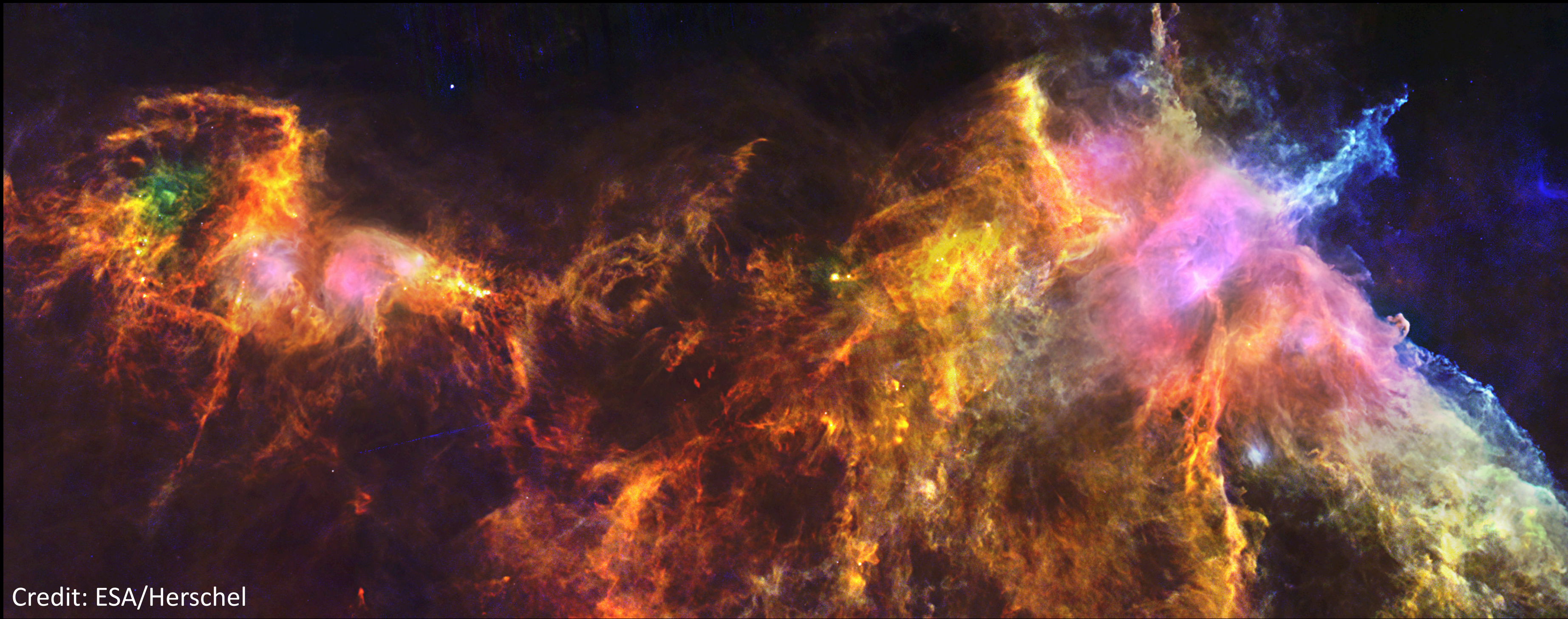
Using Spinning Dust Emission To Constrain The Abundance Of Small Dust Grains In Dense Cores

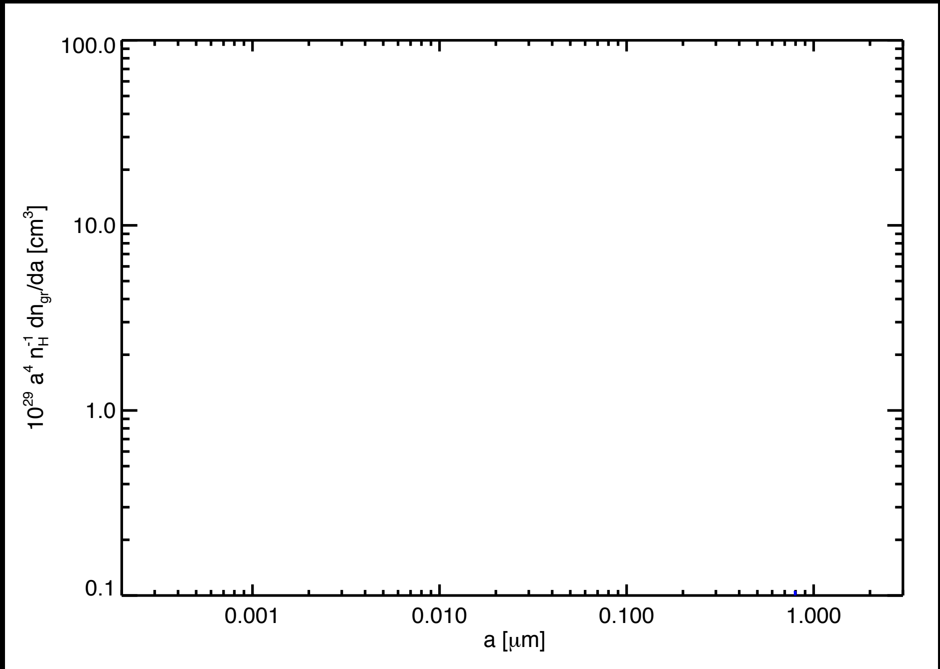

Credit: ESA/Herschel

Christopher T. Tibbs
ESA Research Fellow
ESTEC

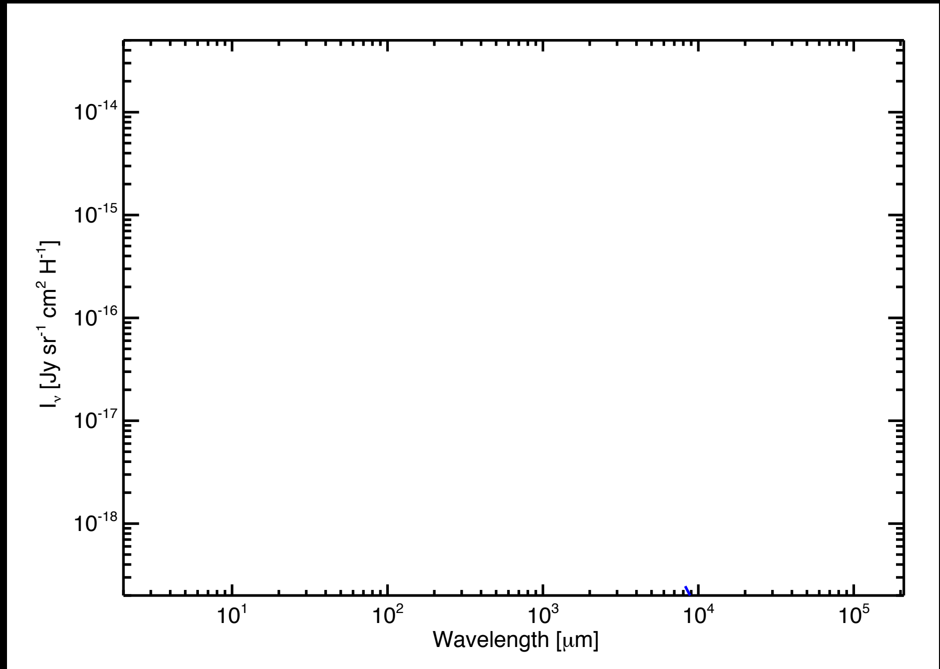
@Chris_Tibbs

Interstellar Dust

Dust Grain Size Distribution



Dust SED



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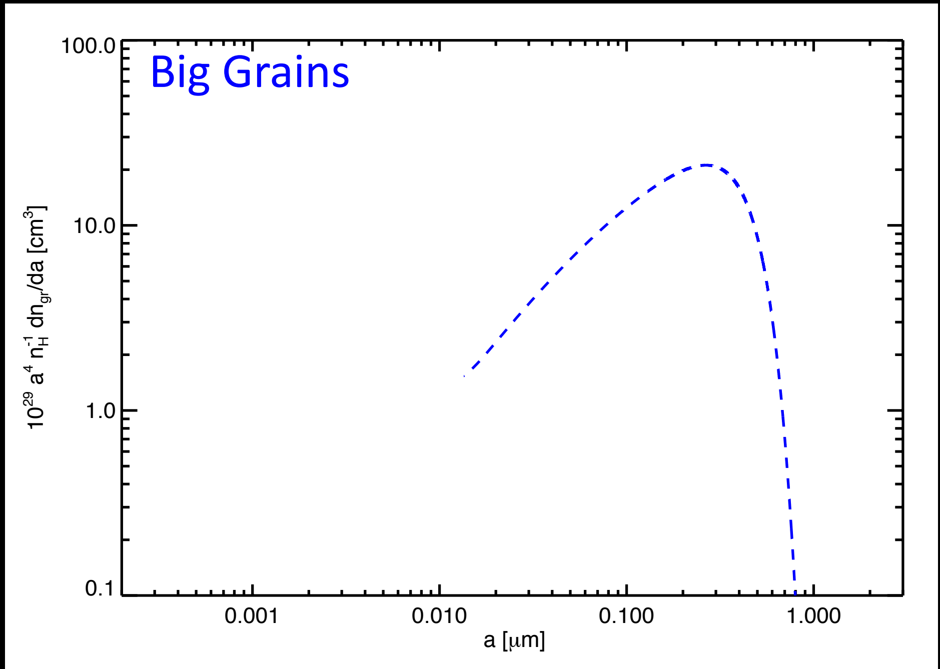

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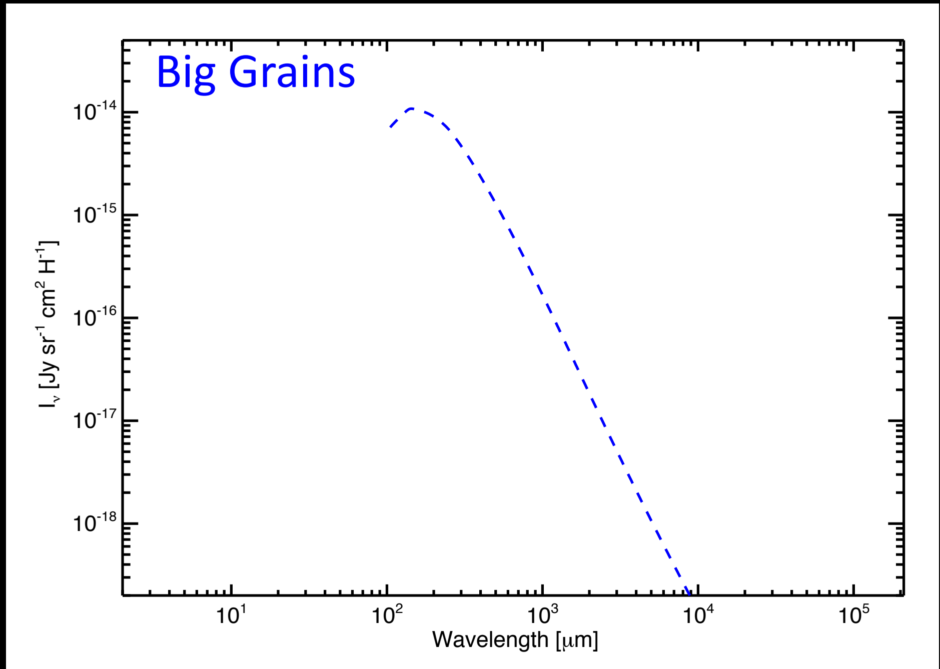

