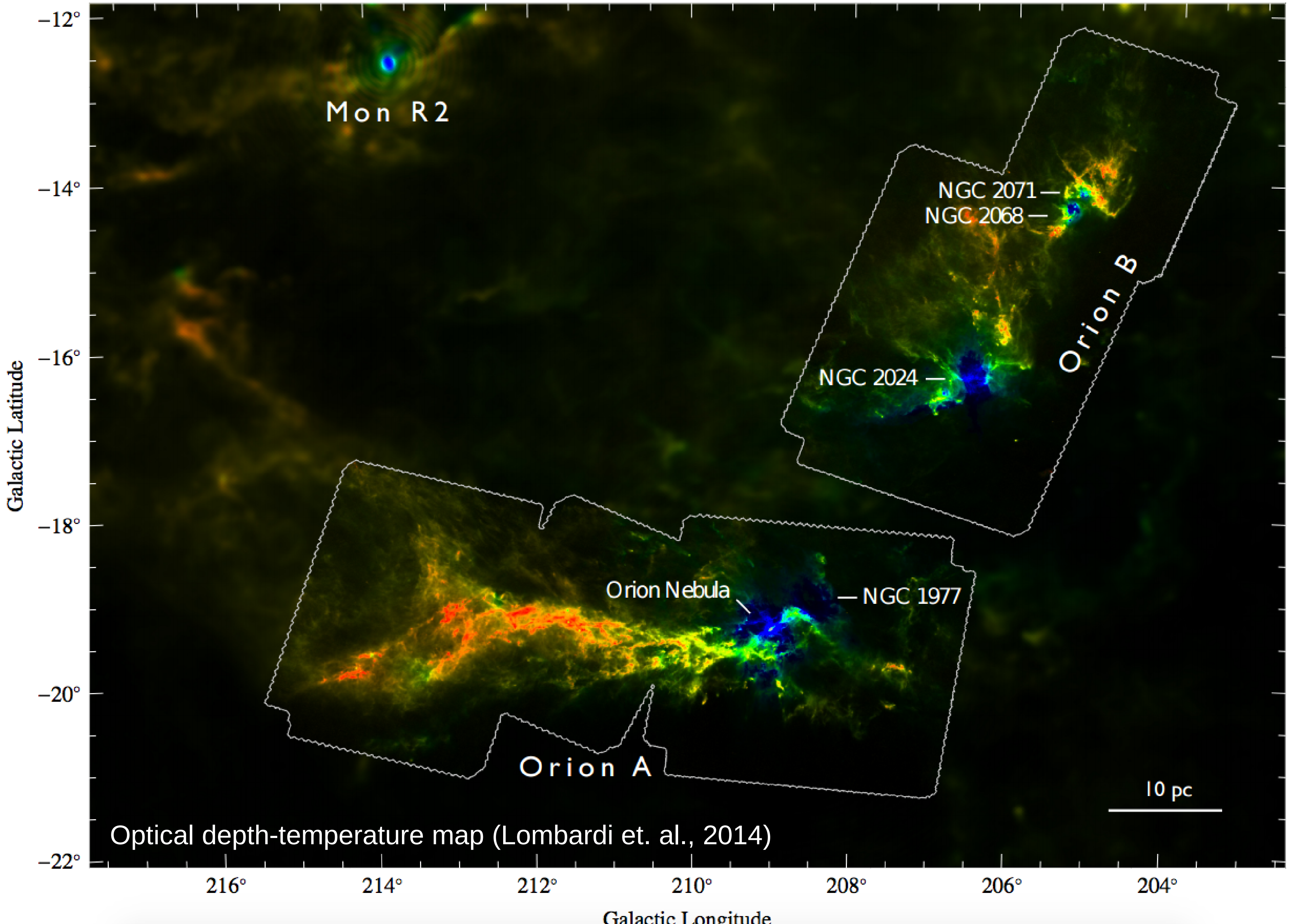
Density scaling relation in Orion A: effects of region selection

O. Stanchev, T. Veltchev, S. Donkov

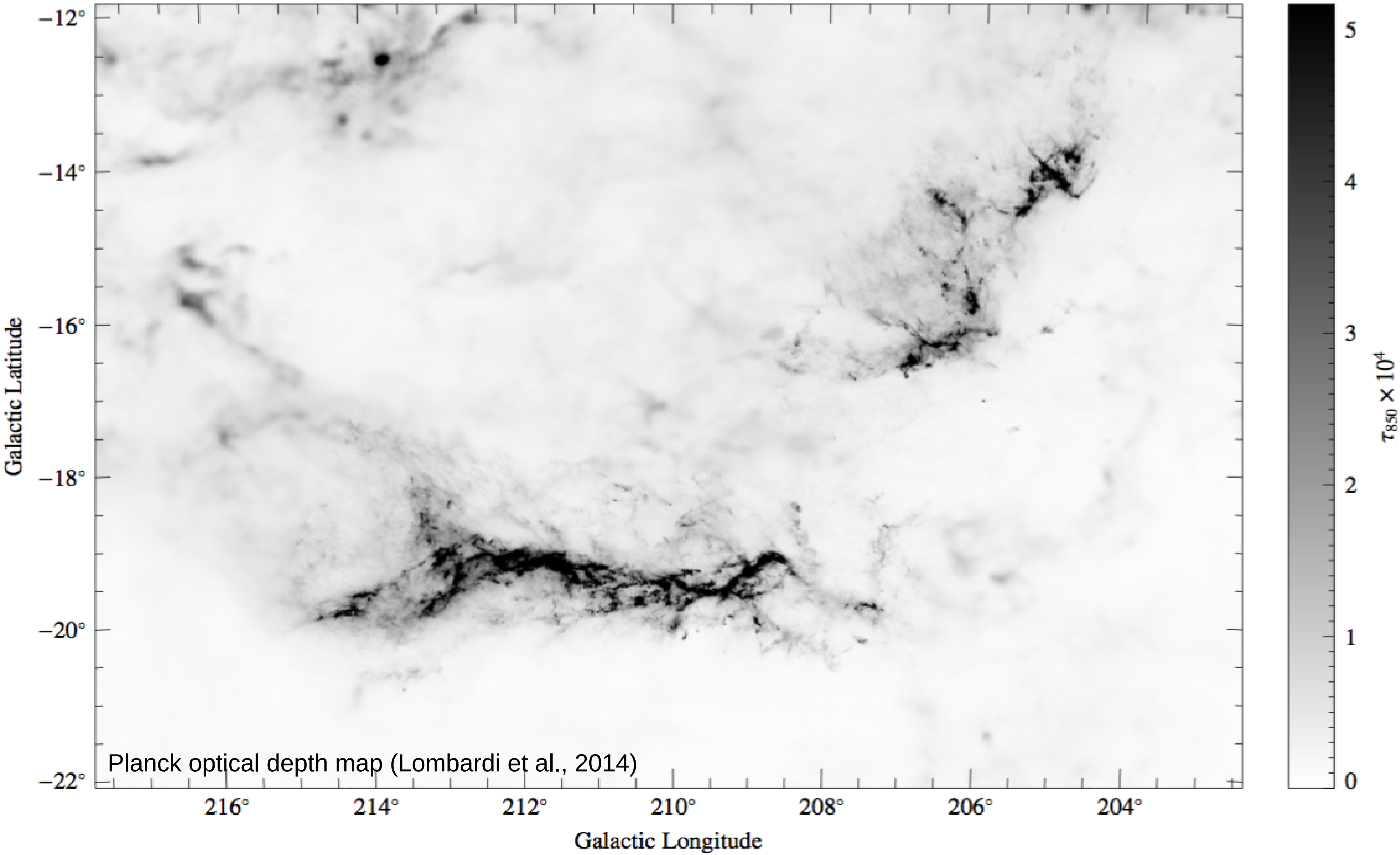
X SERBIAN - BULGARIAN ASTRONOMICAL CONFERENCE, 2016

Goals

1. Derive the density scaling relation in Orion A
2. Study the effects of region selection
3. Test for effects of distance gradient



Optical depth-temperature map (Lombardi et. al., 2014)


−12°
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Galactic Latitude
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210°
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204°
Galactic Longitude
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4
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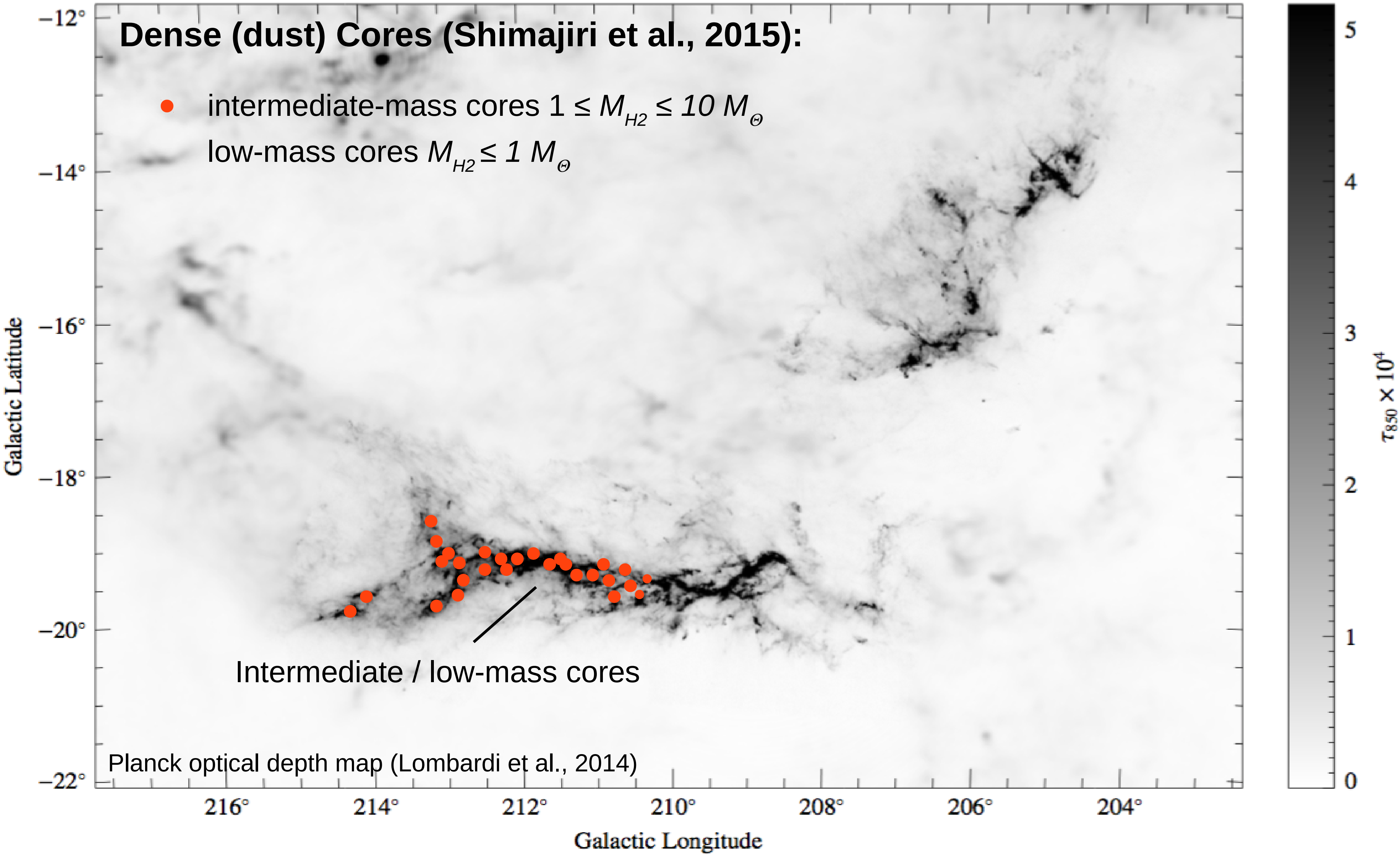
0
$\tau_{850} \times 10^4$
Planck optical depth map (Lombardi et al., 2014)


