

# The $\beta$ Pictoris disk as seen by Herschel

Bart Vandenbussche  
& the disk GT programme team

Herschel and the Formation of Stars and Planetary Systems  
Saro, Sweden, 09/09/2010



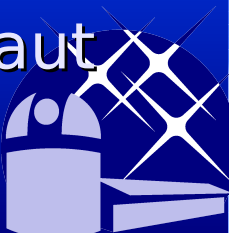
# The Disk GT key programme

- Göran Olofsson (PI)
- Project Scientist team: Göran Pilbratt, Malcolm Fridlund and Ana Heras
- Mission Scientist: Paul Harvey
- SPIRE team: Alexis Brandeker, Göran Olofsson, Mike Barlow, Helen Walker, Tania Lim, James di Francesco, Steve Eales, Bill Dent, Wayne Holland, Rob Ivison, Jane Greewes, Martin Cohen
- PACS team: Bram Acke, Joris Blommaert, Pierre Royer, Bart Vandenbussche, Christoffel Waelkens, Aurora Cicilia-Aguilar, Jeroen Bouwman, Thomas Henning, Eric Pantin
- HIFI team: René Liseau, Michel Hogerheijde, Carsten Dominik
- Targets: nearby debris disks
  - Fabulous Four (Beta Pic, Vega, Fomalhaut, Eps Eri)
  - Tau Cet, Au Mic



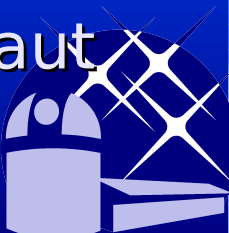
# The Disk GT key programme

- PACS & SPIRE imaging
  - Beta Pic, Vega, Eps Eri, Au Mic, Tau Cet, Fomalhaut
- 69um Forsterite: deep PACS range scan
  - Beta Pic, Vega, Eps Eri, Au Mic, Tau Cet, Fomalhaut
- 63um OI PACS line scan
  - Beta Pic, Vega, Eps Eri, Au Mic, Tau Cet, Fomalhaut
- Full PACS range & SPIRE spectrum
  - Beta Pic
- HIFI H<sub>2</sub>O 557 Ghz / NH<sub>3</sub> 572 Ghz / CI 492 Ghz
  - Beta Pic, Vega, Eps Eri, Au Mic, Tau Cet, Fomalhaut



# The Disk GT key programme

- **PACS & SPIRE imaging**
  - **Beta Pic, Vega**, Eps Eri, Au Mic, Tau Cet, Fomalhaut
- **69um Forsterite**: deep PACS range scan
  - **Beta Pic**, Vega, Eps Eri, Au Mic, Tau Cet, Fomalhaut
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- **Full PACS range** & SPIRE spectrum
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# Disk GT key programme status

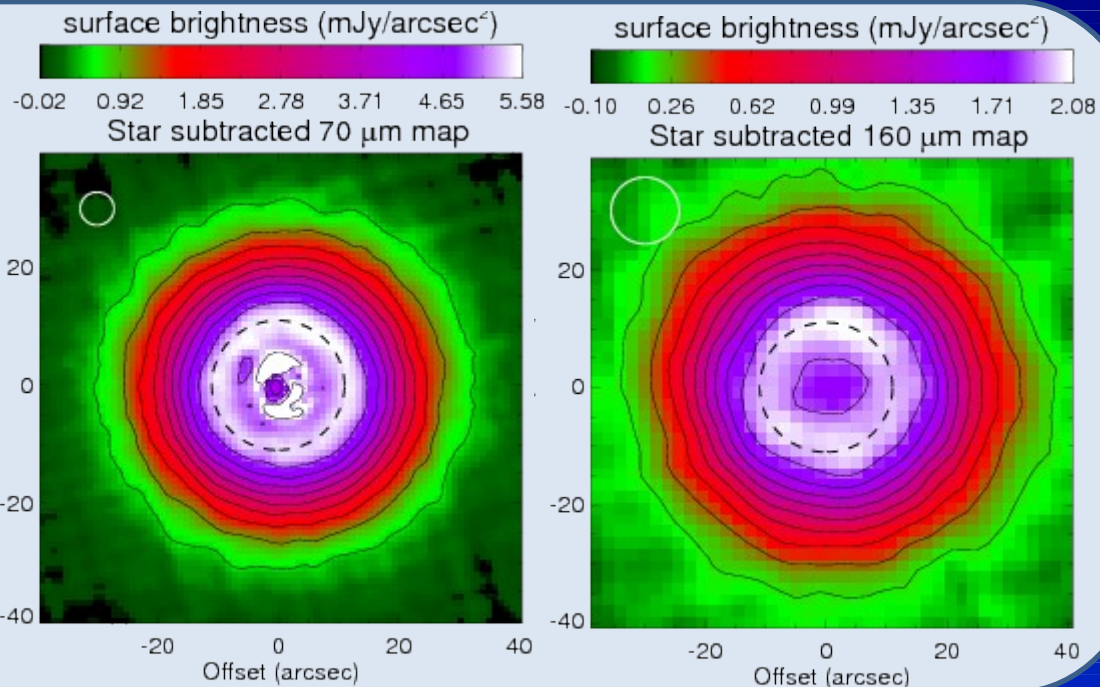
| Star      | P IM | S IM | S full spec | P full spec | P 63um OI | P 69um Forst | H H2O | H Cl |
|-----------|------|------|-------------|-------------|-----------|--------------|-------|------|
| Vega      | X    | X    |             |             | X         | 0            | 0     | 0    |
| Beta Pic  | X    | X    | X           | X           | X         | X            | 0     | 0    |
| Au Mic    | X    | X    |             |             | X         | 0            | 0     | 0    |
| Eps Eri   | O    | X    |             |             | X         | 0            | 0     | 0    |
| Tau Cet   | O    | O    |             |             | X         | 0            | 0     | 0    |
| Fomalhaut | O    | X    |             |             | X         | X            | 0     | 0    |