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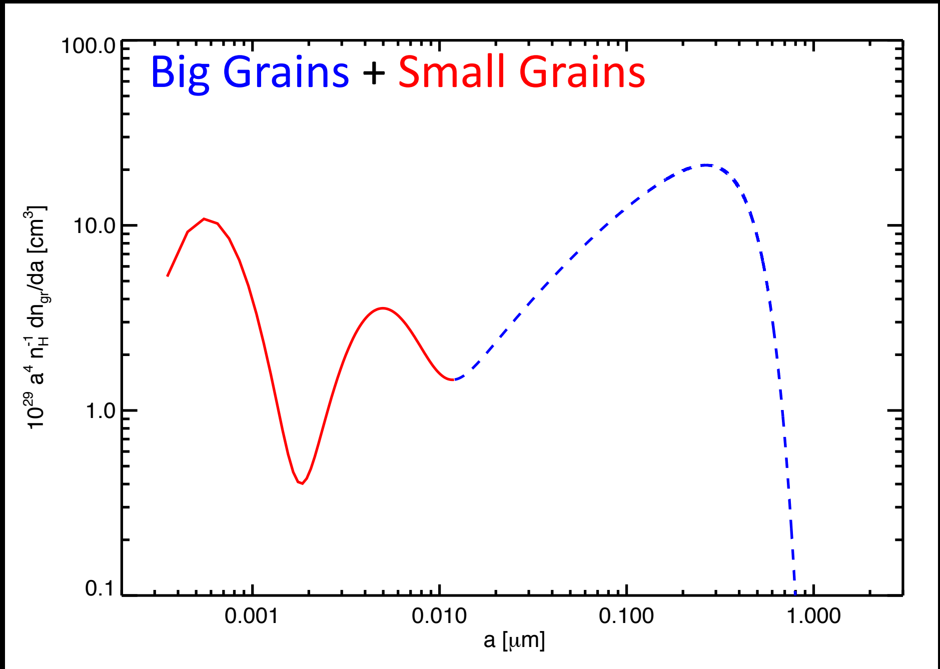

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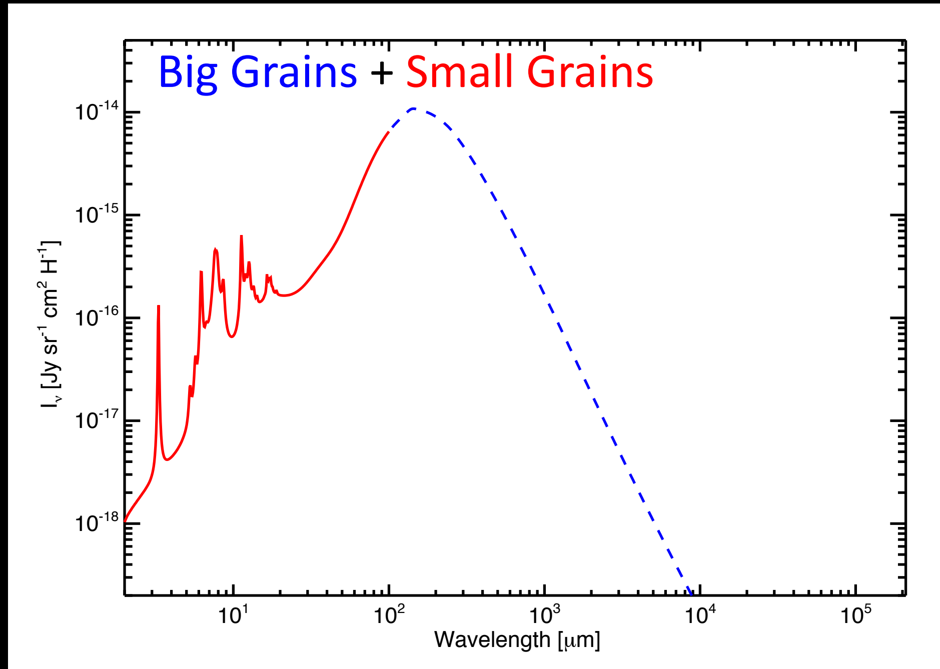

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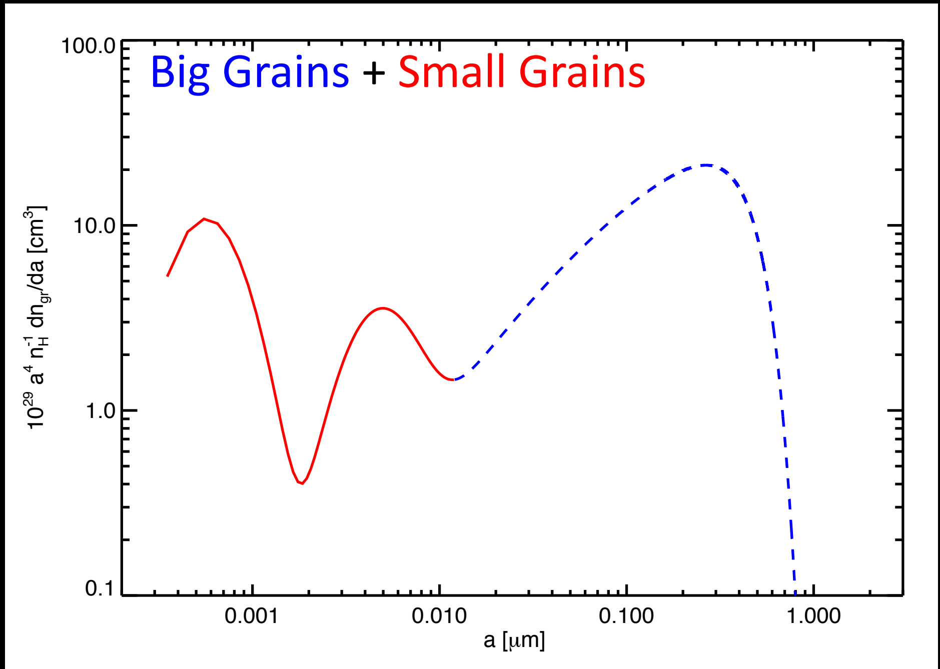

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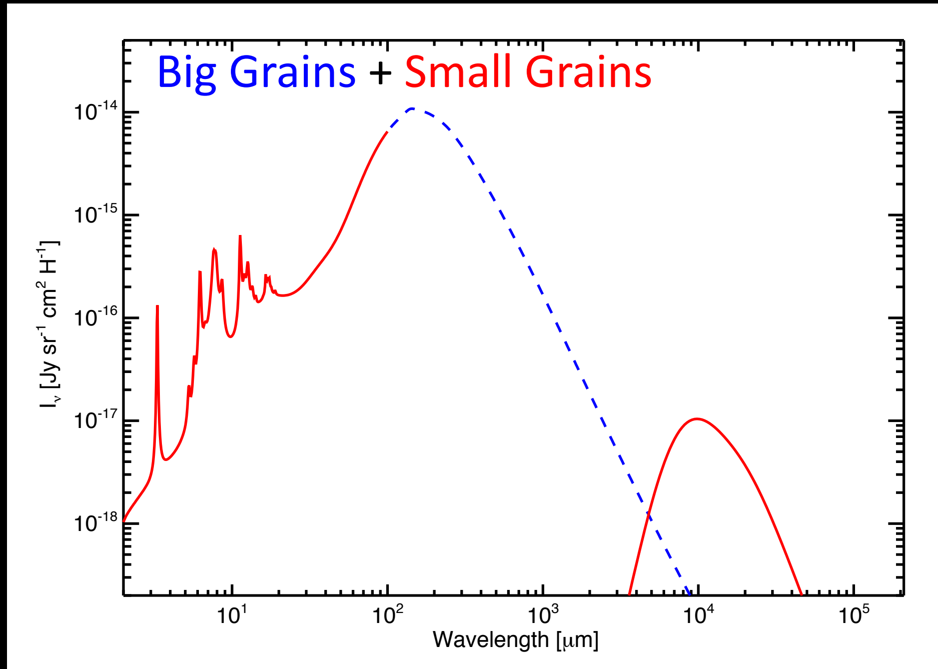
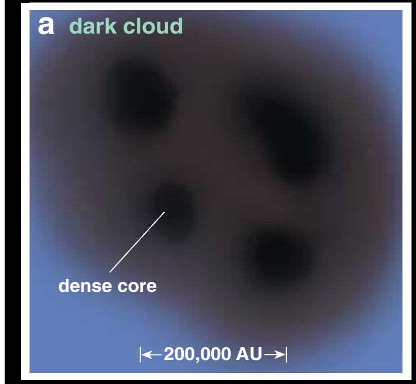


Spinning Dust Emission is long wavelength emission from small interstellar dust grains

Galactic Cores

[Greene, American Scientist, 2001]



What are Galactic Cores?

- Cores are dense environments (≈10^3 – 10^5 cm^{-3}) – the precursors of individual or multiple stars.
- Cores represent the earliest phases of star formation.
- Cores are an integral part of the life cycle of dust – it's important to understand how the dust is processed from the diffuse to dense environments.

Galactic Cores

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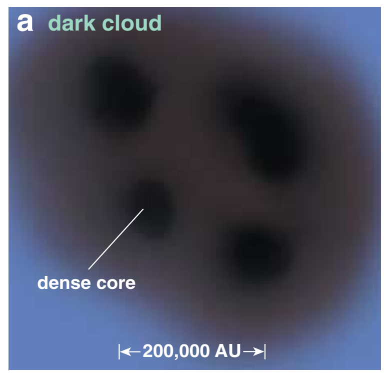

Why Galactic Cores?

- First search for spinning dust emission in dense cores.