Dense (dust) Cores (Shimajiri et al., 2015):
intermediate-mass cores 1 ≤ M_{H2} ≤ 10 M_{Θ}
low-mass cores M_{H2} ≤ 1 M_{Θ}
Intermediate / low-mass cores
Planck optical depth map (Lombardi et al., 2014)
Galactic Latitude
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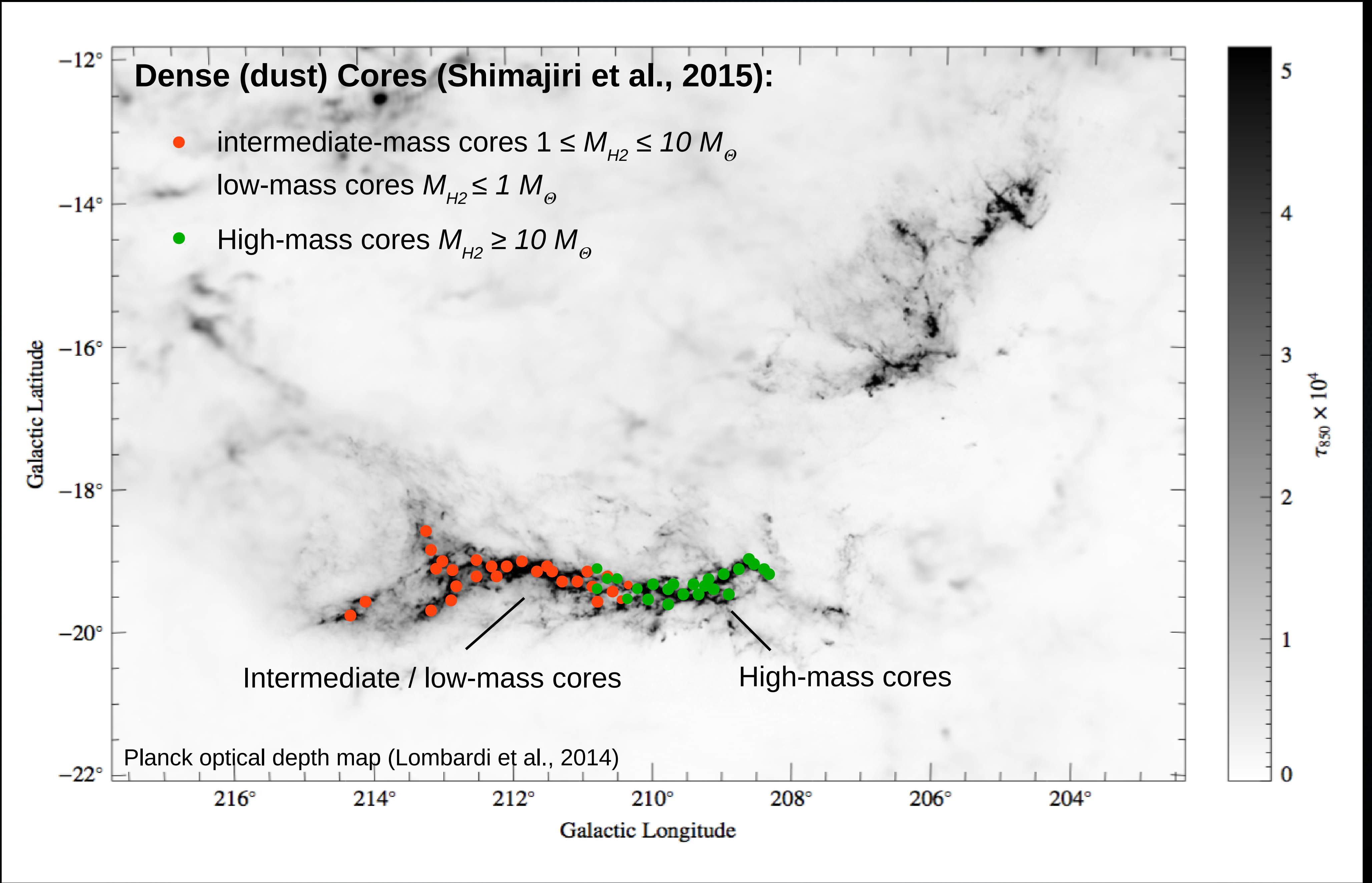

Dense (dust) Cores (Shimajiri et al., 2015):
intermediate-mass cores 1 ≤ M_{H2} ≤ 10 M_{Θ}
low-mass cores M_{H2} ≤ 1 M_{Θ}
High-mass cores M_{H2} ≥ 10 M_{Θ}
Intermediate / low-mass cores
High-mass cores
Planck optical depth map (Lombardi et al., 2014)
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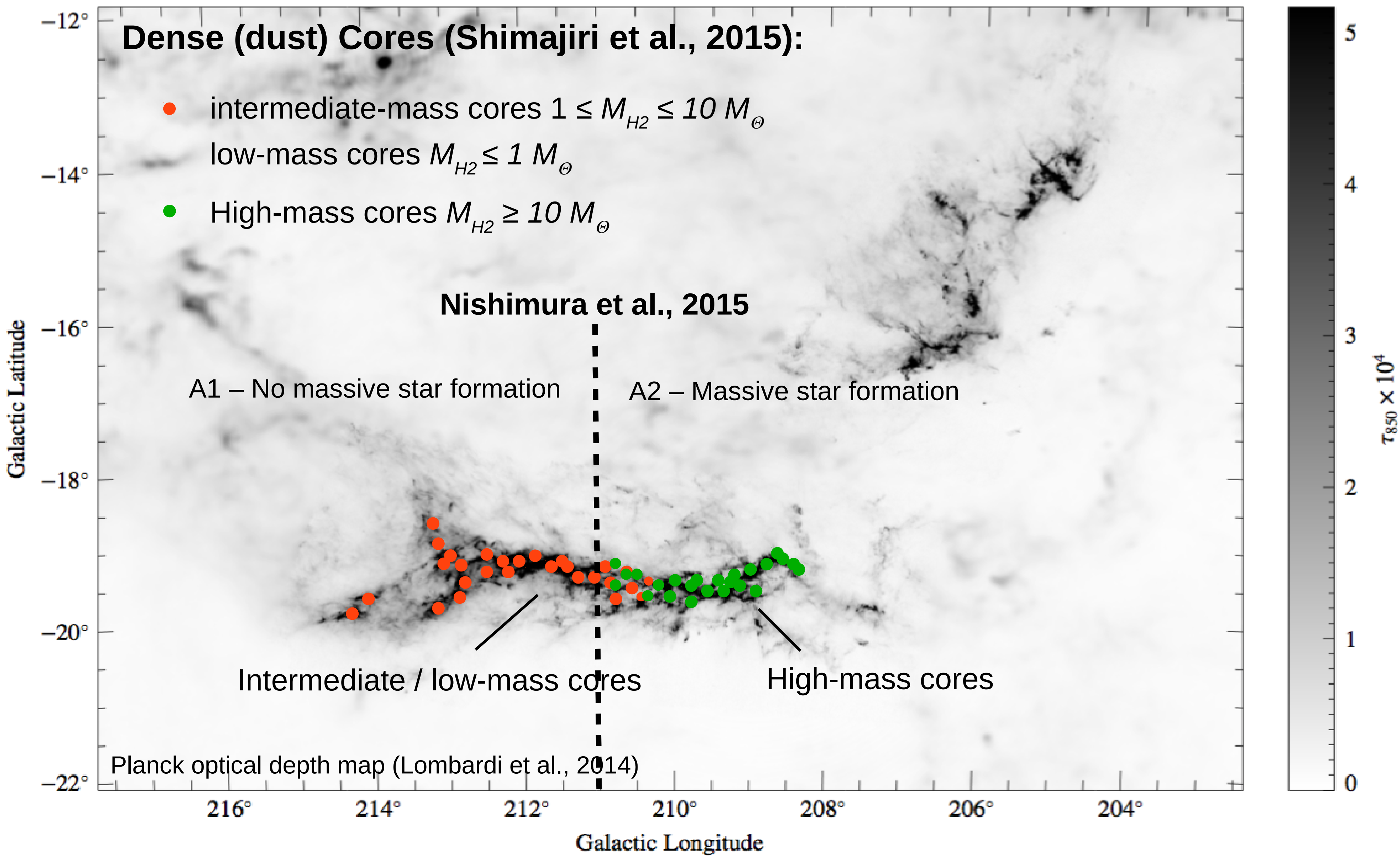

Dense (dust) Cores (Shimajiri et al., 2015):
intermediate-mass cores $1 \le M_{H2} \le 10\ M_\Theta$
low-mass cores $M_{H2} \le 1\ M_\Theta$
High-mass cores $M_{H2} \ge 10\ M_\Theta$
Nishimura et al., 2015
A1 – No massive star formation
A2 – Massive star formation
Intermediate / low-mass cores
High-mass cores
Planck optical depth map (Lombardi et al., 2014)
Galactic Latitude
−12°
−14°
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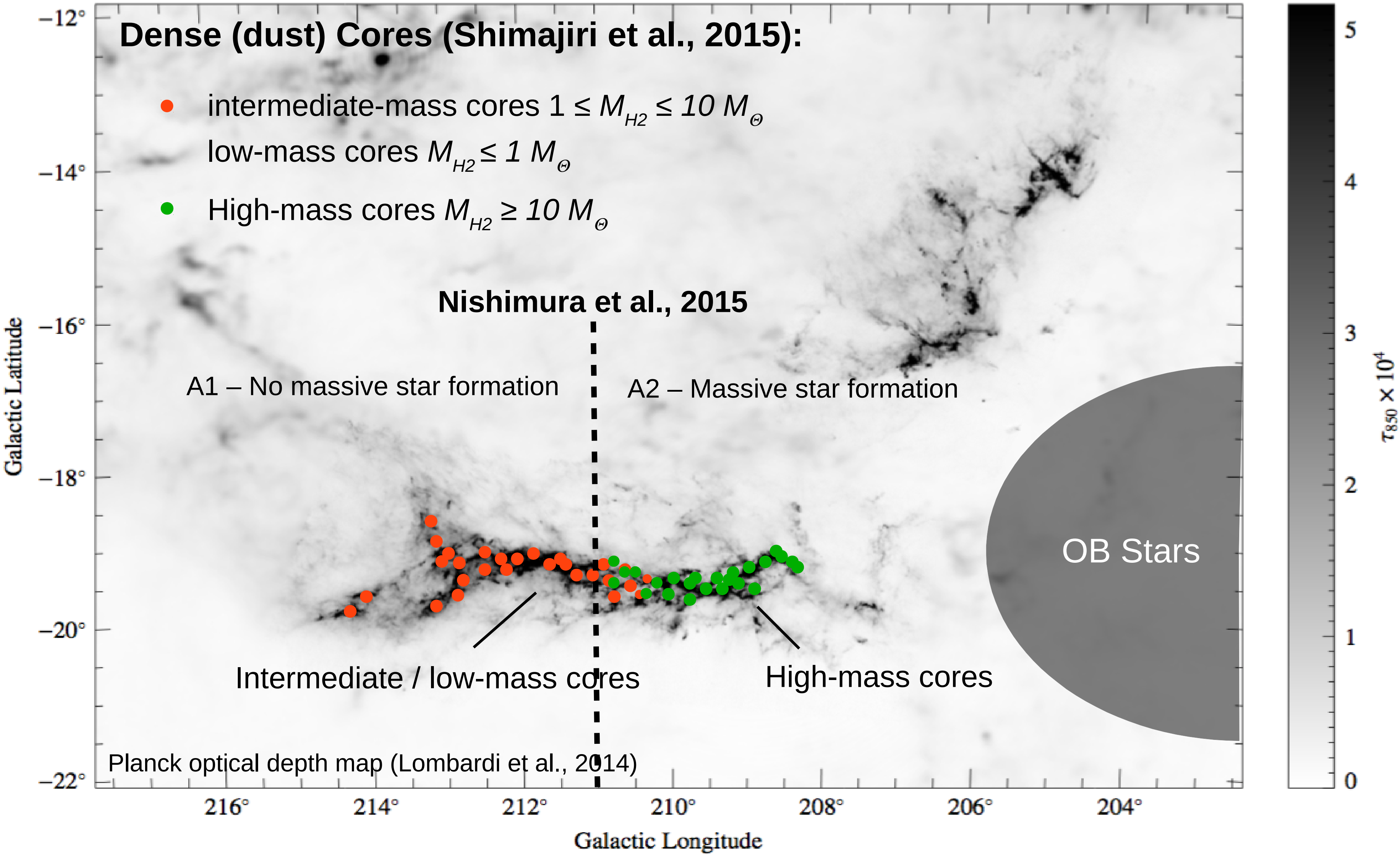

