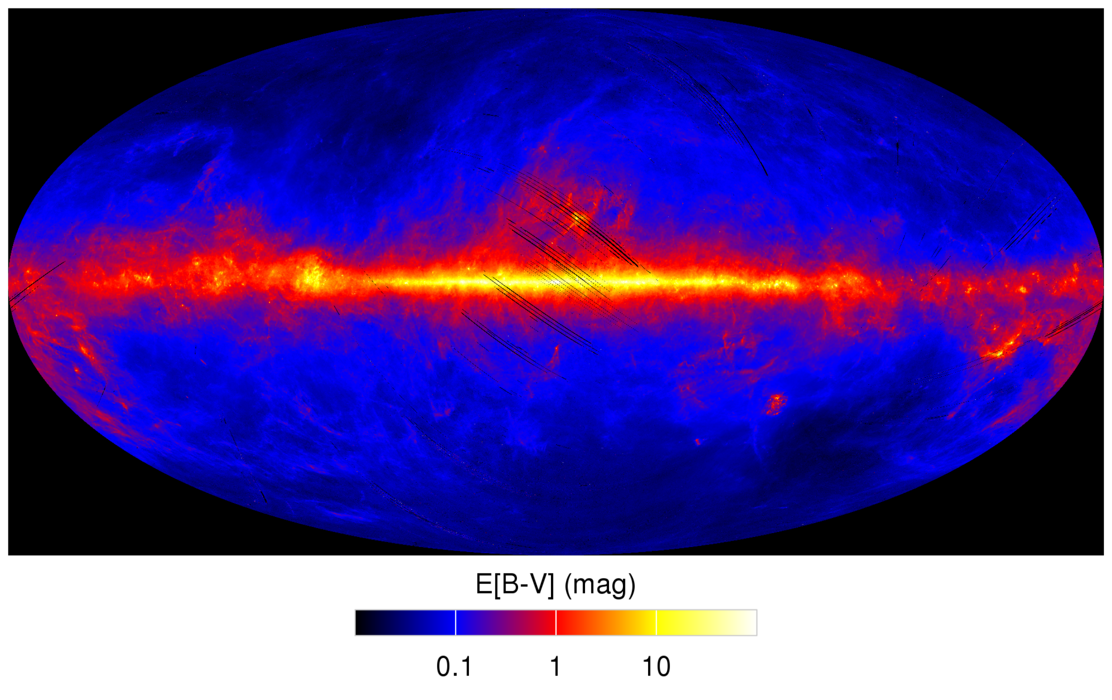
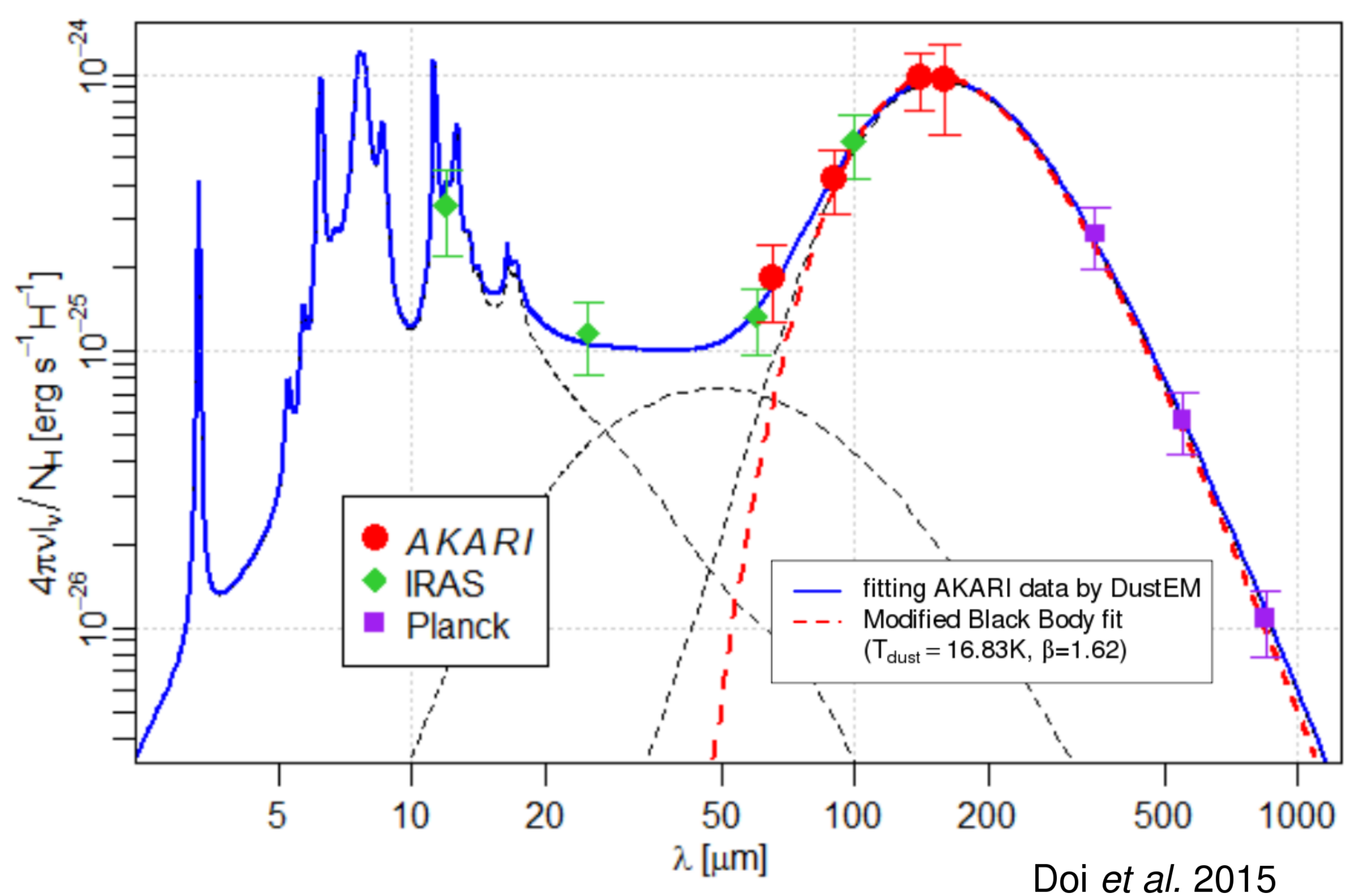
ISM Structures Traced by AKARI FIR All-Sky Dust Map



Yasuo Doi[1], T. Ootsubo[2], S. Takita[2], T. Nakagawa[2], M. Kawada[2], Y. Kitamura[2], S. Matsuura[3], M. Hattori[4], M. Tanaka[5] [1]U. of Tokyo, [2]ISAS, [3]Kwansei U., [4]Tohoku U., [5]Tsukuba U.

FIR dust map from AKARI data

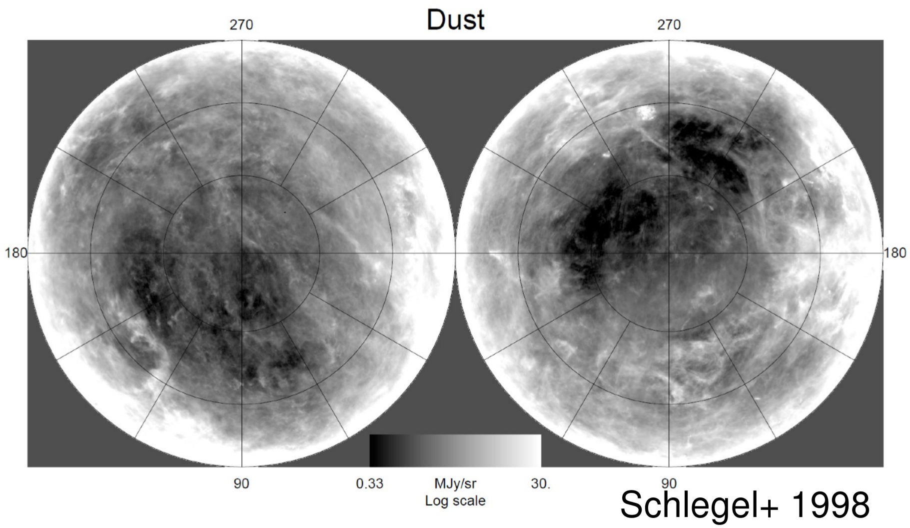
- 90μm, 140μm $\rightarrow T_{col}, \tau$, radiance
  - β: fixed or refer Planck data, etc.
- Model SED fit by DustEM, etc.



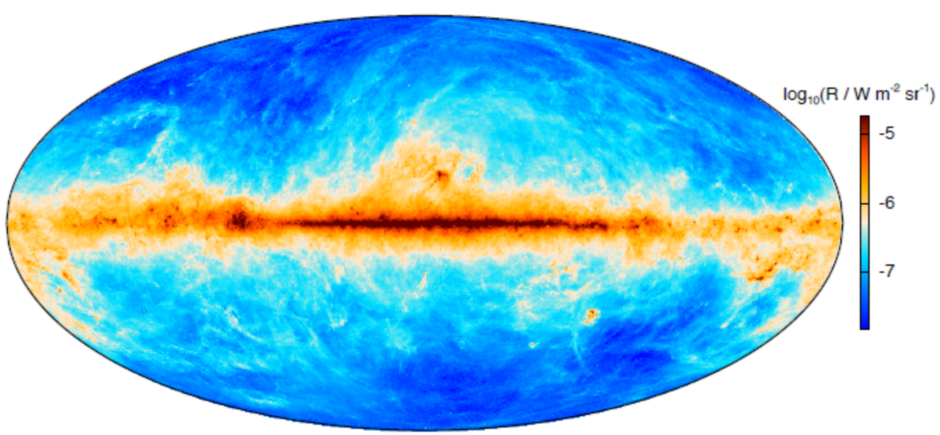
Doi *et al.* 2015

Other FIR dust maps

- SFD : IRAS $5'$ + T_{DIRBE} $60'$
- IRAS + Planck : $5'$
- *cf.* AKARI: $1'$~$2'$

