A NIKA study of two high-mass IRDCs: β variations and mass concentration

Andrew J. Rigby, N. Peretto (Cardiff University, UK)
and the NIKA collaboration.
RigbyA@cardiff.ac.uk

SFDE17, Quy Nhon, Vietnam
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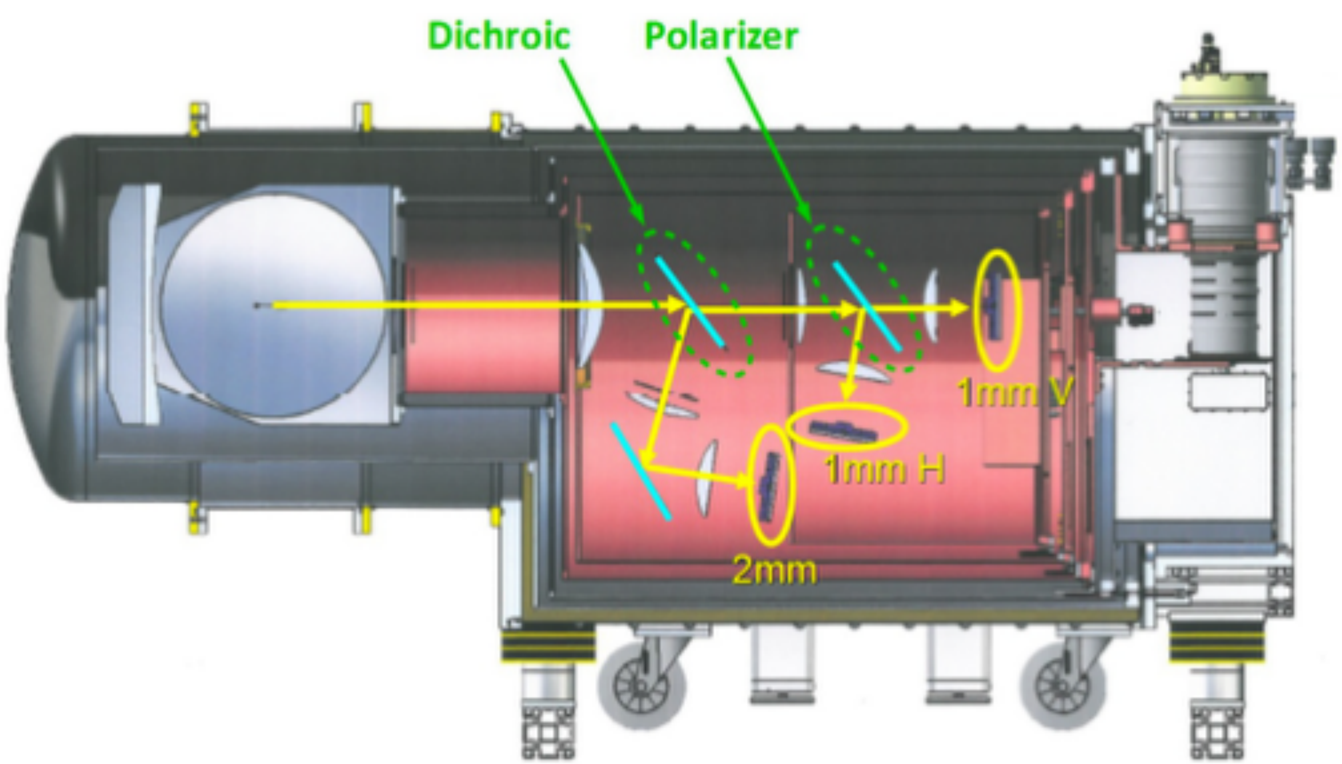
Rigby et al. (2017, in prep)

NIKA

Néel IRAM KIDs Array

- Operational: 2014 — 2015 at IRAM 30-m in Spain.
- Dual band for simultaneous observing at 1.2 mm (260 GHz) and 2.0 mm (150 GHz) observing
- High angular resolution: 12.0" @ 1.2 mm, 18.2" @ 2.0 mm
- 1.8' field of view
- Pathfinder for…

IRAM 30-m telescope, Pico Veleta, Spain



NIKA2

- Installed September 2015, commissioned 2017
- **Now open to the community**.
- 2 x 1 mm (260 GHz) and 1 x 2 mm (150 GHz) arrays.
- Polarisation at 1 mm (see Alessia Ritacco's talk)
- 6.5' field of view

Background

- Thermal dust continuum emission is often described using a modified black body model where the dust emissivity spectral index, **β**, is an indirect probe of the **dust grain population**:

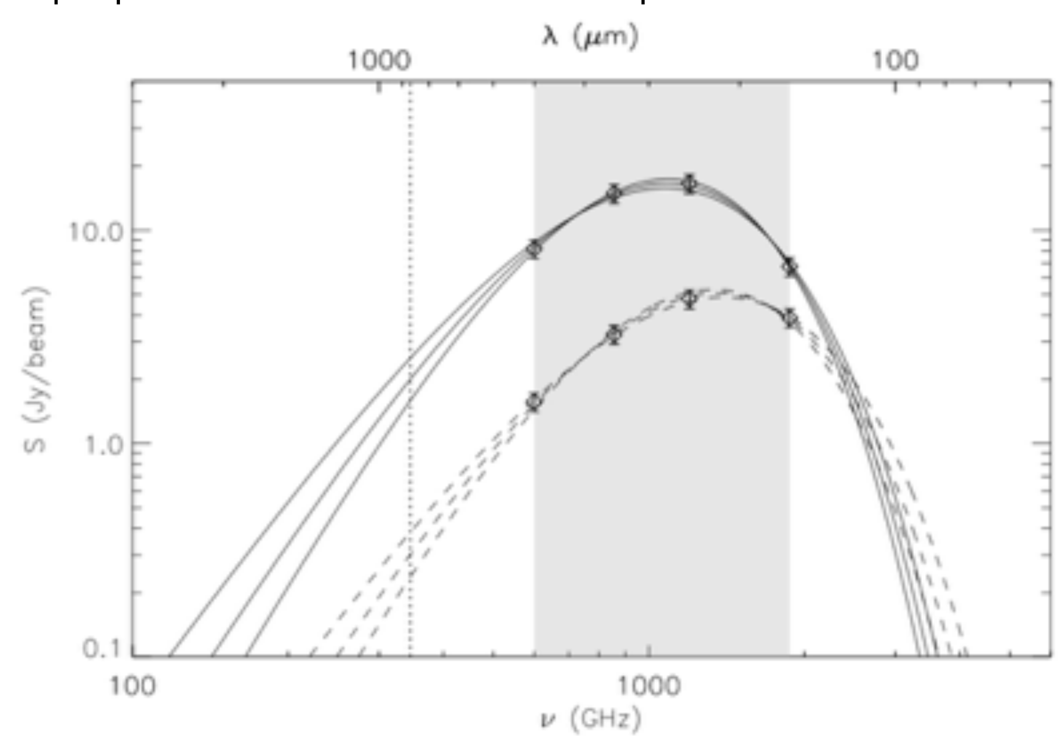
$$I_\nu = N_{\mathrm{H_2}} \mu_{\mathrm{H_2}} m_{\mathrm{H}} \kappa_0 \left(\frac{\nu}{\nu_0} \right)^\beta B_\nu(T_\mathrm{d})$$

- Its value depends on dust grain **size** distribution (and therefore the formation of ice mantles and subsequent coagulation), **composition** and **structure**…

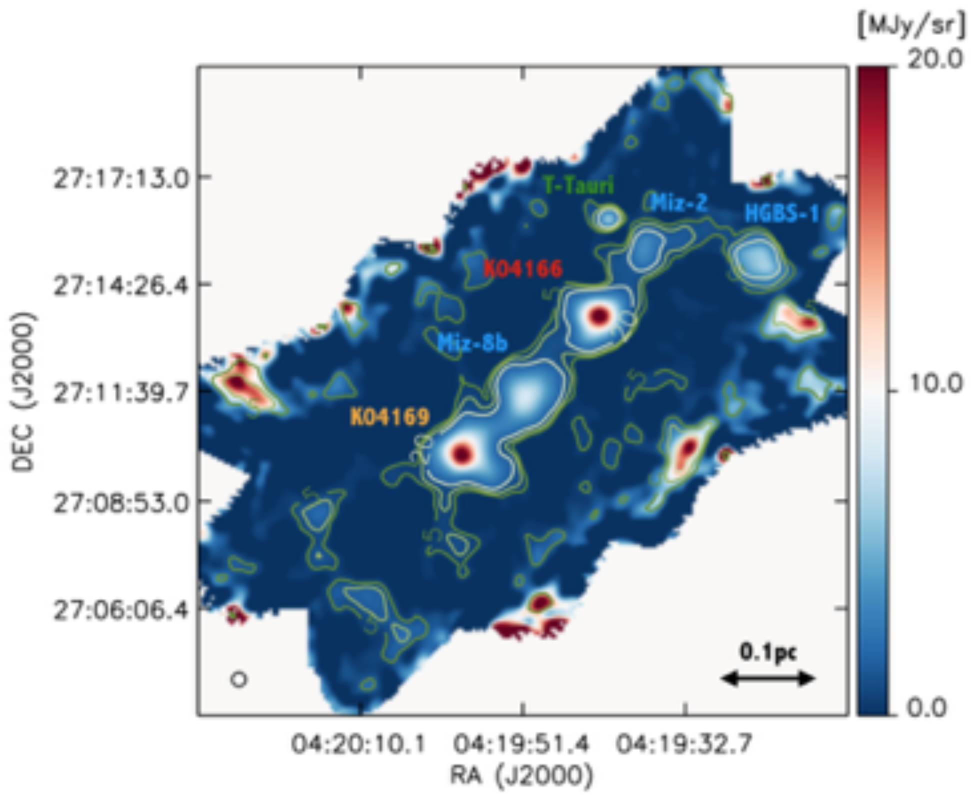
- …and is expected to **change as a function of temperature** (e.g. Agladze+96, Mennella +98, Boudet+05) or in shocked regions (e.g. Gueth+03) and therefore **environment**.

- Often **assumed** to have a **single value** across whole populations of dust clumps.