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Nishimura et al., 2015
A1 – No massive star formation
A2 – Massive star formation
OB Stars
Intermediate / low-mass cores
High-mass cores
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Galactic Latitude
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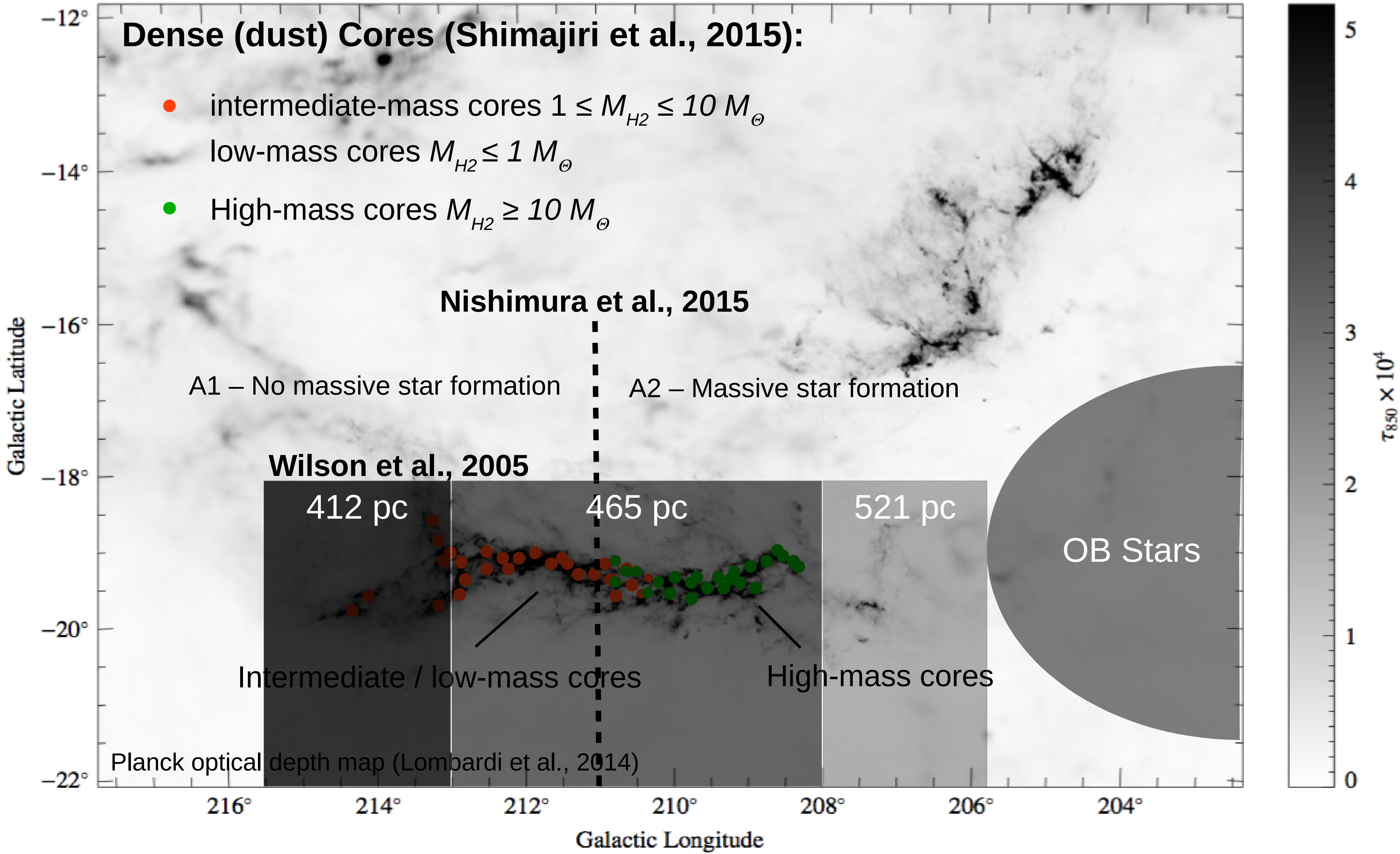

Dense (dust) Cores (Shimajiri et al., 2015):
intermediate-mass cores 1 ≤ M_{H2} ≤ 10 M_{Θ}
low-mass cores M_{H2} ≤ 1 M_{Θ}
High-mass cores M_{H2} ≥ 10 M_{Θ}
Nishimura et al., 2015
A1 – No massive star formation
A2 – Massive star formation
Wilson et al., 2005
412 pc
465 pc
521 pc
OB Stars
Intermediate / low-mass cores
High-mass cores
Planck optical depth map (Lombardi et al., 2014)
Galactic Latitude
Galactic Longitude
−12°
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$\tau_{850} \times 10^4$
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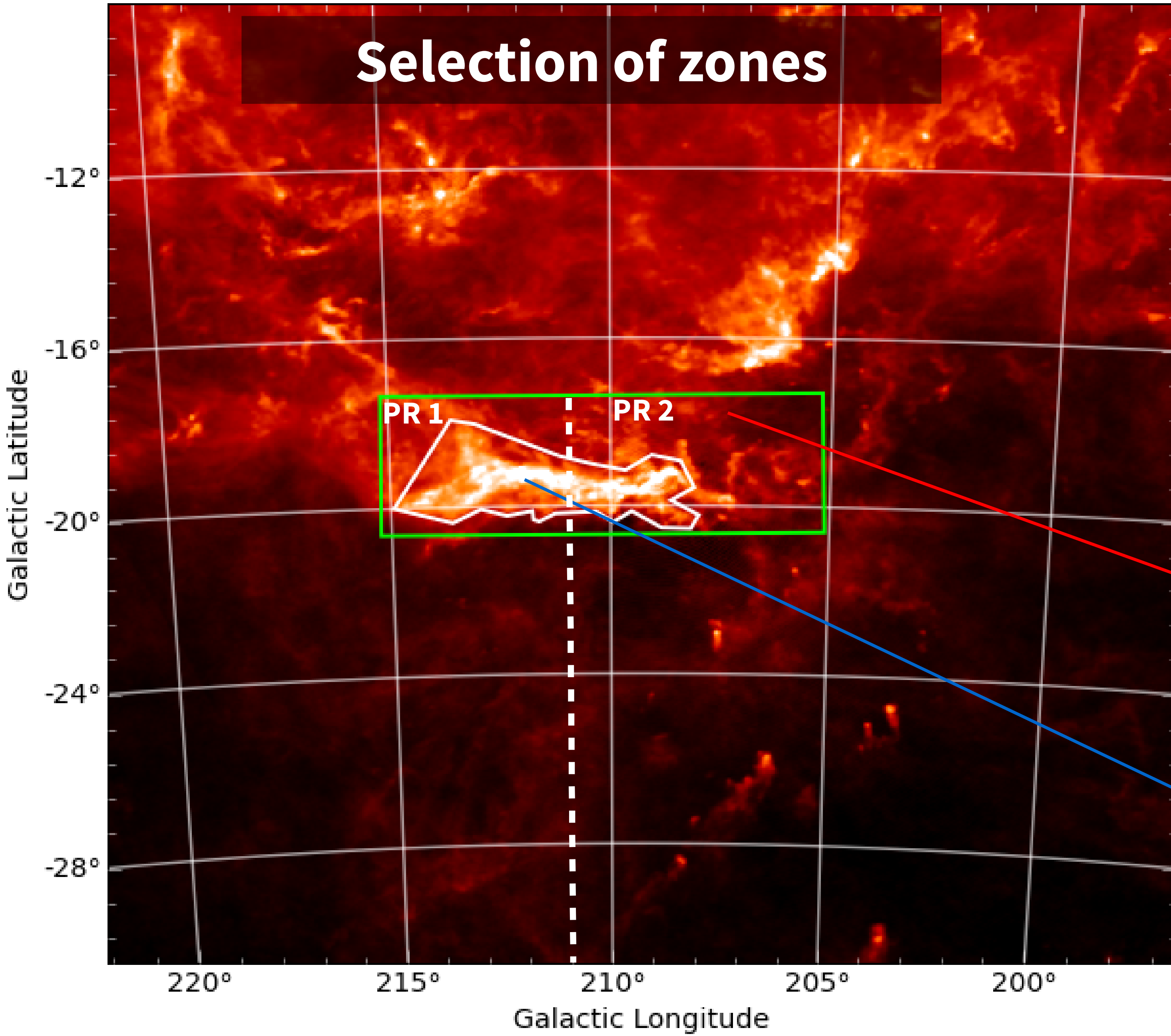
Selection of zones



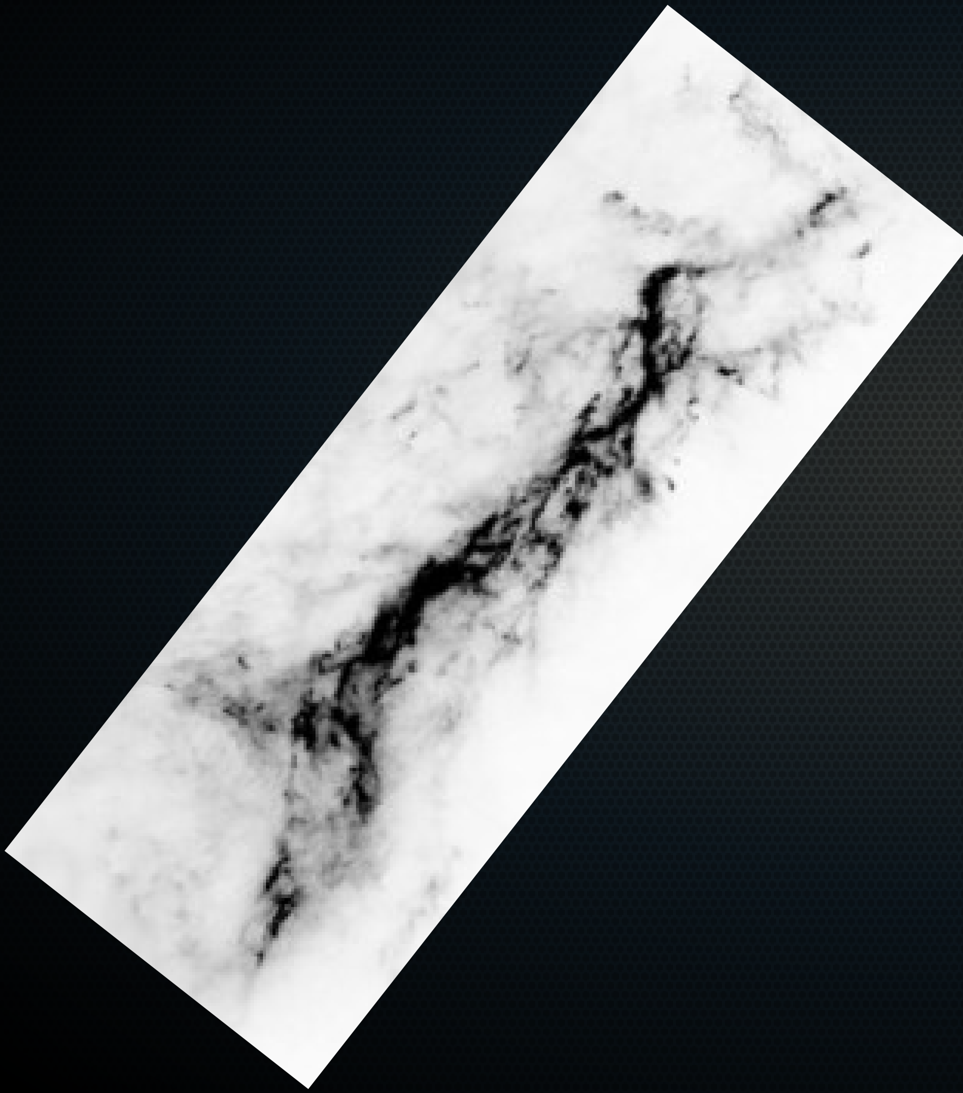
- Planck HFI data map
- Dust opacity (353 GHz)
- HEALPIX to TAN projection

