Are planets and debris correlated? Herschel imaging of 61 Vir

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Why we think debris systems have planets

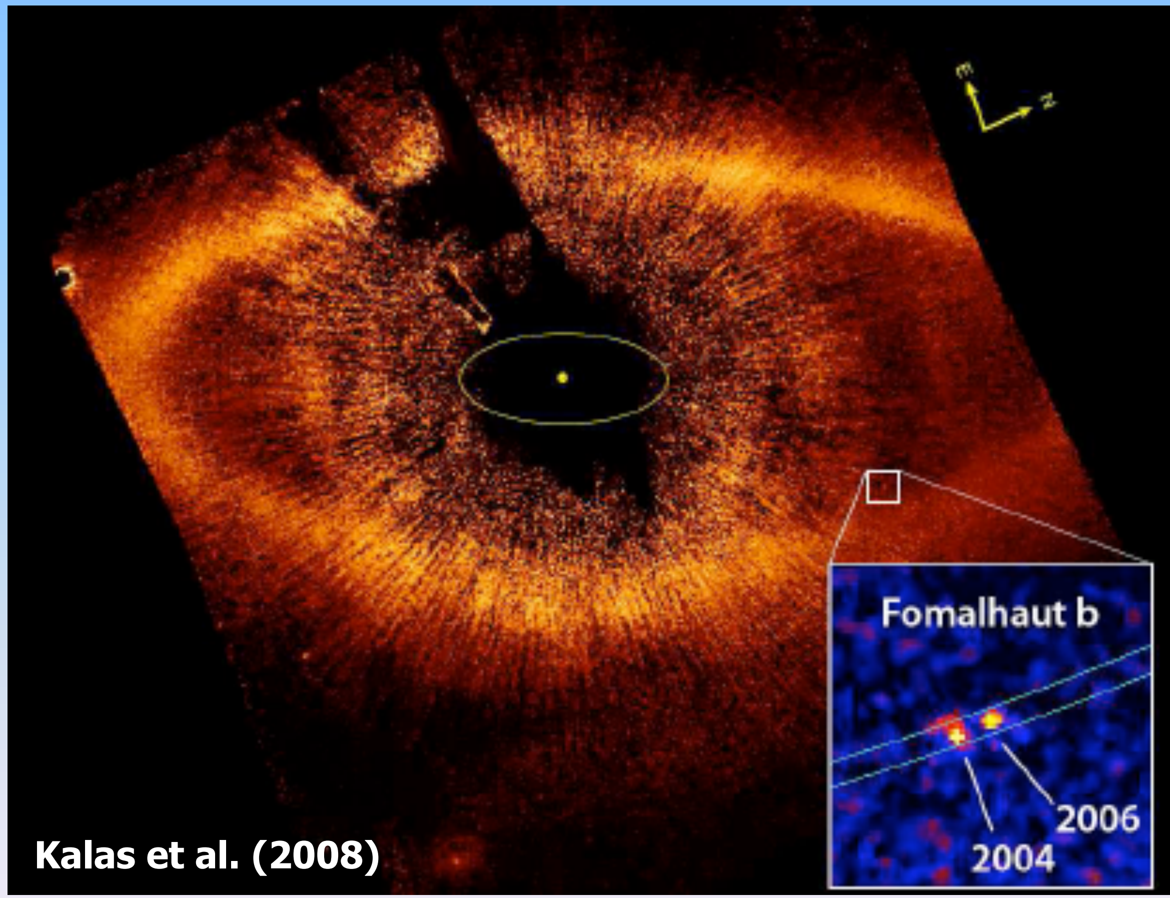
Dust replenished by km-sized planetesimals

