Herschel's Exploration of the Solar Neighbourhood:

Results of the DEBRIS OTKP

Neil Phillips (ALMA/ESO Chile)

ESTEC 2013-10-17

Image credit: NASA/JPL-Caltech

Thanks!

- Everyone involved in *Herschel* development, construction and operation should be very proud of their achievement and the observatory's scientific legacy.

Thanks!

- The DEBRIS consortium:
  - Brenda Matthews (PI; HIA Canada)
  - Jane Greaves (coPI; St. Andrews UK)
  - Bruce Sibthorpe (instrument specialist, data reduction lead; SRON Netherlands)
  - Grant Kennedy (photometry and SED fitting lead; IoA UK)
  - Pierre Bastien, Andy Biggs, Mark Booth, Jerome Bouvier, Hannah Broekhaven-Fiene, Harold Butner, Laura Churcher, Bill Dent, James Di Francesco, Jochen Eisloeffel, Gaspard Duchene, Brett Gladman, James Graham, Antonio Hales, Paul Harvey, Peter Hauschildt, Wayne Holland, Jonti Horner, Eduardo Ibar, Rob Ivison, Doug Johnstone, Paul Kalas, JJ Kavelaars, Alice Koning, Samantha Lawler, Jean-Francois Lestrade, Amaya Moro-Martin, George Rieke (affiliate member), David Rodriguez, Amelie Simon, Rachel Smith, Kate Su (affiliate member), Nathalie Thureau, Stephane Udry, Paul van der Werf, David Wilner, Mark Wyatt, Ben Zuckerman.

Talk Outline

- Debris discs and why *Herschel* was so good
- Survey overview
- Highlight results
- The future and ongoing analysis
- Summary

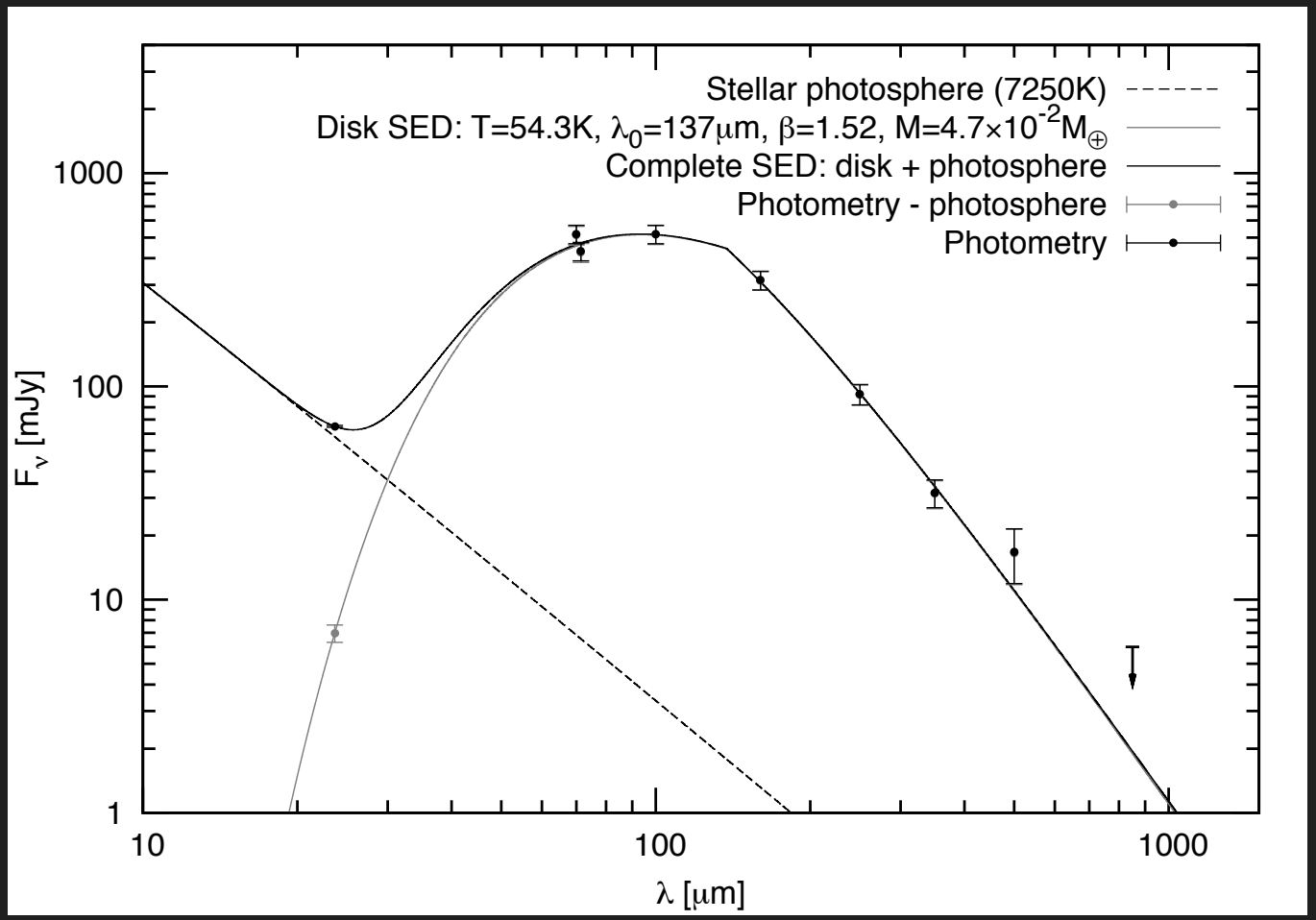
Debris discs in a nutshell

- In mature systems (>10Myr)
- Planetessimal belts can exist where stable relative to star and planet orbits
- Collisions generate dust
- Collisional cascade
- Larger grains remain in belts but radiation forces alter orbits of smaller grains and limit smallest grain size (PR drag, radiation pressure)
- Detected by IR excess over star
- Most detected 10-200AU, 50-200K
- Little gas