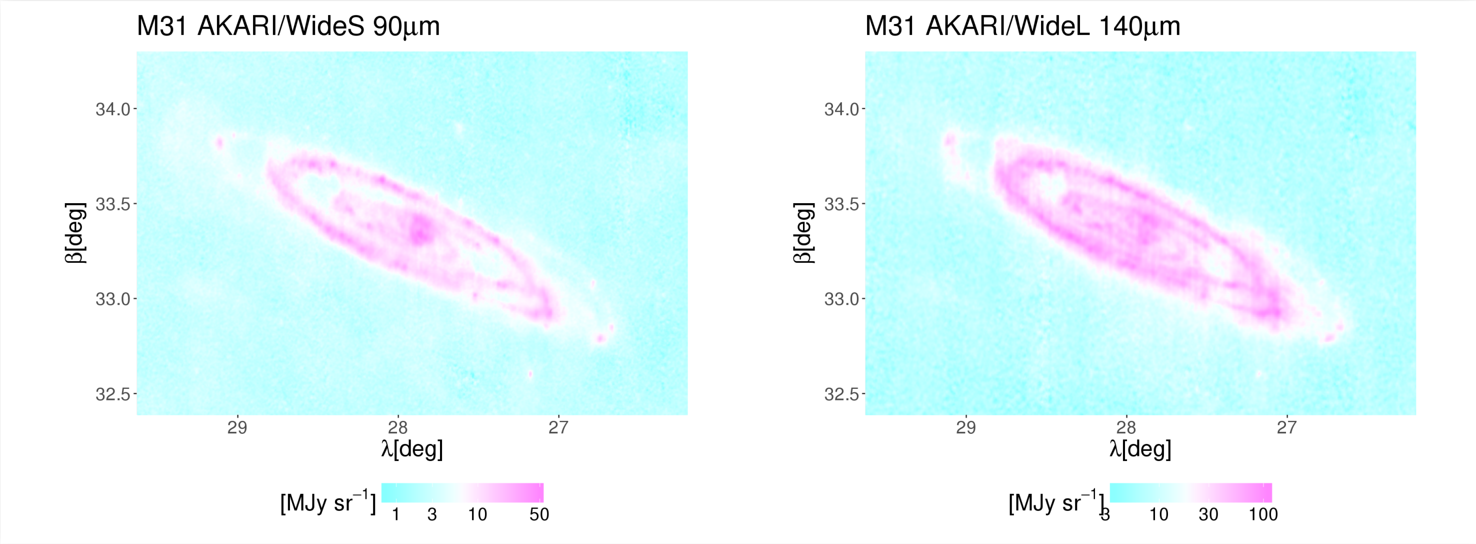


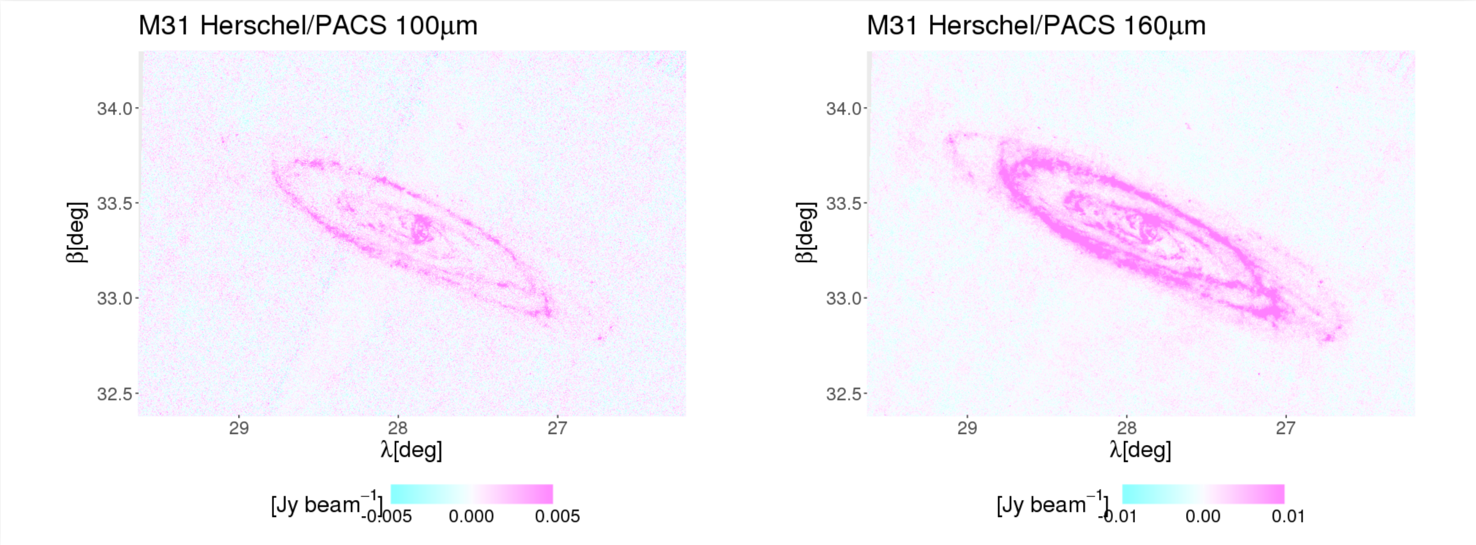
Schlegel+ 1998



Miville-Deschênes+ 2014

M31 AKARI & Herschel images





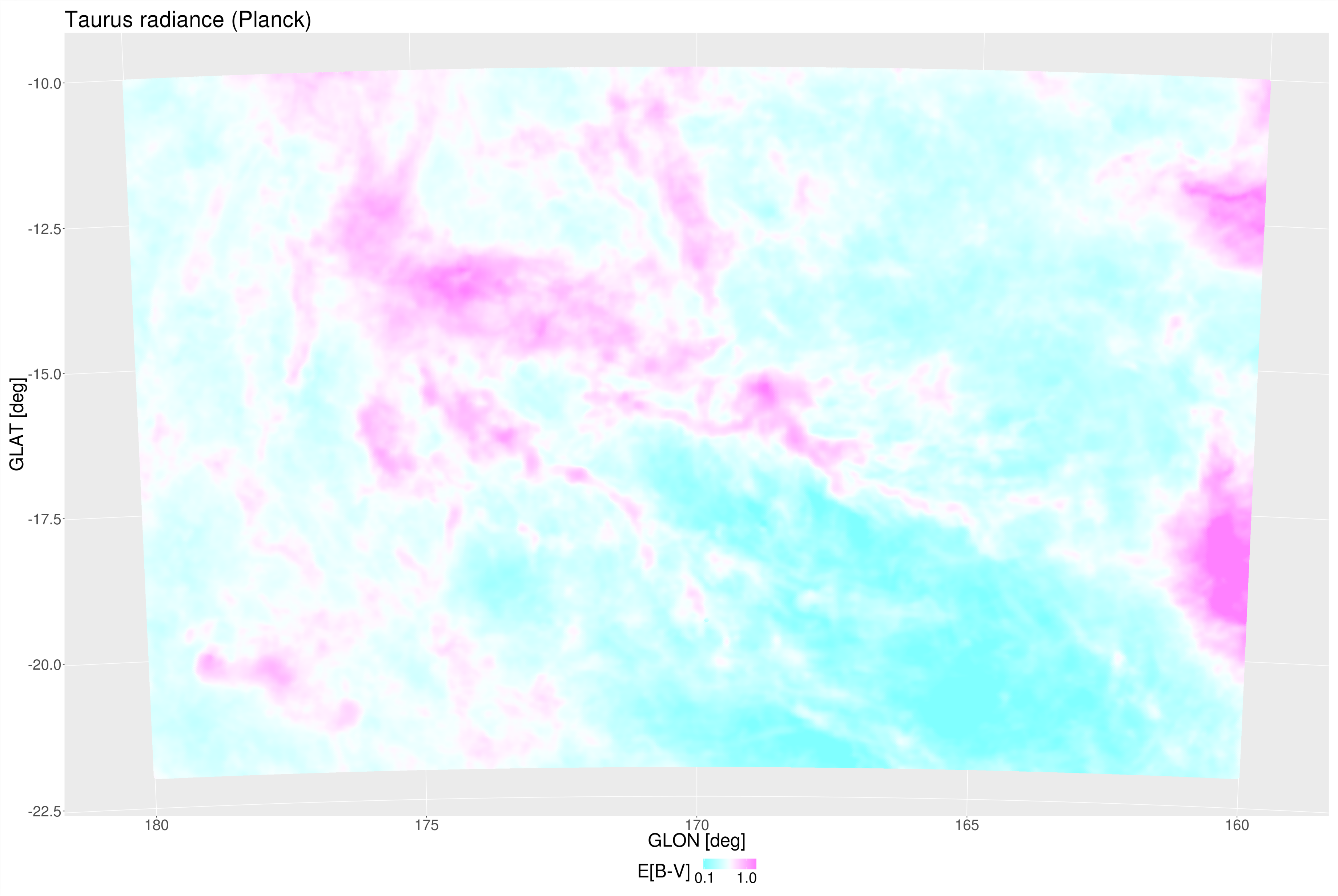
Dust map evaluation

- β: refer Planck data (resolution: $30'$)
- Intensity ratio between 90μm and 140μm $\rightarrow$ T_{col}
- $T_{col}, I_{90\mu m} \rightarrow \tau$
- $T_{col}, \tau, \beta \rightarrow$ radiance $\mathcal{R}$

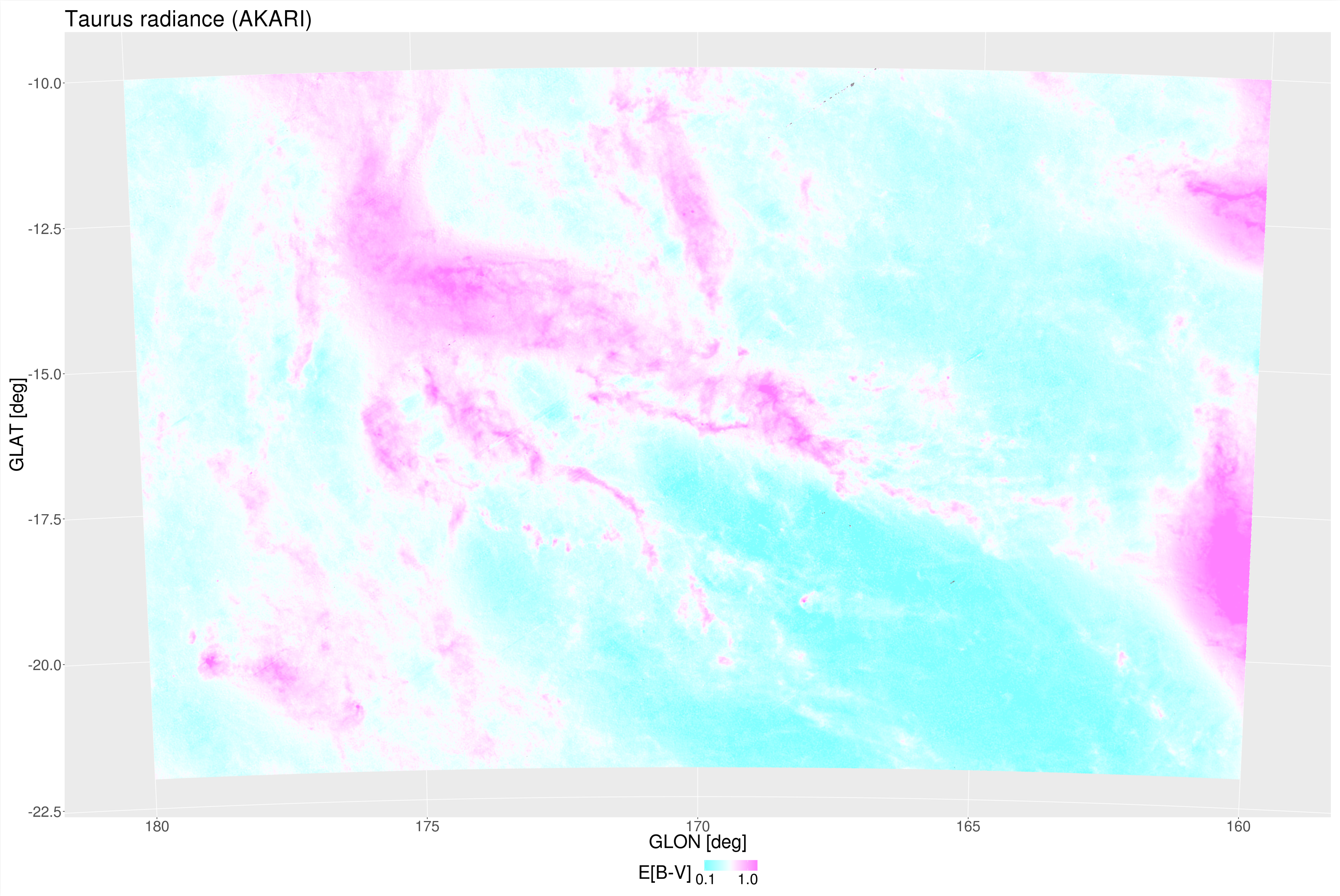
$$\mathcal{R} = \int_\nu I_\nu d\nu = \int_\nu \tau_{\nu_0} B_\nu(T_{col}) \left(\frac{\nu}{\nu_0}\right)^\beta$$

$$= \tau_{\nu_o} \frac{\sigma_s}{\pi} T_{col}^4 \left(\frac{kT_{col}}{h\nu_0}\right)^\beta \frac{\Gamma(4+\beta)\zeta(4+\beta)}{\Gamma(4)\zeta(4)}$$

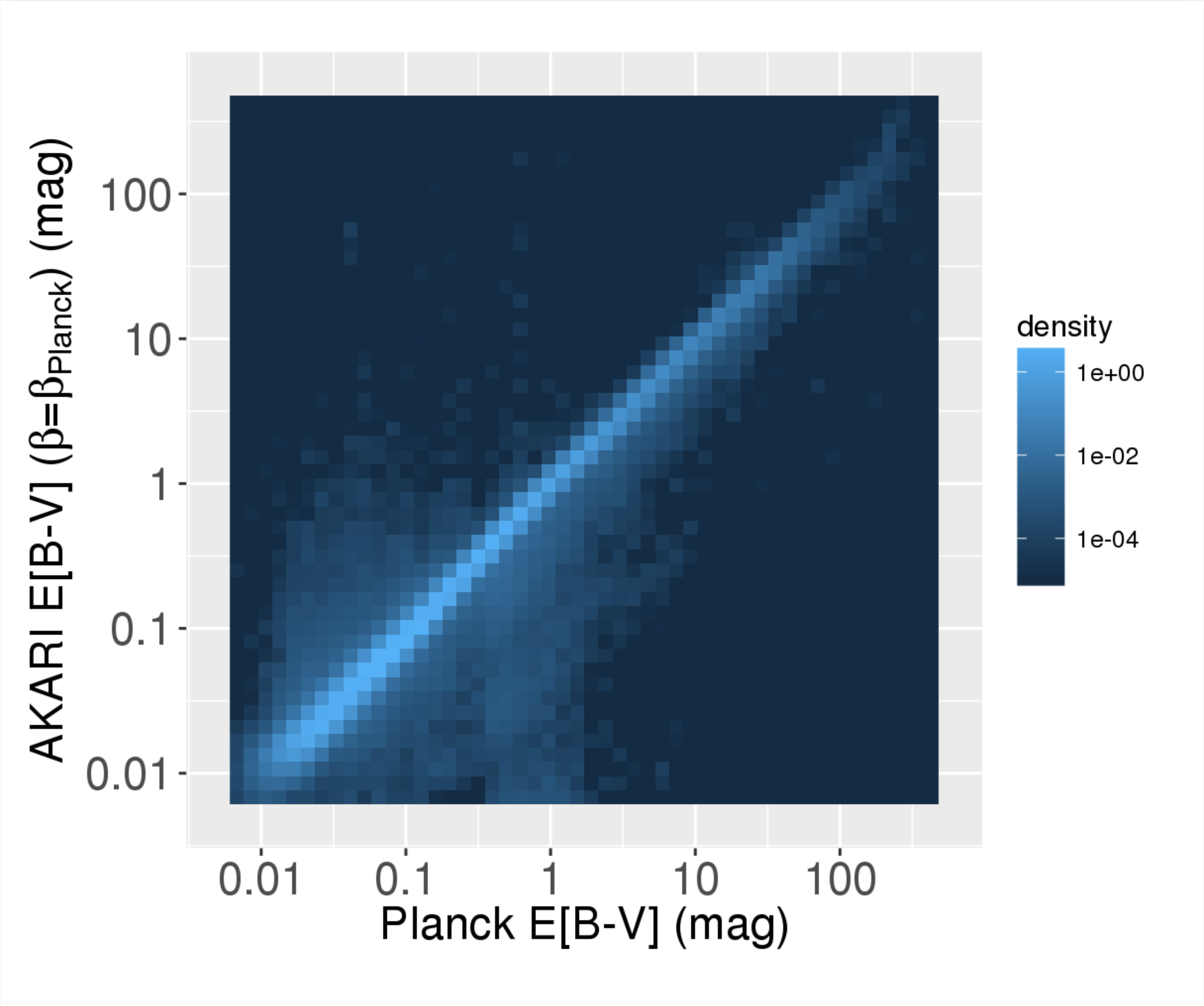
Taurus dust map: Planck



Taurus dust map: AKARI

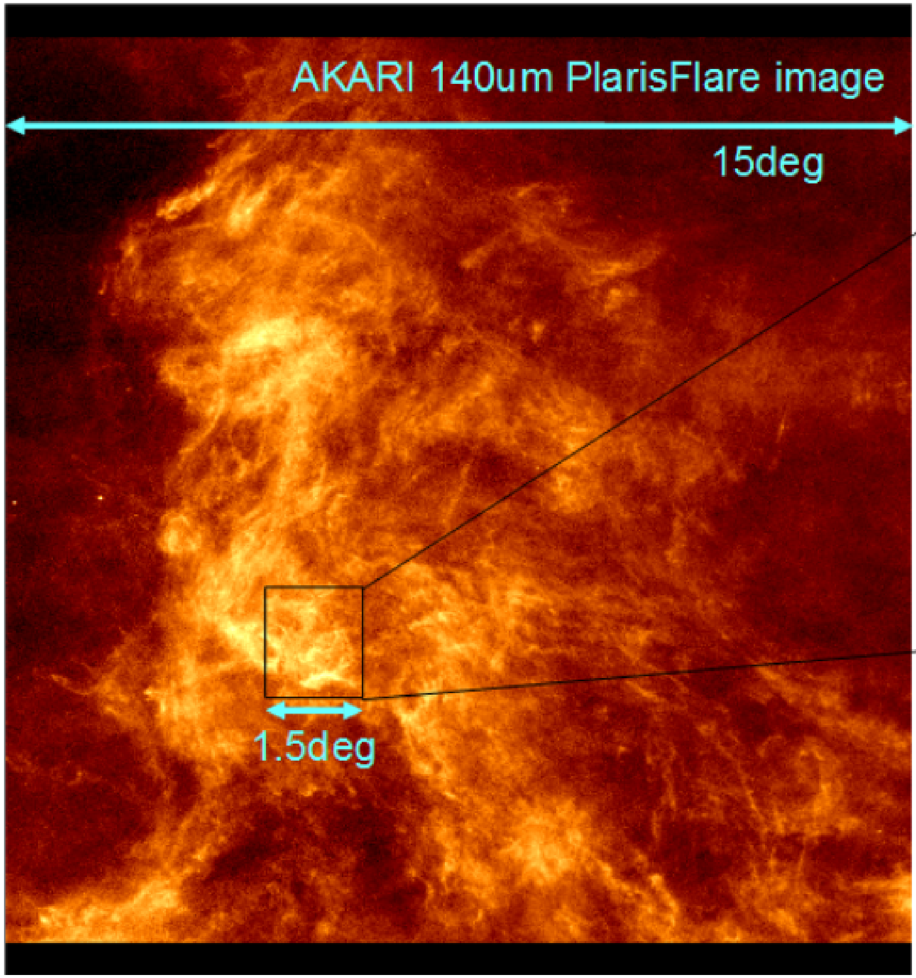


AKARI vs. Planck E[B-V]