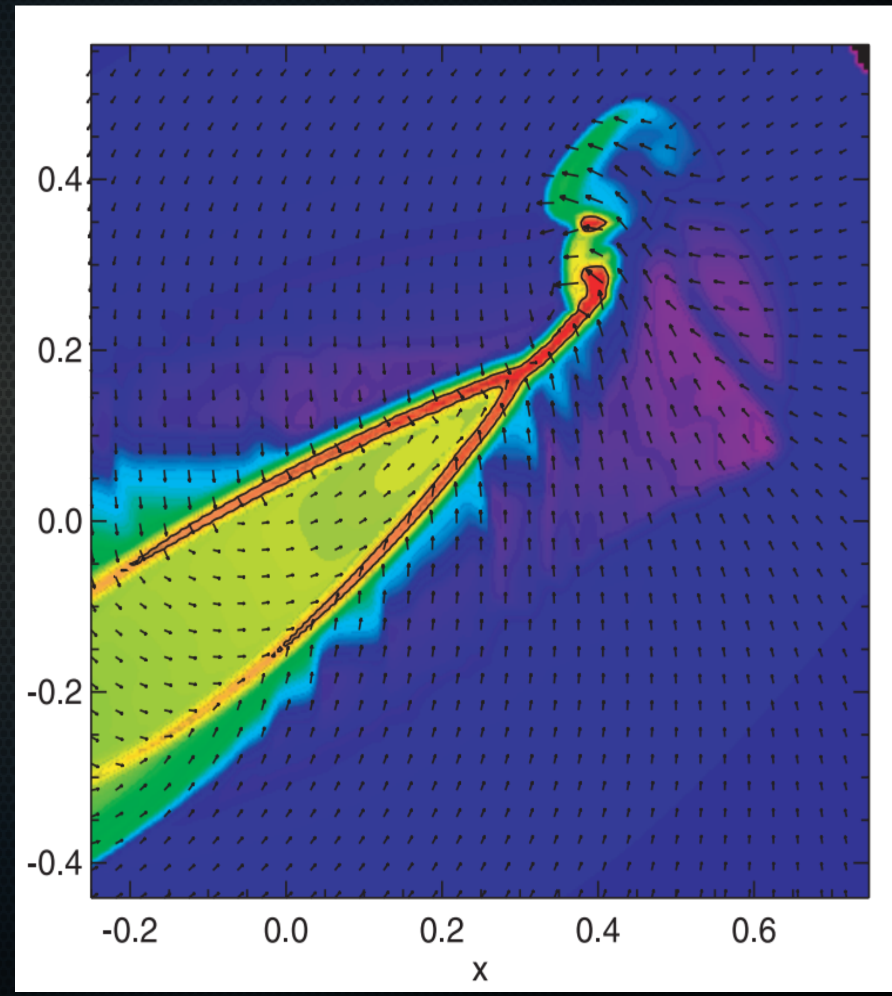
Polygon Ring (PR1, PR2)

Central Filament (CF)

Large scale gravitational collapse + gravitational focusing

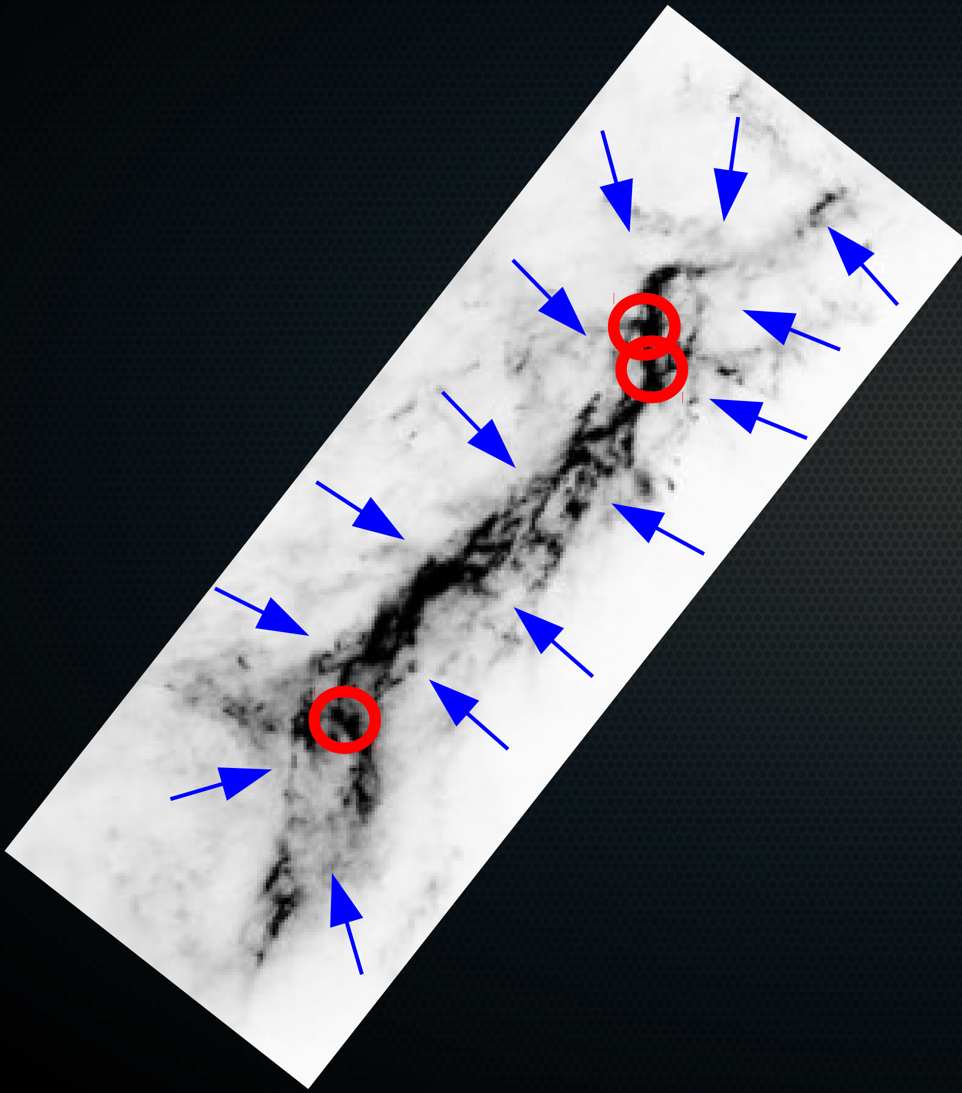
(Hartmann & Burkert, 2007)

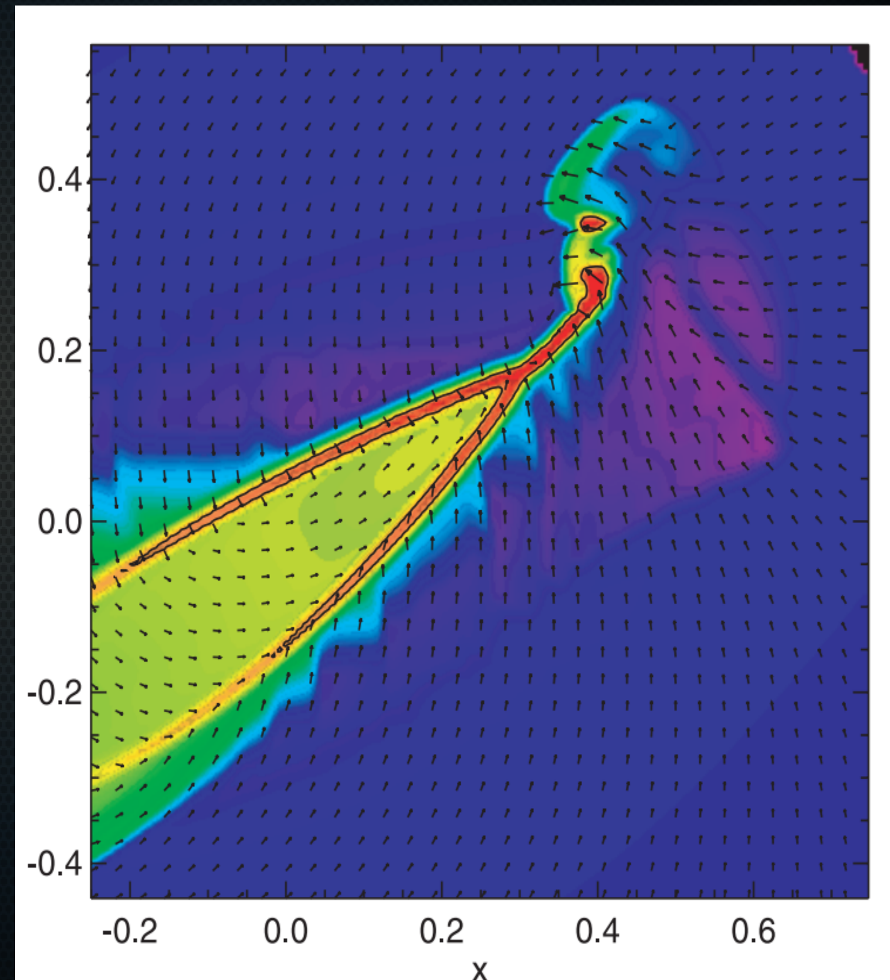




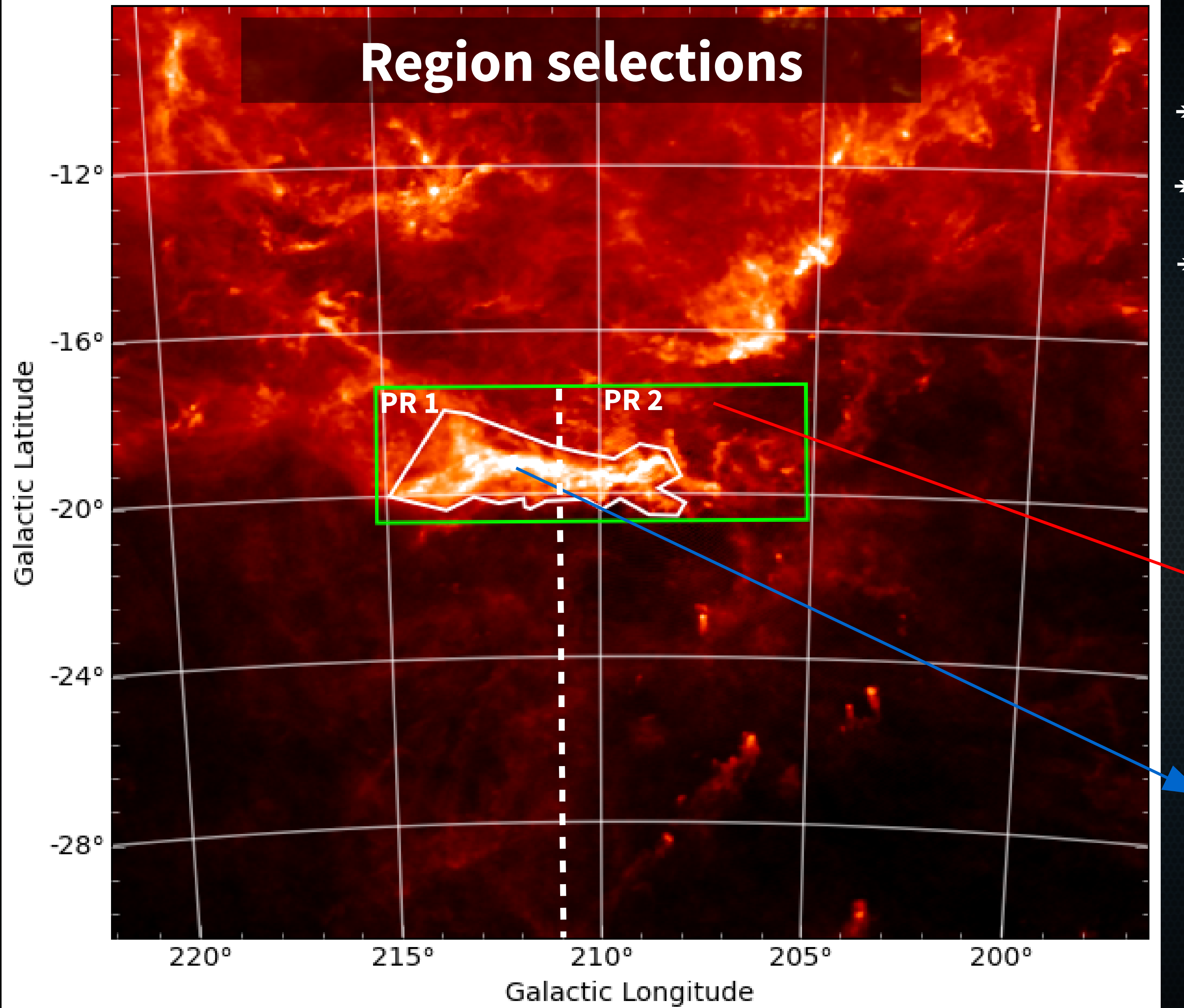
Global gravitational collapse + gravitational focusing