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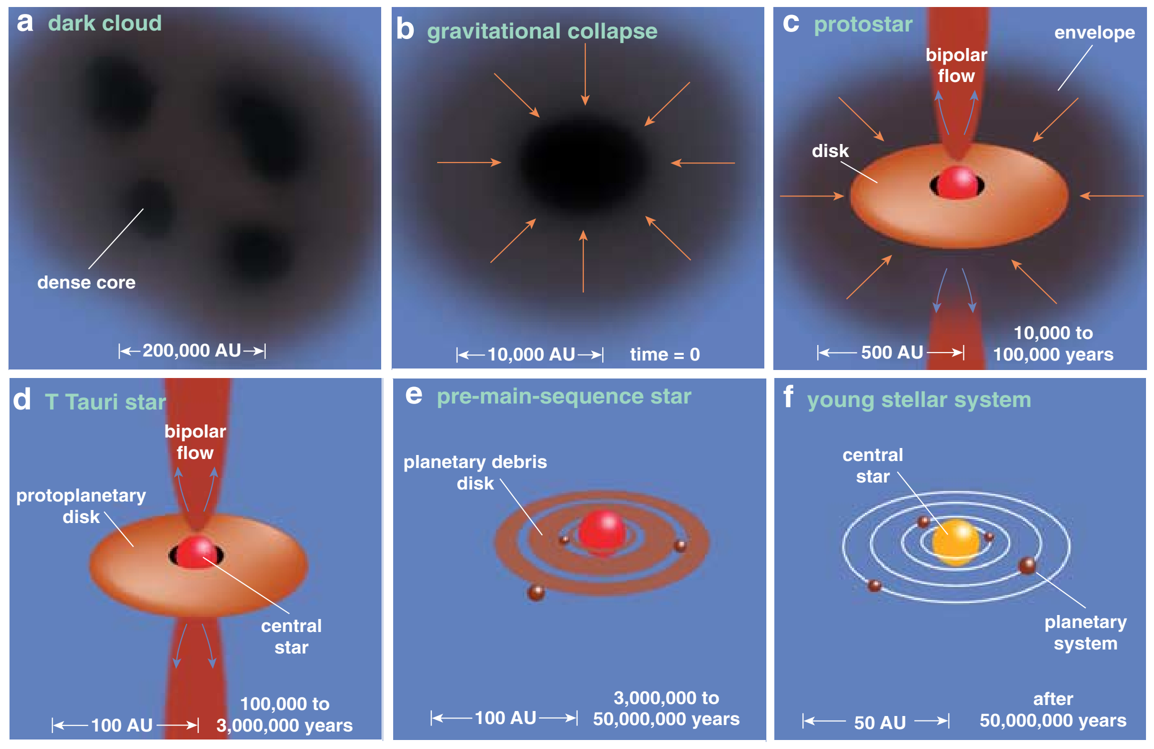

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- Constrain the abundance of small dust grains in dense cores.

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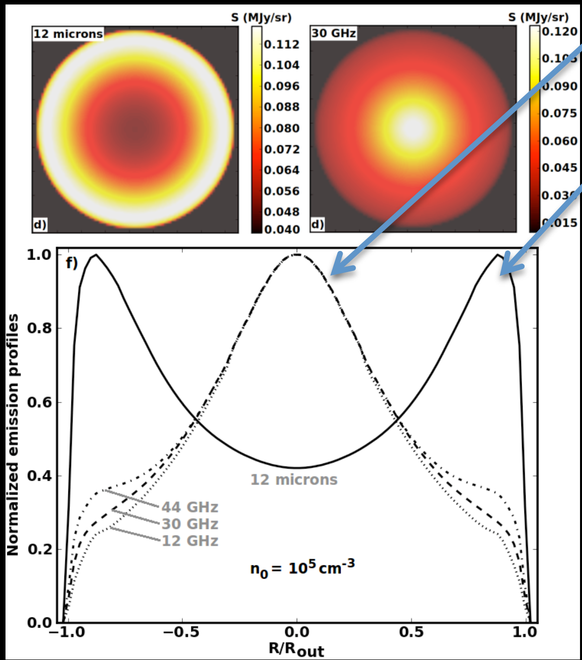
Spinning Dust in Galactic Cores?

Radiative transfer modelling of spherical clouds



[Ysard et al., 2011]

1cm emission

12μm emission

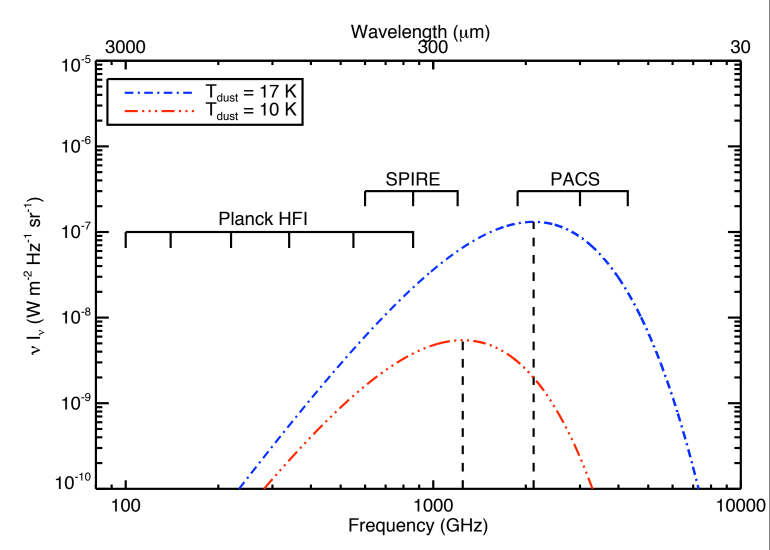
- Mid-IR emission concentrated around the outer edge
- Spinning dust emission concentrated in the center

⇒Spinning dust allows us to determine the presence, and abundance, of small grains in dense cores.

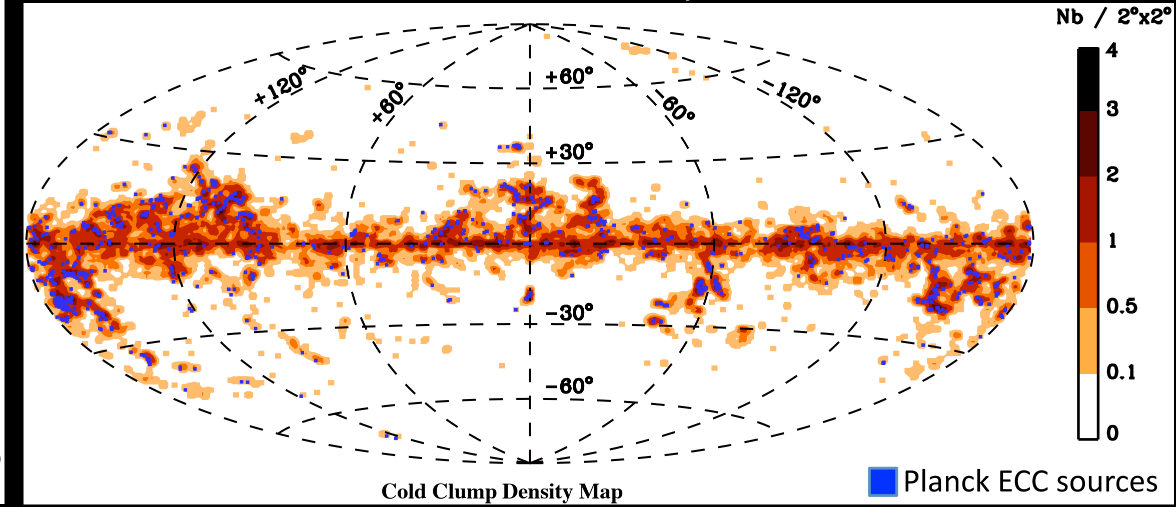
Searching for spinning dust in cores can allow us to constrain the evolution of small dust grains

Observing Galactic Cores

- Cores are much colder than the diffuse ISM ($T_{dust} \approx T_{gas} \approx 10K$) => they emit thermally at long wavelengths i.e. far-IR and sub-mm.
- This makes the combination of Planck and Herschel ideal for observing cores.
- Planck has all-sky coverage at sub-mm wavelengths with sufficient sensitivity to detect these cold, dense environments.
- Herschel does not have the sky coverage or wavelength coverage of Planck, but does have the advantage of improved angular resolution.
- We observed a sample of 15 clumps from the Planck catalogue (corresponding to 34 cores when we looked at the Herschel observations) using the CARMA interferometer at 1cm.

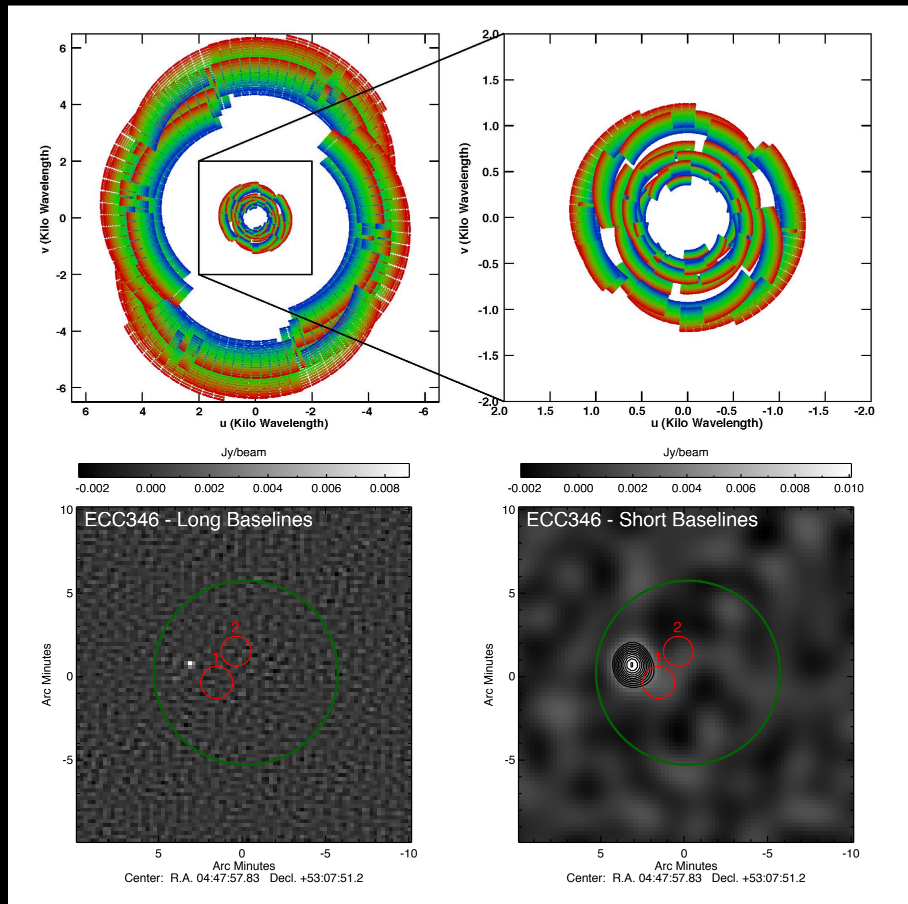


[Planck Collaboration. Planck Early Results. XXIII., 2011]



CARMA Observations

Each Planck clump was observed for 8 hours, and data reduction was performed using the data pipeline developed by Muchovej et al. (2007). The CARMA data were split into 2 based on the (u,v) coverage, with each dataset being imaged separately.