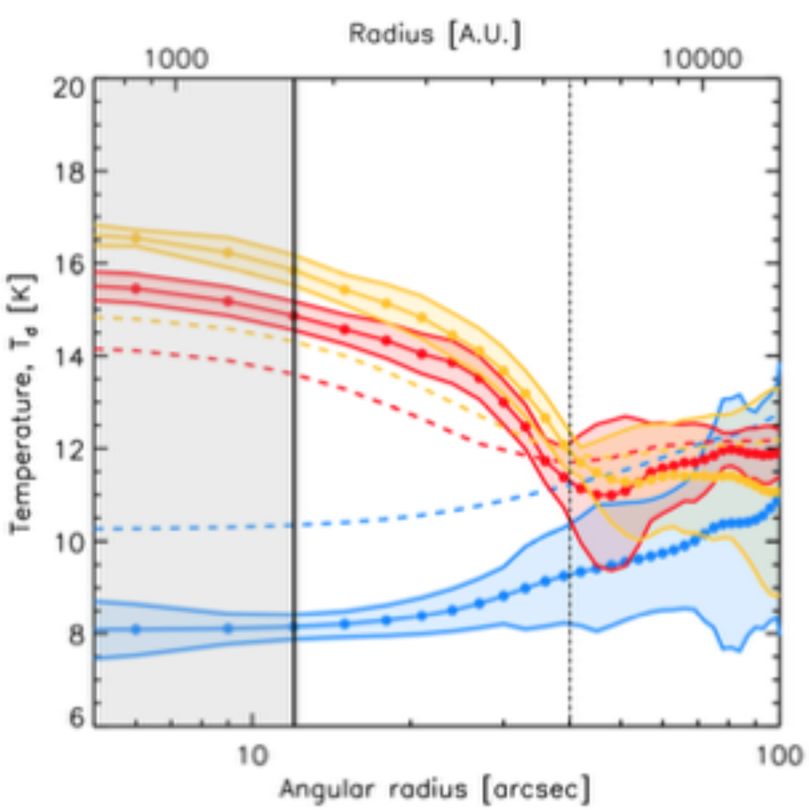
- A well-documented degeneracy exists between T_d and β when fitting *Herschel* data with moderate amounts of noise: **long-wavelength data** is **key** to constraining **β** e.g. Sadavoy et al. (2013) →

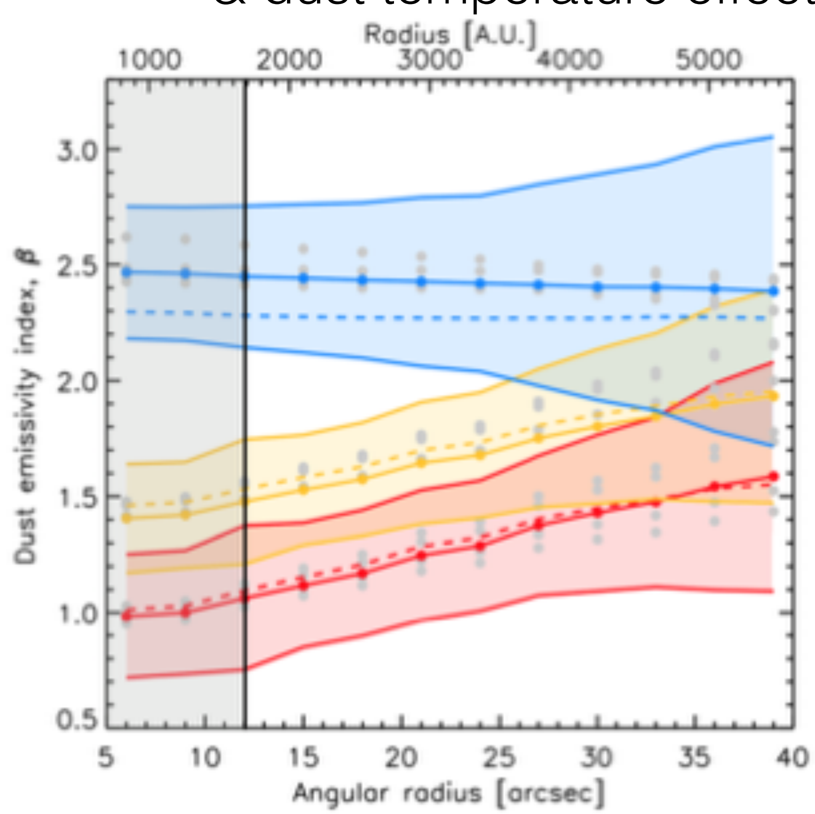


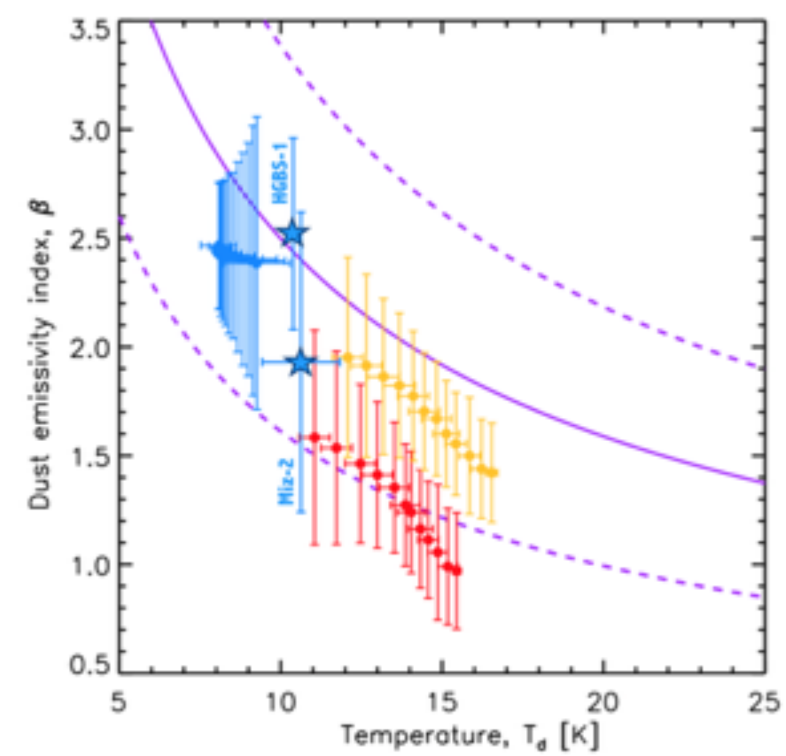
Recent results with NIKA:



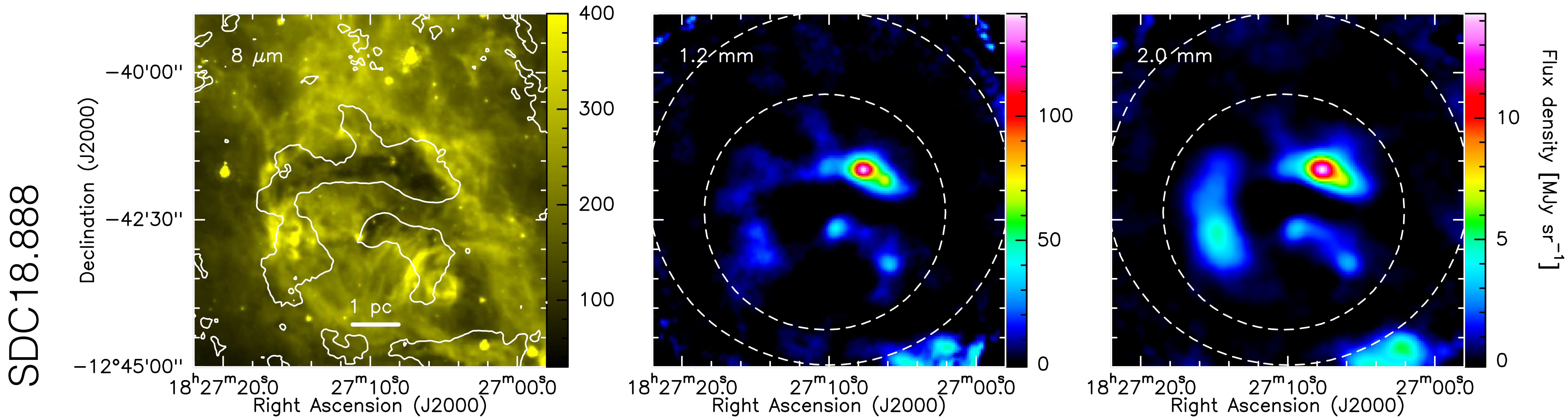
- Bracco et al. (2017) study low-mass cores in the Taurus B213 filament (d ~ 140 pc).
- Abel-inversion technique to simultaneously determine column density and T_d profiles from *Herschel* 160, 250 & 350 μm data.
- Constrain β using the ratio of 1.2 mm to 2.0 mm intensity with NIKA
- Decreasing β profiles found towards the centre of two protostellar cores, reaching ~1.0 & 1.5.
- β 2.4 and constant in the pre-stellar core.
- T_d - β anti-correlation found: decreasing β due to grain growth & dust temperature effects.



