Bolocam observations of a sample of *Herschel* cold clumps

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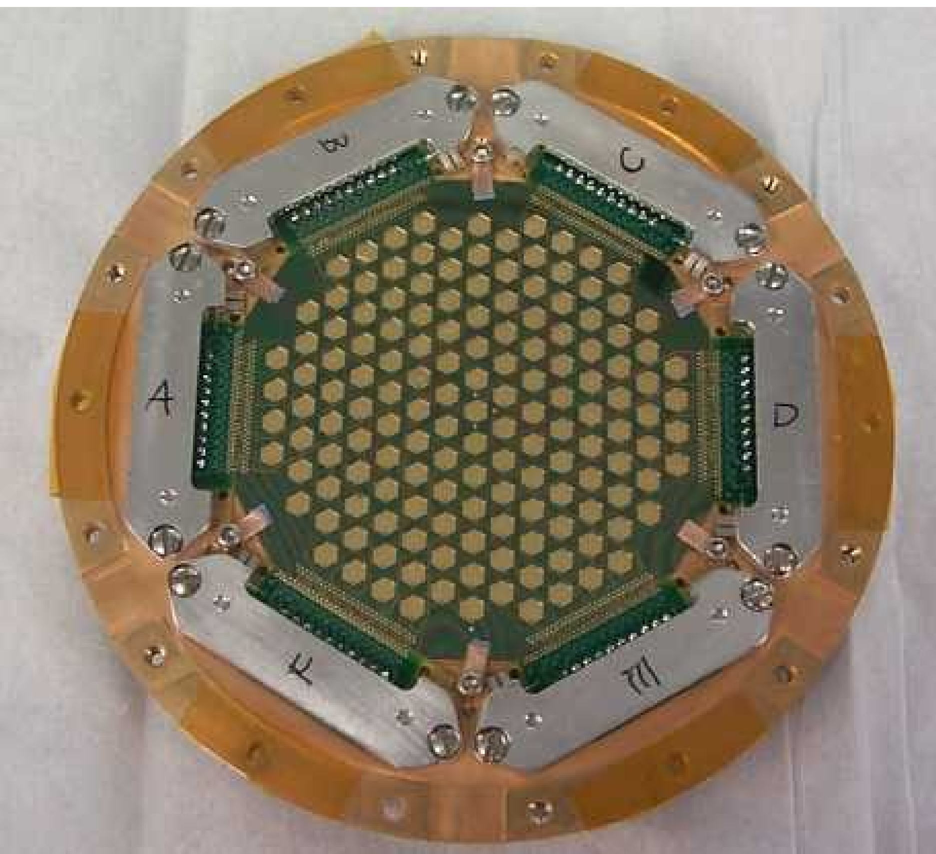
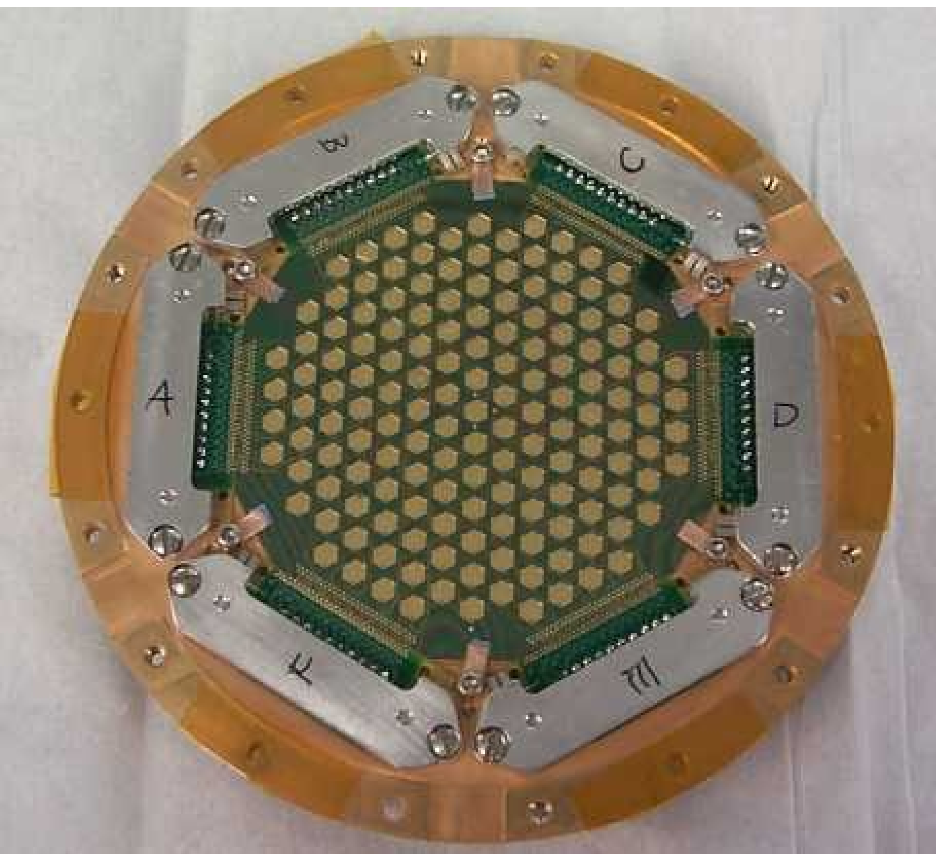
Caltech Submillimeter Observatory

- Located near the summit of Mauna Kea, Hawaii, at ~4070 meters, with 10.4-meter submillimeter dish
- Bolocam: 1.1mm continuum at 31”, 8' circular FoV



Caltech Submillimeter Observatory

Decommissioned
18 September 2015.