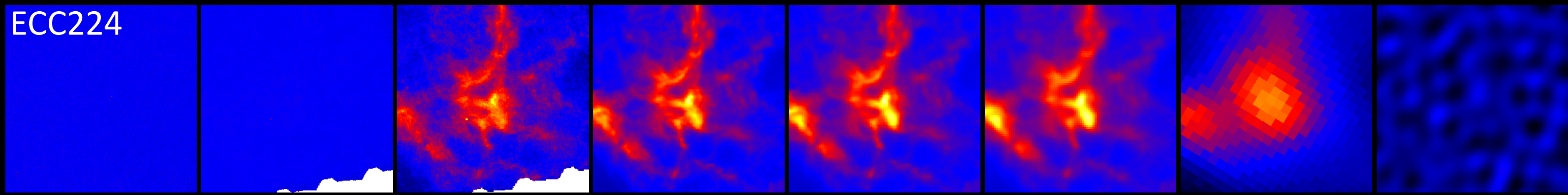


Long Baselines	Short Baselines
2.0 – 8.0 kλ	0.3 – 2.0 kλ
≈0.3 – 2 arcmin	≈2 – 12 arcmin

Photo Credit: E. Leitch

[Tibbs et al., 2015]

Characterising our Galactic Cores - ECC224



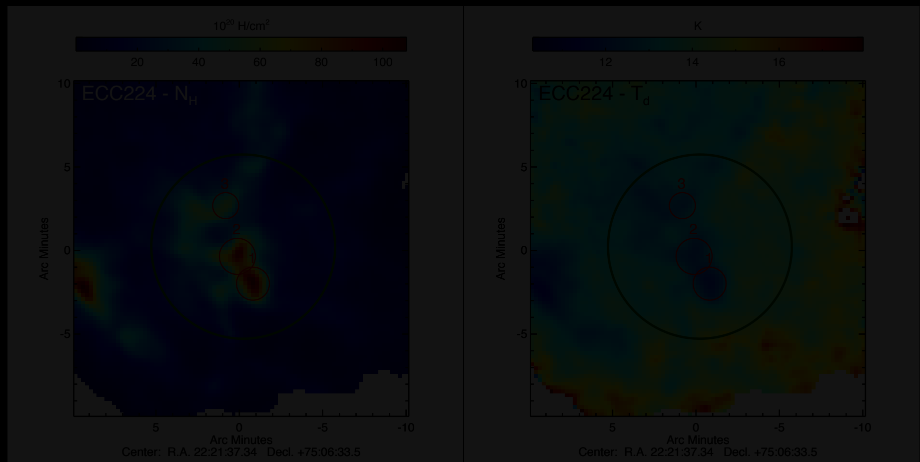
Fit the Herschel 160, 250, 350, and 500 µm data on a pixel-by-pixel basis to produce maps of N_H and T_d

(modified black body with $\beta = 2$)

Use N_H and distance to estimate n_H for each core

n_H

$$\overline{n}_H = \frac{3\overline{N}_H}{2L}$$



Use T_d to estimate G_0 for each core

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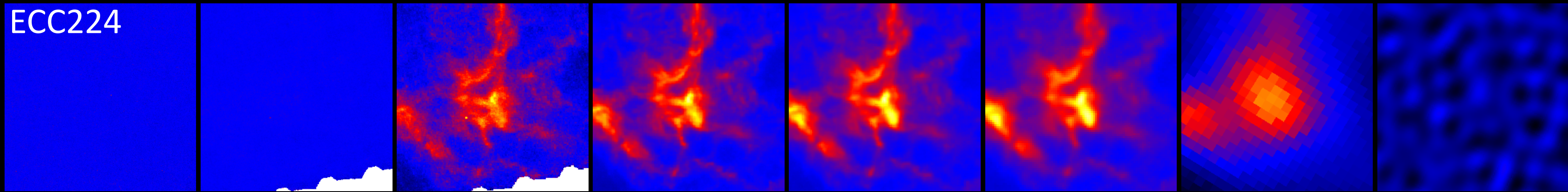
$$\overline{G}_0 = \left(\frac{\overline{T}_d}{17.5K}\right)^{4+\beta}$$

[Tibbs et al., 2015]

Characterising our Galactic Cores - ECC224

PACS 70µm PACS 100µm PACS 160µm SPIRE 250µm SPIRE 350µm SPIRE 500µm Planck 850µm CARMA 1cm



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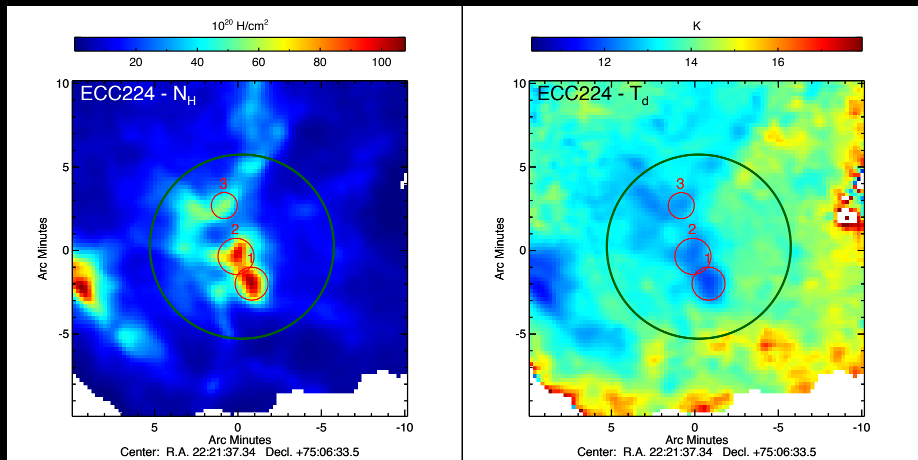

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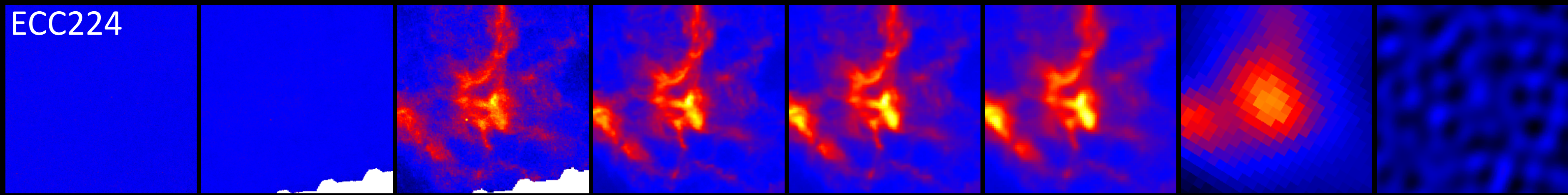

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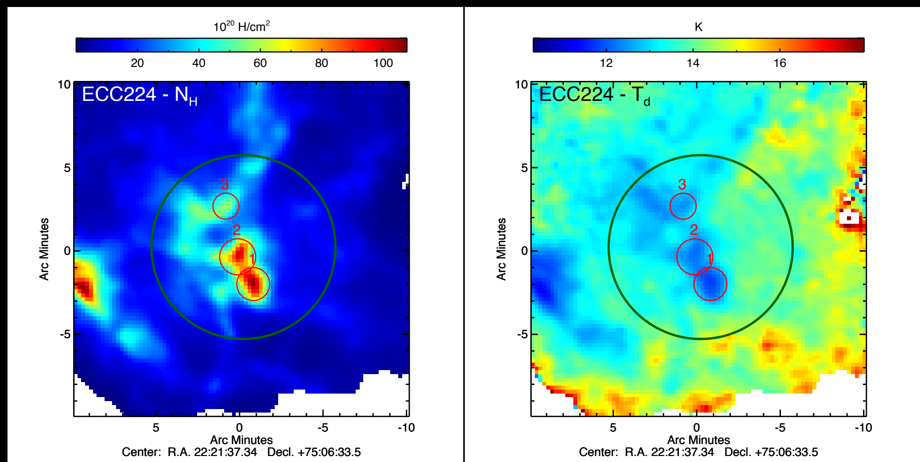

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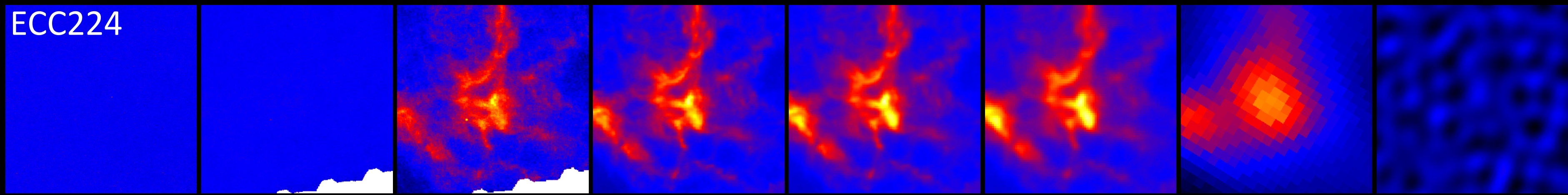

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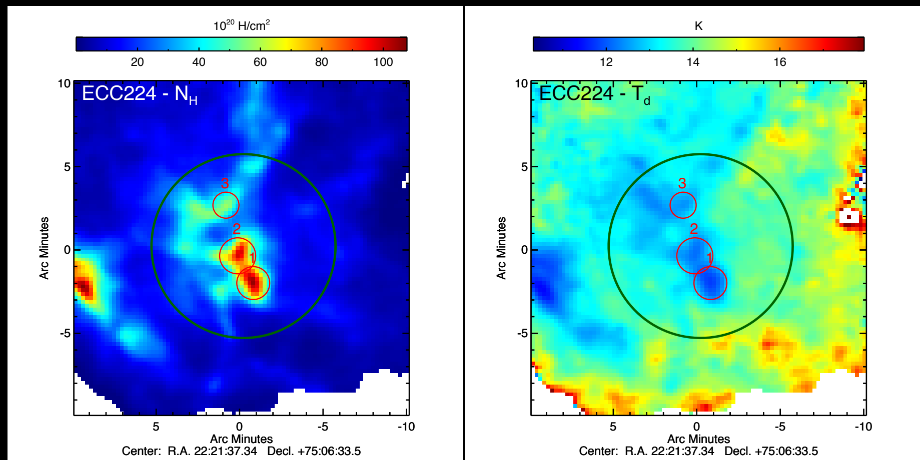