Debris disks stirred somehow

Cleared inner regions

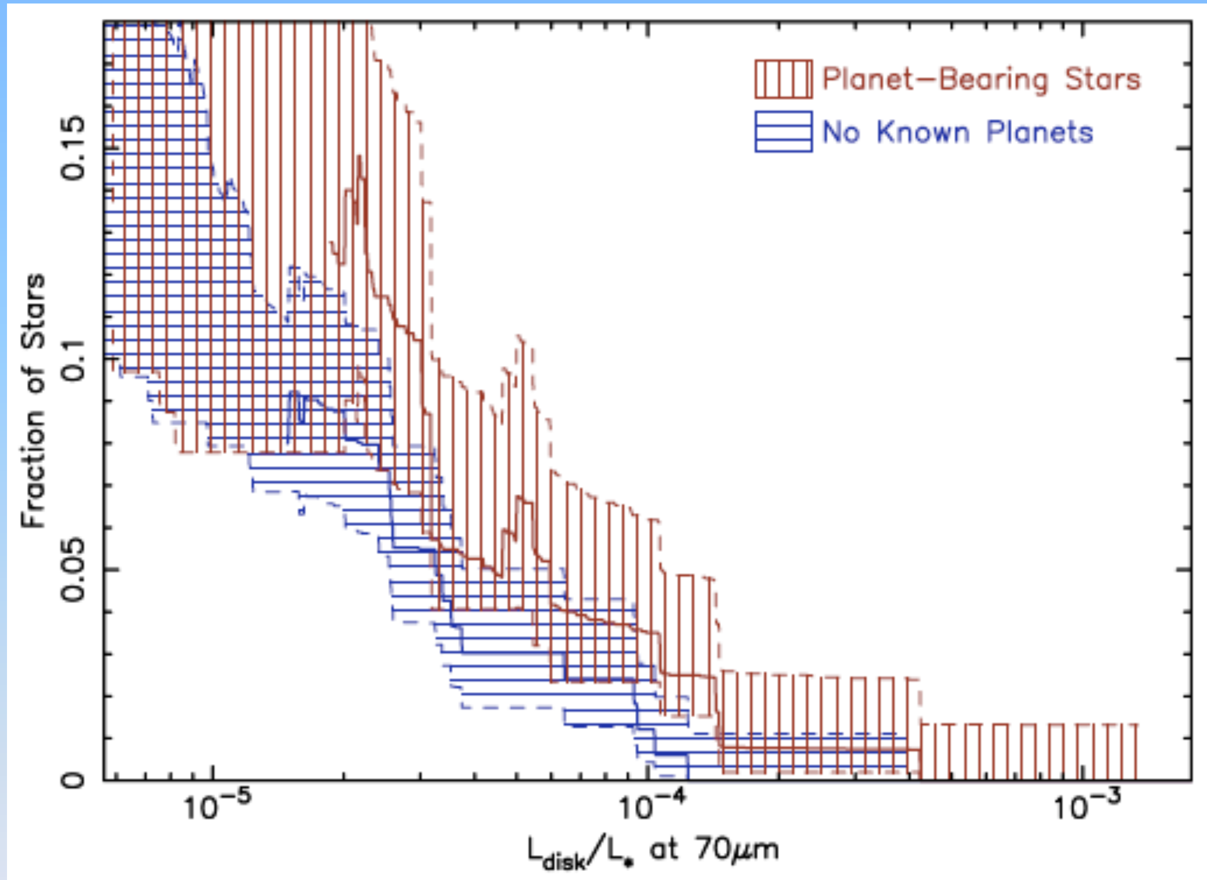
Some disks are asymmetric

Some systems actually have planets



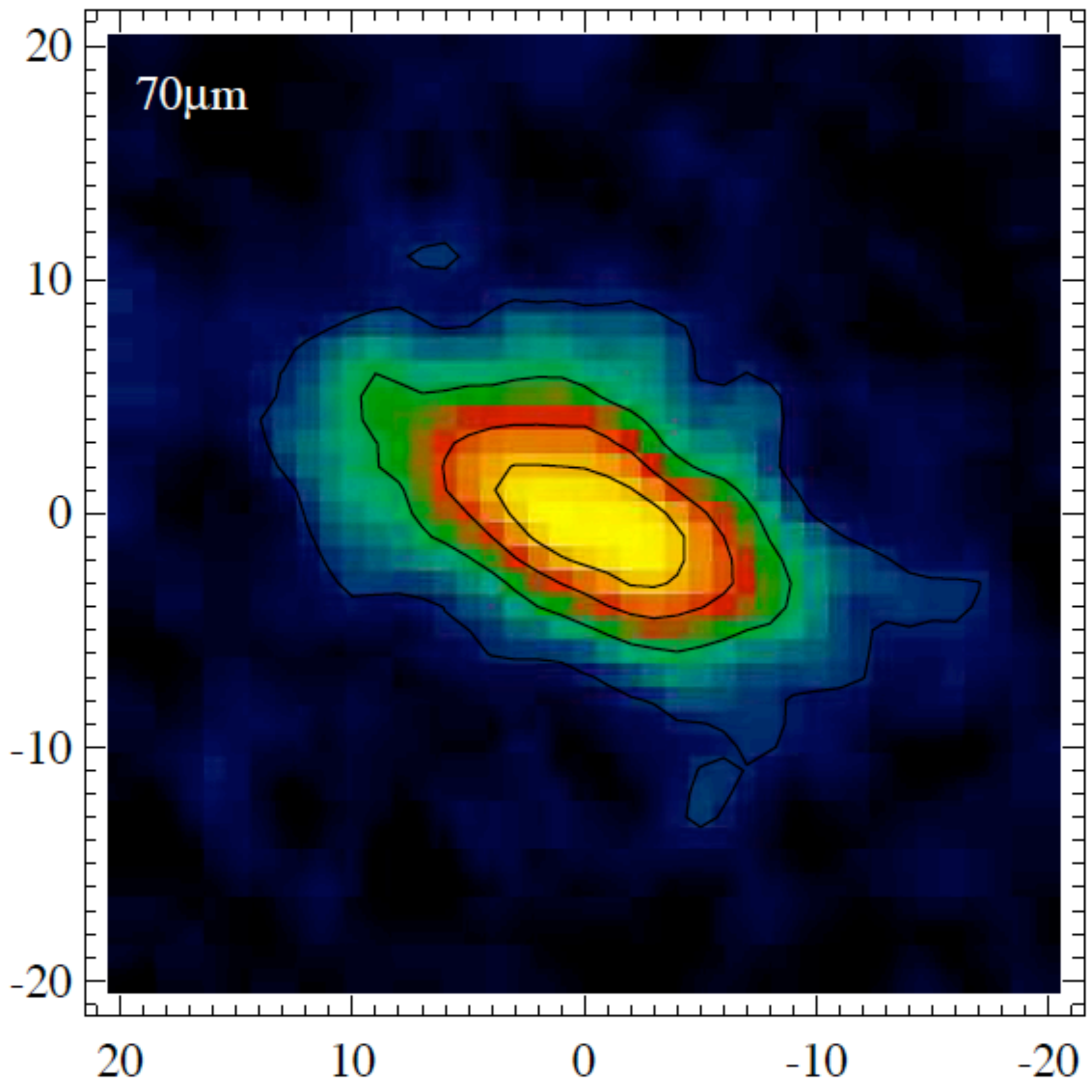
But planet hosts don't always have debris

Taking just planets from radial velocity studies, no difference in fractional luminosity distributions of the disks around stars with and without planets (Bryden et al. 2009)