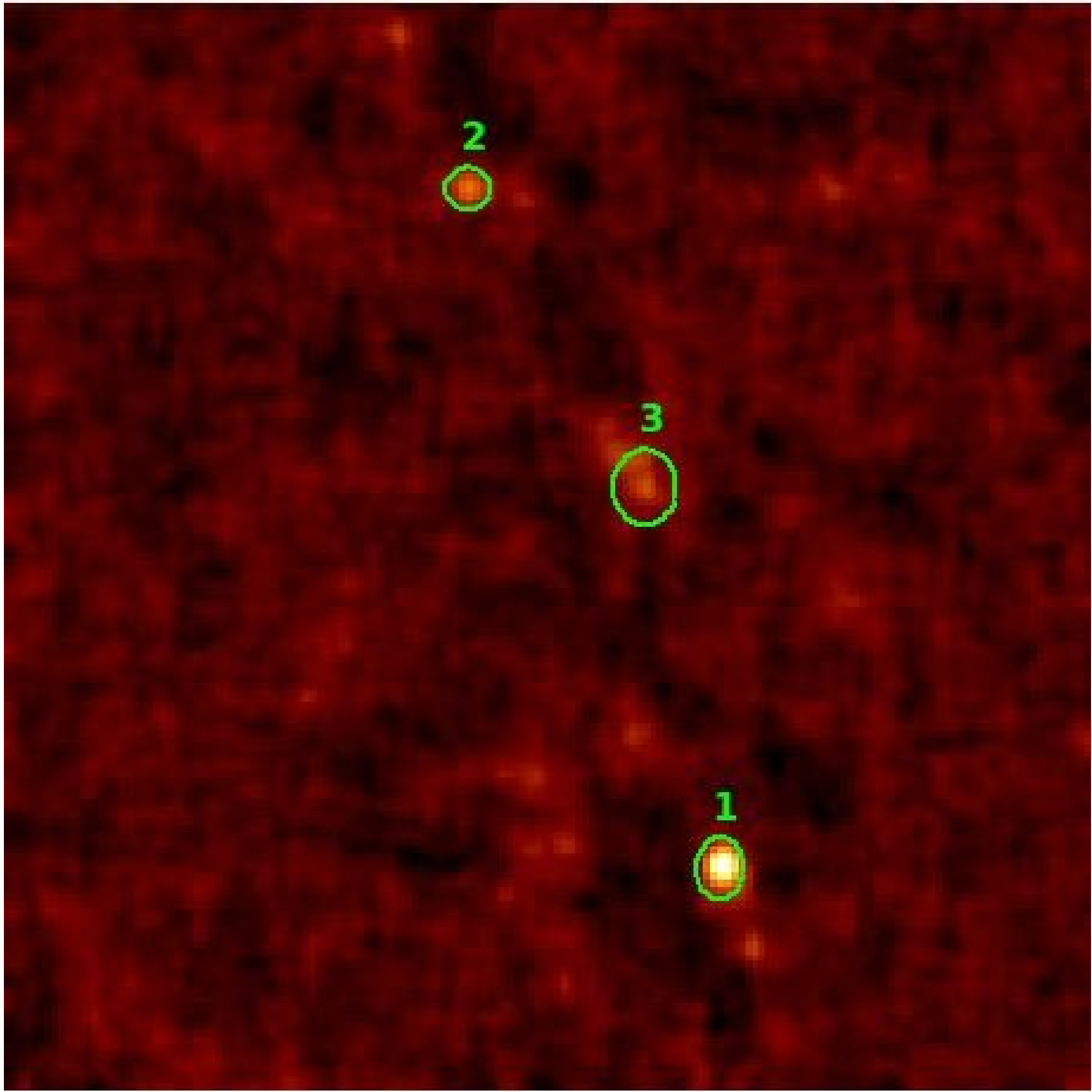
Observations

- Bolocam Follow-up 15-18 Dec 2010: 19 *Planck* cold clumps
- Target selection was done based on the Planck data and in conjunction with the Herschel target selection to ensure wavelength coverage for SED fitting and the determination of dust emissivity index beta.
- 11 of the cold clumps are in the public ECC, 8 were in the proprietary (at the time) Cold Core Catalogue of *Planck* Objects (C3PO)
- Mapsize: 30' x 30' uniform coverage (full size 38' x 38') → comparable in size with the Herschel maps

Detections

- Bolocam 1.1mm observations were reduced to maps, and then convolved to 40” resolution (the common resolution to be used with Herschel maps, too).
- 2D clumpfind was run at 5-sigma detection threshold, following the clumps to 3-sigma.

→ total of ~20 detections in 9 fields



Problem: Spatial Filtering

- Bolocam filters out extended emission while it is subtracting the sky signal (e.g., Aguirre et al. 2011). Thus, the maps are not so easily combined with the unfiltered Herschel data.
  - Also, the estimated Signal-to-noise was slightly optimistic, as this filtering was not accounted for. On hindsight, it would have been better to go for fewer but deeper maps.

Dealing with Spatial Filtering I

- Iterative mapping (Enoch et al. 2006, 2007)
  - Computationally intensive and time-consuming
- Characterize the signal transfer function based on the source shape (Sayers et al. 2011)
  - Transfer function is only weakly dependent on the source shape (10% change compared to an unresolved source signal transfer function) → it is good enough to use a single unresolved source signal transfer function
  - However, the shape of the source is still needed!