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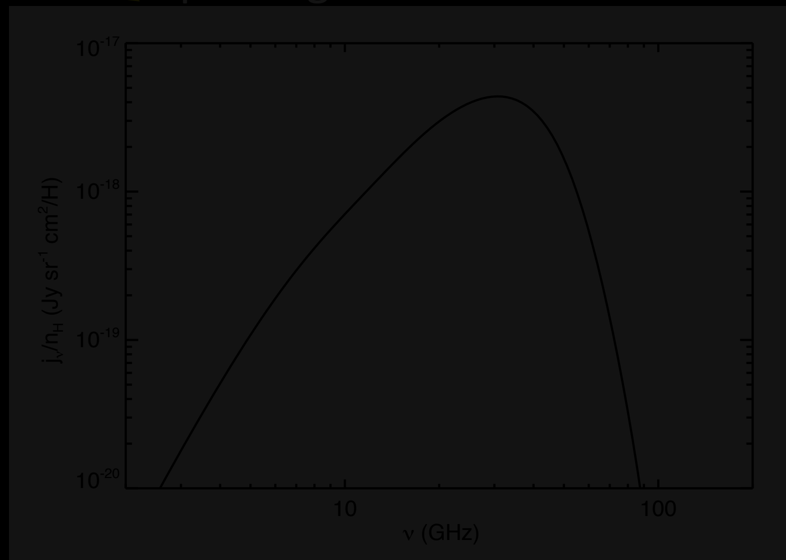
Spinning Dust Parameters		
n_H (H/cm^3)	Hydrogen number density	Estimated from N_H [This analysis]
G_0	Radiation field	Estimated from T_d [This analysis]
T_{gas} (K)	Gas temperature	Estimated from CO [Wu et al., 2012]
μ (Debye)	Dipole moment	9.3
$x_H = n_{H+}/n_H$	Hydrogen ionization fraction	0
$X_C = n_{C+}/n_H$	Carbon ionization fraction	10^{-6}
$Y = 2n_{H2}/n_H$	Molecular hydrogen fraction	0.999

Using these input parameters we run the spinning dust model SPDUST [Ali-Haimoud et al., 2009] to produce the predicted spinning dust curve.

Use parameters as input for the spinning dust model

Spinning Dust Emission



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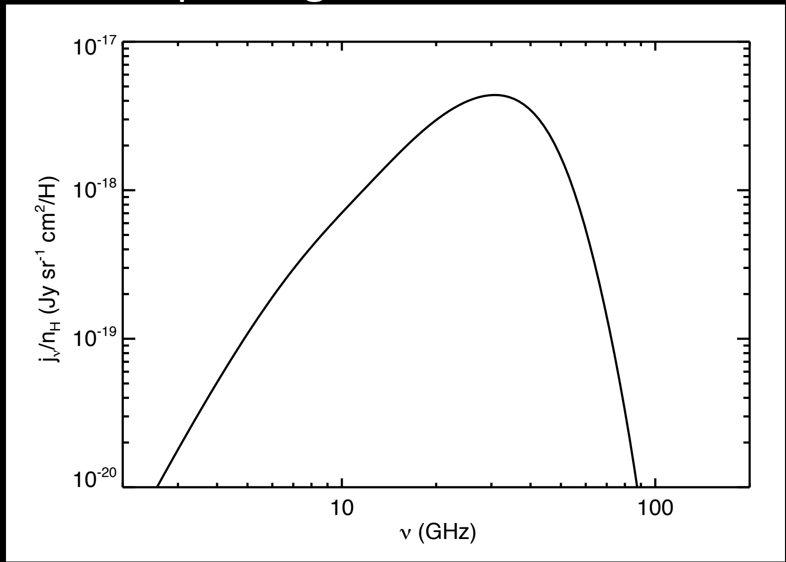

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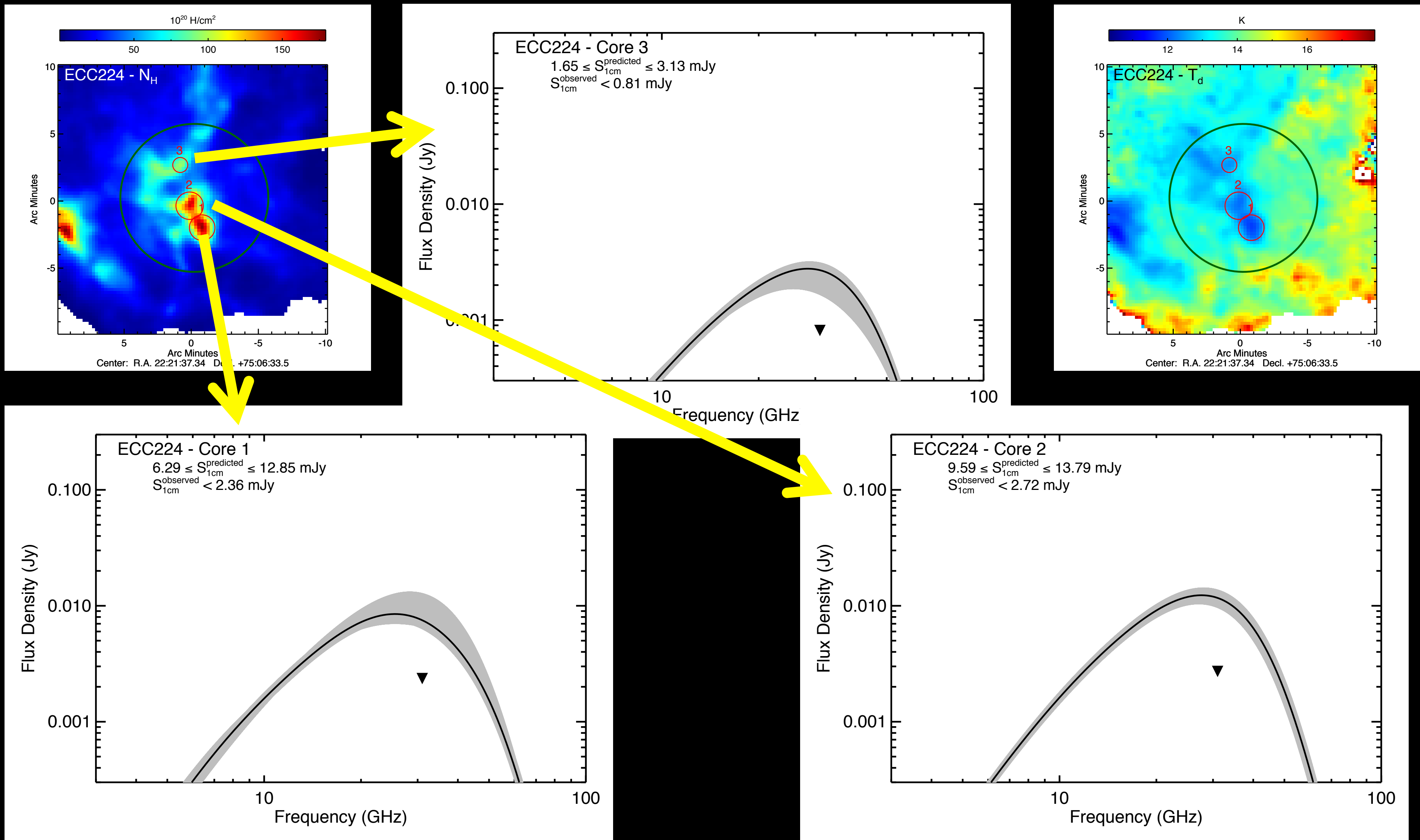
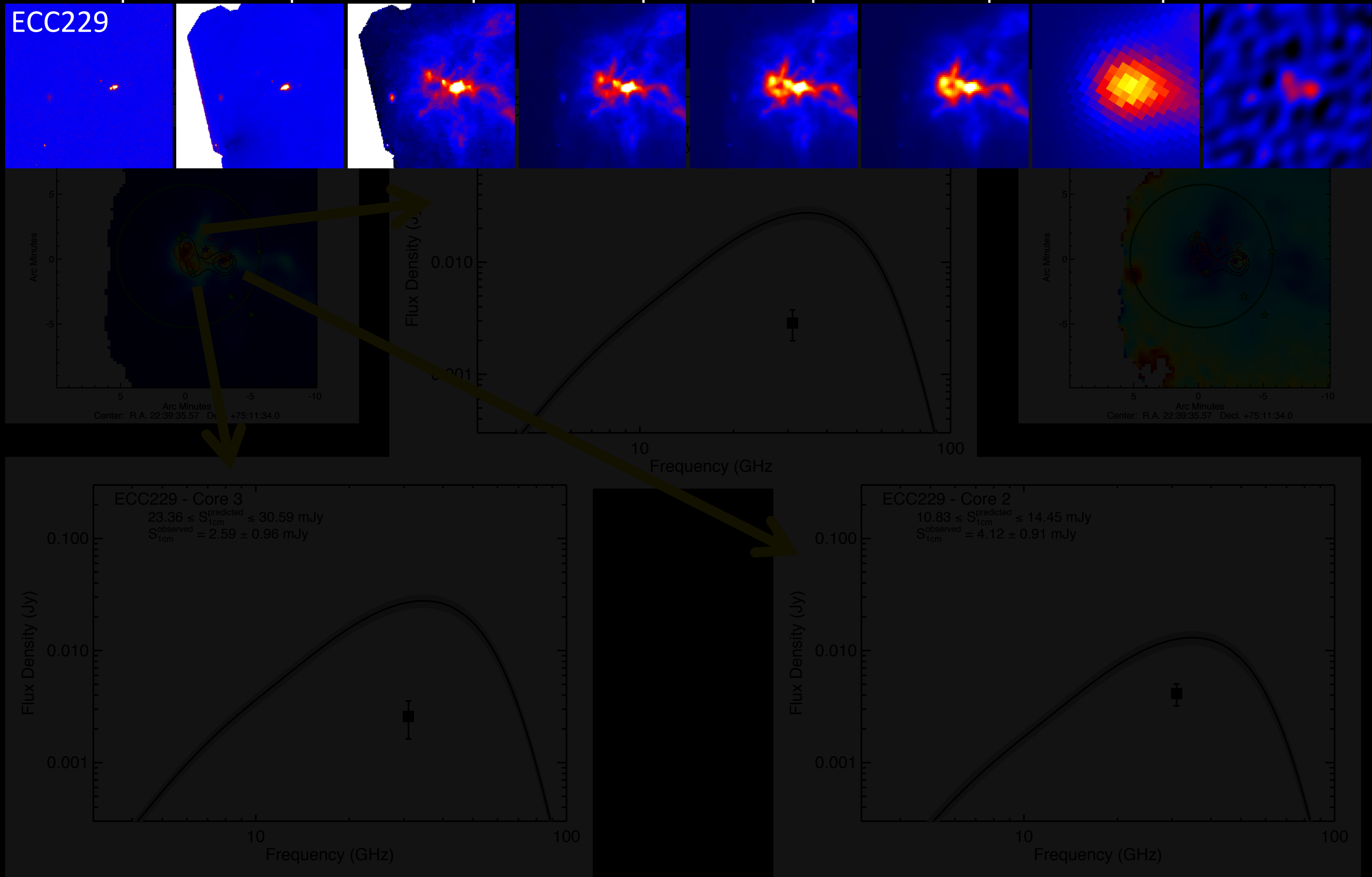
Spinning Dust In Galactic Cores? - ECC224