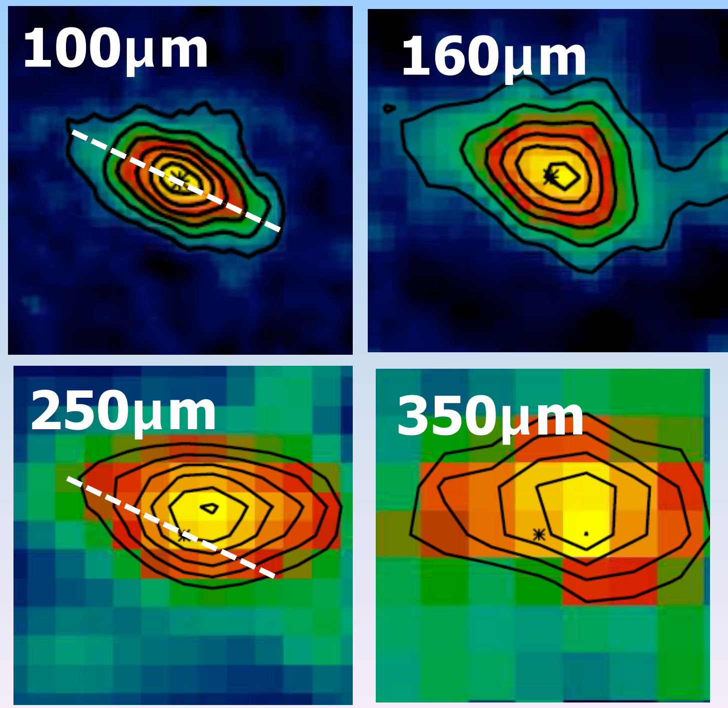


Perhaps expected as debris is >>10AU and planets are <<10AU, but conditions that form planets might be expected to leave debris

Herschel images of 61 Vir debris disk



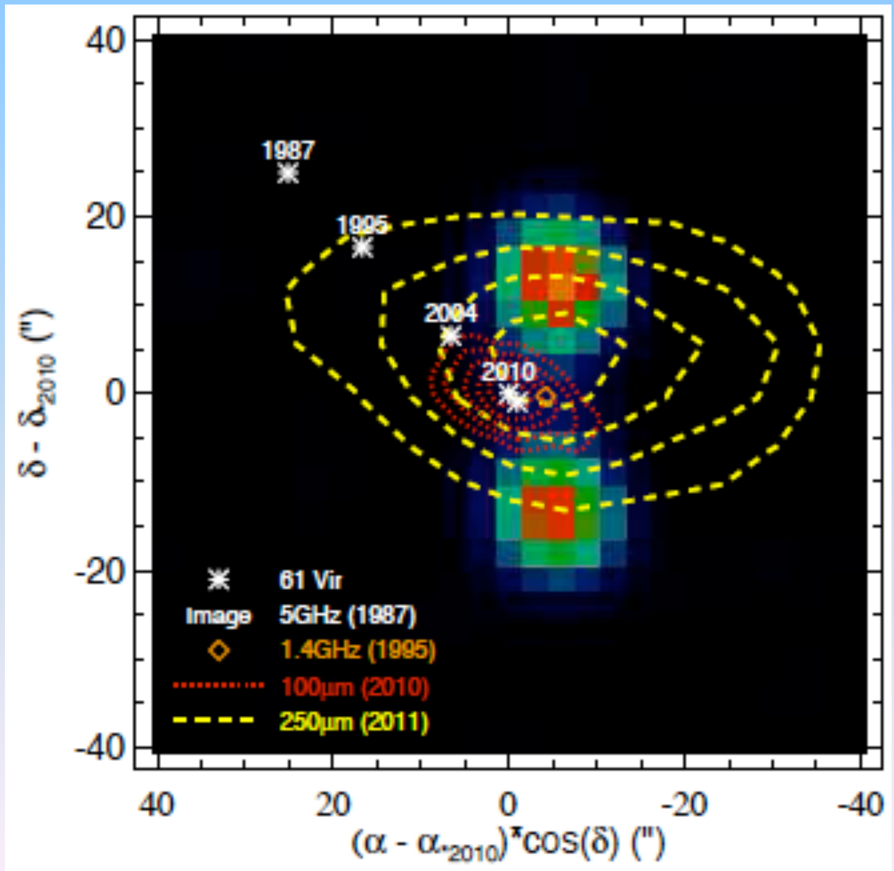
At 8.5pc, 61 Vir is 8th nearest G star; it was imaged at 70-160µm with PACS and 250-500µm with SPIRE as part of DEBRIS
(Wyatt et al., in prep)

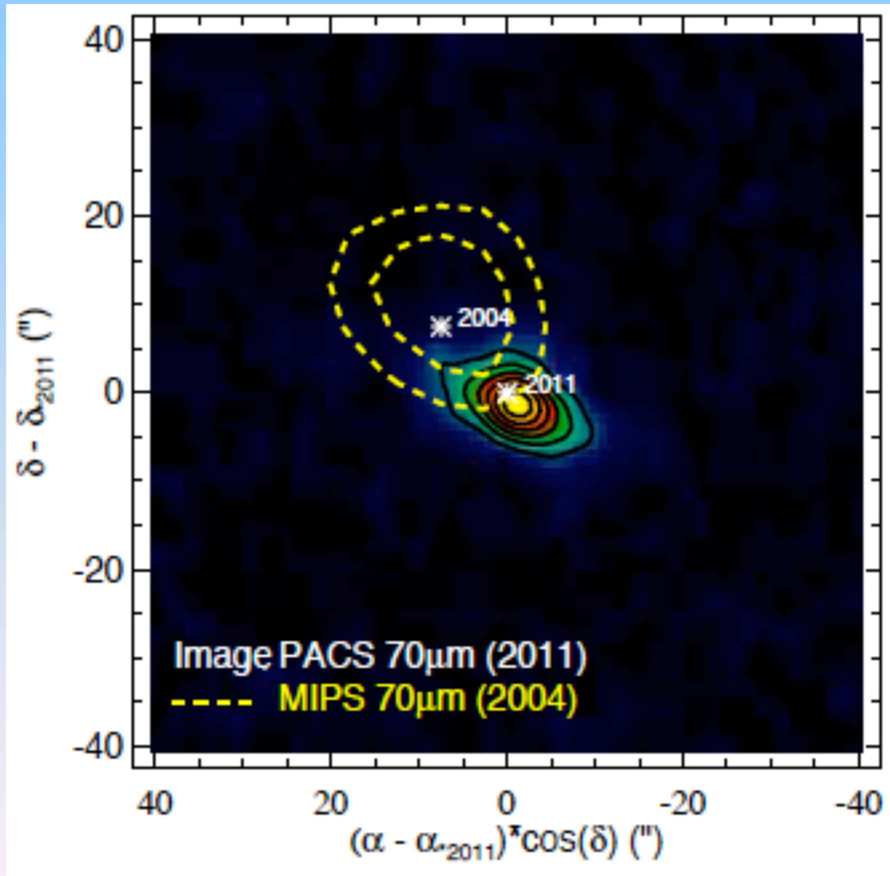


Confused… but still a disk

Radio images show two sources centred on current location of 61 Vir, so is *disk* emission extragalactic?