Dust distribution -> planetessimal distribution -> planet orbits

Why *Herschel*: SED characterisation

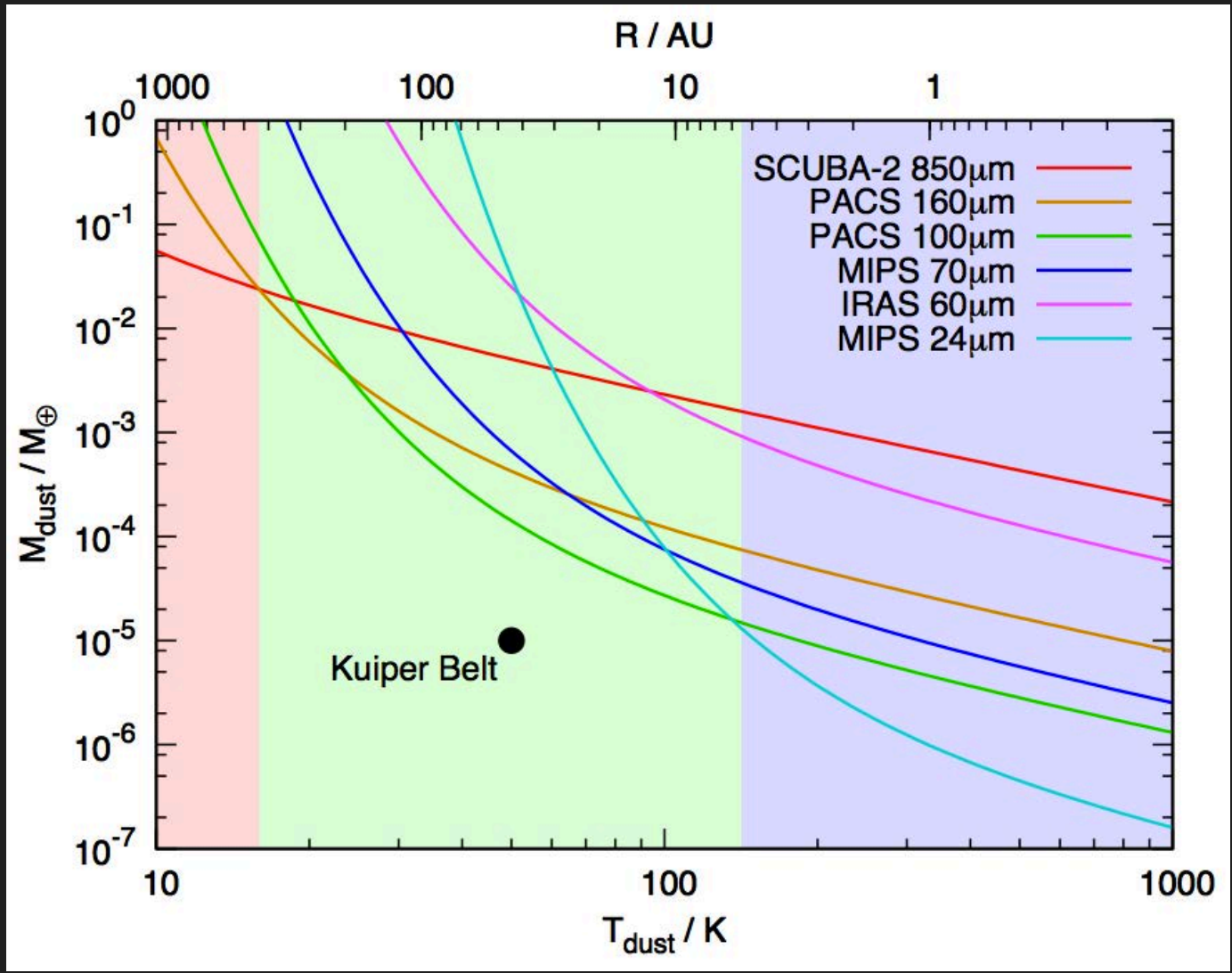
- PACS + MIPS perfect to characterise temperature
- SPIRE bonus to constrain β, λ_0 when detectable



λ_{peak} = 160μm @ T = 32K; λ_{peak} = 24μm @ T = 212K

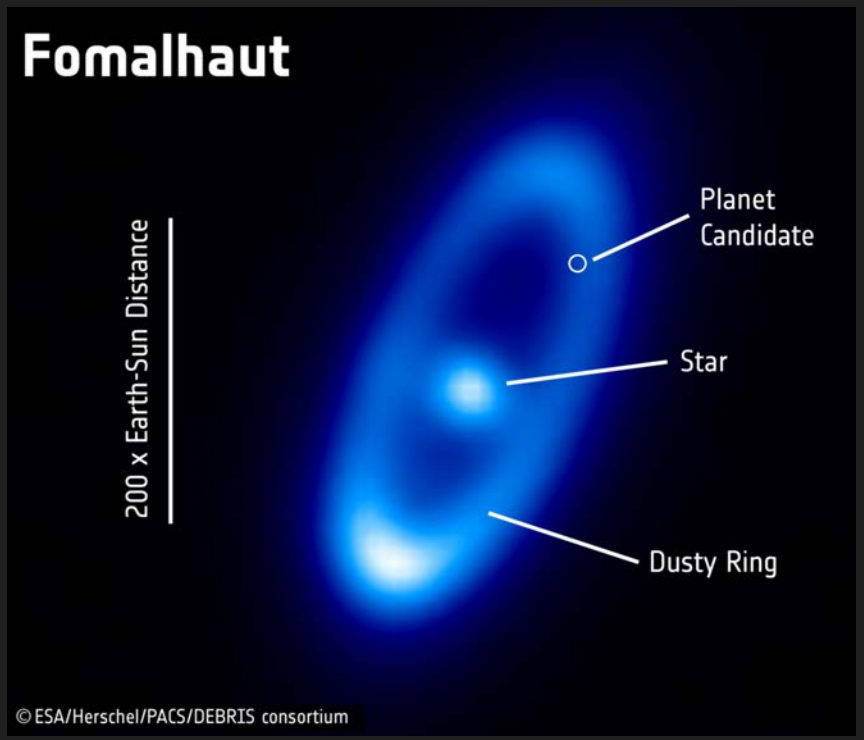
Why *Herschel*: dust sensitivity!

- Ex.: Sun @ 17pc
- Star-disc contrast increases to longer wavelengths
- PACS-100 optimum of contrast vs. S/N for typical cool Kuiper Belt like discs.

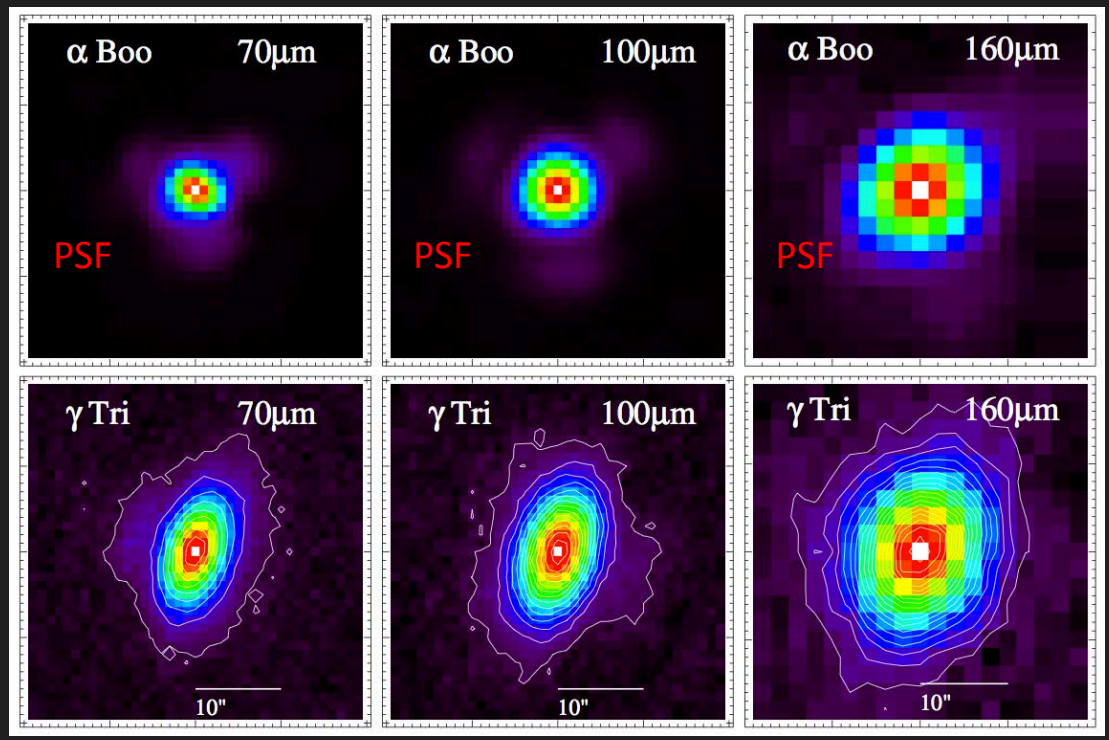


Why *Herschel*: spatial resolution

- PACS-70/100 3-4 times sharper than MIPS-70 (previous FIR best)
- Resolve the most nearby / big discs with PACS



