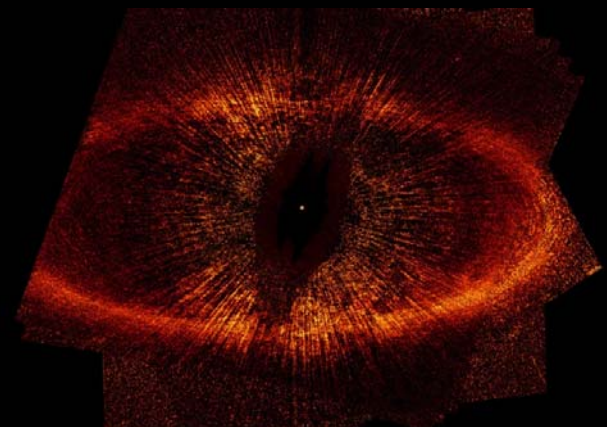
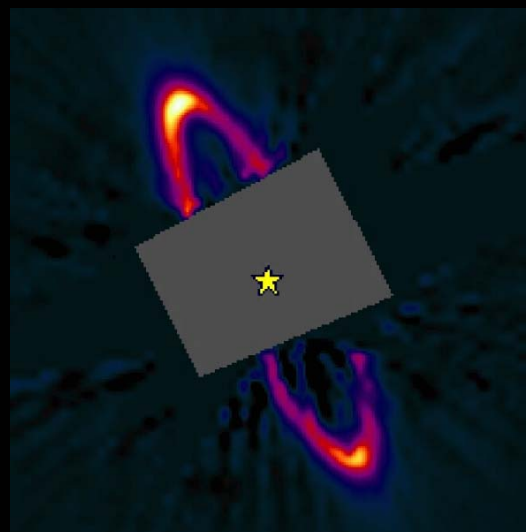
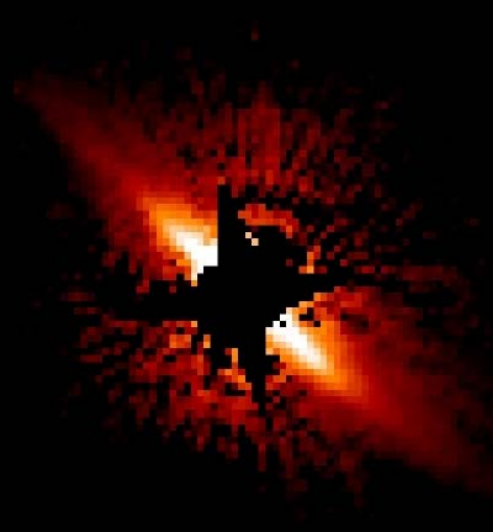


# Gas in Debris Disks

Clues to the Late Stages of Planet Formation

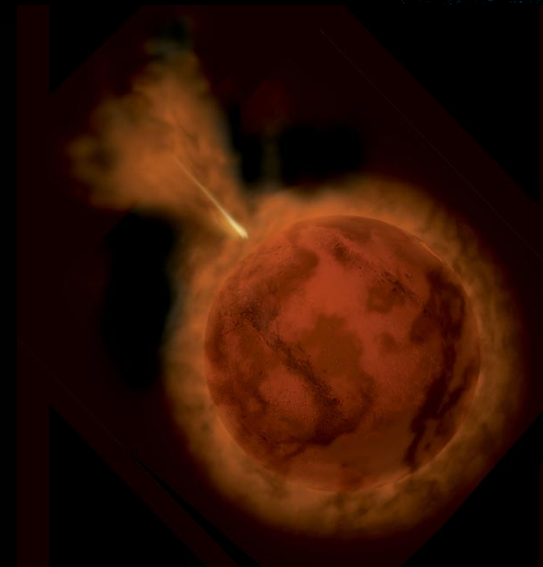
Dr. Aki Roberge (NASA GSFC)



# Debris Disks

- Wide range of ages :  
~ 10 Myr to ~ 1 Gyr
- Optically thin disks
  - Few lunar masses or less of dust
  - Short dust lifetimes
- Secondary material (not primordial)
- Delivery of volatiles to terrestrial planet surfaces  
(e.g. Morbidelli et al. 2000)

