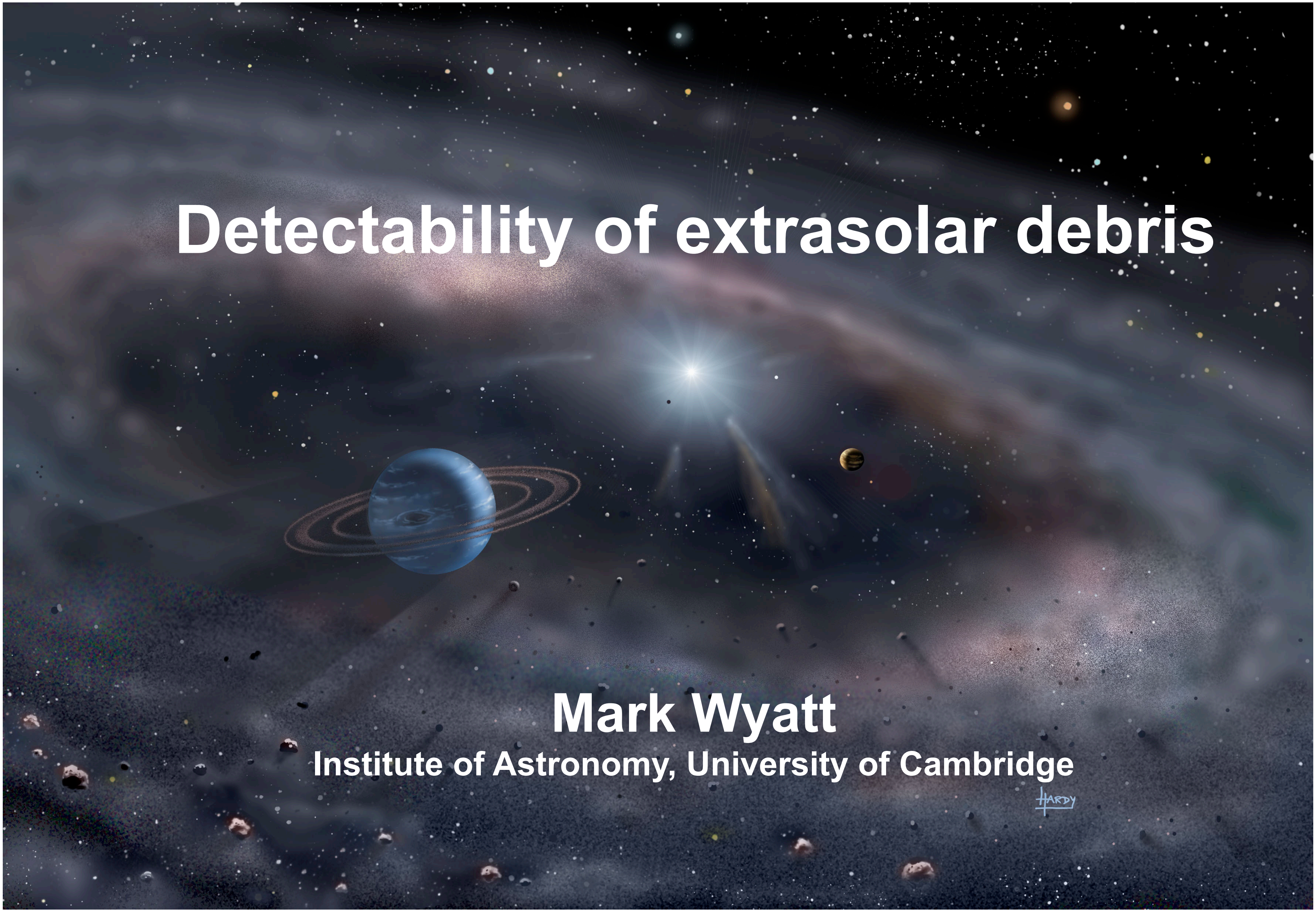
Detectability of extrasolar debris



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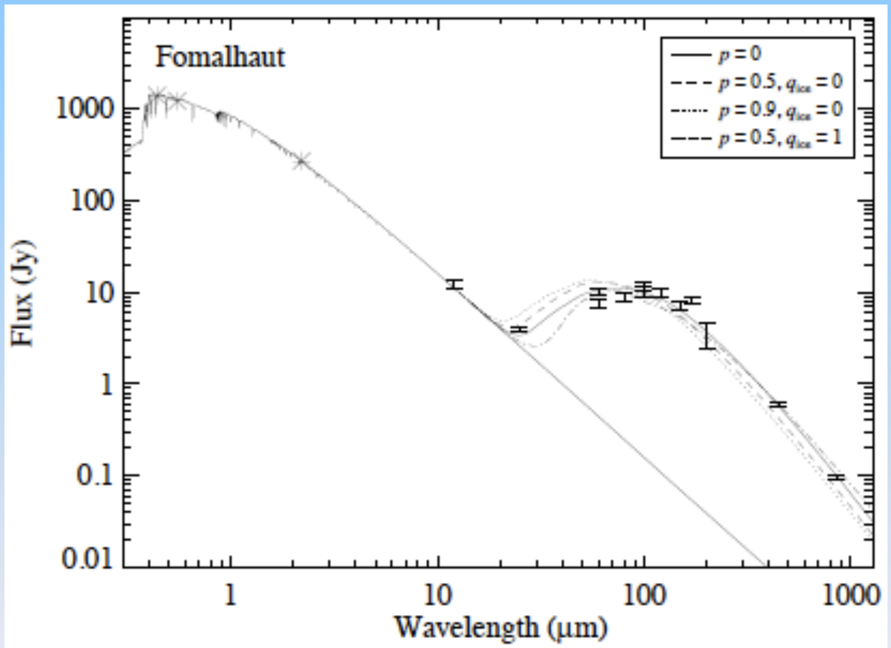
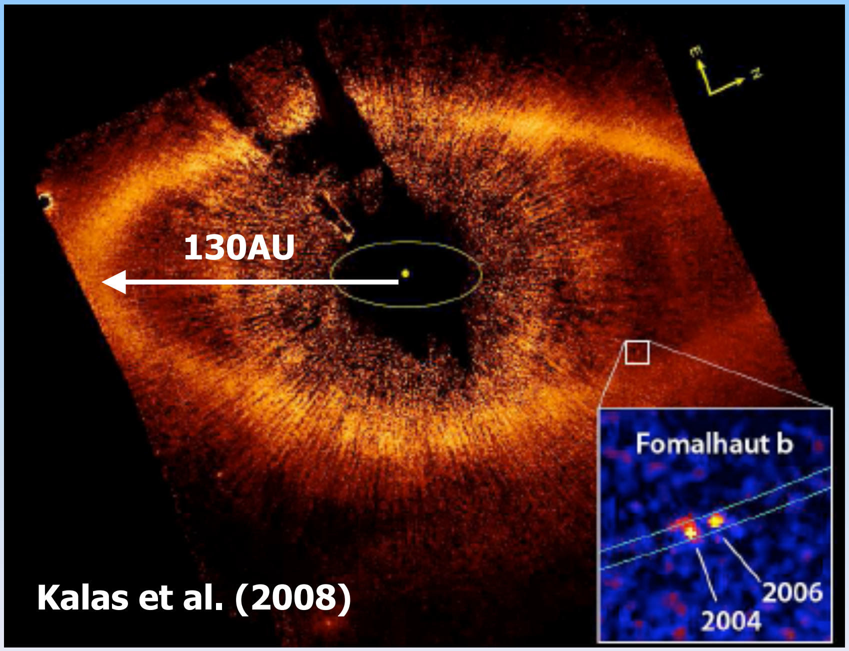
Why image extrasolar debris?