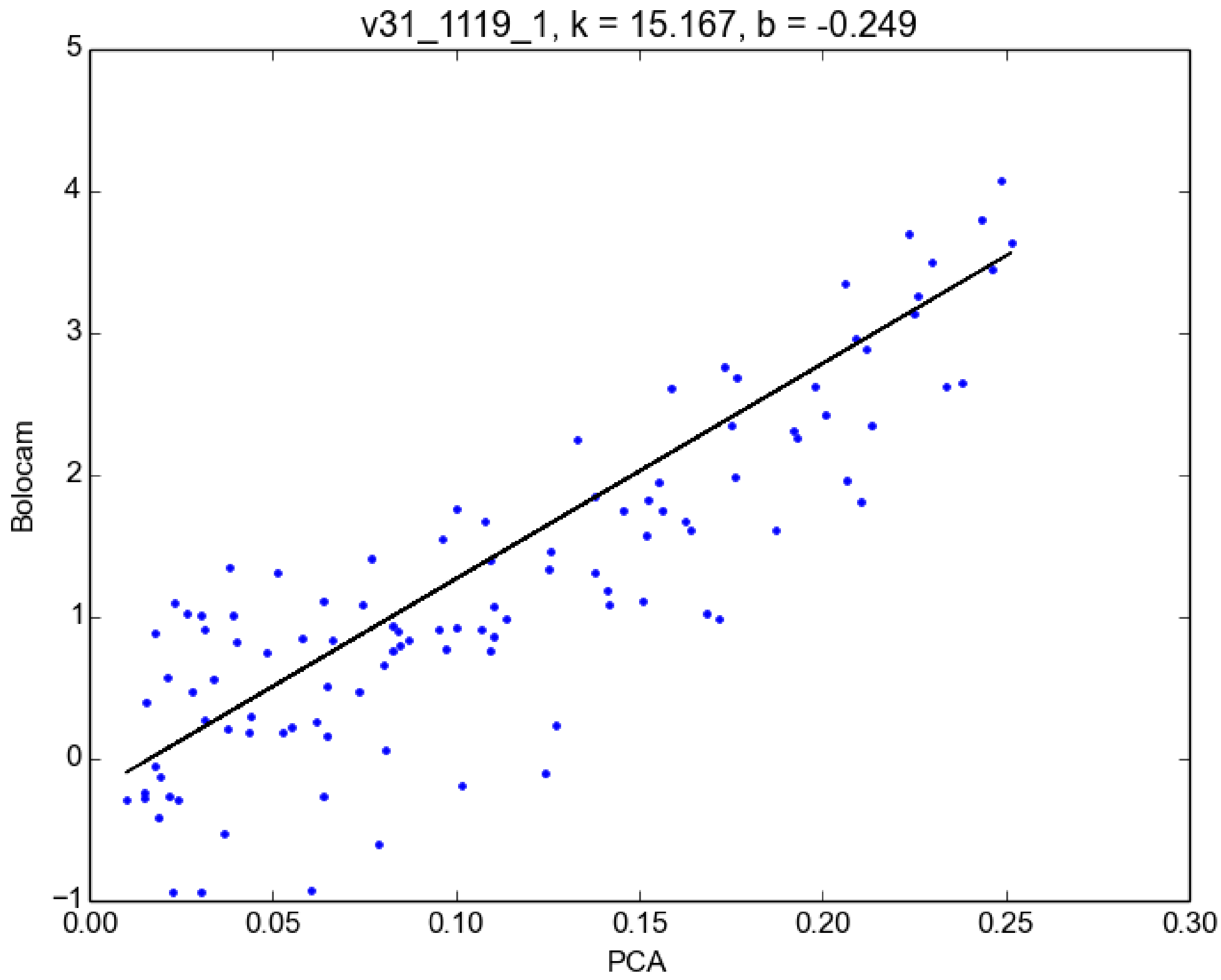
Dealing with Spatial Filtering II

- How to get the (unfiltered) source shape?
- Using Sextractor to find the sources on the (unfiltered) 500µm Herschel maps → returns 2D Gaussian ellipse fits of the detected sources.
  - Worked fine is some cases, but in others, Sextractor was clearly picking up something much more extended → measure the FWHM by hand
- 2D Gaussian shapes normalized to 1 and fed through the signal transfer function code → filtered source shape with the flux attenuated.