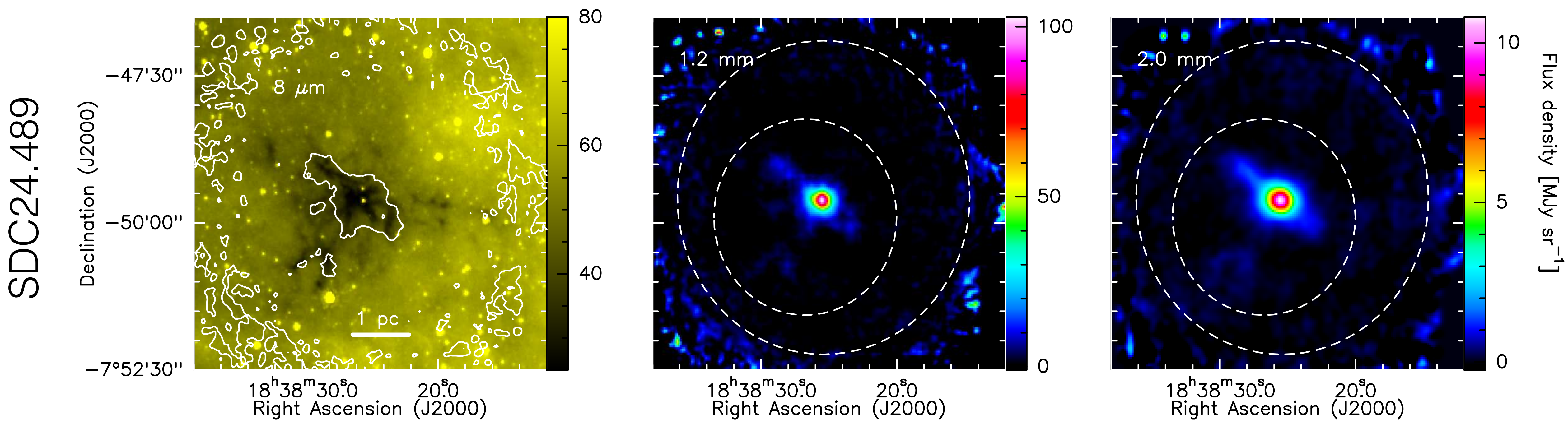




NIKA observations



SDC18 (l=18.888°, b=-0.476°): d = 4.4 kpc, field size = 8.6 pc



SDC24 (l=24.489°, b=-0.689°): d = 3.3 kpc, field size = 6.4 pc

Creating maps of β

Method:

1. Convolve 1.2 mm and 2.0 mm images to a common resolution of 20”.

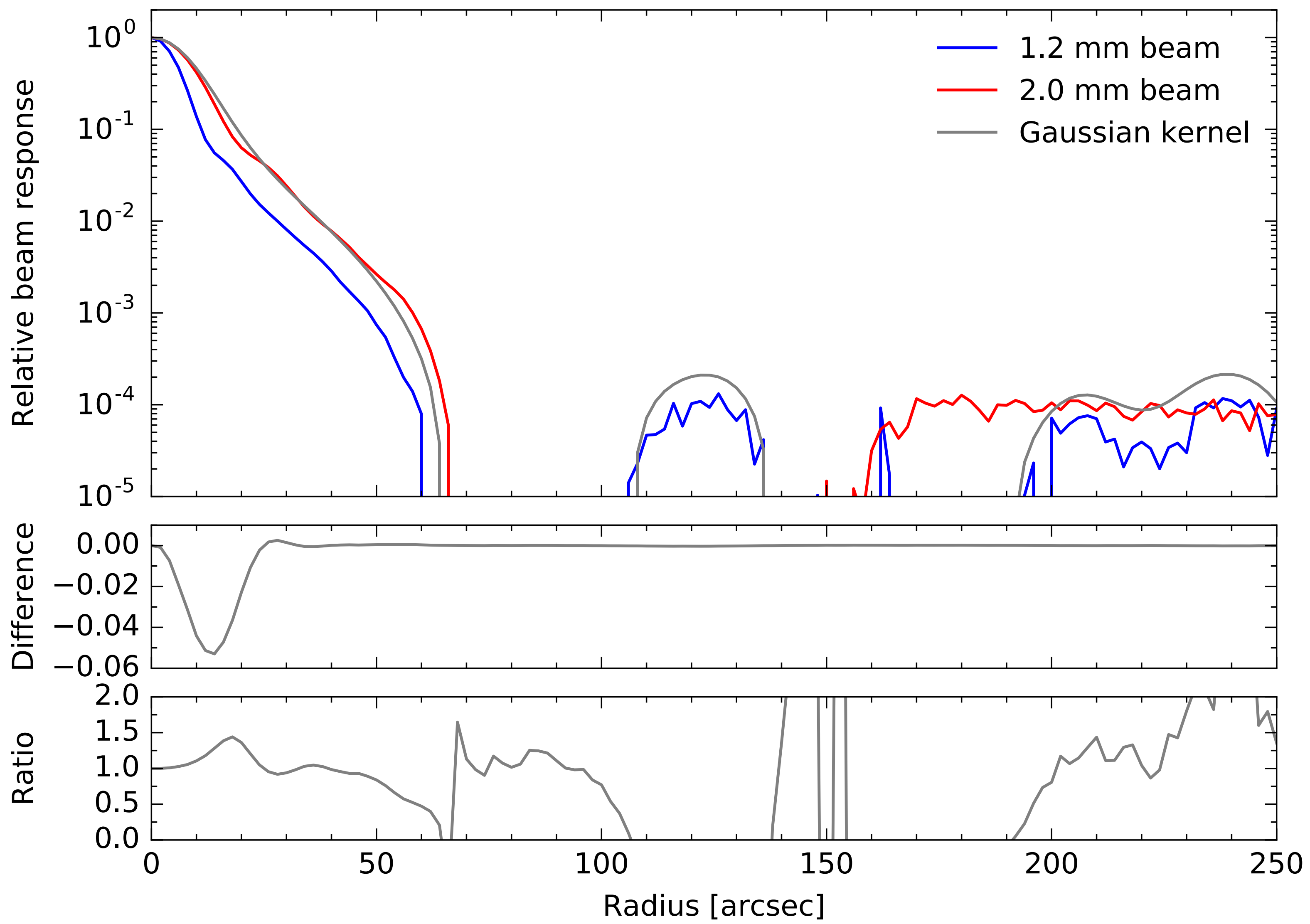
2. Create map of their intensity ratios

3. Convert β using some model for the dust temperature

$$\beta = \ln\left(\frac{I_1}{I_2}\frac{B_2(T_\mathrm{d})}{B_1(T_\mathrm{d})}\right) \times \left[\ln\left(\frac{\nu_1}{\nu_2}\right)\right]^{-1}$$

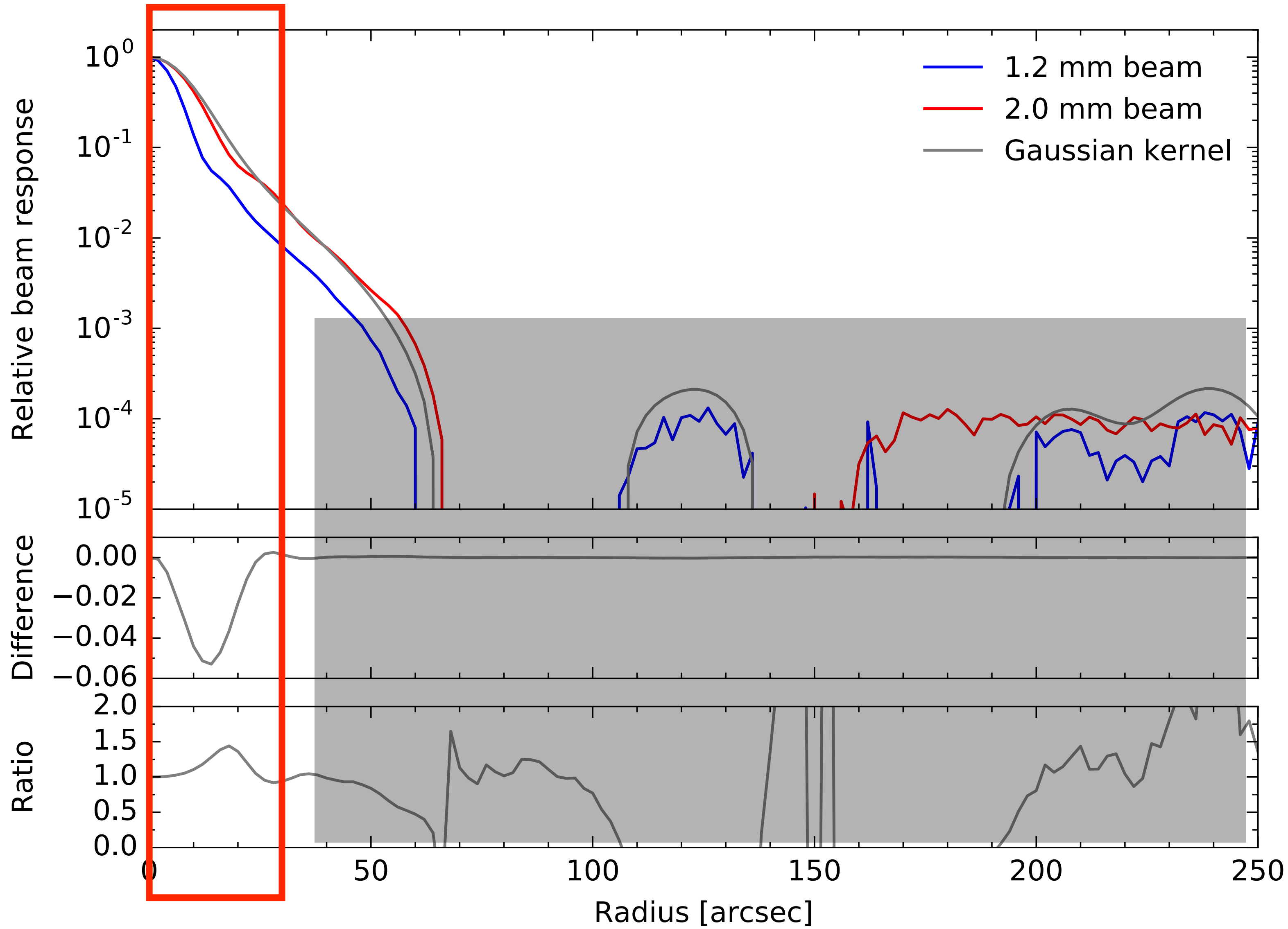
Note: take care with artificial features…

Beam and PSF effects



A significant fraction of the power in the NIKA beam is contained in non-Gaussian sidelobes.