Omnipresence of ISM filaments

One of the key findings of Herschel



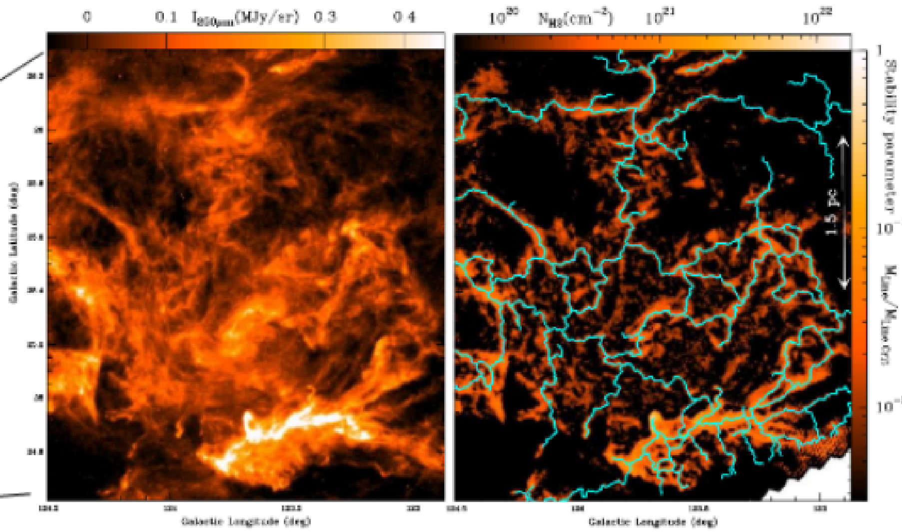


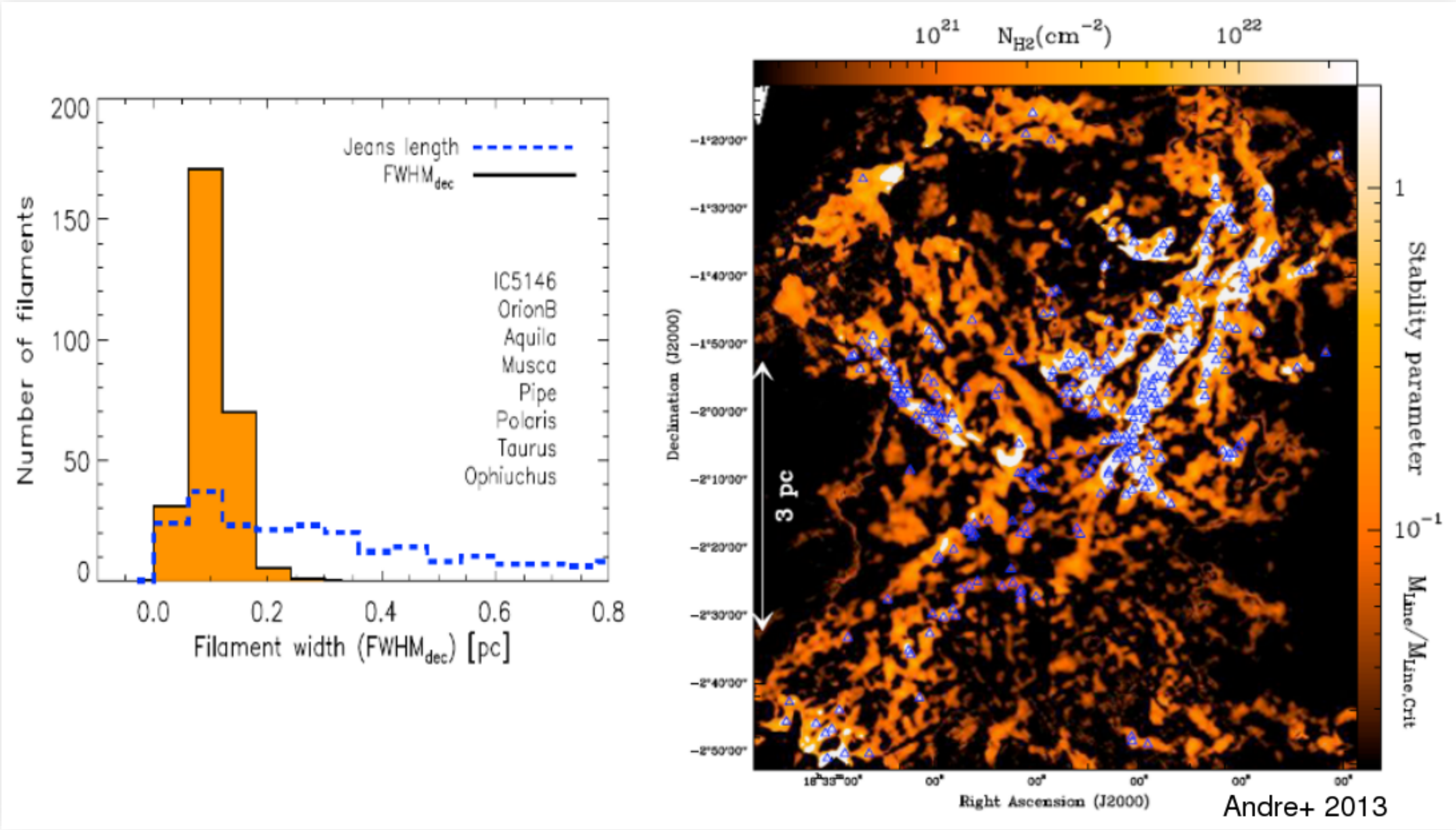
Figure 1. Left: *Herschel*/SPIRE 250 μm dust continuum map of a portion of the Polaris flare translucent cloud ($d \sim 150$ pc) taken as part of the HGBS survey (e.g. Miville-Deschênes et al. 2010, Ward-Thompson et al. 2010). **Right:** Corresponding column density map derived from *Herschel* data (André et al. 2010). The contrast of the filaments has been enhanced using a curvelet transform (cf. Starck et al. 2003). The skeleton of the filament network identified with the DisPerSE algorithm (Sousbie 2011) is shown in light blue. Given the typical filament width ~ 0.1 pc (Arzoumanian et al. 2011 – see Fig. 4 below), this column density map is equivalent to a *map of the mass per unit length along the filaments* (see color scale on the right).

Arzoumanian+ 2011

Filaments and star formation activities

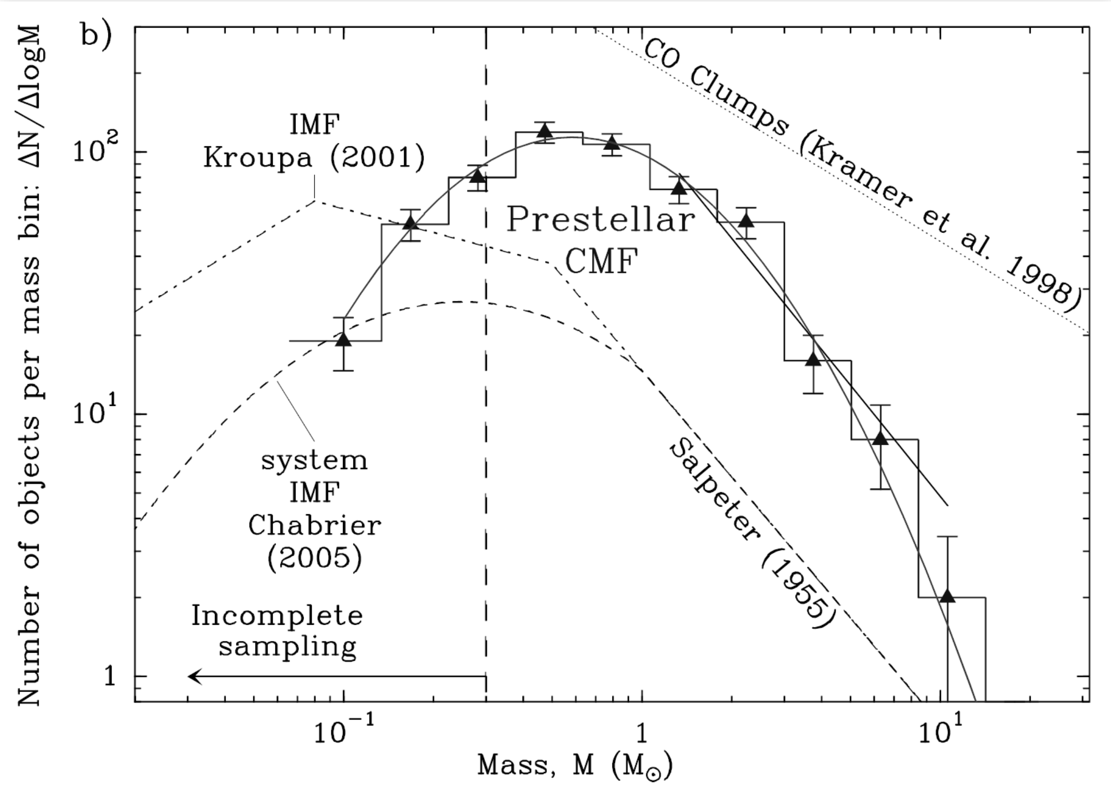
"universal" ~ 0.1pc width of the filaments

$> 70\%$ prestellar cores found in filaments



Mass Function of Dense Cores

Aquila CMF obs. by Herschel

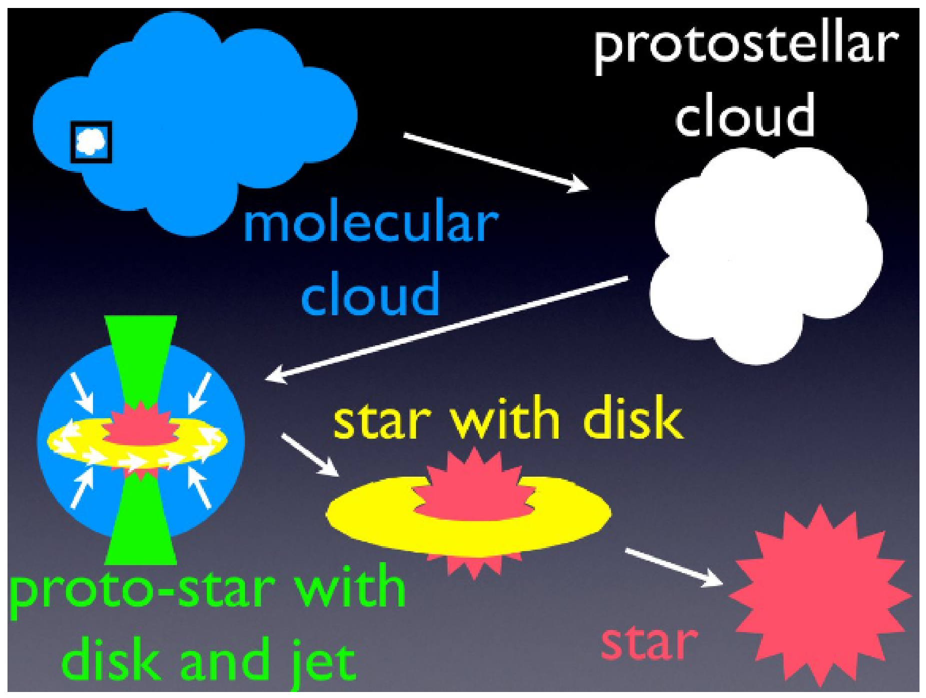


(Könyves *et al*. 2010; André *et al*. 2010)

