Structure of the Polaris flare revealed by SPIRE

Marc-Antoine Miville-Deschênes (IAS, Orsay, France)

on behalf of the SAG 4 "Evolution of Interstellar Dust"

P. G. Martin, A. Abergel, J. P. Bernard, F. Boulanger, G. Lagache, L. D. Anderson, P. André, H. Arab, J.-P. Baluteau, K. Blagrave, M. Cohen, M. Compiègne, P. Cox, E. Dartois, G. Davis, R. Emery, T. Fulton, C. Gry, E. Habart, M. Huang, C. Joblin, S. C. Jones, J. Kirk, T. Lim, S. Madden, G. Makiwa, A. Menschchikov, S. Molinari, H. Moseley, F. Motte, D. A. Naylor, K. Okumura, D. Pinheuro Gocalvez, E. Polehampton, J. A. Rodon, D. Russeil, R. Saraceno, S. Sidher, L. Spencer, B. Swinyard, D. Ward-Thompson, G. J. White, A Zavagno

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Outline

- Structure of the ISM and the Polaris flare
- How well does SPIRE restore diffuse emission ?
- Power spectrum analysis

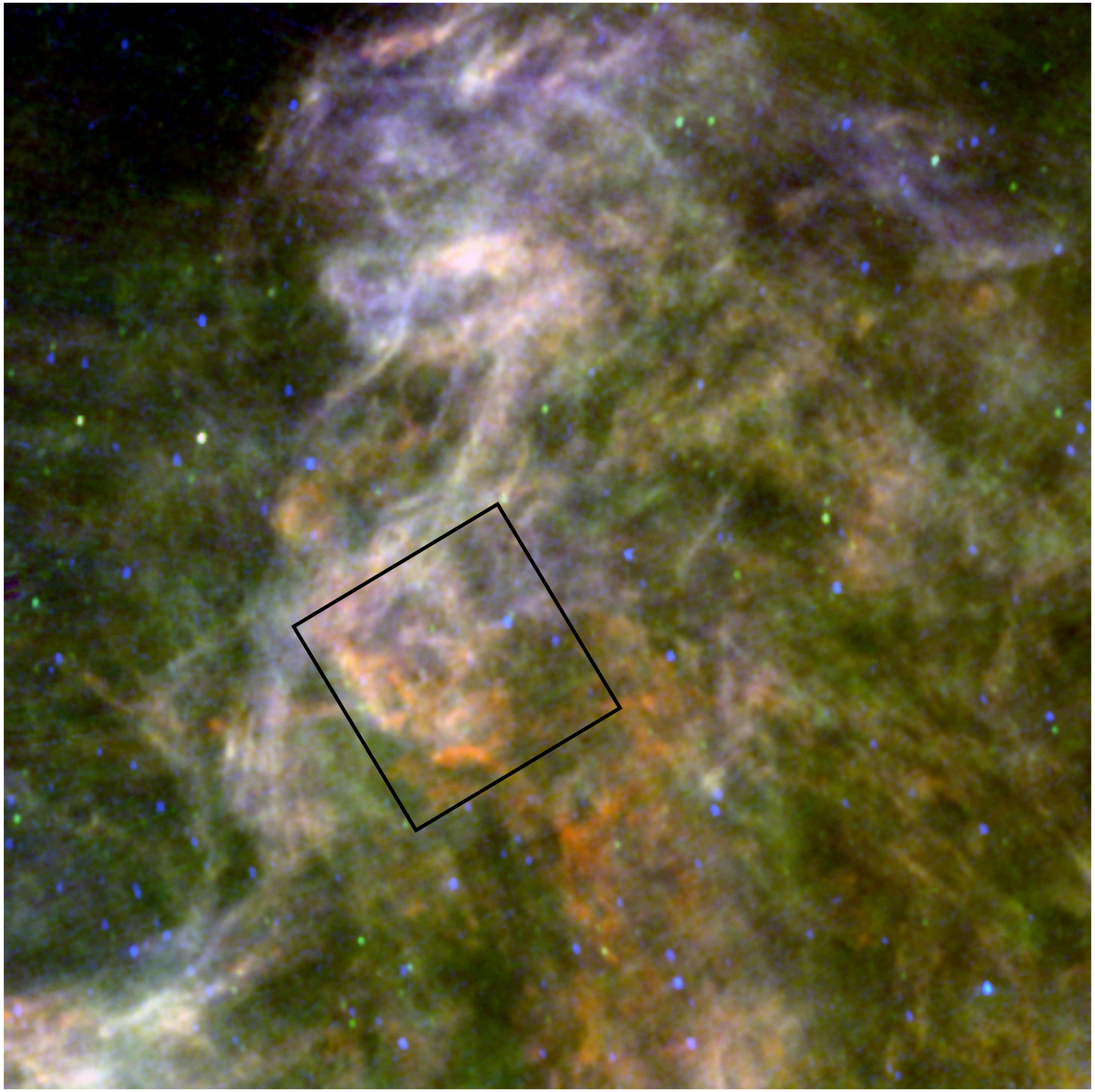
Background and goal

- What governs the structure of the ISM ? direct impact on the CMF and IMF.
  - Complex physics : turbulence, magnetic field, thermal instability
  - Need for direct comparison with numerical simulations
  - Importance of the density field (compare to the velocity field)
  - Power spectrum of column density --> power spec. of the 3D density field

- Need for a careful selection of fields and emission tracers

- Goal : use of long wavelength dust emission of cirrus clouds to study the 3D structure of the diffuse ISM.
  - uniformely heated by the ISRF : no local source of UV photons
  - extinction low enough to neglect radiative transfer
  - dust temperature rather uniform : dust emission is a good tracer of the total column density
  - traces all phases (atomic, molecular)

View of the Polaris flare with IRAS

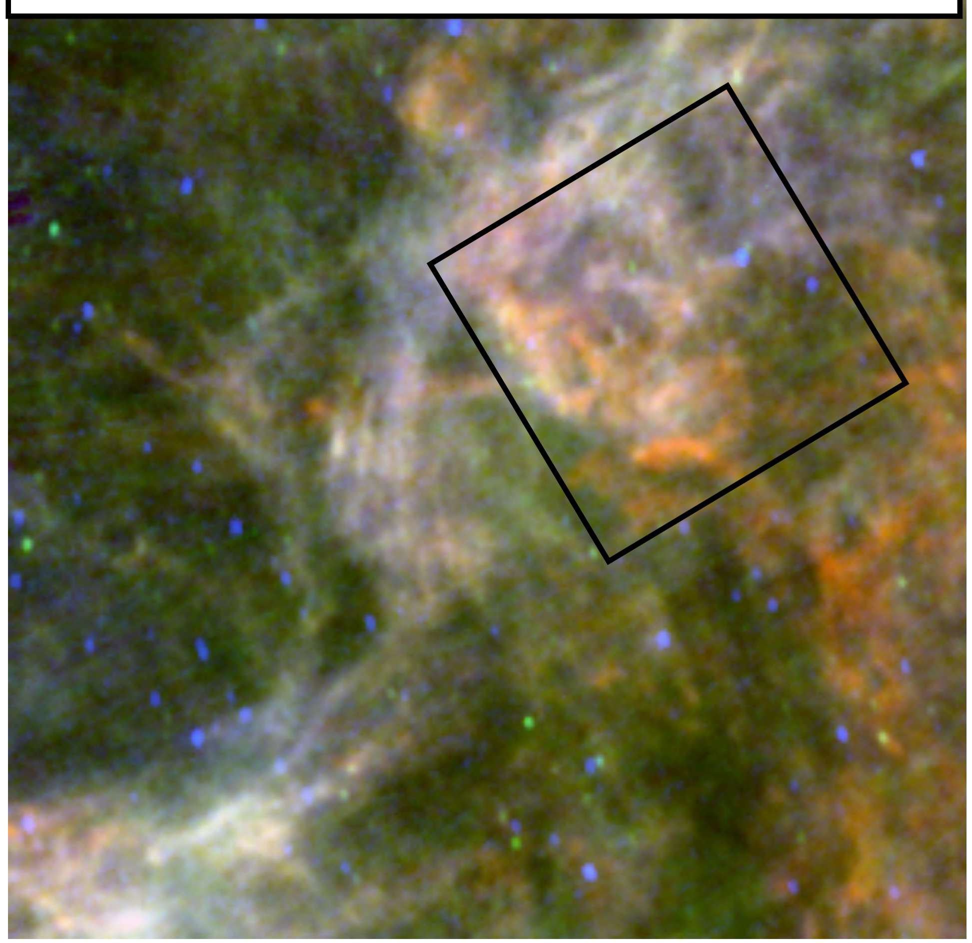


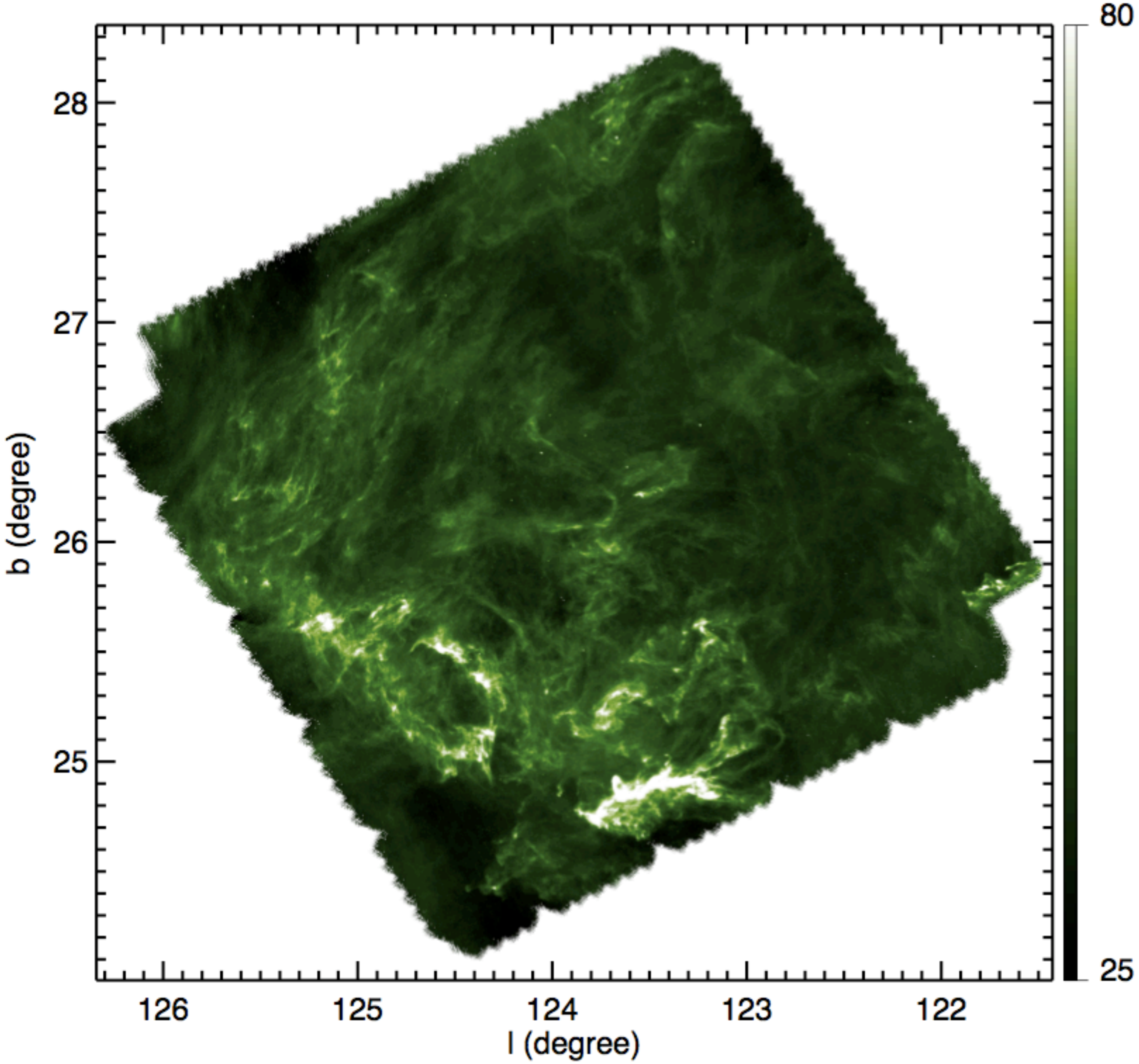
- R : 100 micron,
  G : 60 micron,
  B : 12+25 micron

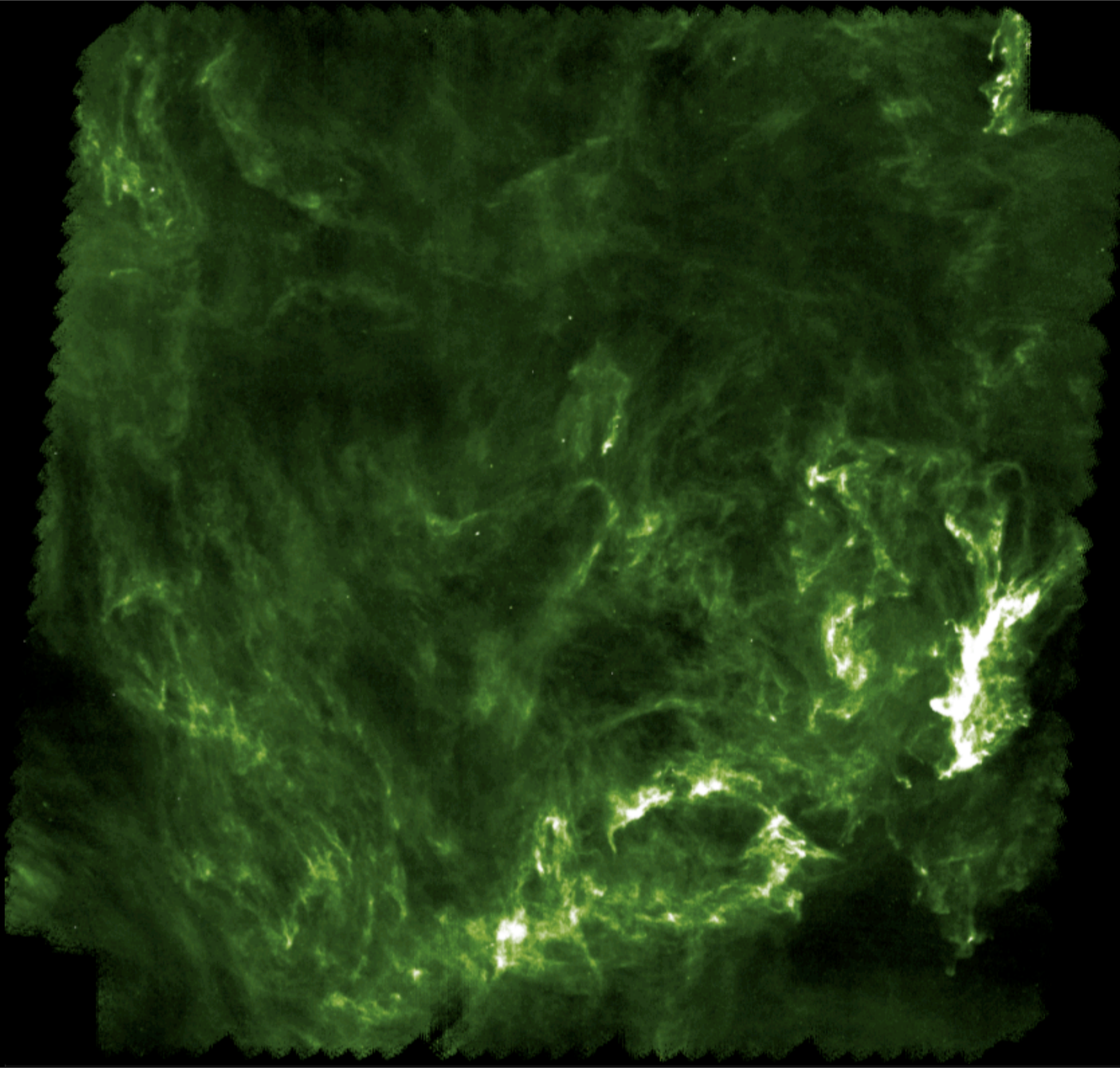
- Dense cirrus cloud
  - 150 pc
  - significant CO emission
  - several proto-stellar cores but no star formed
- Ideal target to study the early phases of star formation
  - formation of molecular clouds
  - role of dust
  - structure of the ISM