Emission spectrum shows dust thermal emission, used to infer radius of parent planetesimal belt

Imaging measures radius, finds asymmetries, used to infer planets that are hard to detect otherwise

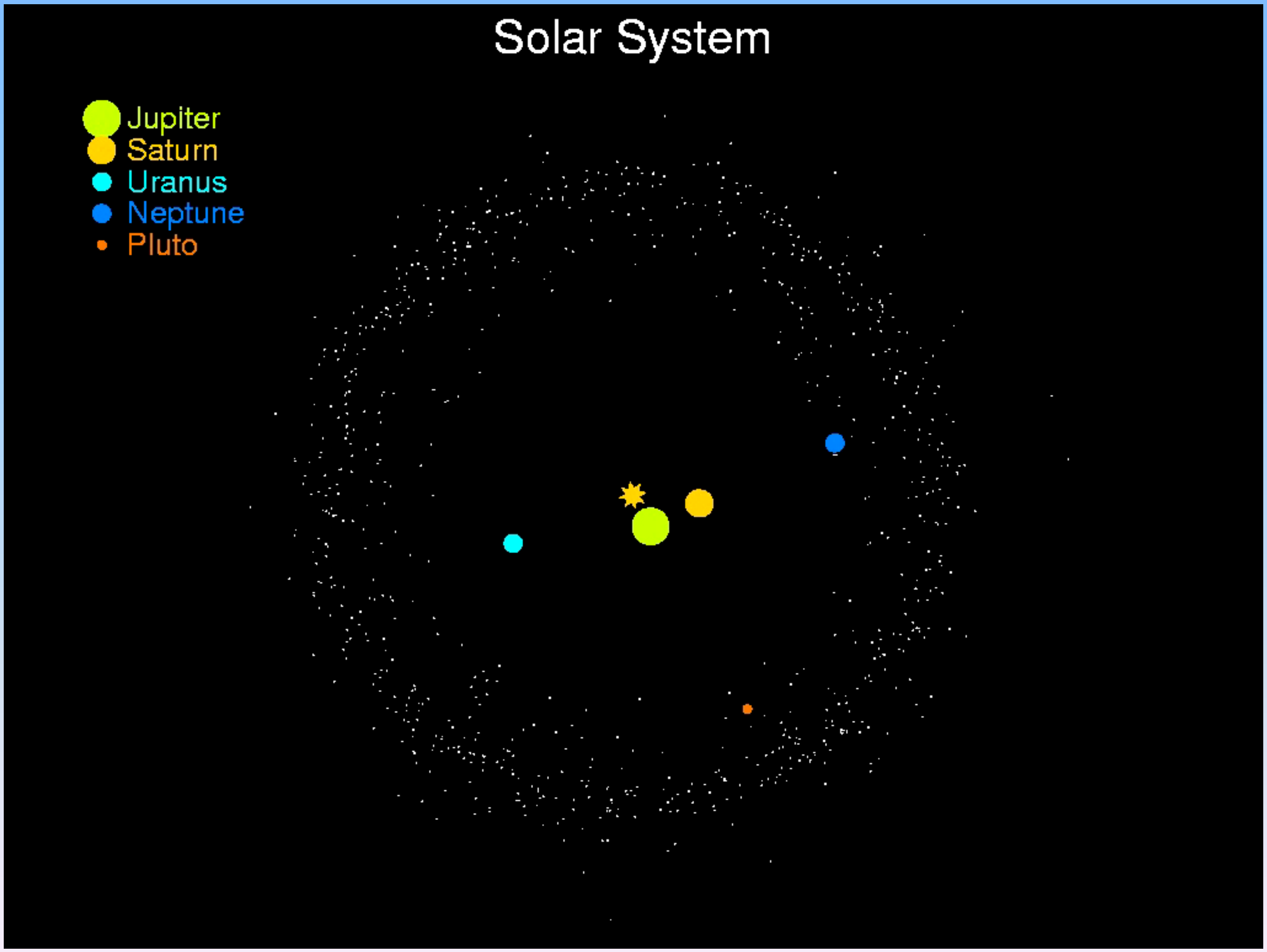




EG: debris disc and planet around 200Myr A5V star Fomalhaut

Why image Solar System debris?