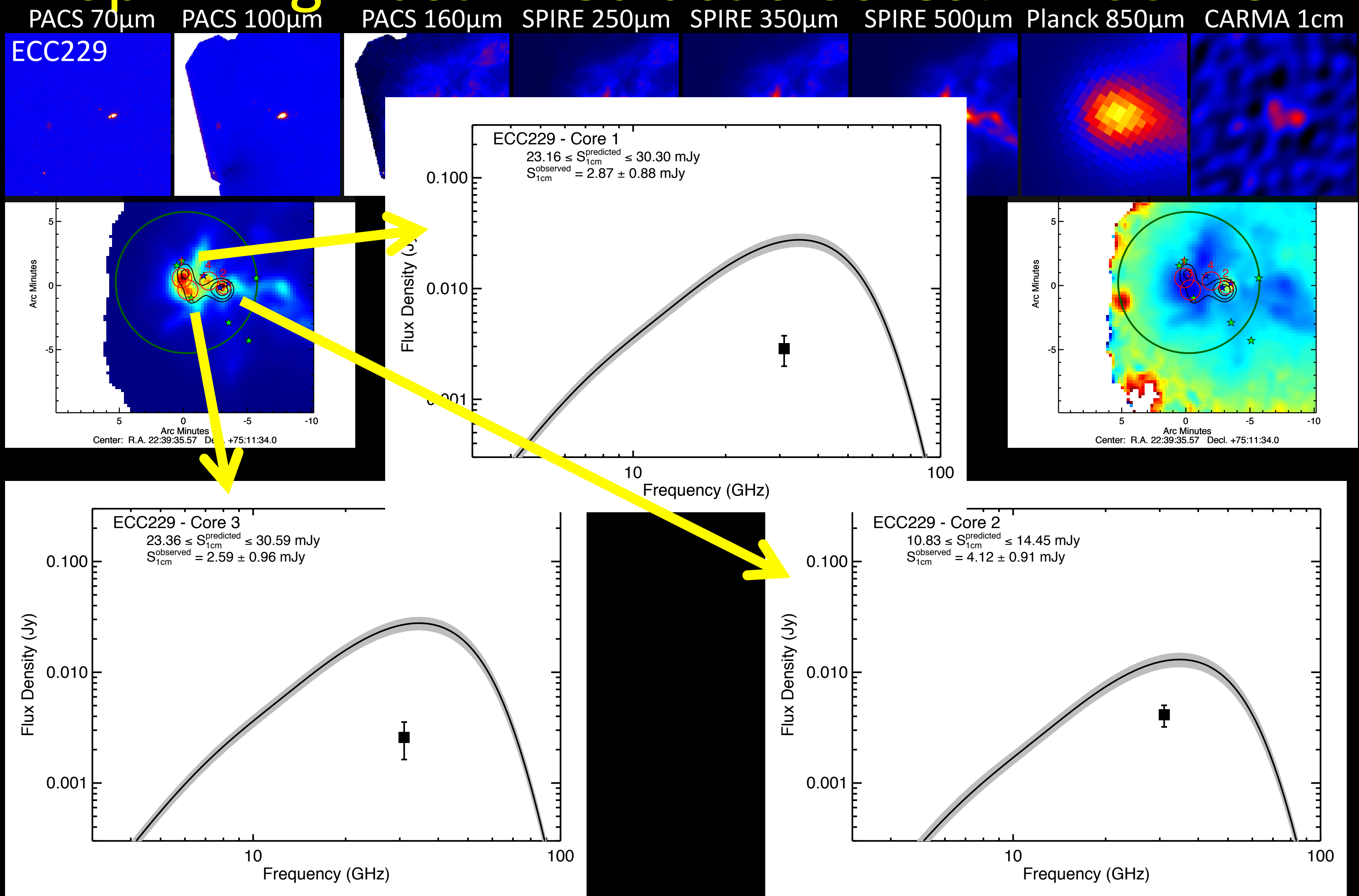
[Tibbs et al., 2015]

Spinning Dust In Galactic Cores? - ECC229



[Tibbs et al., 2015]

Spinning Dust In Galactic Cores? - ECC229



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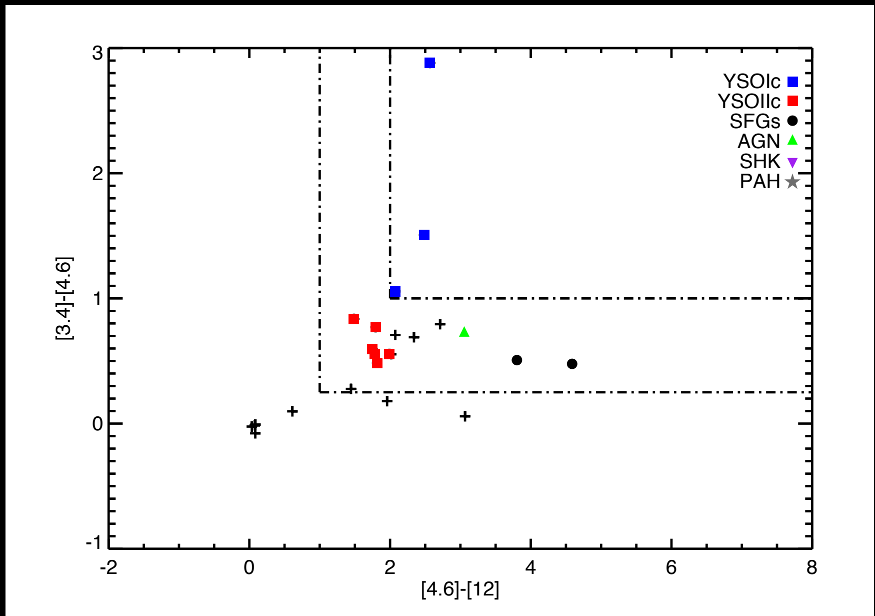
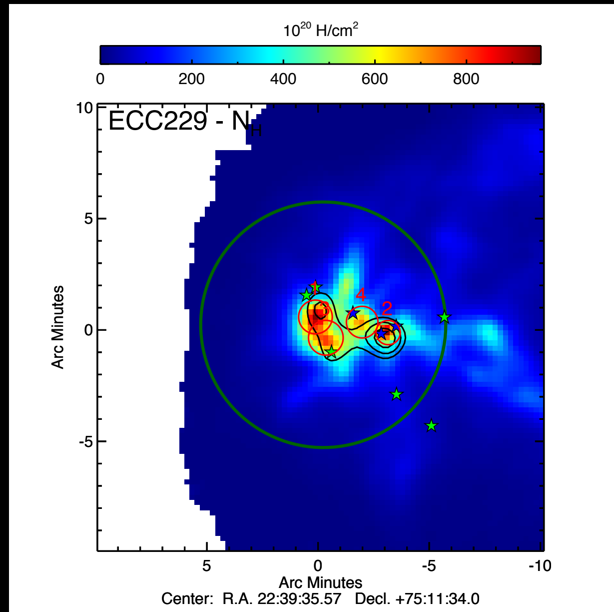
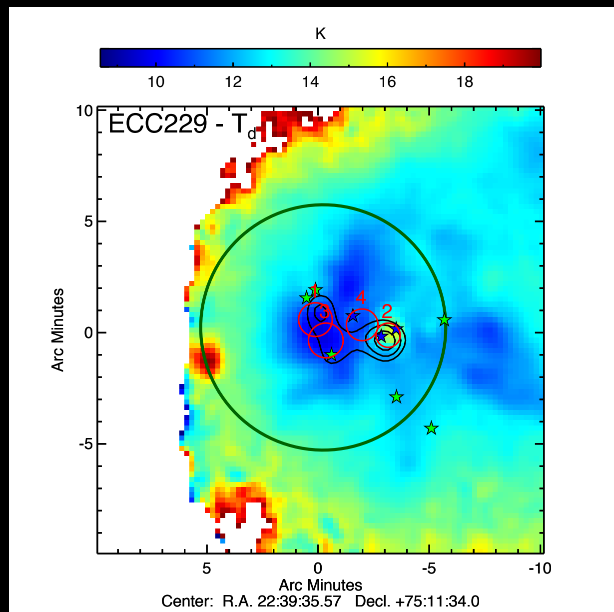




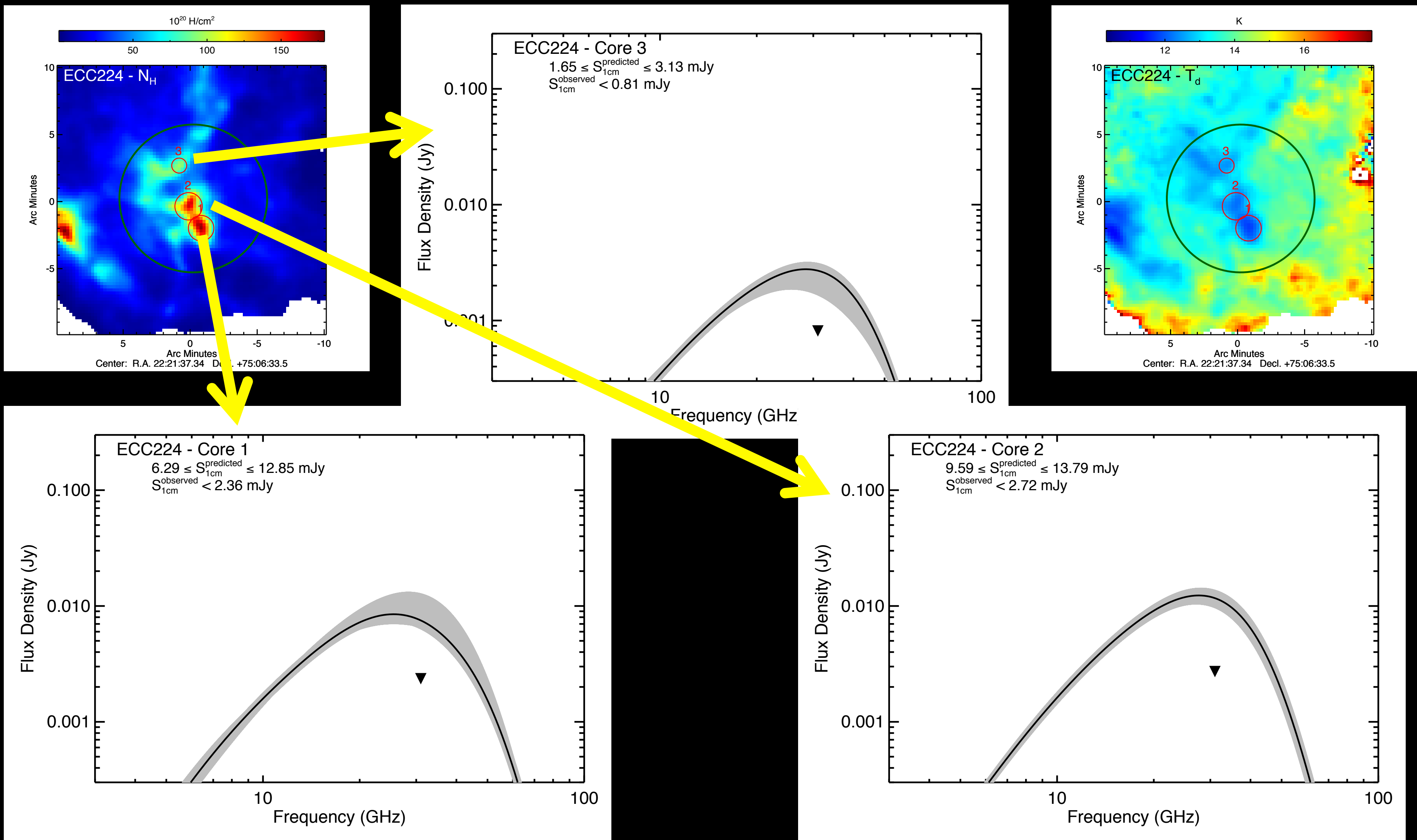


Use WISE point source catalogue and colour-colour criteria developed by Koenig et al (2012) to identify candidate young stellar objects (YSOs) in each of our CARMA observations.