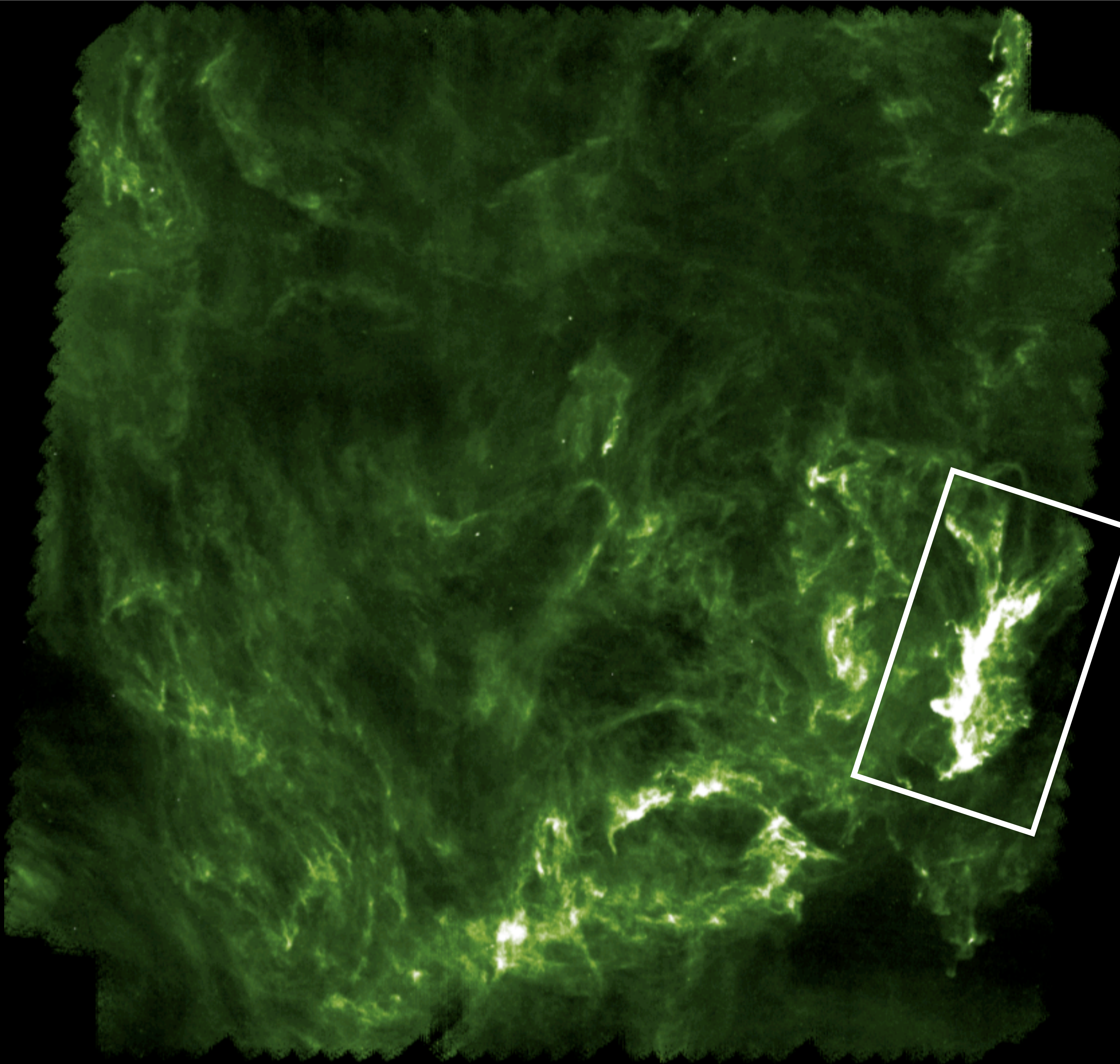
...and here comes Herschel-SPIRE

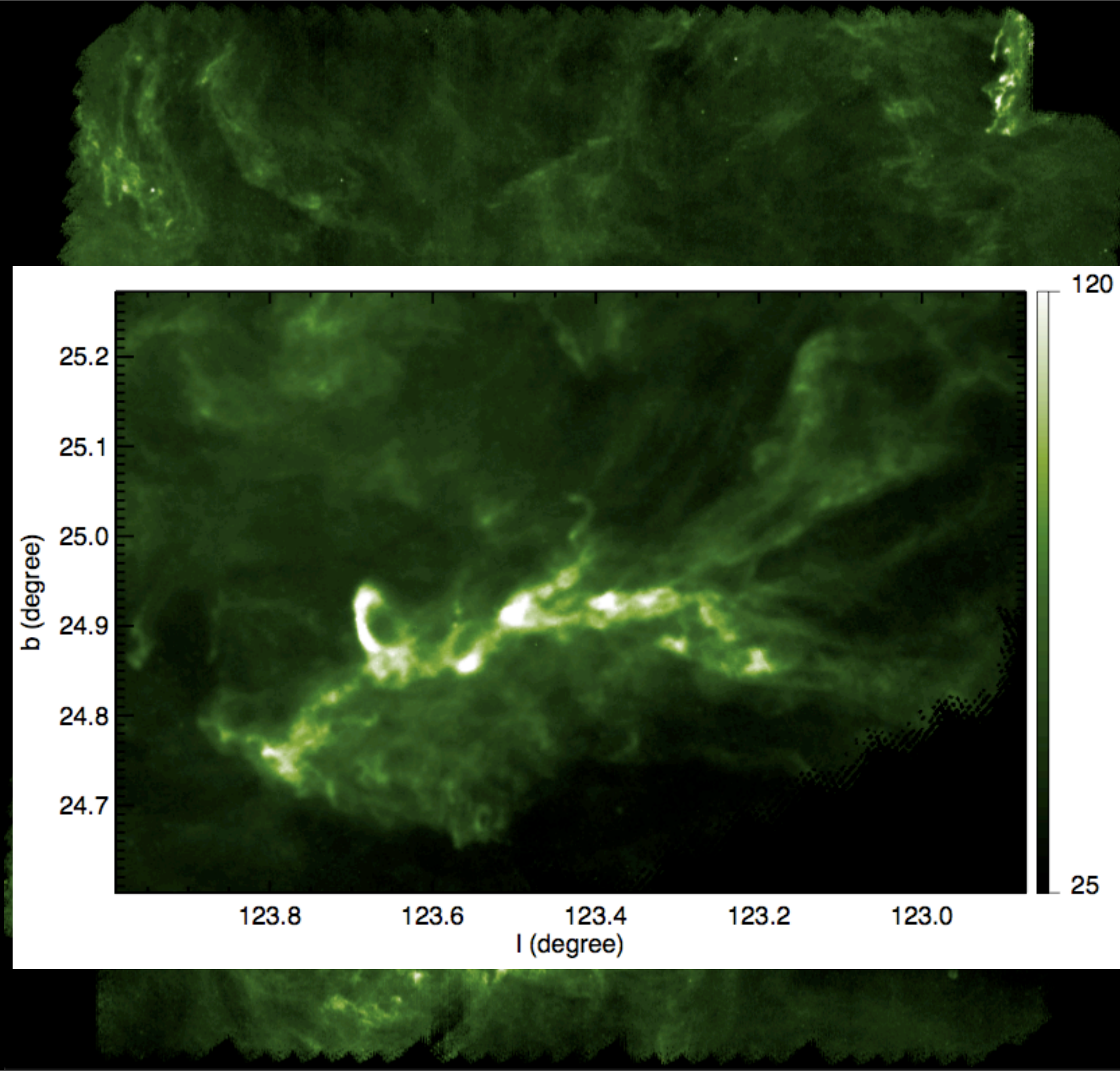
- Spectacuar increase of the angular resolution
- Provides, for the first time, a uniform view of the ISM structure at scales from 0.01 to 8 pc



