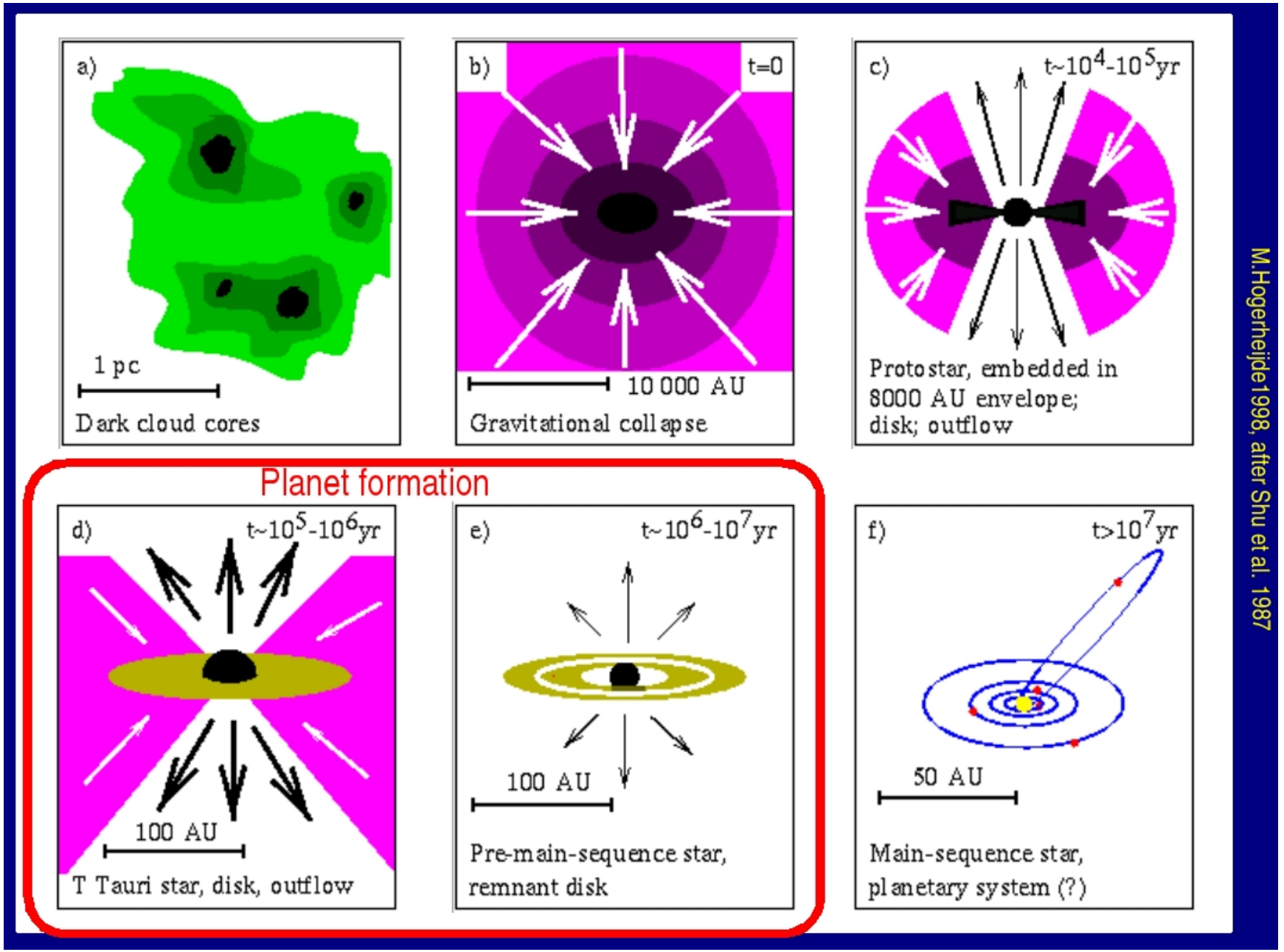
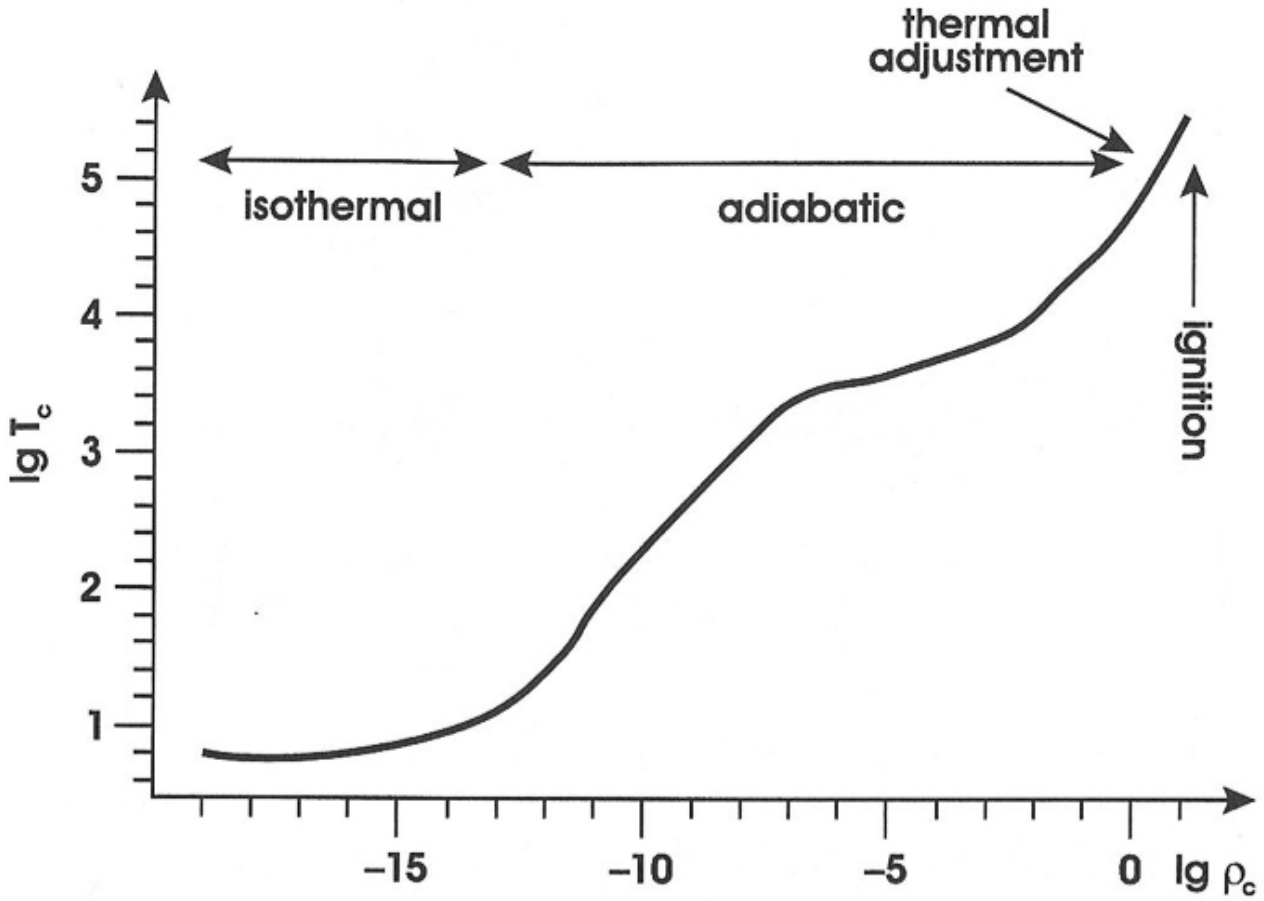
# Star Formation and Young Stellar Objects