Filament formation – a 'missing link' in the star formation processes

From $\sim$ 100pc GMCs to $<$ 0.1pc prestellar cores

A giant leap in the spatical scale



http://www.astro.washington.edu/users/sjschmidt/A101/lectures.html

Necessity for the large spatial dynamic range in the observations

From > 100pc GMCs to < 0.1pc prestellar cores

$> 10^3$ difference in spatial scales

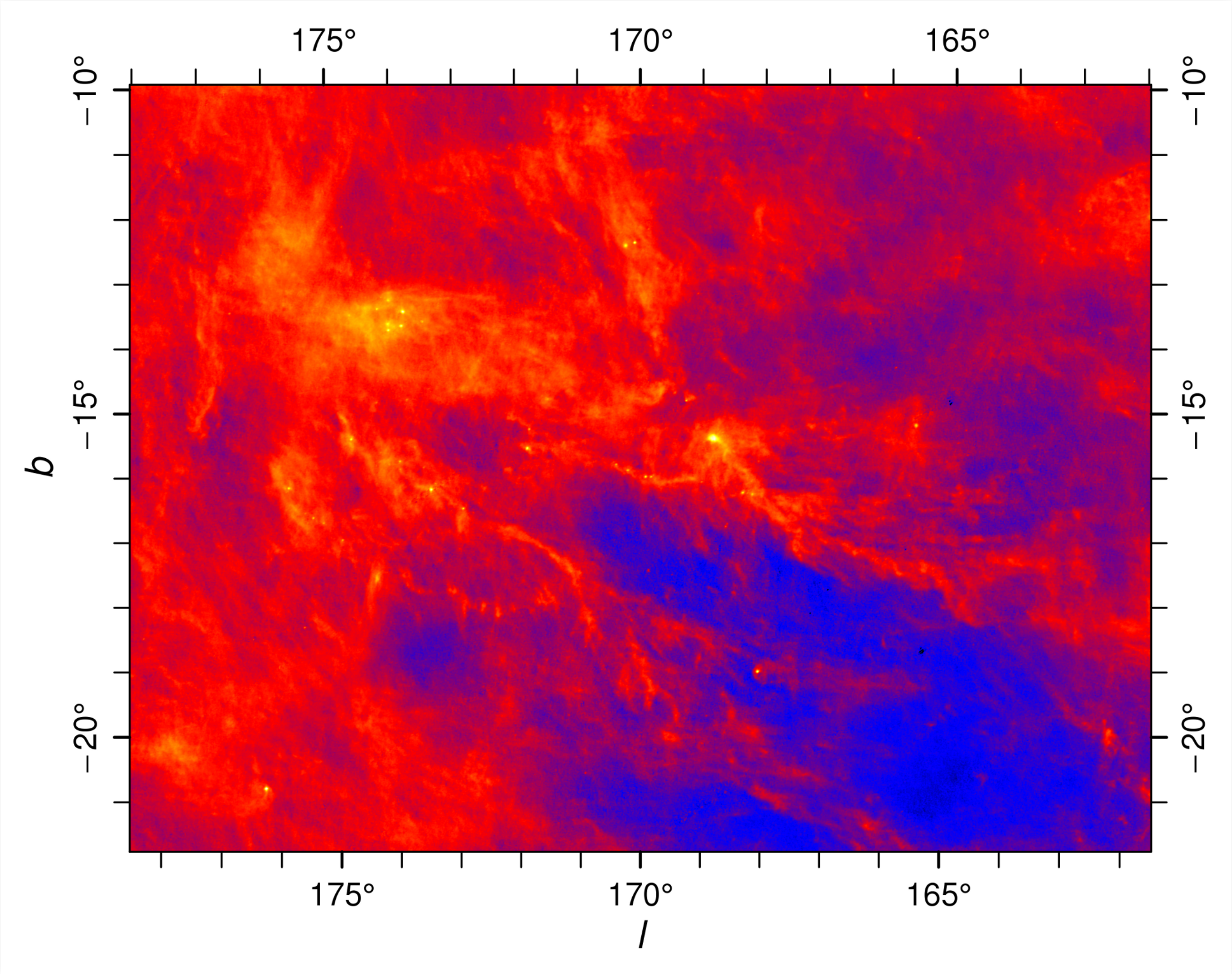
Obs. with high spatial resolution & spatially extended emission – "spatial dynamic range"

↓

Advantage of the AKARI All-sky Survey

Filament extraction @ Taurus

Filament typical width: ~ 0.1 pc $\Leftrightarrow 2.5'$ @ 140pc



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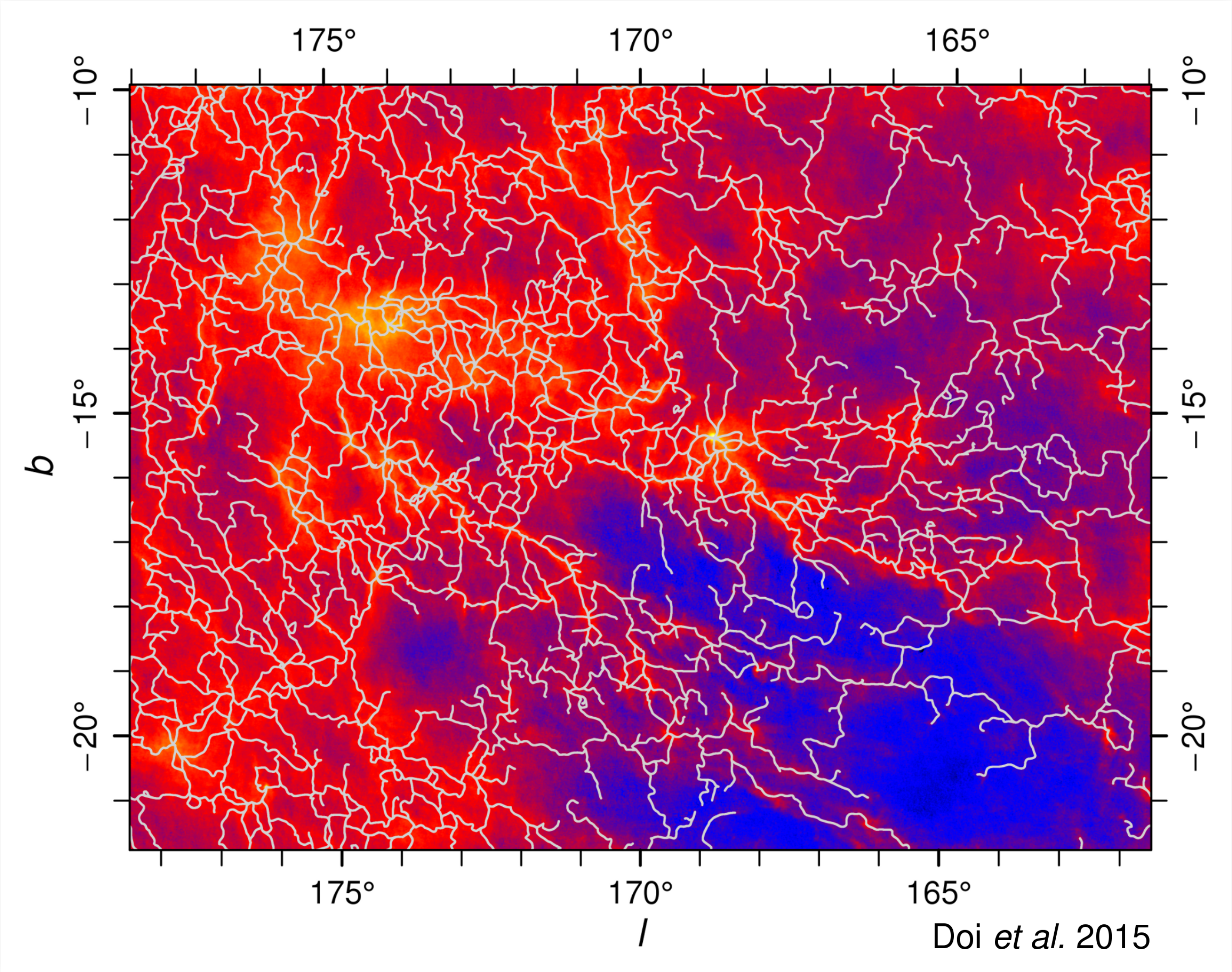


Filament extraction methods

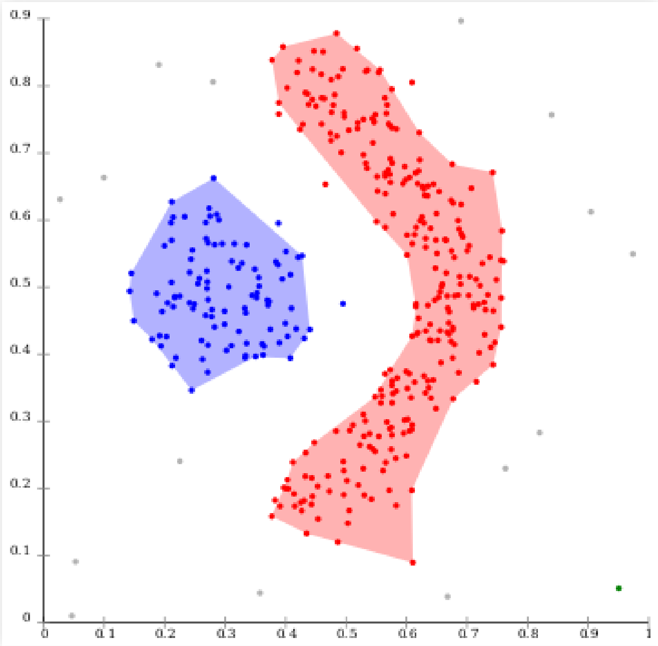
- DisPerSE (Sousbie, 2011, MNRAS, 414, 350)
- Rolling Hough Transform (RHT; Clark et al. 2014 ApJ 789, 82)
- FilFinder (Koch et al. 2015, MNRAS, 452 (4), 3435)

These methods extract linearly elongated structure by design -- omit detailed structure of ISM.

ISM structure identification

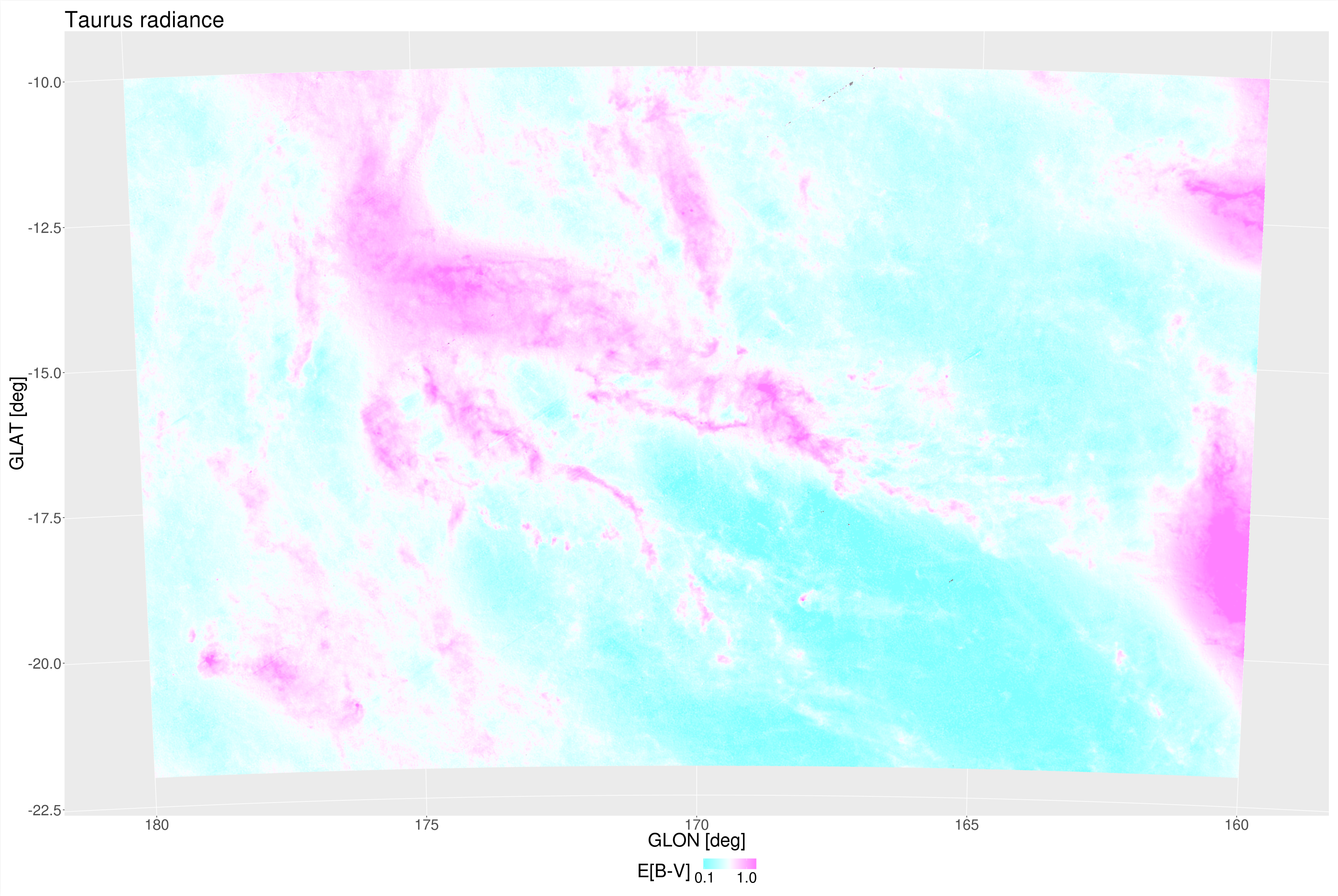
density-based clustering method

- estimate surface density of data points
- find data points above a threshold value
- background noise can be eliminated
- structure of clusters is not presupposed