(Hartmann & Burkert, 2007)





Region selections



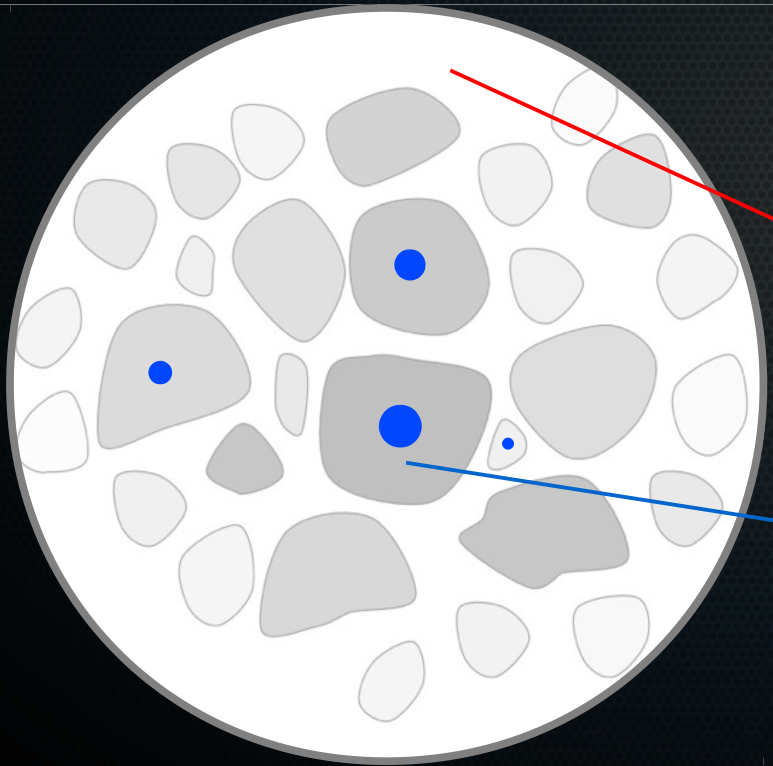
- Planck HFI data map
- Dust opacity (353 GHz)
- HEALPIX to TAN projection

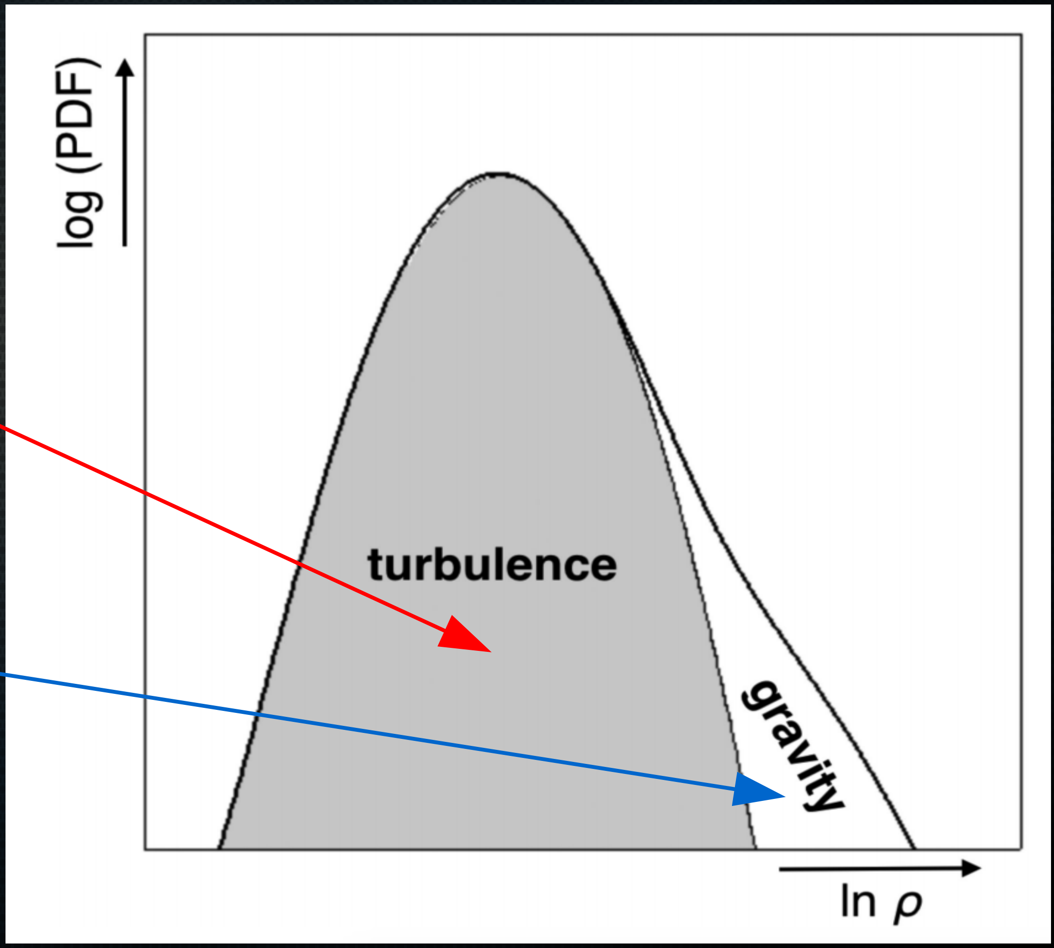
Polygon Ring (PR1, PR2)
Predominantly turbulent domain

Central Filament (CF)
Gravoturbulent domain

N-PDFs as a tool for studying MC structure

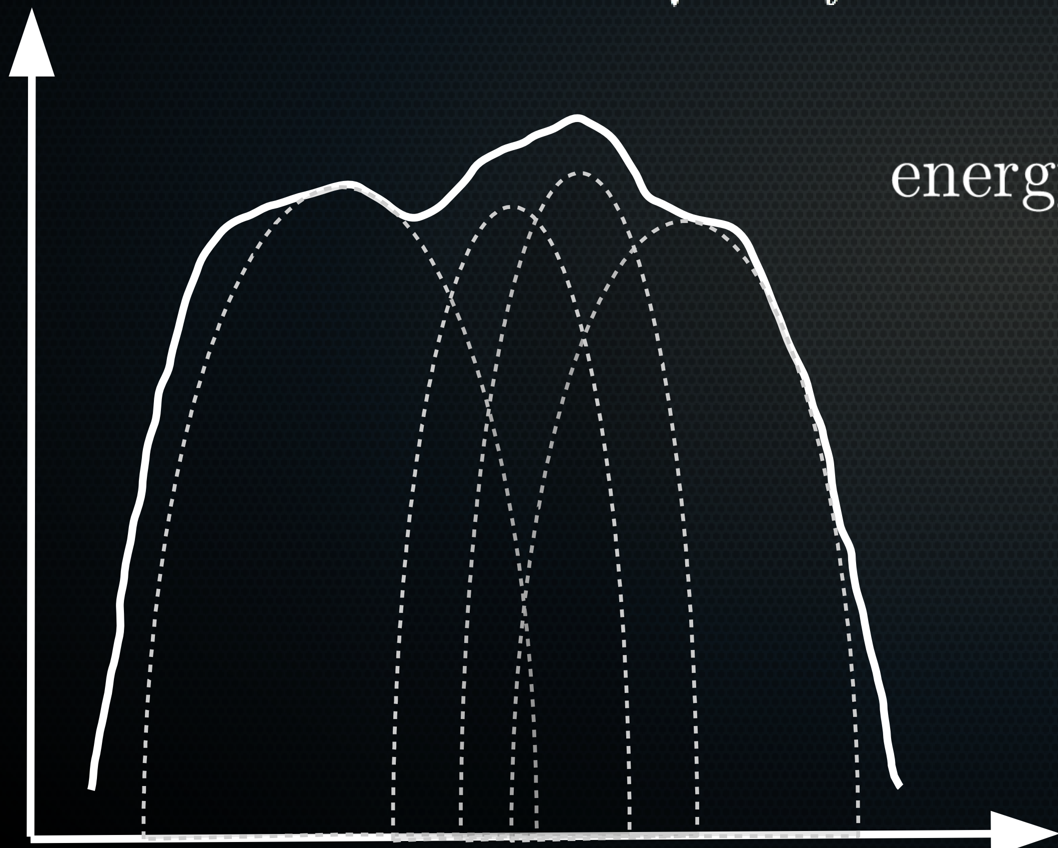
(Turbulence + Gravity in N-PDFs)





Decomposition of the column - density PDFs (Stanchev et al., 2015)

$$\mathrm{lgn}_i(N; a_i, N_i, \sigma_i) = \frac{a_i}{\sqrt{2\pi\sigma_i^2}} \exp\left(-\frac{[\log(N/N_i)]^2}{2\sigma_i^2} \right), \qquad (1 \leq i \leq m)$$