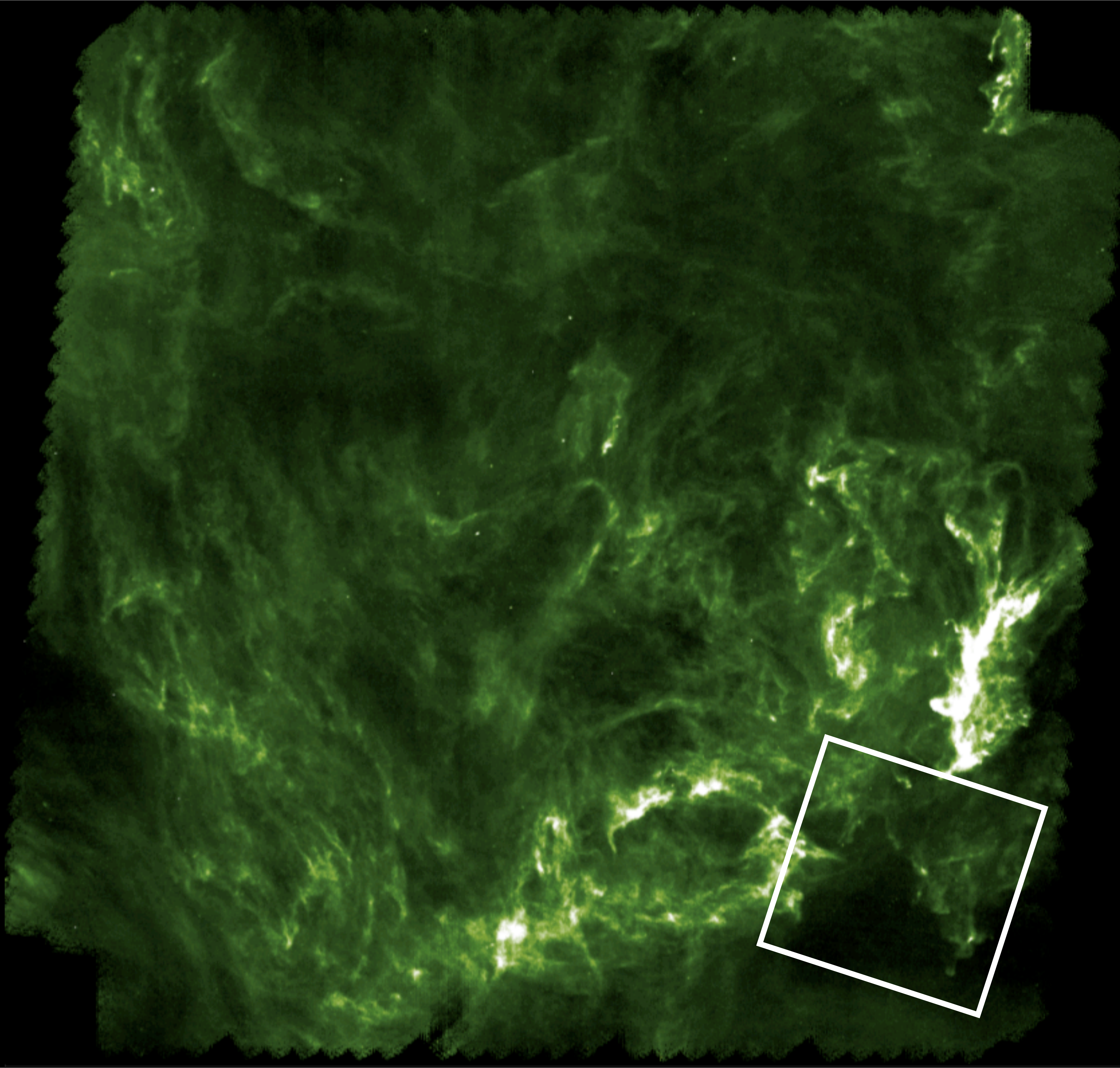


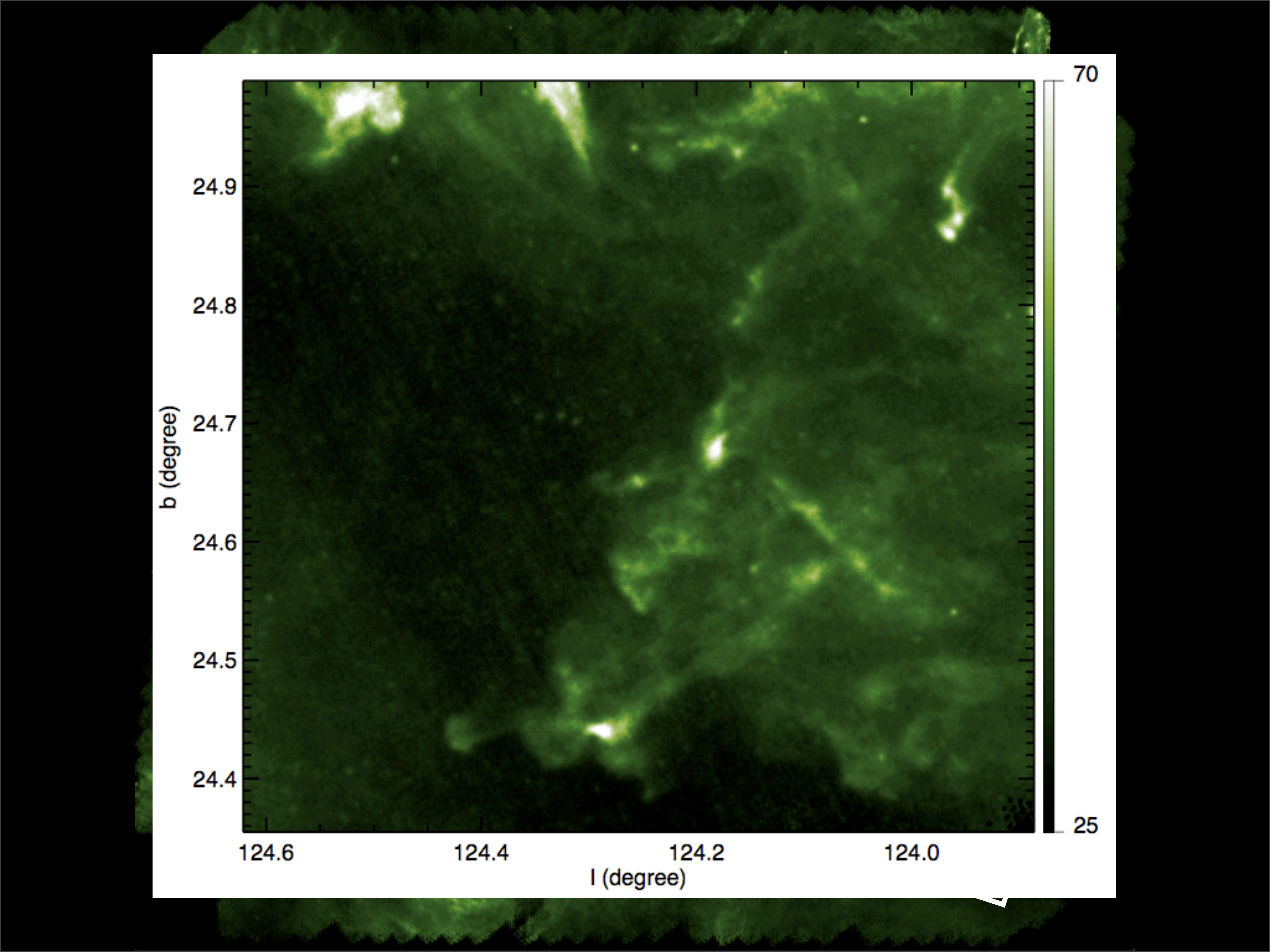


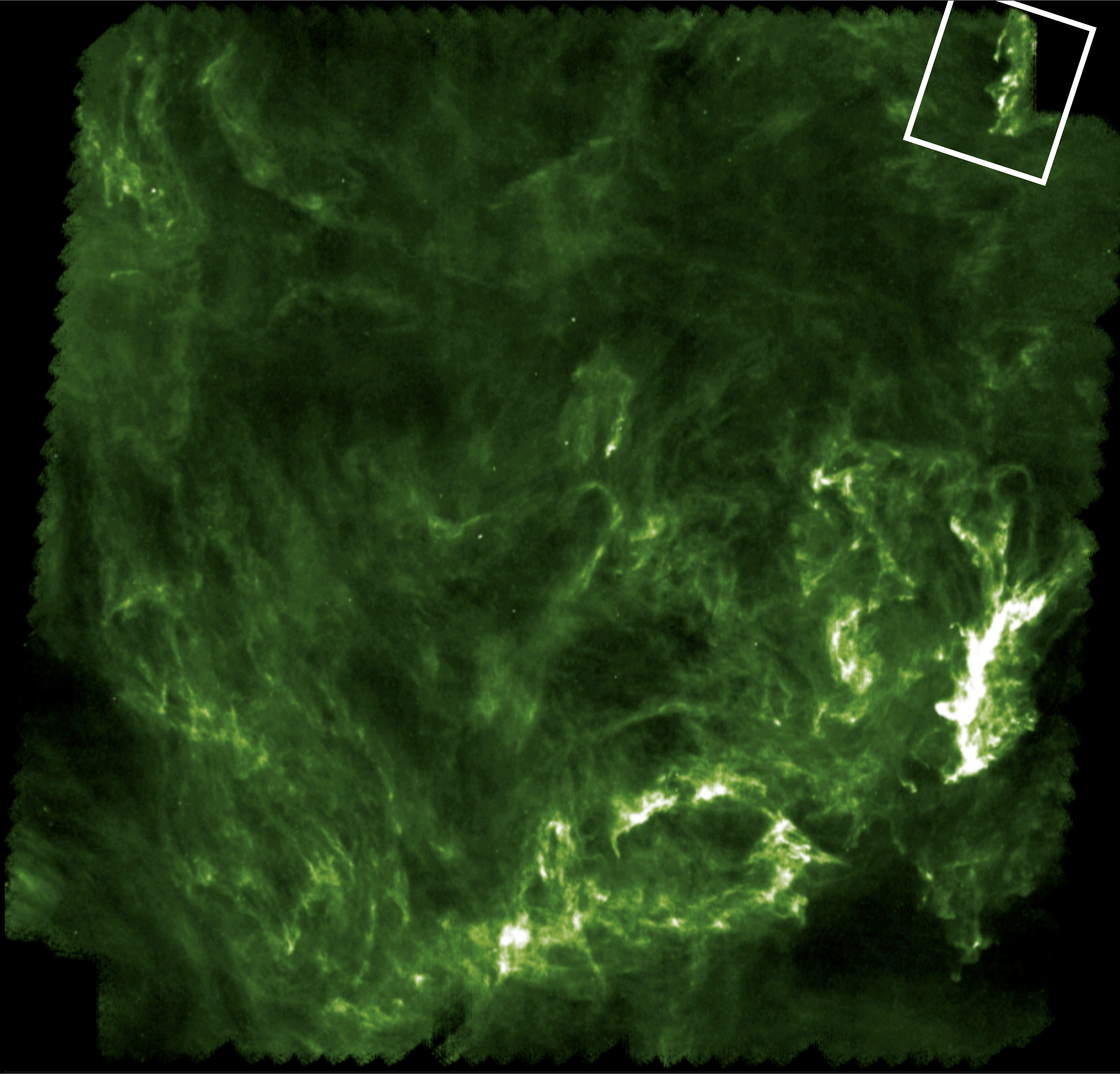


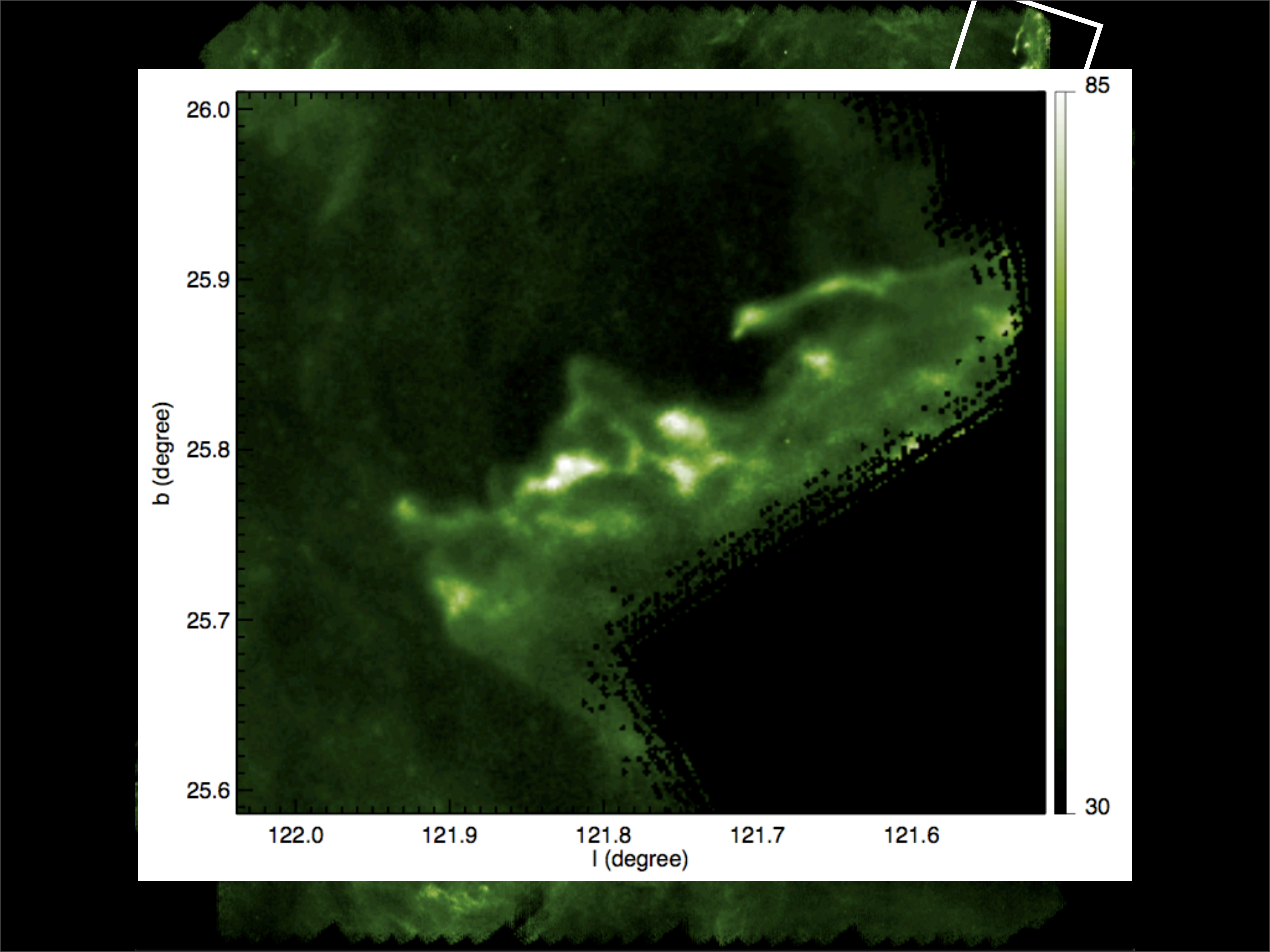


120
25
25.2
25.1
25.0
24.9
24.8
24.7
b (degree)
123.8
123.6
123.4
123.2
123.0
l (degree)

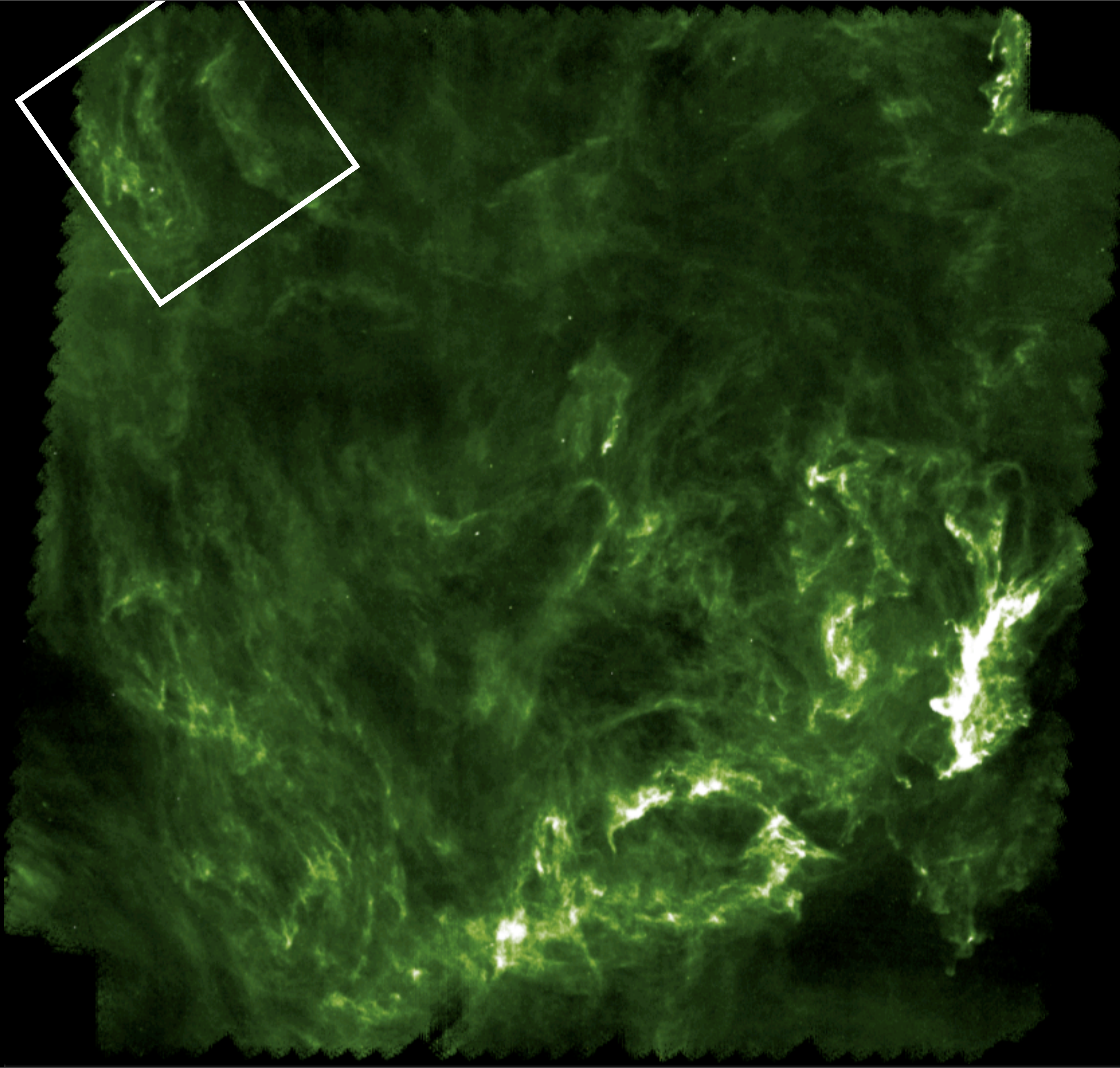


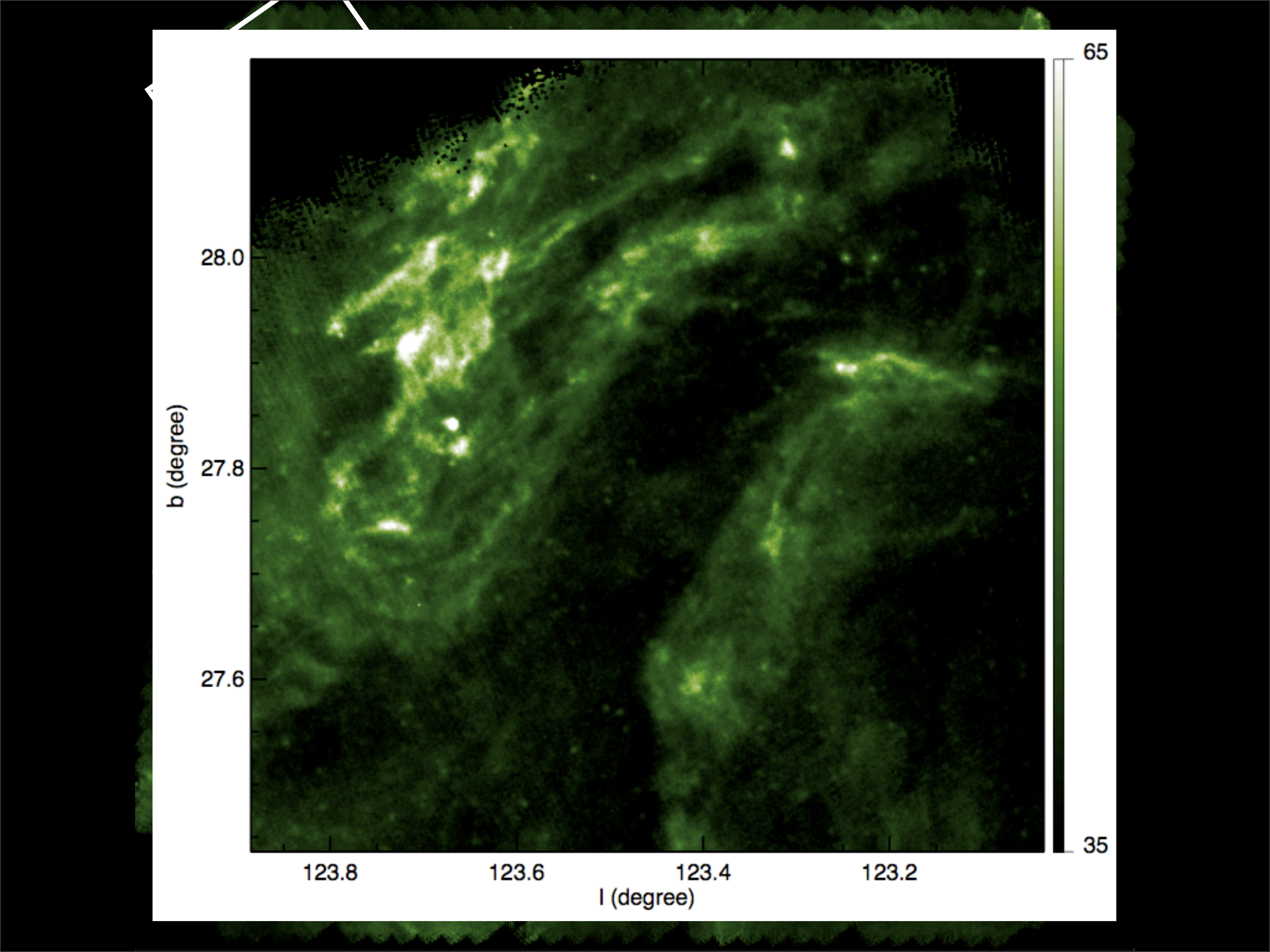

70
25
24.9
24.8
24.7
24.6
24.5
24.4
b (degree)
124.6
124.4
124.2
124.0
l (degree)