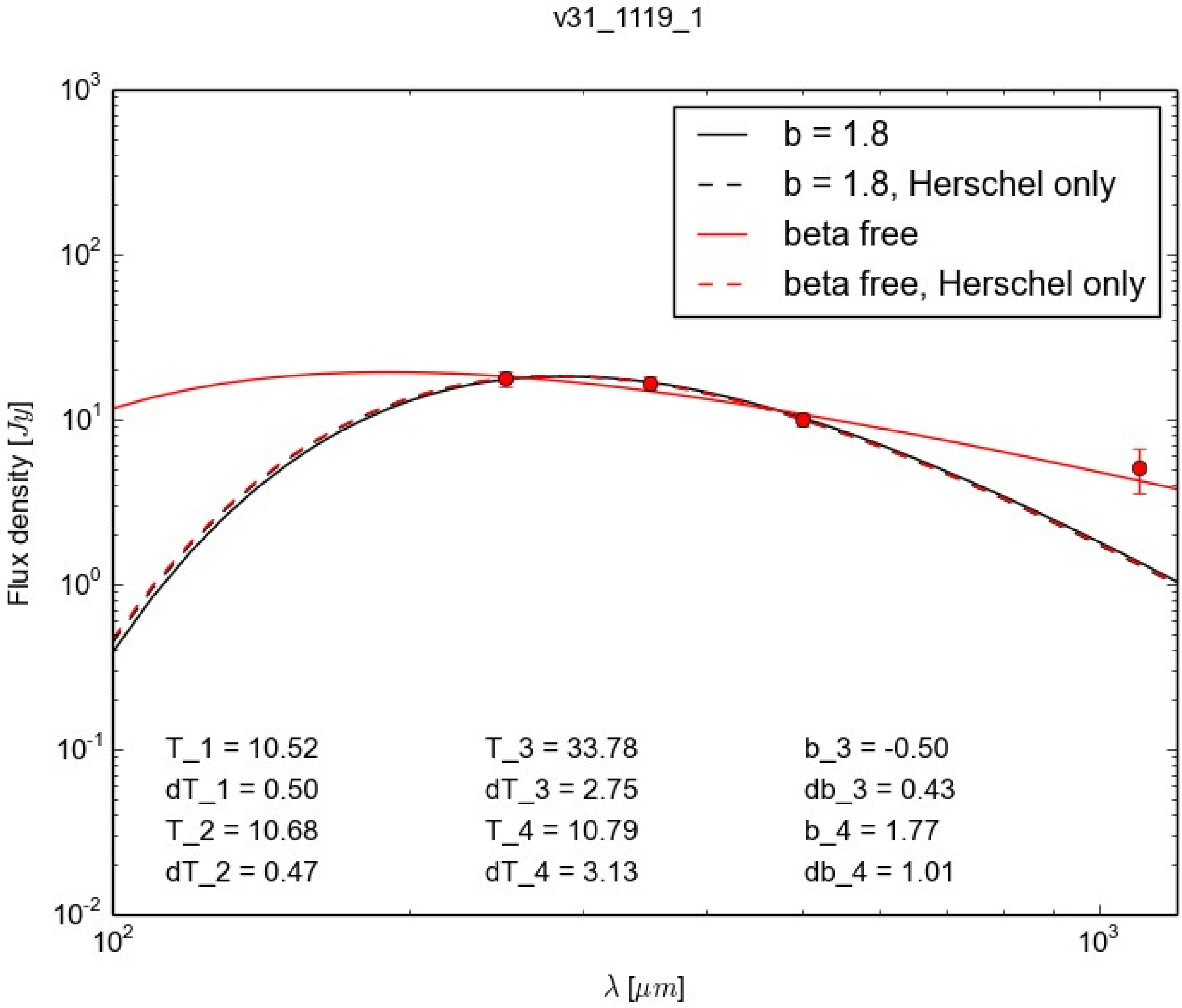
Dealing with Spatial Filtering III

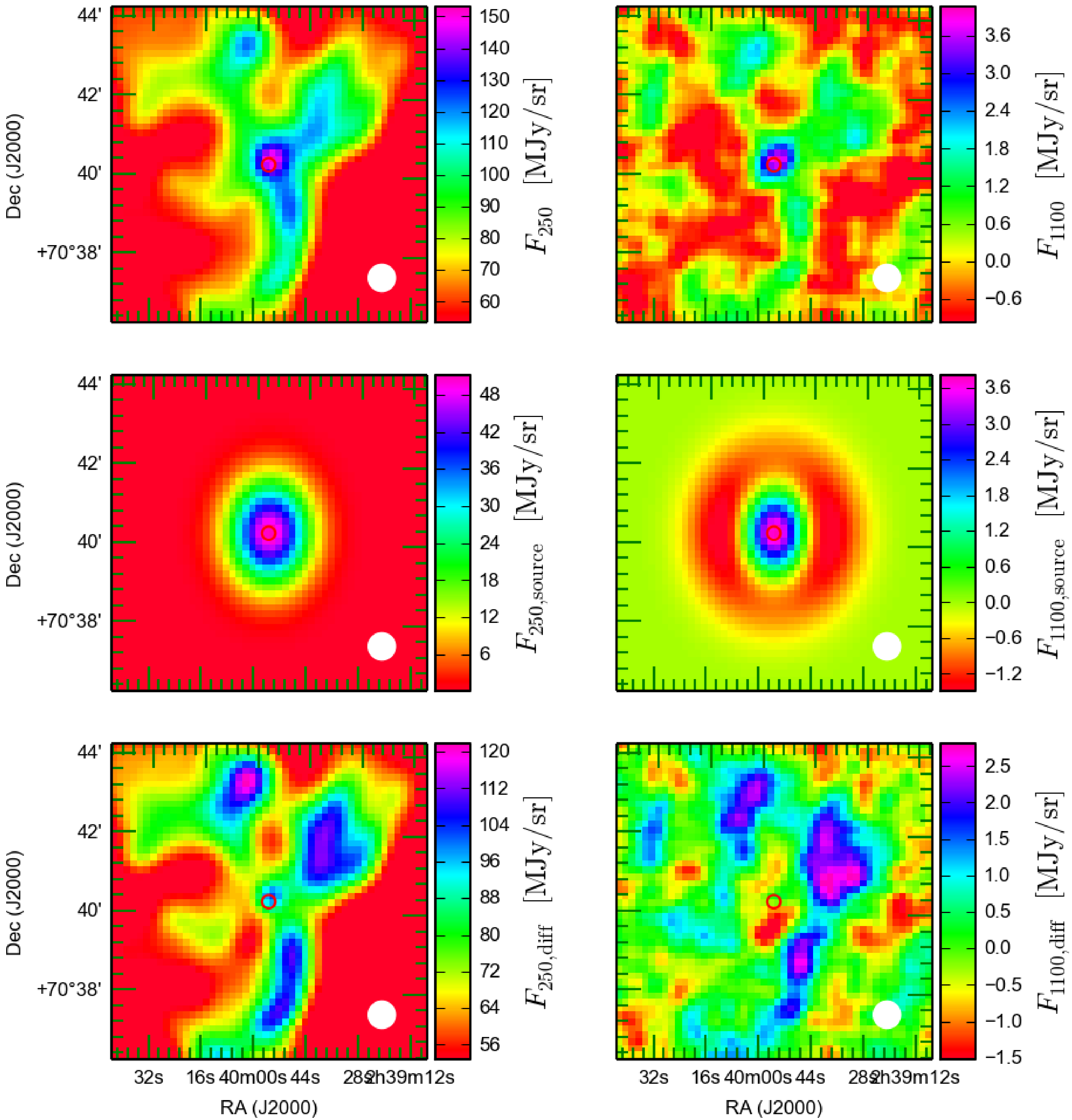
- Filtered shape is fitted to the Bolocam map with a simple zero level and scaling factor.
- Same scaling factor is used to scale up the unfiltered shape and the total flux is calculated.
- Herschel maps are treated in a similar way: convolved to 40” and resampled to the same pixels as the Bolocam maps, (unfiltered) 2D Gaussian shape is fitted, and then scaled up by the scaling factor to calculate the total flux belonging to the source.
- Works reasonably well.