PACS-70, Acke et al. 2012, 130AU ring @ 7.7pc



PACS; DEBRIS / Booth et al. 2013, large broad disc @ 34.4 pc

Herschel Key Programmes

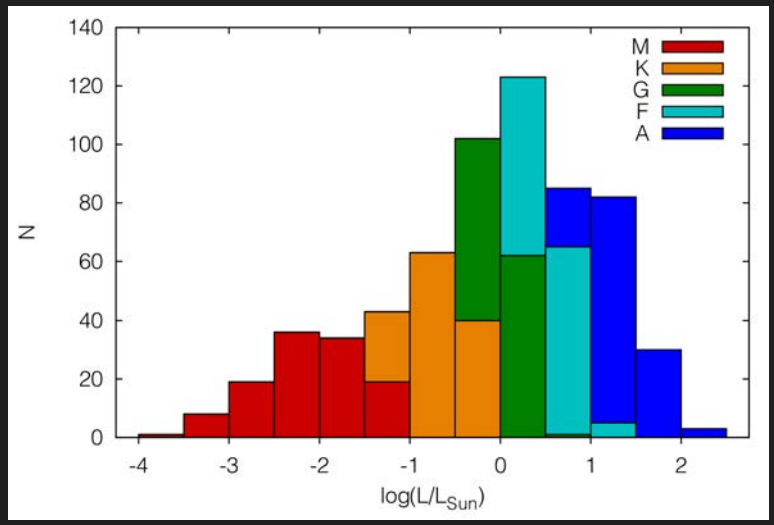
- GT: Stellar Disk Evolution (PI: Olofsson)
  - Sexy Six: Vega, Fomalhaut, β Pic, ε Eri, AU Mic, τ Cet
  - PACS+SPIRE maps and spectroscopy for some
- OTKP DEBRIS (PI: Matthews)
  - "Disc Emission via a Bias-free Reconnaissance in the IR and Sub-mm"
  - Unbiased census of ~500 nearby star systems of A to M SpT
  - PACS-100/160 focus with SPIRE and PACS-70 follow-up
  - Flux-limited – all systems observed to same depth
- OTKP DUNES (PI: Eiroa)
  - "Dust around NEarby Stars"
  - Detailed study of selected F-K SpT stars within 20pc
  - PACS-100+160 focus with SPIRE and PACS-70 follow-up
  - Contrast-limited – integration times to detect all photospheres
- Huge overlap: almost all targets were in DEBRIS proposed sample

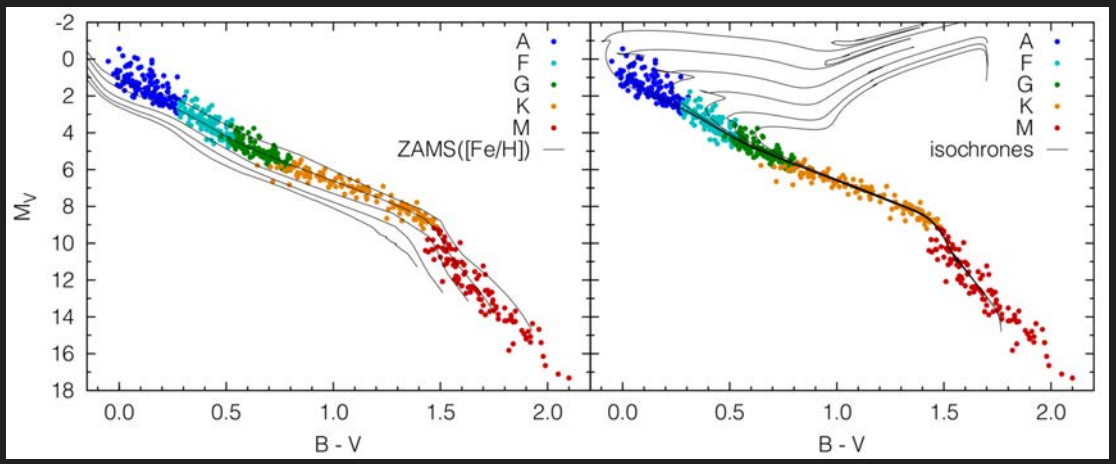
DEBRIS survey

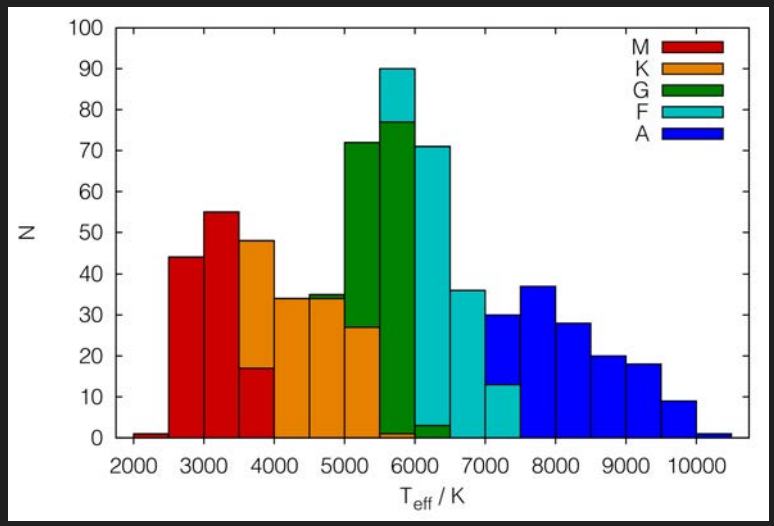
- Minimally biased legacy survey of nearby main-sequence star systems
- 140 hours allocated
- 446 systems in 5 volume-limited SpT subsamples, subject to cut in predicted galactic cirrus confusion
- M: 8.6pc, K: 15.6pc, G: 21.3pc, F: 24.1pc, A: 45.5pc
- Main-sequence primary stars A0-M7
- Naturally include spread of ages, metallicities, multiplicity
- Many FGK targets shared with DUNES team under data sharing agreement
- For all: PACS-100 @ 2 mJy/beam, PACS-160 @ 4 mJy/beam
- Follow-up: PACS-70 for resolved discs + SPIRE for bright

DEBRIS survey cont

- Sample selection from Phillips et al. 2010
- Samples as complete as possible at the time, including resolved components
- Good starting point for other nearby star surveys