AU Mic – 12 Myr  
Krist et al. (2004)



# Gas in Debris Disks

- Ten debris disks w/ circumstellar gas

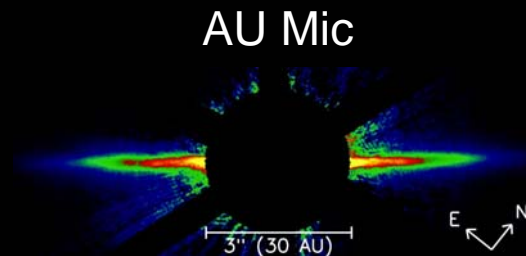
Firm: Beta Pic, 49 Ceti, Sigma Her, HD32297

New: HD158352, HD118232, HD21620, HD142926

Confusing: 51 Oph, AU Mic

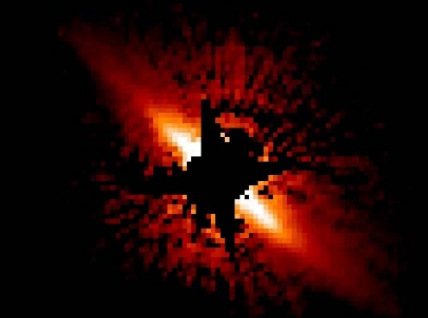


Golimowski et al. (2006)



Liu (2004)