ASTR 5420

April 5, 2015

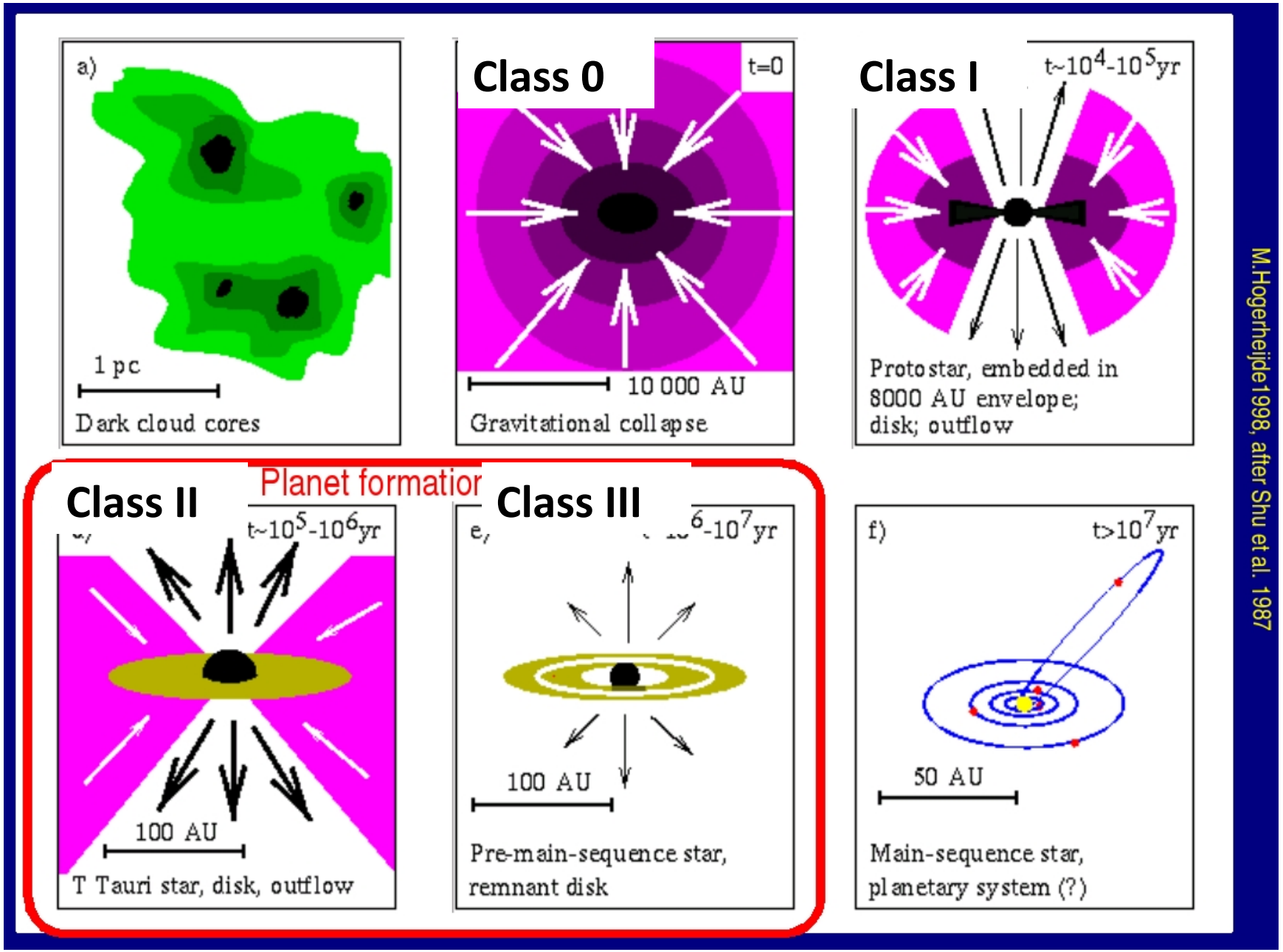

a)
1 pc
Dark cloud cores
b)
t=0
10 000 AU
Gravitational collapse
c)
t~10^4-10^5yr
Protostar, embedded in
8000 AU envelope;
disk; outflow
Planet formation
d)
t~10^5-10^6yr
100 AU
T Tauri star, disk, outflow
e)
t~10^6-10^7yr
100 AU
Pre-main-sequence star,
remnant disk
f)
t>10^7yr
50 AU
Main-sequence star,
planetary system (?)
M.Hogerheijde1998, after Shu et al. 1987