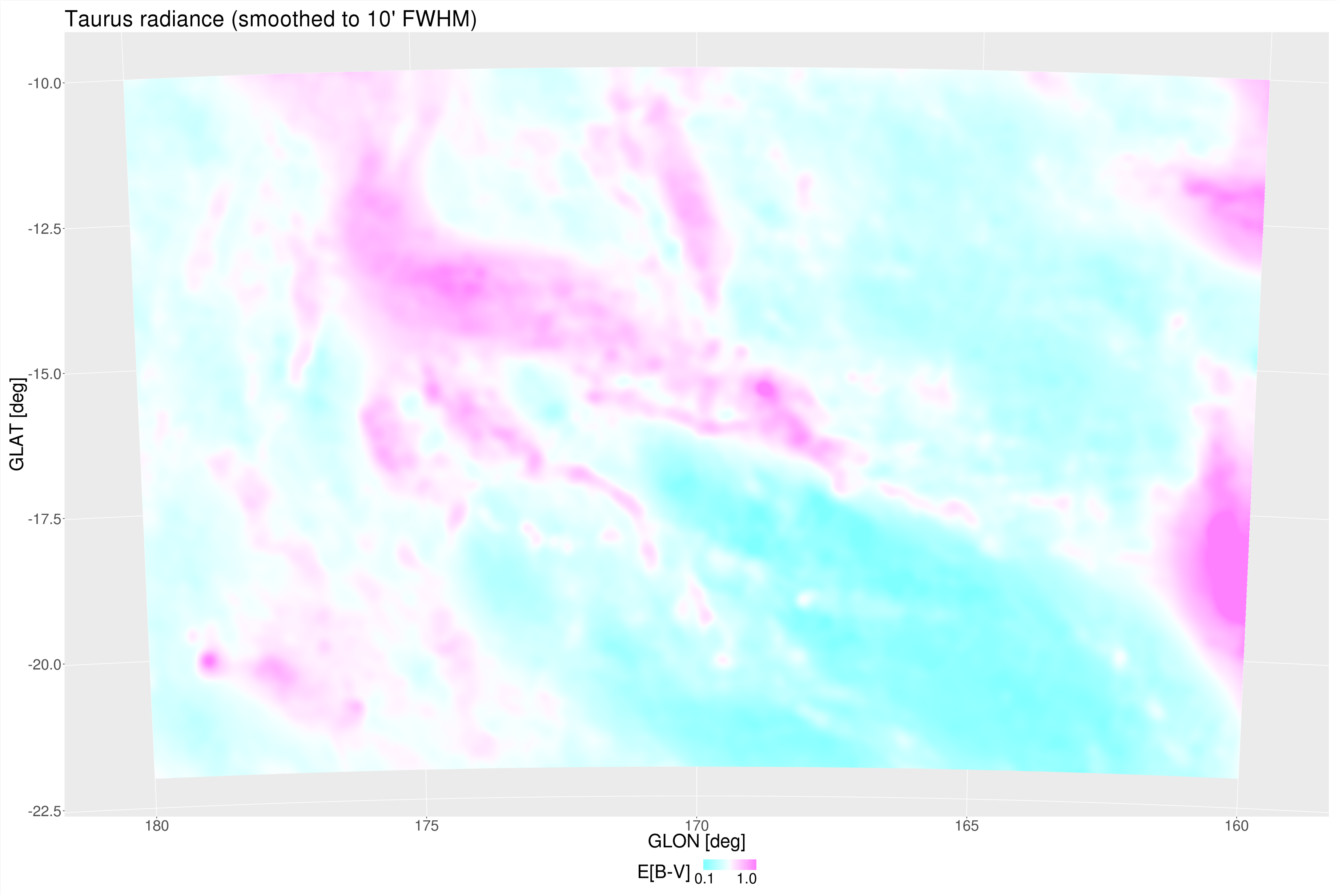


(image from Wikipedia)

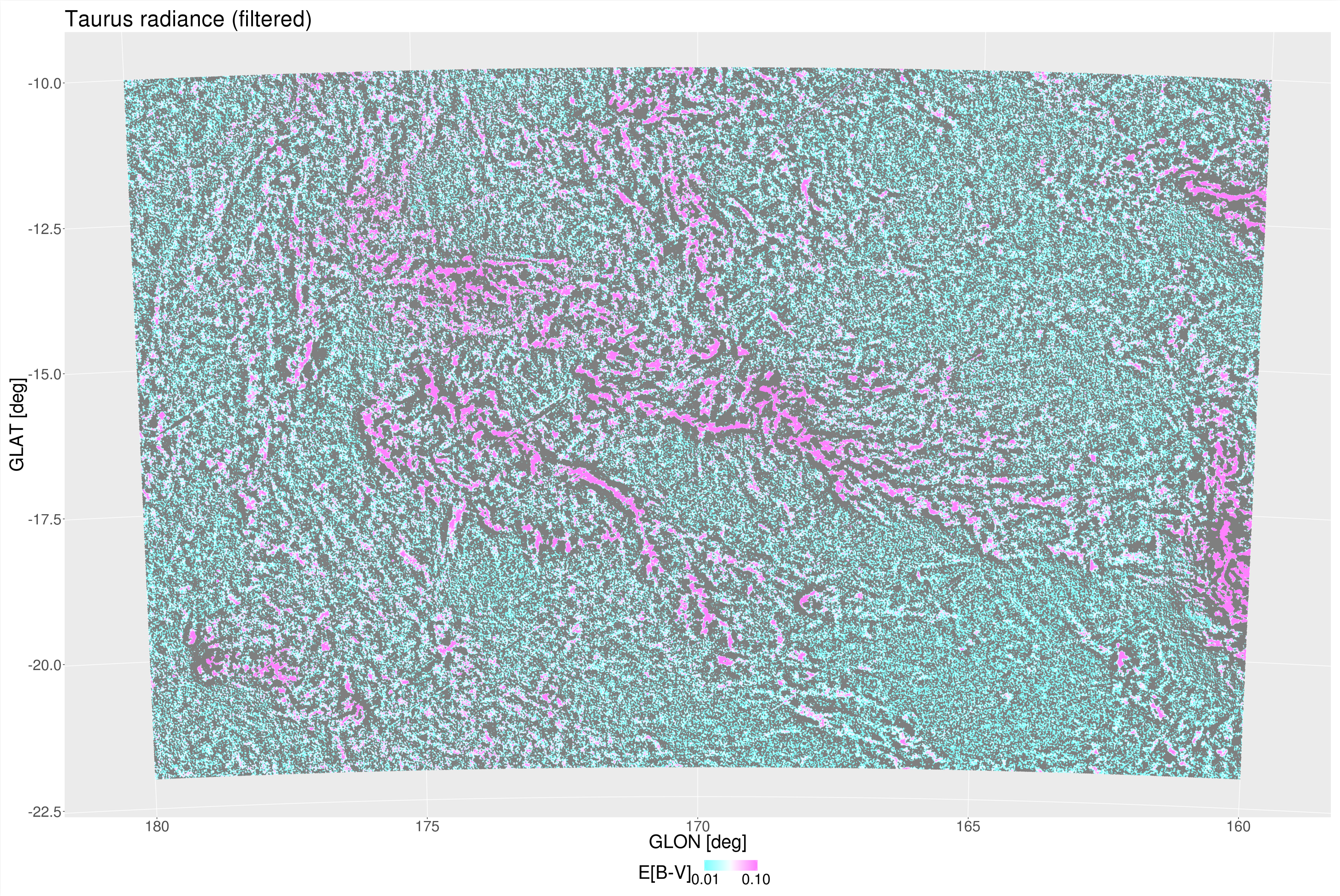
ISM structure identification in Taurus



ISM structure identification in Taurus



ISM structure identification in Taurus



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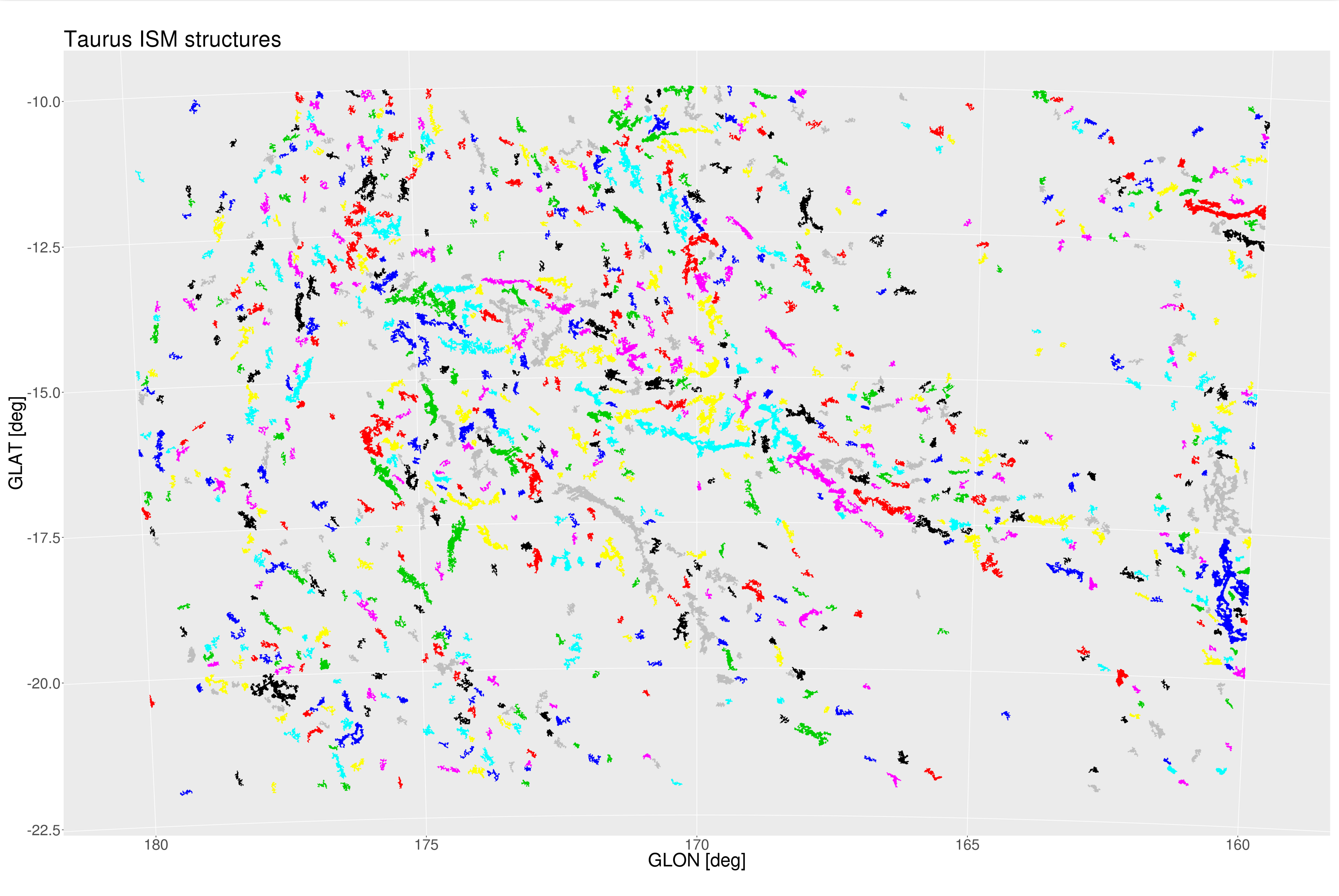
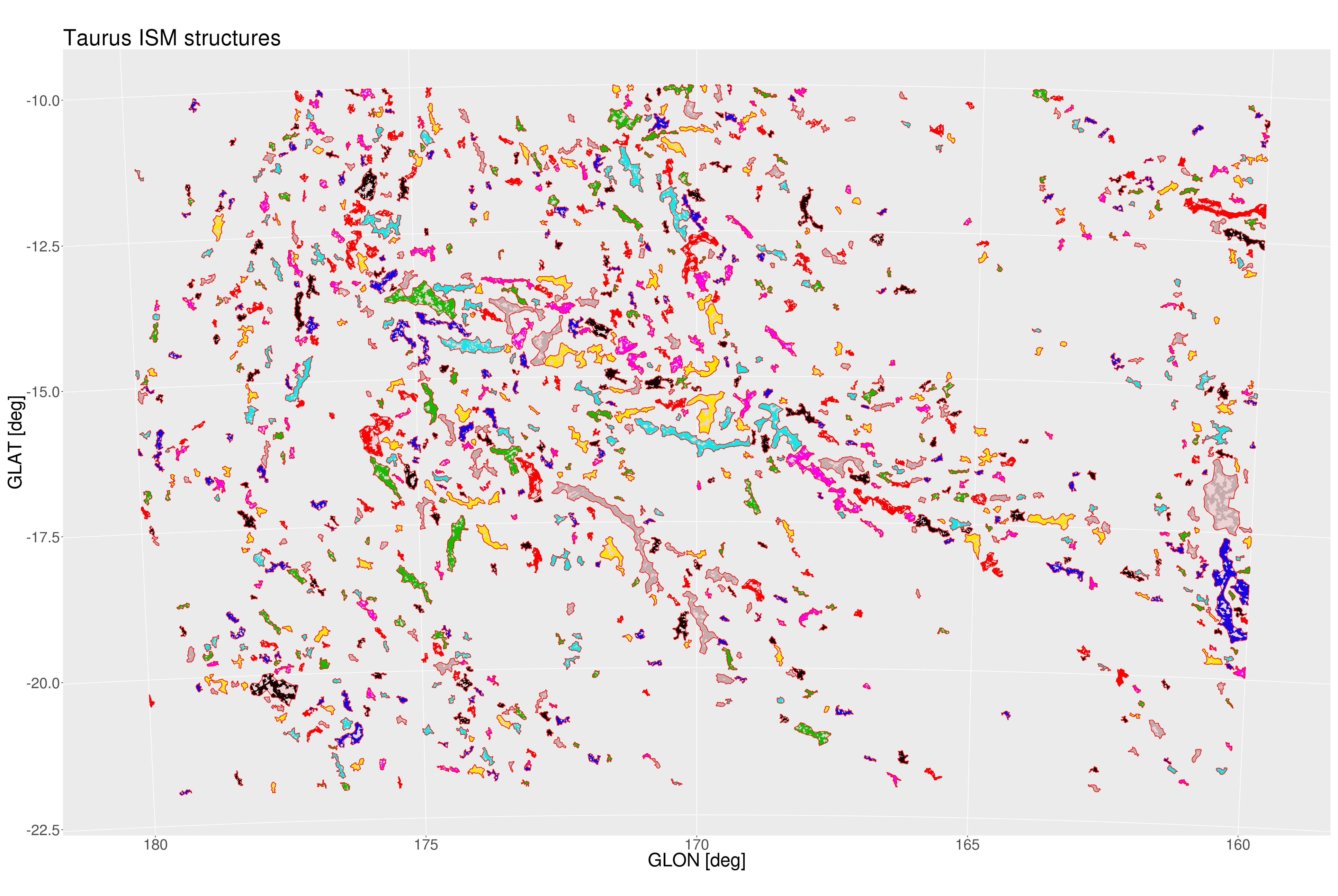