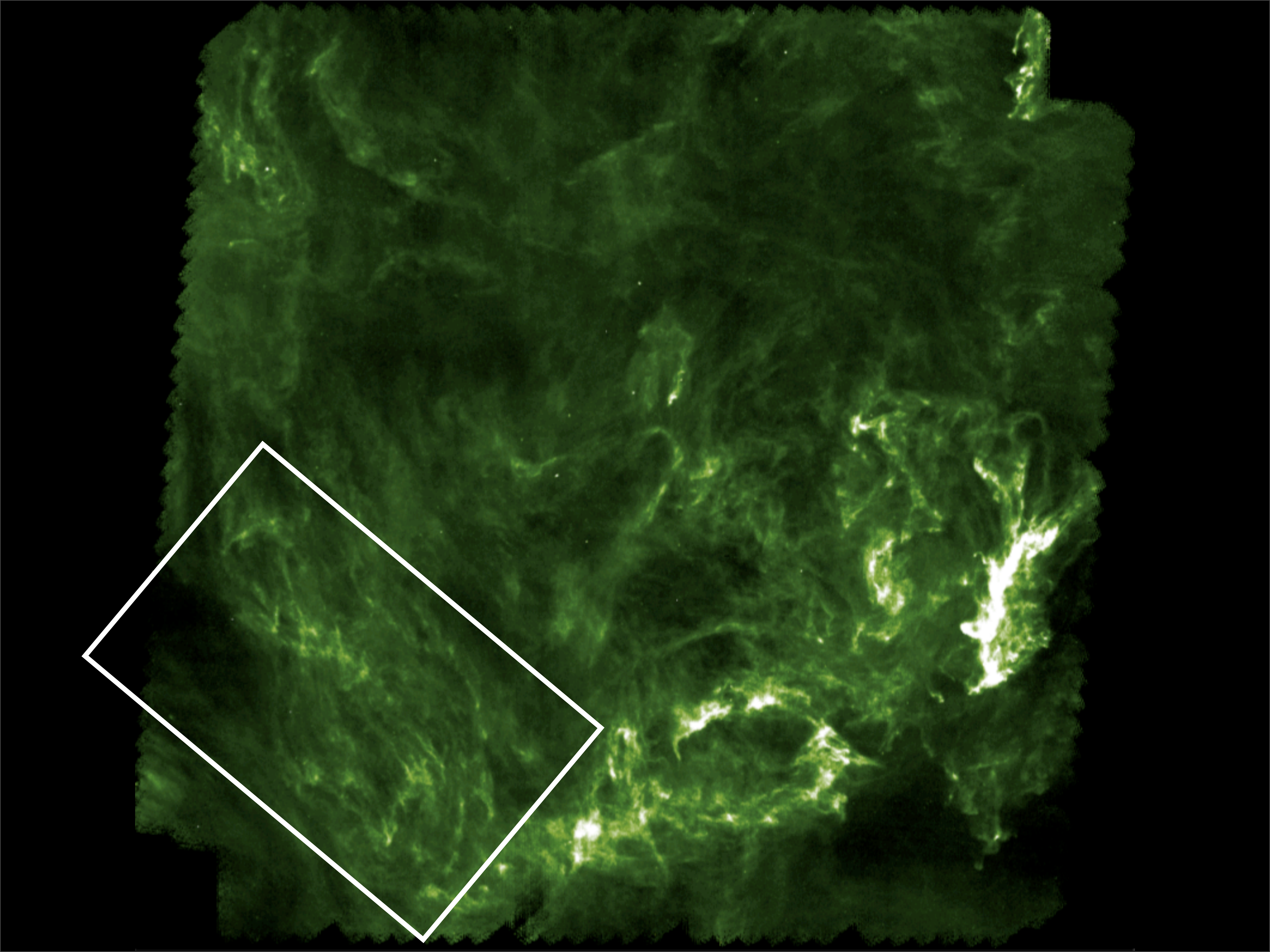


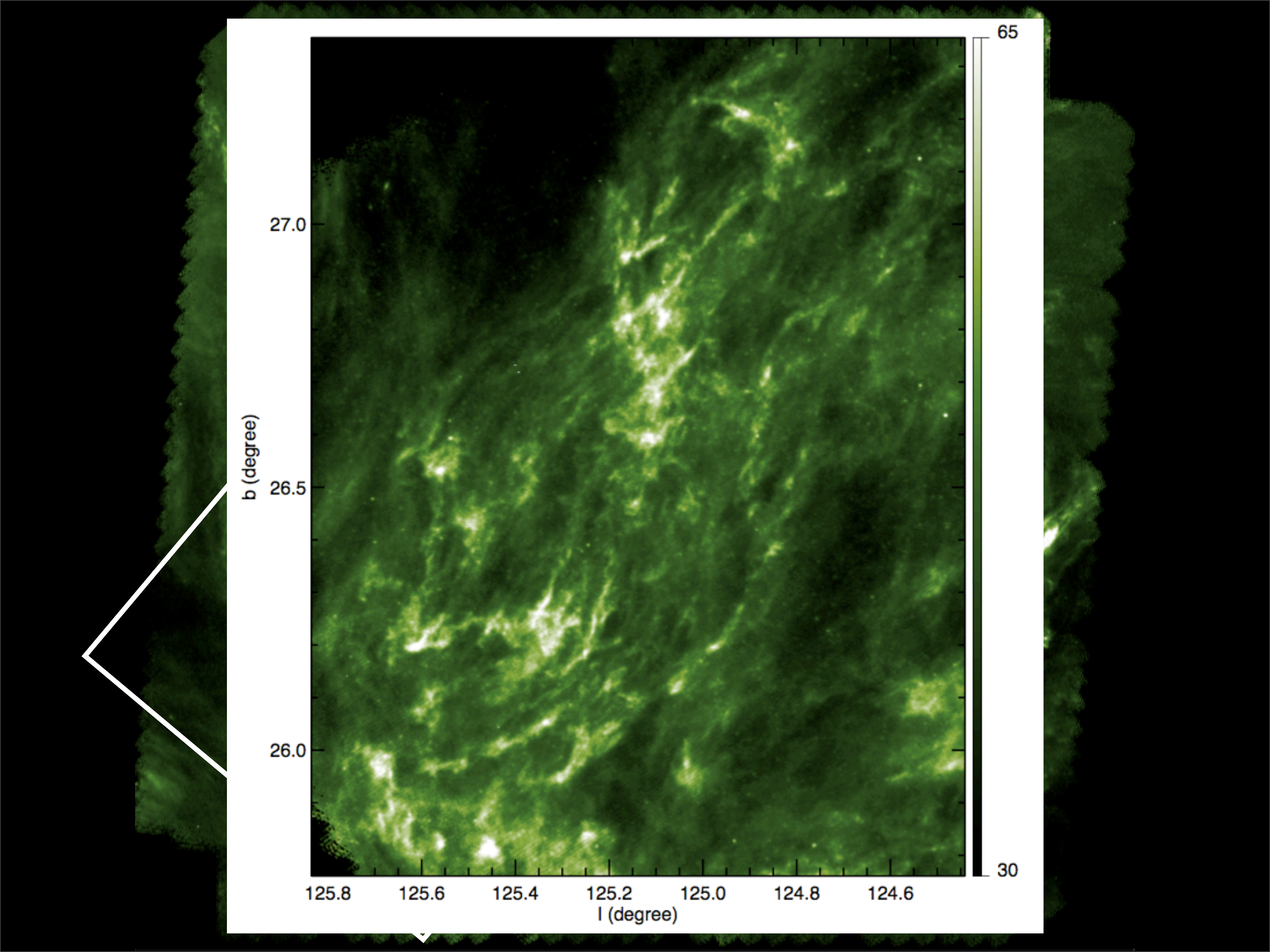
26.0
25.9
25.8
25.7
25.6
b (degree)
122.0
121.9
121.8
121.7
121.6
l (degree)
85
30





65
35
28.0
27.8
27.6
b (degree)
123.8
123.6
123.4
123.2
l (degree)

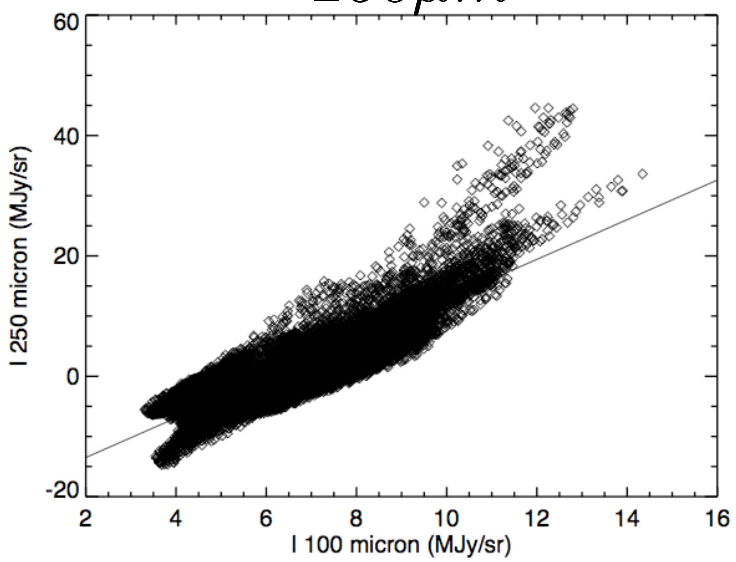




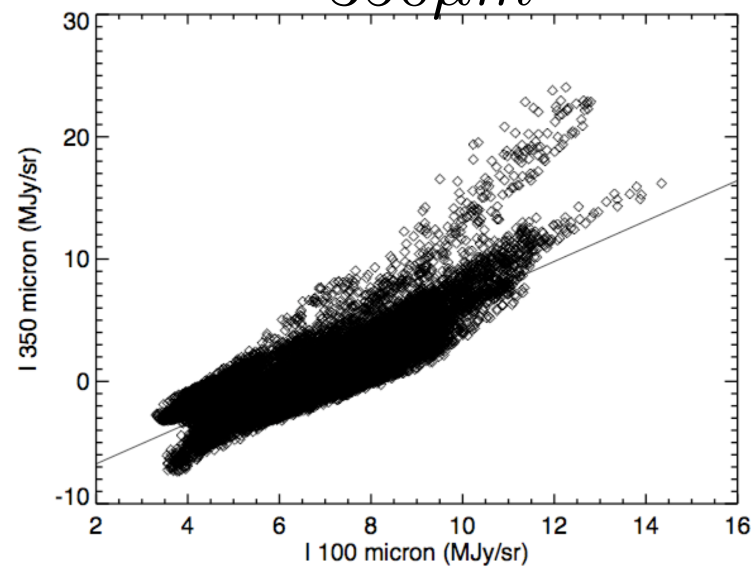
65
30
27.0
26.5
26.0
b (degree)
125.8
125.6
125.4
125.2
125.0
124.8
124.6
l (degree)

IRAS (100 micron) - SPIRE correlation @ 5arcmin

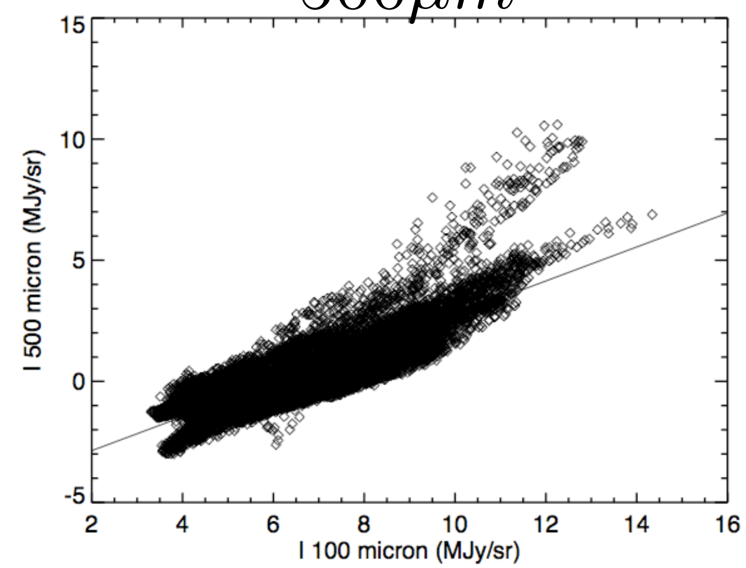
$250\mu m$

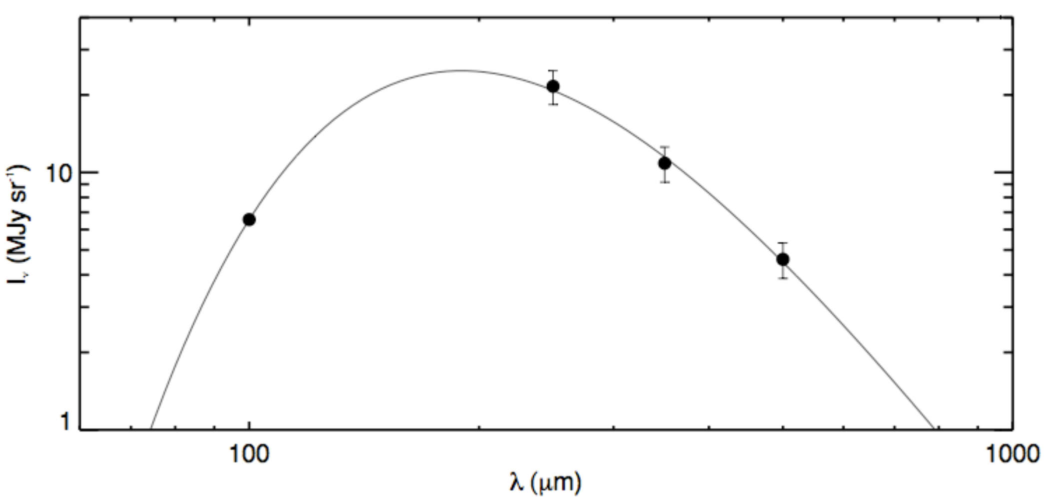


$350\mu m$



$500\mu m$





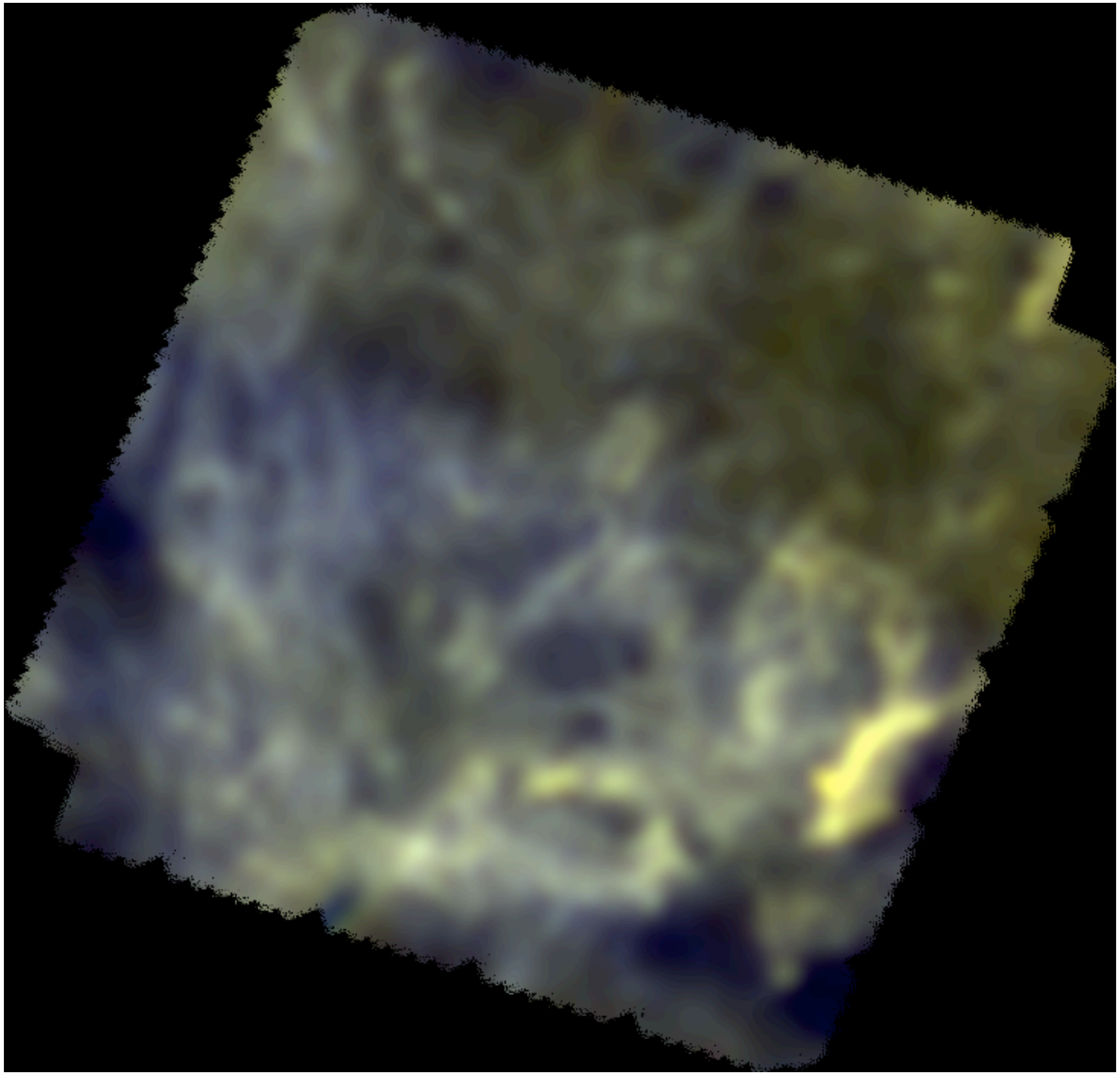
$$T = 14.5 \pm 1.6K$$
$$\beta = 2.3 \pm 0.6$$

- Global correlation between SPIRE (5 arcmin) and IRAS 100 micron reveals a dust spectrum in accordance with expectations (Bernard et al. 1999 - PRONAOS observations)
- Variations around the correlation much stronger than the noise levels
- SPIRE-SPIRE correlation extremely tight

How well does SPIRE map diffuse emission ?