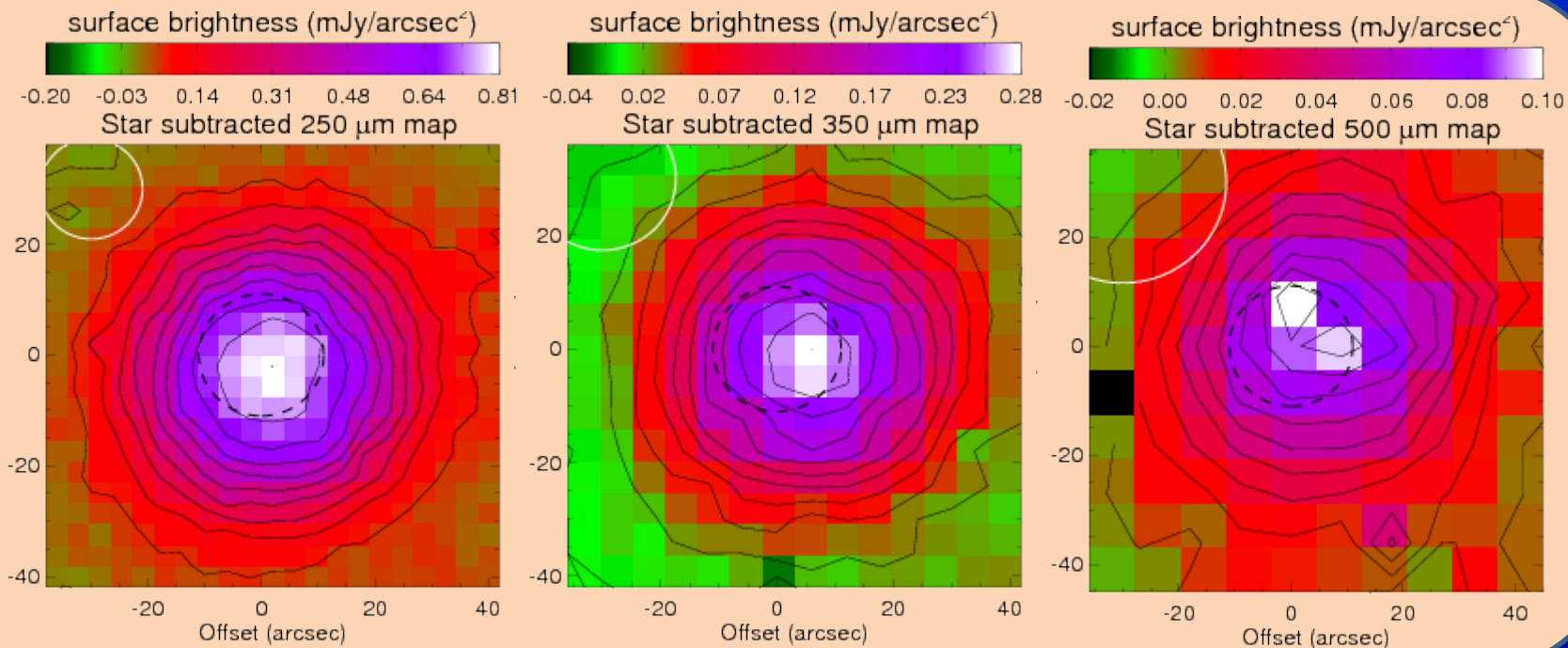
# Vega

Resolved disk  
at 11" (85 AU)  
radius

PACS



SPIRE



*Sibthorpe et al. 2010*

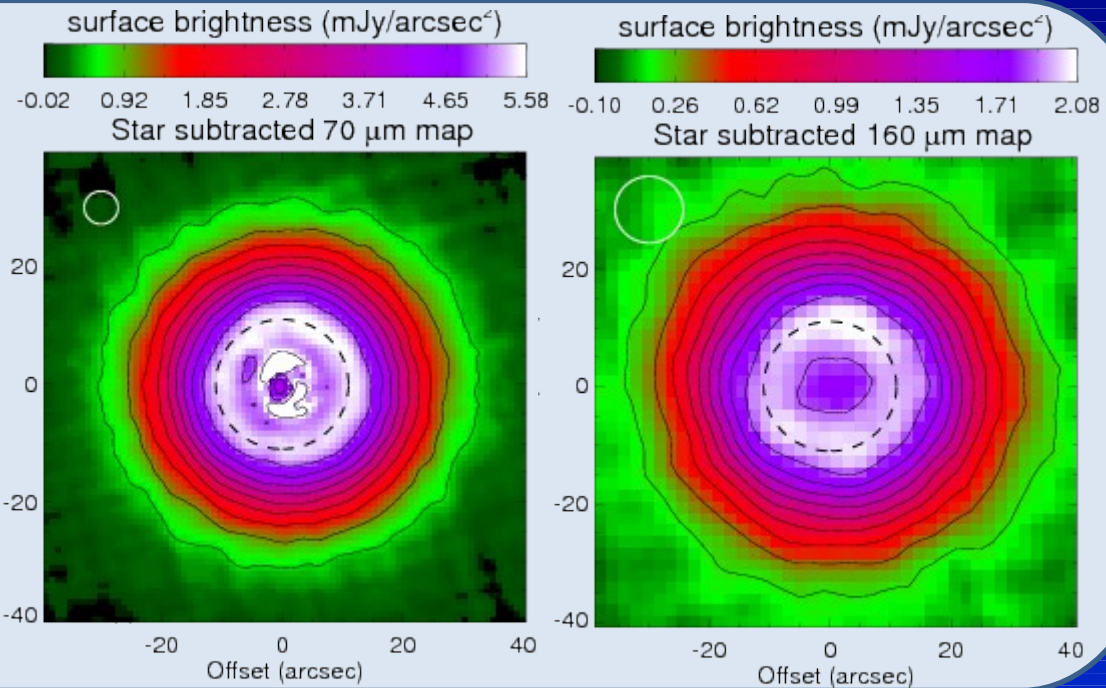


*Sibthorpe et al. 2010*

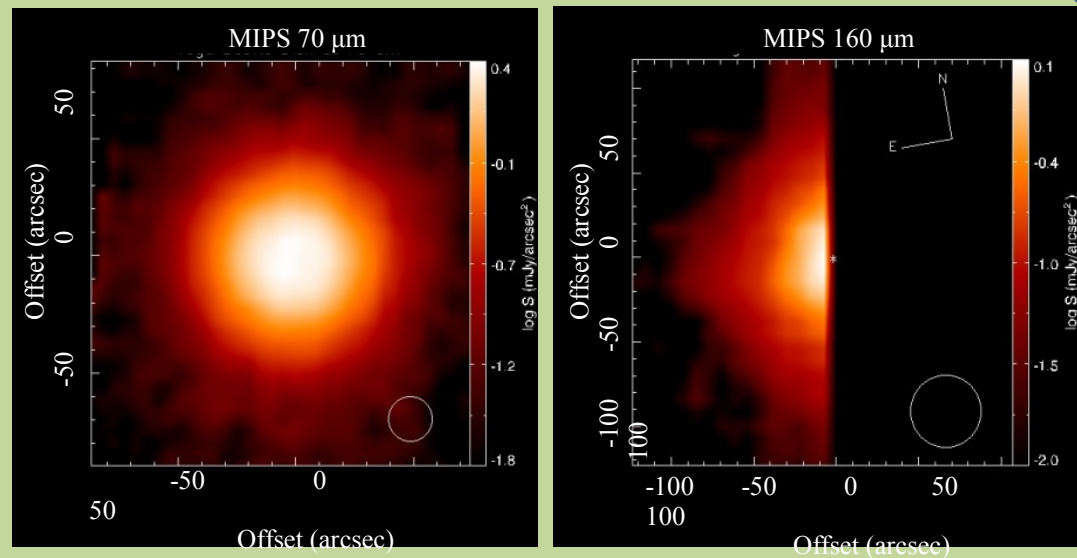
# Vega

Resolved disk  
at 11" (85 AU)  
radius

PACS



Spitzer/MIPS

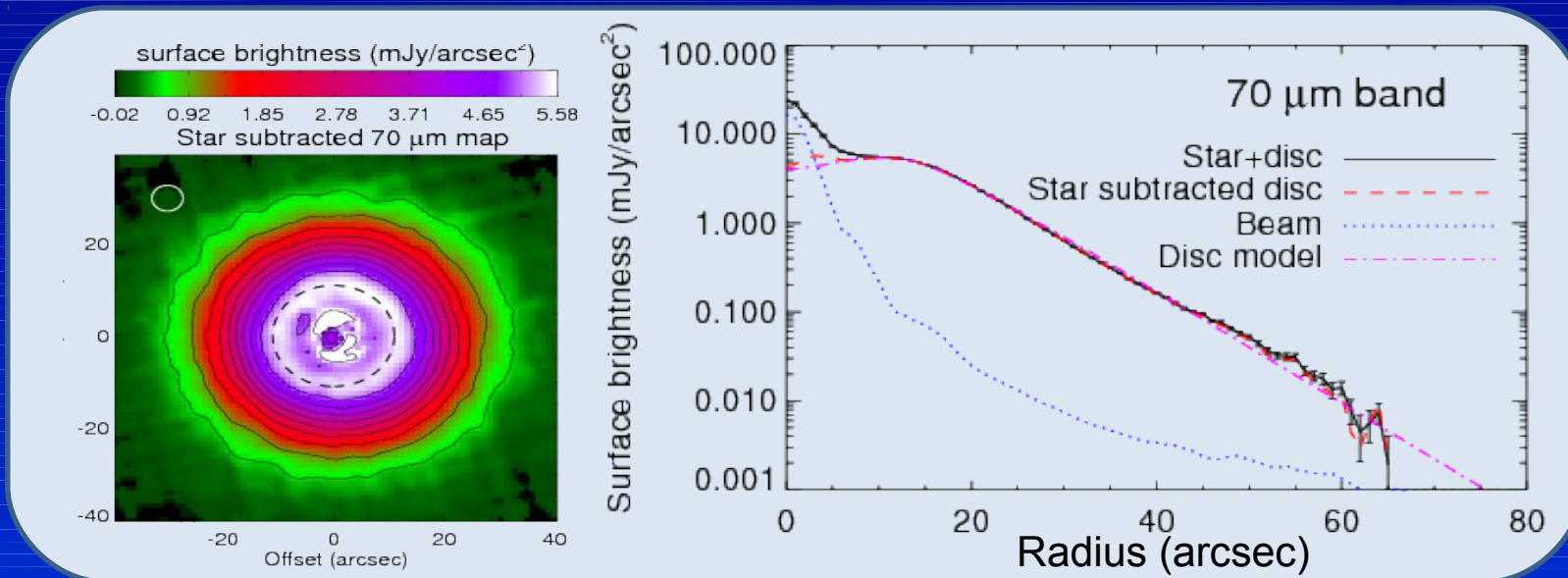


Su et al. 2005

*Sibthorpe et al. 2010*

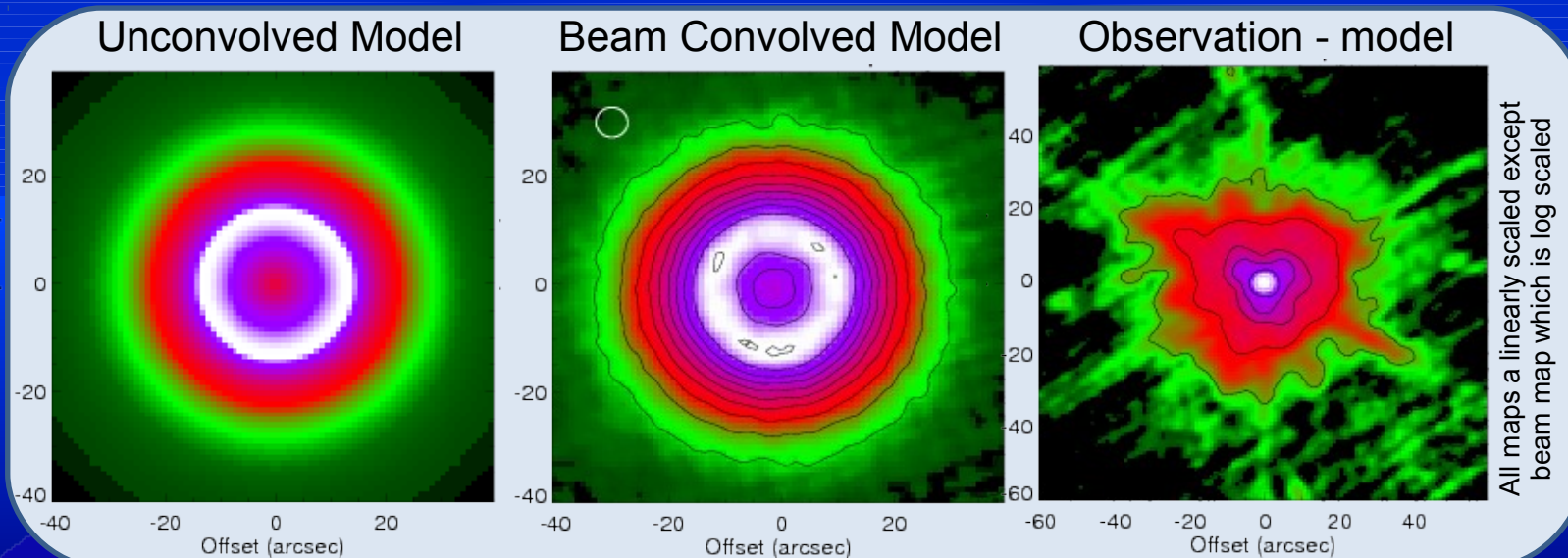


# Smooth radial surface brightness



Model:

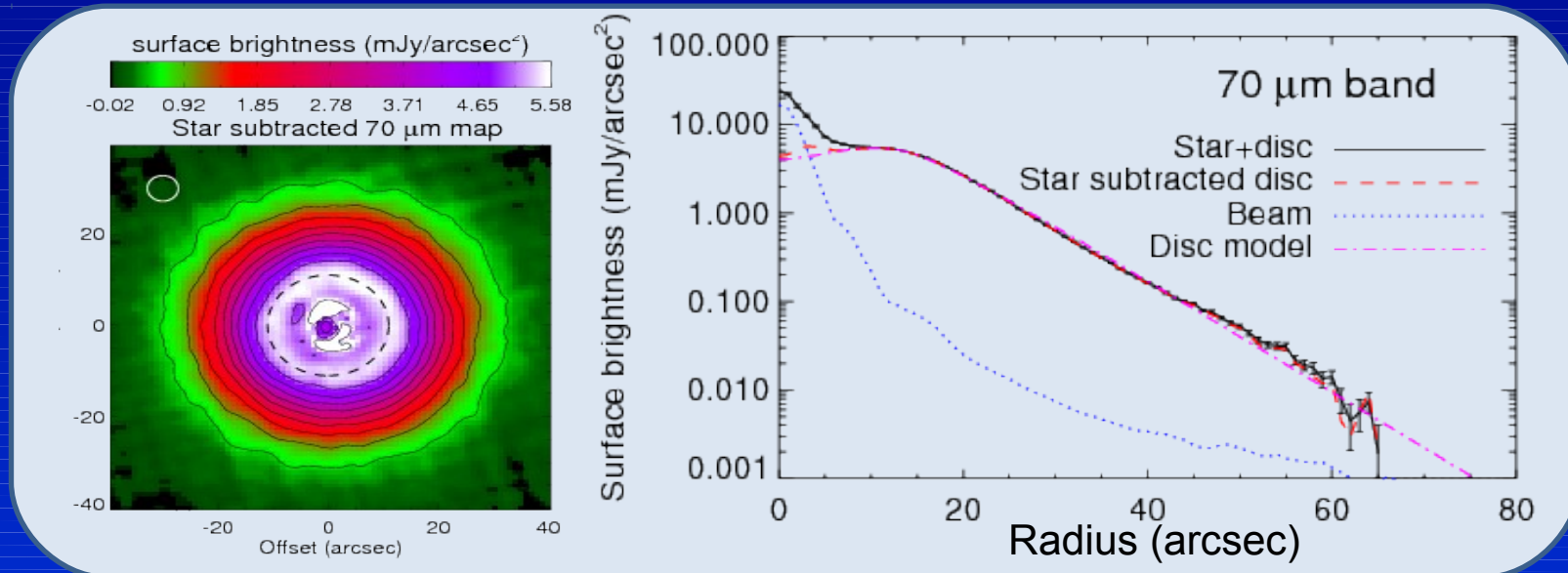
Inner disk:  
Gaussian  
FWHM 20"



Outer disk:  
 $\log_{10}(S_{\nu}) \propto$   
 $-0.63r$

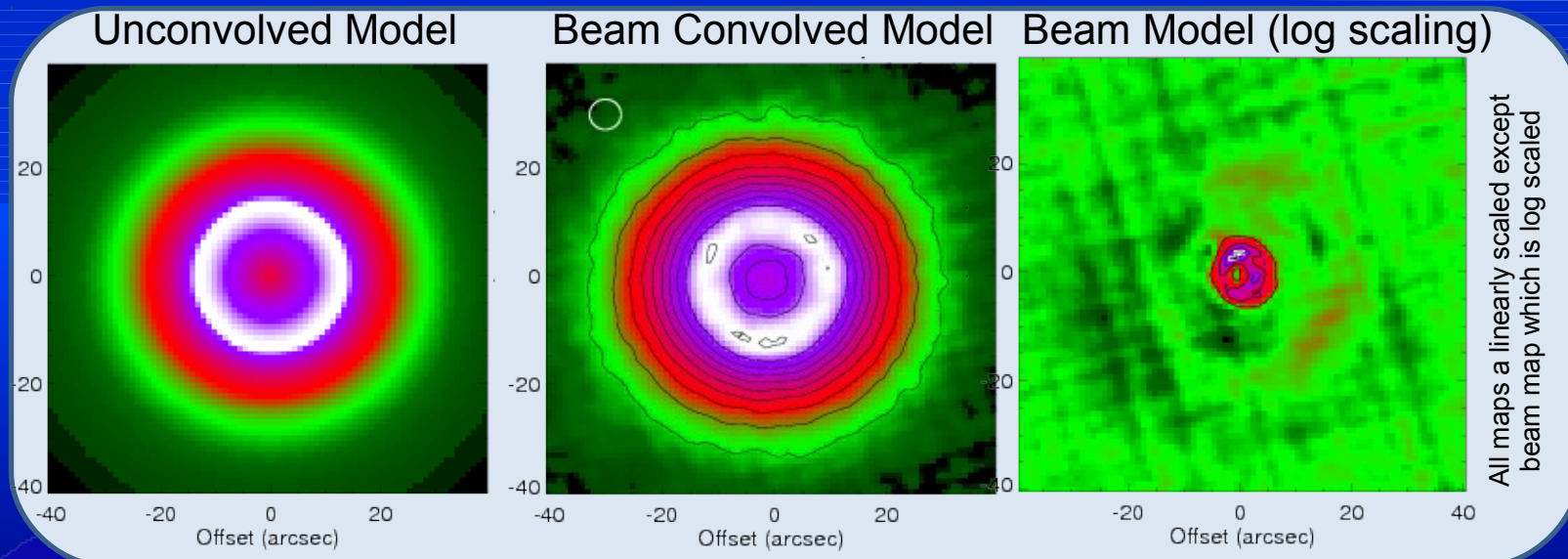


# Smooth radial surface brightness



Model:

Inner disk:  
Gaussian  
FWHM 20"

