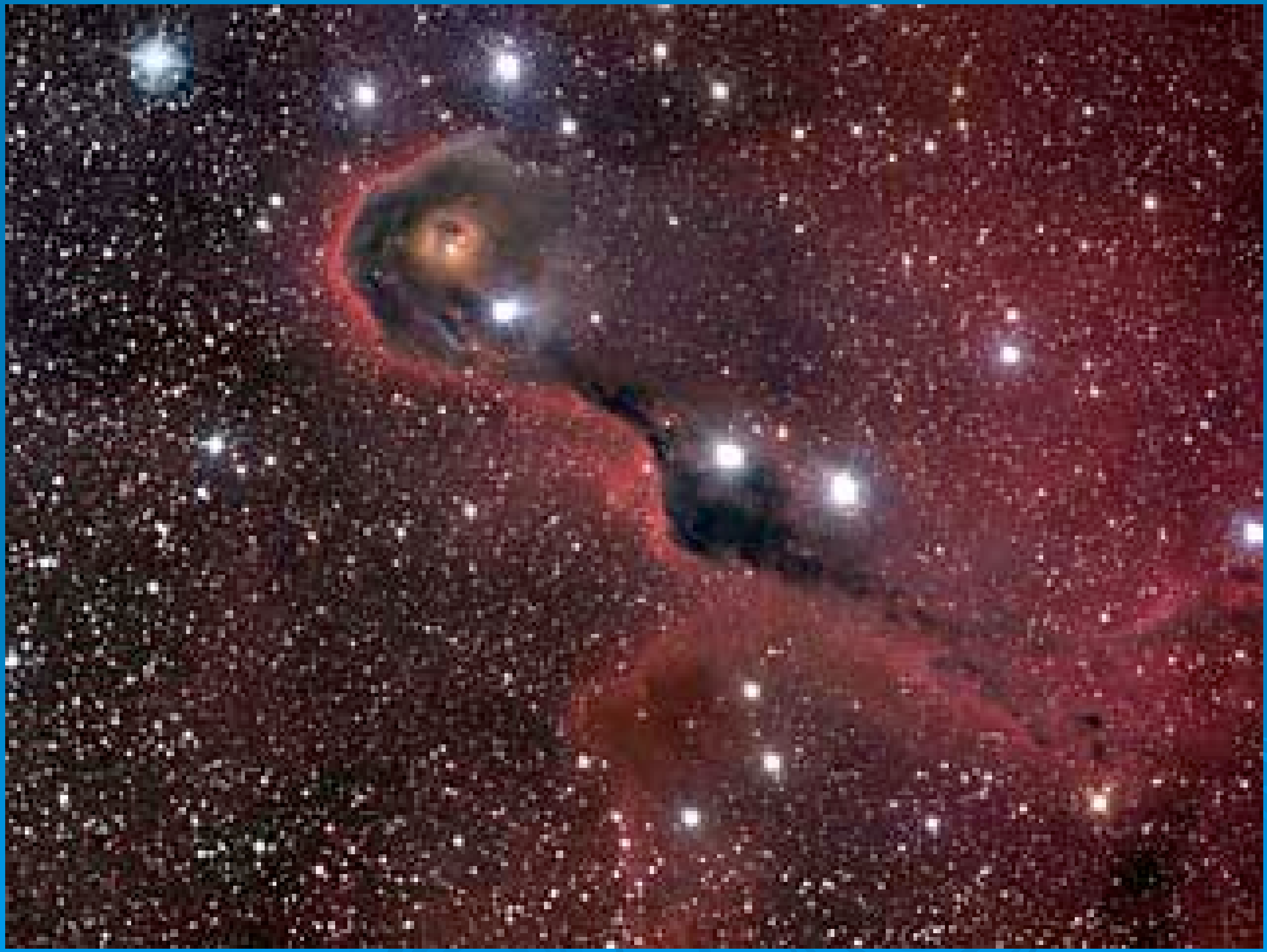
JPL The Launch of The Spitzer Space Telescope SIRTF



Spitzer Space Telescope Launched Aug. 2003, expect a 5 yr life.