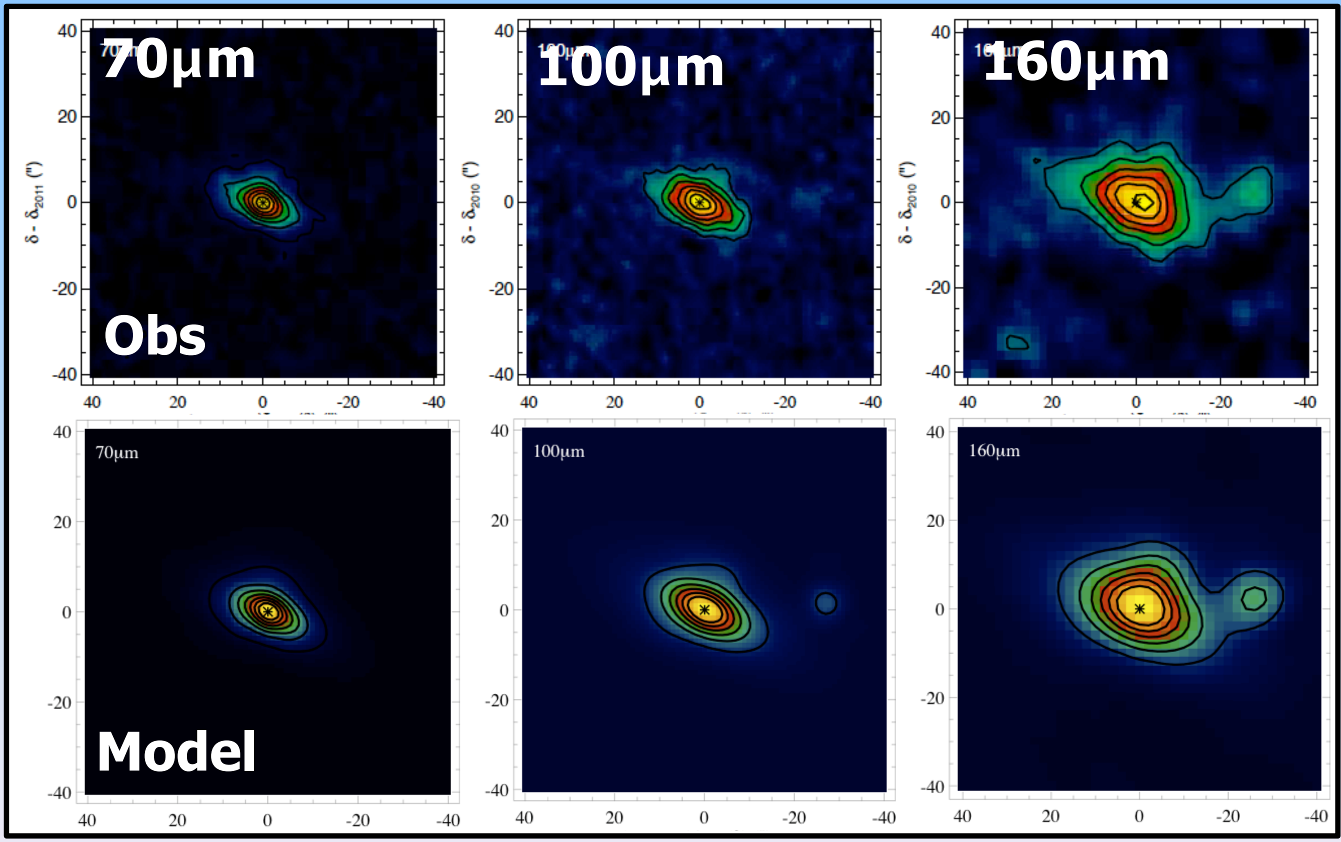
61 Vir was imaged at 70μm in 2004, showing emission centred on star, not 11″ away as expected if background

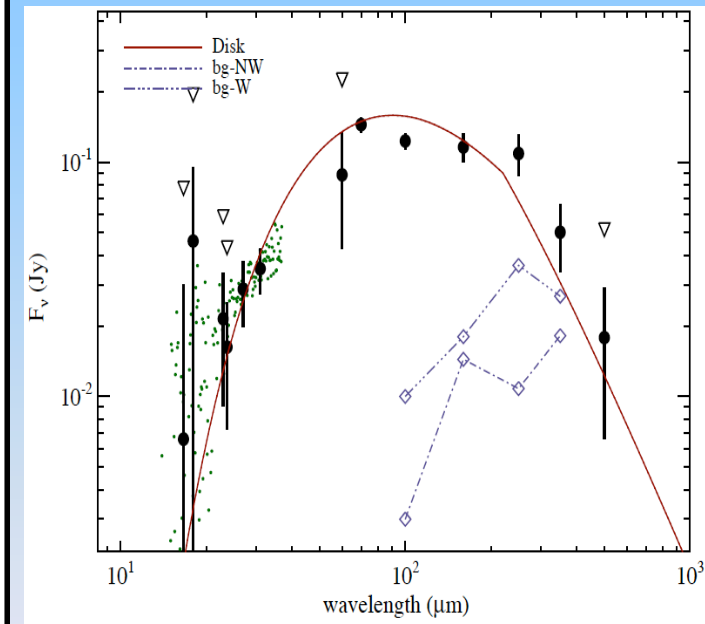




Where is the dust?