- R : 350 micron
- G : 250 micron
- B : IRAS (IRIS) 100 micron

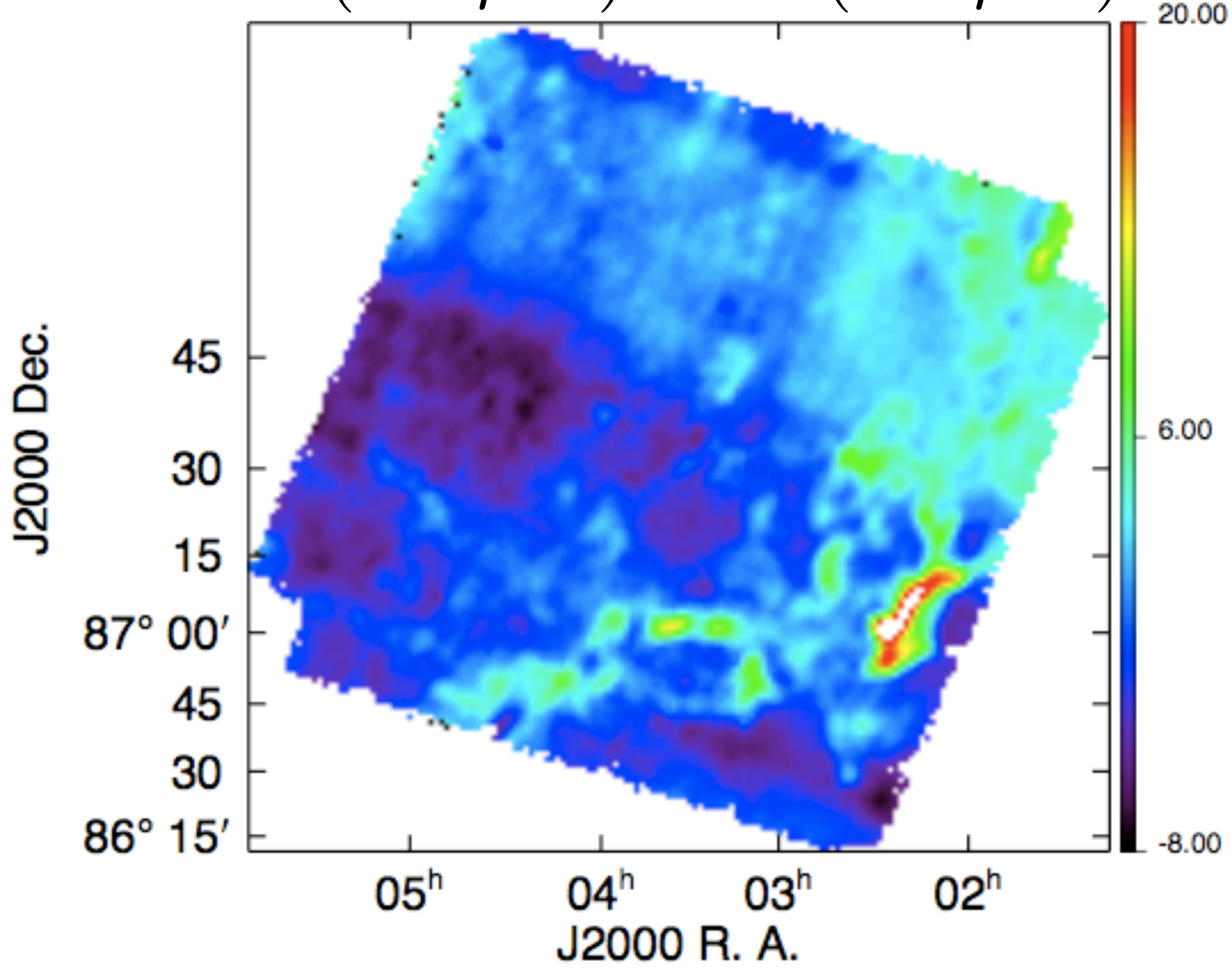
- Dust properties variations
- Large scale systematic effect due to residual 1/f noise



How well does SPIRE map diffuse emission ?

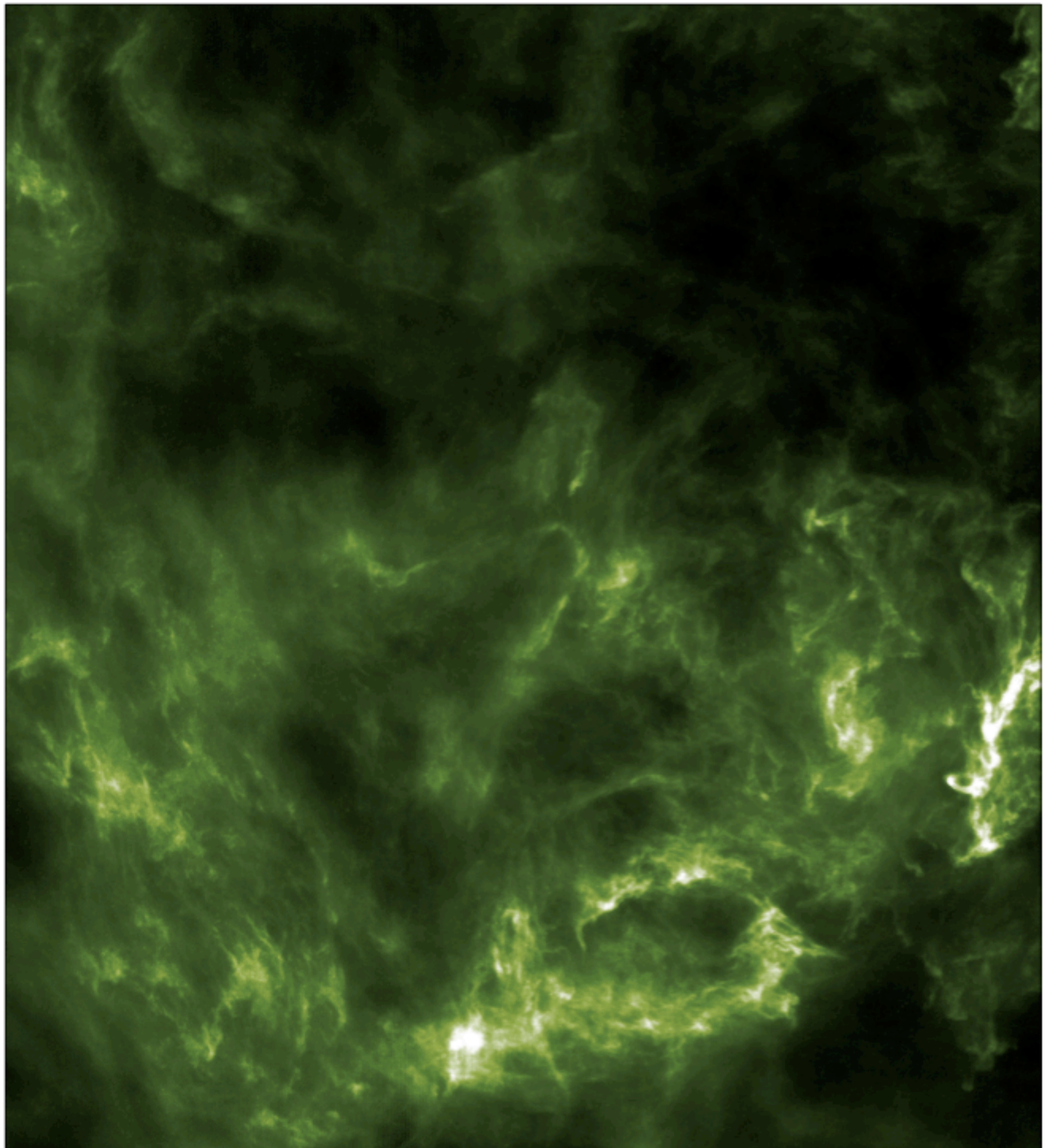
- Clear difference at large scales between IRAS and SPIRE
- Comparison with Planck at 350 and 500 micron would allow to confirm this result.
- Probably room for improvement on the removal of the 1/f noise (thermistor correlation)