- We know where the planets are
- We know where most planetesimals are
- But we don't know where the dust is



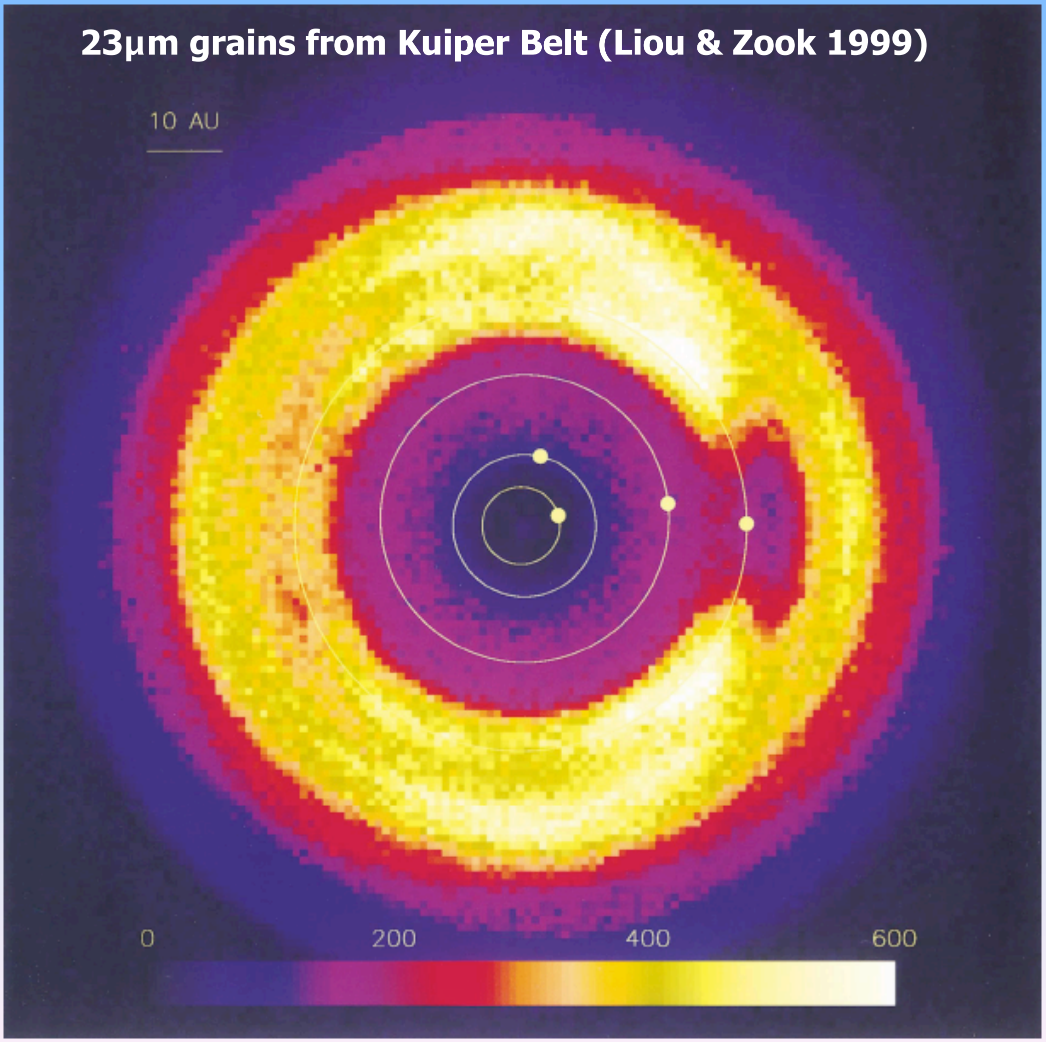
Dynamical evolution of small grains

- Dynamical evolution of small grains from KB followed numerically

- Spiral toward star due to P-R drag, interacting with planets through resonant trapping and scattering

(e.g., Liou & Zook 1999; Moro-Martin & Malhotra 2002, 2003, 2005)

- But more sophisticated models required to include collisions (e.g., Stark & Kuchner 2010)