Models explain all observations with 30-350AU disk (surface density ~$r^{-1.3}$) with temperatures 1.9x black body, but most emission is <100AU as 2 rings at 40 and 90AU fit observations almost as well

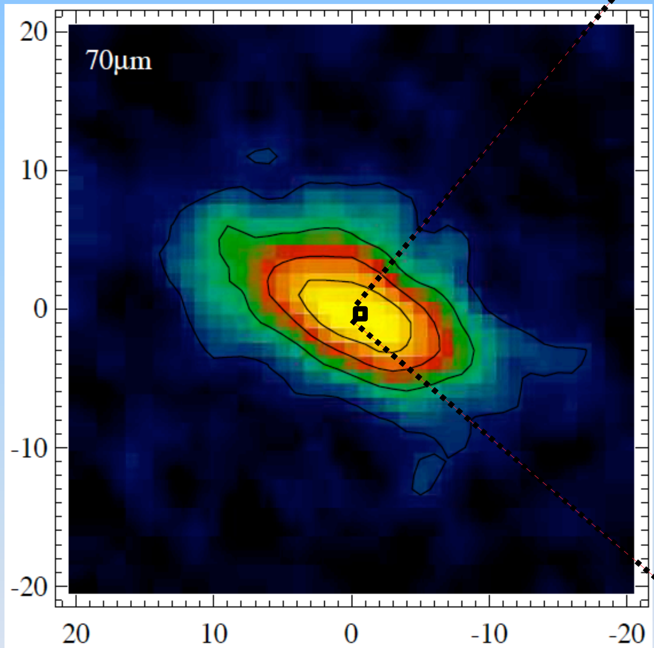


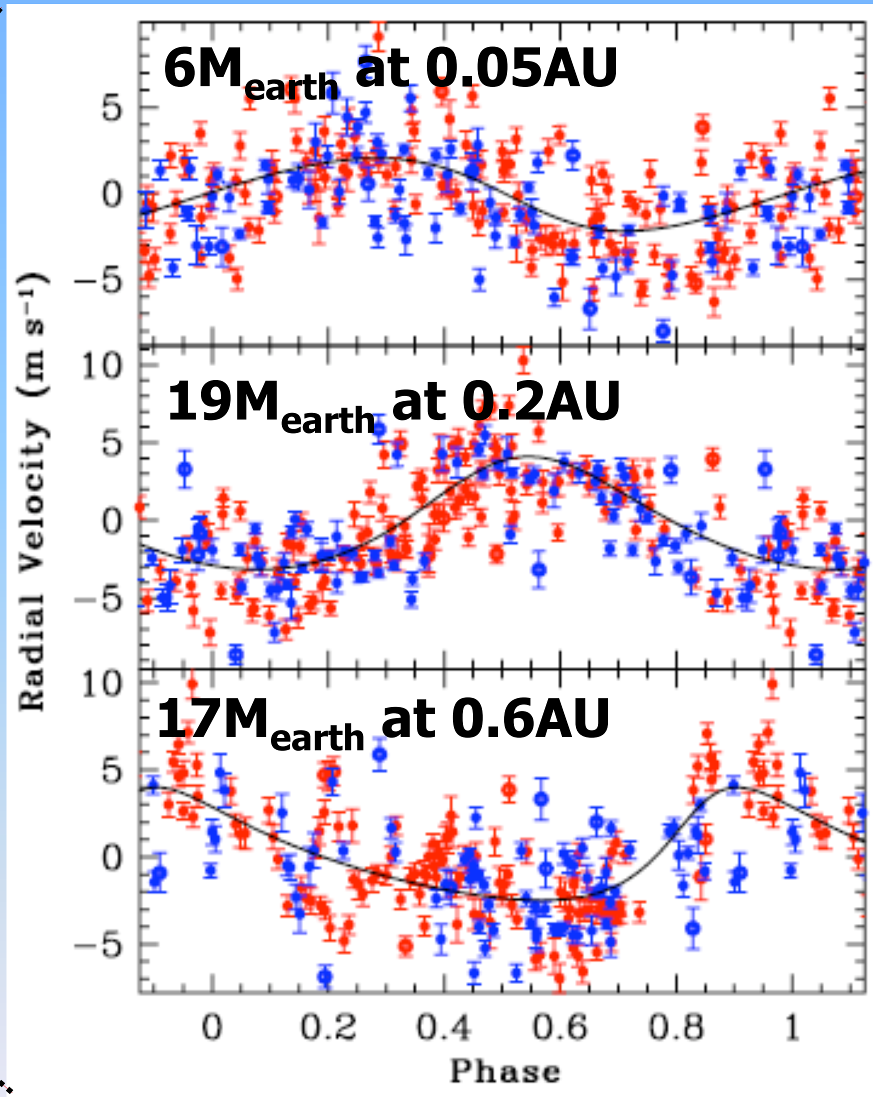


What is the relevance to planets?

61 Vir planets

Also three sub-Saturn-mass planets orbiting within 1AU
(Vogt et al. 2010)





Planets are well inside disk inner edge, so is it just a coincidence?

Interaction between RV planets and disk

If planetary system is aligned with disk, then 77^{o} inclination increases planet masses by 3%