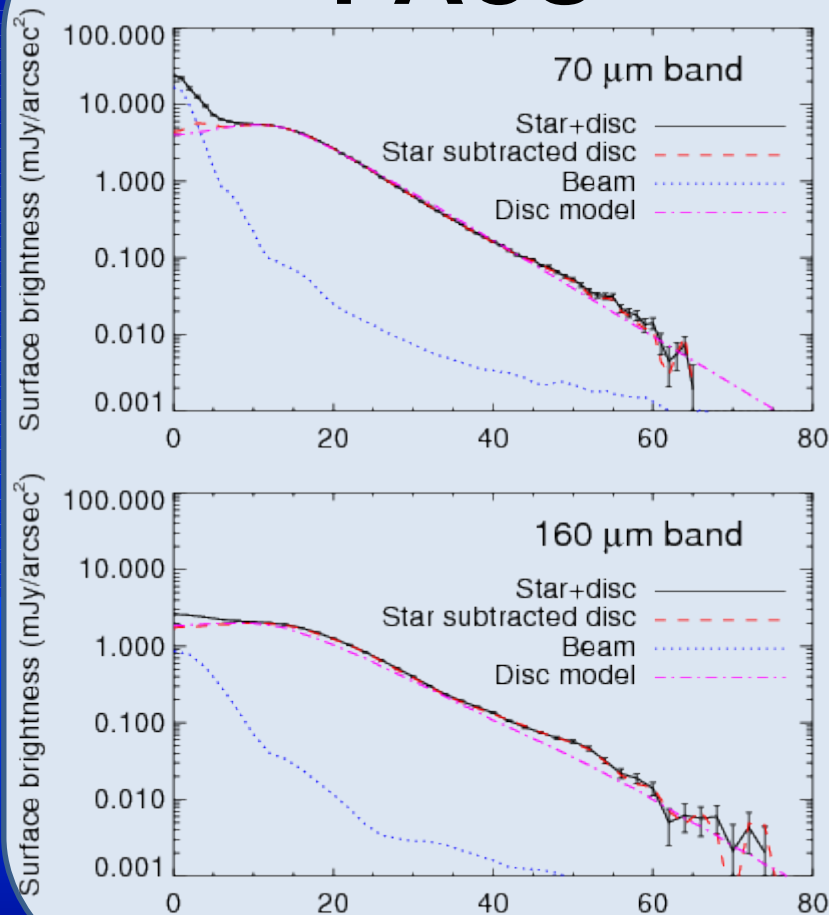


Outer disk:  
 $\log_{10}(S_v) \propto -0.63r$

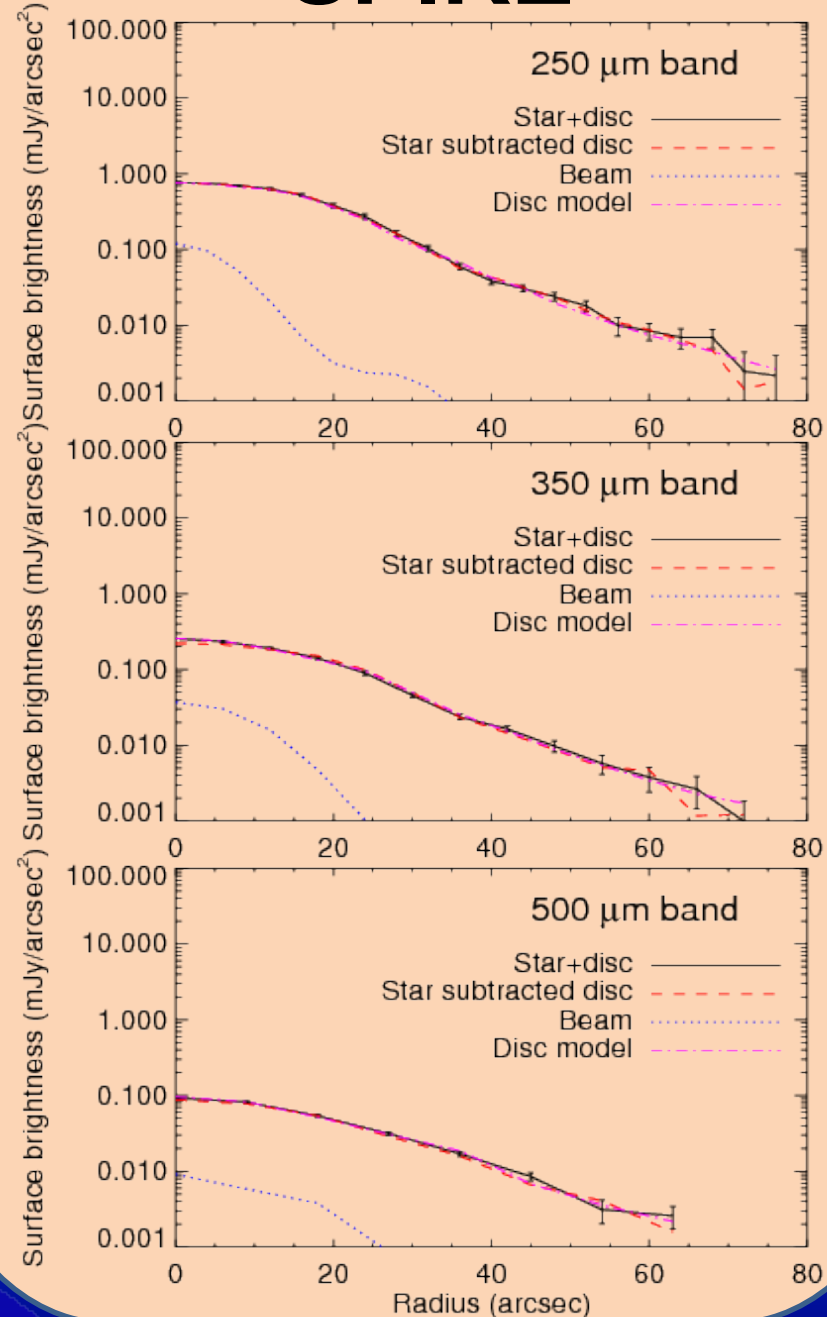


# Same profile fits PACS + SPIRE

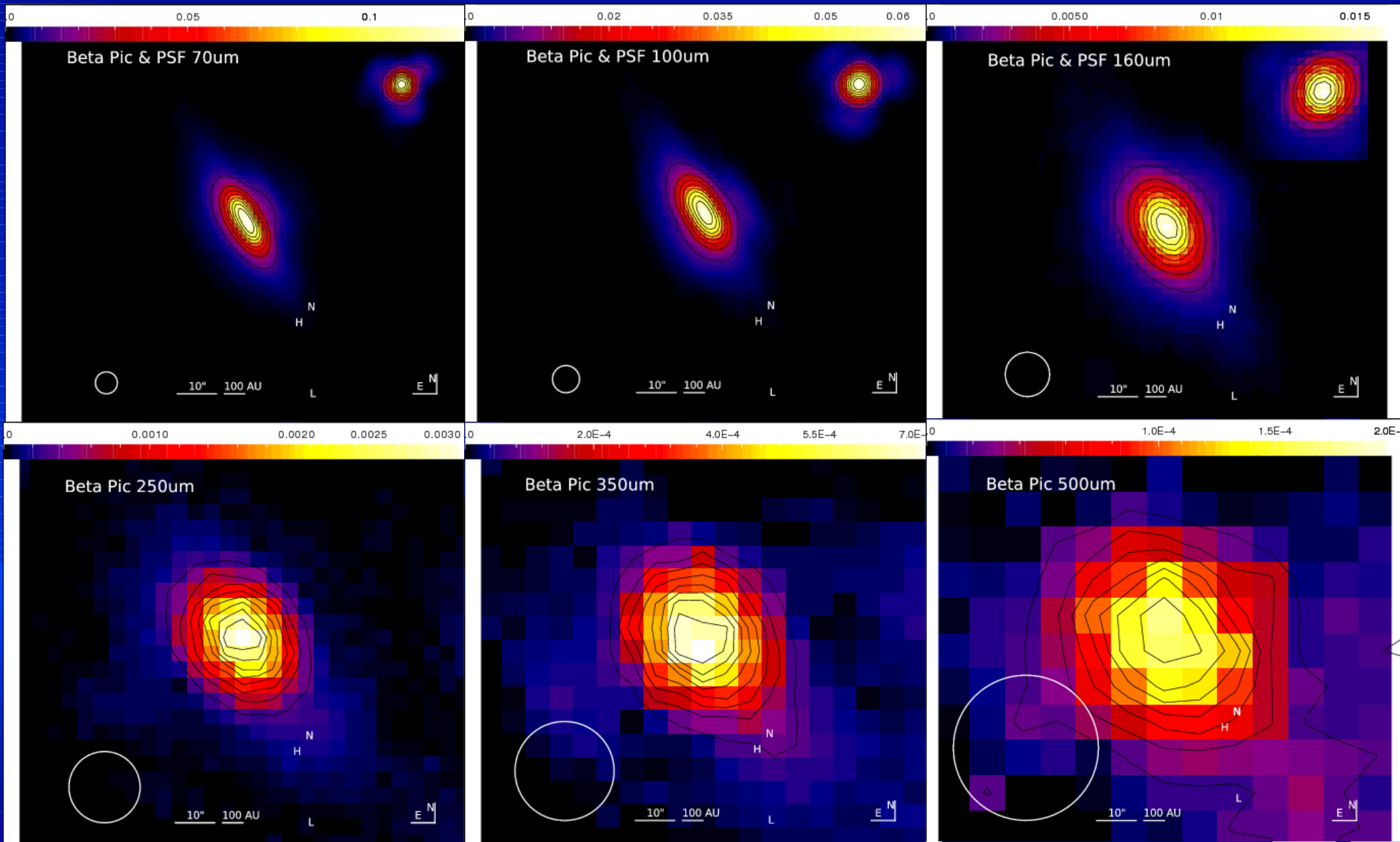
## PACS



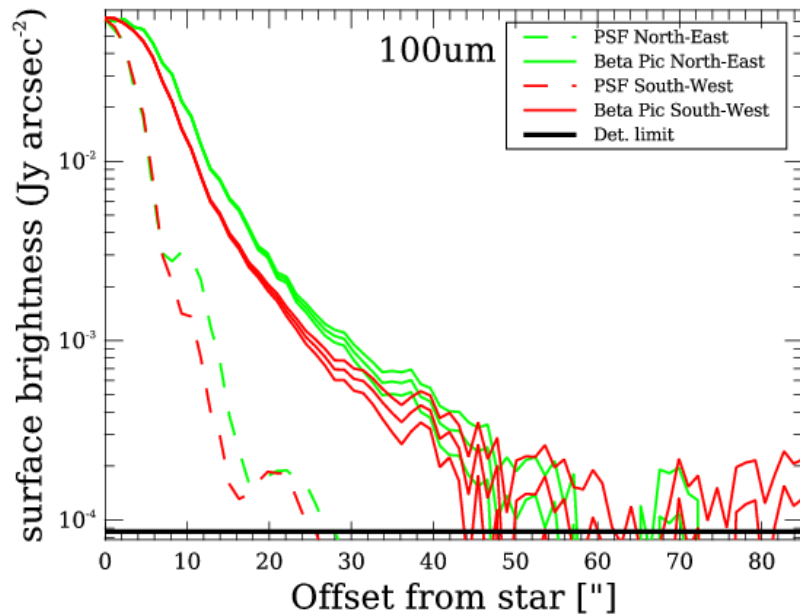
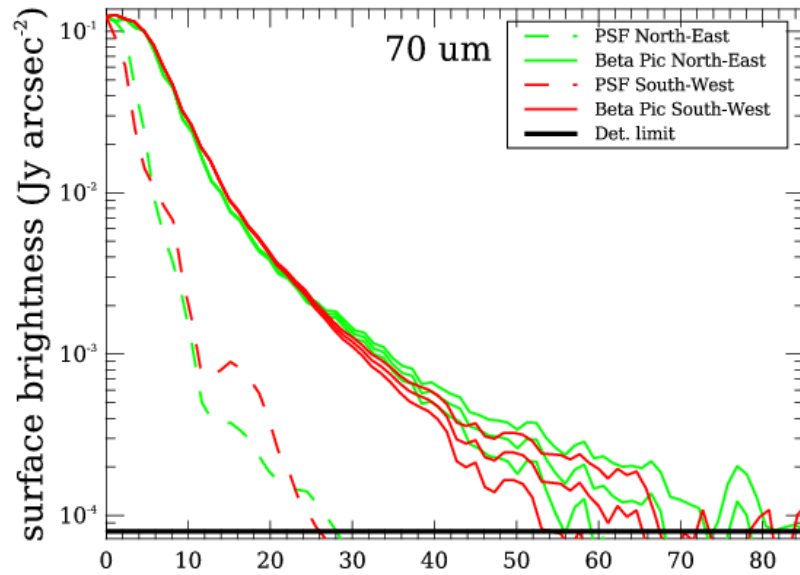
## SPIRE



# Beta Pic PACS & SPIRE imaging



# Beta Pic surface brightness profile

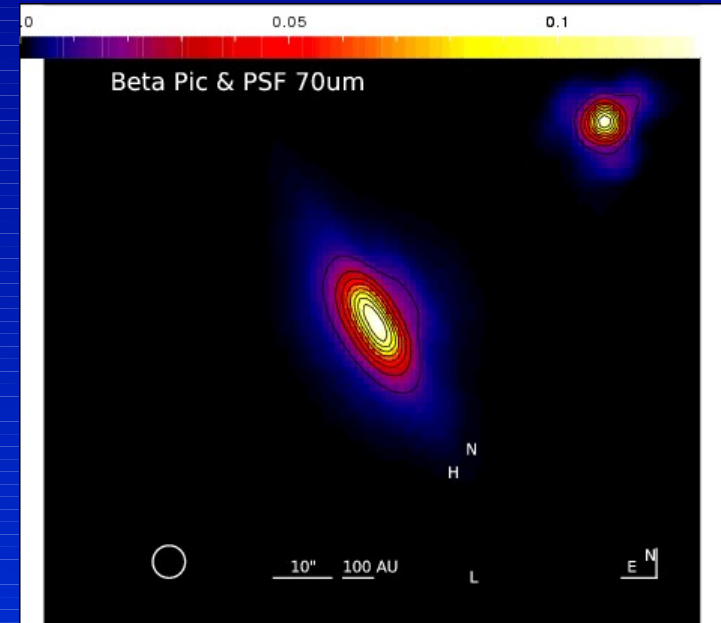


- Not resolved in vertical direction
- Along the disk: 90% of the FIR emission originates in region  $< 200\text{AU}$  radius from the star
- Assymetries / departures from PSF within uncertainties PSF