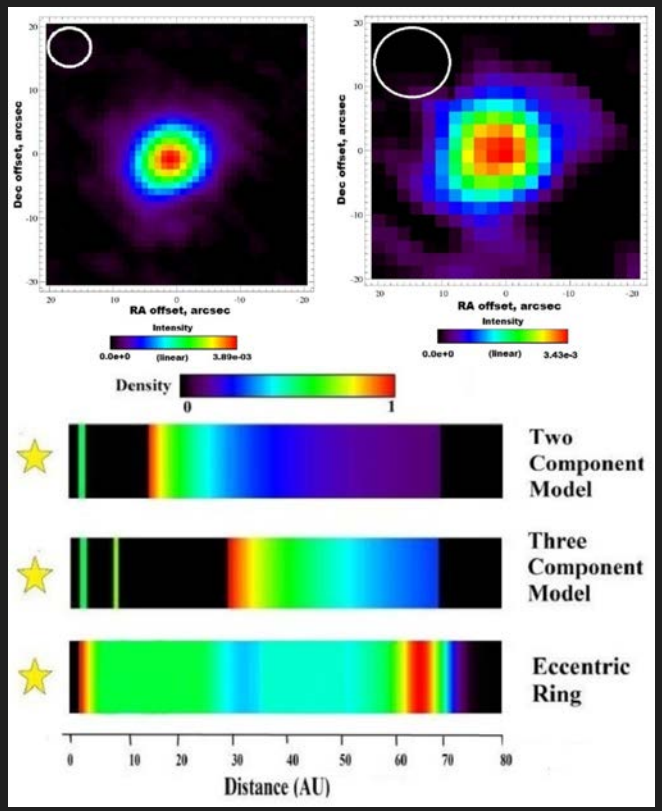




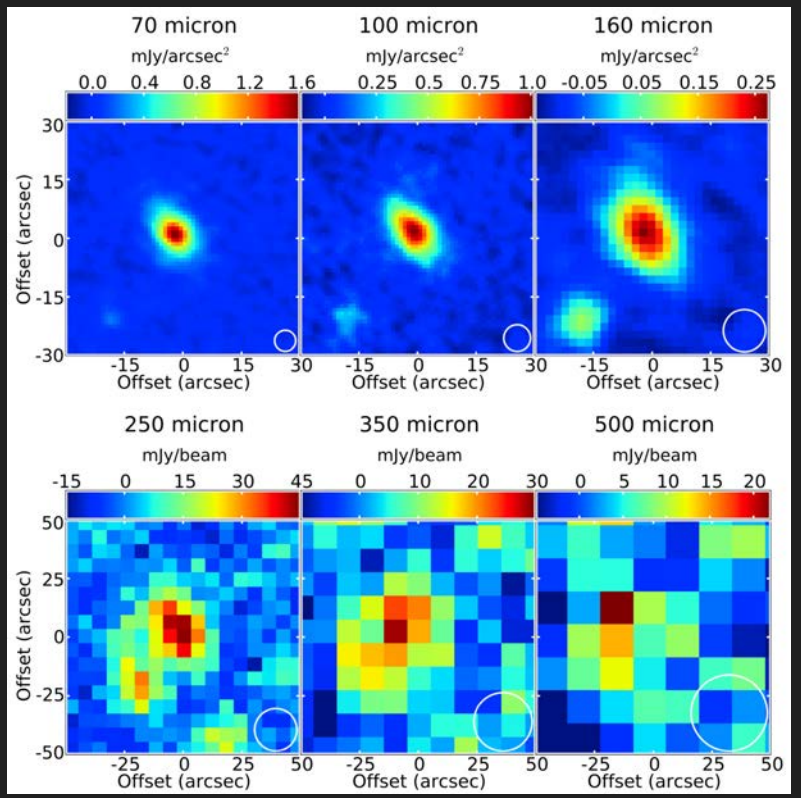
Results: resolved discs

- PACS resolves scales ~ 50-200 AU

β Leonis (A3 V @ 11.0pc)
Churcher et al. 2011



γ Dor (F1 V @ 20.5pc)
Broekhaven-Fiene et al. 2013

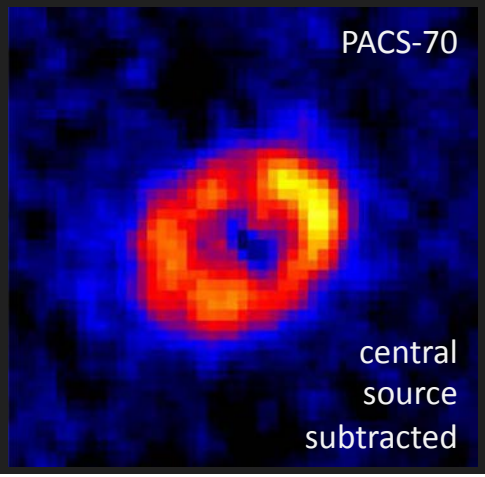


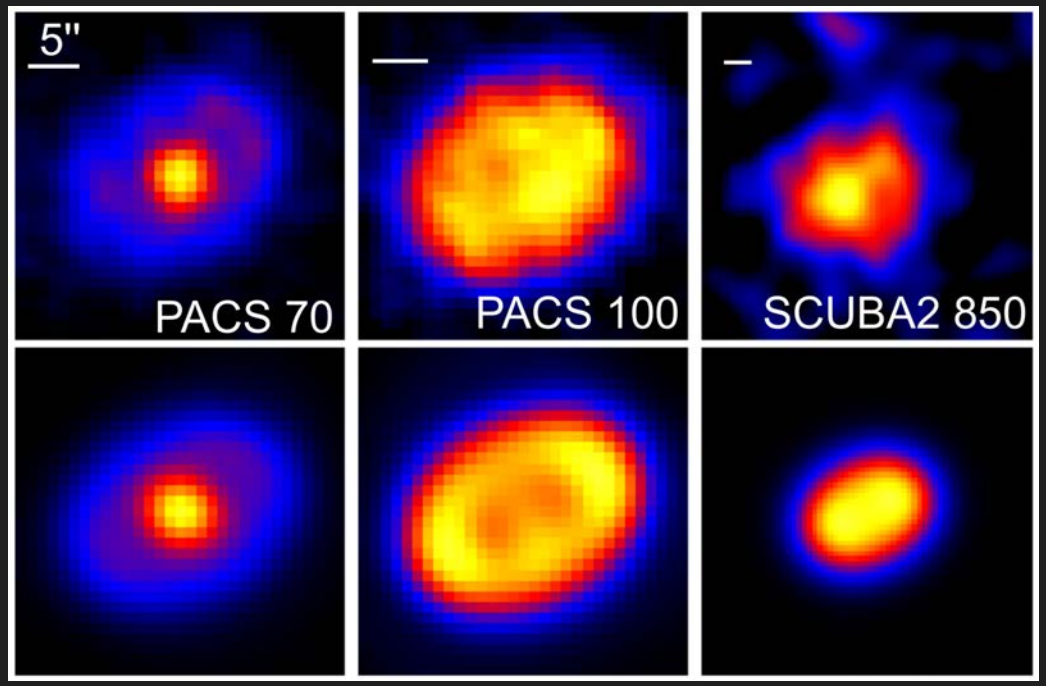
Resolved discs: size vs. T?

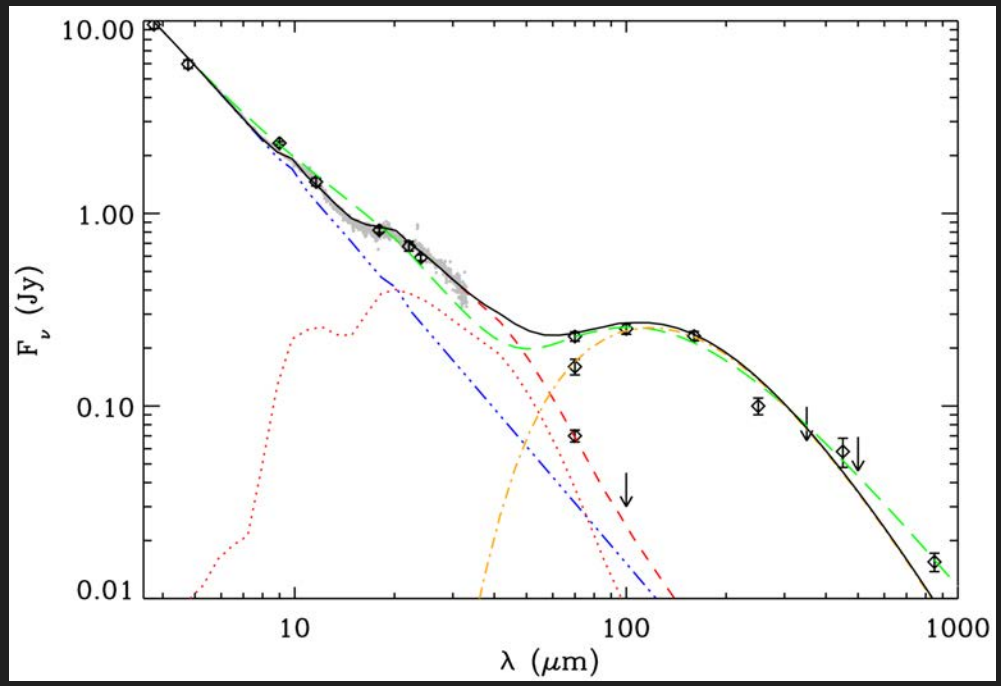
- Small grains hotter than BBs for their distance due to inefficient thermal emission
- SEDs -> BB T -> distance
- Booth et al. 2013: 9 resolved discs around A type star systems
  - Deconvolved radii, and T_{BB} from SED fits
  - Real radii 1--2.5 times bigger than from BB
  - BB works for the most luminous stars (~A0) due to large blowout grain size
  - No trend with age
  - All have deconvolved size increasing from 70 to 160um – colder dust at larger distances, but blowout halos?