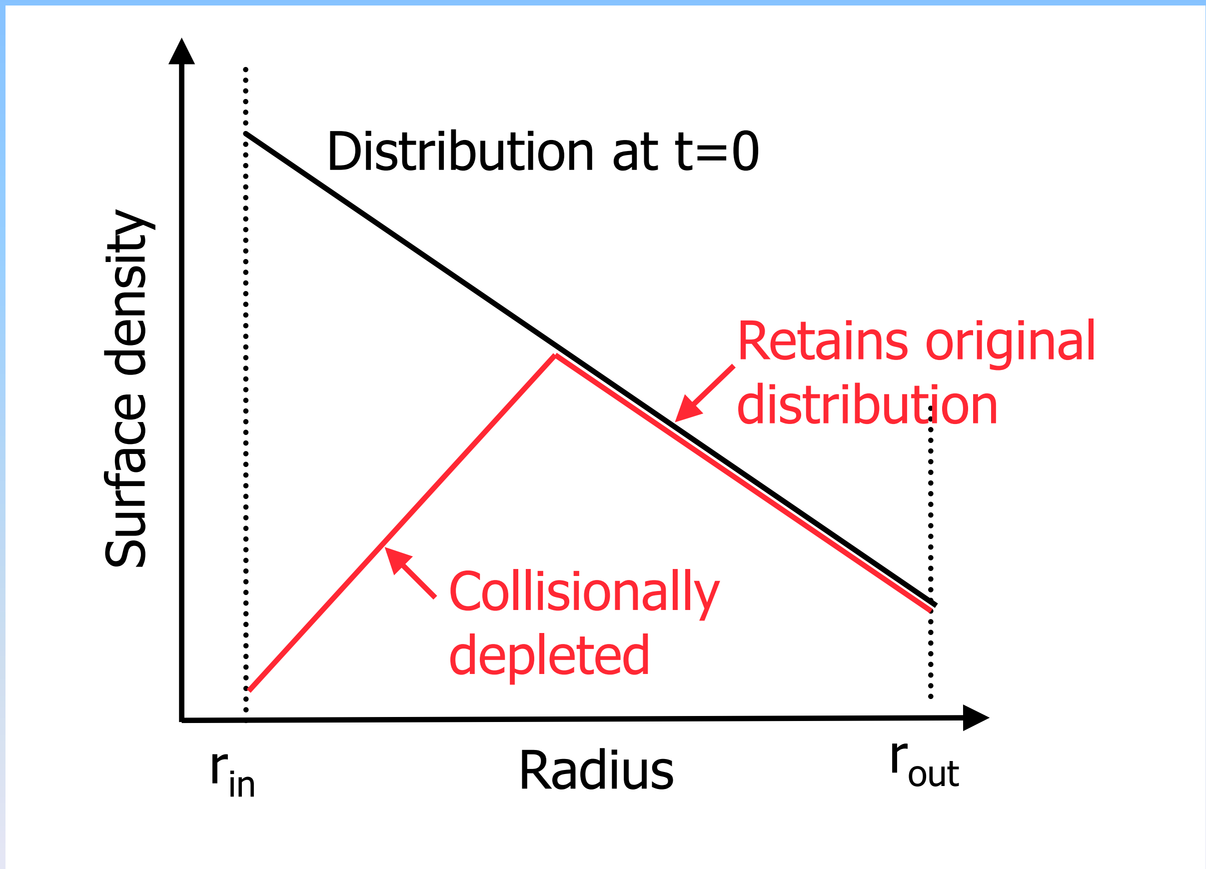
Secular perturbation timescales are >60Gyr, so no dynamical interaction…

… unless there are planets in 1-30AU region

No evidence from RV for such planets, and no disk asymmetries to implicate planets, but inner regions empty of planetesimals

But inner hole could be collisionally depleted

Consider a disk initially extending r_{in} to r_{out}



Rapid collisional erosion creates surface density $\sim r^{7/3}$ inside some radius

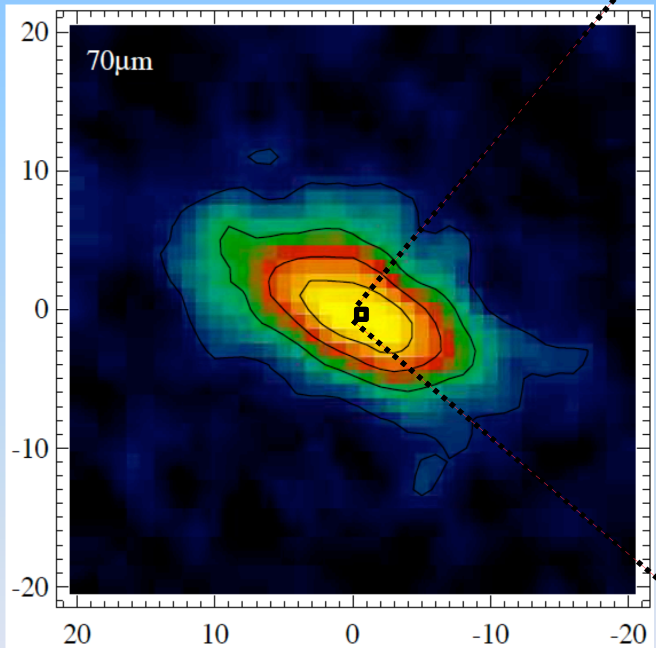
61 Vir observations reproduced with turnover at 43AU

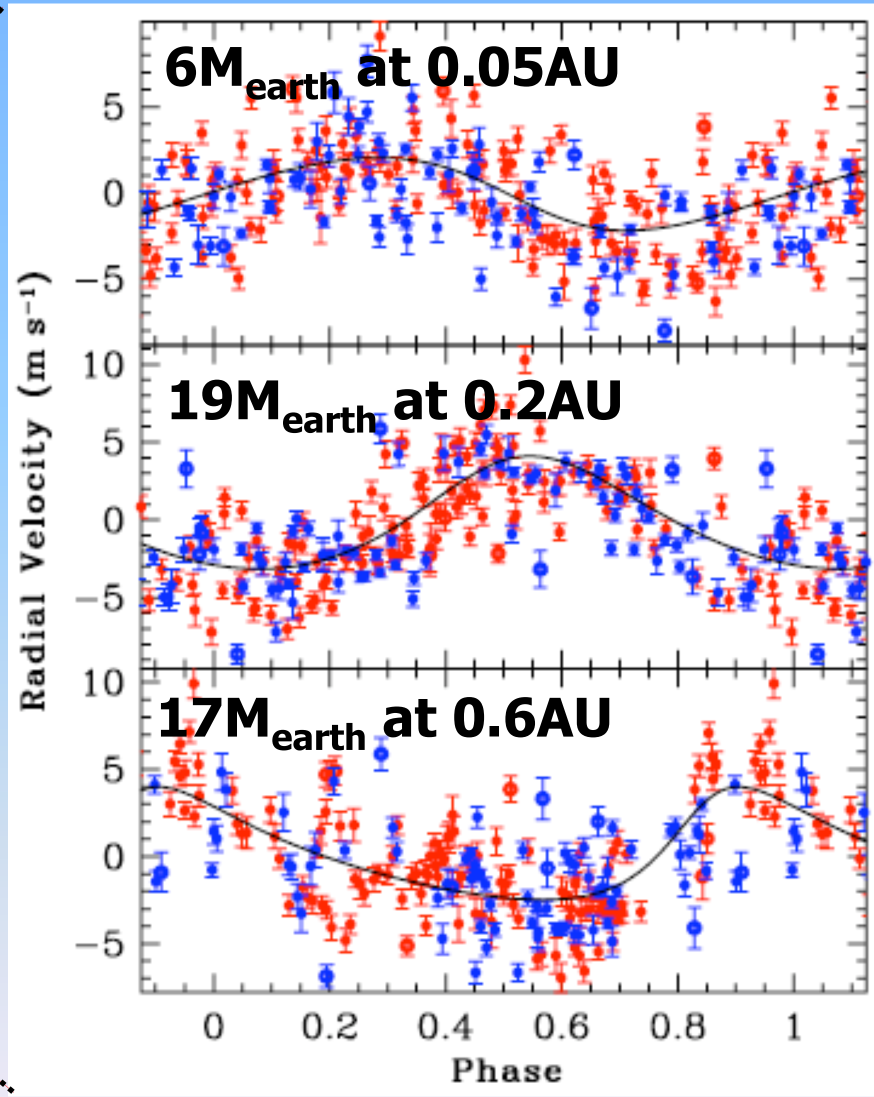
Requires 2-5km planetesimals and mass surface density 0.4% MMSN