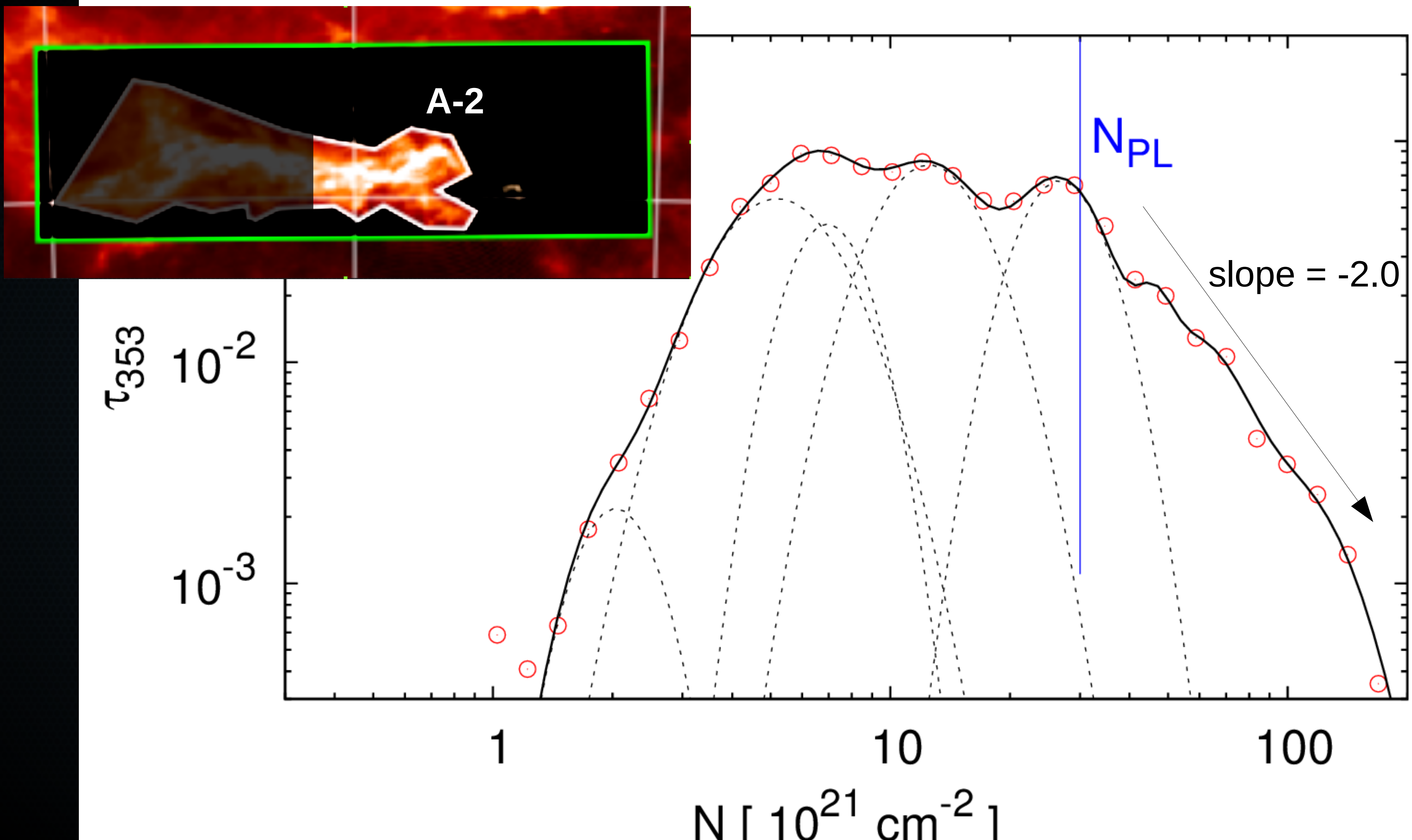


energy injection scale $\leq$

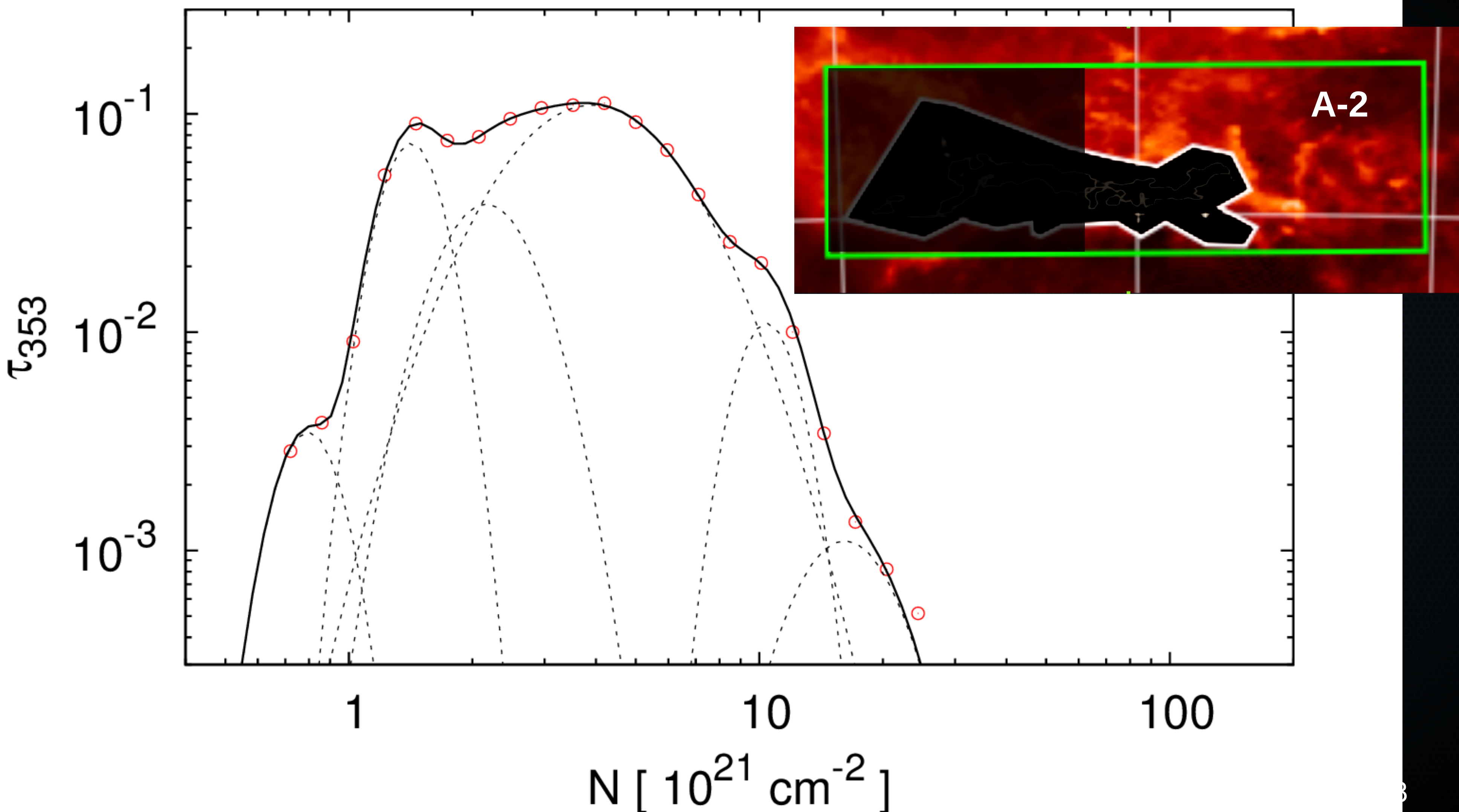
$$L_i = \sqrt{\frac{a_i}{\sum_i a_i}} R$$