Beam and PSF effects



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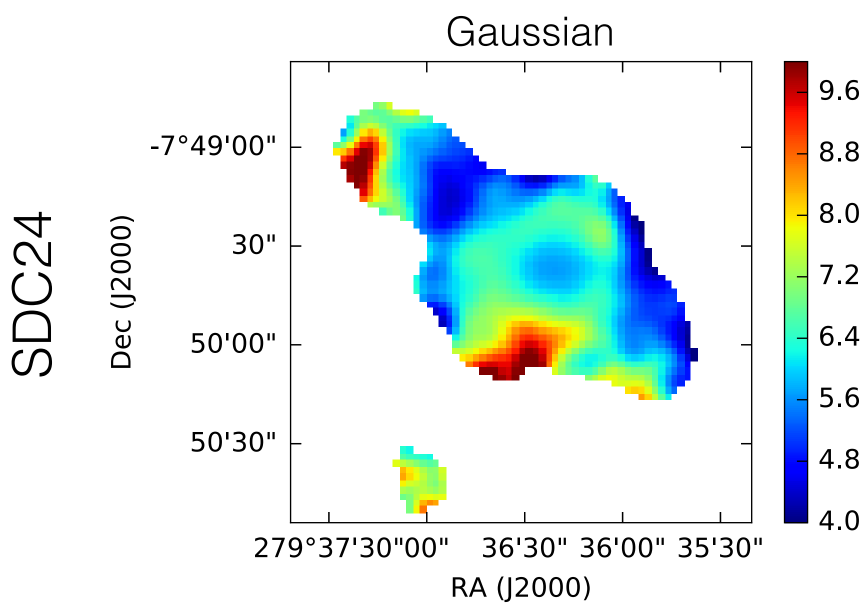
Q: Could these introduce artificial features into e.g. ratio of 1.2 mm to 2.0 mm emission and derived quantities?



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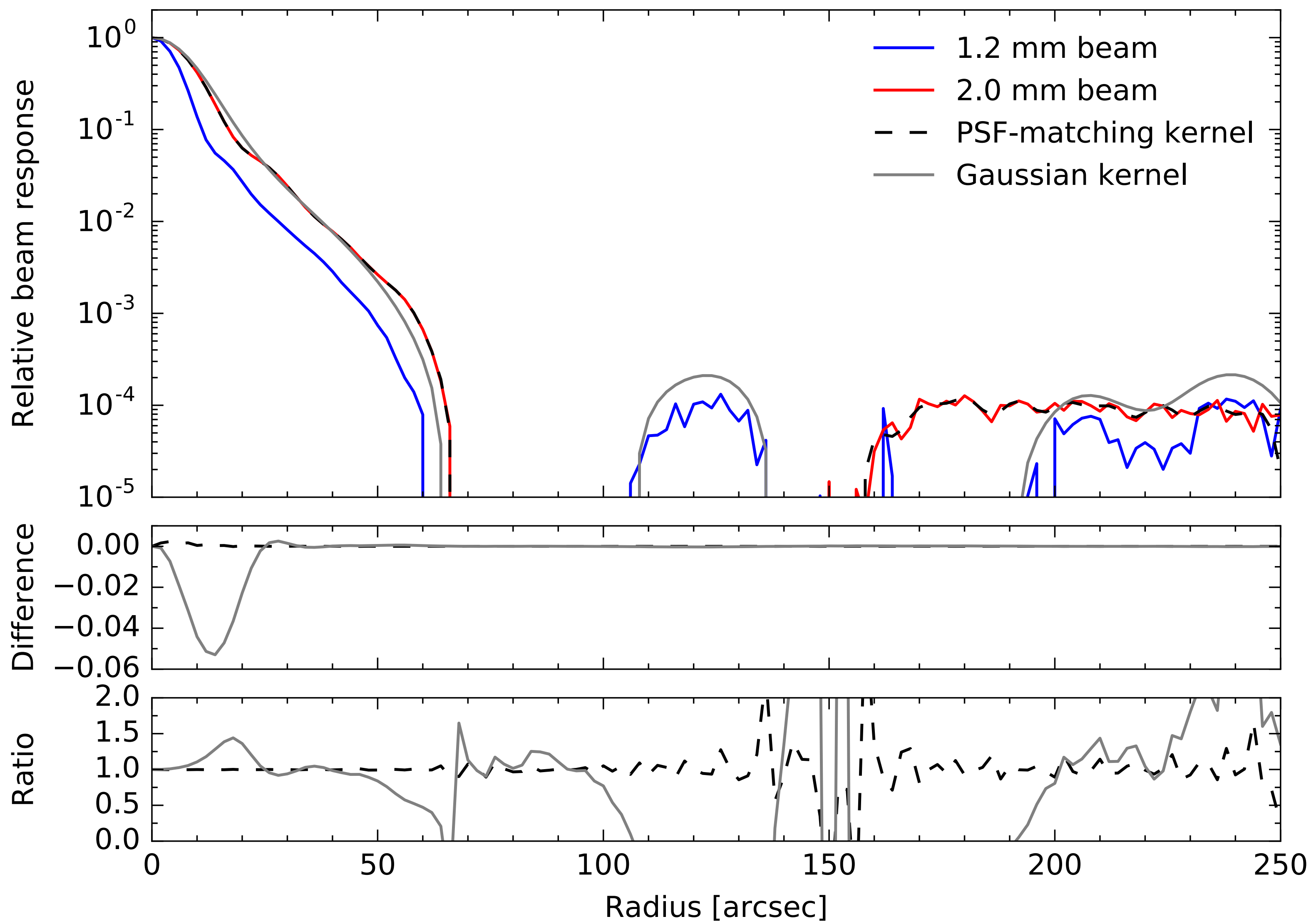

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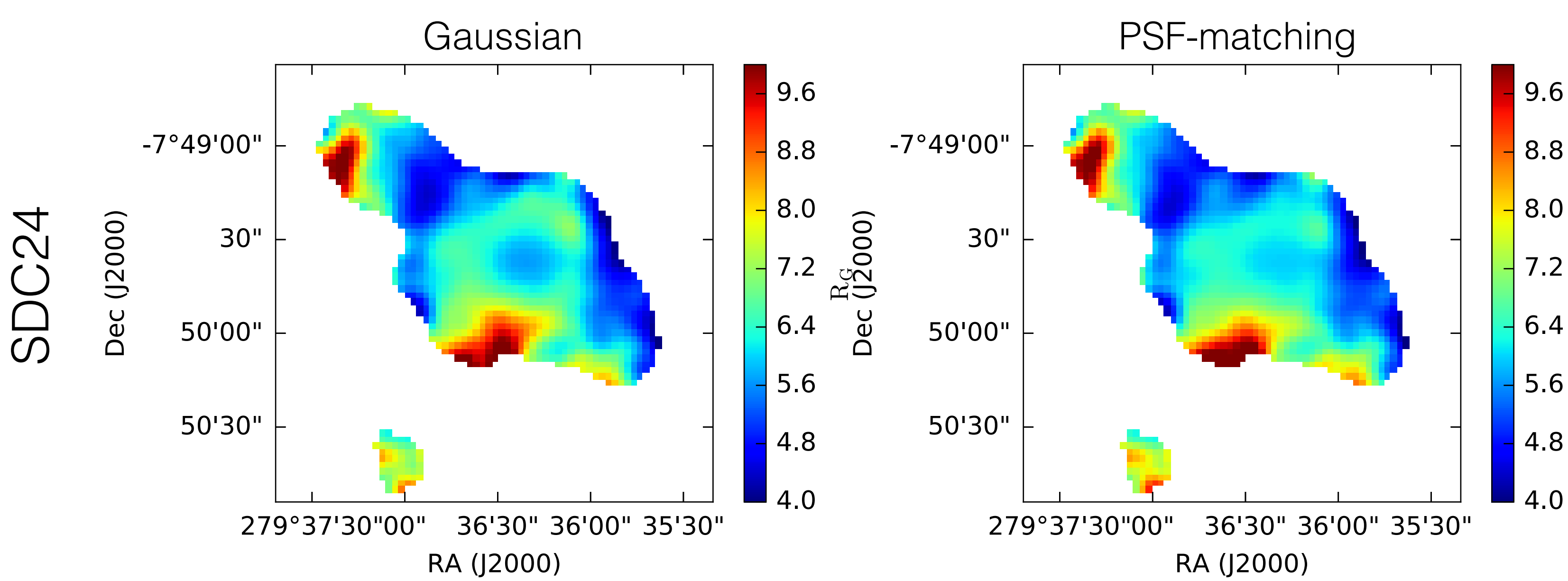
Generate average PSFs from three Uranus beam maps at 1 mm & 2 mm.

⇒ Create (circularly-averaged) convolution kernel to account for sidelobes using P*ython photutils/psf*.

(e.g. Gordon+08, Aniano+11, Pattle+15, http://dirty.as.arizona.edu/~kgordon/mips/conv_psfs/conv_psfs.html)



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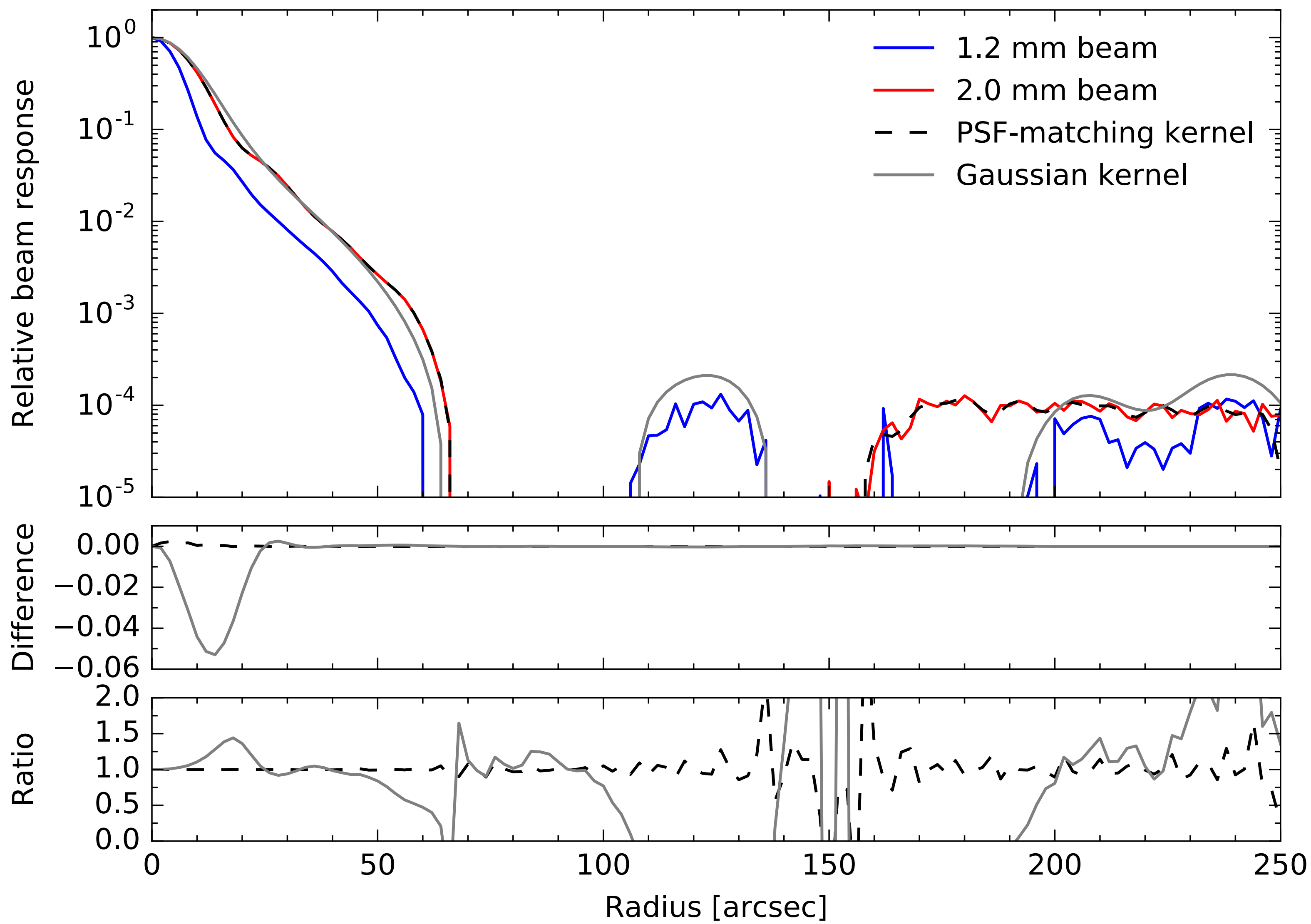