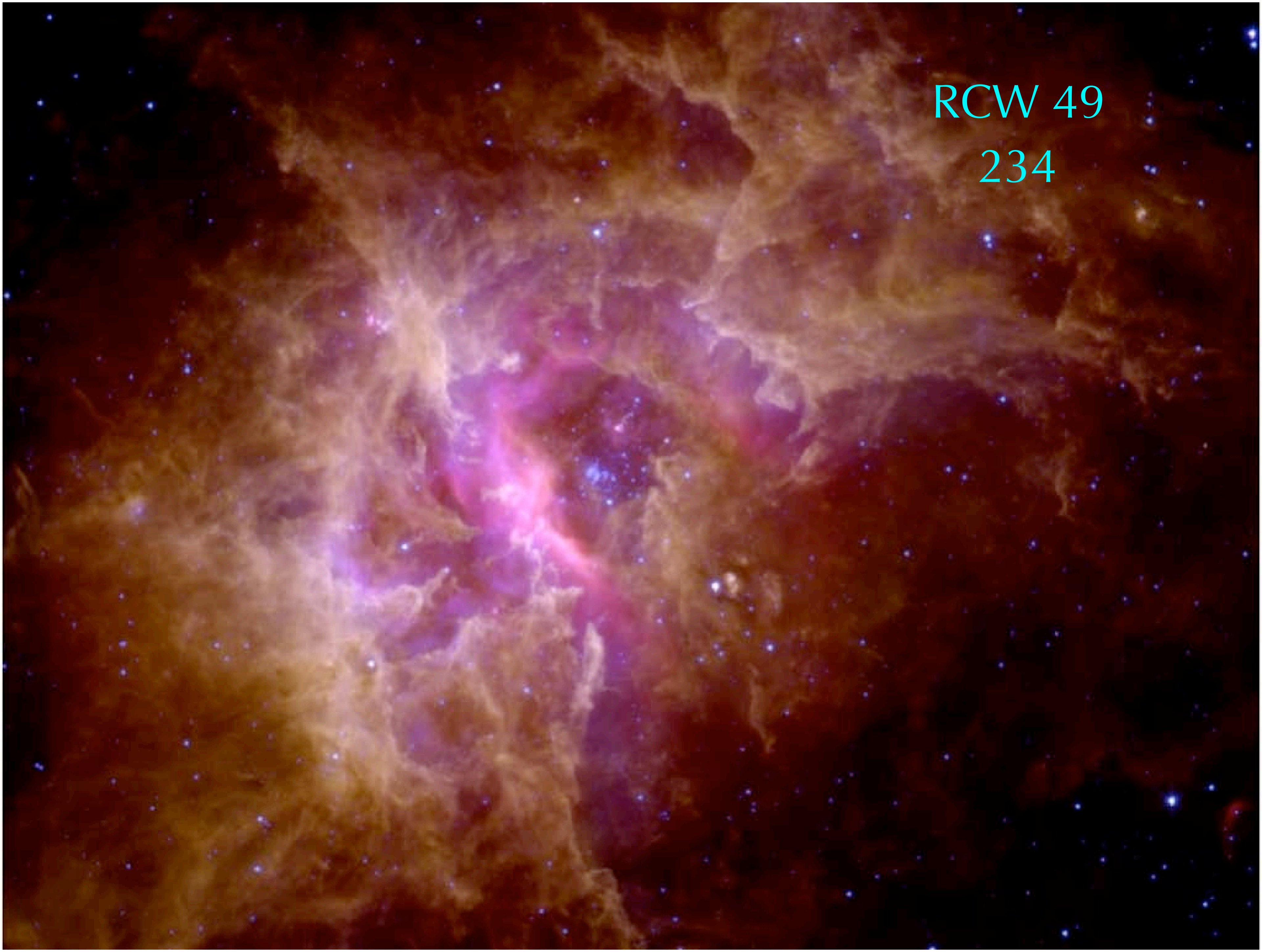

C. Lachata

Visible to Infrared Views

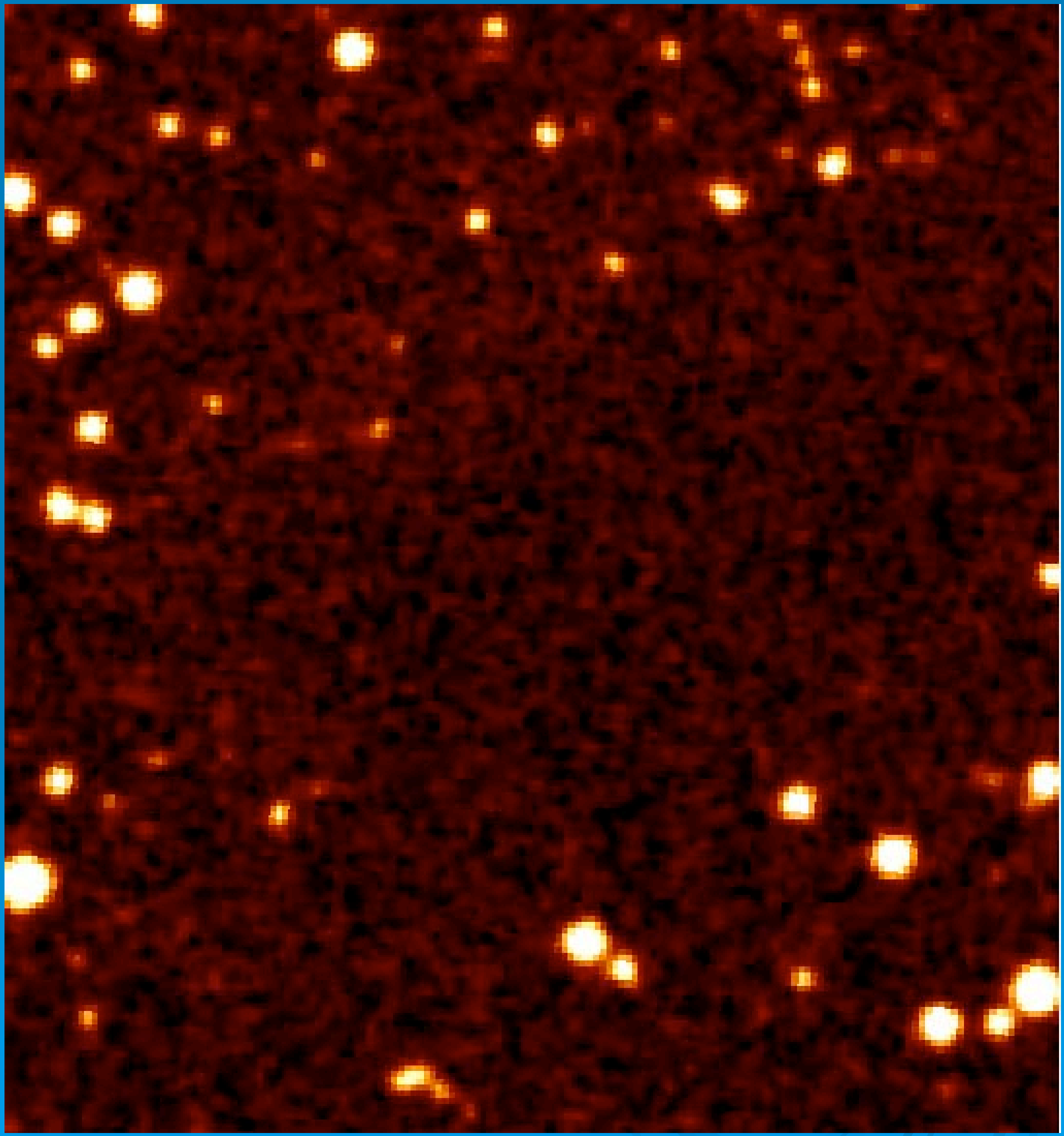



RCW 49
JHK
(2MASS)


RCW 49
HK1


RCW 49
234