Taurus ISM structures
GLAT [deg]
-10.0
-12.5
-15.0
-17.5
-20.0
-22.5
GLON [deg]
180
175
170
165
160

ISM structure identification in Taurus



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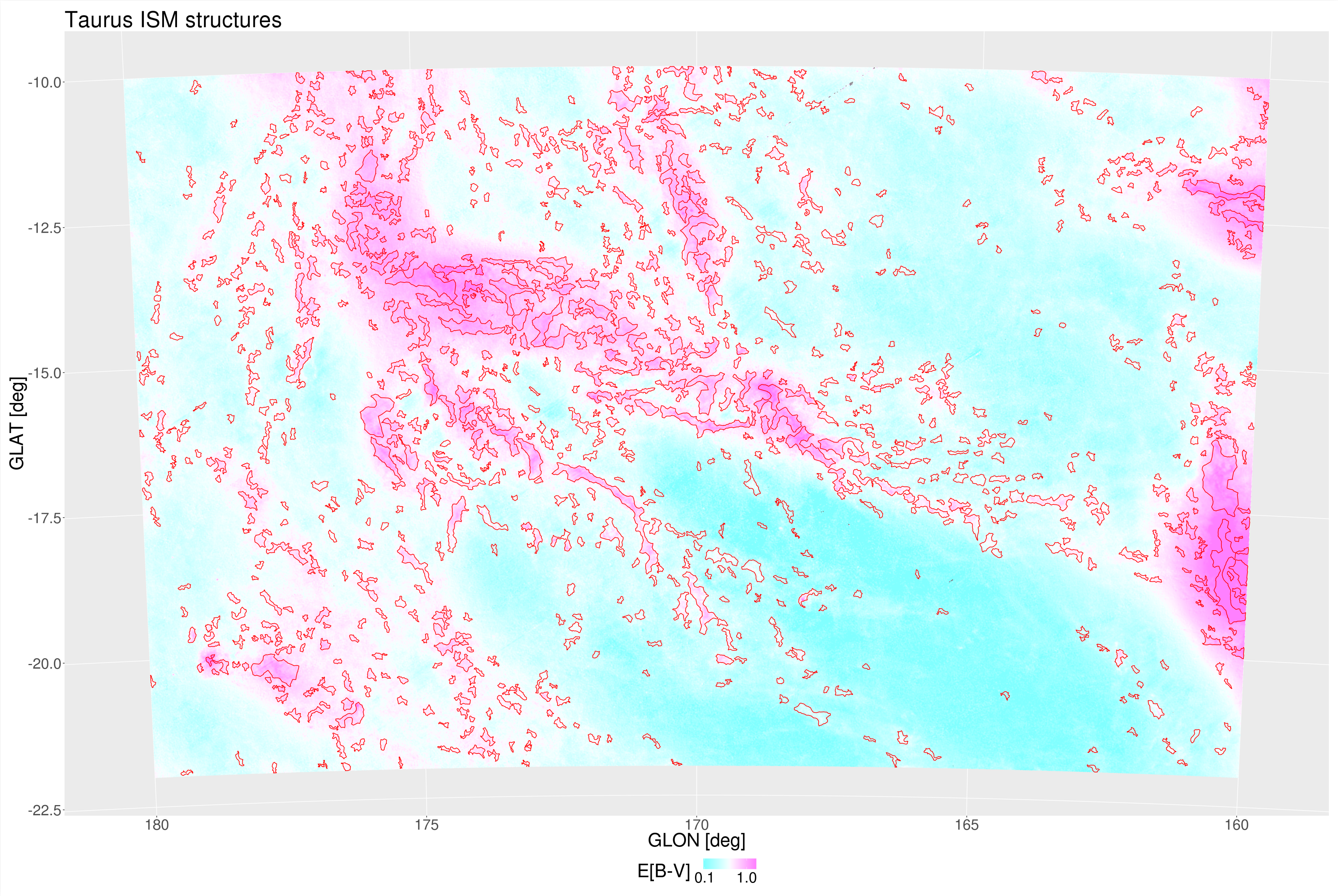
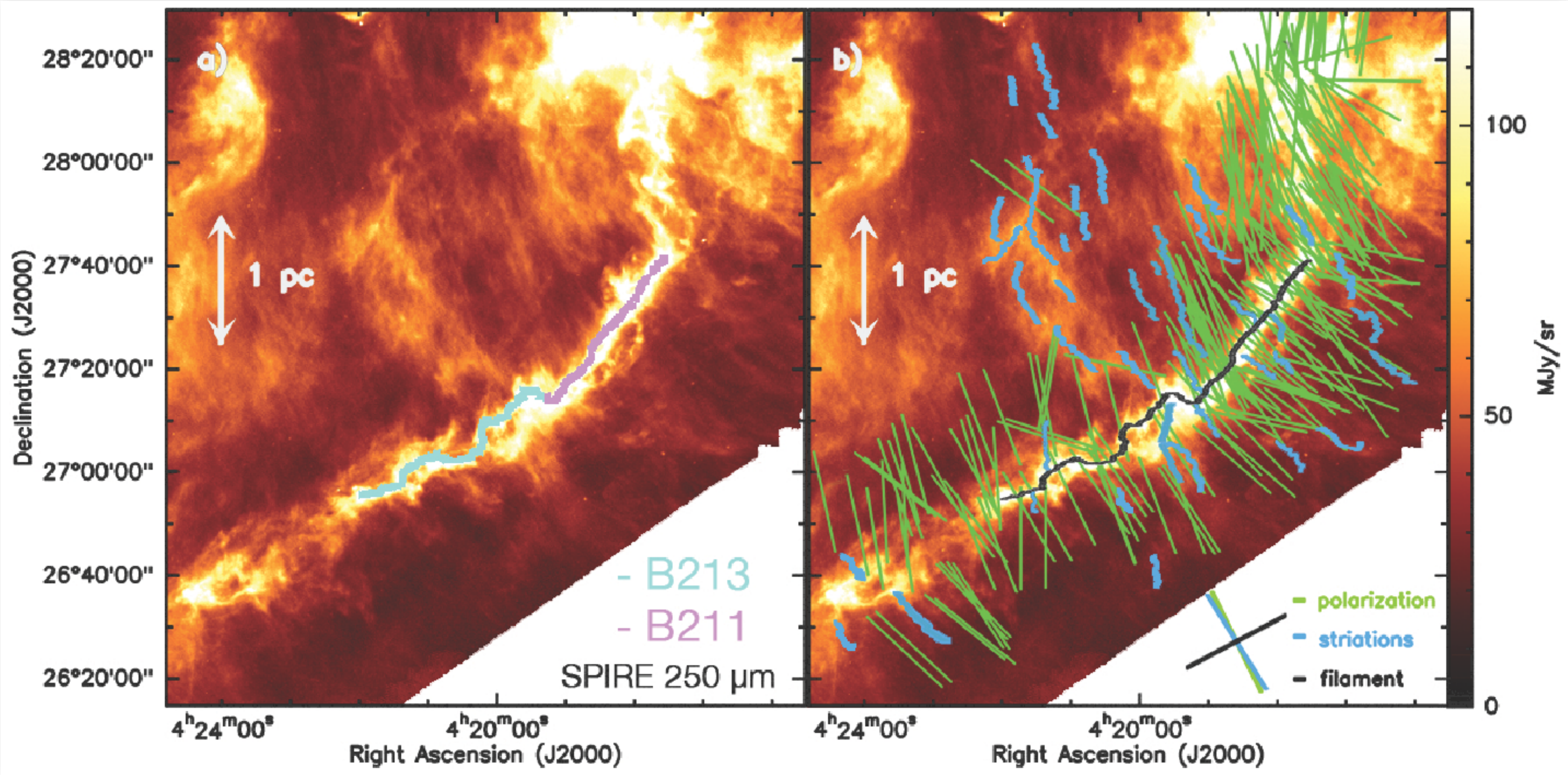
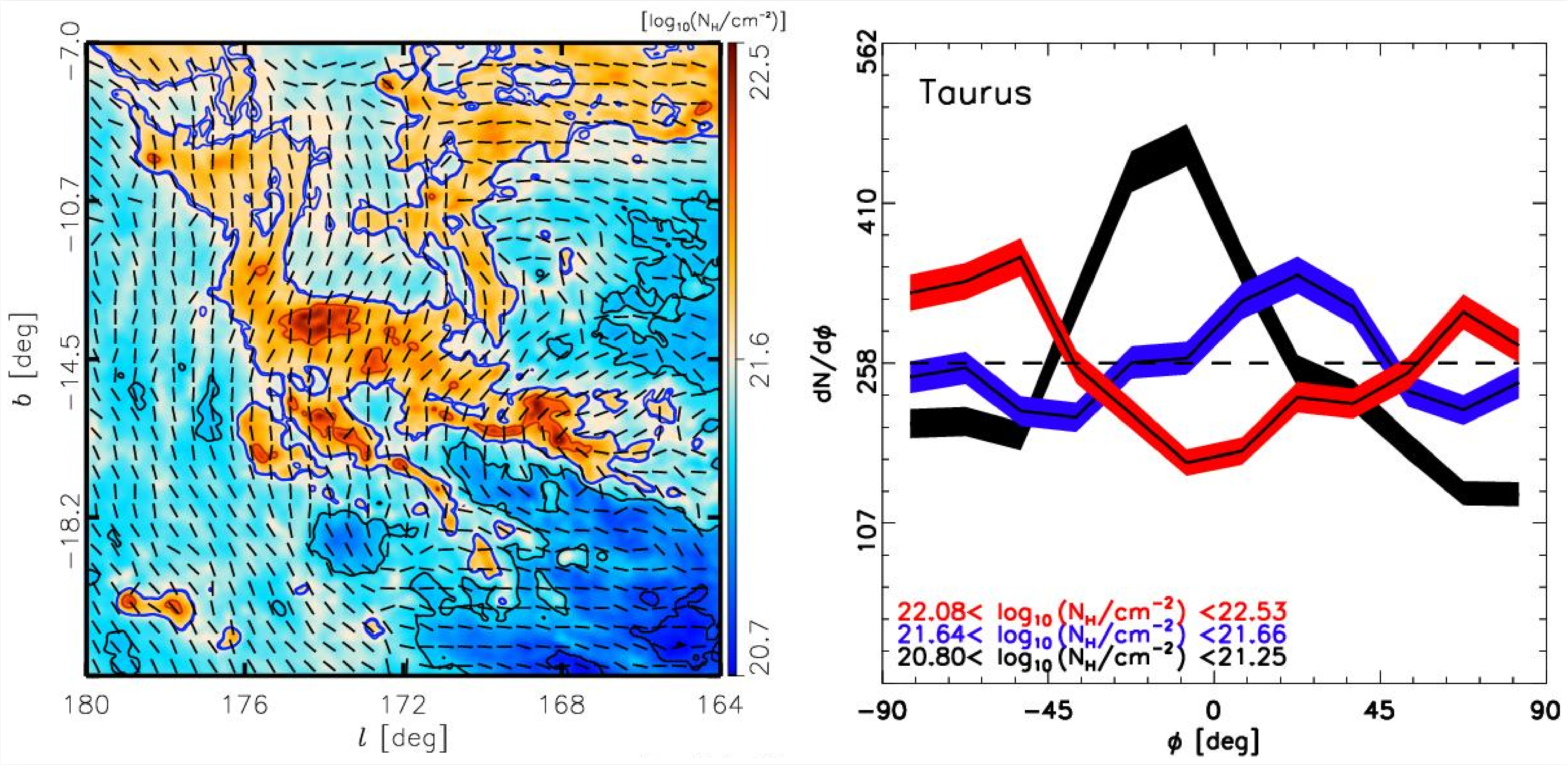


Filaments formation and alignment with B-field



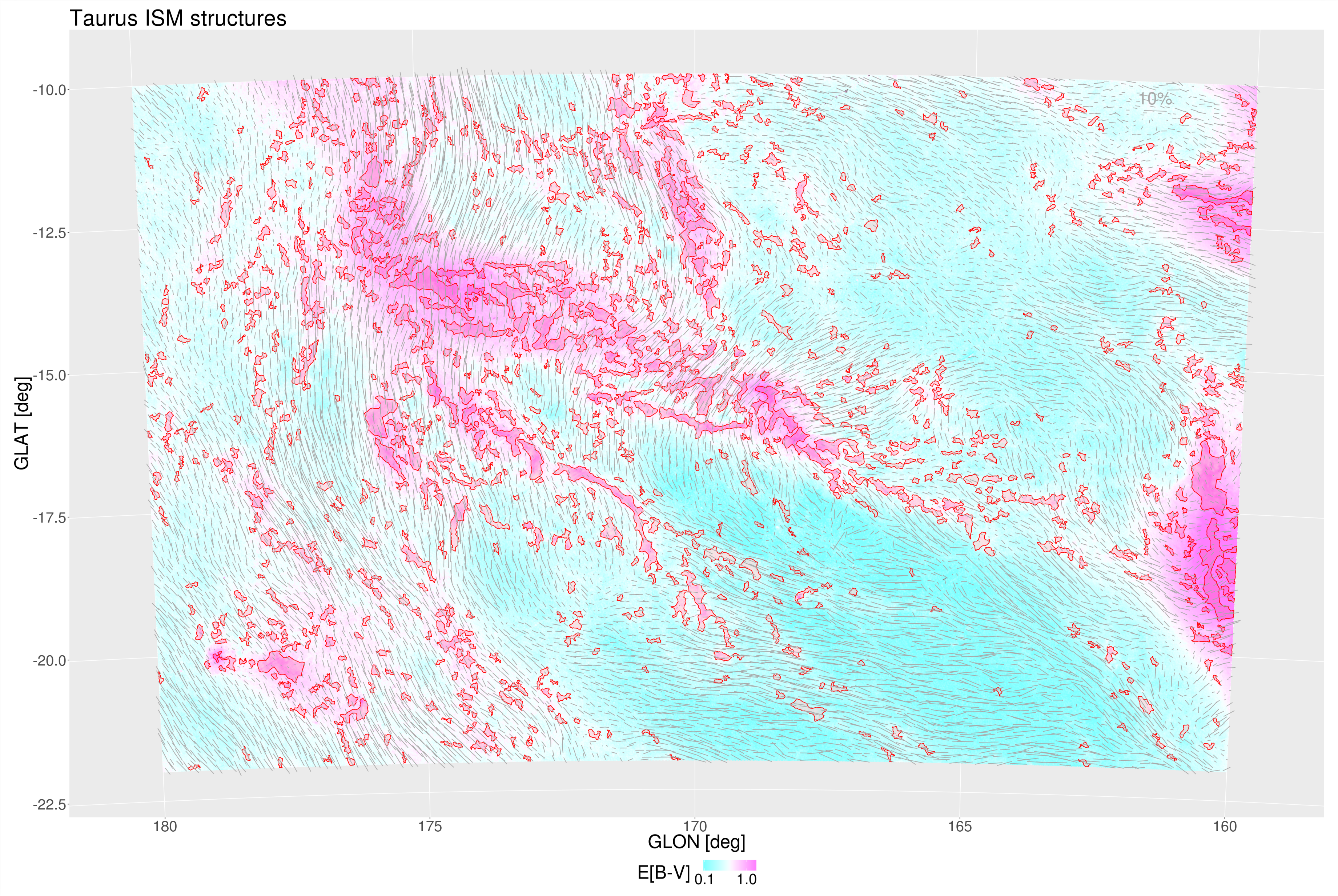
(Palmeirim+ 2013, A&A, 550, A38)