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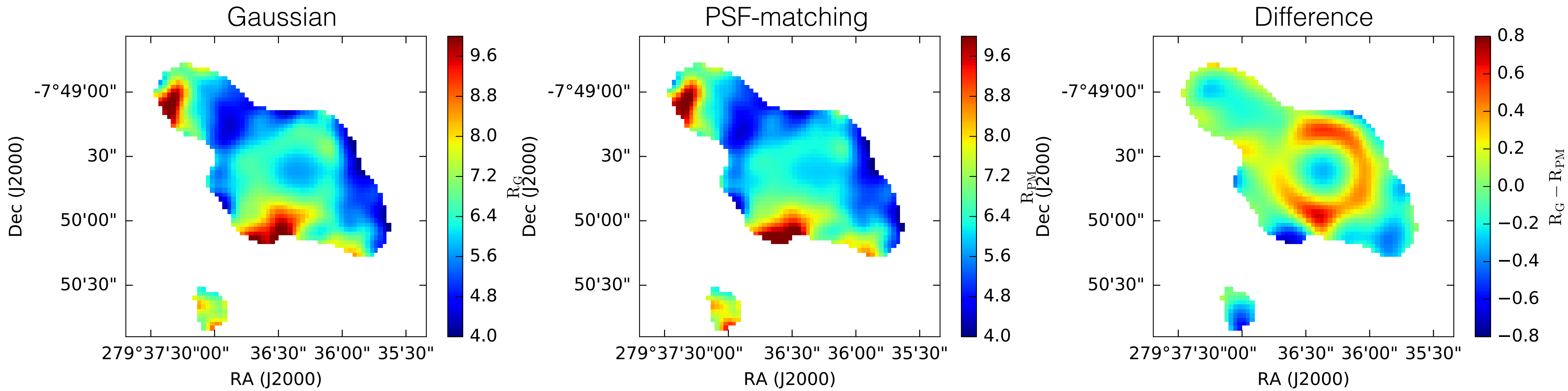
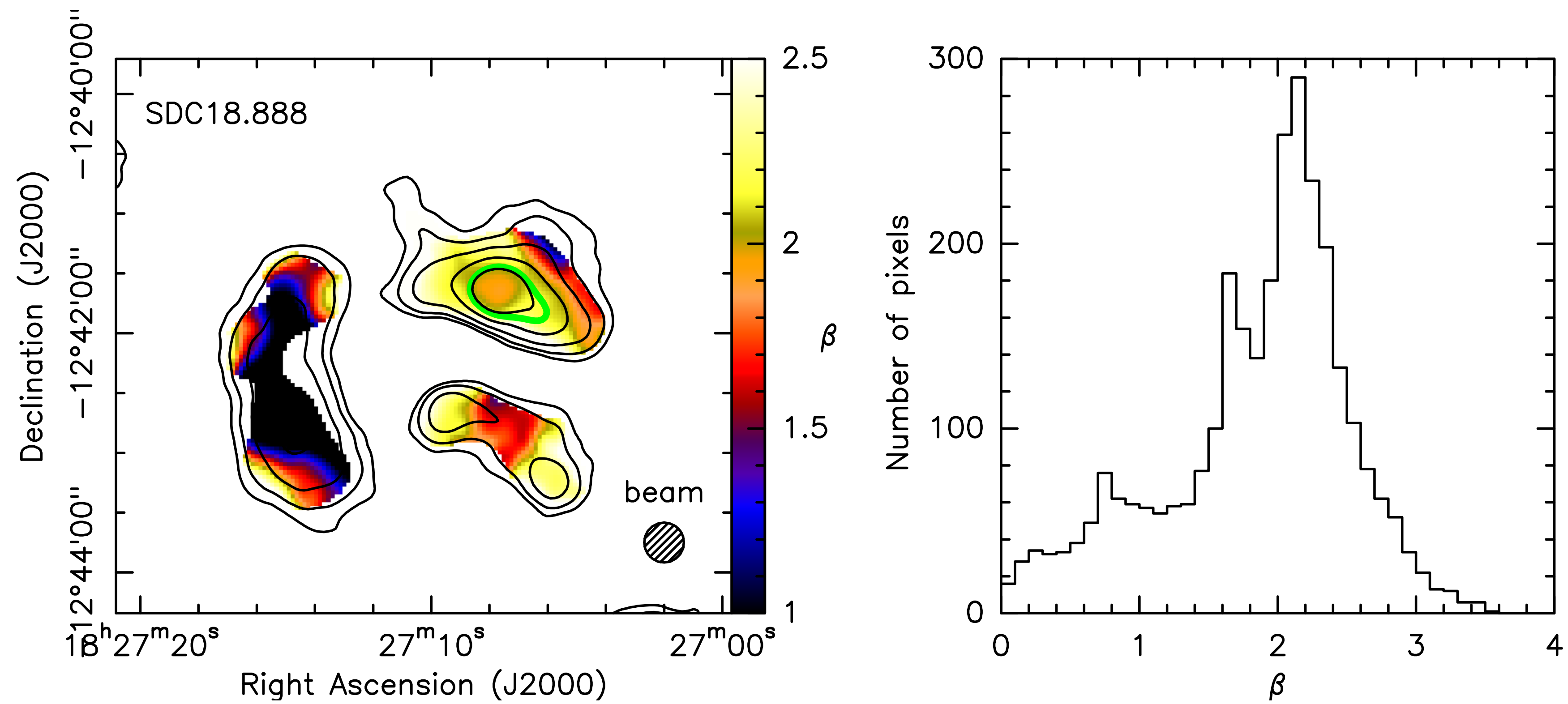
A: Yes.