Until inner edge (or asymmetries) are imaged, planets at 1-30AU are uncertain

Merits of an unbiased survey

Also three sub-Saturn-mass planets orbiting within 1AU
(Vogt et al. 2010)





These planets were not known when disk-planet correlations were last considered – is there a correlation with low-mass planets?

Nearest 60 G stars

Consider unbiased sample of nearest 60 G stars (Phillips et al. 2010).
11 have planets:

5 high-mass planet systems (at least one planet has $M_{pl}>M_{saturn}$)
None have debris, consistent with debris and planets being uncorrelated
(2/12 of nearest 120 G stars with high-mass planets have disks)

6 low-mass planet systems (all planets have $M_{pl}<M_{saturn}$)
4 have debris, 1 of the undusty systems has M4 companion at 210AU.
As 15% normal stars have detectable debris, ≥4 out of 6 is 1% event

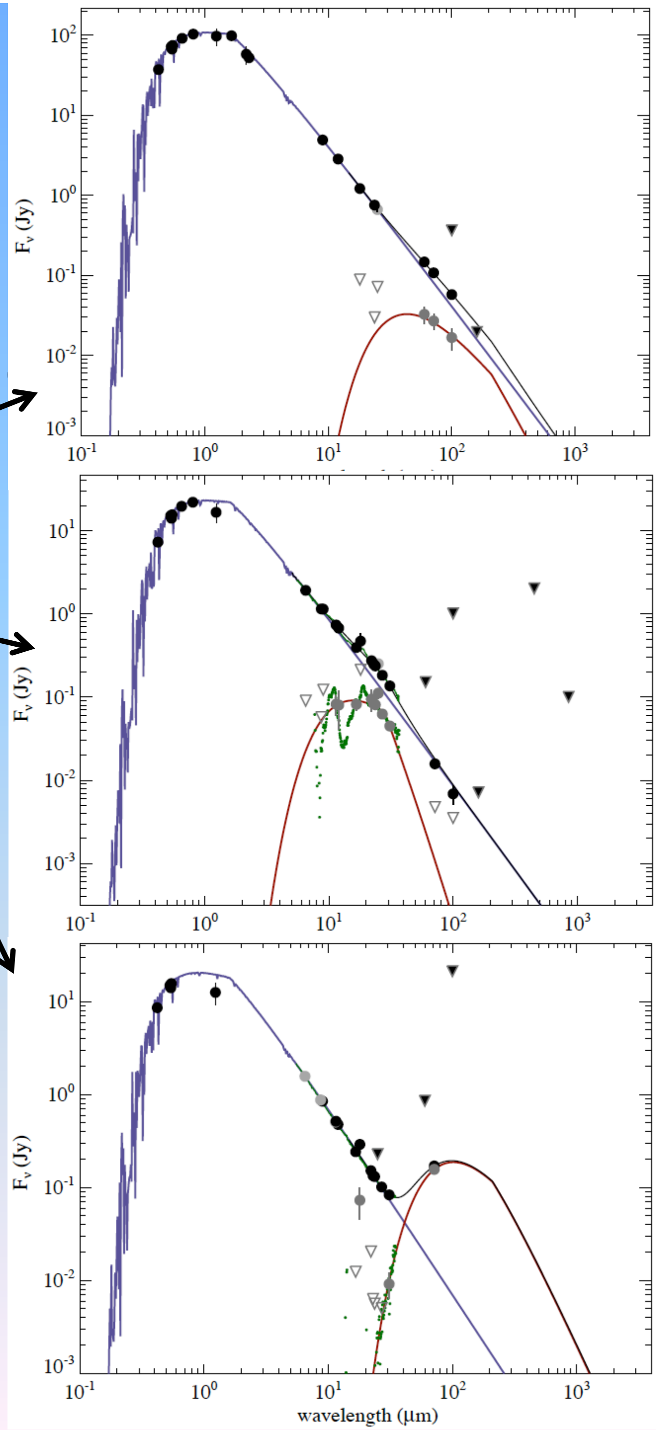
Small number stats, but this is first hint that systems with only low-mass planets (detectable in current RV surveys) are preferentially dusty

G stars with low-mass planets and debris

Star	Planets	Debris
HD20794	3x 2-5M_{earth} <0.4AU	Dust 17AU
61 Vir	3x 5-24M_{earth} <0.5AU	Dust 30-350AU
HD69830	3x 10-20M_{earth} <0.7AU	Dust at 1AU
HD38858	1x 32M_{earth} 1AU	Dust 21AU
HD102365	1x 17M_{earth} 0.5AU	No dust
HD136352	3x 5-12M_{earth} <0.5AU	No dust