η CrV (F2 V @ 18.3pc)

- Duchene et al. 2013 (in prep.)
- Full radiative transfer modelling of large observational dataset
- Constrain dust properties and geometries in two belts

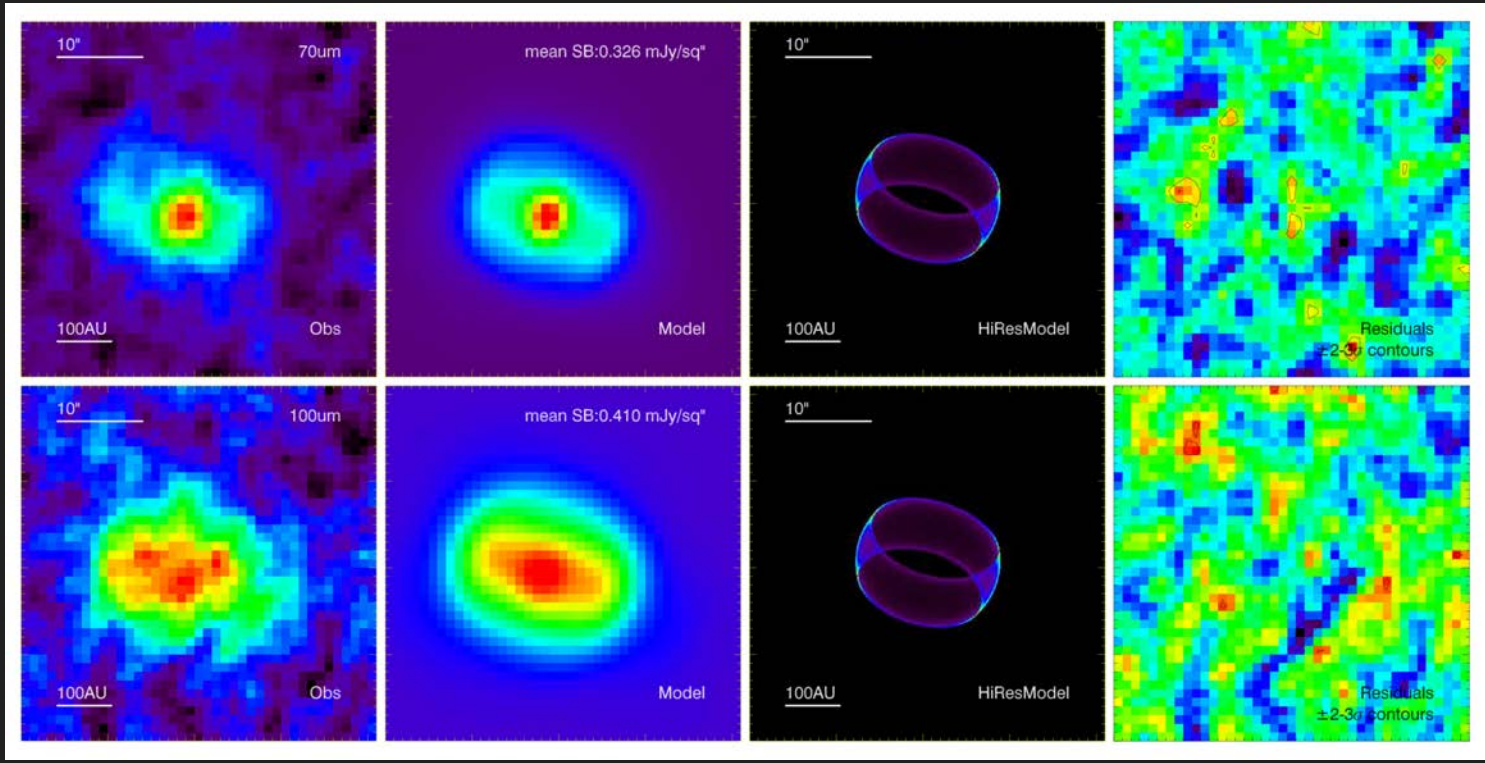






Discs in multiple systems: 99 Her

- Kennedy et al. 2012: circumbinary polar-ring disc
- F7 V + K4 V, 15.7pc, 6-10 Gyr
- Show disc is not aligned with binary plane



Debris in multiple systems: δ Scl

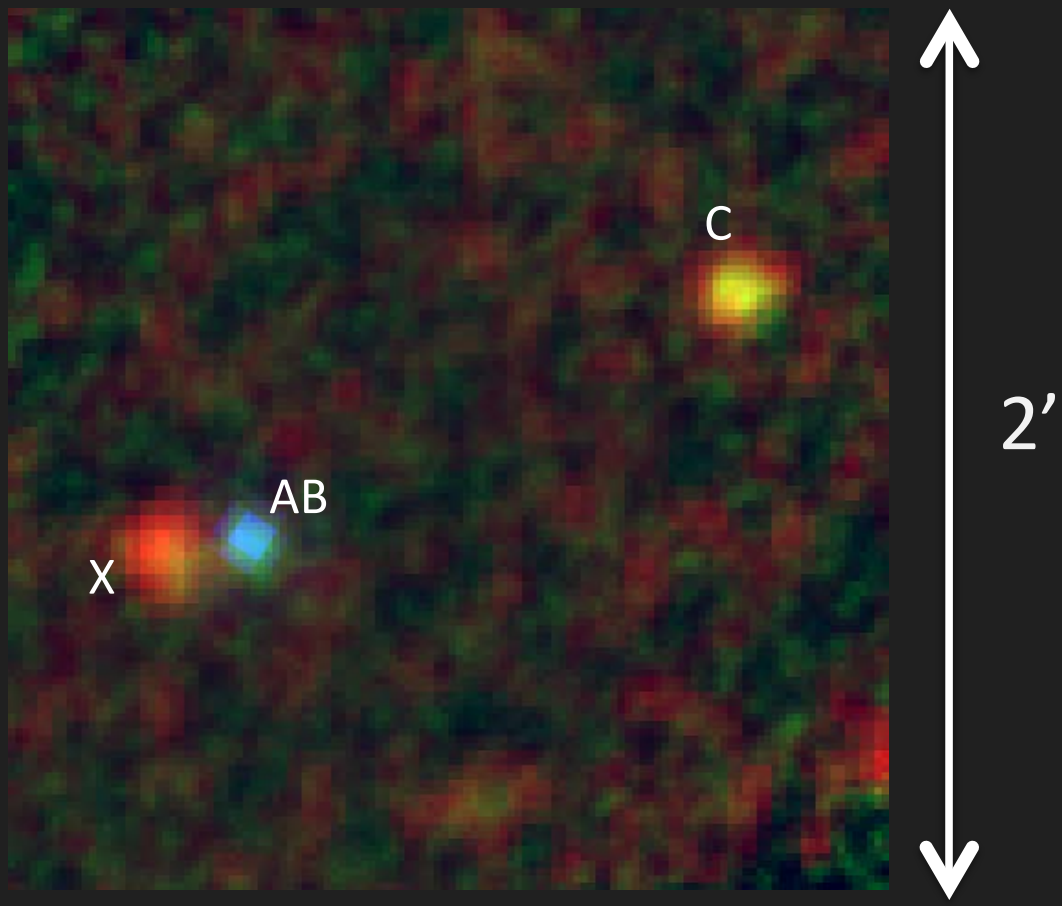
Four stars, two debris discs and a galaxy!