SDC24

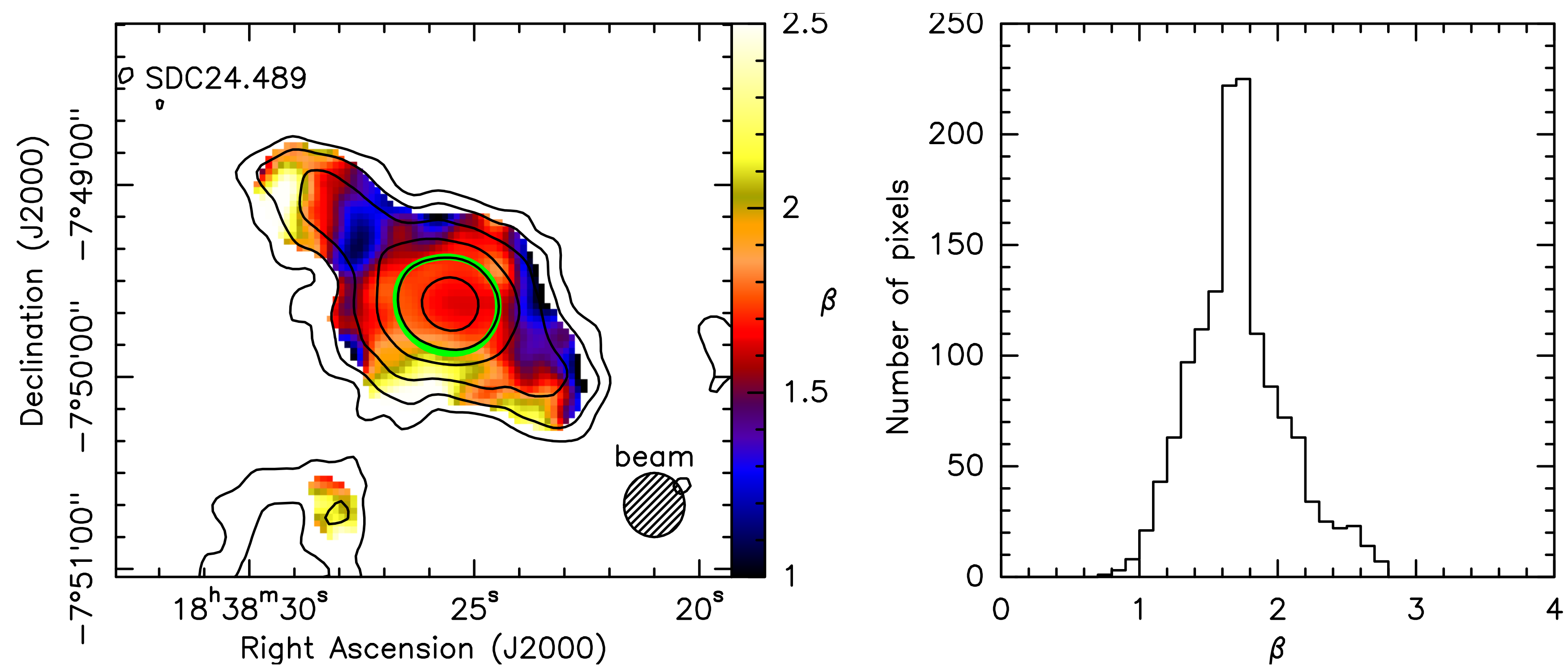


β Maps

SDC18:
T_d = 14.32 ± 1.36 K



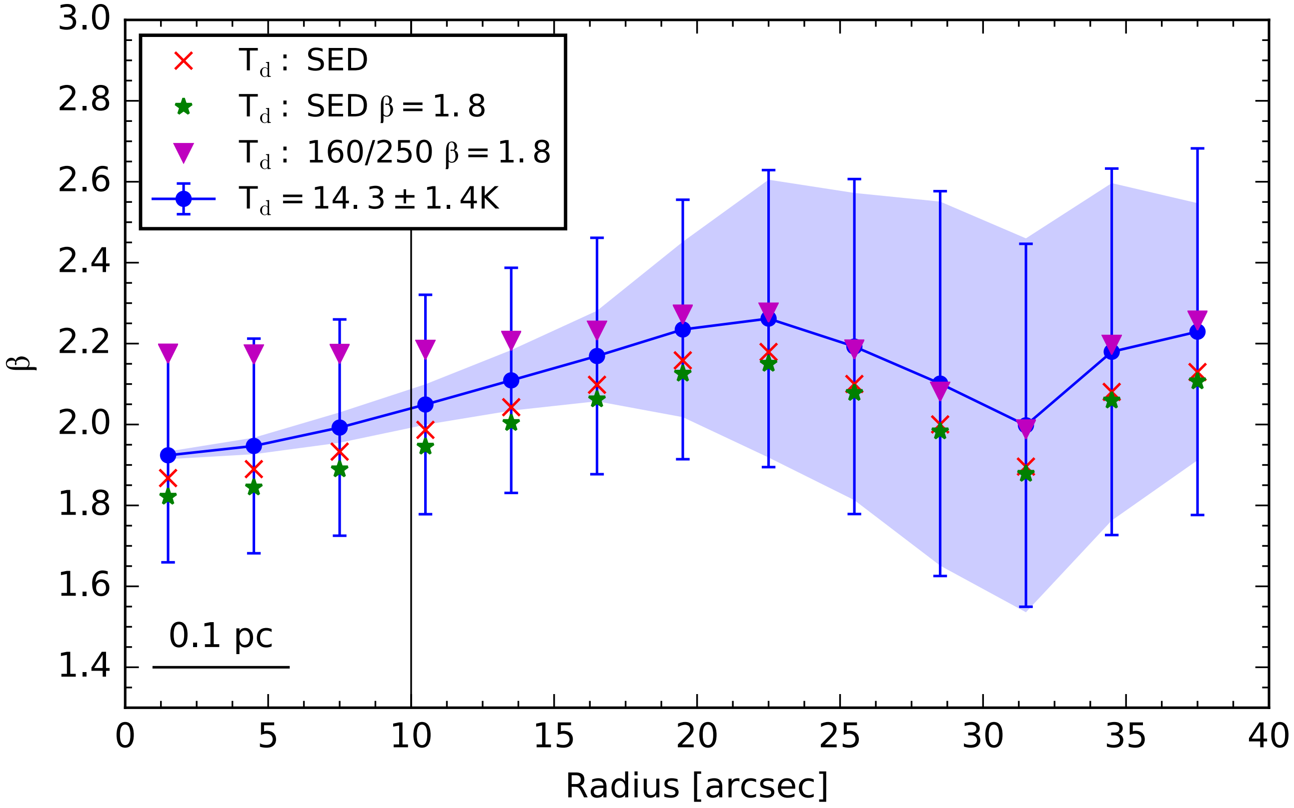
SDC24:
T_d = 14.15 ± 1.32 K



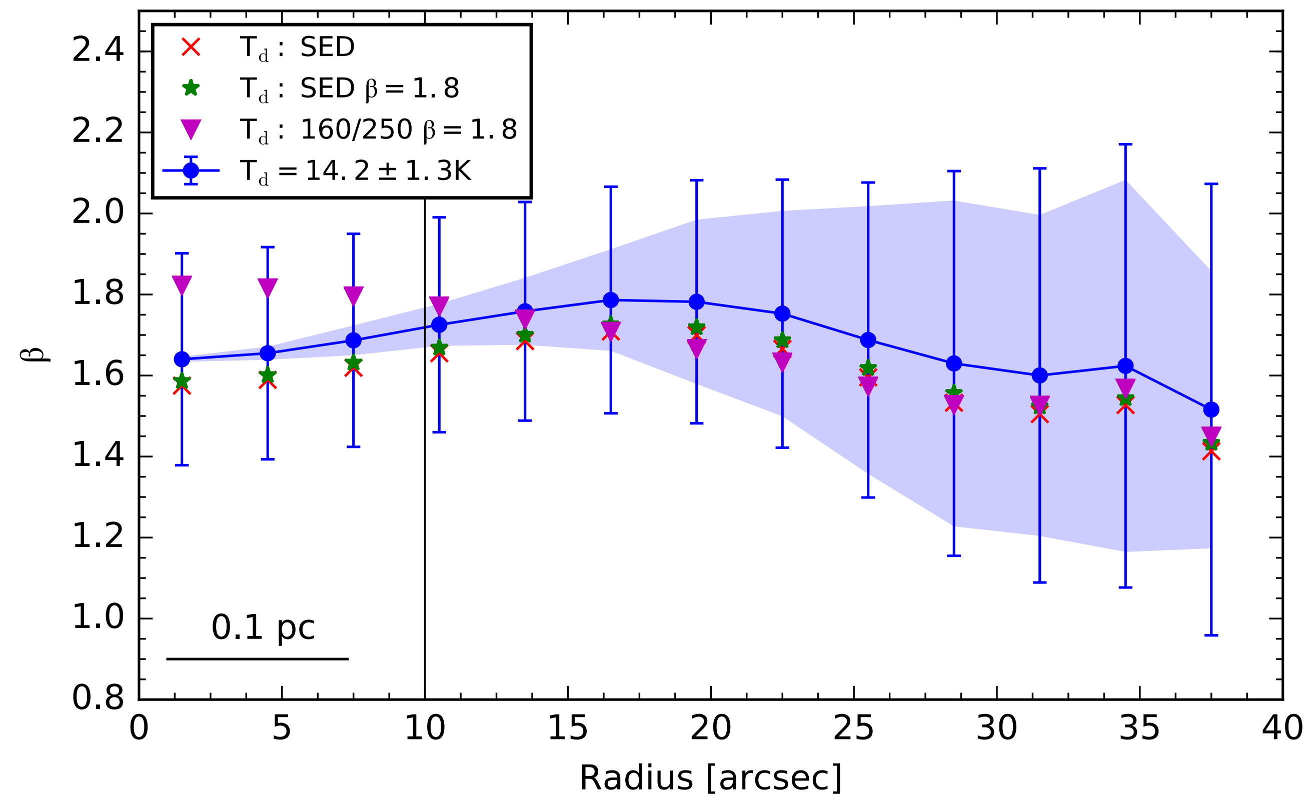
Assuming a global temperature for each cloud, derived by SED fitting.
Black contours: SNR 2, 4, 8, 16, 32, …
Green contours: SNR > 25 corresponding to Δβ <0.1 resulting from noise

Radial variations in β

SDC18



SDC24



Profiles:

Measure mean β in annulae centred on 1 mm emission peaks.

Shaded regions: σ in each annulus

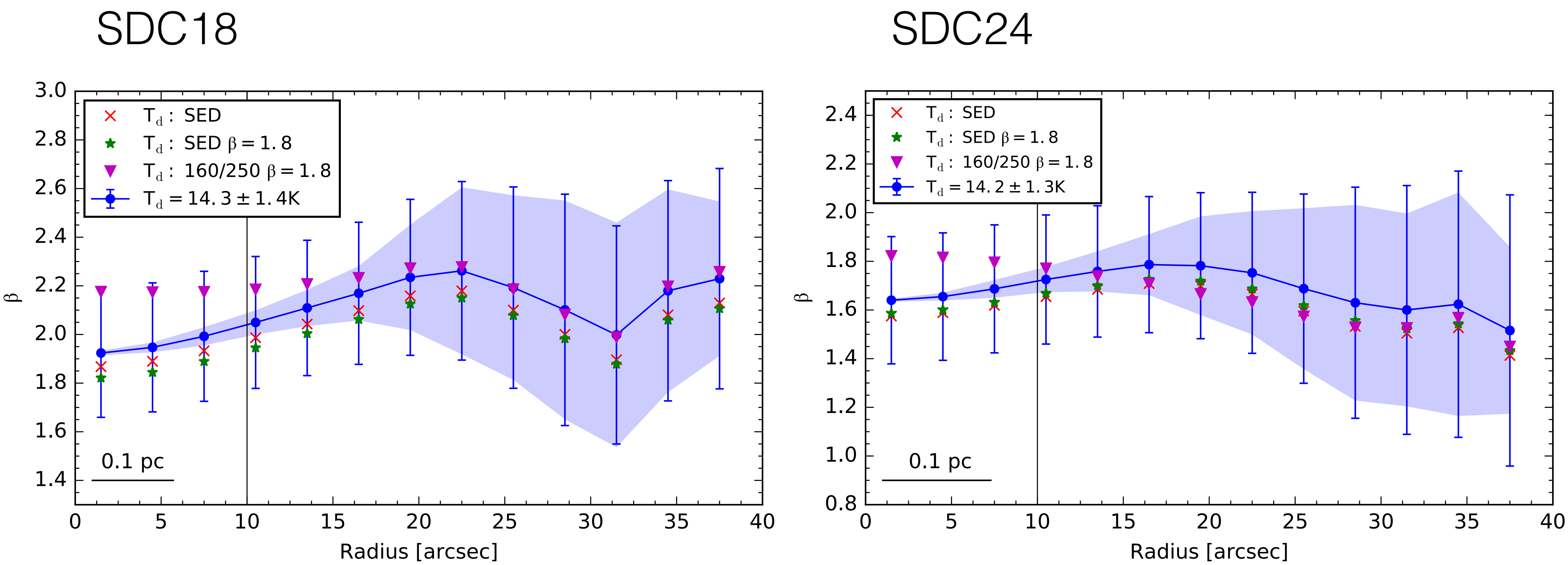
Error bars: Including systematics (calibration errors, ΔT_d, …)

SDC18: β = 2.08 ± 0.09 (random) ± 0.25 (systematic)

SDC24: β = 1.70 ± 0.09 (random) ± 0.25 (systematic)

⇒ No significant radial trend, but significant differences between IRDCs

Radial variations in β



To what extent is the profile governed by the assumption of a single dust temperature?