# Pre-main sequence core evolution



# Low mass YSOs (<2$M_{sun}$)

- Class 0 – cloud cores just beginning core collapse
- Class I – embedded star, infalling envelope
- Class II – no envelope, just disk accretion (Classical T Tauri)
- Class III – no accretion, still pre-main sequence (weak-line T Tauri)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Dark cloud cores
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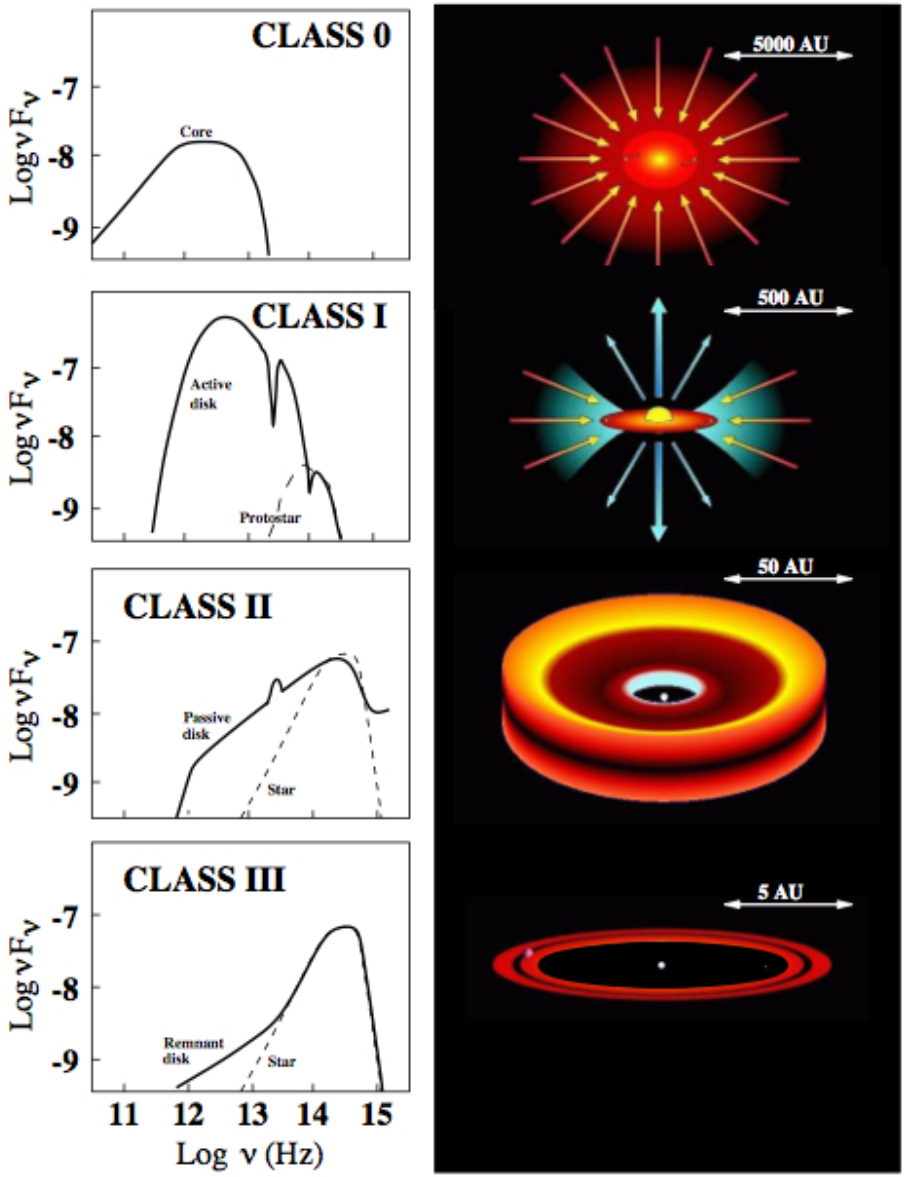
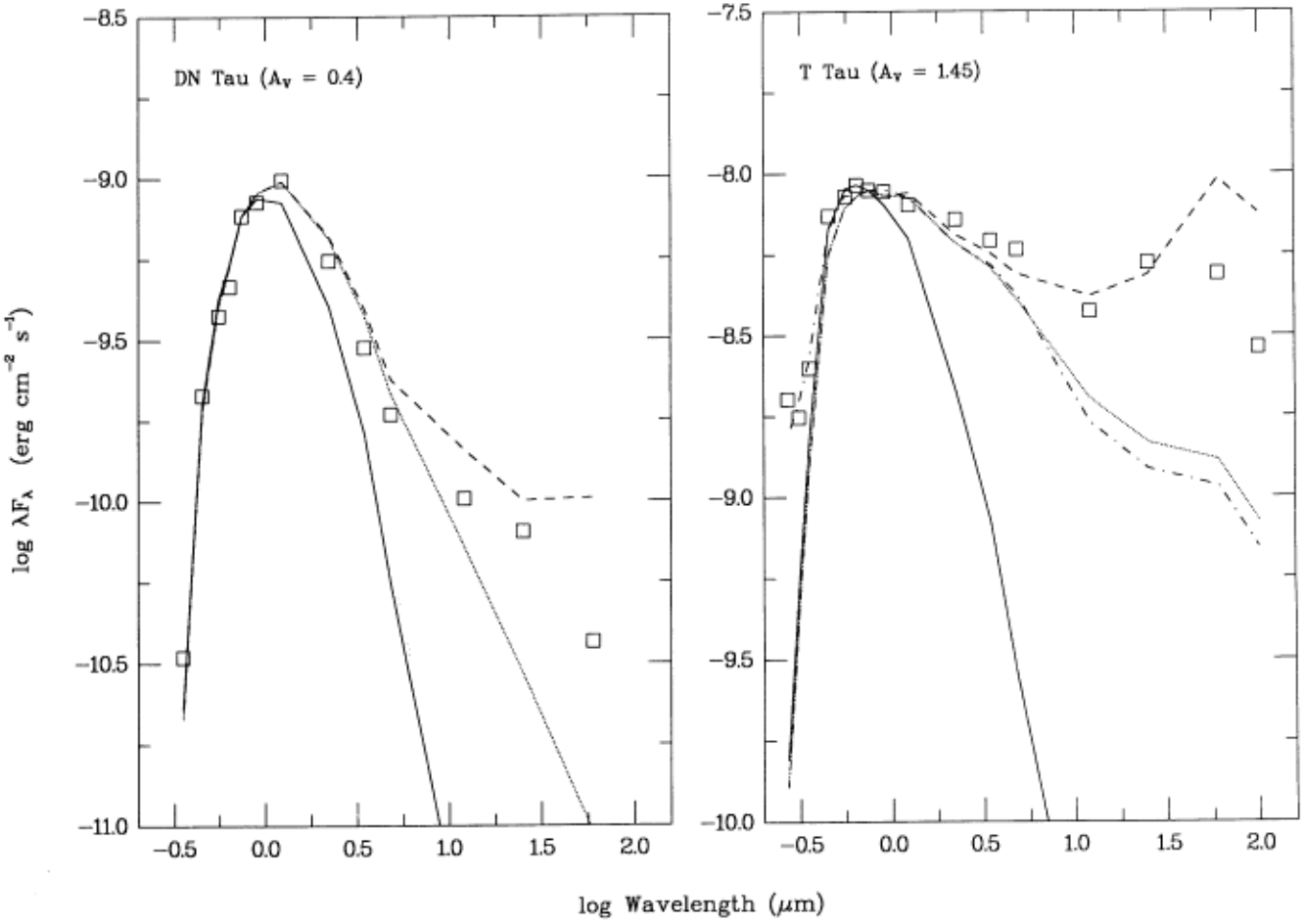