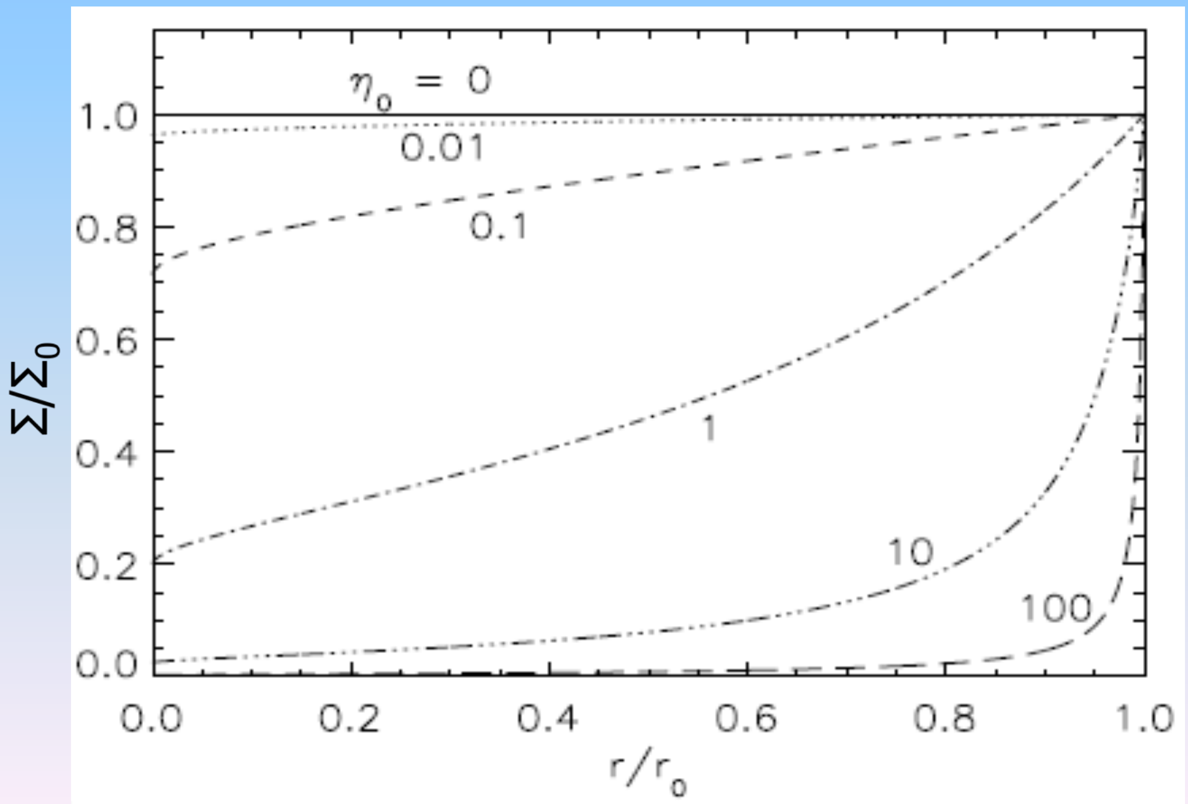


Collisions vs P-R drag

Consider a planetesimal belt at r_0 producing dust of one size that evolves by P-R drag and collisions. The steady state distribution of surface density is (Wyatt 2005):

$\Sigma = \Sigma_0 / \{1+4\eta_0[1-(r/r_0)^{0.5}]\}$

$\eta_0 = 5000\Sigma_0[r_0/M_*]^{0.5}/\beta = t_{pr}/t_{col}$



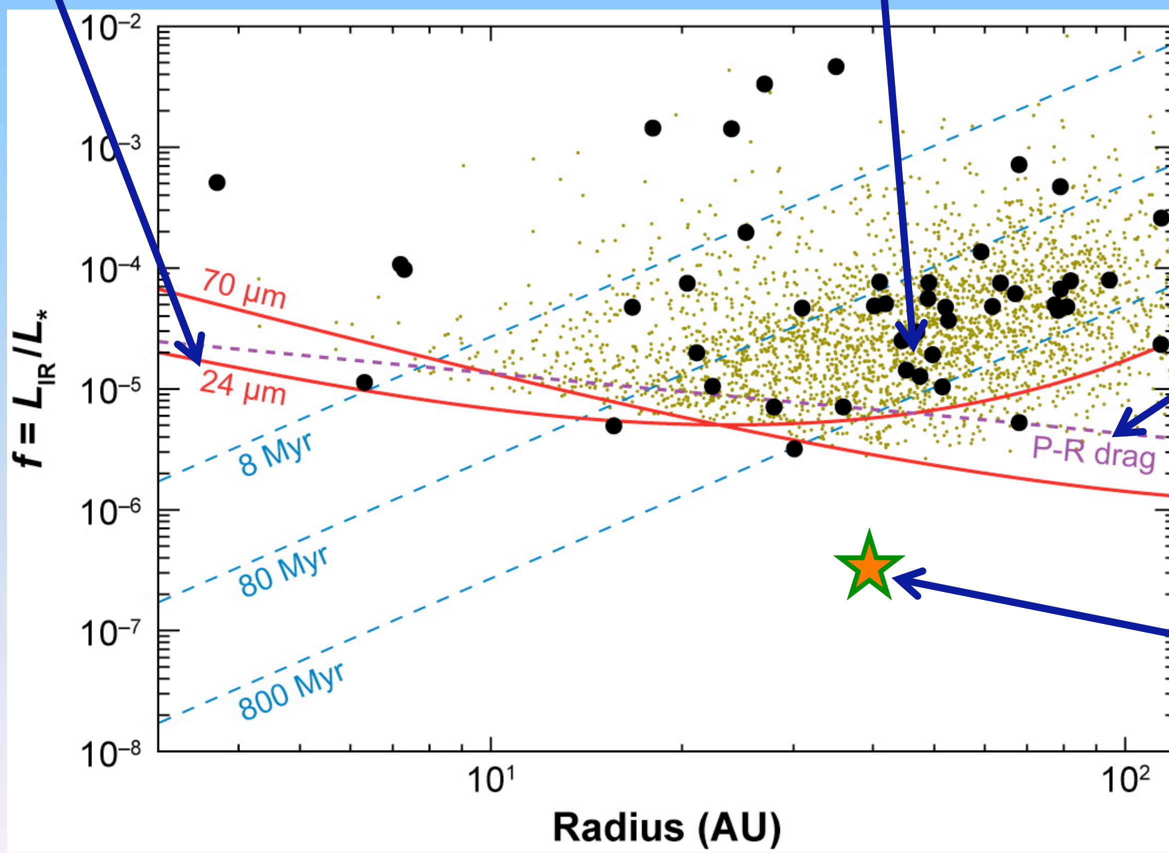
If $\eta_0 << 1$ dust reaches the star without collision

If $\eta_0 >> 1$ dust is destroyed before leaving the belt

Detectability of P-R dominated disks

Only disks with $F_{disk}/F_{*}>0.1$ can be detected

All known disks are above this limit



The limit below which P-R drag is important for smallest dust has similar fractional luminosity