Example of the fitting I



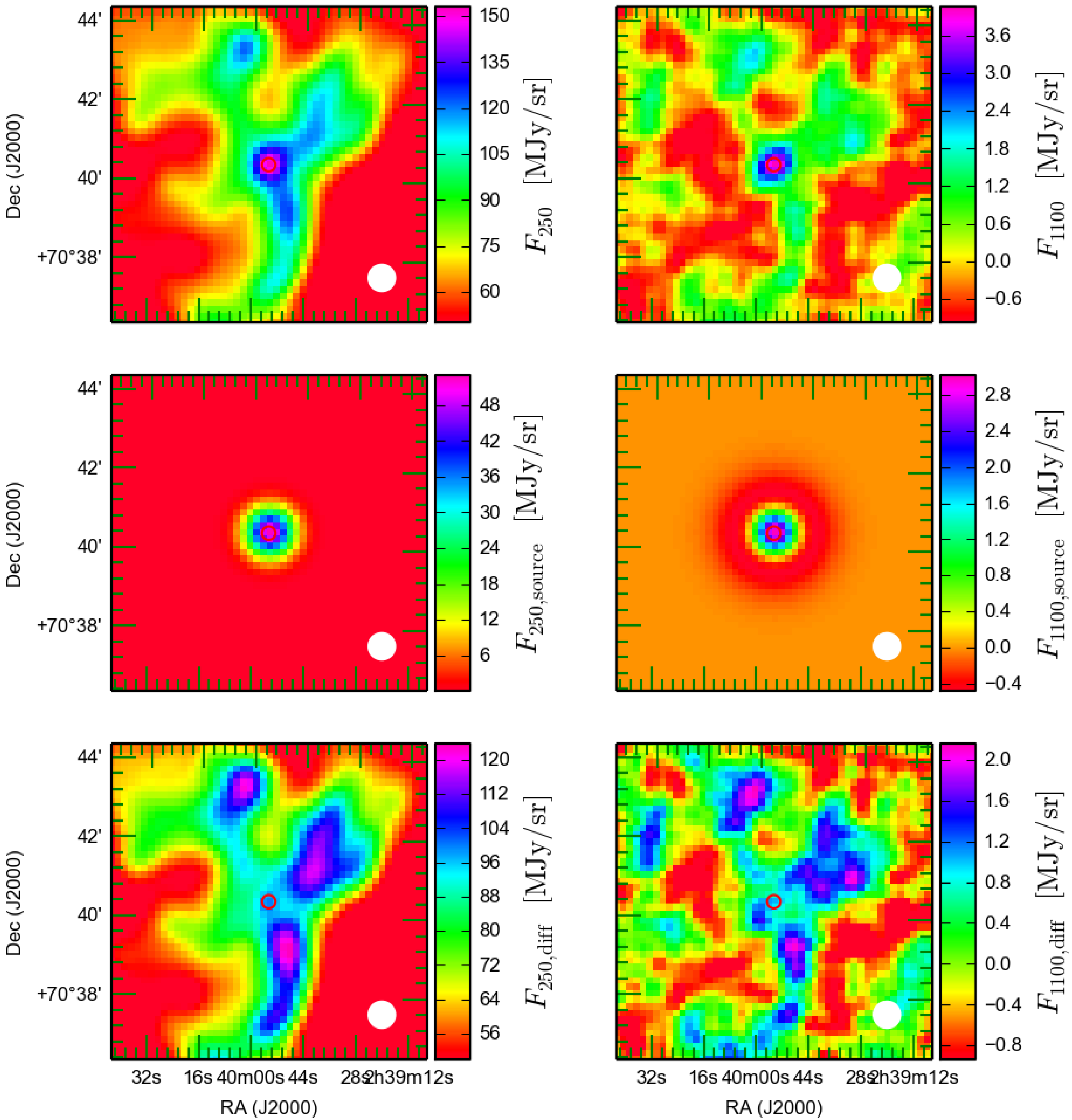
Example of the fitting I





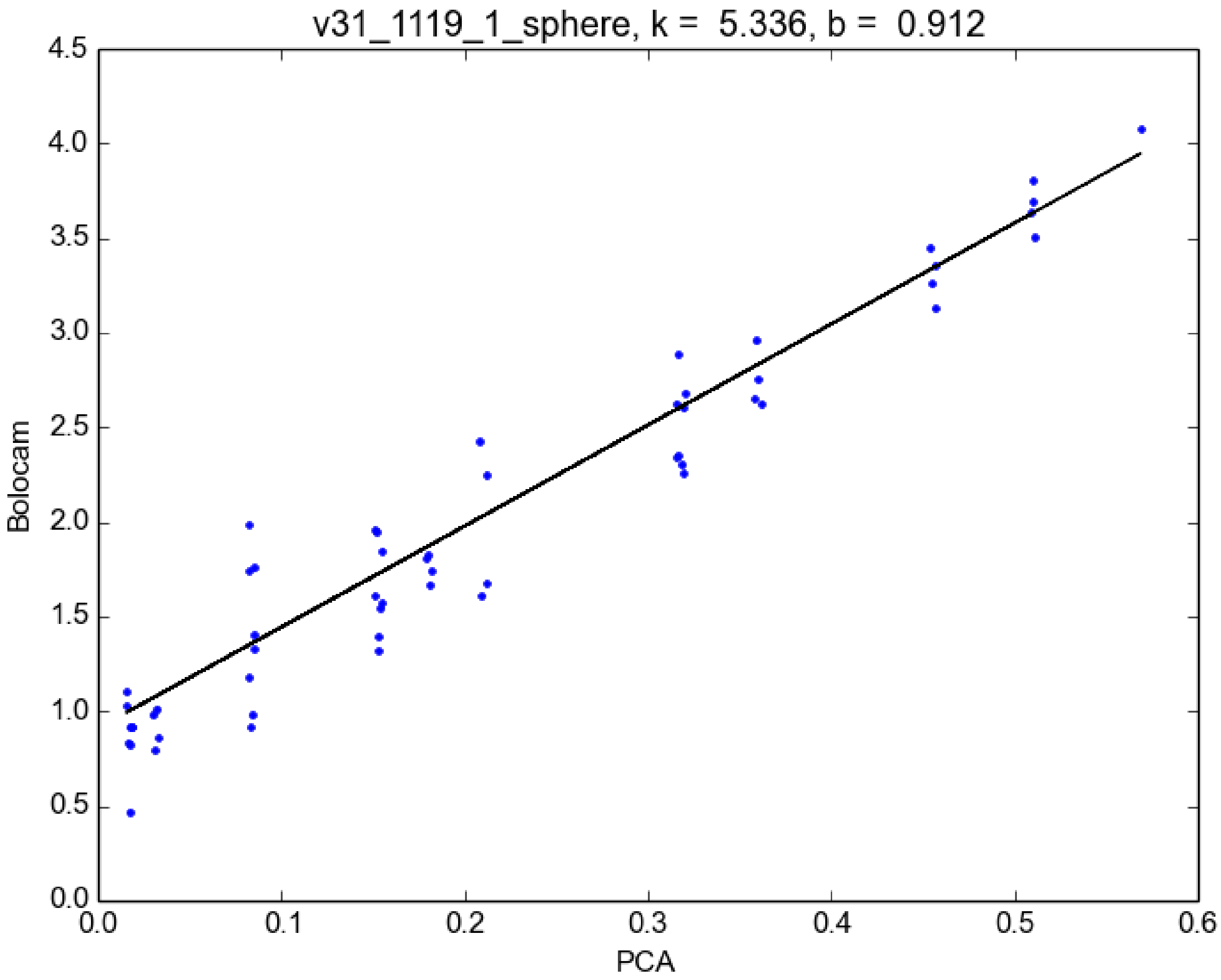
Sextractor is trying to fit the extended emission.

→ wrong shape!