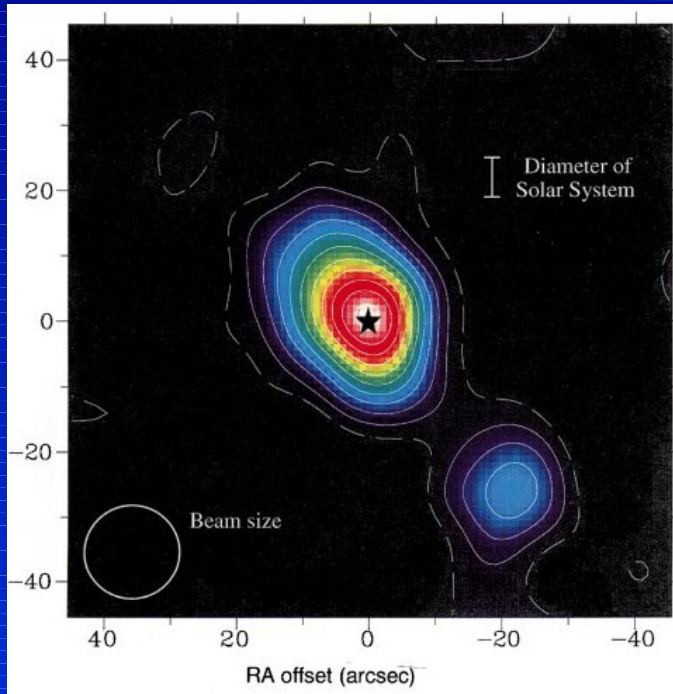


# Beta Pic FIR morphology

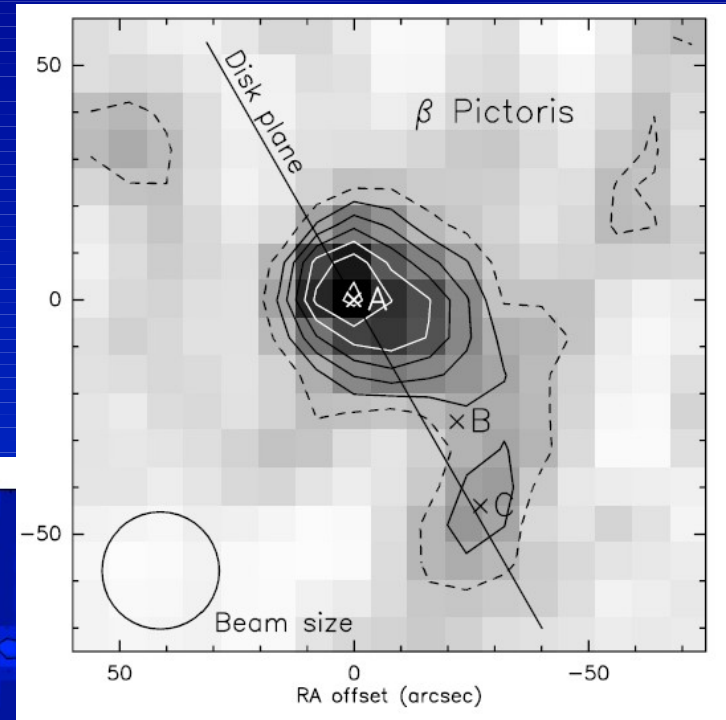
- Well resolved in PACS 70, 100, 160 $\mu$ m
- Marginally resolved in SPIRE 250, 350 $\mu$ m, not at 500 $\mu$ m
- Position angle 30.8deg cfr optical
- Disk resolved along the disk, not in vertical direction
- Assymetries / departures from PSF within uncertainties PSF



# FIR counterpart of submm blobs

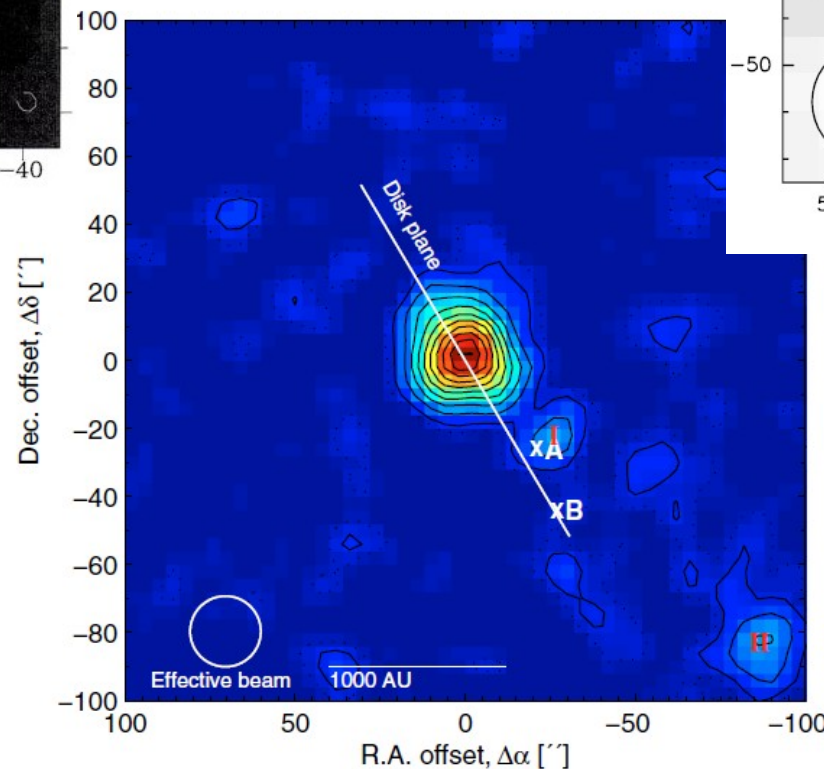


Holland et al. 1998  
850 $\mu\text{m}$



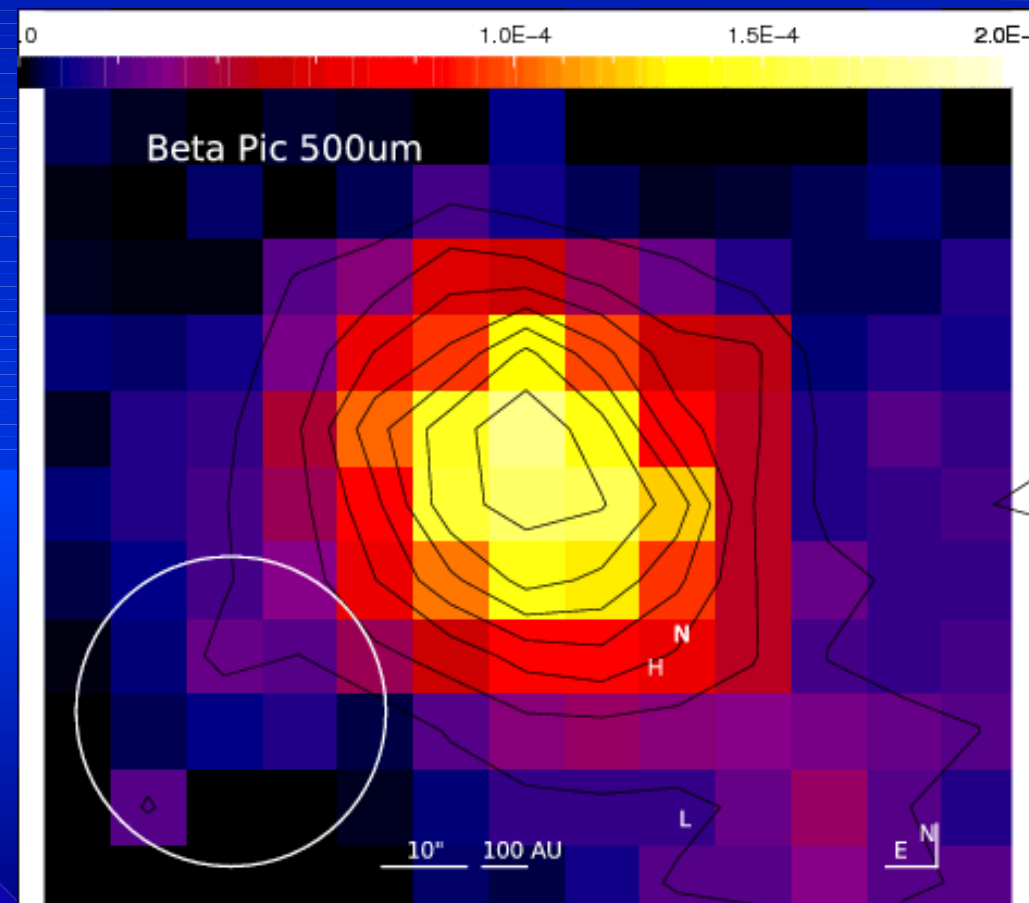
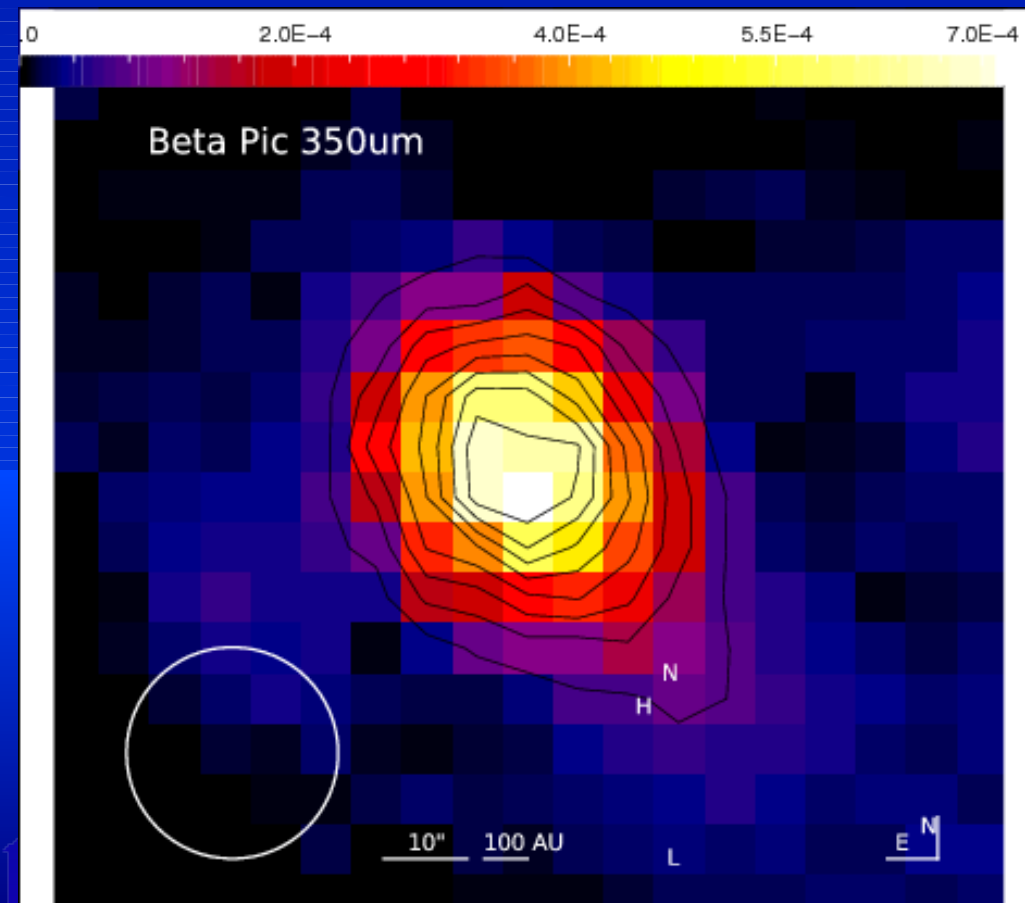
Liseau et al. 2003  
1.2mm