- ● Single temperature derived from aperture photometry and SED fits
- ▼ Temperature map derived from 160/250 μm ratio, requires β = 1.8), 20" res.
- ★ 4-point SED fit with Herschel 160, 250, 350 & 500 μm, fixed β = 1.8, 40" res.
- ✕ 4-point SED fit, free β, 40" res.

Mass concentration

We create column density maps at different resolutions (assuming fixed β we have determined):

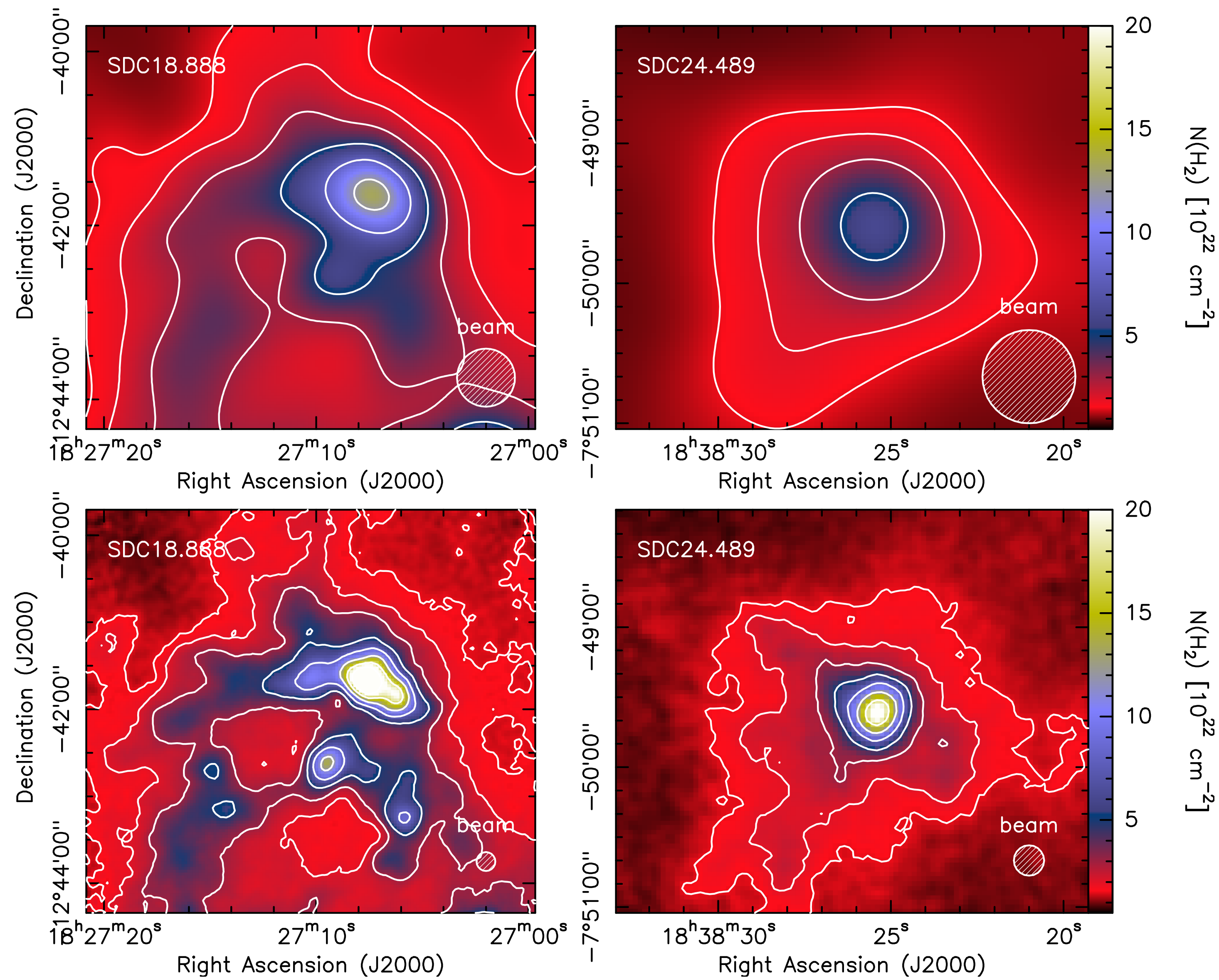
- 40”: 4-point SED fit (2 d.o.f.)
- 27”: 3-point SED fit (1 d.o.f.)
- 20”: 250 μm intensity, T from 160/250 μm ratio.
- 13”: 1 mm intensity, & previous T map (at 20”).

and combine following Hill et al. (2012) and Palmerim et al. (2013) to maintain information at different spatial scales:

$$f_{H_2}^{l-s} = \widetilde{N}_{H_2}^{s} - \widetilde{N}_{H_2}^{s} * G_l,$$

$$N_{H_2}^{13''} = N_{H_2}^{40''} + f_{H_2}^{40''-27''} + f_{H_2}^{27''-20''} + f_{H_2}^{20''-13''}$$

e.g. at 27” we add the 27” column density map to that at 40” and subtract a residual 27” smoothed to 40” map.