$\leq$ energy dissipation scale

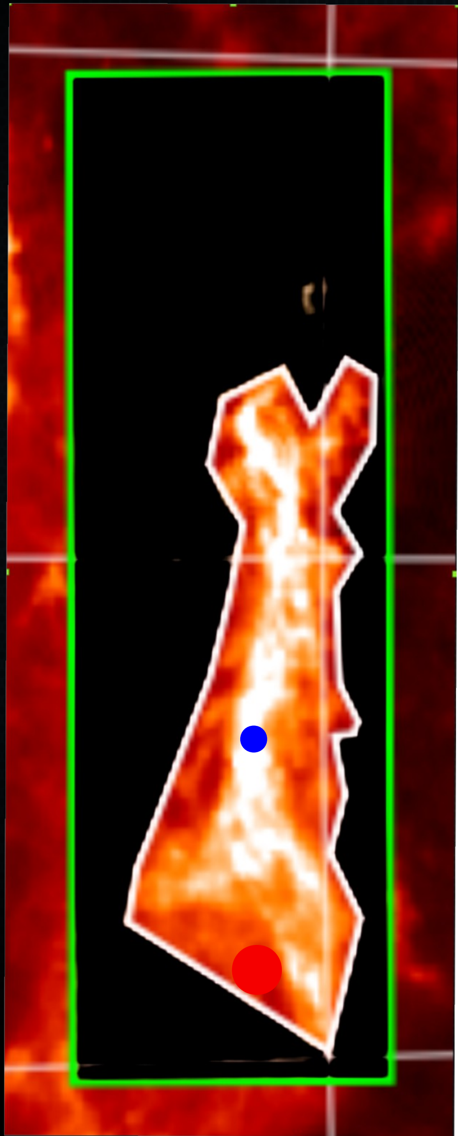
Central Filament: Region A-2

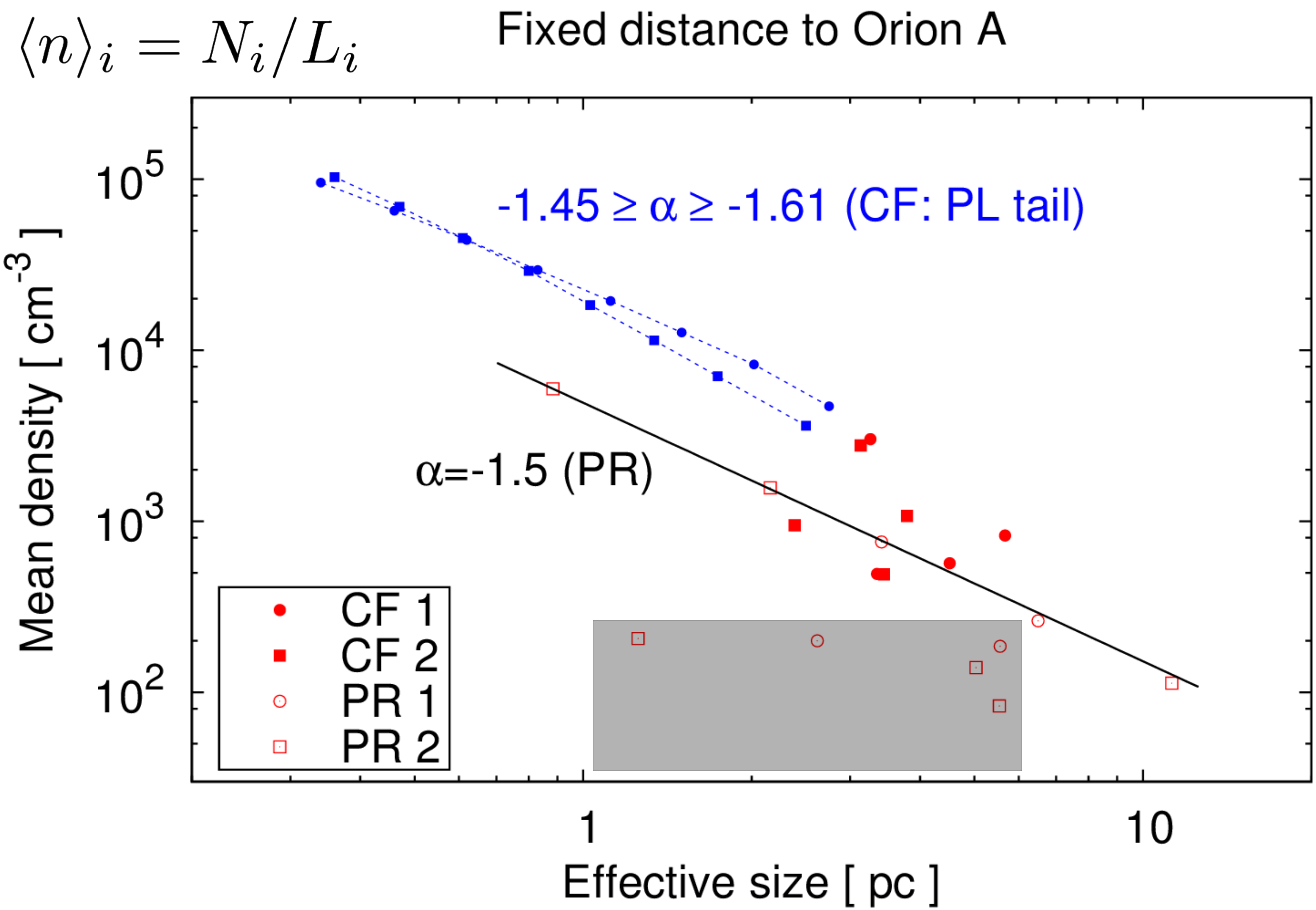


Polygonal ring: Region A-2

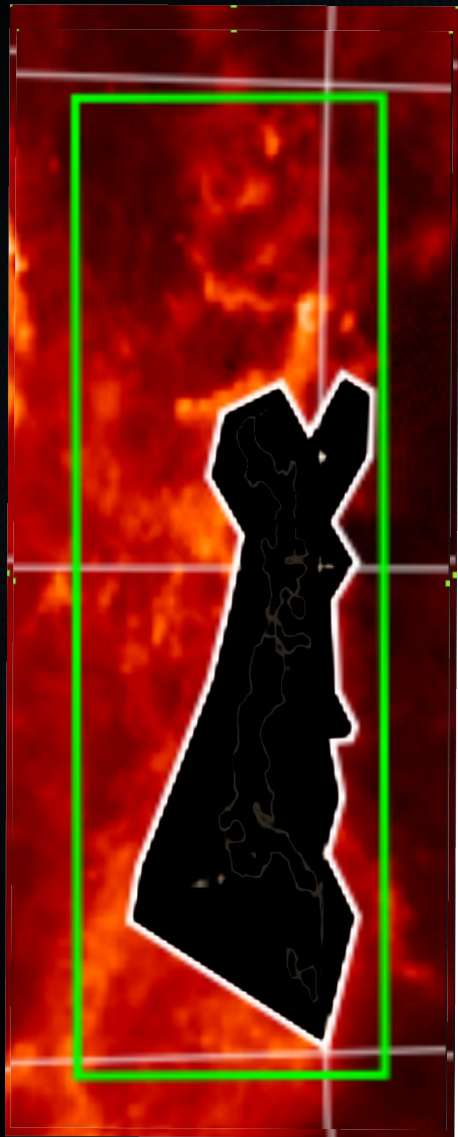


Density scaling relations

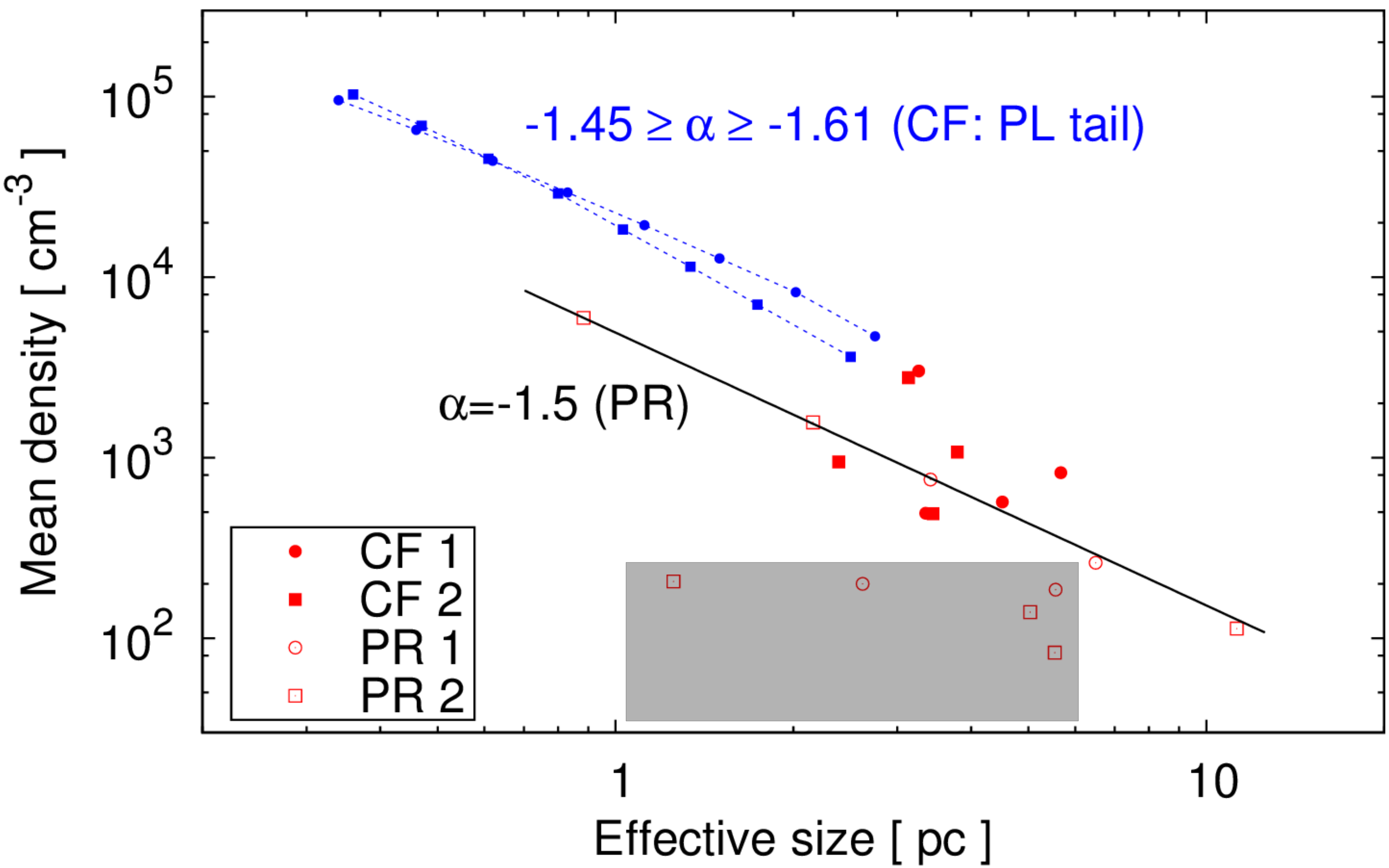




Density scaling relations



$$\langle n \rangle_i = N_i / L_i$$



Density scaling relations

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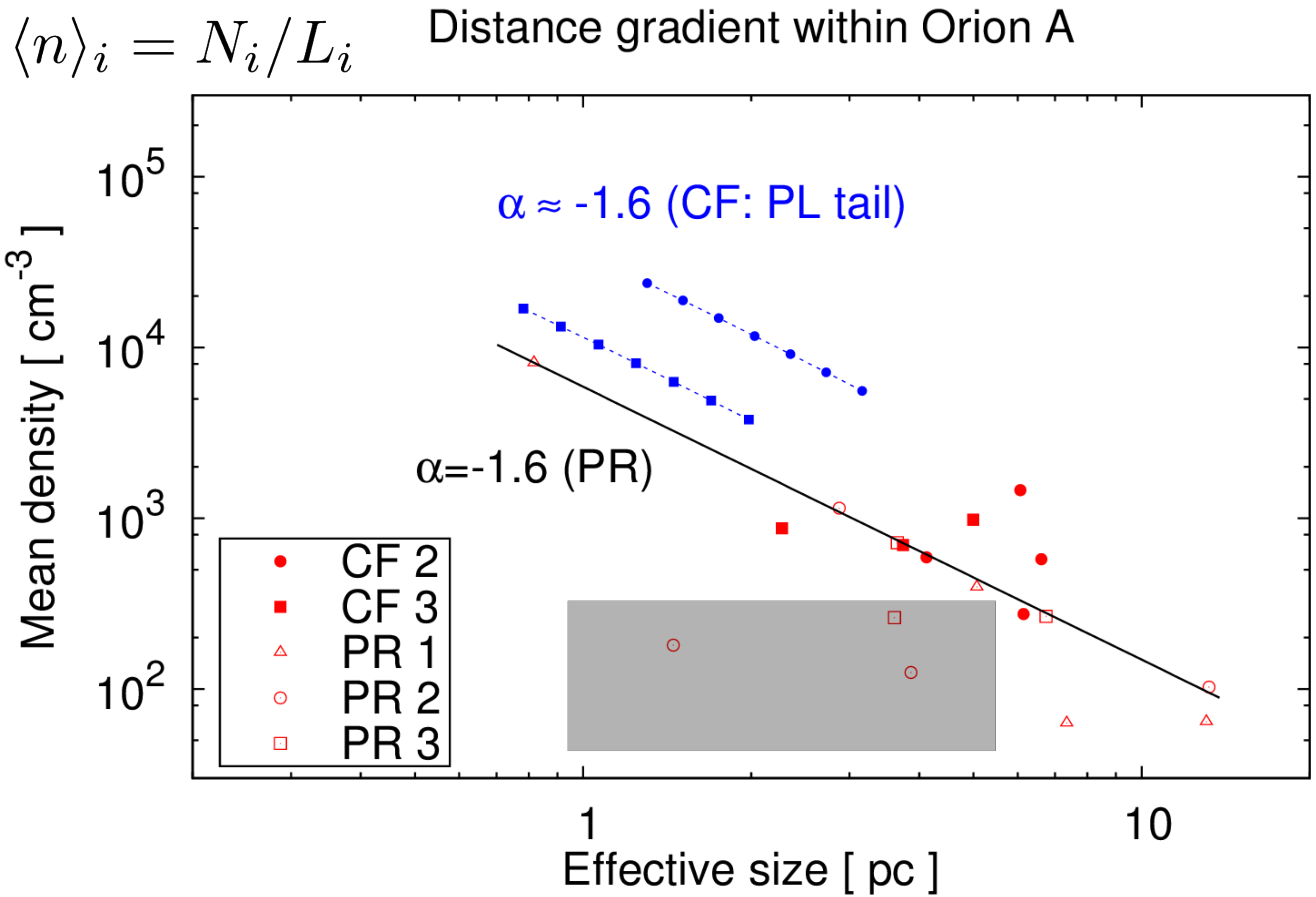


Conclusions

1. Orion A is a self-gravitating star forming region. Probably this is a relevant conclusion because:

   - The slope of the PL tail (about -2) for the CF zone suggests a well developed density profile inside the high-density CF regions, typical for self-gravitating cores.

   - The density scaling law of the dense lognormal components in the diffuse vicinity of Orion A is identical to the one derived for their counterparts in the CF.

2. The high slope of the common density scaling relation (about -1.5) is indicative rather for a gravo-turbulent regime than for a purely turbulent one (about -1, Larson 1981).

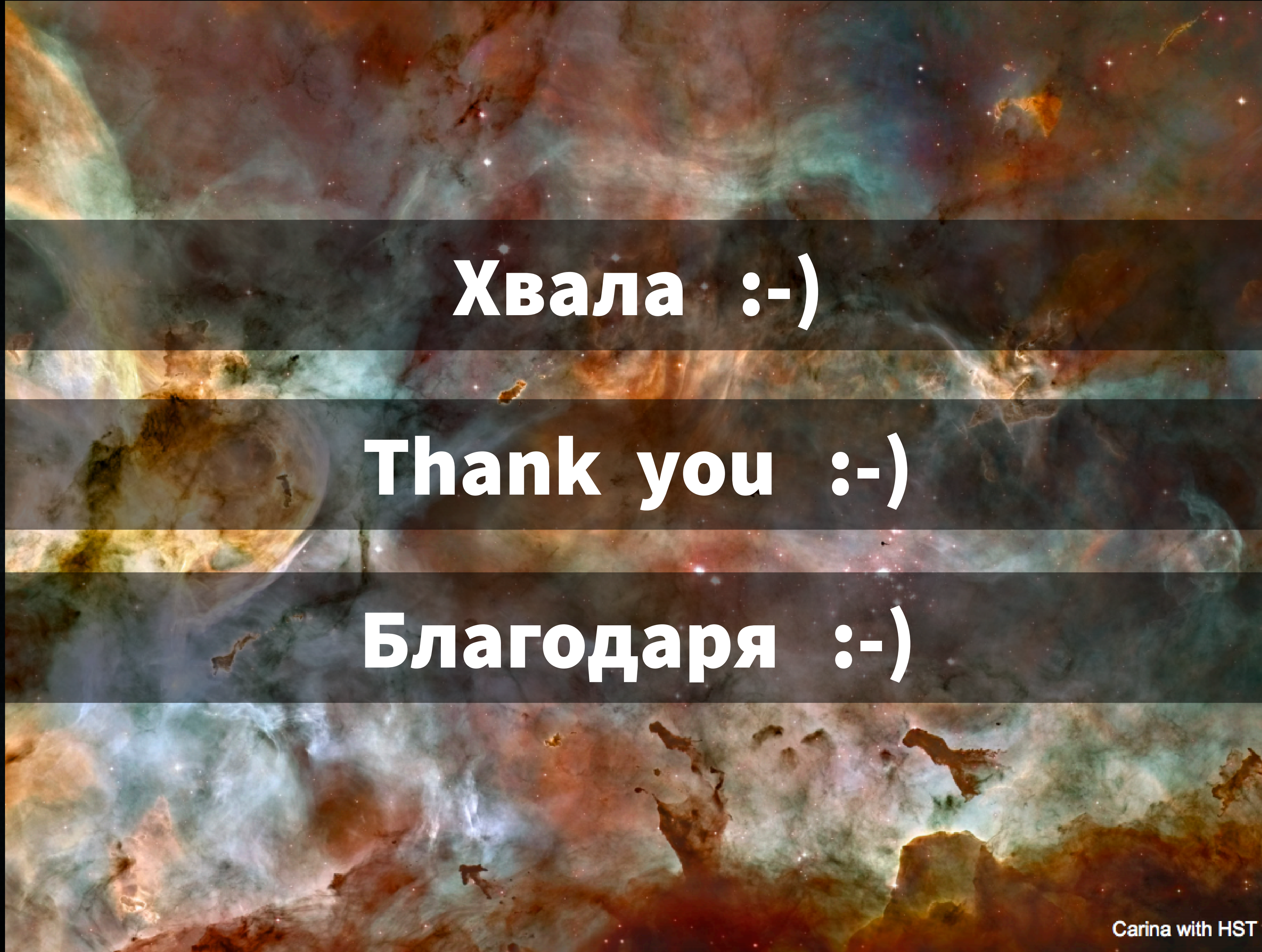
3. The distance gradient effect does not affect the density scaling law.