Red = discovered since 2010

Nothing unique about dust properties in this sample (e.g., inner edges are 1 to 30AU)



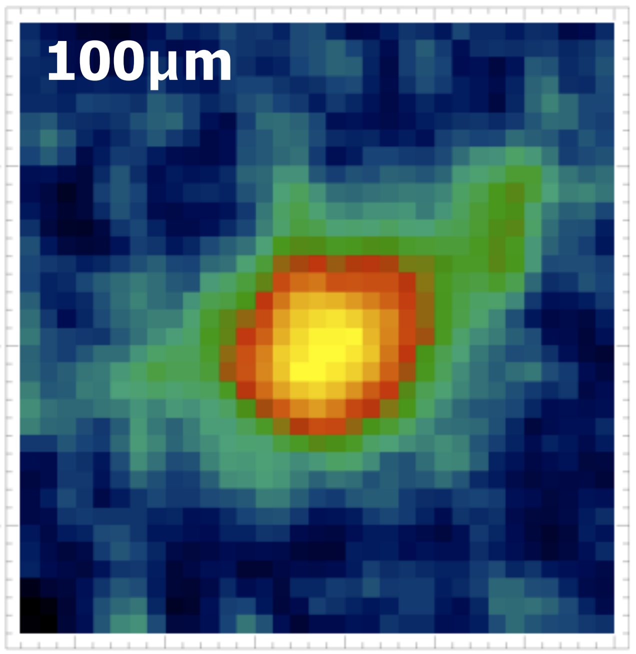
Nearest 60 M stars

Of an unbiased sample of nearest 60 M stars, 4 have planets:

2 high-mass planet systems (at least one planet has $M_{pl}>M_{saturn}$)
None have debris

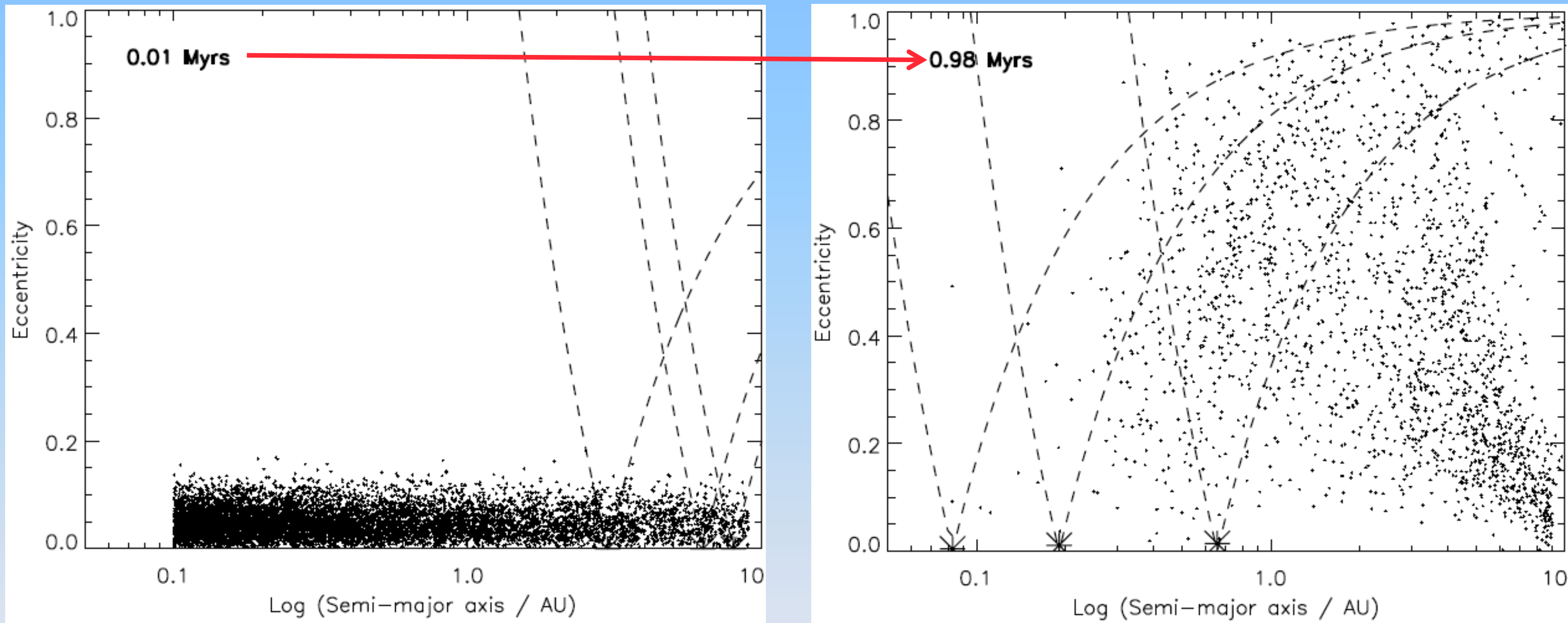
2 low-mass planet systems (all planets have $M_{pl}<M_{saturn}$)
1 has debris, 1 not observed with Herschel (or MIPS)

GJ581, 4(6) planets in 2-18M_{earth} range within 0.3(0.8)AU has cold dust resolved with PACS
(Lestrade et al. in prep)



Origin of low-mass planet-debris correlation?

The formation of a system with low-mass planets is also conducive to the formation of a debris disk that is bright after Gyr – why?



If planets start at 8AU then migrate in (Alibert et al. 2006), many planetesimals end up outside outermost planet in dynamically stable region (Payne et al. 2009)

Conclusions

(1) Herschel resolved the emission toward exoplanet host star 61 Vir showing dust is located 30-350AU

(2) Also discovered dust emission toward planet hosts HD20794 and GJ581

(3) Emerging trend: systems with low-mass planets (that are detectable in current RV surveys) more frequently have debris

(4) Likely related to the planet formation process