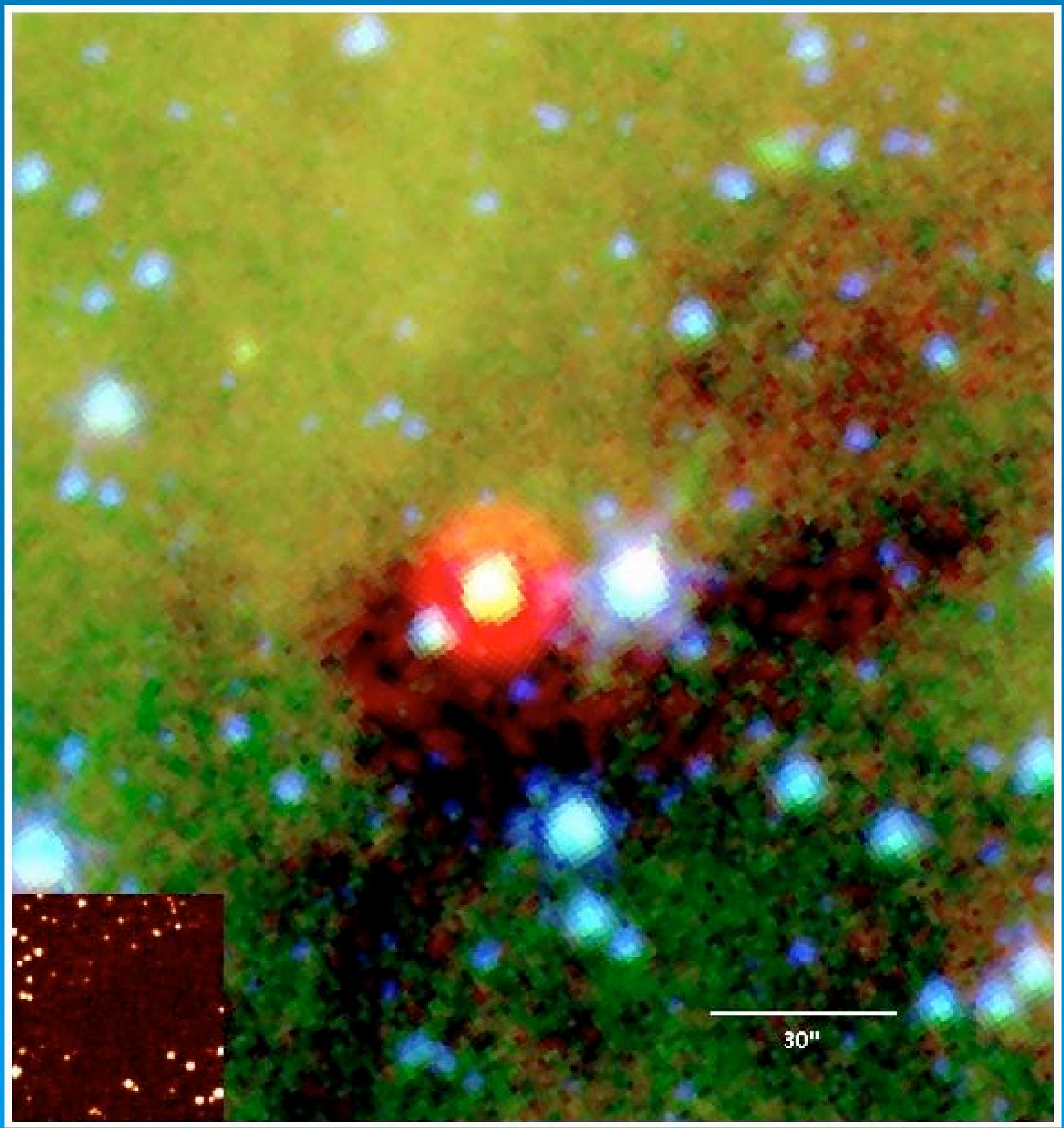
A Dark Molecular Cloud



L1014 distance ~ 600 ly, but somewhat uncertain.

Red light image;dust blocks stars behind and our view of what goes on inside.