Phillips et al. in prep

A0 + (K7+M0) + K1

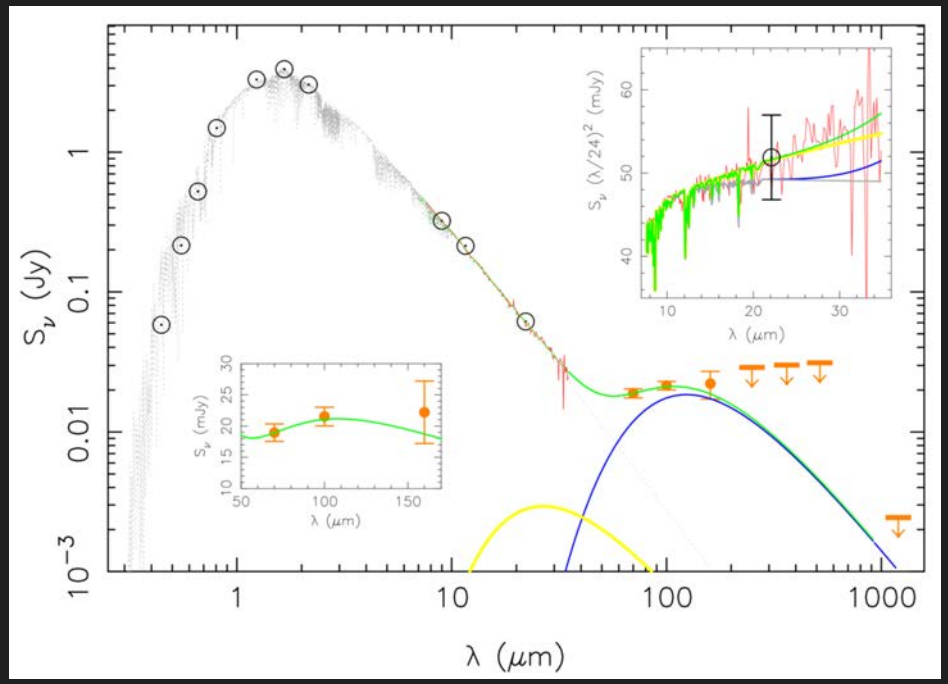
AB Dor => 30-70Myr

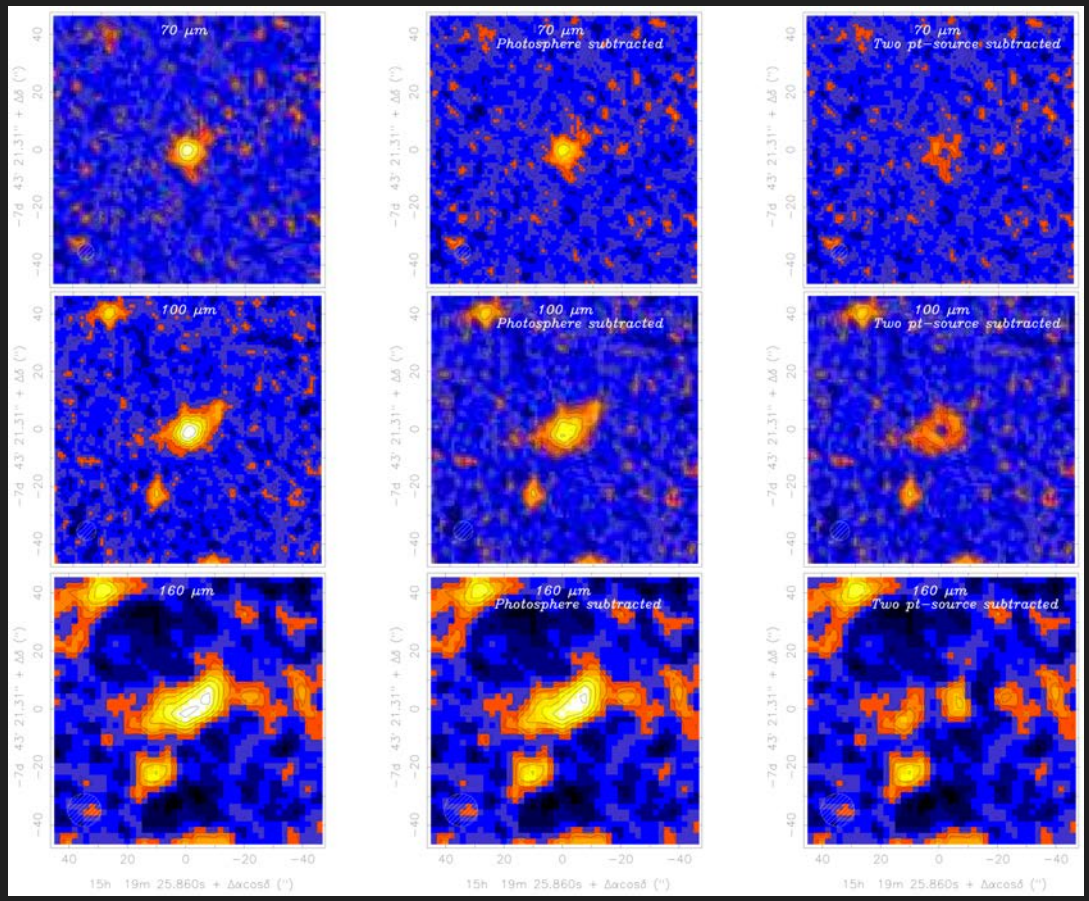
24, 100, 160µm



Debris <-> planets: GJ 581

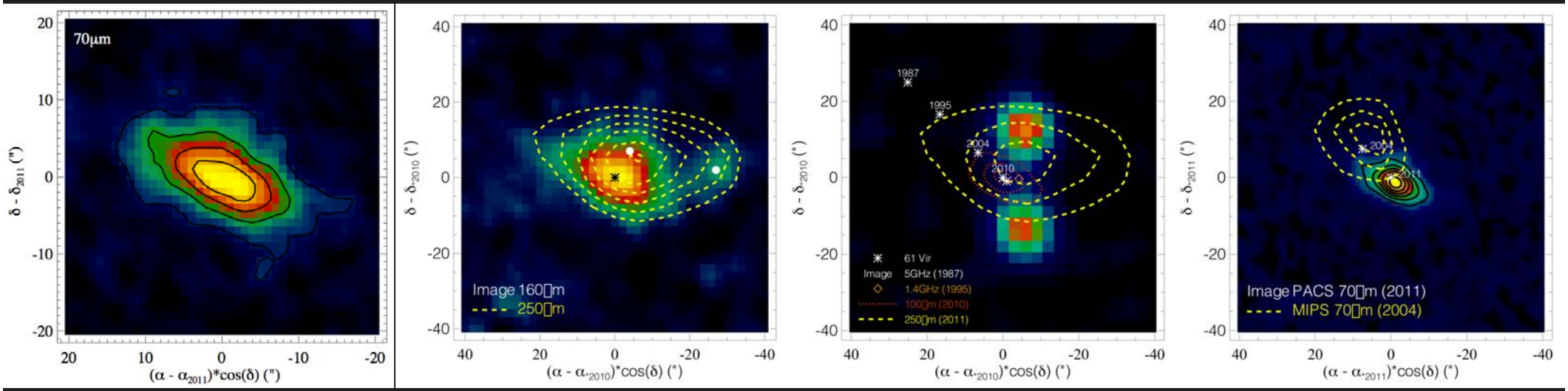
- 4 low mass planets in 0.03 – 0.22 AU
- M3 V, 2-8 Gyr, 6.3pc
- Lestrade et al. 2013
- Debris @ 25 to 60 AU





Debris <-> planets: 61 Vir

- Wyatt et al. 2012, G7 V @ 8.6pc
- 3 low mass planets within 1AU, debris from 30AU out.
- Nothing known between 1-30AU – cleared by planets?
- More contamination issues