Filamets alignment with B-field



(Planck Collaboration+ 2016, A&A, 586, A138)

ISM structure vs. Planck B-field



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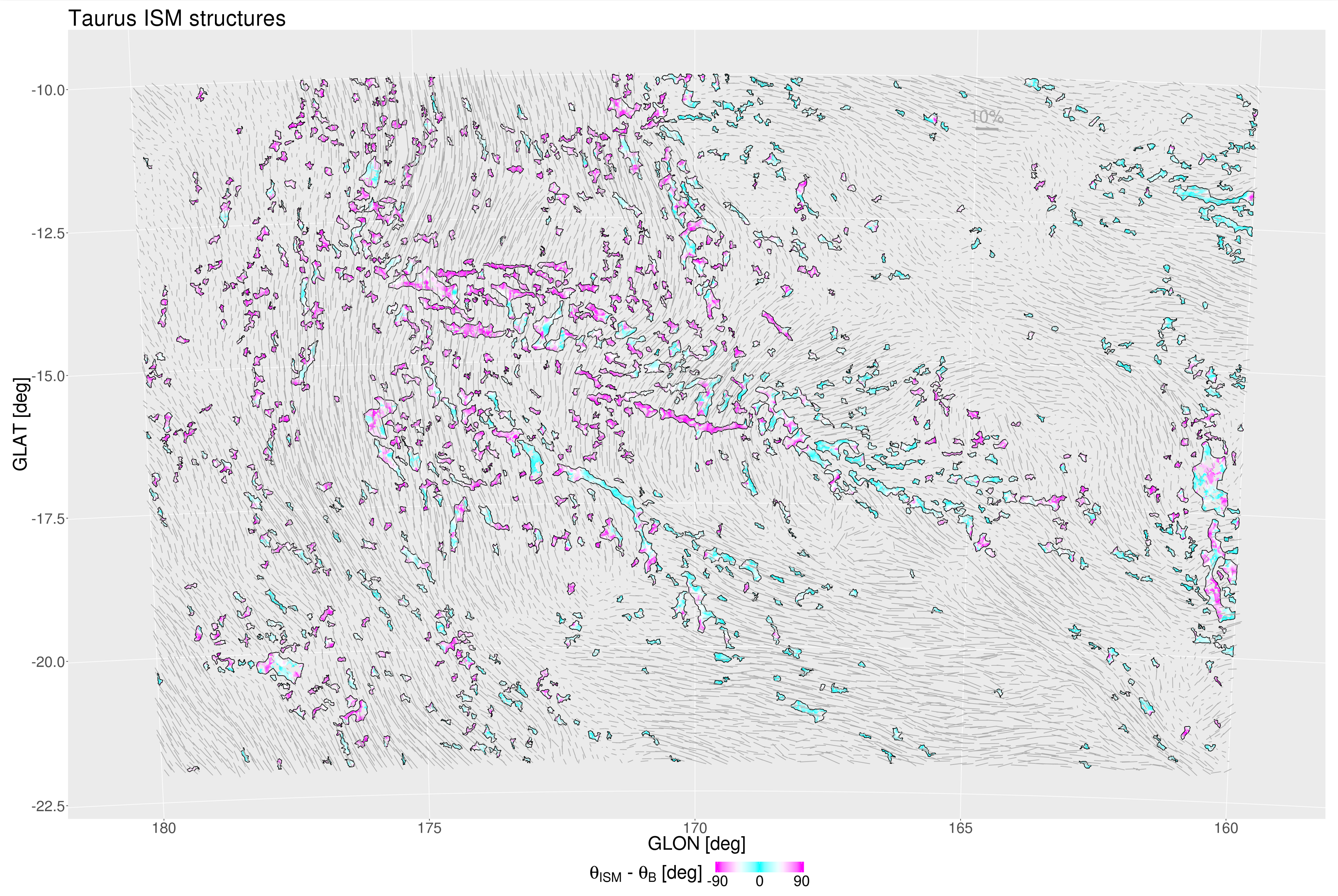
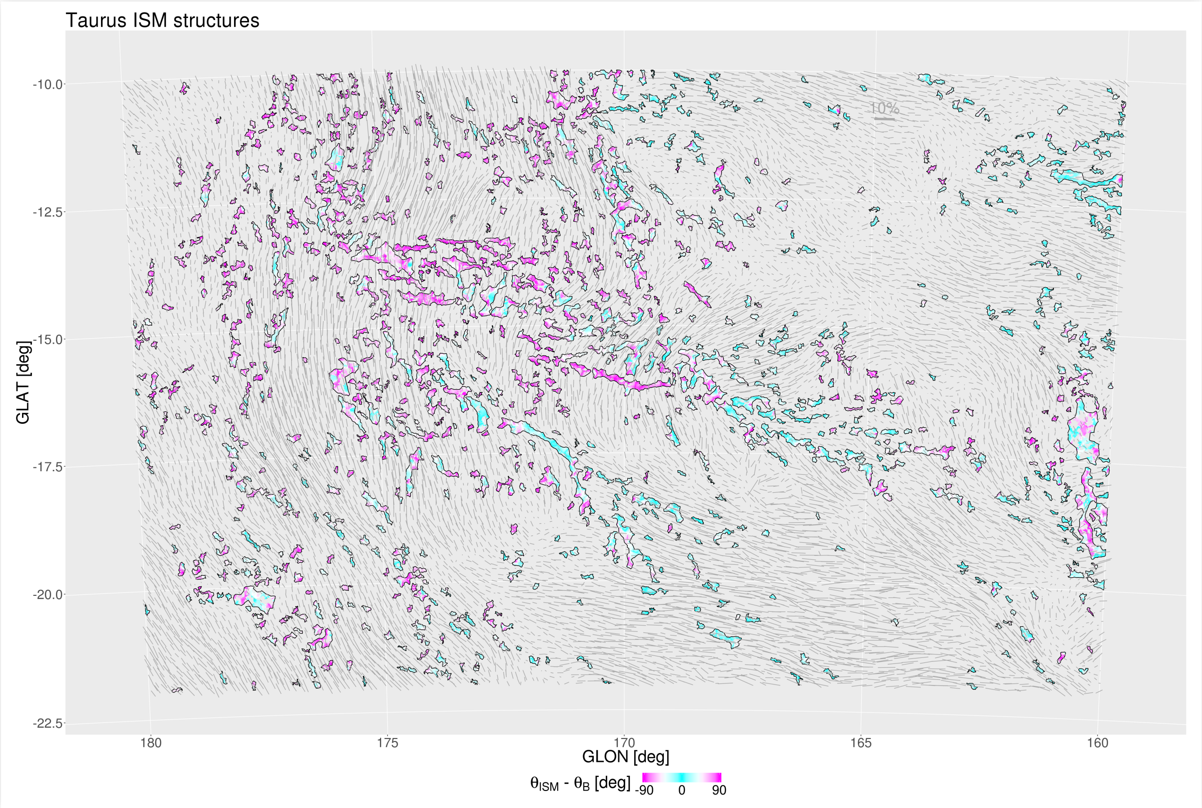
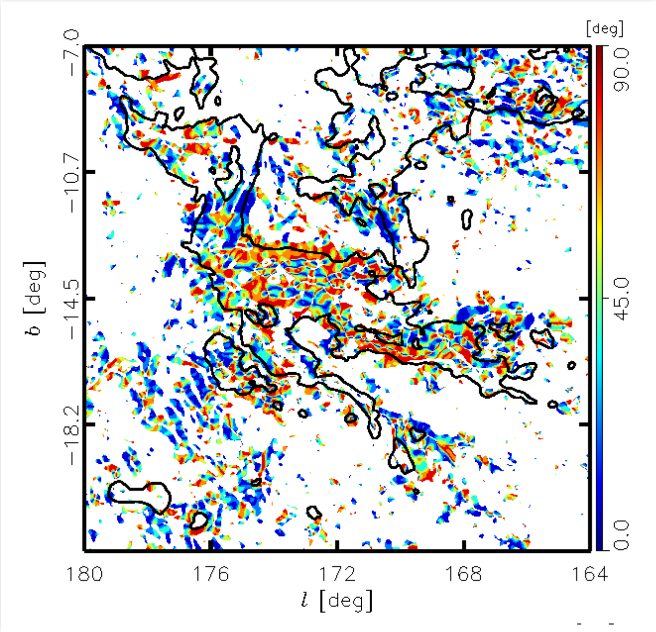


ISM structure vs. Planck B-field

AKARI



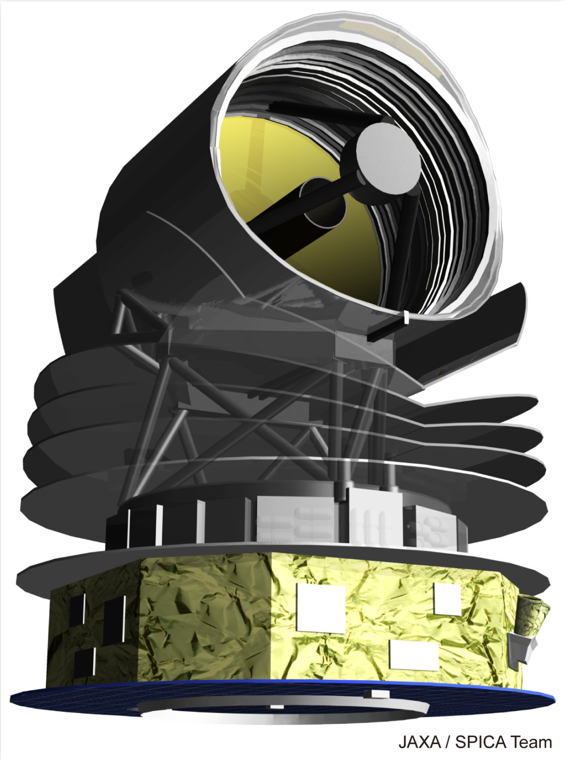
Planck



(Planck Collaboration+ 2016, A&A, 586, A138)

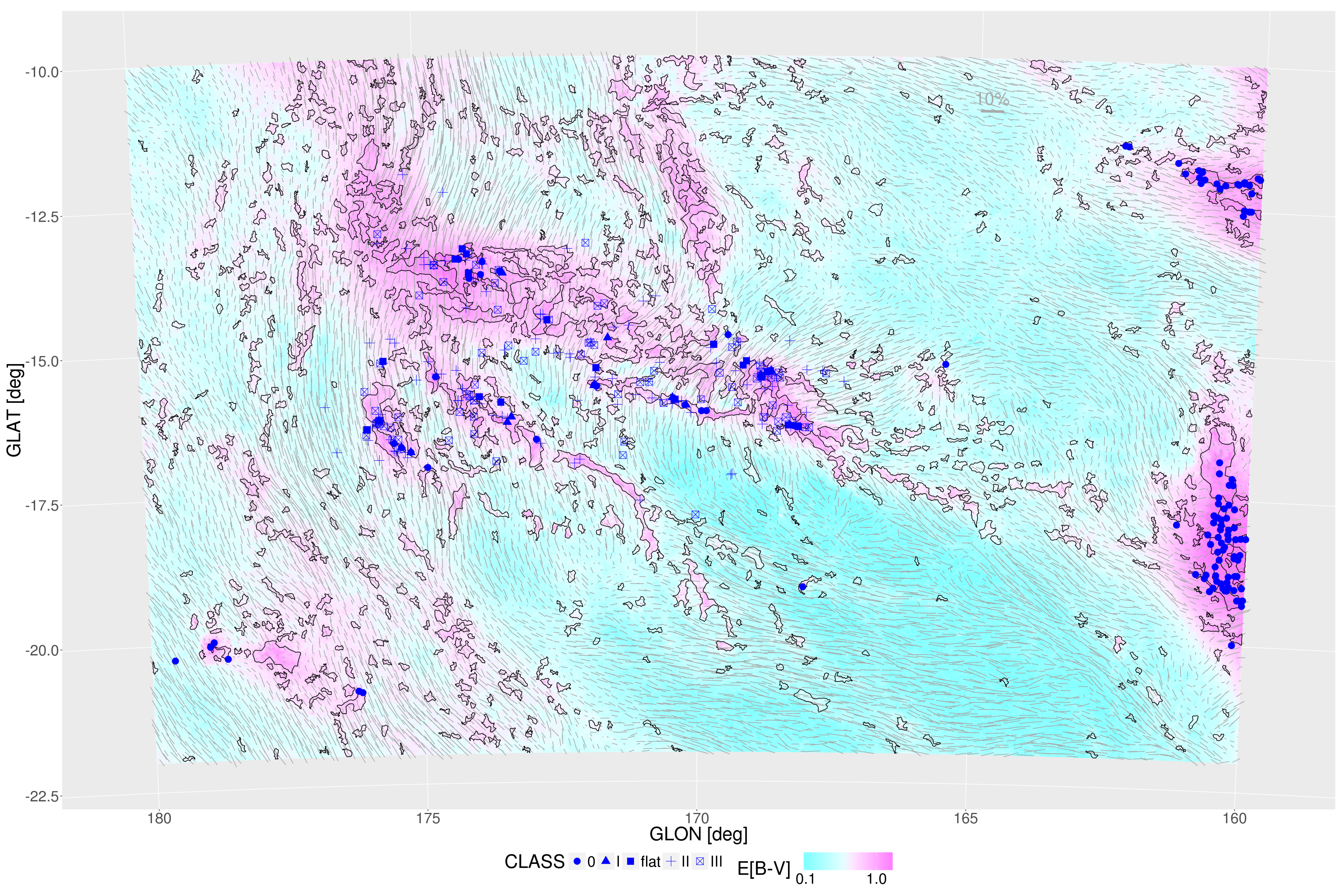
Relative angle of θ_{ISM} and θ_{B}

- High-density ISM structure $\perp$ B-field
- Low-density ISM structure $||$ B-field
- Bimodality is not as clear as seen by Planck
- Higher spatial resolution required for B-field