CLASS 0
Core
CLASS I
Active disk
Protostar
CLASS II
Passive disk
Star
CLASS III
Remnant disk
Star
Log νF_ν
-7
-8
-9
11
12
13
14
15
Log ν (Hz)
5000 AU
500 AU
50 AU
5 AU

Isella, 2006

# Intermediate-Mass YSOs

- 2 – 10 $M_{sun}$
- Class II/III = Herbig Ae or Herbig Be objects
- Basically scaled-up T Tauri objects, but hotter and brighter
- Distinct from Classical Ae/Be stars, which are evolved stars
- O stars evolve too quickly for a YSO stage

# YSOs detected by IR excess

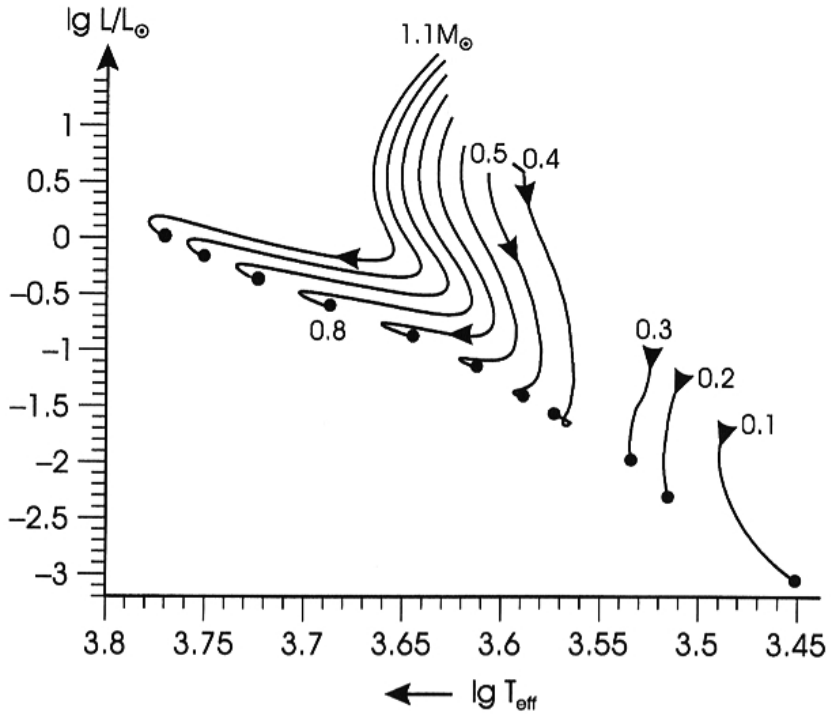


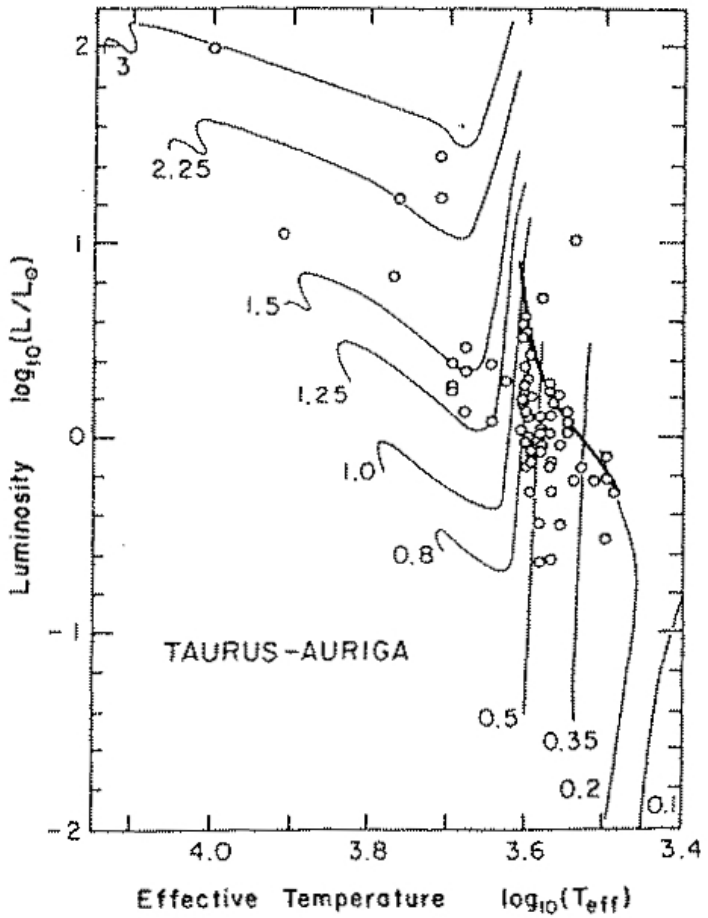