$$I(250\mu m) - \alpha I(100\mu m)$$

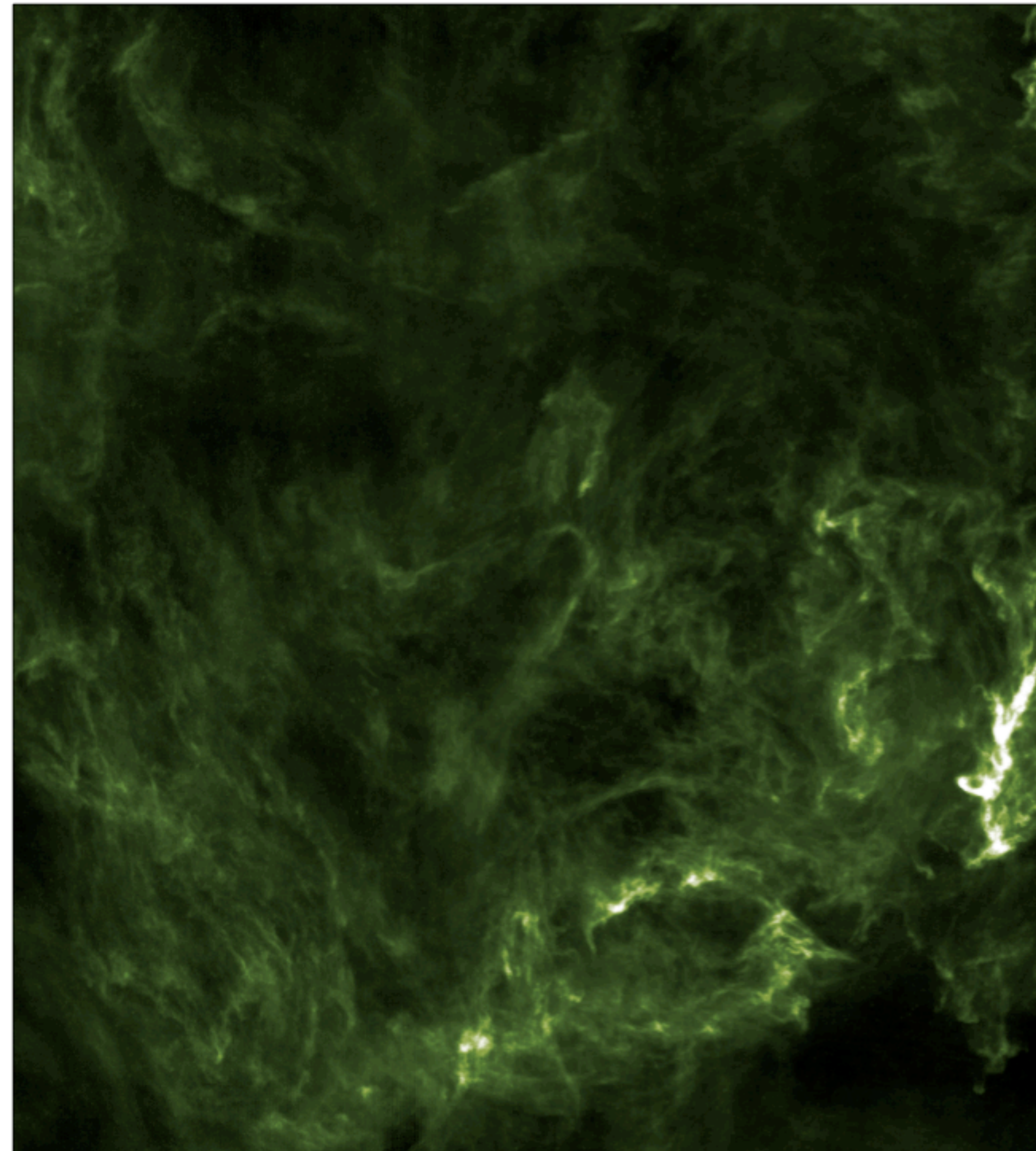


Tentative restoration of the large scale emission

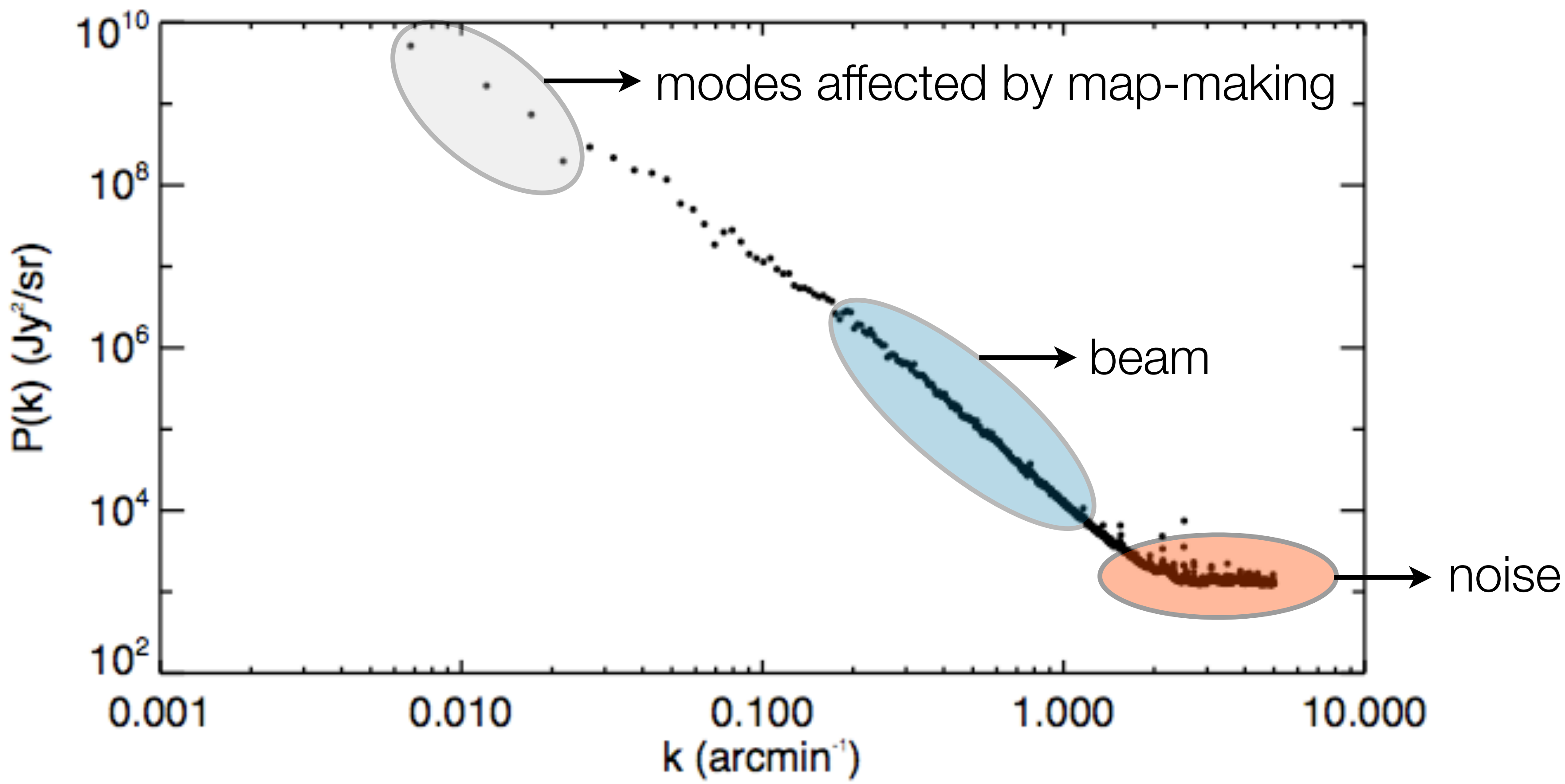
Spire 250 micron + IRIS 100



Spire 250 micron



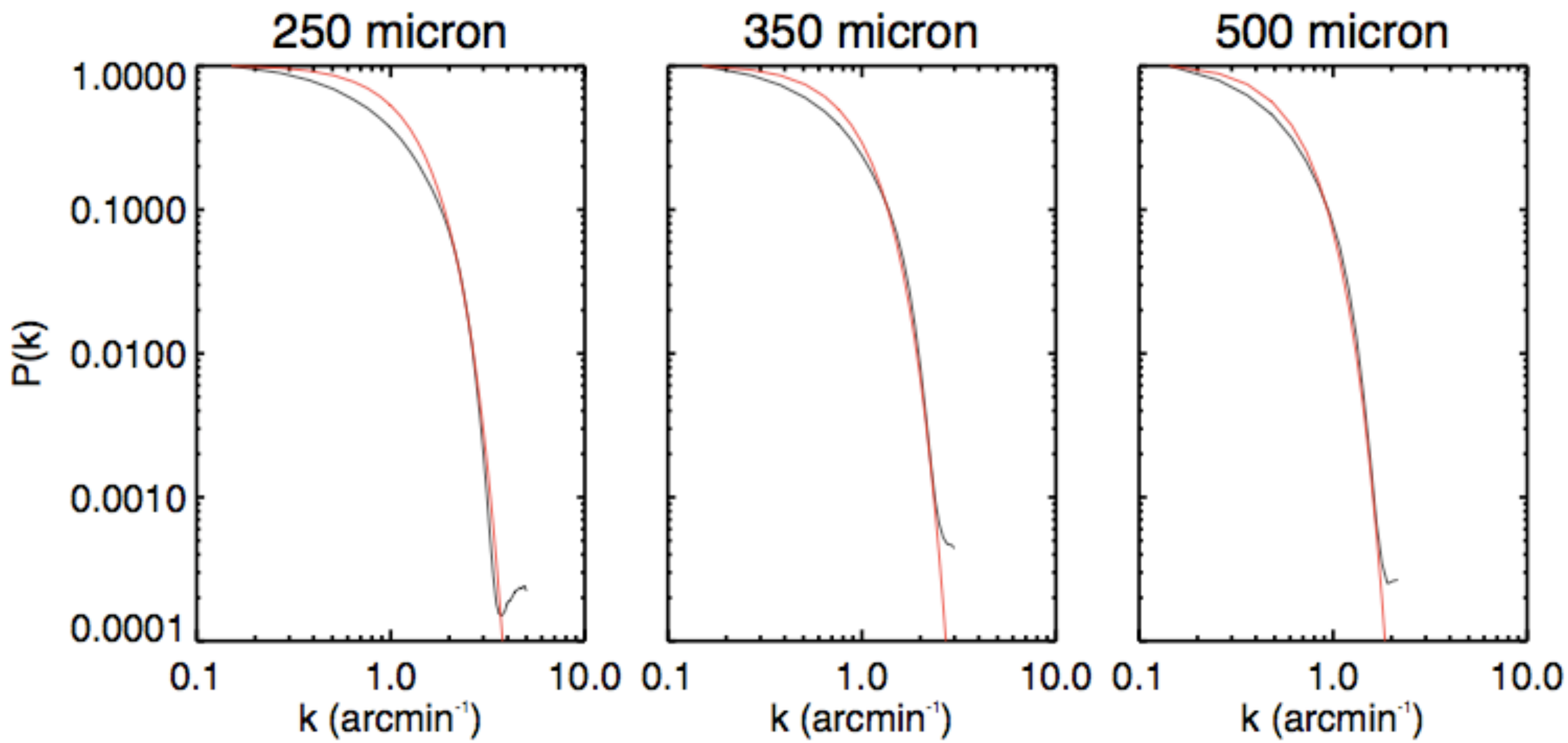
Power spectrum of the 250 micron Polaris map



$$P(k) = \phi(k)[A_0 k^\gamma + S_0] + N(k)$$

transfer function — ISM — sources/CIBA — noise floor

SPIRE beam power spectrum

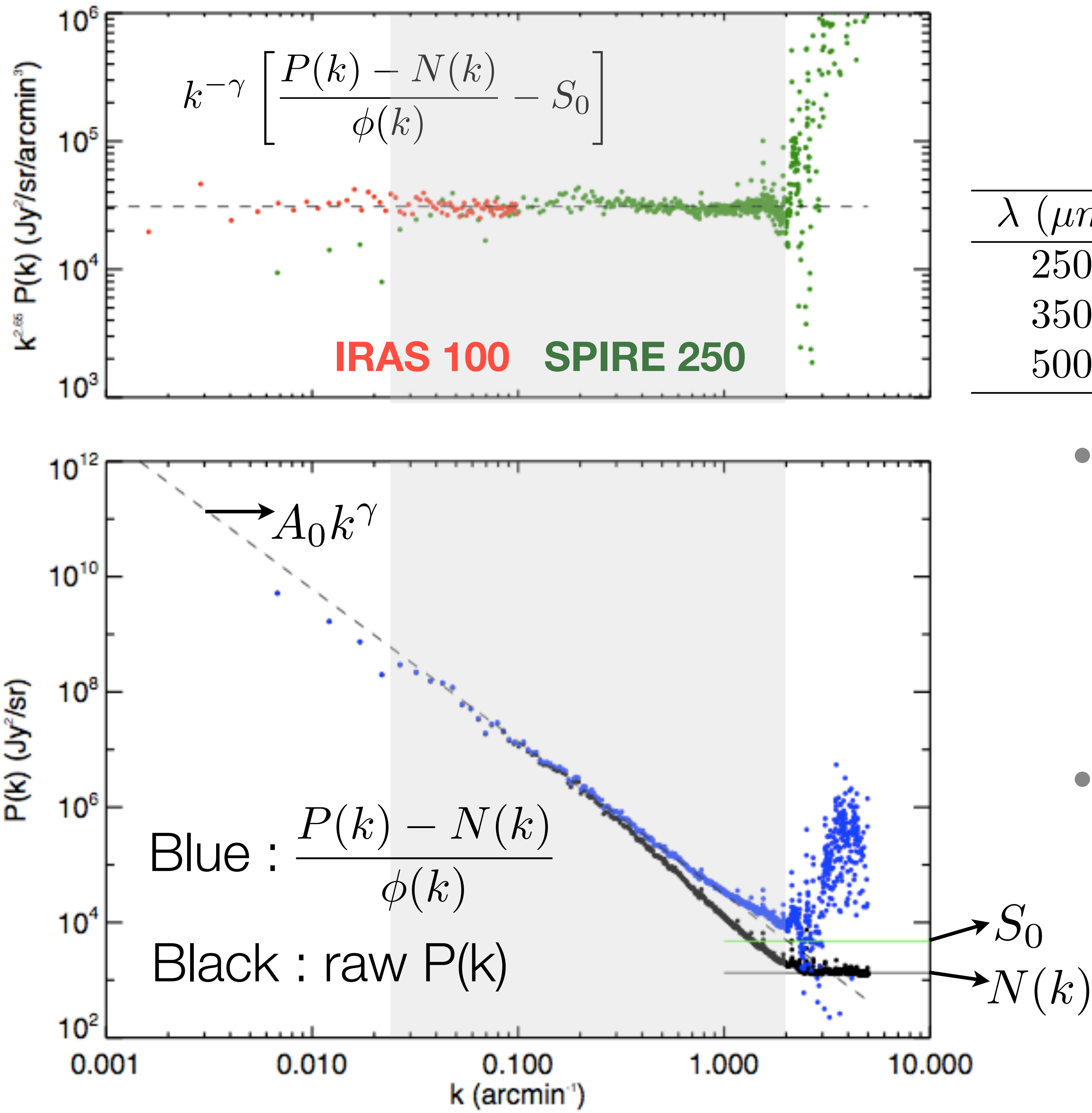


Red : Gaussian beam

Black : beam measured on Neptune

Power spectrum modelling

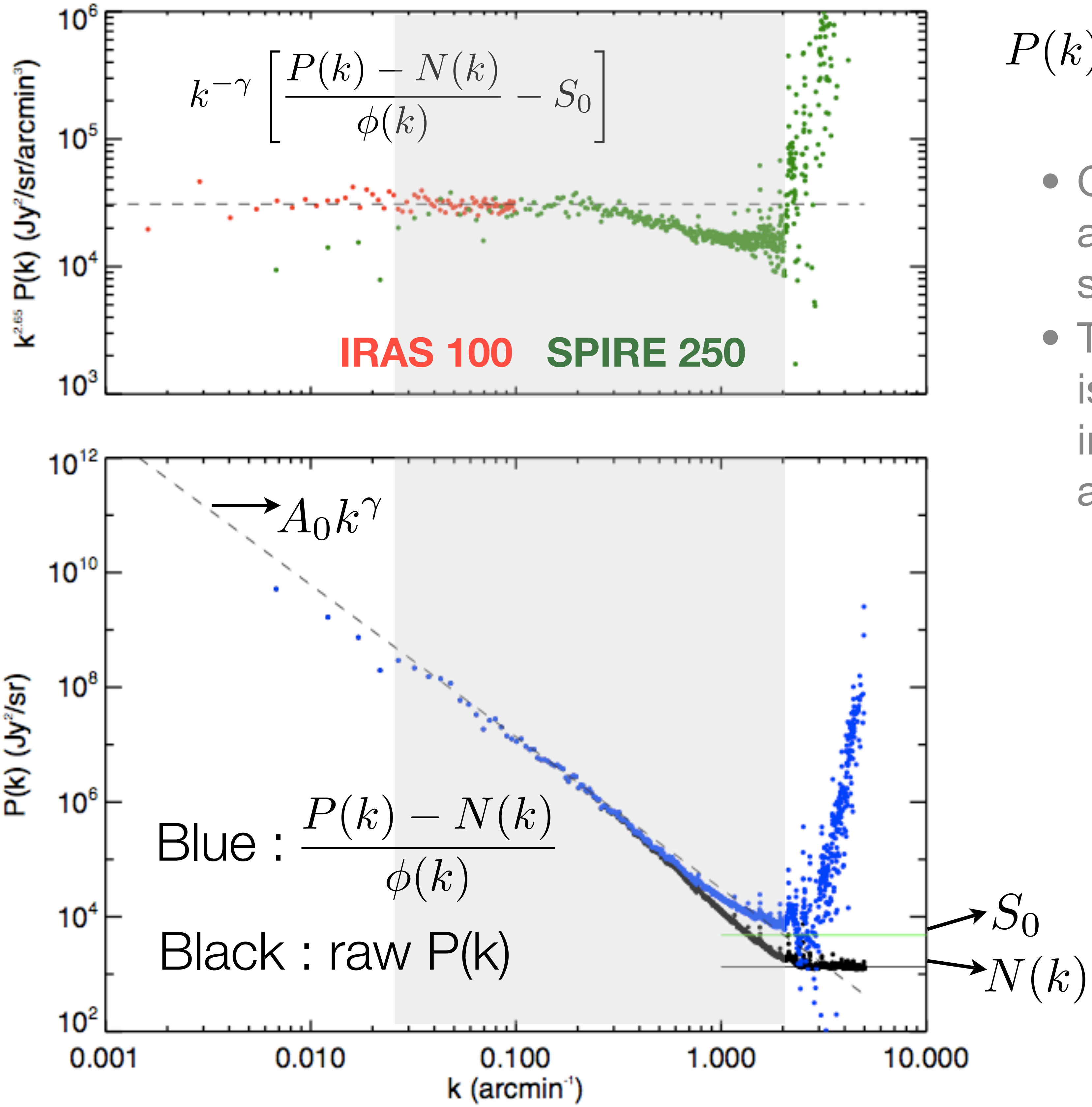
$$P(k) = \phi(k)[A_0 k^\gamma + S_0] + N(k)$$



λ (μm)	γ	S_0 ($Jy^2 sr^{-1}$)
250	-2.65 ± 0.10	$5 \pm 2 \times 10^3$
350	-2.69 ± 0.13	$4 \pm 2 \times 10^3$
500	-2.62 ± 0.17	$1 \pm 1 \times 10^3$

- Power spectrum slope
  - Compatible with previous estimates using CO and 100 micron emissions
  - Typical of molecular clouds
- Detection of a white term compatible with the expected level of the Cosmic Infrared Background Anisotropies (CIBA)

Power spectrum modelling : Gaussian PSF

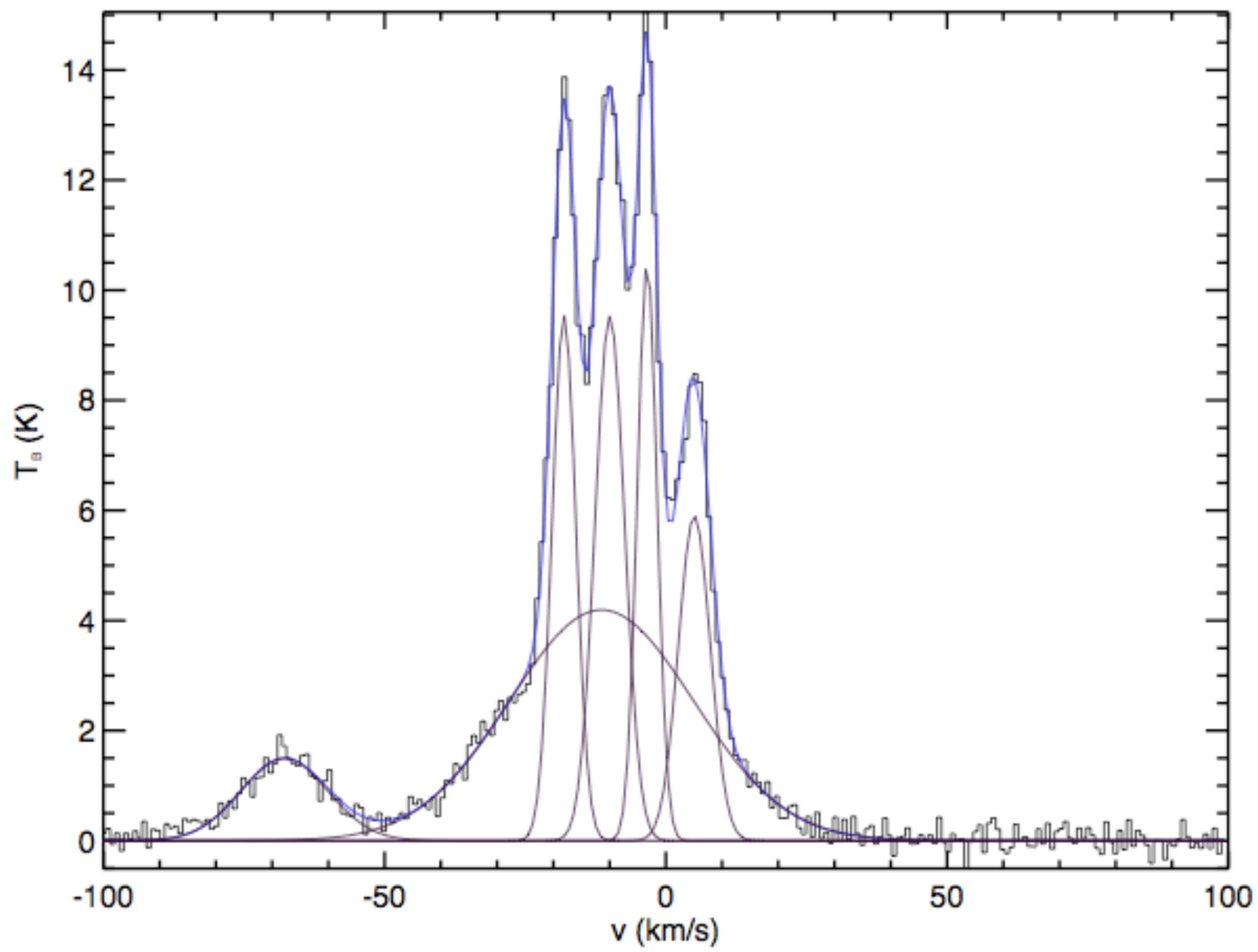


$$P(k) = \phi(k)[A_0 k^\gamma + S_0] + N(k)$$

- Gaussian beam is a bad approximation for power spectrum analysis
- The use of the measured beam is crucial : secondary lobes impact on the power estimate at arcmin scales

What is the density power spectrum of diffuse ISM ?