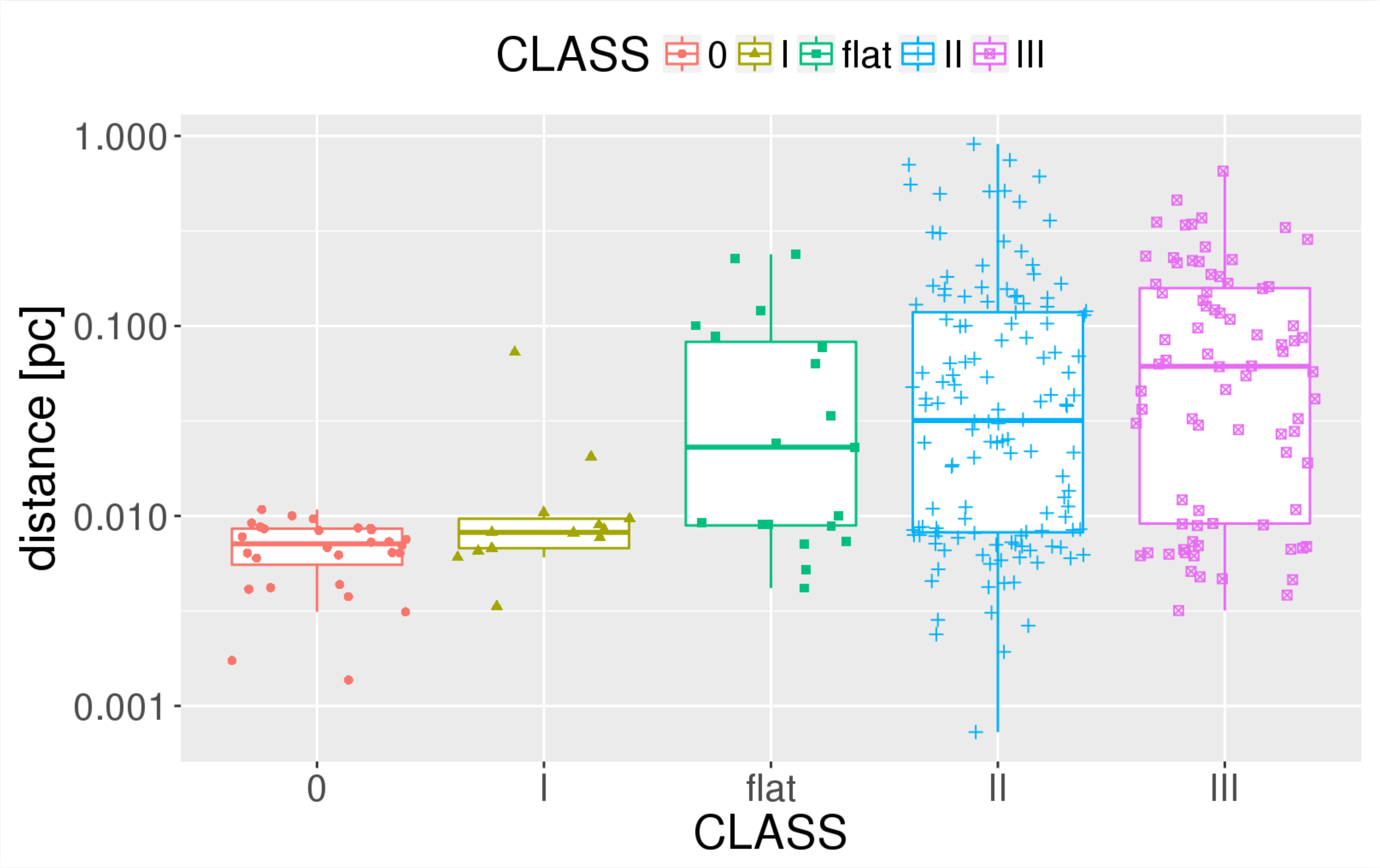


We need SPICA!

YSO distribution



YSO distance from adjacent ISM peaks



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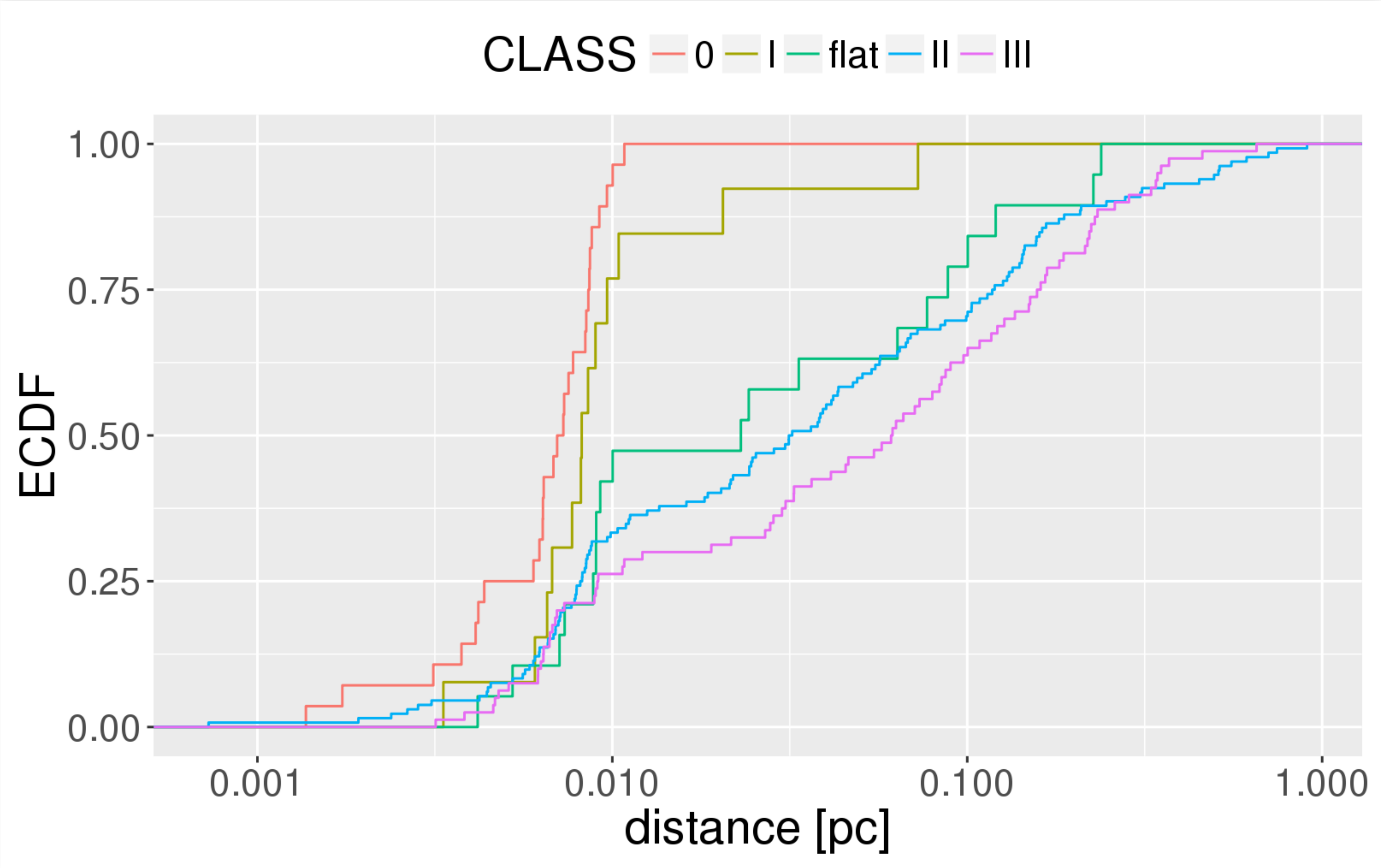
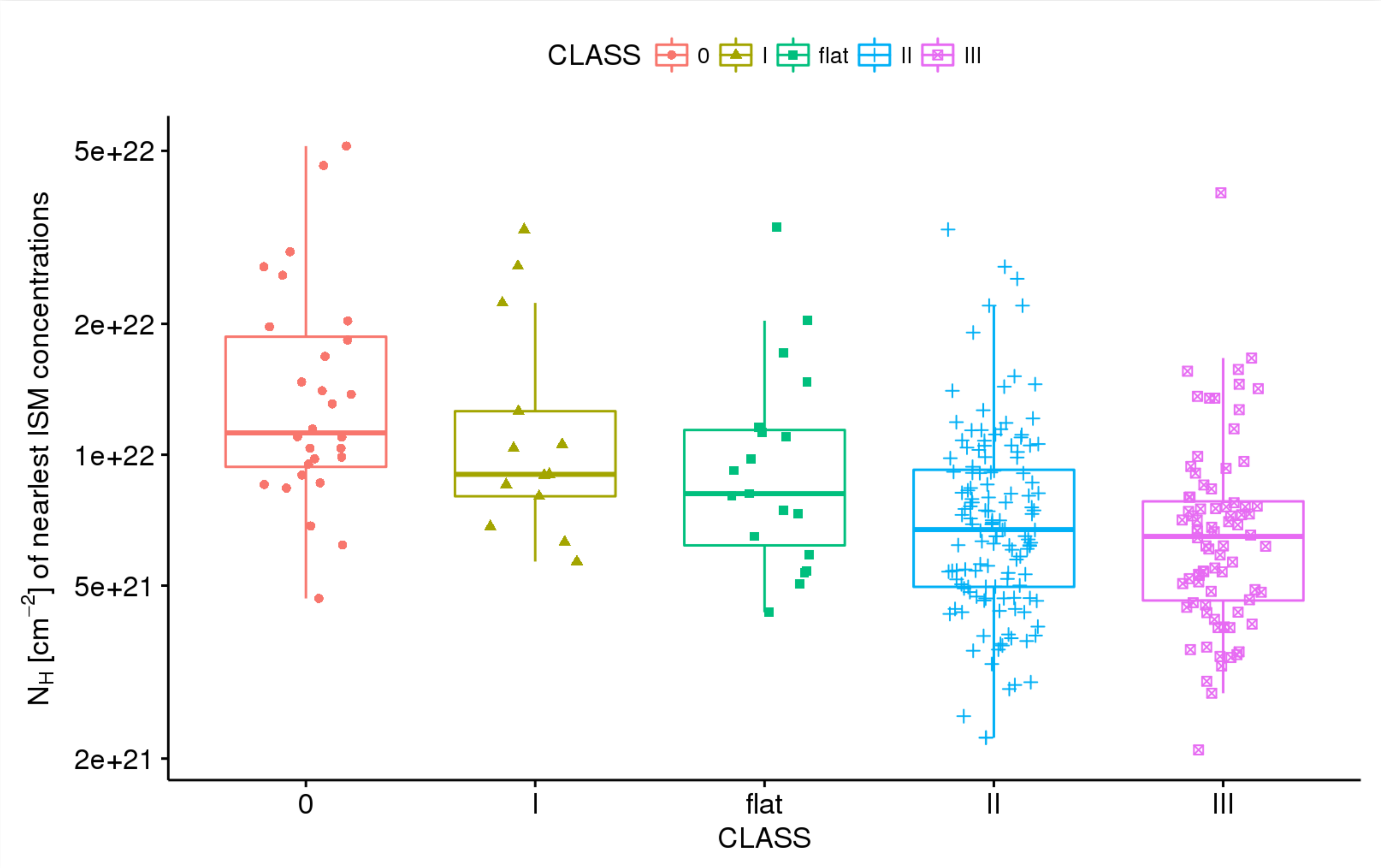


YSOs vs. ISM concentrations

- "distance" correlates with age of the sources
  - $0.1\ \mathrm{pc} = 0.1\ \mathrm{km\ s^{-1}} \times 10^6$ yrs
  - age-evolution of the YSO distributions (Doi+ 2015, PASJ, 67(3), 50)

Dust column at adjacent ISM peaks



YSOs vs. ISM concentrations

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  - age-evolution of the YSO distributions (Doi+ 2015, PASJ, 67(3), 50)
- "density" correlates with age of the sources
  - age-evolution of ISM structures (filaments)
  - mass loss rate: $< 10\ \mathrm{M_\odot pc^{-1} Myr^{-1}}$
  - *cf.* mass accretion rate: $27 - 50\ \mathrm{M_\odot pc^{-1} Myr^{-1}}$ (Palmeirim+ 2013, A&A, 550, A38)

Statistical inference on age evolution of star-formation environment "after" the formation of stars.

life cycle of filaments

1. mass accretion along B-field (through striations)
2. exceeds critical mass $\rightarrow$ starts to form stars
3. termination of mass accretion
   - eating up surrounding material
   - strip off by SNe shocks
   - *cf.* $M_{\mathrm{dense\ cores}}/M_{\mathrm{filament}} \leq 15\%$ (*eg.* André+ 2014)
4. dissipation due to ISRF/radiation from internal YSOs
   $\rightarrow$ star-formation ends