# Accretion detected by UV excess

- Material accreting onto a star is shock-heated to high temperatures

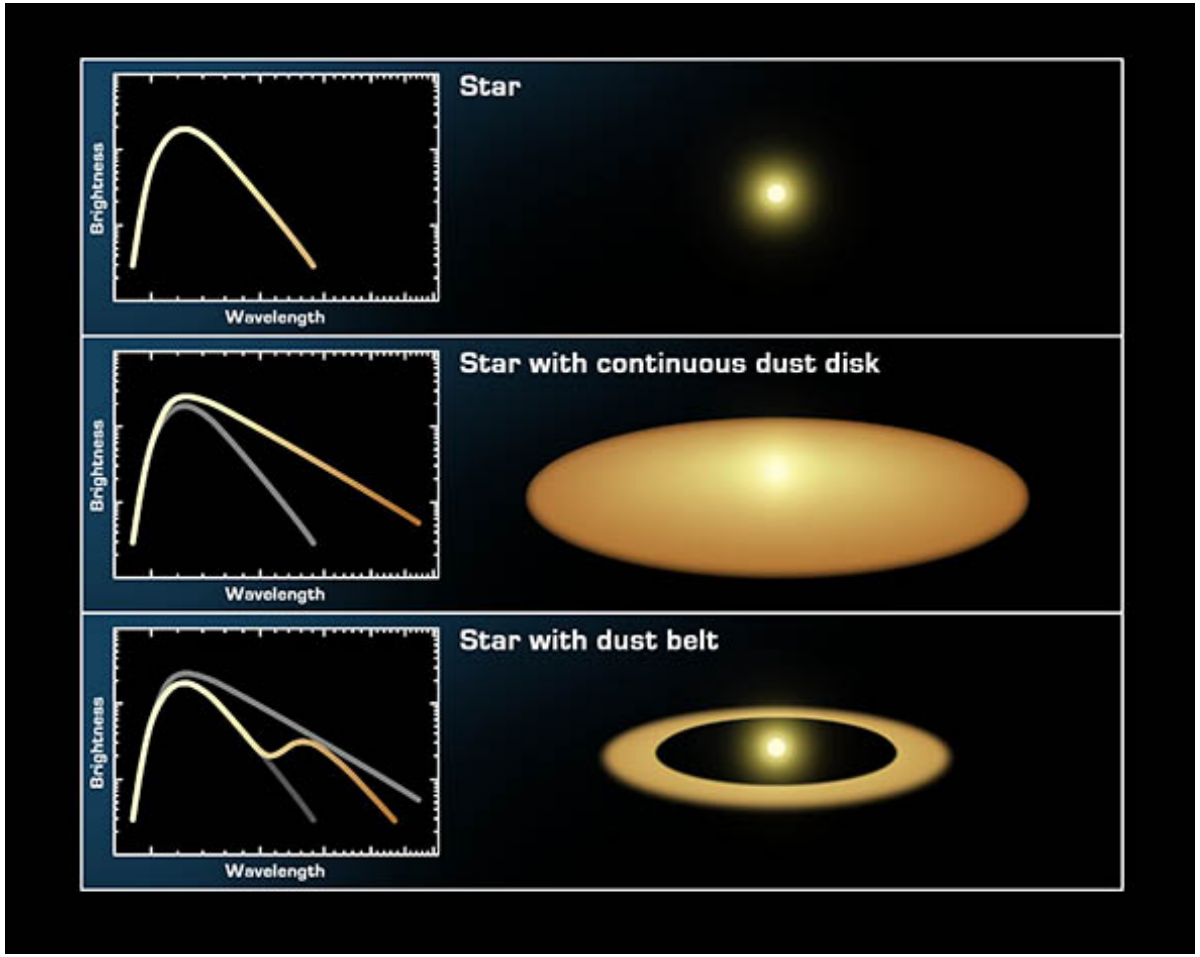
$$L_{\rm acc} = \frac{GM\dot{M}}{R}$$

# Pre-main sequence evolution

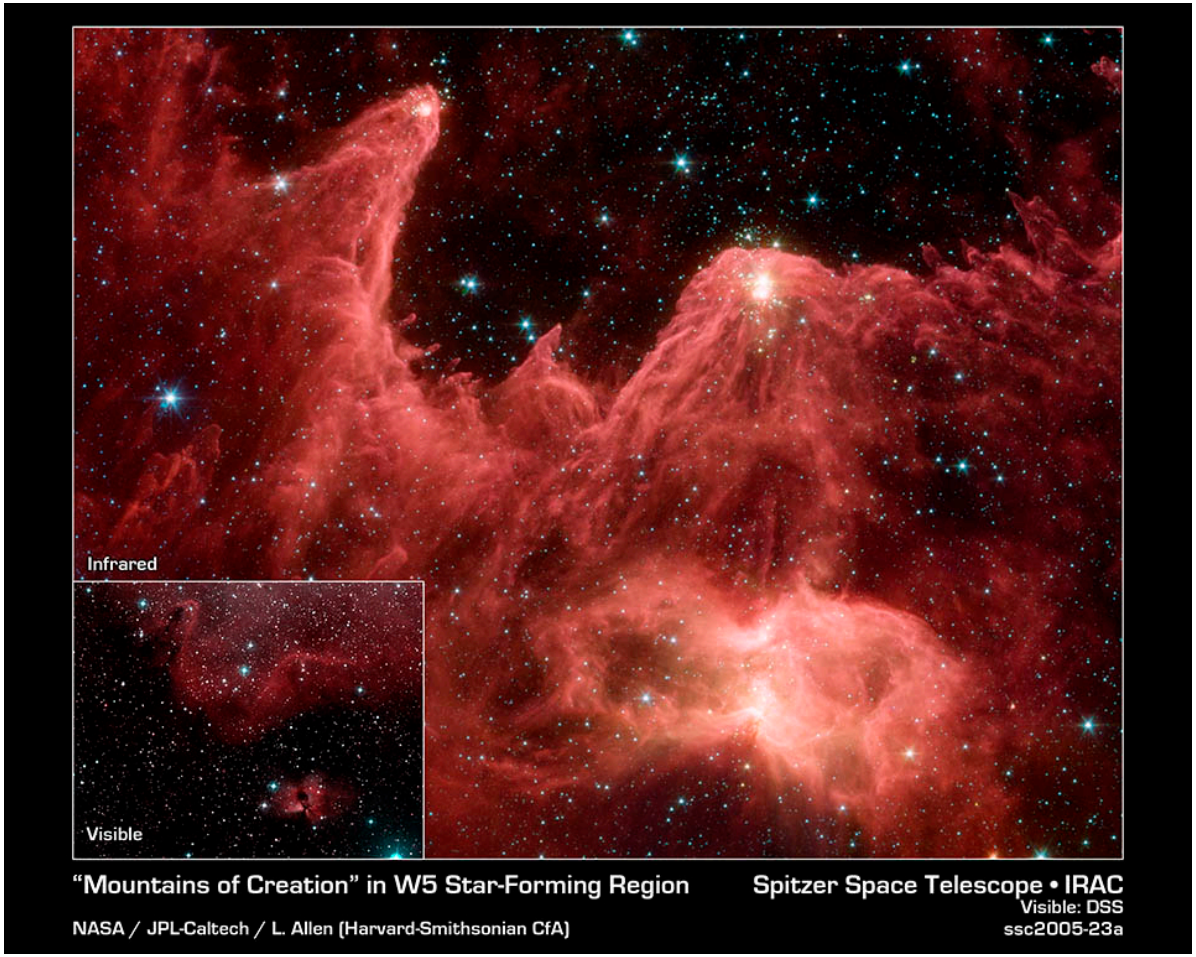


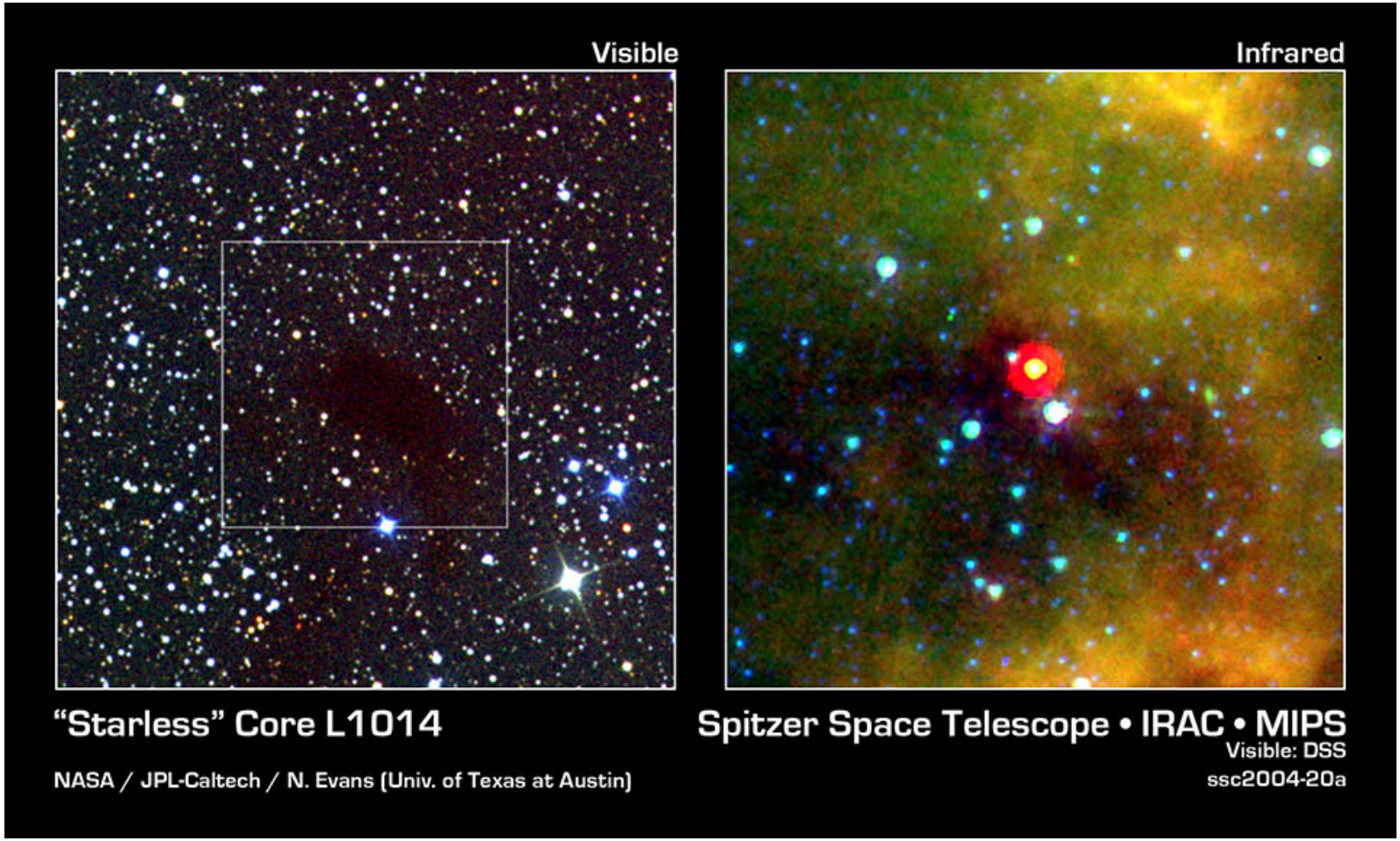