The KB is below this limit

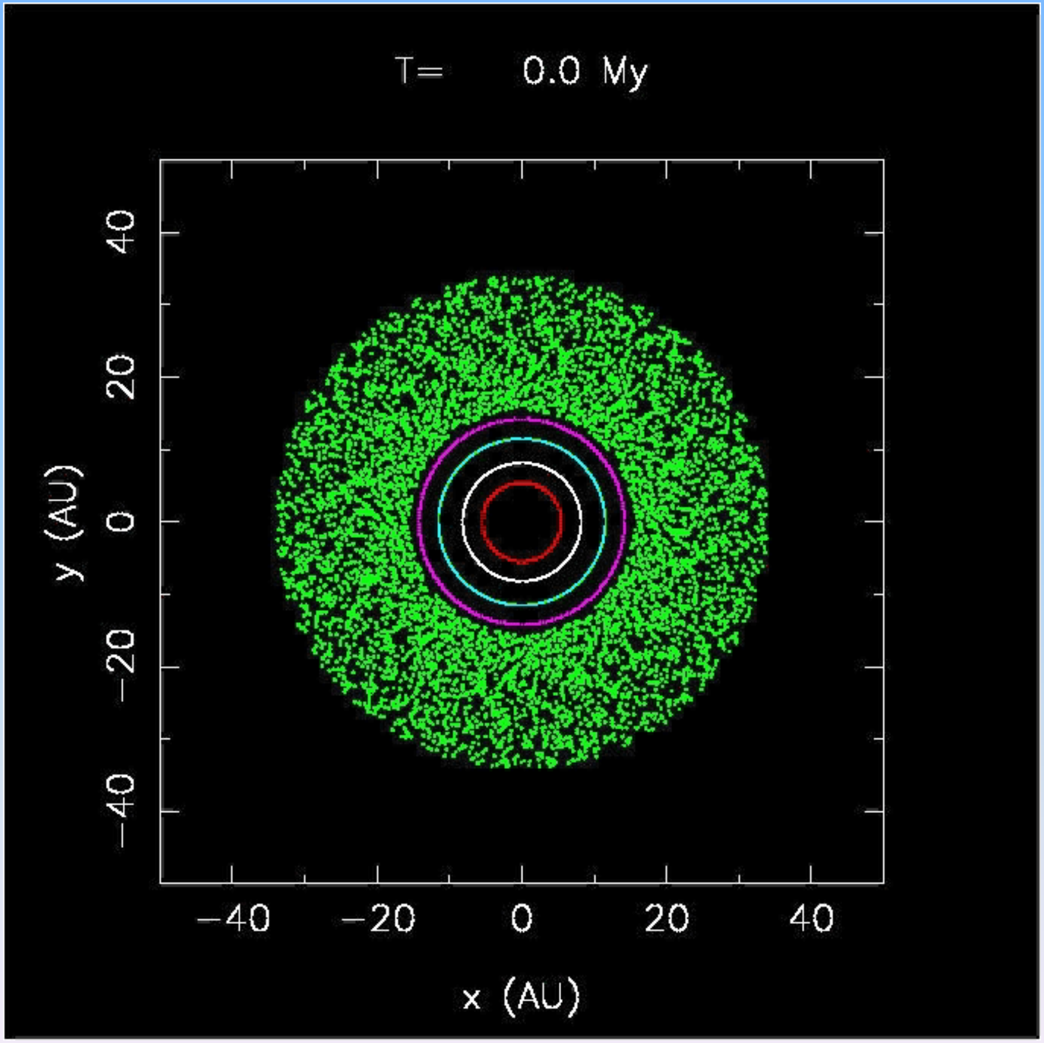
Wyatt et al. (2007)

Kuiper belt evolution

Nice model starts with a more massive Kuiper belt ($35M_{earth}$) outside a more compact planetary system

Planetary system becomes unstable after ~800Myr scattering Uranus and Neptune into Kuiper belt causing depletion

Explains missing mass problem, late heavy bombardment, …



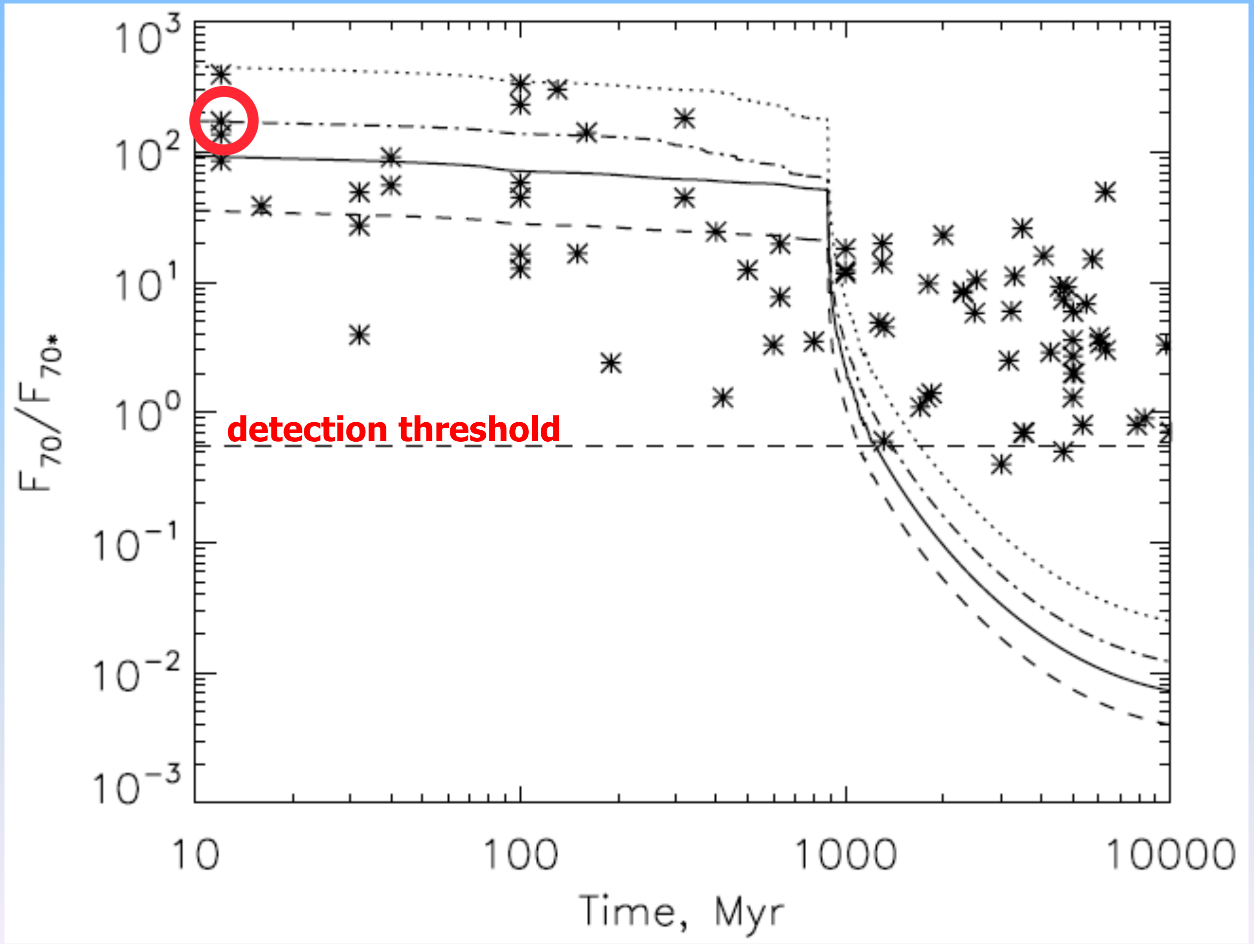
(Tsiganis et al 2005; Morbidelli et al. 2005; Gomes et al. 2005; …)