HD32297

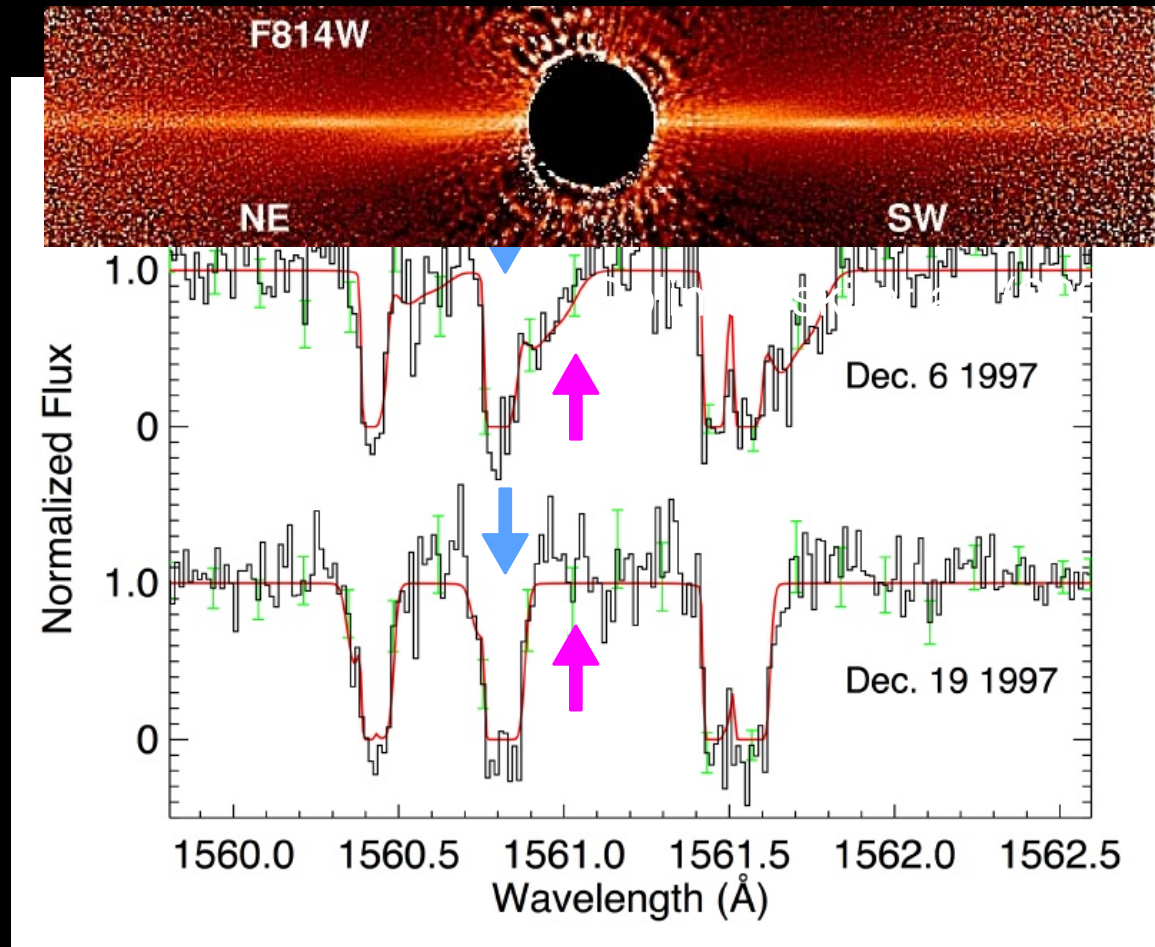


Schneider et al. (2005)

- Primordial gas ( $H_2$ ) largely dissipated
- Mostly atomic and ionic gas from planetesimals