# Disks Detected from IR excess



# Star Formation Regions



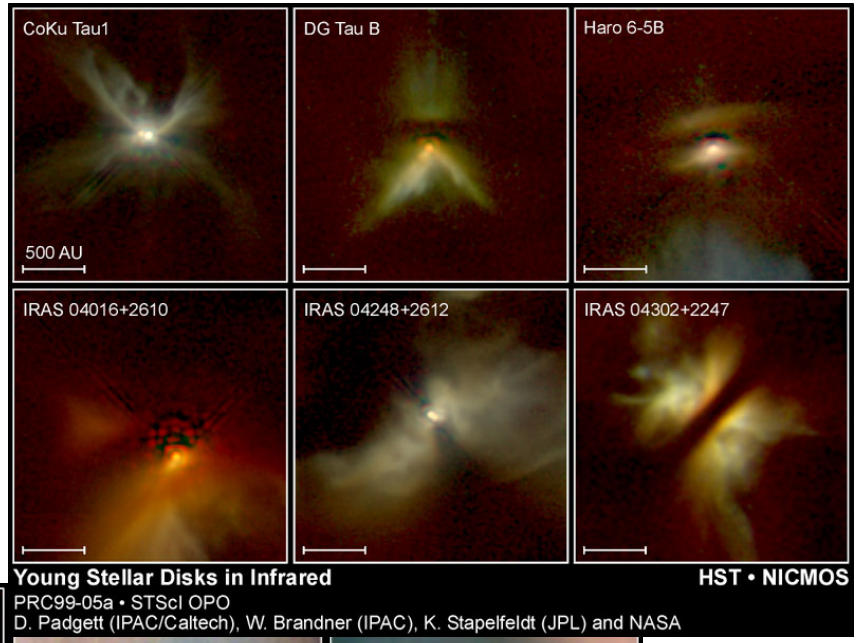
# Class 0

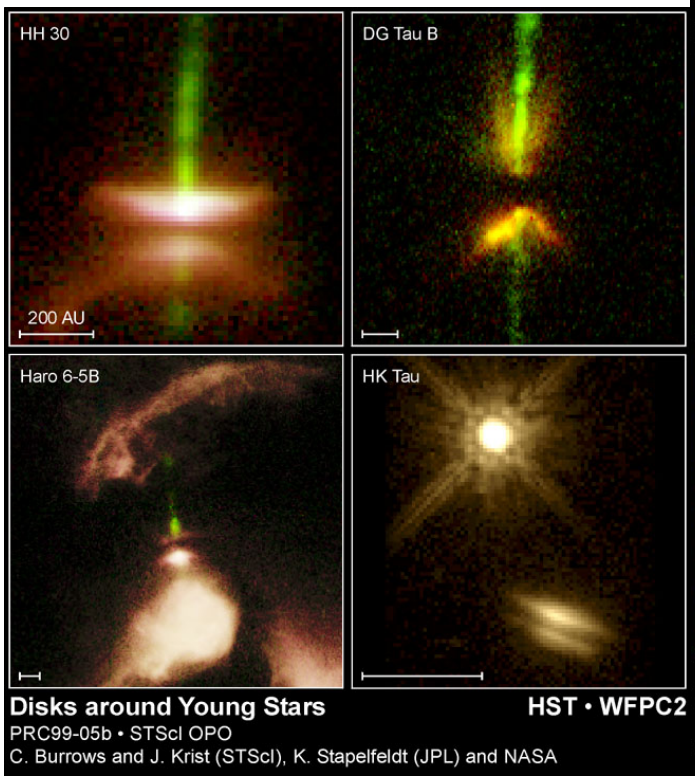

Visible
Infrared
"Starless" Core L1014
NASA / JPL-Caltech / N. Evans (Univ. of Texas at Austin)
Spitzer Space Telescope • IRAC • MIPS
Visible: DSS
ssc2004-20a