KB detectability through time

Before the LHB, KB dust was readily detectable in far-IR

After the LHB, mass loss means the KB is soon too faint to detect

If correct there should be analogues to the KB around young stars



(Booth et al 2010)

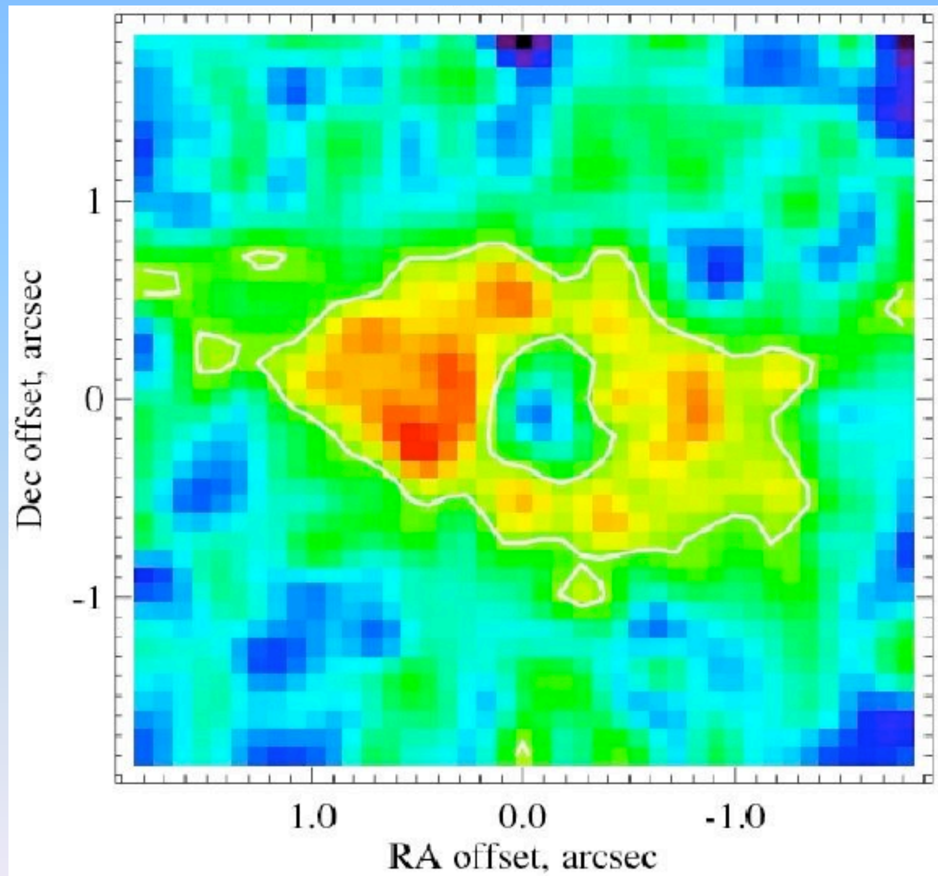
Young Kuiper belt analogue?

HD191089 is 12Myr F5V at 54pc

Mid-IR images at 18μm with TReCS show a ring of emission with inner edge at 28AU

Tentative brightness asymmetry suggestive of perturbations from planet on eccentric orbit

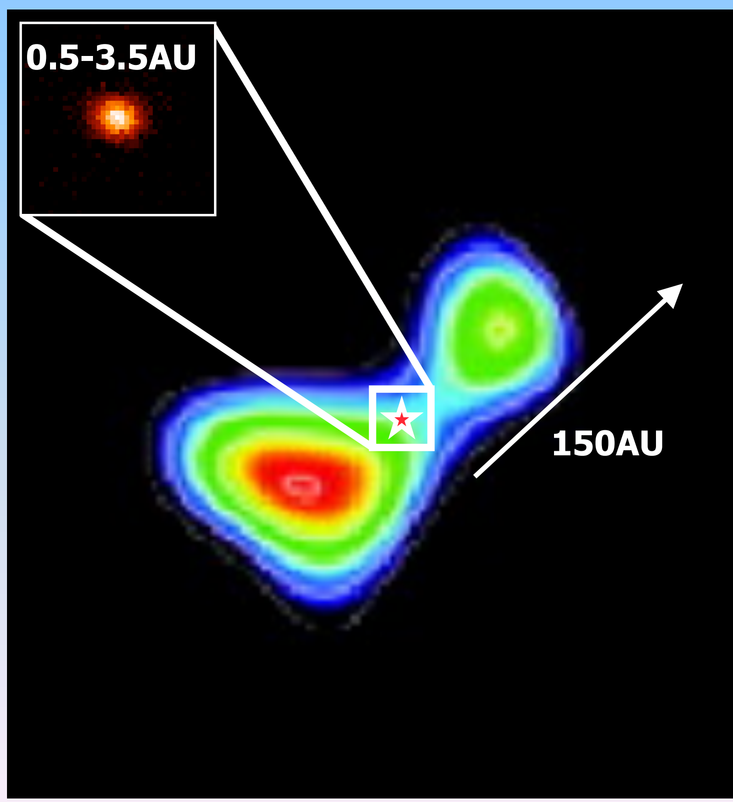
Inner regions empty of dust



(Churcher, Wyatt & Smith, in prep.)