Nilsson et al. 2009  
870 $\mu\text{m}$

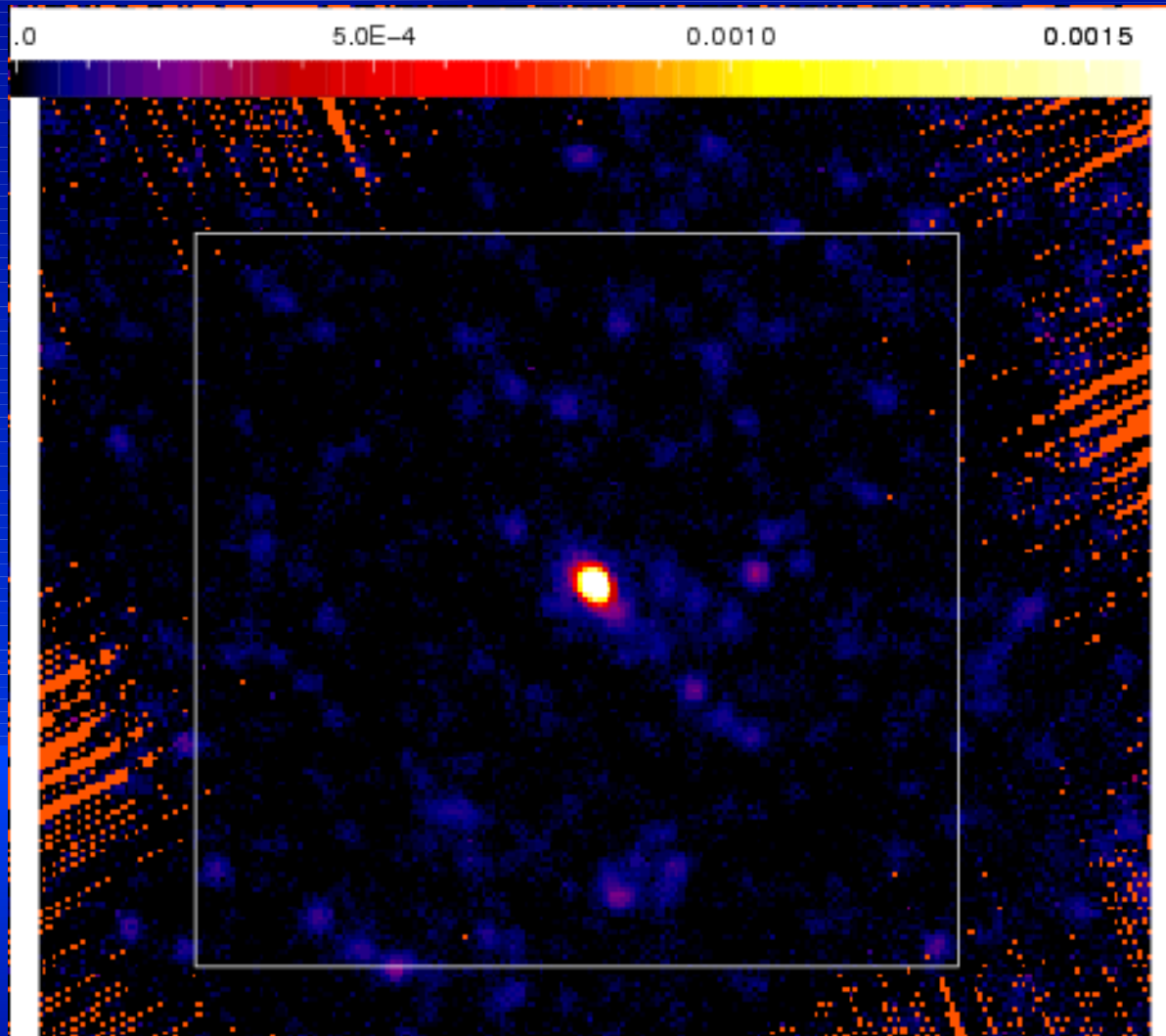


# FIR counterpart of submm blobs

- Blob in the South west at 350 & 500 $\mu$ m coincides with flux peaks seen at 850 and 870 $\mu$ m by Holland et al. (1998) and Nilsson et al. (2009)



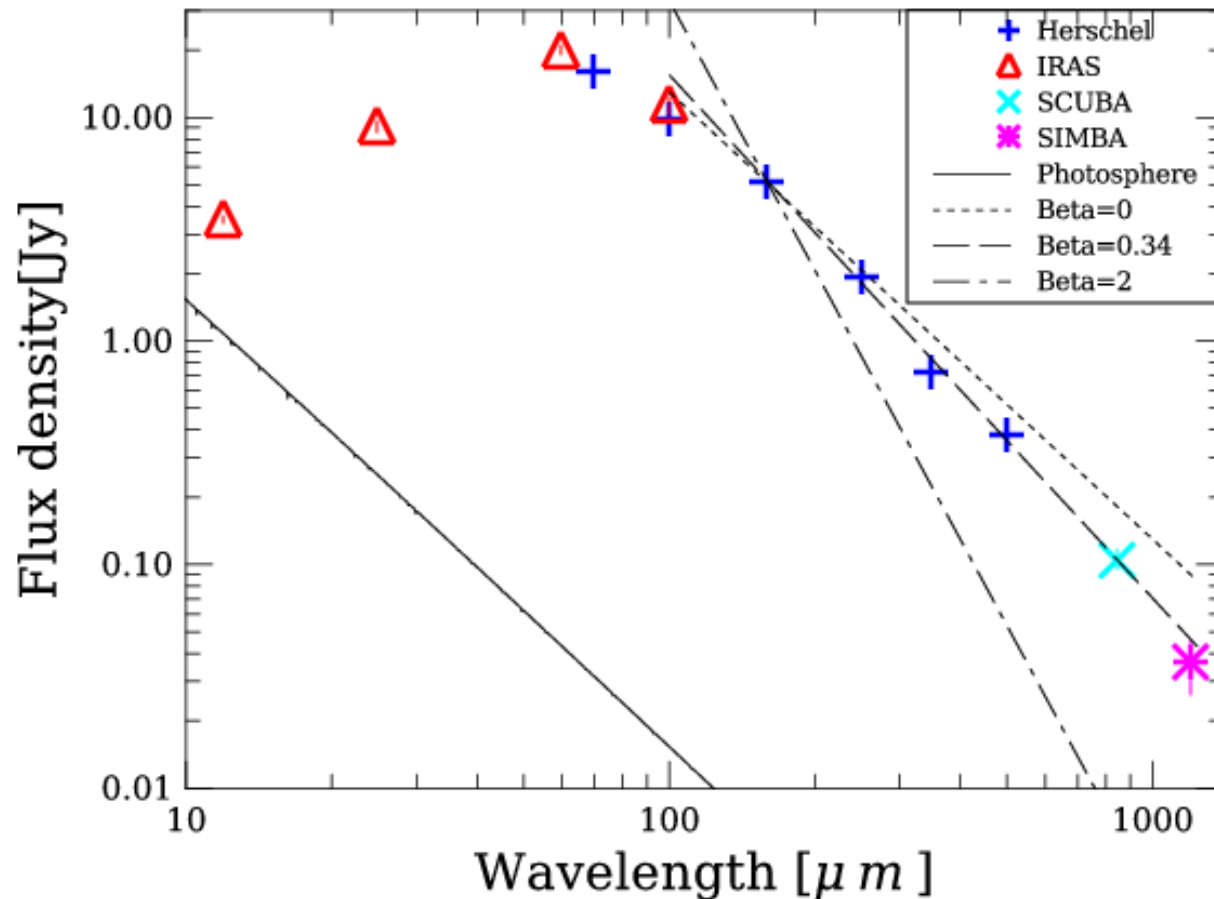
# FIR counterpart of submm blobs



- But 100 arcmin<sup>2</sup> SPIRE map shows +50 sources cfr blob
- Likely background source



# Beta Pic full disk SED



FIR spectral index  
 $\beta = 0.34 \pm 0.07$

$$F_\nu \sim \nu^{(2+\beta)}$$

$\beta=0$  : rayleigh-jeans

$\beta=2$  : ISM



# Beta Pic FIR/submm SED slope

- $\beta < 1$  conflicts with size distribution predicted by standard models of collisional cascade equilibrium
- Possible interpretations
  - Collisions of porous grains can produce flatter size distribution
  - Deep impact: flatter size distribution
  - System not in local collisional cascade equilibrium, cfr 'wavy' size distributions in dynamical simulations