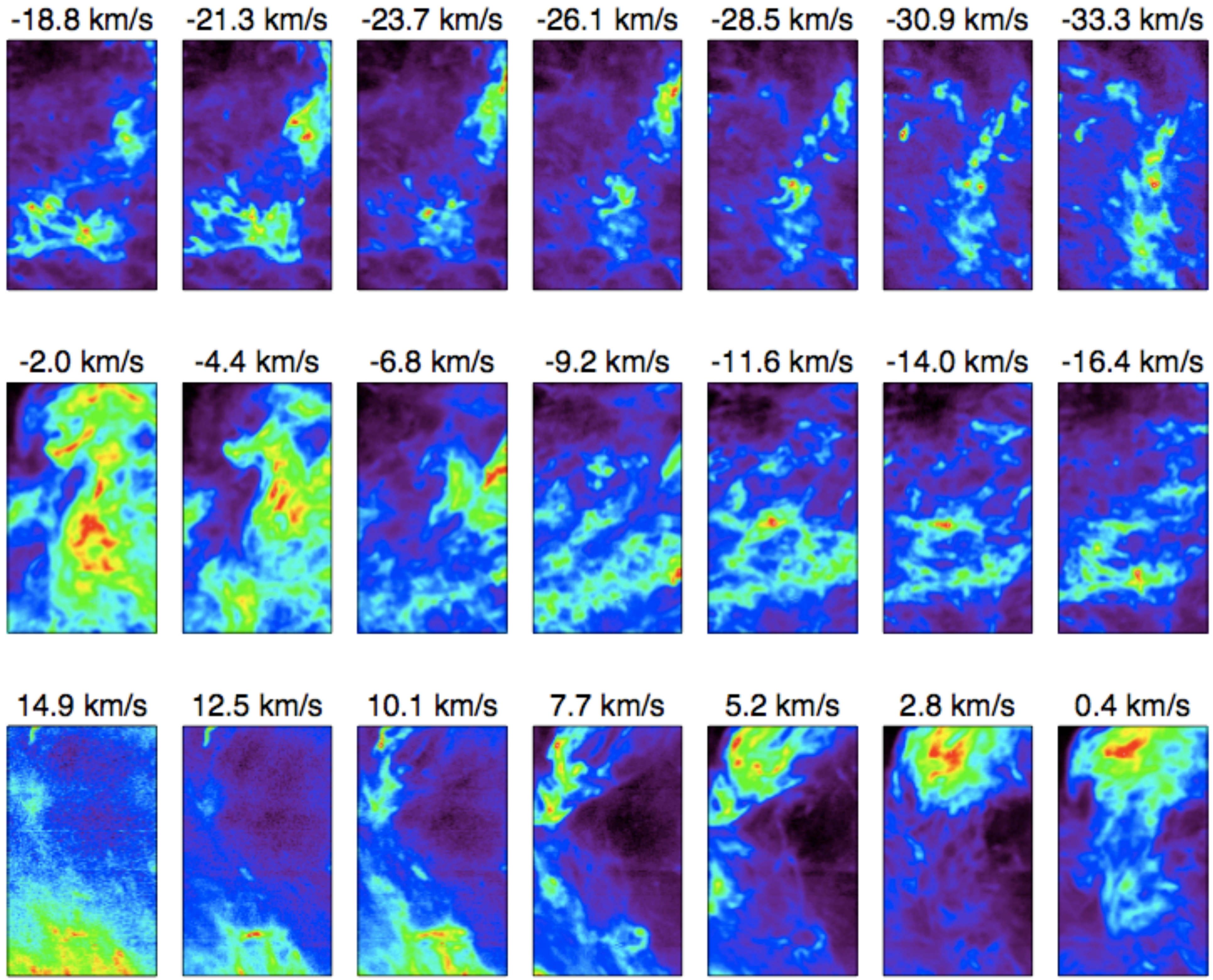
- A power spectrum of -2.7 is very different than subsonic, compressible turbulence (-3.7).
- **Supersonic** and/or **magnetic** turbulence can produce flatter (~ -3) density spectrum without a strong modification of the velocity spectrum
- **Thermal instability** : the local production of stable cold structure modifies dramatically the density structure of the flow.
    - The many narrow features on top of a smooth broad line is the sign of cold, spatially disconnected structures moving in the same velocity field as the warm gas.
    - The warm and cold phases probably do not have the same power spectrum.
- Detailed comparison with gas phase (21 cm, CO), polarization (Planck) and numerical simulations is needed.



A 21cm spectrum
of the Polaris flare cirrus
Miville-Deschenes et al. (in prep.)

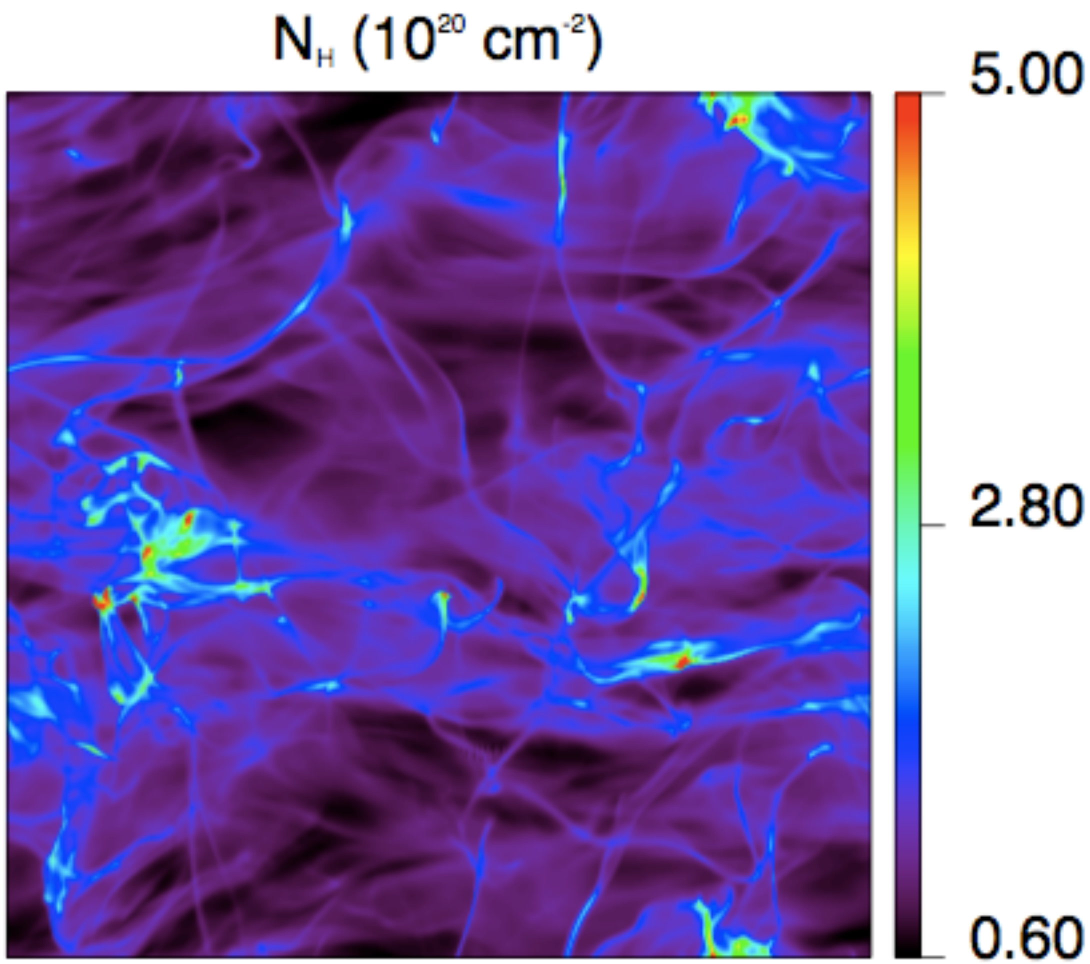
21 cm observations of Polaris

- Green Bank Telescope (9’ - this figure)
- DRAO (1 arcmin)

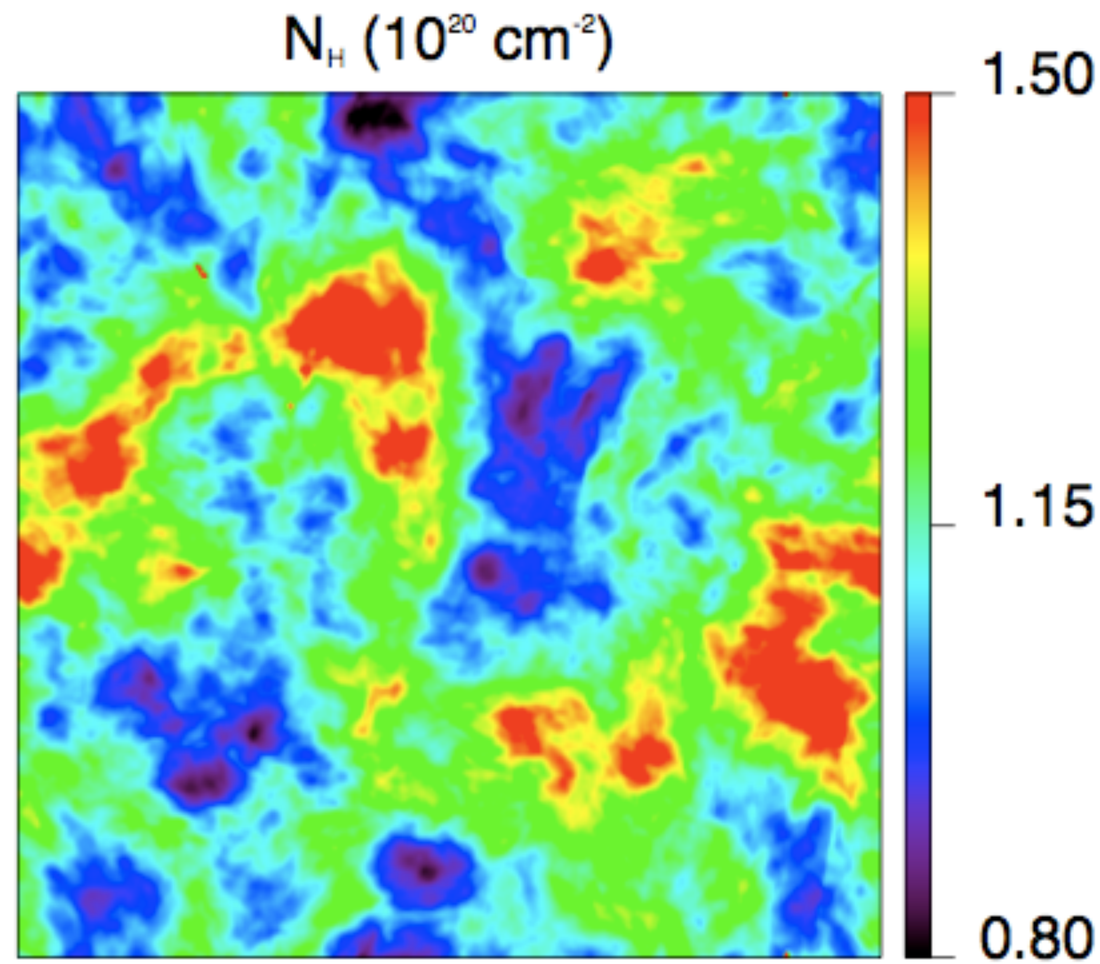


Illustrative comparison with MHD simulations

- Preliminary study of MHD simulations including the HI thermal instability (collaboration with Hennebelle & Audit).