Forming Star Seen in Infrared



Three Color Composite:
Blue = 3.6 microns
Green = 8.0 microns
Red = 24 microns

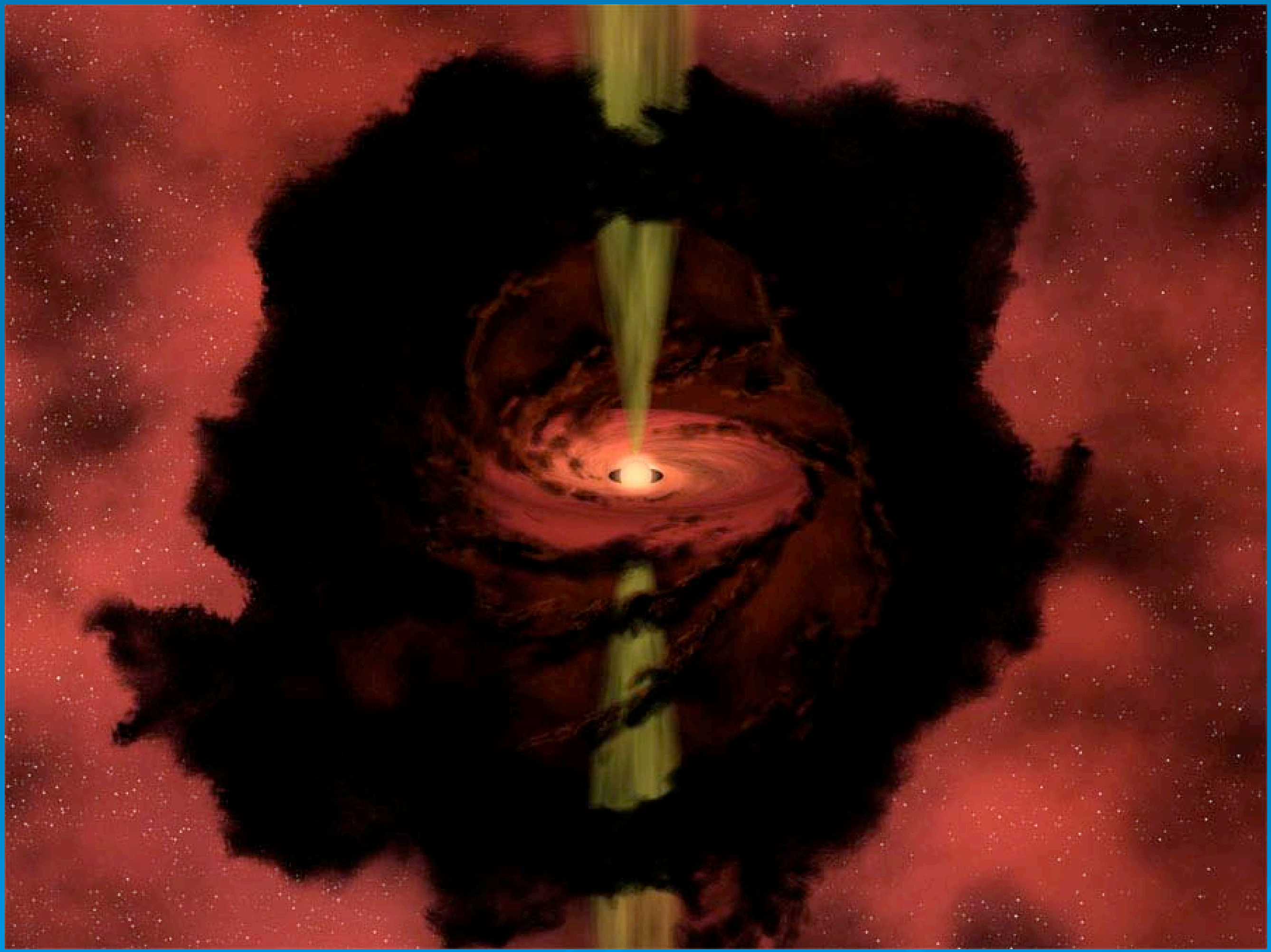
R-band image from DSS at Lower left.

We see many stars through the cloud not seen in R. The central source is NOT a background star.