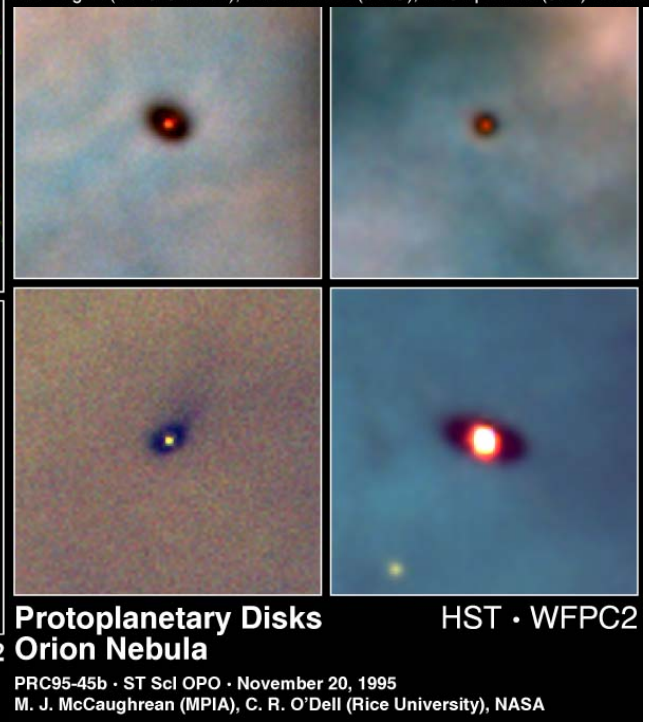
# Class I


- HH = Herbig-Haro objects
- Clumps of material ejected from outflow

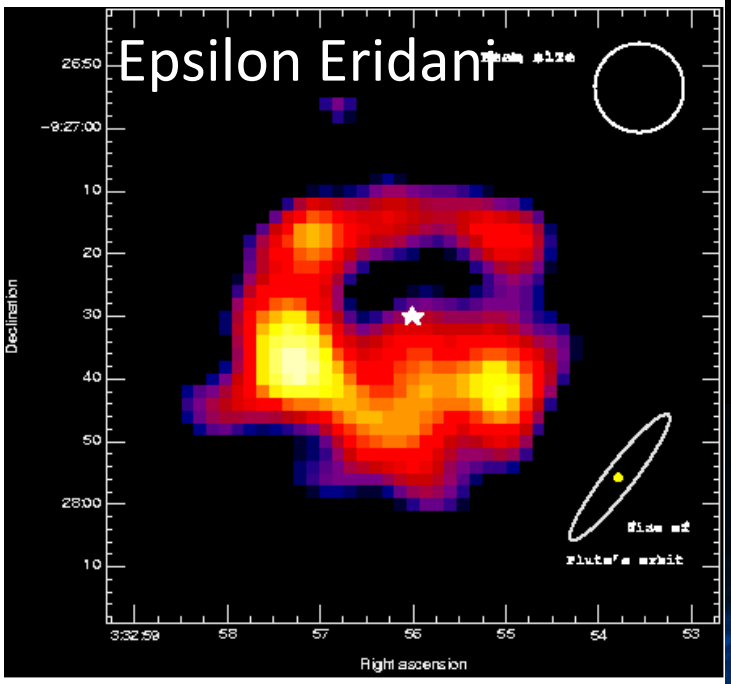
# Class II- Protoplanetary Disks

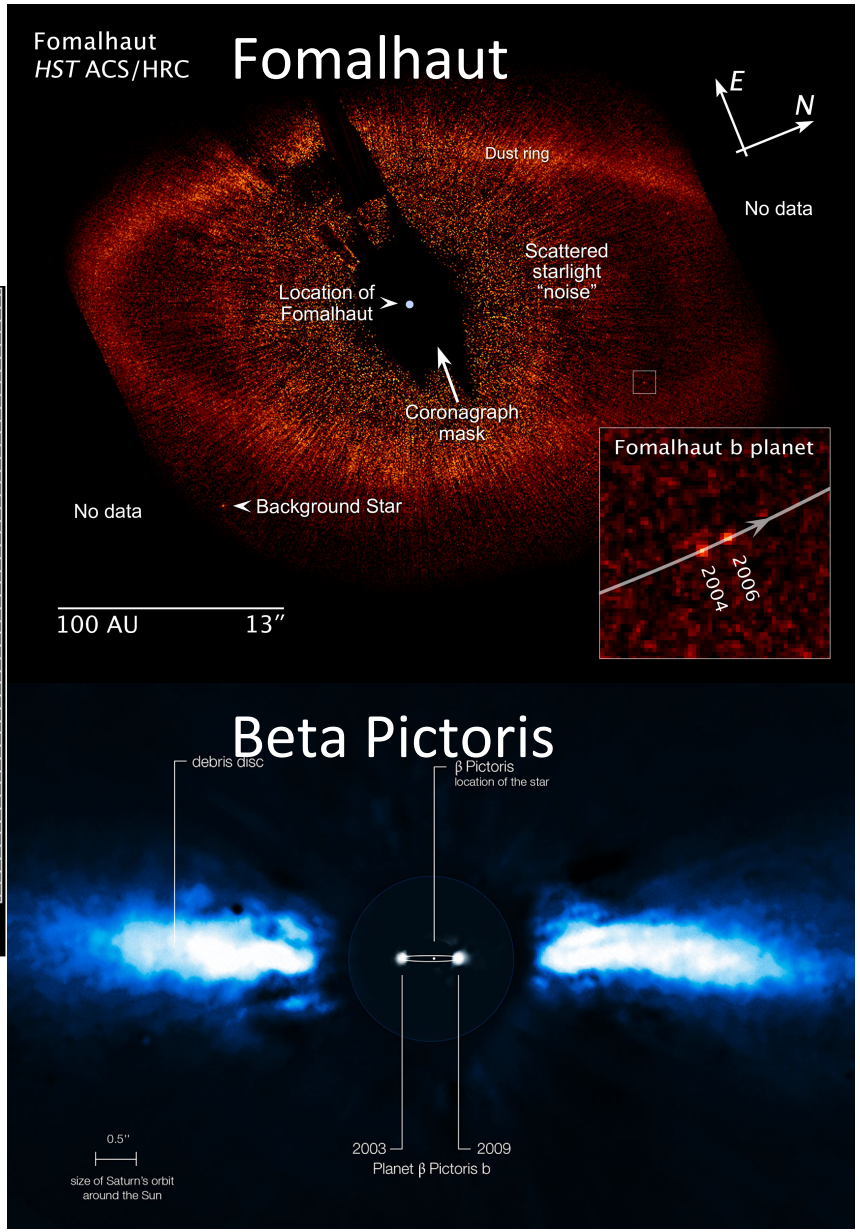


# Debris Disks



# Properties of PMS stars

- Energy source is mostly gravitational
- May have deuterium or lithium burning
  - $D + H \rightarrow {}^{3}He$
  - ${}^{7}Li + H \rightarrow {}^{4}He + {}^{4}He$
- Fully convective – well-mixed composition
- Highly variable: accretion, winds, outflows
- Fast spin rates

# Disk Lifetimes

1-10 Myr average lifetime