Hot dust

Several systems are now known that have hot dust at a few AU (Beichman et al. 2005; Song et al. 2005; Absil et al. 2006), many of which also have an outer planetesimal belt

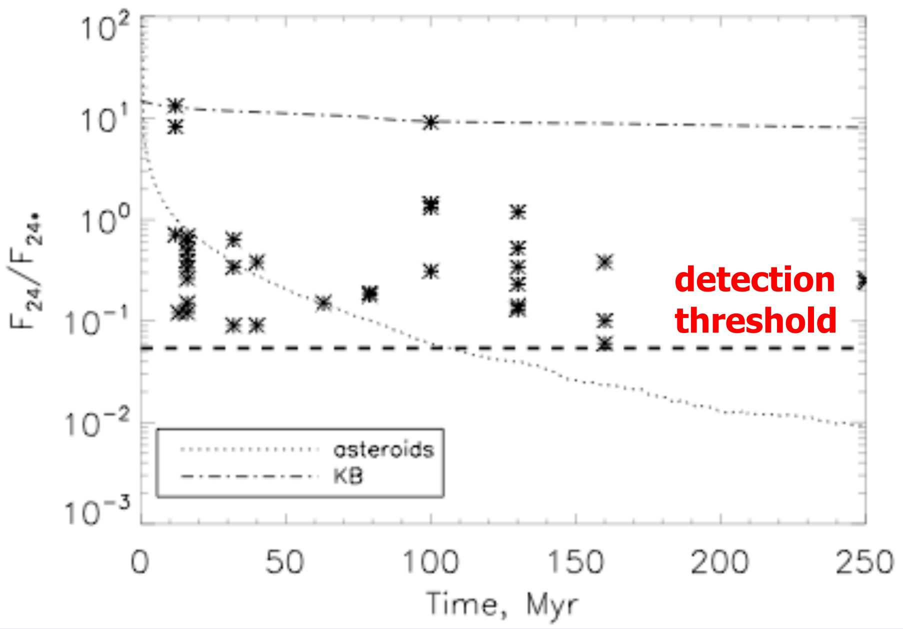


The 1Gyr F2V η Corvi has 150AU planetesimal belt imaged at 450μm (Wyatt et al. 2005)

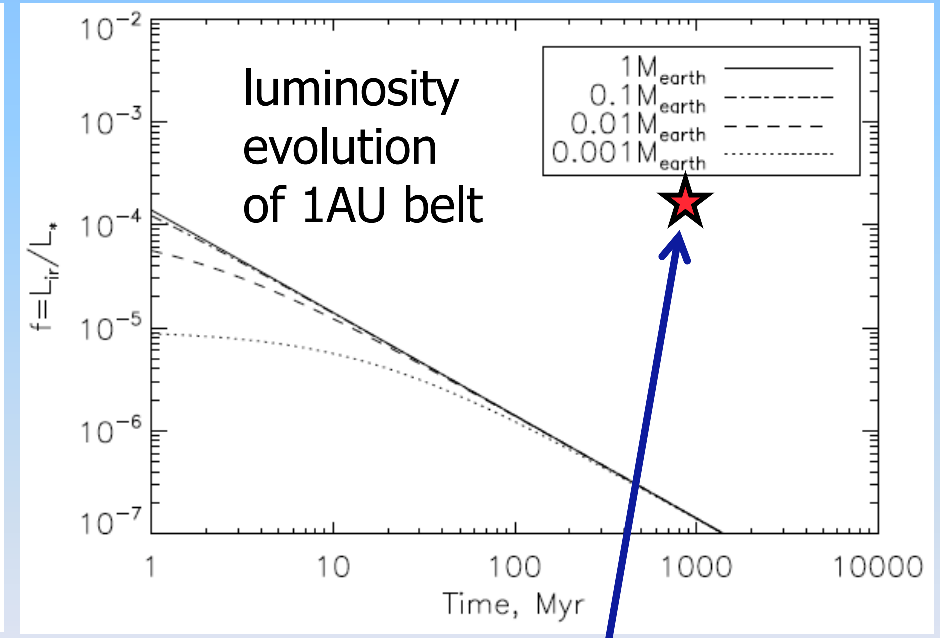
But 18μm emission is 0.5-3.5AU (Smith et al. 2008; Smith, Wyatt & Haniff 2009)

Old asteroid belts are not detectable

Our asteroid belt fell below detection threshold after ~100Myr (Booth et al., in prep)