L1014 is forming a star

C. Young et al. ApJS, 154, 396

Artist's Conception



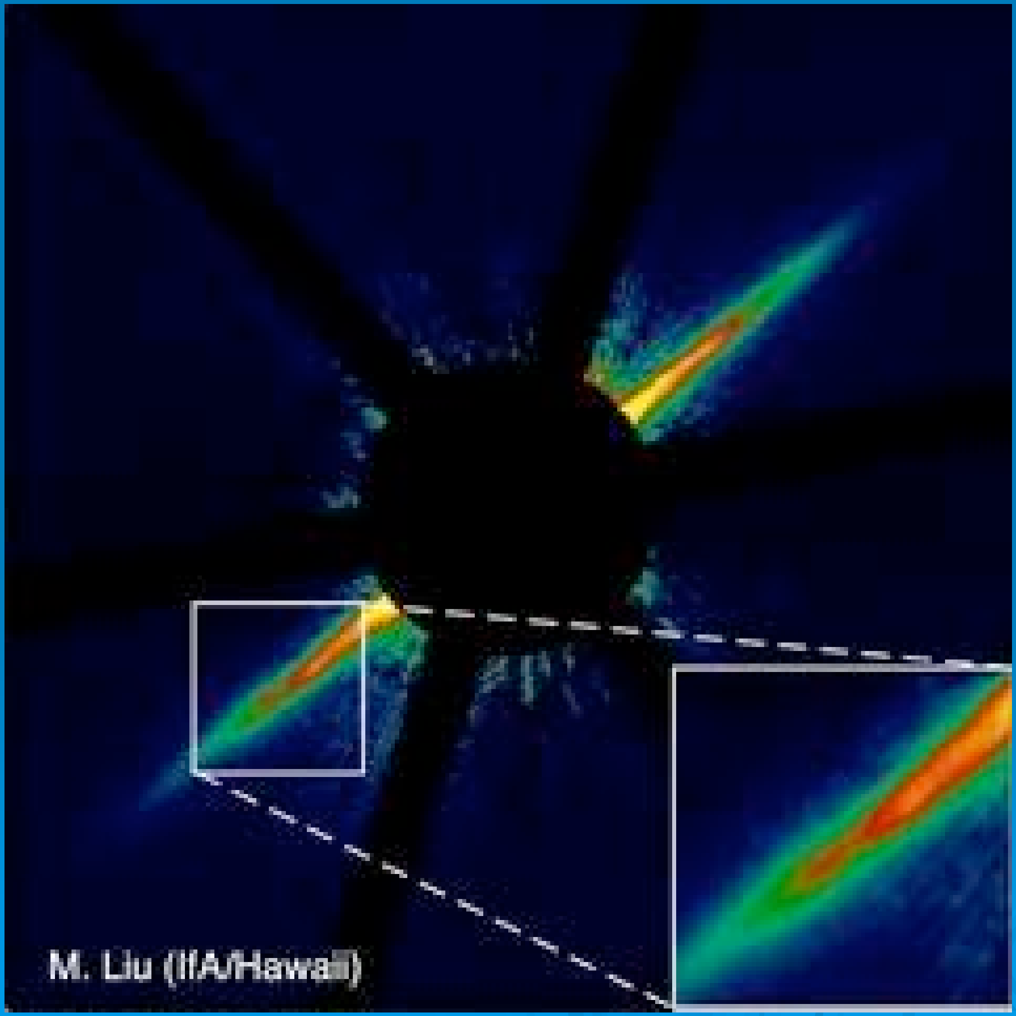
Features:
Dusty envelope
Rotation
Disk
Bipolar outflow

R. Hurt, SSC

The Protostar

- Evolution of the collapsing gas cloud
  - At first, collapsing gas stays cool
  - Dust, gas emit photons, remove energy
  - At $n \sim 10^{11}$ cm^{-3}, photons trapped
  - Gas heats up, dust destroyed, pressure rises
  - Core stops collapsing
  - The outer parts still falling in, adding mass
  - Core shrinks slowly, heats up
  - Fusion begins at $T \sim 10^7$ K
  - Protostar becomes a main-sequence star

The Disk



The Star (AU Mic) is blocked in a coronograph. Allows you to see disk. Dust in disk is heated by star and emits in infrared.