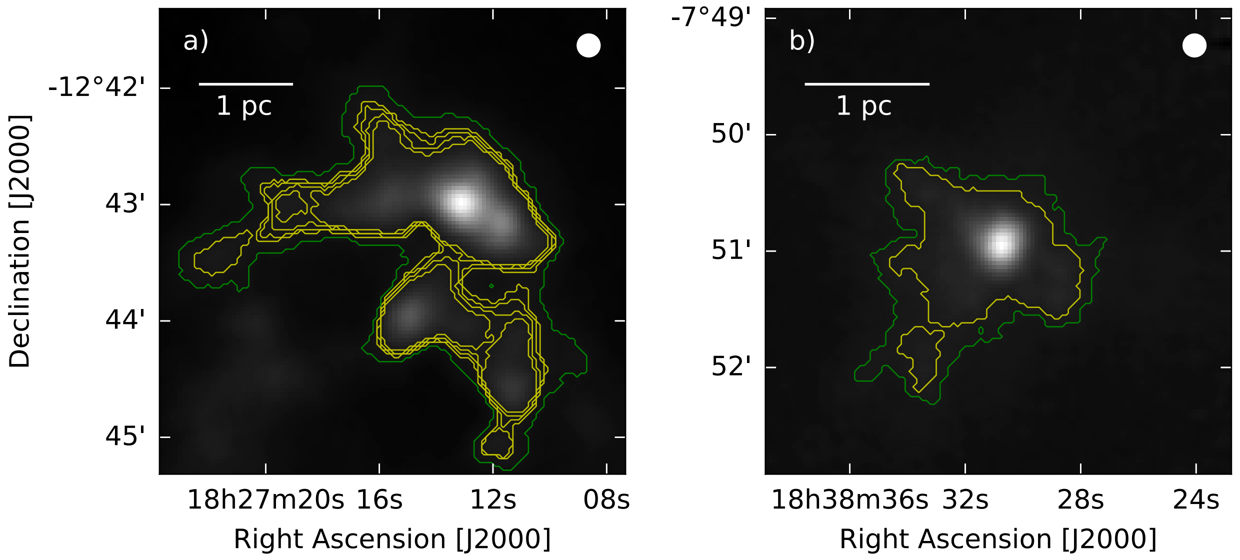


Mass concentration

SDC18 has a mass of 6620 ± 820 M⊙ within R_{eff} = 1.54 pc

SDC24 has a mass of 590 ± 120 M⊙ within R_{eff} = 0.85 pc

⇒ Dendrogram analysis



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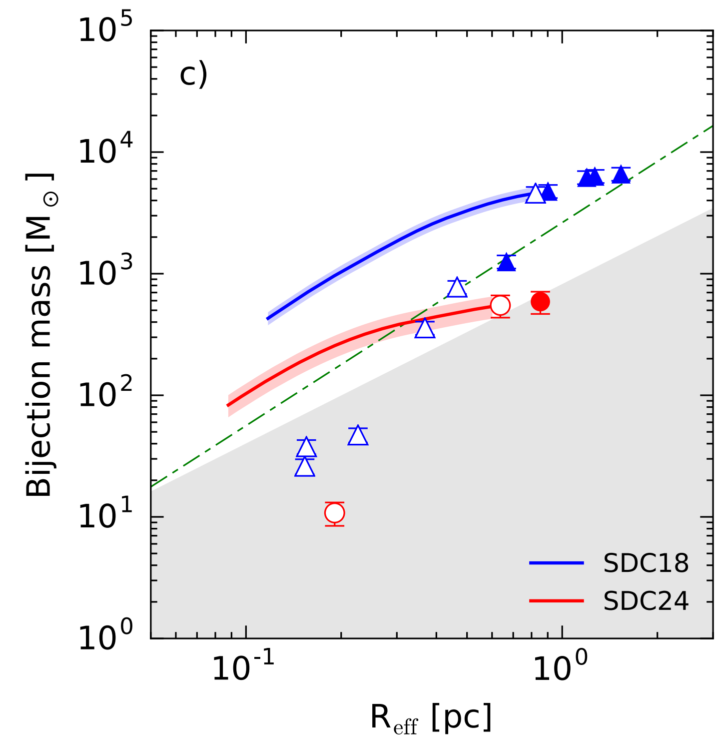
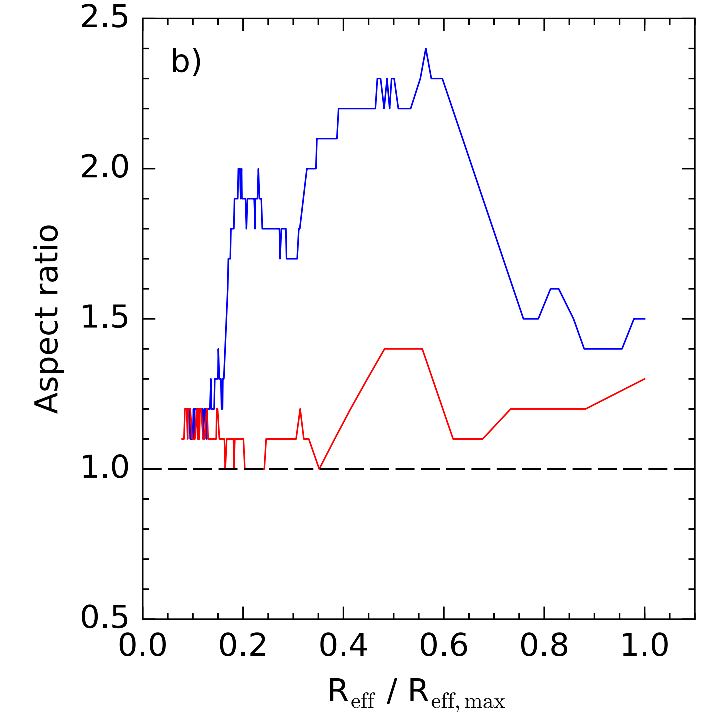
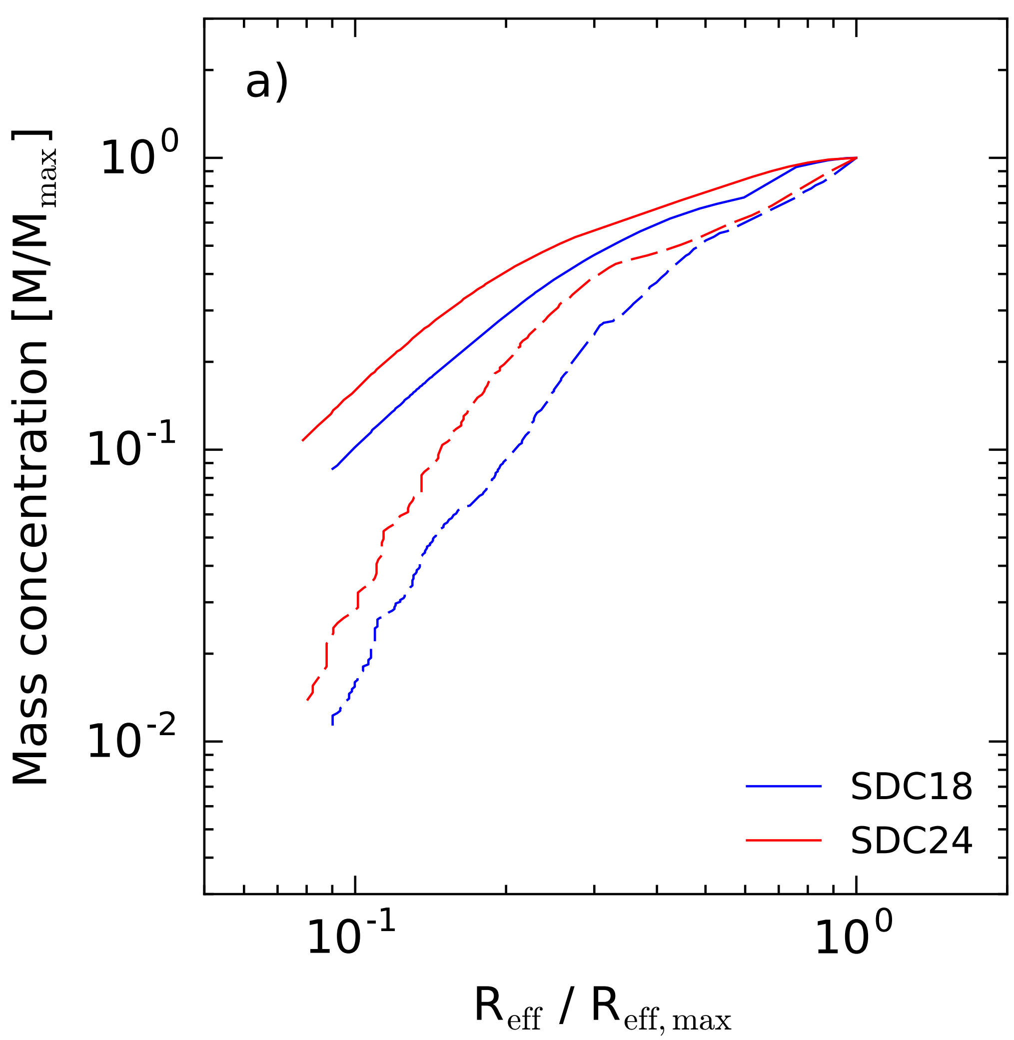






Although SDC18 is more massive, mass in SDC24 is *more concentrated*:

Initial conditions or evolution?

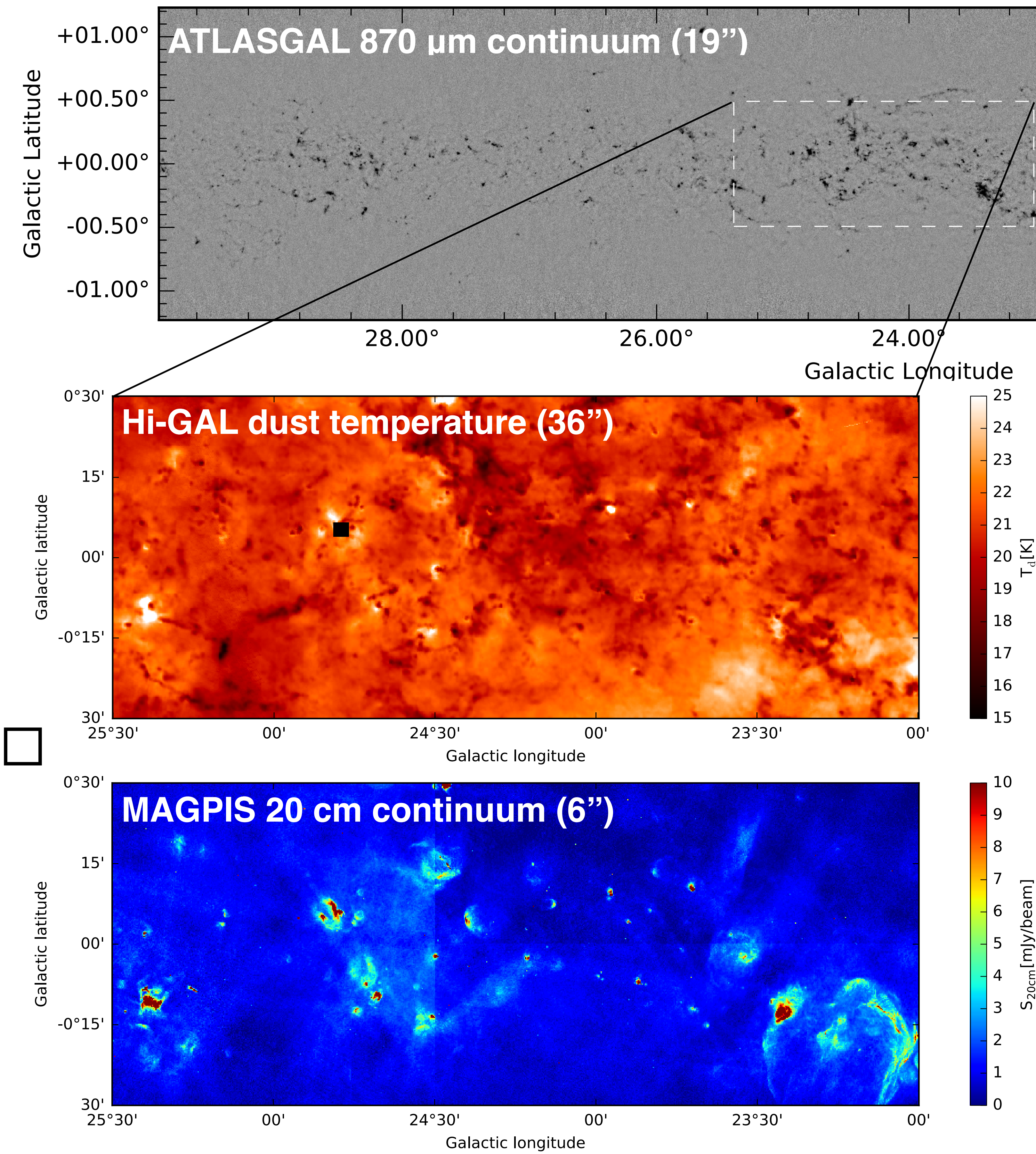
70 micron luminosity may reveal clues. L_{70}/M similar in both, indicating no significant difference in evolutionary state.

No evidence of a rich stellar cluster yet in SDC24.

Caveat: a change in SFE?

Probably relating to **initial conditions.**

GASTON: Galactic Star Formation with NIKA2



Guaranteed 200 hours beginning Winter 2017.

75 hours studying pre-BD in Taurus.
70 hours on HMSF.
55 hours on dust properties in Taurus.

HMSF:

- Unbiased survey of a >2.5 sq. degree patch
- Higher sensitivity than ATLASGAL by a factor of ~15 and JPS by ~5.
- Test core-fed and clump-fed models across a wide range of masses.

Summary & conclusions

- **We have created maps of** β, the dust emissivity spectral index, from the ratio of 1.2/2.0 mm emission (assuming a single dust temperature).
- **No** significant systematic **radial variations** detected in our data, though we are only able to probe to 2 beam radii before noise dominates.
- **Different β** values in SDC18 and SDC24 arising from **different environments**.
- Absolute values uncertain: **Δβ~0.25**, limited by the calibration uncertainties
- **Mass concentration greater in SDC24** than SDC18, possibly as a result of the more spherical initial state. Global collapse is more rapid than fragmentation in SDC24.

Perspectives for GASTON:

- Absolute β values limited as discussed above, use *Planck* to calibrate?
- GASTON will be more sensitive than these NIKA observations, expecting to reach ~1.2 & 1.5 mJy/beam at 1 & 2mm, in its HMSF field, though a separate field in Taurus and Ophiuchus is planned. A larger statistical sample to follow.
- Expansion of the mass concentration study.

Rigby et al. (2017, in prep)