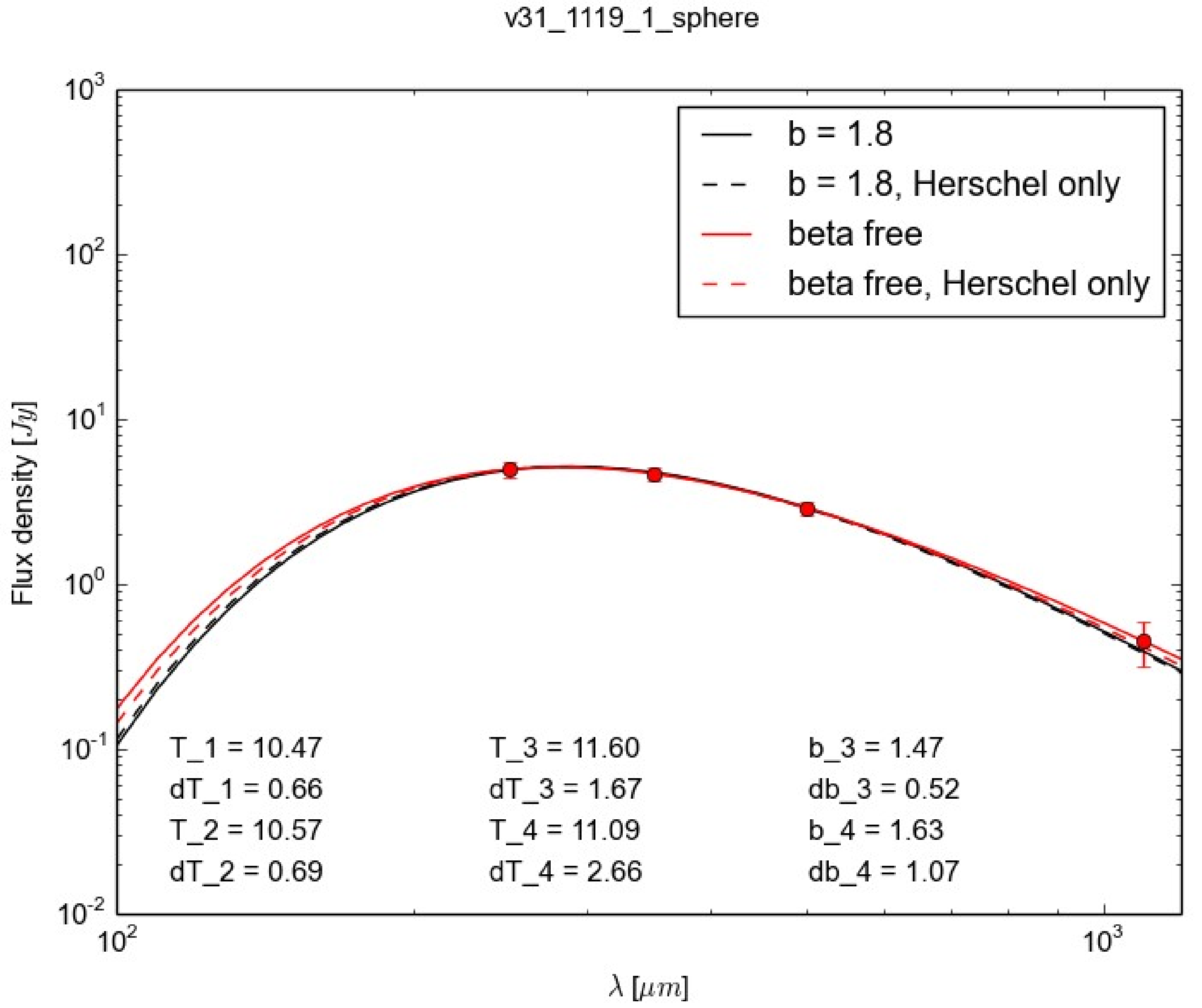


Trying a smaller, spherical gaussian shape.

Example of the fitting II



Example of the fitting II



Distance, Mass and Size

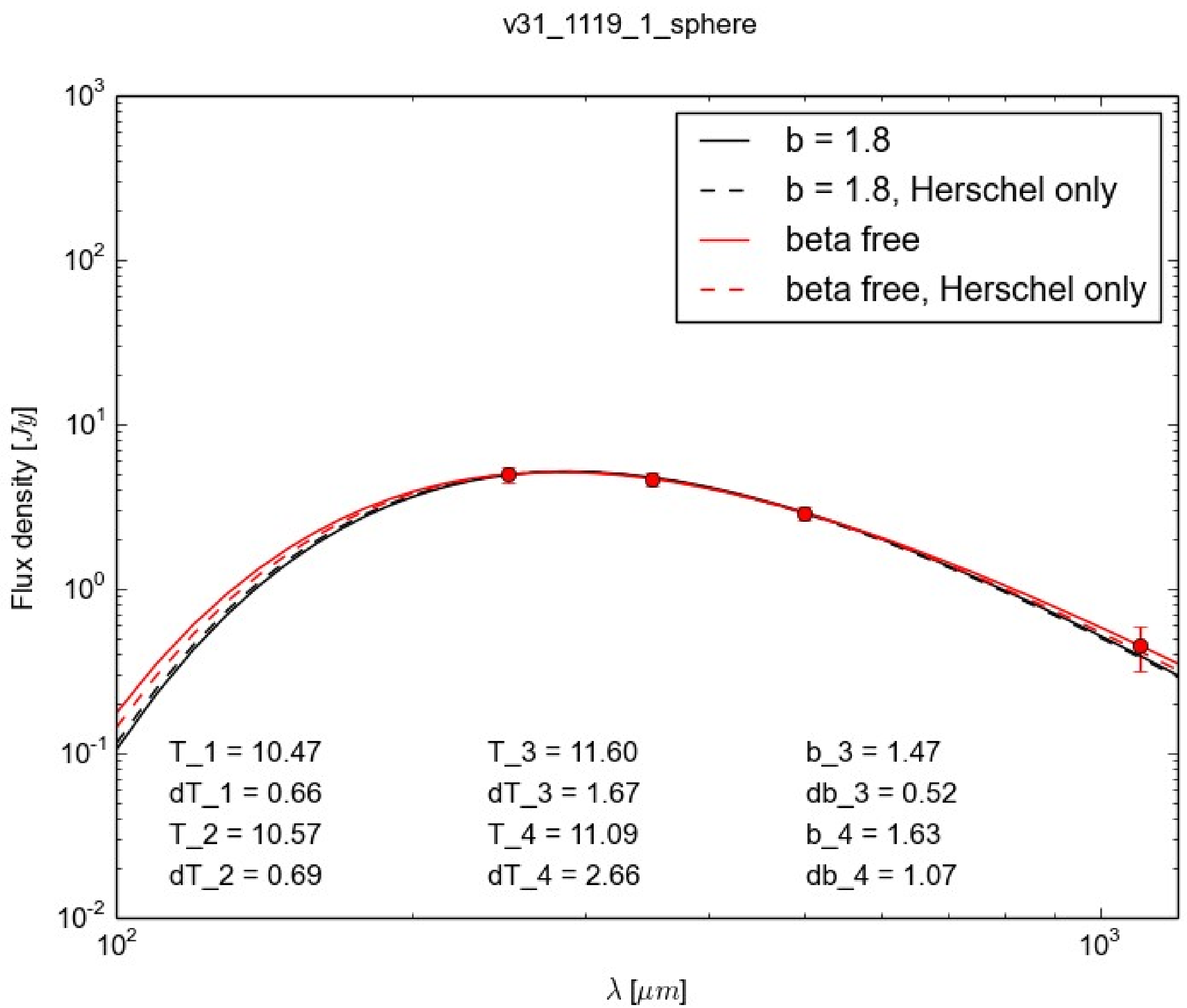
- Distance (from various methods, see Montillaud et al. 2015) varies from 200 pc to almost 2 kpc (40” ~ 0.04 – 0.4 pc), with relative errors from 5% to 50%, typically 20%.
- SED temperatures 10 – 20 K.
- Masses (SED temperature with beta = 1.8 & distance) range from couple tenths to over a hundred solar masses.
- Comparing the sizes of the clumps to similar mass & temperature Bonnor-Ebert spheres reveals that they are much more compact and thus should be collapsing.