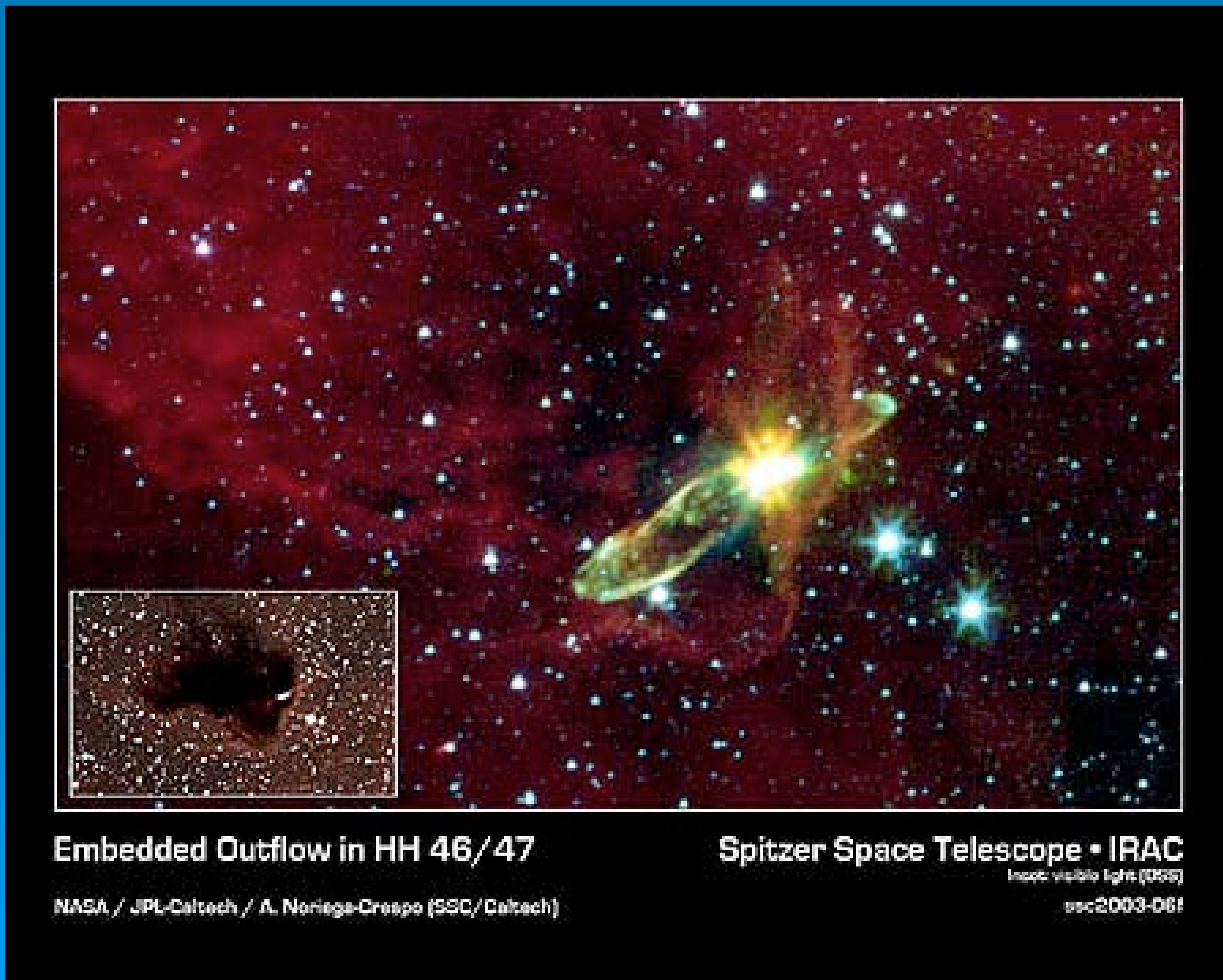
Angular Momentum

- Measure of tendency to rotate
  - $J = mvr$
- Angular momentum is conserved
  - J = constant
  - As gas contracts (r smaller), v increases
  - Faster rotation resists collapse
  - Gas settles into rotating disk
  - Protostar adds mass through the disk

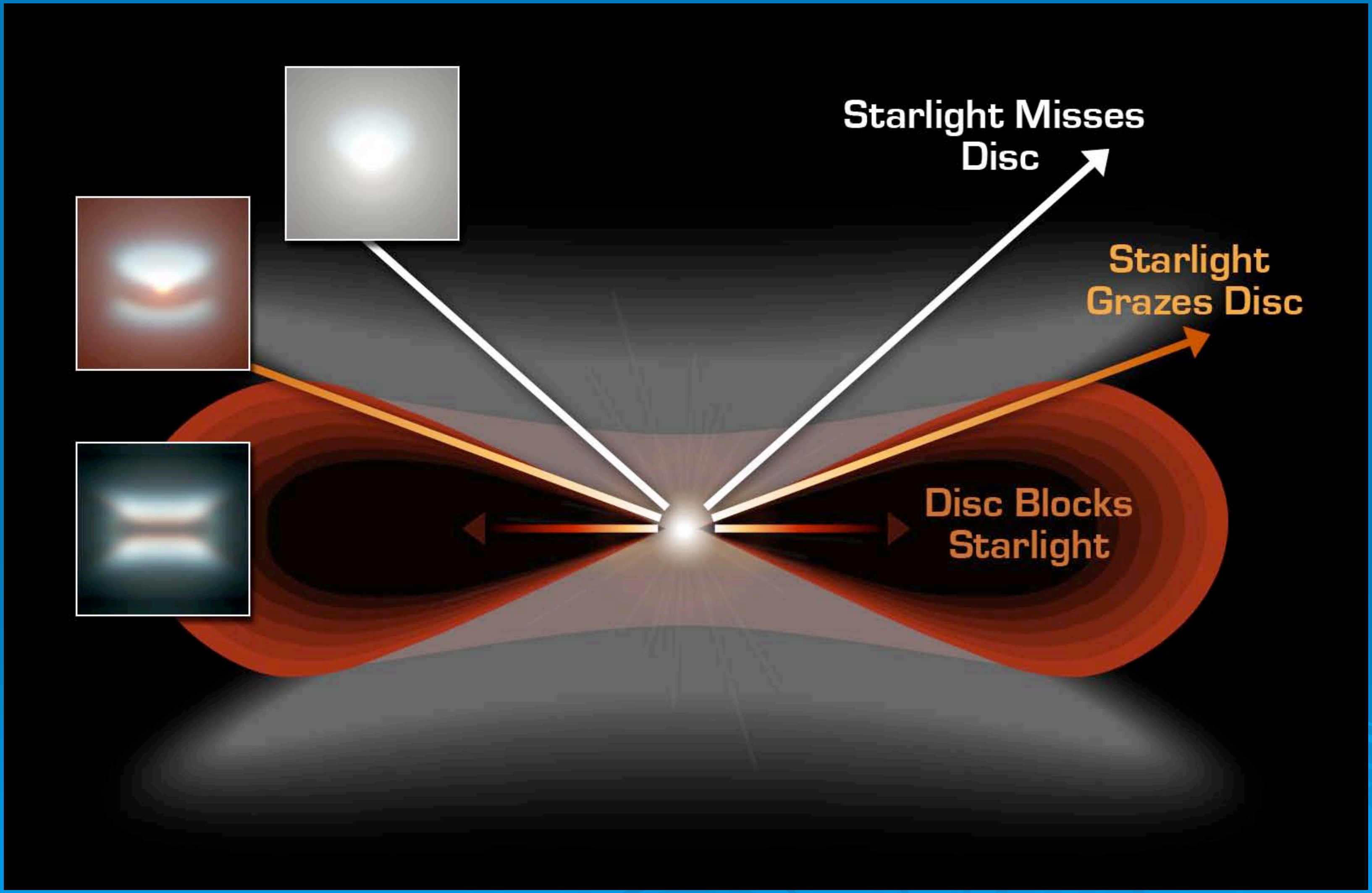
The Wind

- Accretion from disk will spin up the star
  - Star would break apart if spins too fast
- Angular momentum must be carried off
- The star-disk interaction creates a wind
- The wind carries mass to large distances
  - $J = mvr$, small amount of m at very large r
  - Allows star to avoid rotating too fast
- Wind turns into bipolar jet
  - Sweeps out cavity