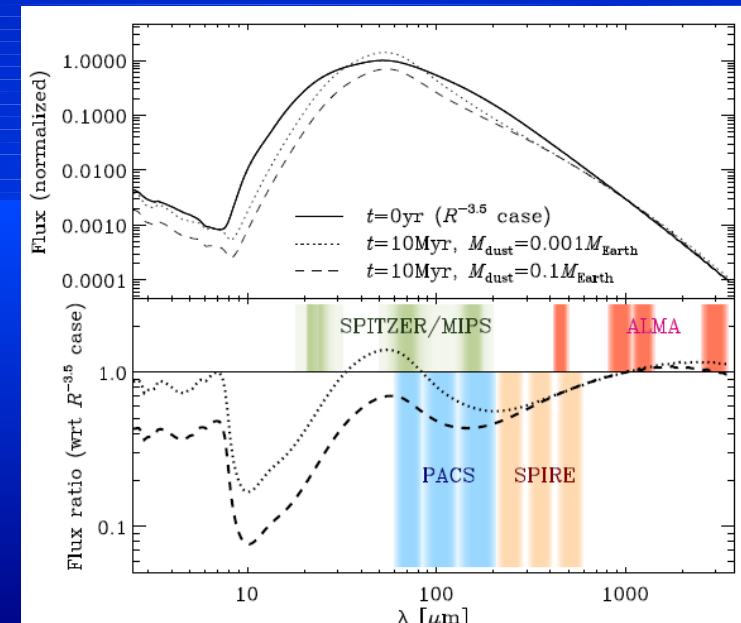
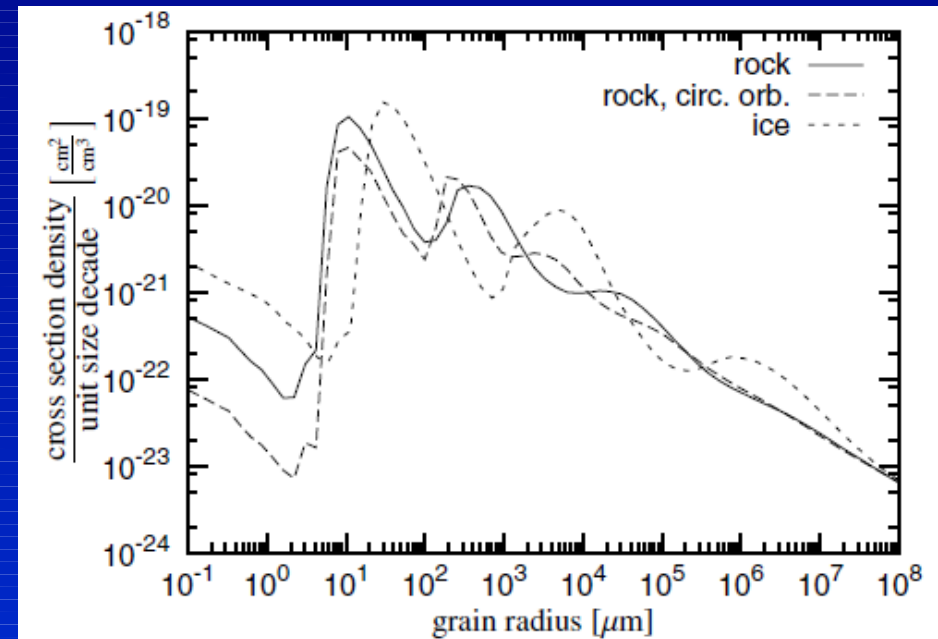
# Wavy size distributions and SED of debris disks

*Krivov (2006):*

- Underabundance of small particles blown out by radiation pressure
- Less impactors for population of grains just bound
- More impactors for next population
- Etc...
- Leads to wavy size distribution

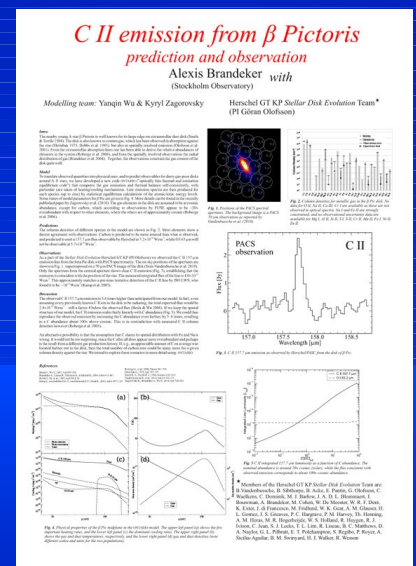
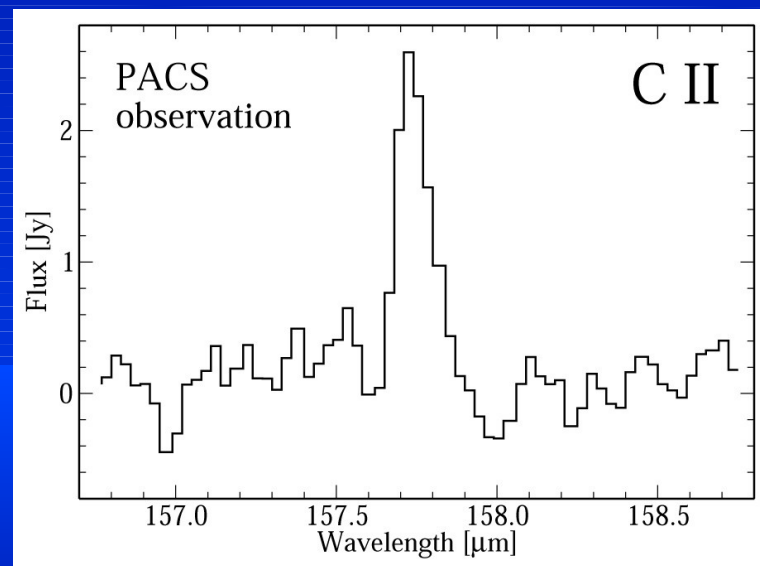
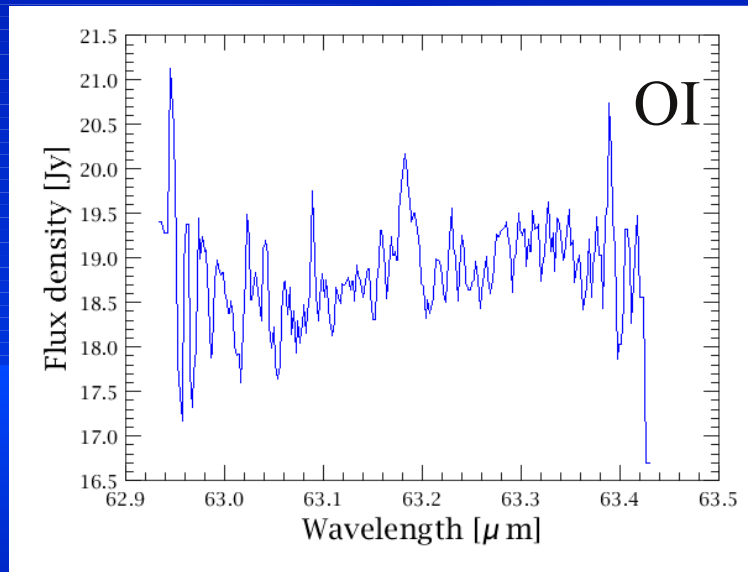
*Thebault & Augerau (2007):*

- Departure of  $N \sim R^{-3.5}$  size distribution can give small  $\beta$  in FIR



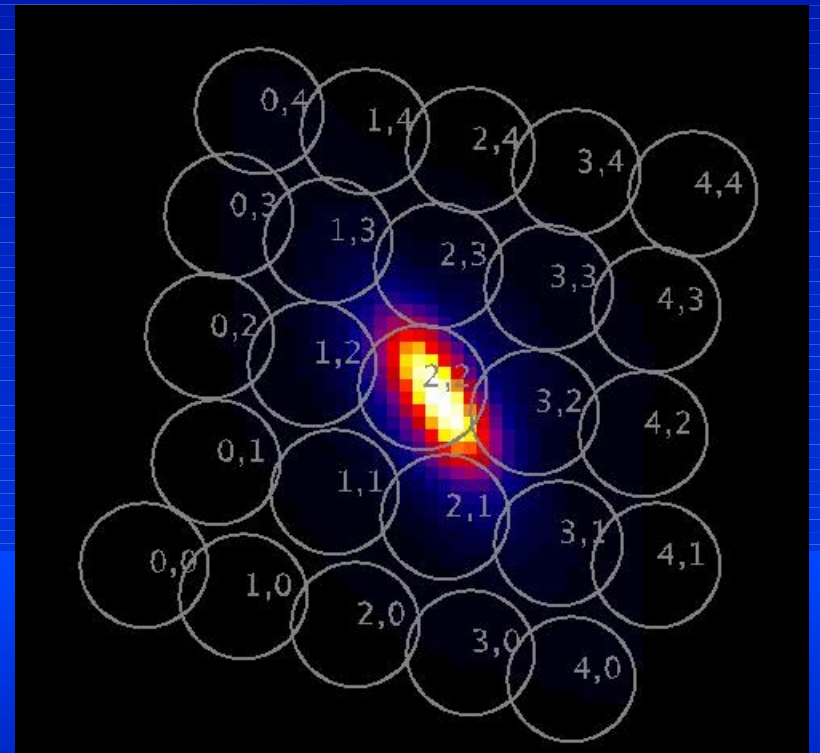
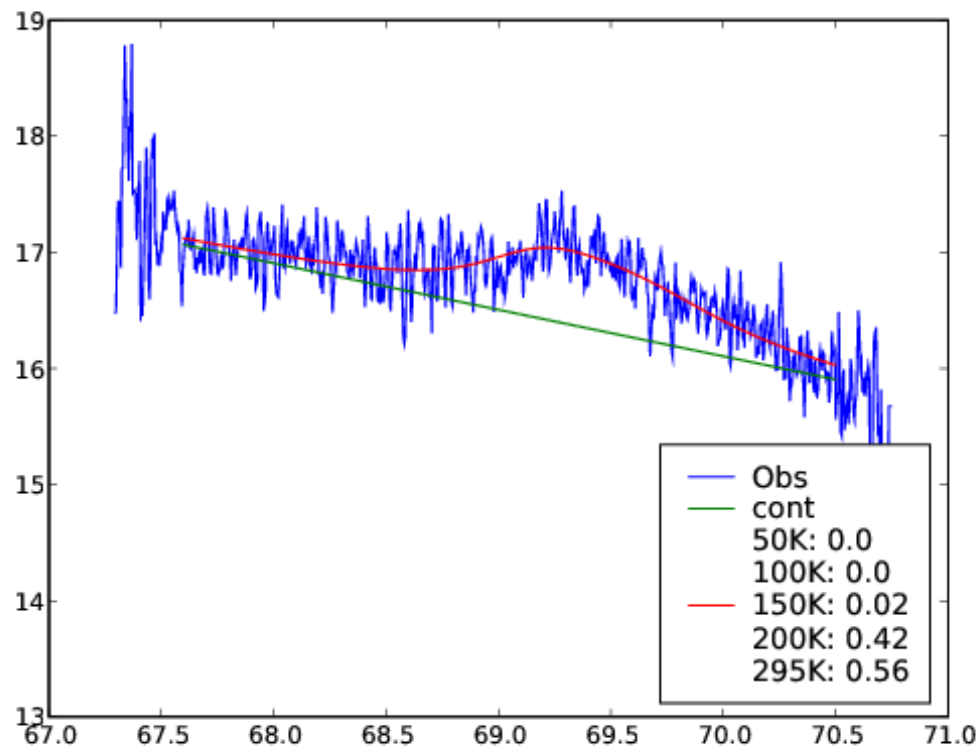
# Gas line spectroscopy Beta Pic