<B>=5 microG, gamma~-2.5



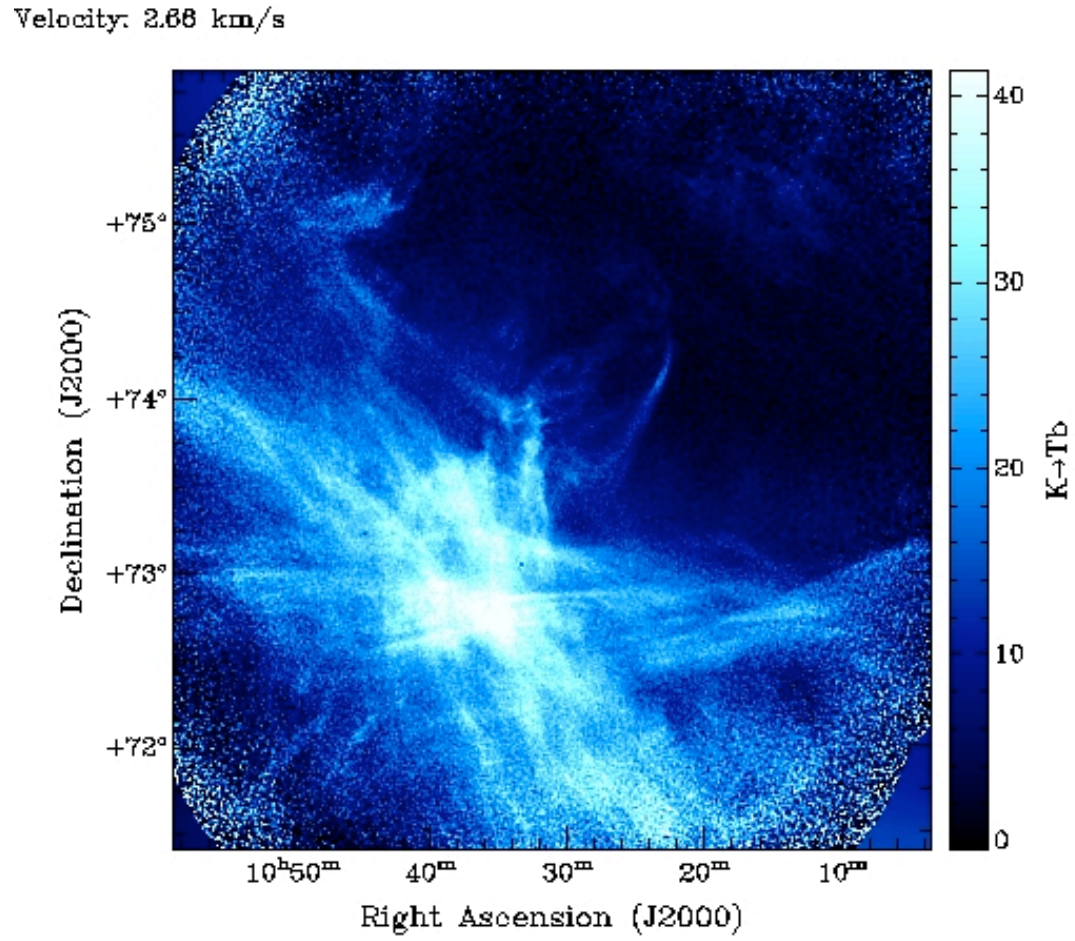
<B>=0 microG, gamma~-3.5

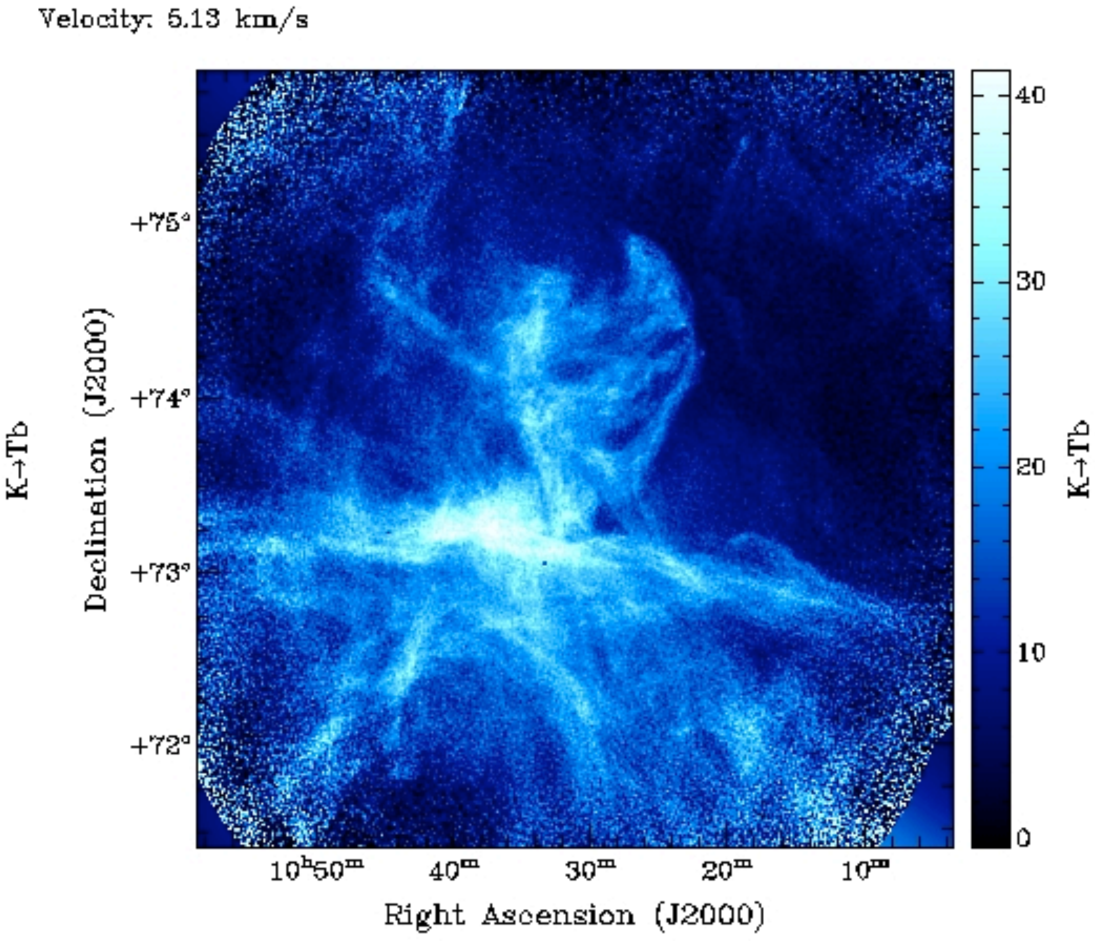
Conclusion

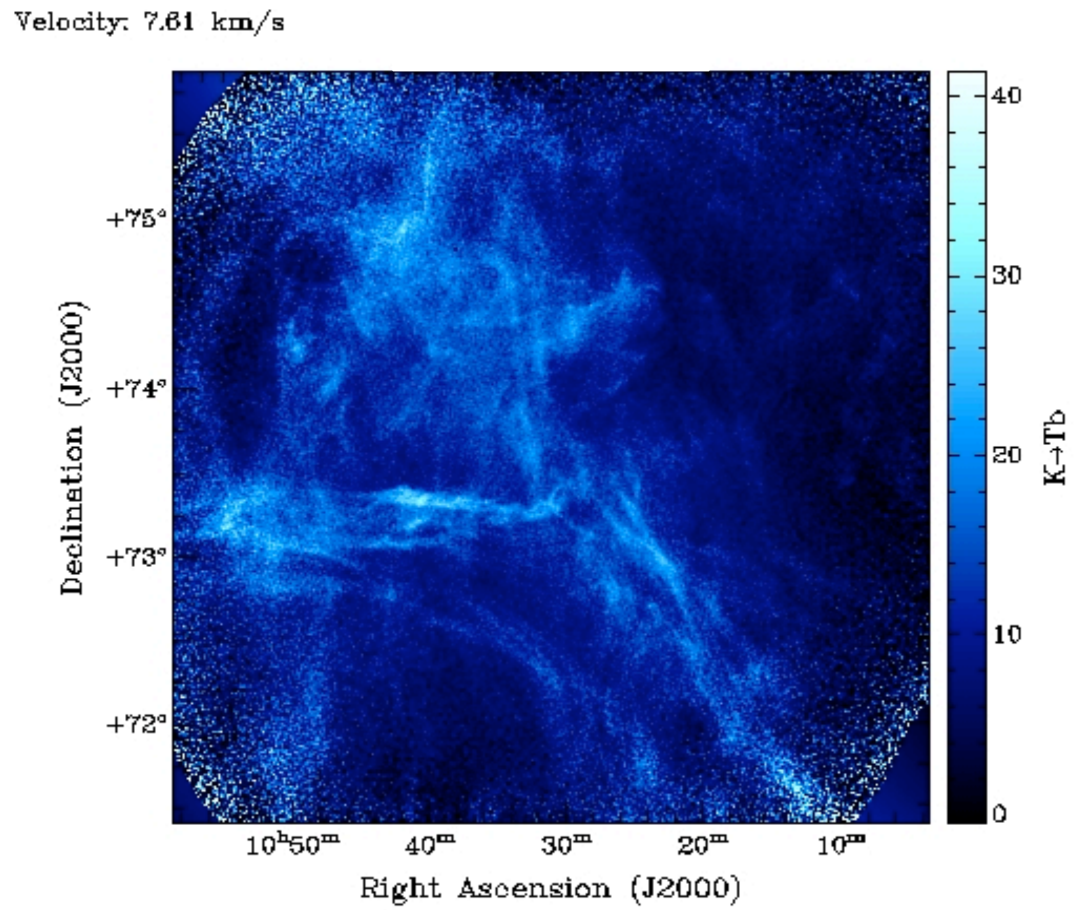
- First time the diffuse ISM is uniformly sampled from 0.01 to 8 pc : SPIRE provides an ideal opportunity to study the ISM structure which sets the initial conditions of the star formation

- Global understanding of the power spectrum features
  - SPIRE does not recover large scale diffuse emission perfectly yet but the quality of the data processing is excellent at such an early stage
  - SPIRE beam is significantly different than a Gaussian
  - Power spectrum slope (-2.7) seen in CO and 100 micron at large scales extends down to 30 arcsec (0.02 pc).
  - Marginal detection of the CIBA, in accordance with expectations

- Comparison with numerical simulations and 21 cm observations is ongoing : preliminary results shows the importance of the magnetic field





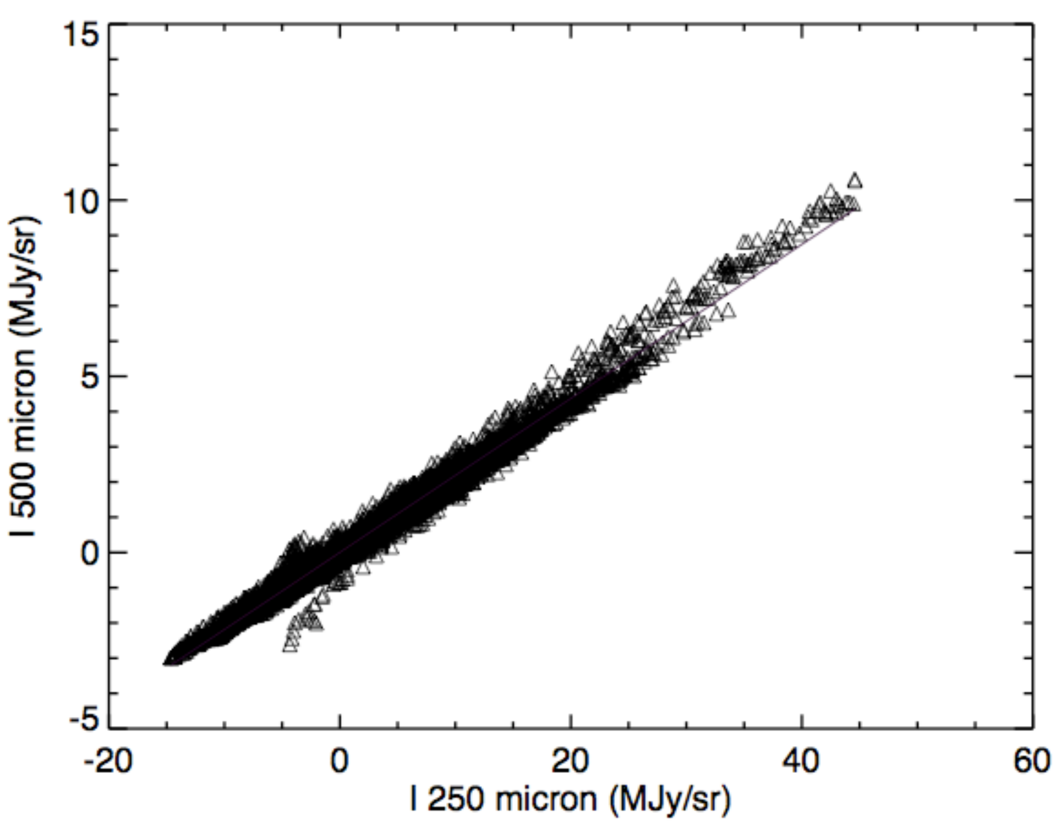


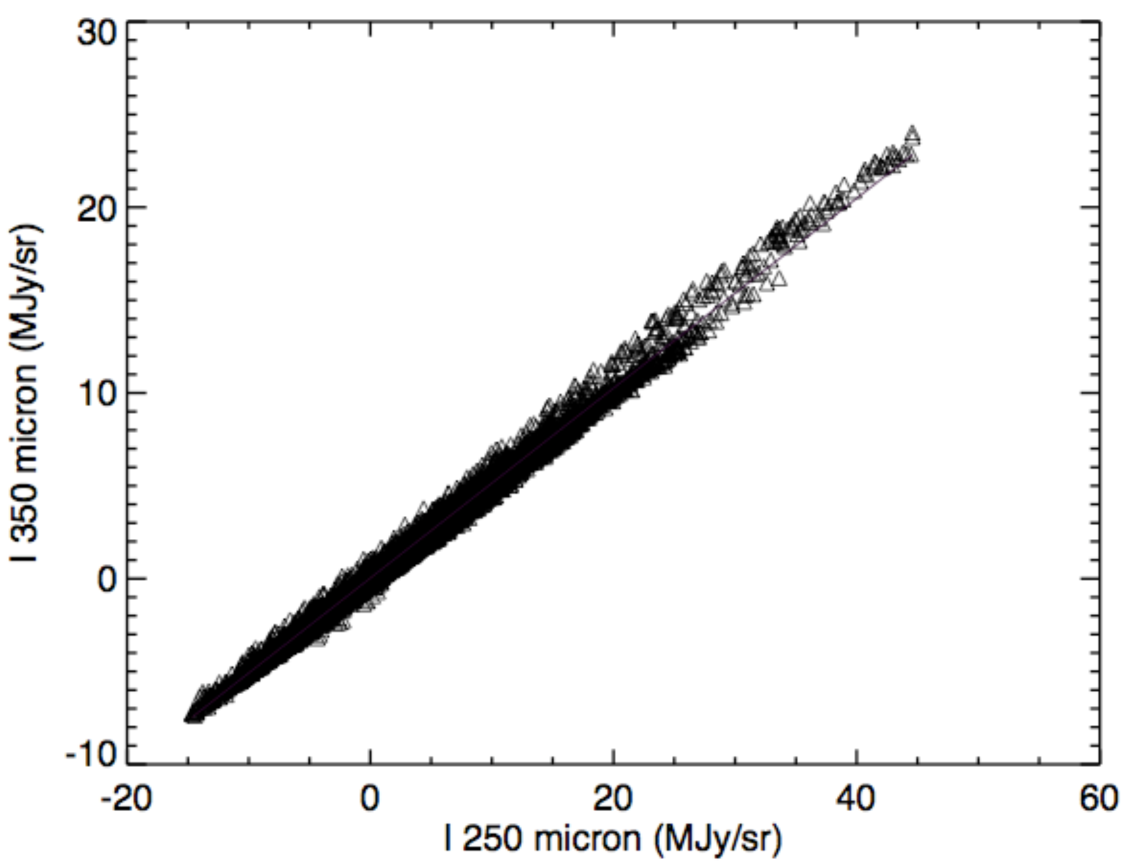
Filamentary structure of the diffuse HI:
magnetic turbulence ?

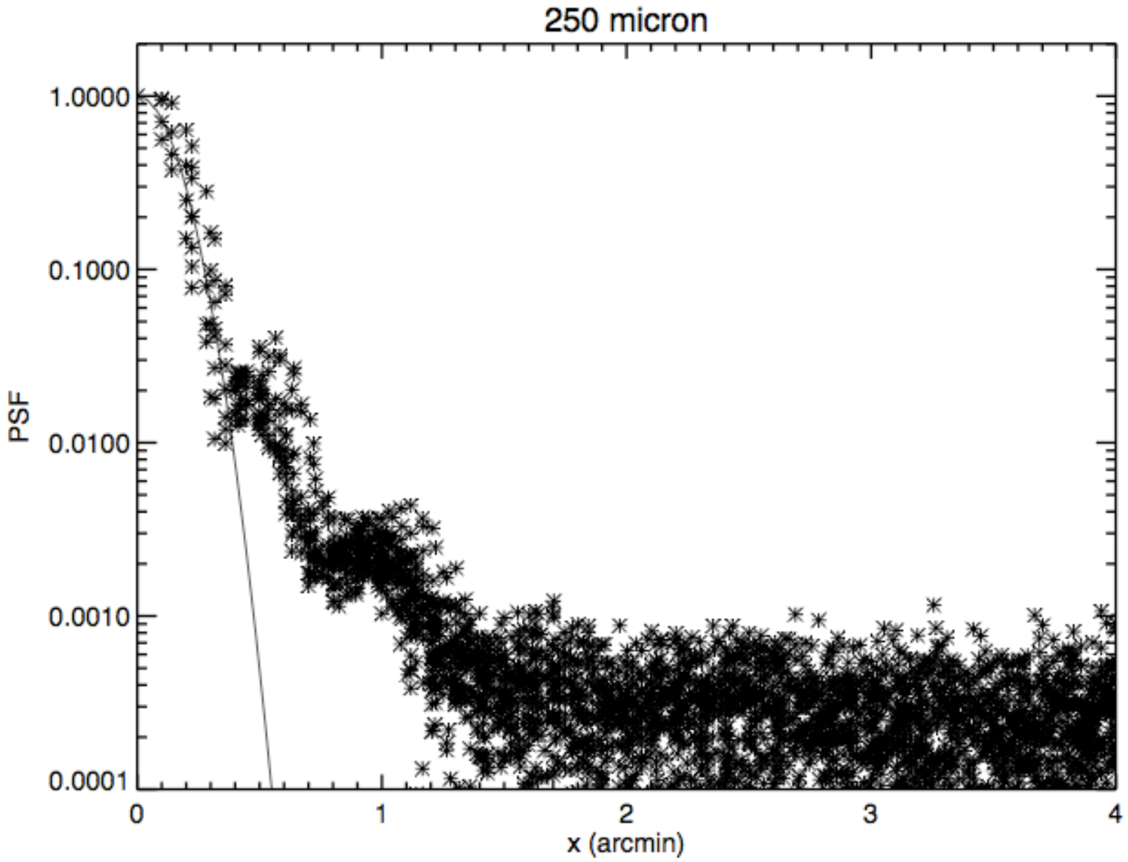
21 cm observations (DRAO)
Velocity channels only 2.6 km/s apart

Martin et al. (in preparation)

SPIRE-SPIRE correlation at 5 arcmin







- Total(Beam)/total(Gaussian)
  - 250 micron : 1.35
  - 350 micron : 1.31
  - 500 micron : 1.25