Protostellar or starless?

- Two methods (Montillaud et al. 2015): Koenig et al. 2012 based on WISE colour-magnitude and the Herschel temperature profile of the clumps.
- Of the 22 clumps examined, 3 remain unclassified, 3 are deemed starless and 16 have indications of protostars.

Dust emissivity index

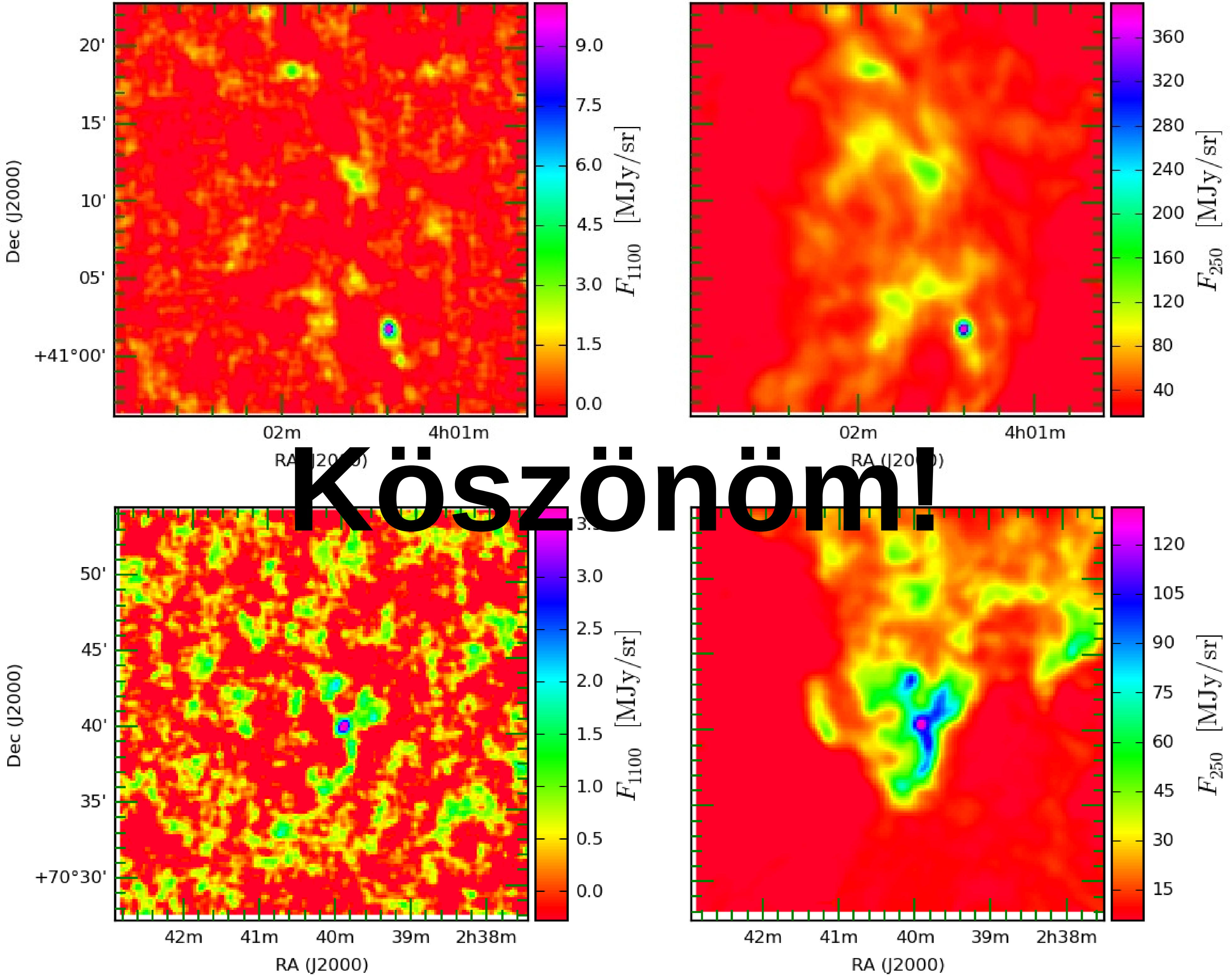
- Bolocam points fit well in the SED with the Herschel fit in almost all cases with beta ~1.8. Large deviations are only seen when the estimated shape is clearly wrong.



Conclusions

- 22 clumps detected in 9 fields
- 18 protostellar, 3 starless, 3 unclassified
- Herschel data is enough to fit the slope in most cases, the addition of the Bolocam point confirms beta ~1.8.
  - However, these are 1) mainly protostellar sources, and 2) of moderate column density (a couple of tens of A_V). Thus, one wouldn't expect to see lots of cold dust unlike in L183.

Köszönöm!


Dec (J2000)
20'
15'
10'
05'
+41°00'
02m
4h01m
RA (J2000)
F_{1100} [MJy/sr]
0.0
1.5
3.0
4.5
6.0
7.5
9.0
F_{250} [MJy/sr]
40
80
120
160
200
240
280
320
360
50'
45'
40'
35'
+70°30'
42m
41m
40m
39m
2h38m
0.0
0.5
1.0
1.5
2.0
2.5
3.0
15
30
45
60
75
90
105
120