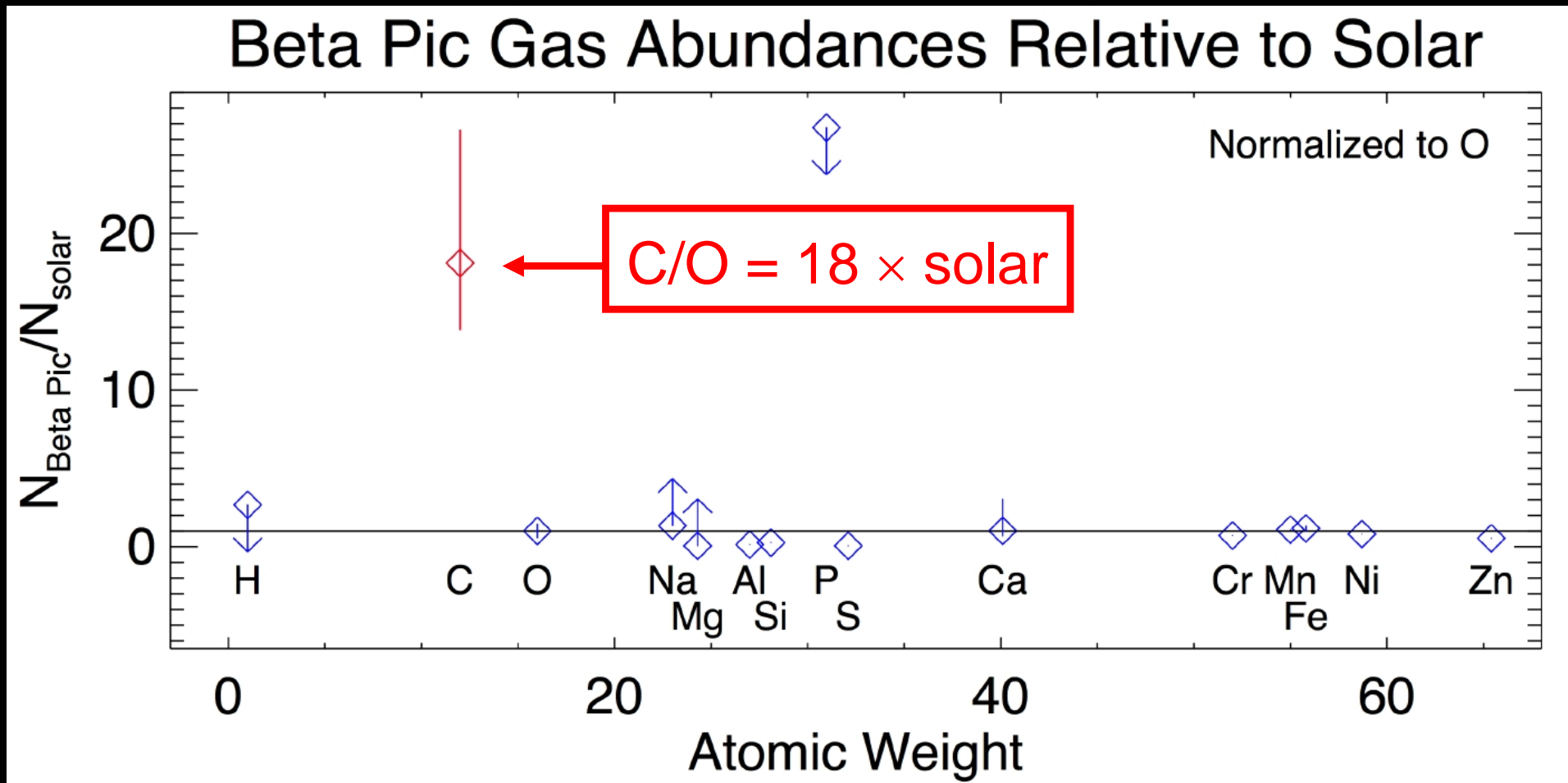
# Debris Gas in Beta Pic

- Beta Pictoris
  - 12 Myr old
  - Edge-on disk
- Narrow unvarying features at  $v = v_H$  : stable gas
- Variable redshifted features : star-grazing planetesimals (FEBs)



Roberge et al. (2000)

# Beta Pic Gas Composition

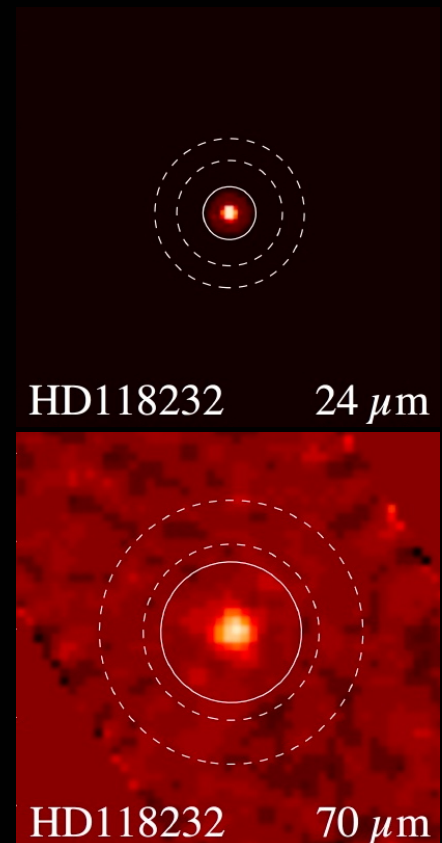
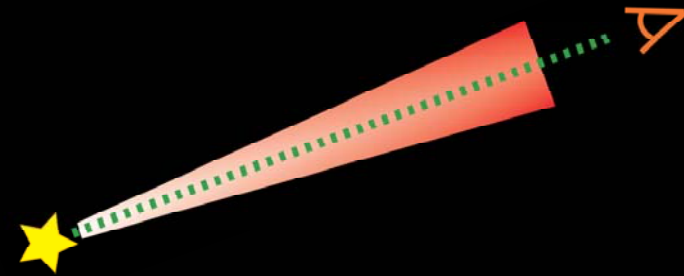


Roberge et al. (2006)