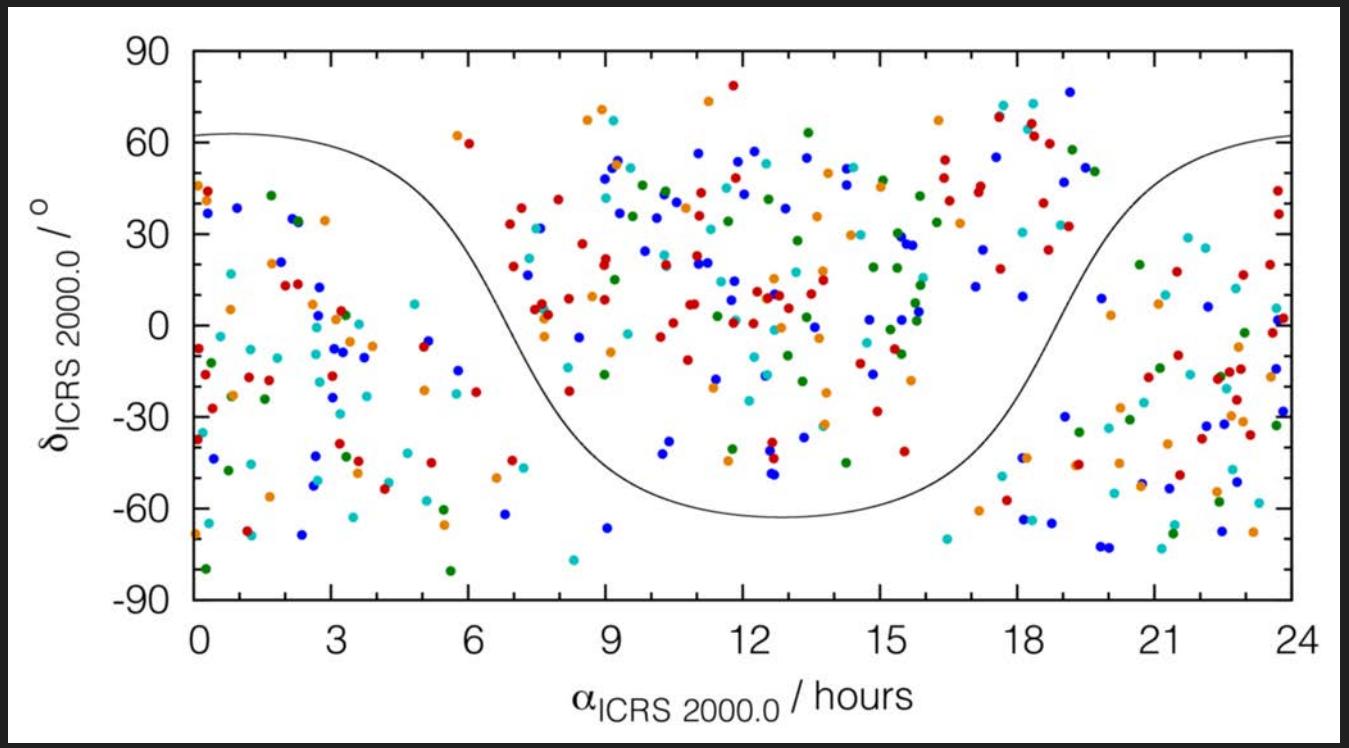


Debris <-> planets?

- Can start to look at statistics
- Previous studies: no global correlation
- Wyatt et al. 2012 nearest 60 G-type systems:
  - increased debris incidence in systems with low mass planets (< 95 M_Earth): 4/6 c.f. 15-25%
  - Decreased incidence in systems with higher mass planets: 0/5 c.f. 15-25%

Bi-product: Galaxy number counts

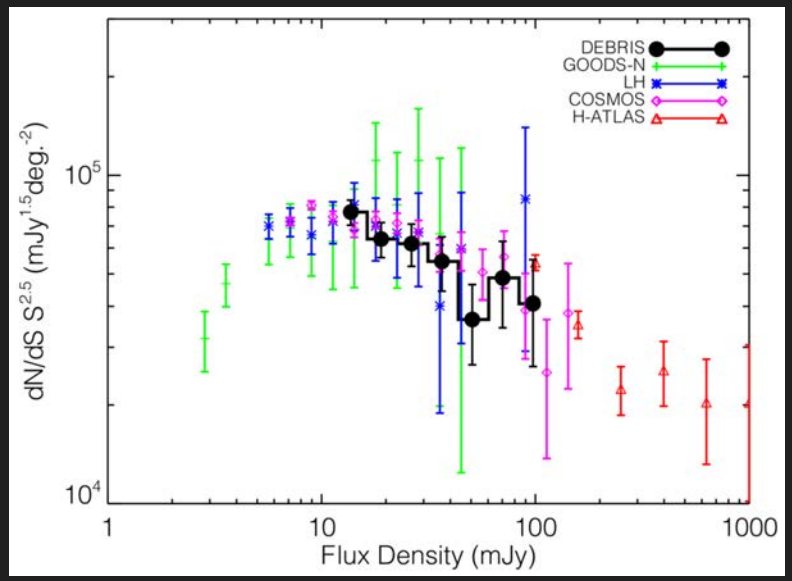
- Deep PACS 100/160 maps distributed randomly all over sky away from galactic confusion => test for cosmic variance in galaxy number counts.

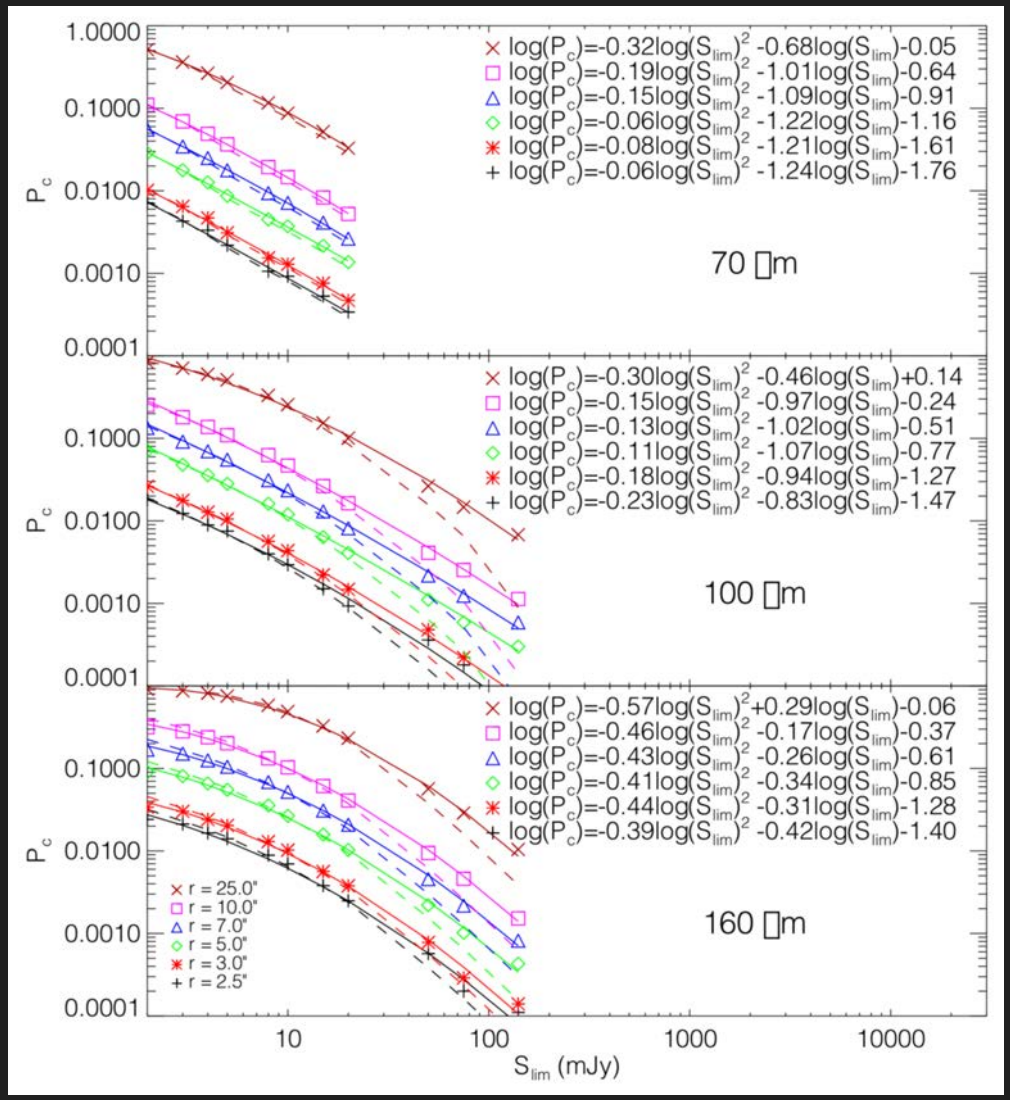


DEBRIS fields

Galaxy counts & contamination

- Sibthorpe et al. 2013
- 36% chance of 3σ galaxy within 10'' in PACS-160 maps
- Caution in disc modelling