The Bipolar Jet

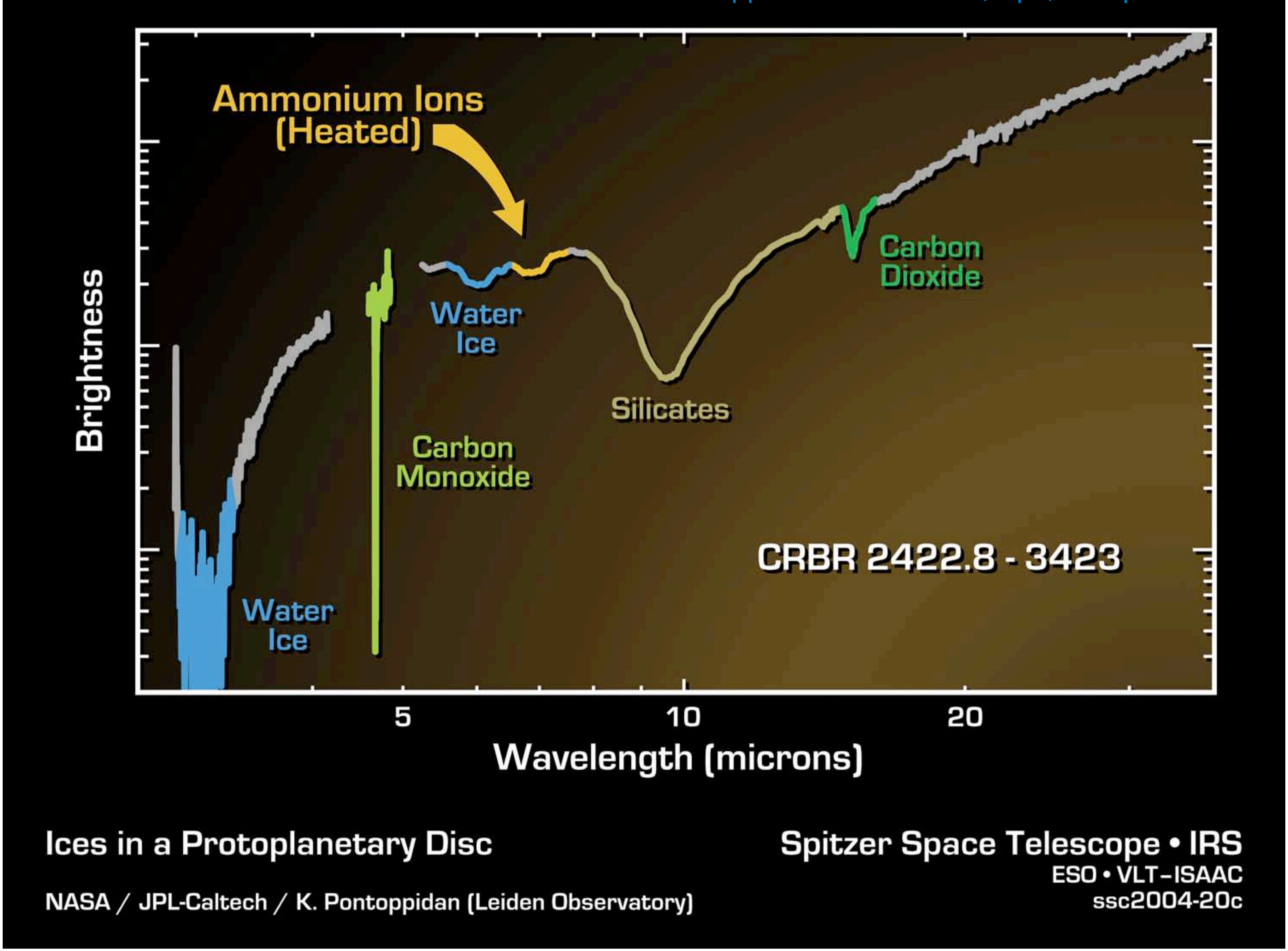


Studying the Disk

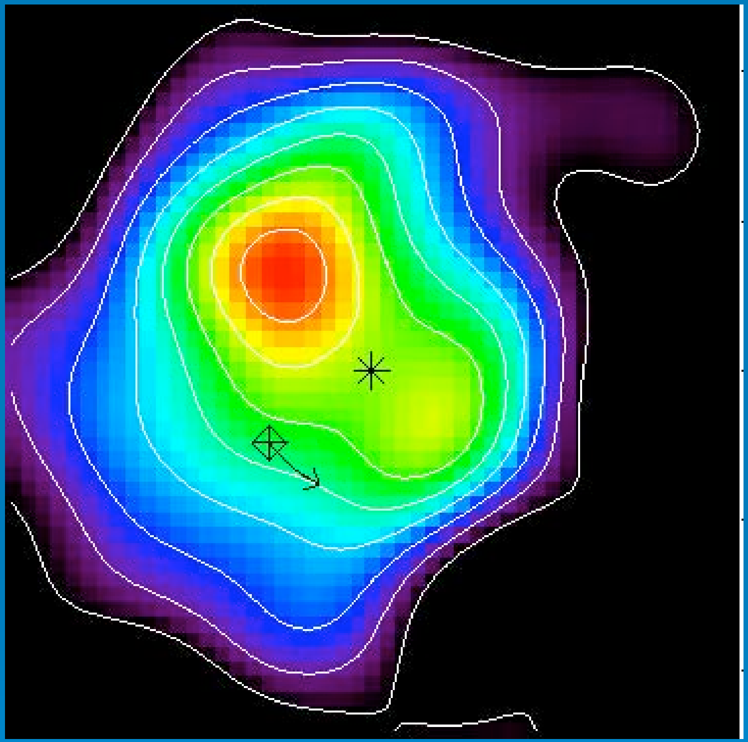


Robert Hurt, SSC

Pontoppidan et al. 2004/5, ApJ, accepted



Planet Formation

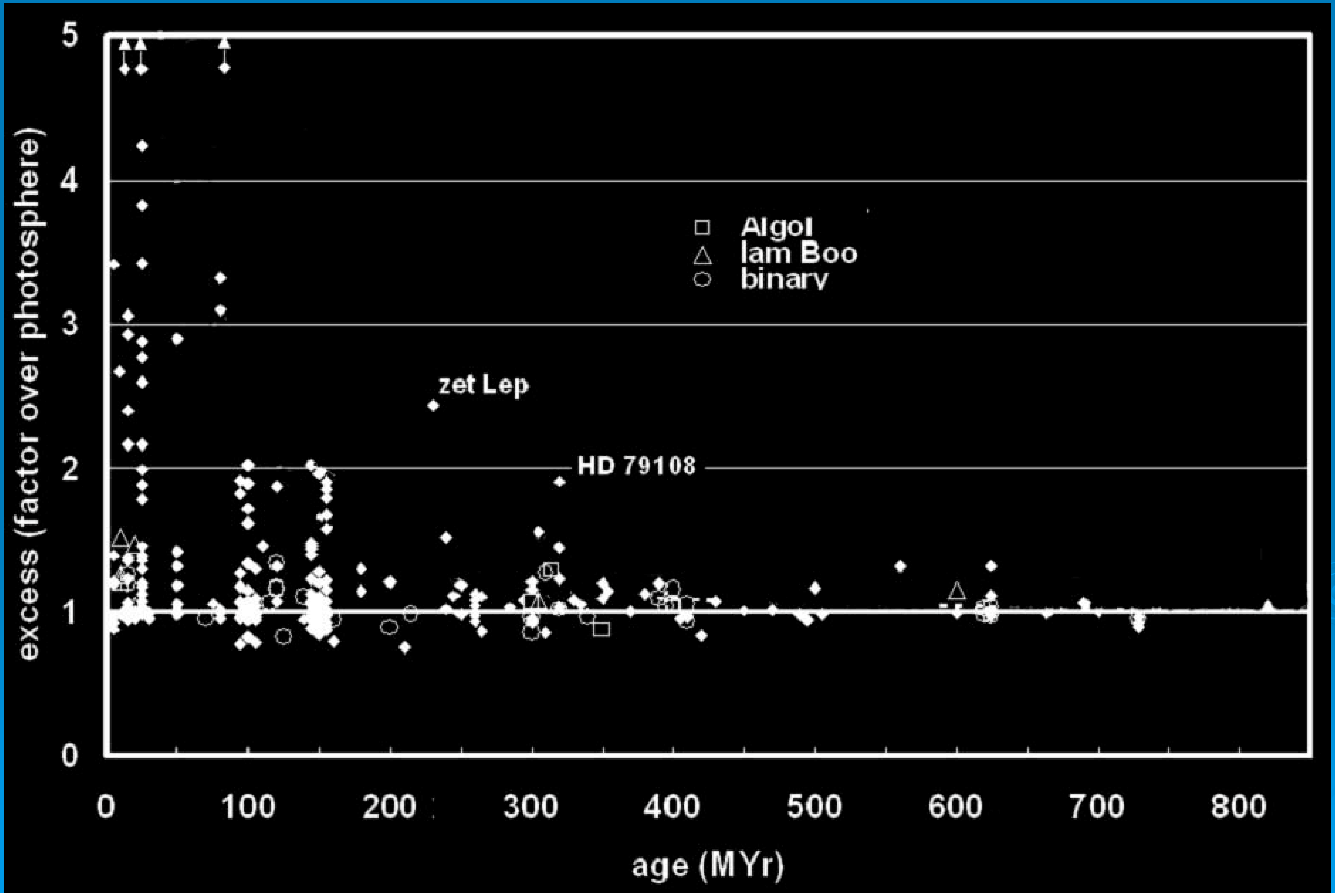


SMM image of Vega shows dust peaks off center from star (*). Fits a model with a Neptune like planet clearing a gap. Can test by looking for motion of clumps in debris disk.

SMM image of Vega
JACH, Holland et al.

Model by Wyatt (2003), ApJ, 598, 1321

Disks versus Age of Star
Evidence for Collisions



Binary Stars

- About 2/3 of all stars are in binaries
  - Most common separation is 10-100 AU
- Can binary stars have disks?
  - Yes, but binary tends to clear a gap
  - Disks well inside binary orbit
  - Or well outside binary orbit

Brown Dwarfs

- Stars range from 0.07 to ~100 M_{sun}
- Jupiter is about 0.001 M_{sun}
- Brown dwarfs between stars and planets
  - Dividing line is somewhat arbitrary
  - Usual choice is 13 $M_{jupiter}$
  - Brown dwarfs rarely seen as companions to stars
  - But “free-floaters” as common as stars
  - Many young BDs have disks
    - Planets around BDs?