6 of our 34 cores appear to be associated with at least 1 YSO candidate, but only 3 cores detected at 1cm

[Tibbs et al., 2015]

Constraining Dust Grain Evolution Using Spinning Dust – ECC224



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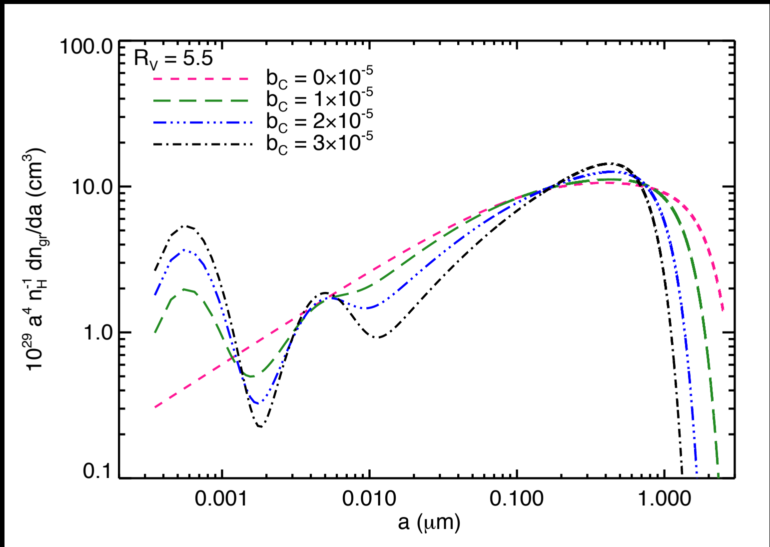
Constraining Dust Grain Evolution Using Spinning Dust

Dust Grain Size Distribution



Dust grain size distribution based on observations of the Milky Way
[Weingartner & Draine, 2001]

Produce spinning dust curve for a range of different dust grain size distributions

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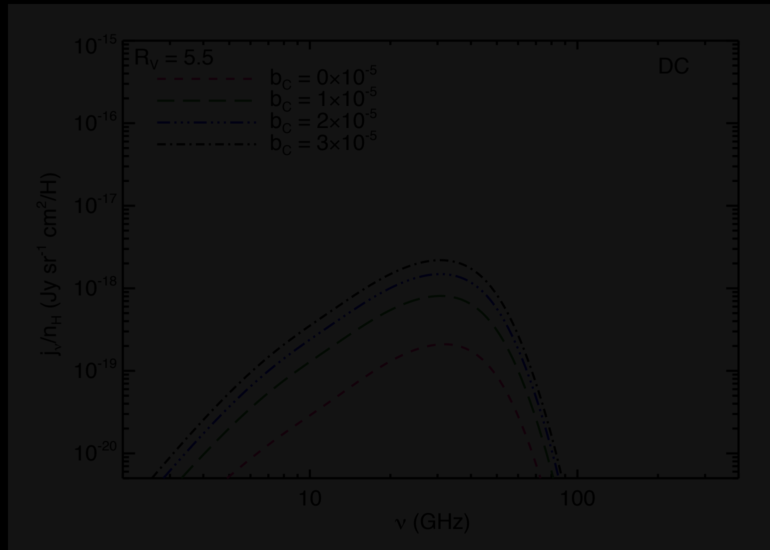

For each core we produce the estimated spinning dust curve for a range of values of b_C

b_c = abundance of small carbonaceous dust grains

[Tibbs et al., 2016]

Constraining Dust Grain Evolution Using Spinning Dust

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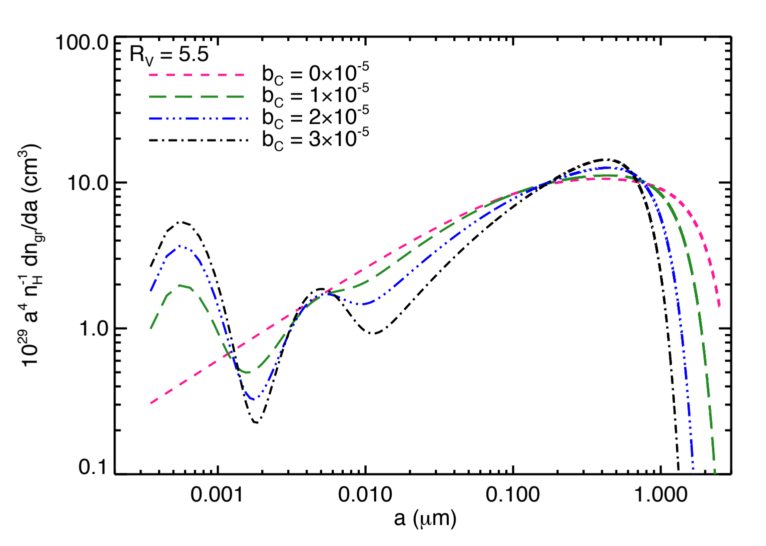

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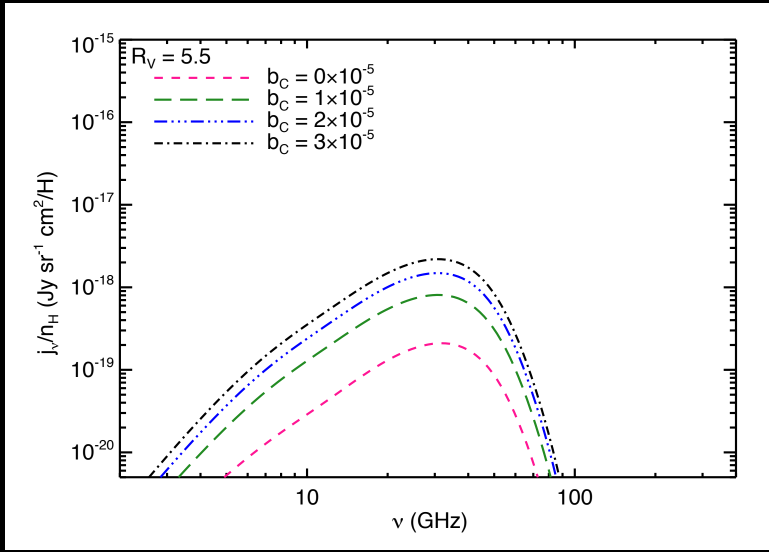

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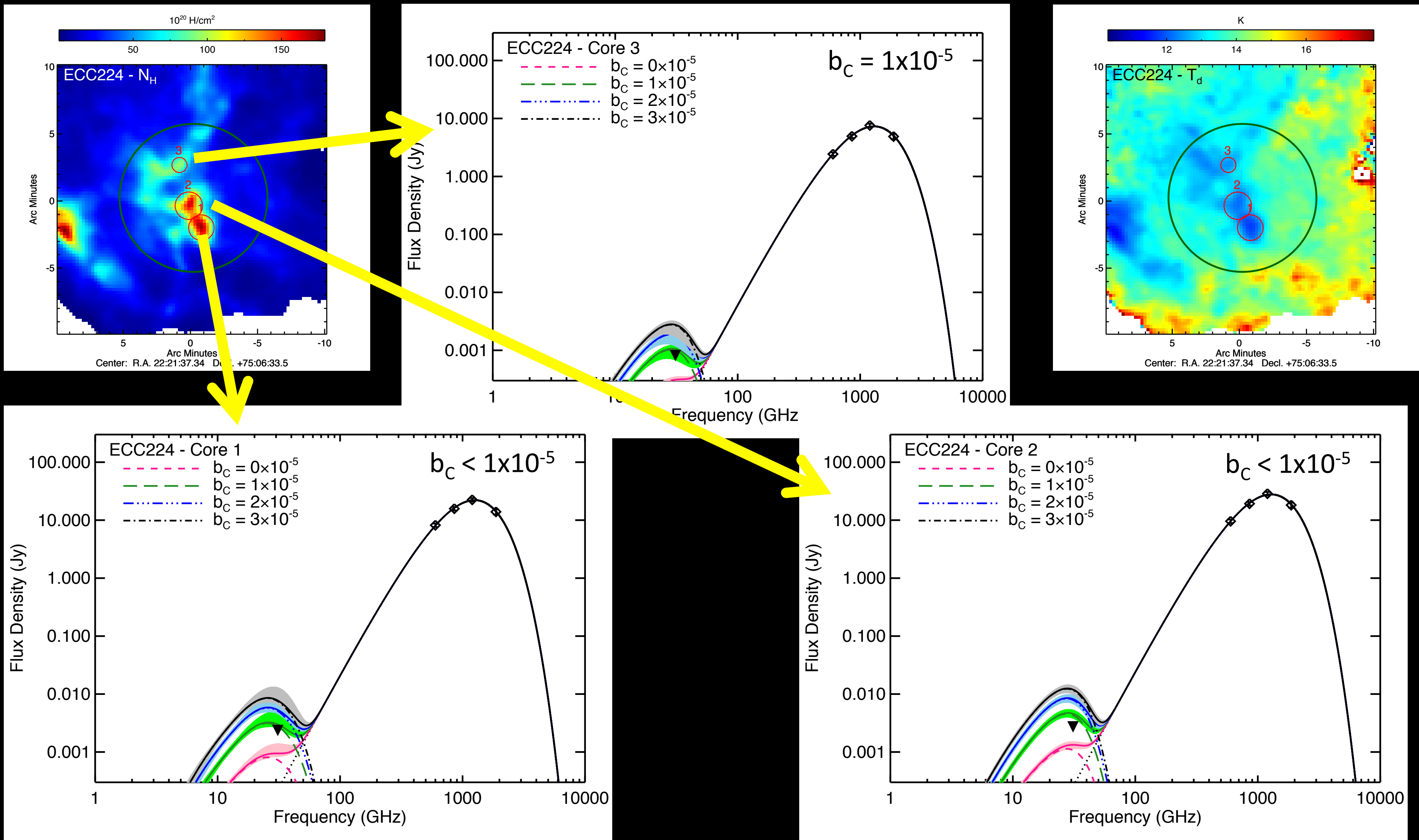