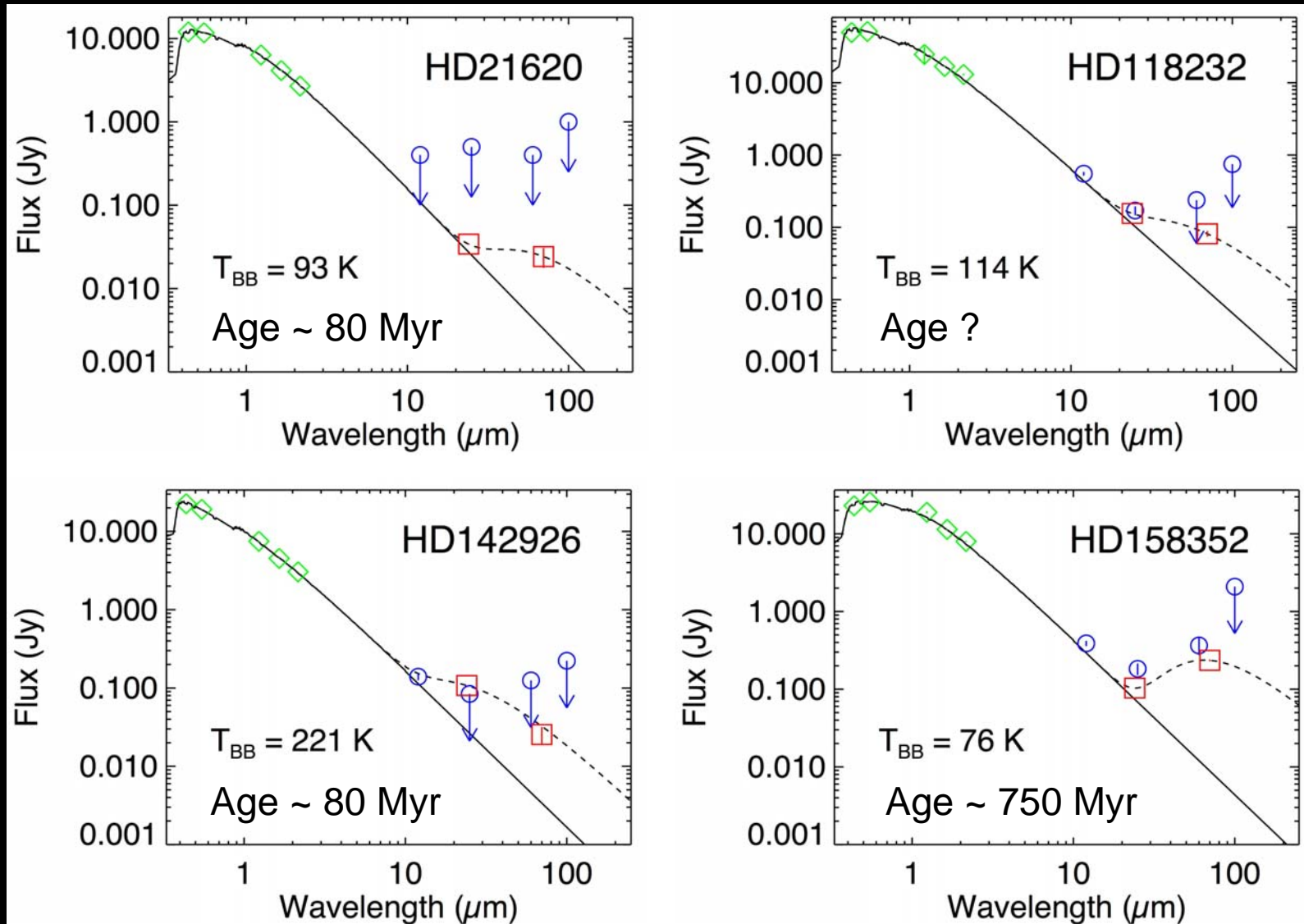
C-rich AGB stars:  $C/O < 1.2$   
(Mattsson et al. 2007)

# A Search for Disks w/ Gas

- Why do we know so little?
  - Cold gas, low abundances
  - Need edge-on disks
- Spitzer survey for circumstellar dust
  - Target stars have CS gas
  - Shell stars: evolved stars, classical Be stars, and protoplanetary / debris disks