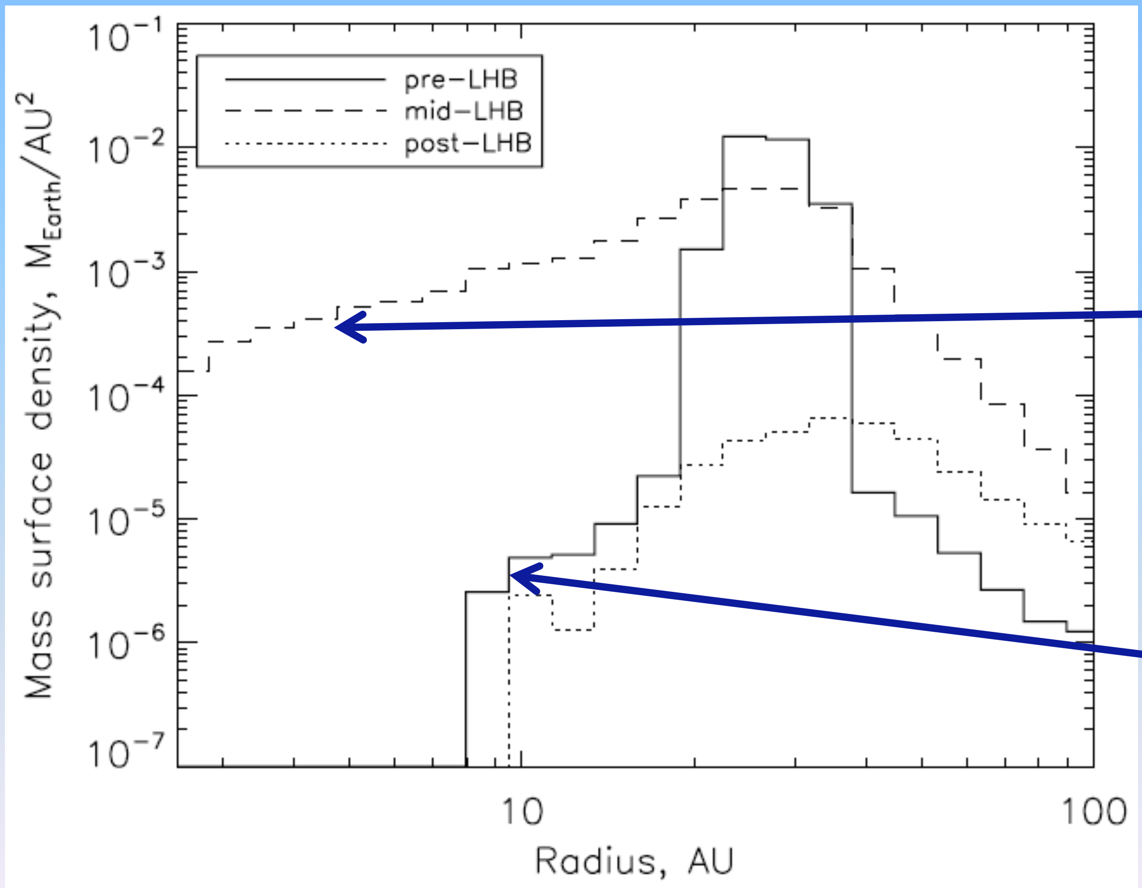
Collisional erosion means close-in asteroid belts fade quickly (Wyatt et al. 2007)



The hot dust around η Corvi (and all but youngest stars) is 1000x too bright for its age

Origin in outer planetesimals?

Kuiper belt mass distribution in Nice model (Booth et al. 2009)



Mass is transported into the inner regions:

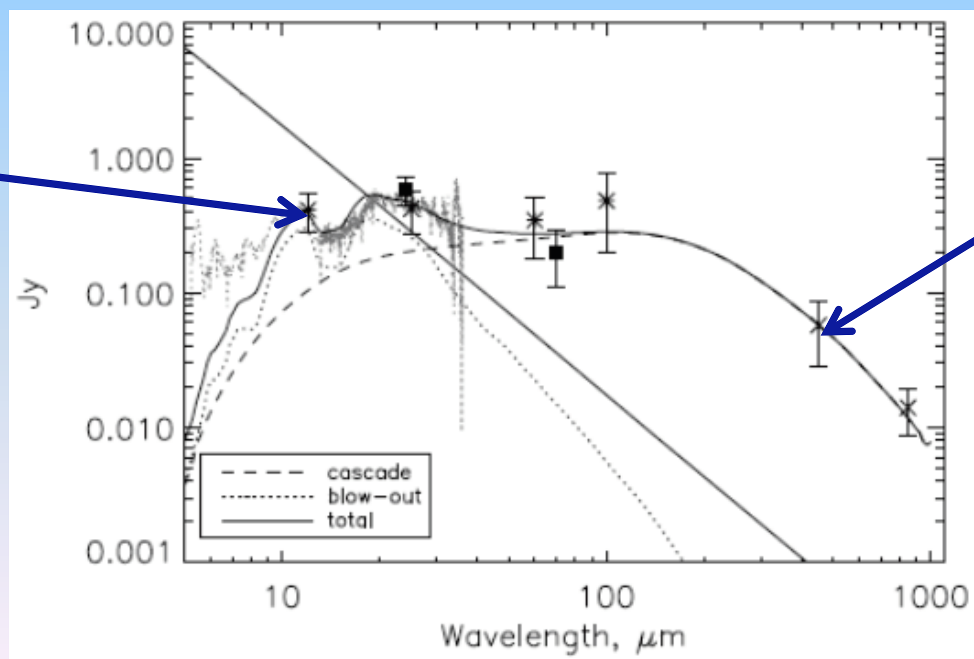
- During the LHB. Possible, but short-lived (~100Myr) and few systems undergo LHB
- At all times as comets. But how much dust is produced (Nesvorny et al. 2010)

Understanding the competition

Competition between a comet's dynamical evolution and collisions, radiation forces, sublimation, disintegration is complex, and knowing the distribution of SS dust inside KB essential

But could explain hot dust; e.g., η Corvi explained by planetesimal belt with pericentre 0.75AU, apocentre 150AU, current mass $5M_{earth}$ (Wyatt et al. 2010)

Mid-IR sees dust released in sublimation and collisions at pericentre



Sub-mm images see apocentre

Conclusions

- Currently detectable debris disks may be analogues to young Solar System, and constrain uniqueness of Solar System evolution

- Several systems have hot dust that may be analogous to cometary activity

- Need observations of Solar System dust distribution to understand competition between radiation, sublimation, dynamics, collisions

- Future observations will detect low mass disks that can be compared to current Kuiper belt dust distribution