- Line scan OI 63um - detection
- Full PACS SED scan shows CII 157 um emission 6x stronger than predicted
- See poster by Alexis Brandeker, this conference



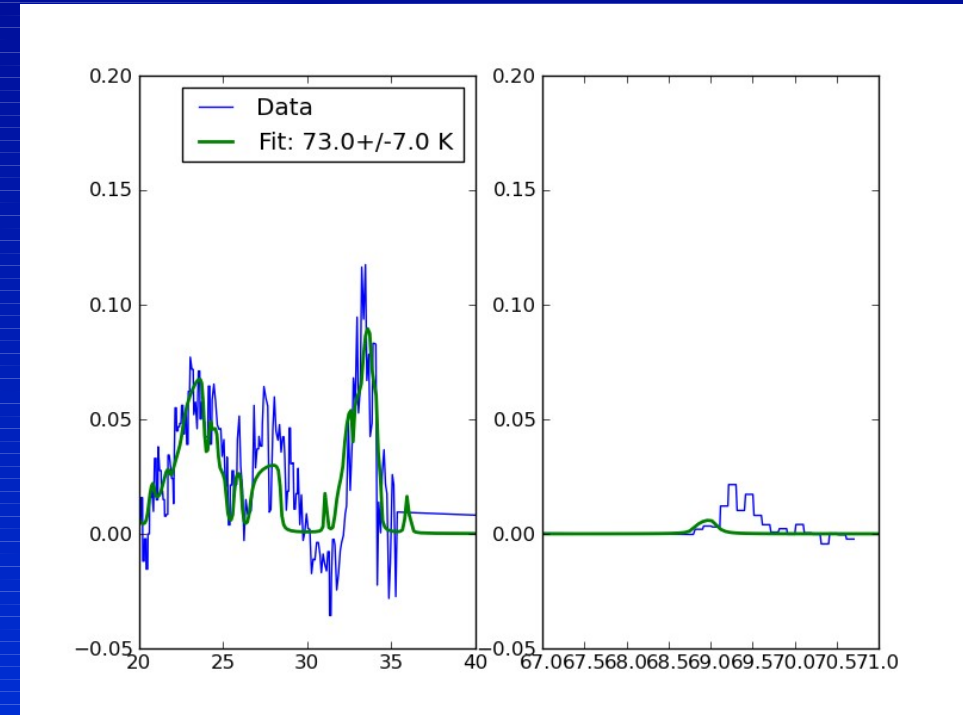
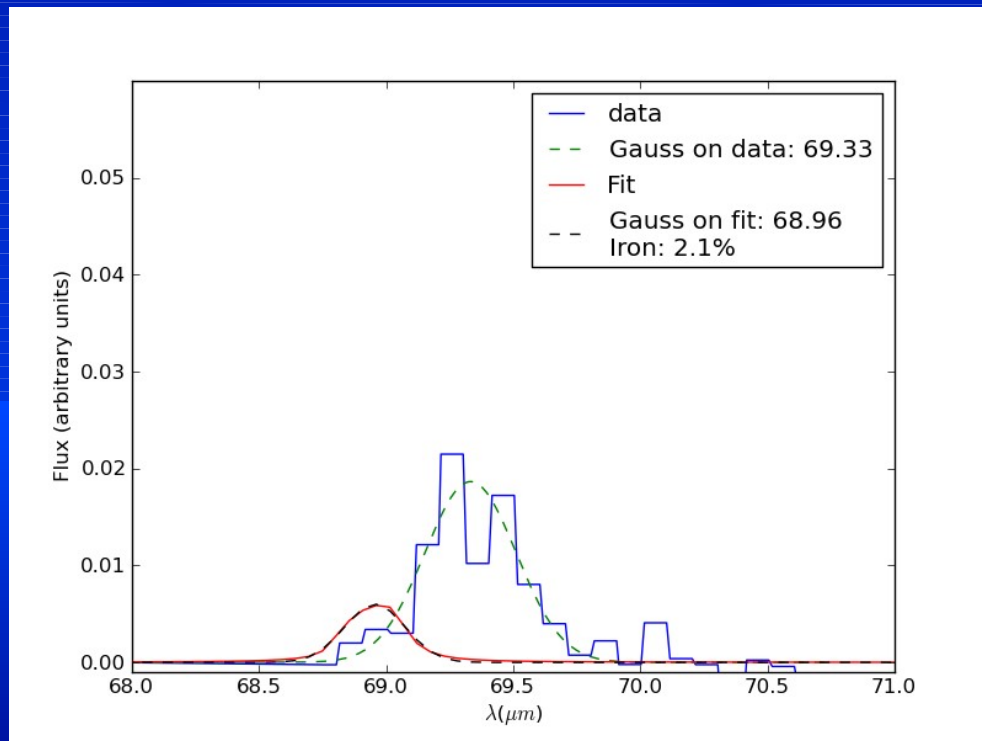
# Beta Pic dust spectroscopy

Forsterite 69 $\mu$ m clearly detected in central spaxel



# Beta Pic forsterite – first analysis

Fit of Spitzer 35um crystalline silicate spectrum [Chen 2007] – 75K yields 69um forsterite peak shortwards of observed peak

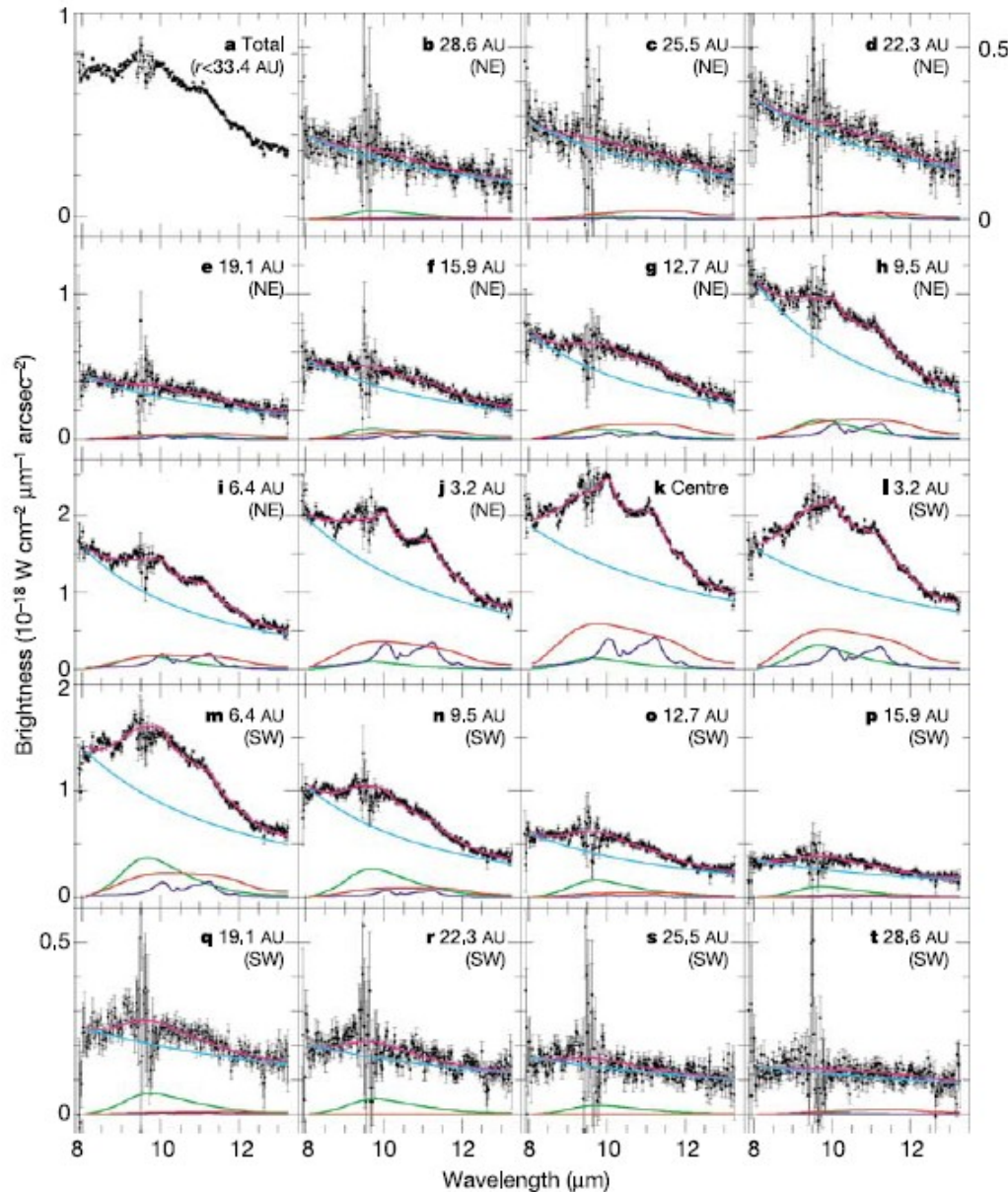


- Larger grains ?
- $\sim 2\%$  Fe ?



# Beta Pic hot crystalline silicates

Okamoto (Nature, 2004):  
Subaru spatially resolved  
spectra show hot (1200K)  
crystalline silicates close  
to the star



# Beta Pic Forsterite - questions

- Relation to hot, small crystalline silicates close to the star
- Size, temperature, Fe content
- Origin
  - Primordial (strong radial mixing or local production)
  - Parent body processing
  - Sand-blasting in situ production
  - Thermal annealing of dust from infalling comets



# Beta Pic - outlook

- Instrumental characterisation key to further work
  - Photometer
    - PSF characterisation: deconvolution
  - Spectrometer broad feature reliability
    - Transient correction
    - Drift correction
- Full dust component model [*Pantin et al. In prep*]
- Forsterite nature [*de Vries et al. in prep*]
- Gas modeling [*Brandeker et al. in prep*]