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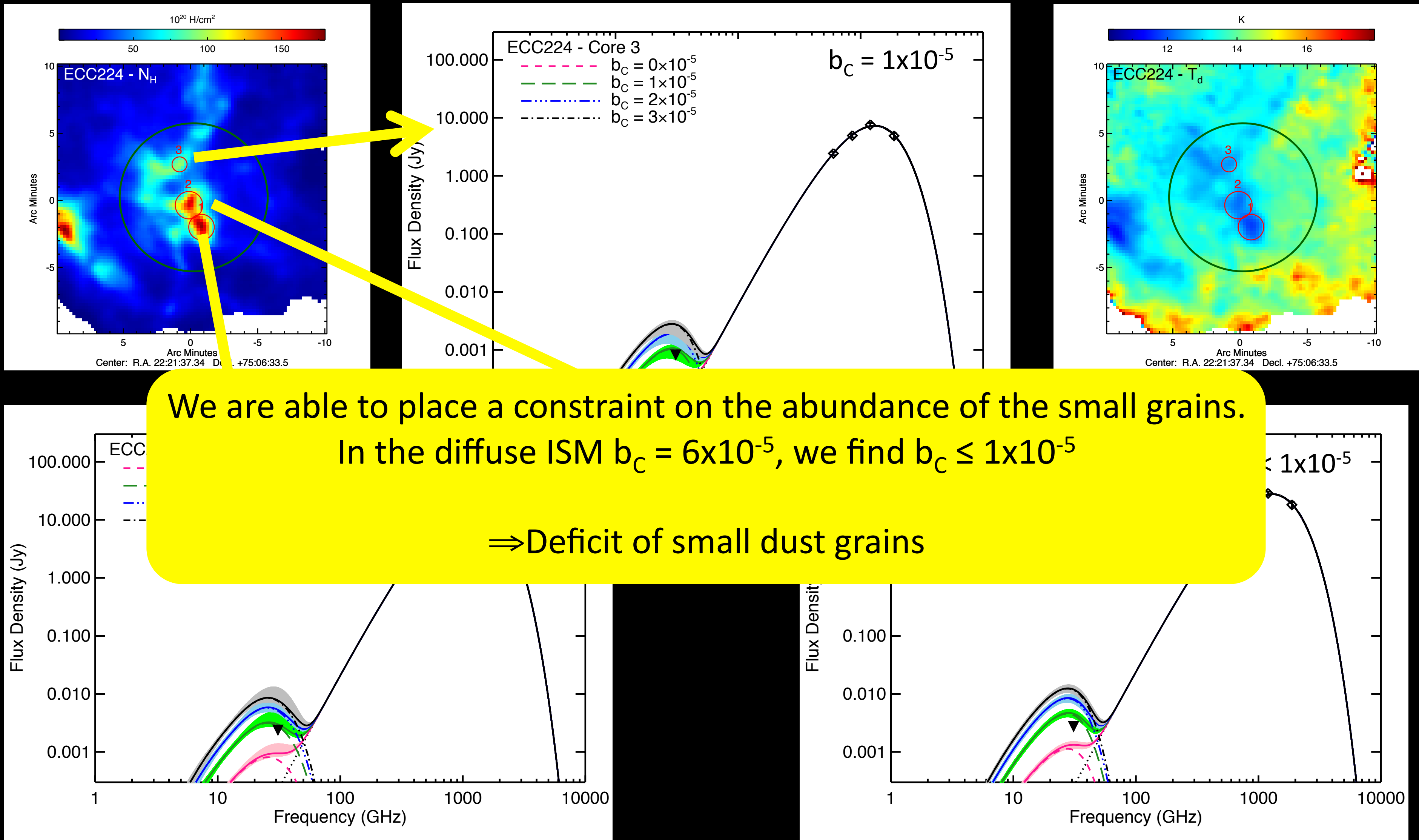

We are able to place a constraint on the abundance of the small grains.
In the diffuse ISM $b_C = 6\times10^{-5}$, we find $b_C \leq 1\times10^{-5}$

$\Rightarrow$Deficit of small dust grains

[Tibbs et al., 2016]

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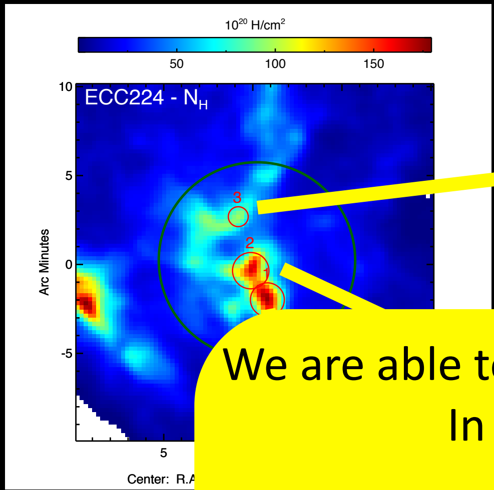

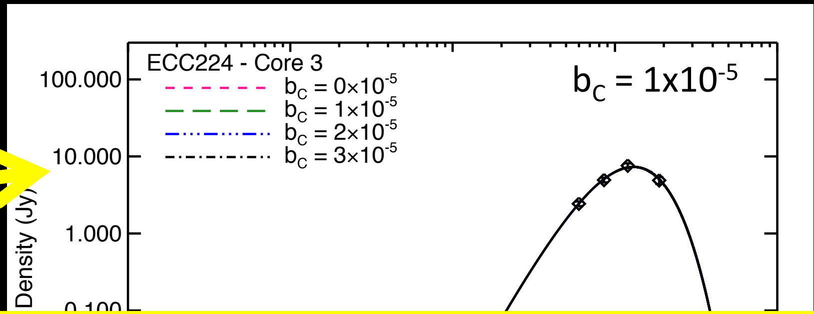

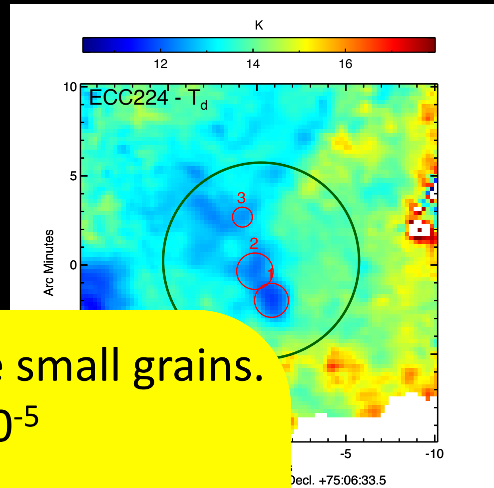

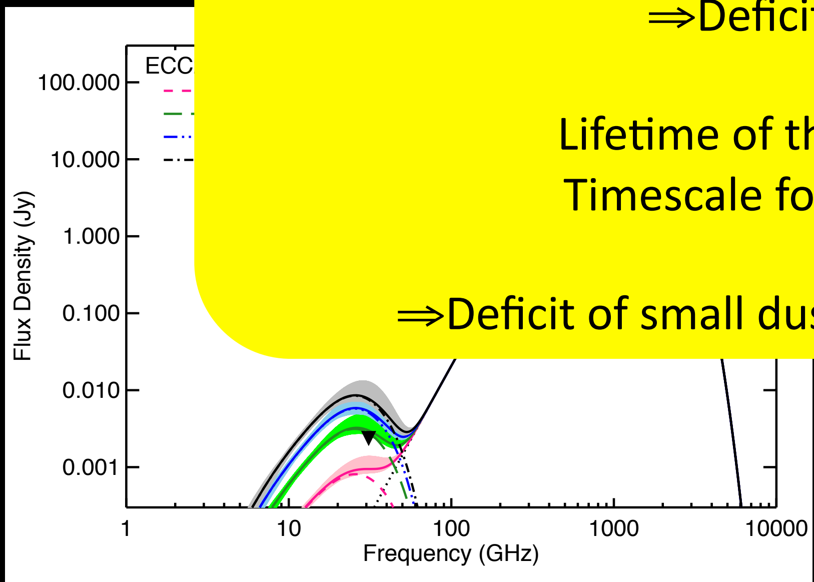

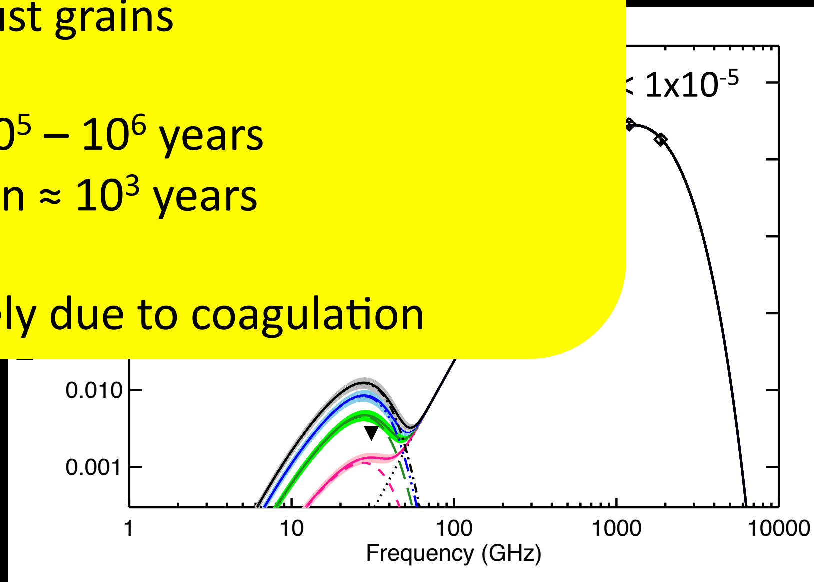

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Lifetime of the cores ≈ $10^5 – 10^6$ years
Timescale for coagulation ≈ 10^3 years

$\Rightarrow$Deficit of small dust grains likely due to coagulation

[Tibbs et al., 2016]

Conclusions

- Spinning dust emission has been observed in a wide variety of Galactic environments and we searched for it in a new environment: dense Galactic cores.
- Using Herschel far-IR observations we estimated n_H and G_0 for all of the cores.
- Using these derived properties we modelled the spinning dust emission for 4 different grain size distributions.
- By comparing the predicted level of spinning dust to our CARMA observations we constrained the abundance of small dust grains.
- We found a deficit of small grains for our entire sample, and it is likely due to dust grain coagulation.
- This is the first time that spinning dust has been used as a tool to study interstellar dust grains.

Using spinning dust observations at 1cm we have shown that it is possible to constrain the abundance of the small interstellar dust grains in Galactic cores.