# New Disks with Gas & Dust



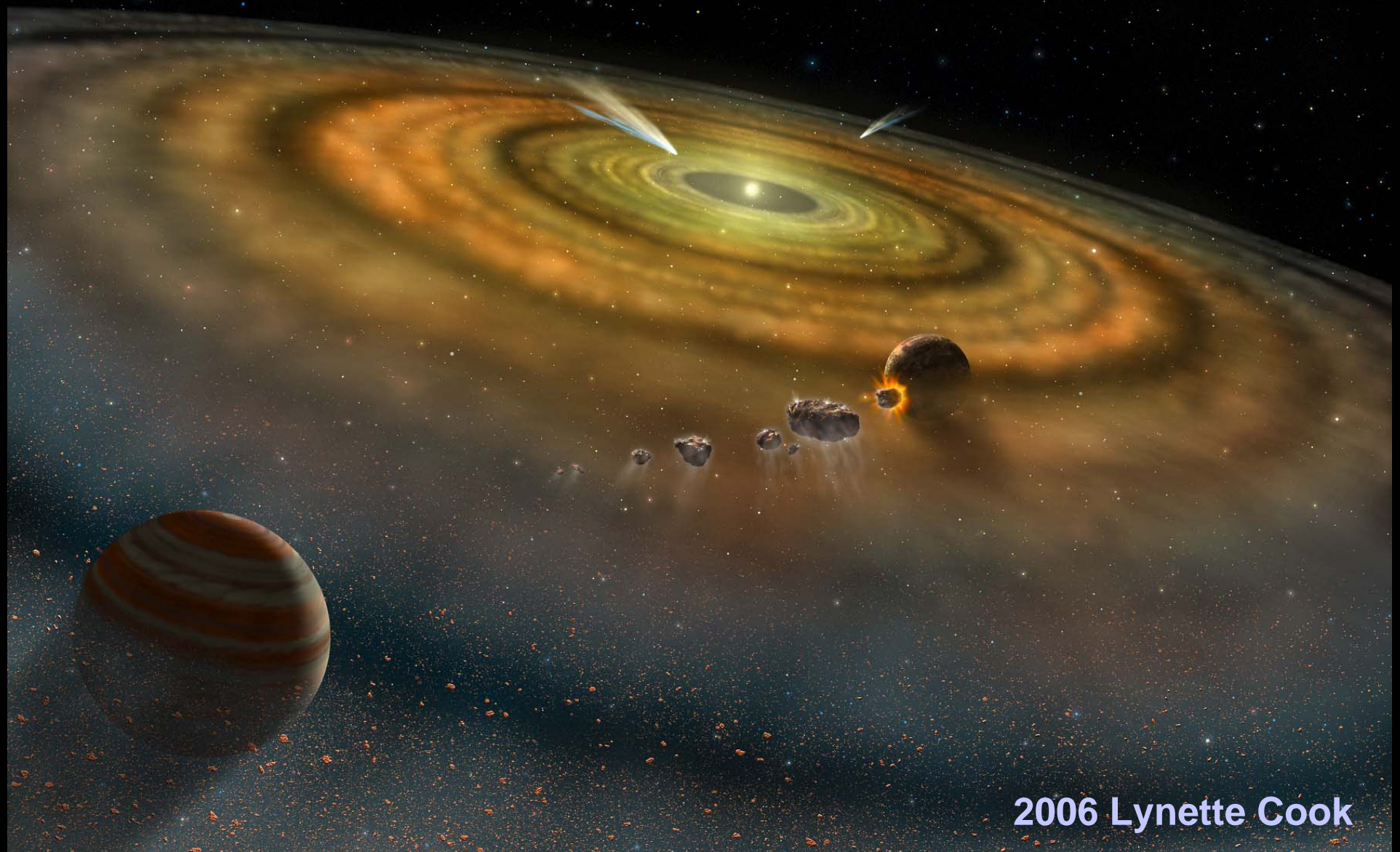
Roberge & Weinberger (2008)

# Disks Among the Shell Stars

- Disk fraction  $\geq 48\% \pm 14\%$ 
  - 7 known disks + 4 new disks out of 23
  - Could be as high as 65%
  - Normal MS A-stars:  $32\% \pm 5\%$  (Su et al. 2006)
- Young stars as well as old ones in shell class
- Debris gas emission: Herschel GASPS, ALMA







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Dr. A. Roberge – “Gas in Debris Disks: Clues to the Late Stages of Planet Formation”