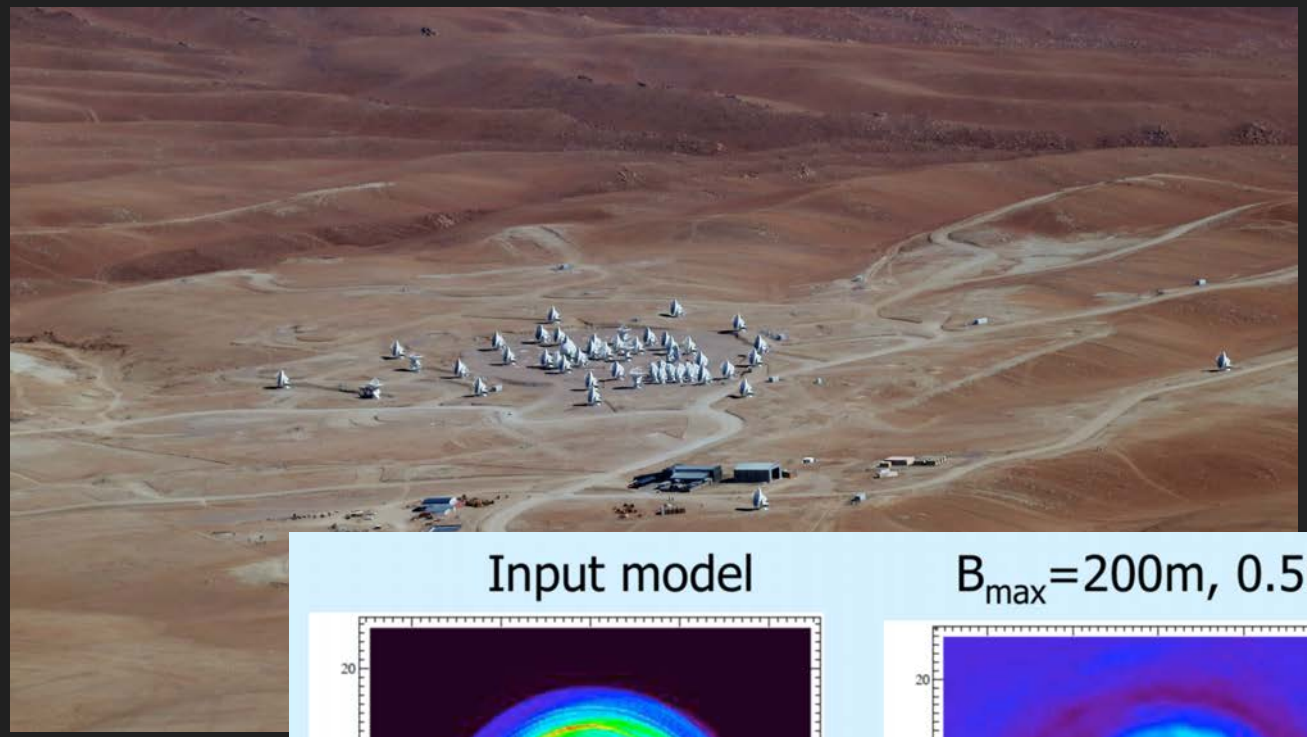


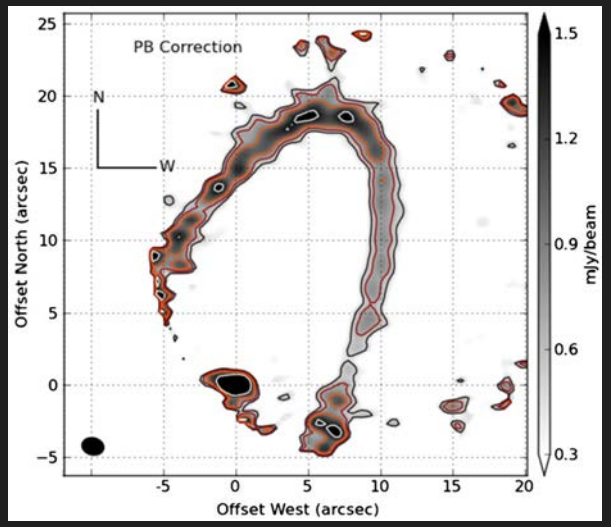


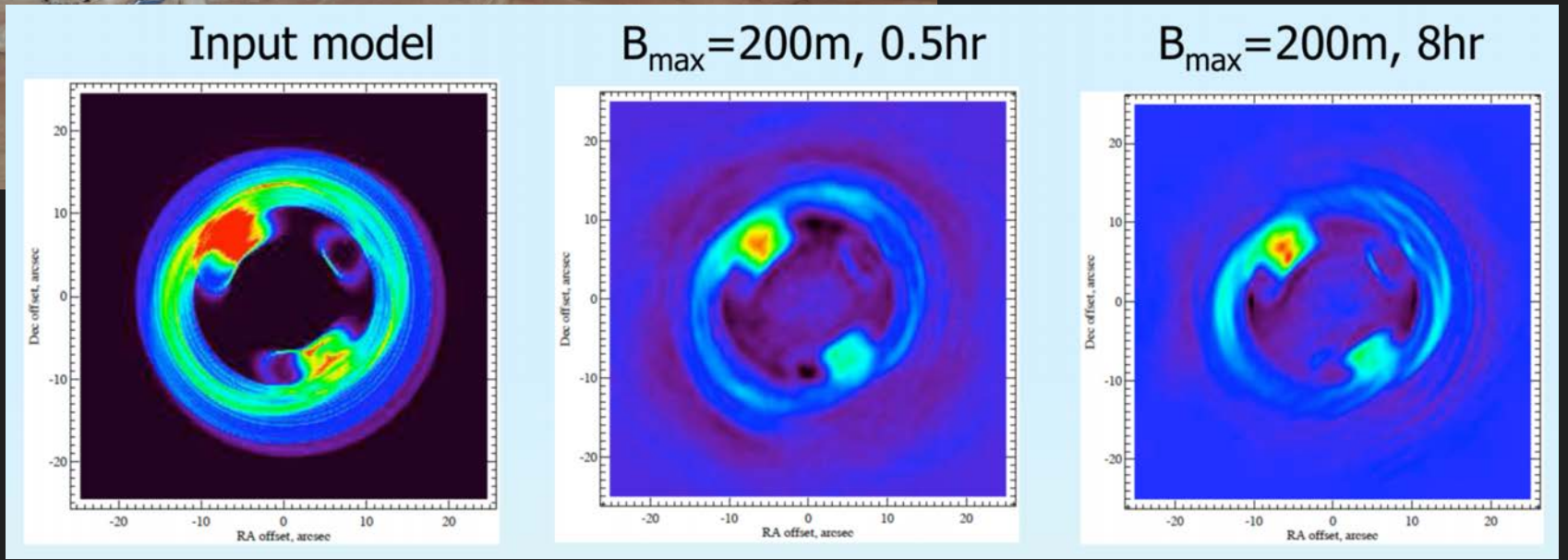
Some general results

- Incidence around mature M stars rare but not zero (GJ 581)
- See Sibthorpe talk later for Sun-like star discs
- A star incidence slightly reduced by resolving confusion (Thureau et al. in prep.)
- Final catalogue and statistics being worked on
- Low mass planets and debris correlated
- Contamination a big problem at PACS-160 and longer
- Sub-mm fluxes generally low – SCUBA-2 survey redesigned due to DEBRIS results, and challenge for ALMA
- PACS resolved images creating a lot of work for modelling individual systems, but most cases degenrate – want more resolution!

The future: ALMA







Boley et al. 2012, Wyatt

Summary

- PACS resolved tens of debris discs, and SPIRE provided important SED constraints, allowing detailed modeling of many systems for the first time
- PACS resolution also showed up and helped mitigate galaxy contamination
- Much left to do:
  - DEBRIS statistical goals
  - Detailed modeling of more resolved systems
  - Meta-analysis of data from multiple projects
- Future exciting but challenging!