Software used:

healpix2tan — Map pre-processing

astropy — A Community Python Library for Astronomy — Extraction (masking) of zones

C++ + gnuplot — N-pdf decomposition, scaling relations



Carina with HST

Decomposition of the column - density PDFs

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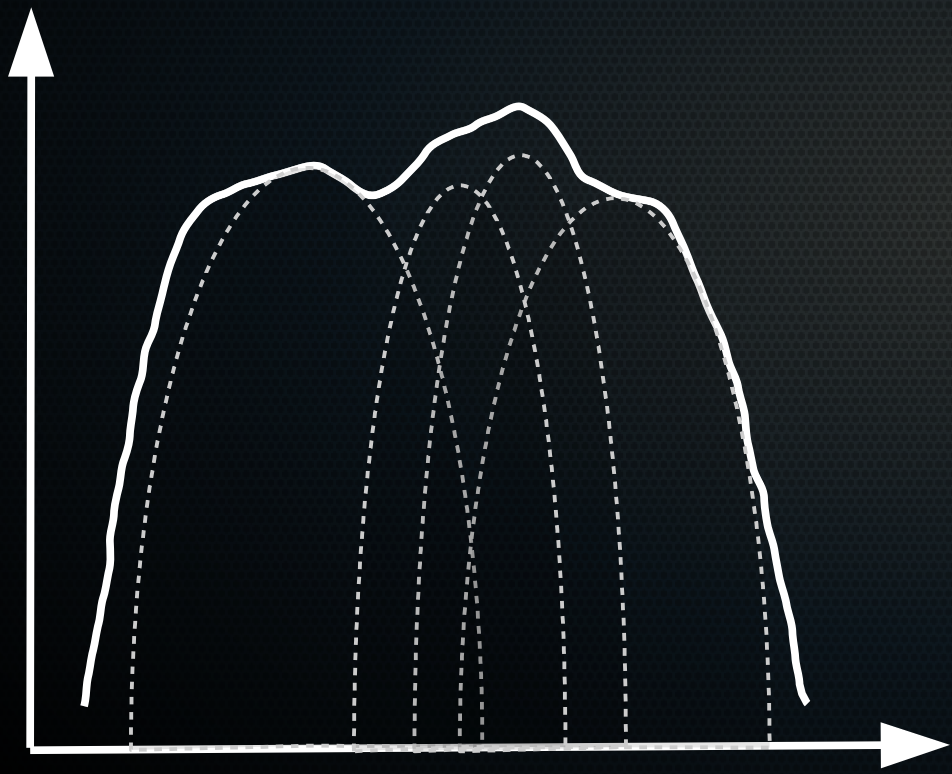

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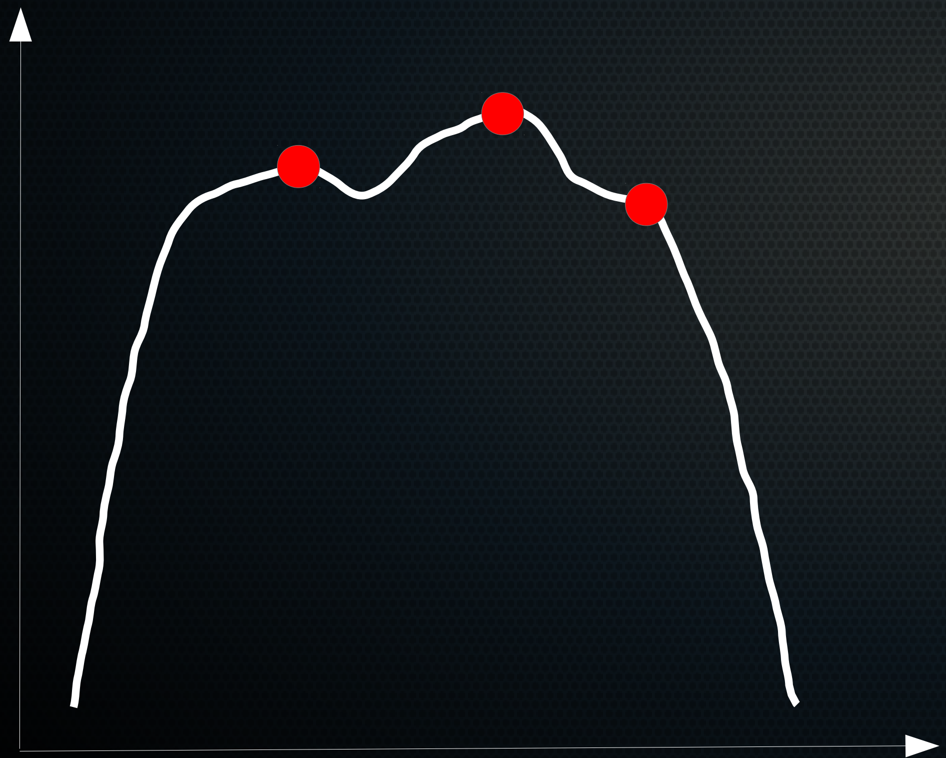
1. Prominent local peaks: $N_i^{(0)}, \sigma_i^{(0)}, a_i^{(0)}$



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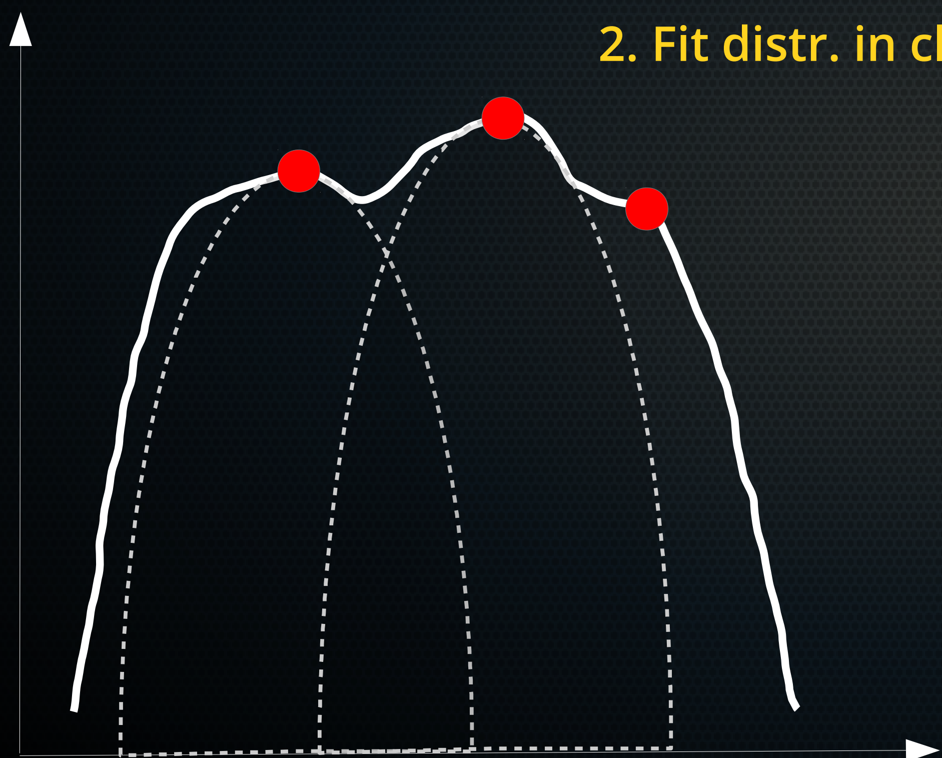
1. Prominent local peaks: $N_i^{(0)}, \sigma_i^{(0)}, a_i^{(0)}$

2. Fit distr. in close vicinities of the peaks: $N_i^{(1)}, \sigma_i^{(1)}, a_i^{(1)}$



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3. Compose the total fitting function: $\sum_{i=1}^{m} \mathrm{lgn}_i$

$$\mathrm{lgn}_i(N; a_i, N_i, \sigma_i) = \frac{a_i}{\sqrt{2\pi\sigma_i^2}} \exp\left(-\frac{[\log(N/N_i)]^2}{2\sigma_i^2}\right), \qquad (1 \le i \le m)$$

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4. Fit the whole distribution: $N_i^{(2)}, \sigma_i^{(2)}, a_i^{(2)}$

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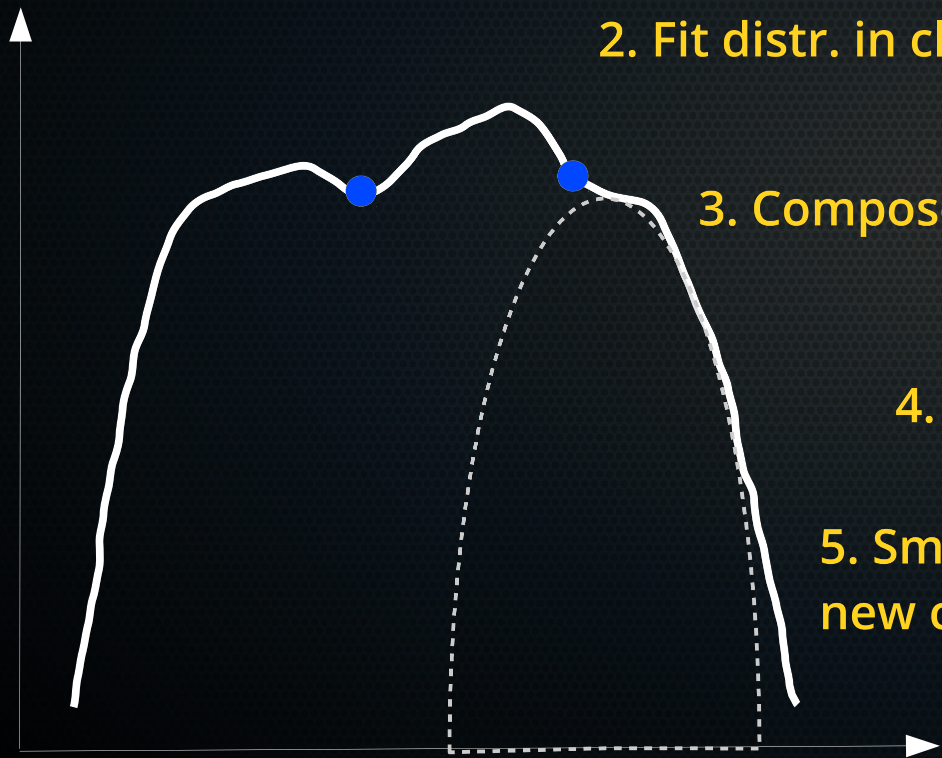

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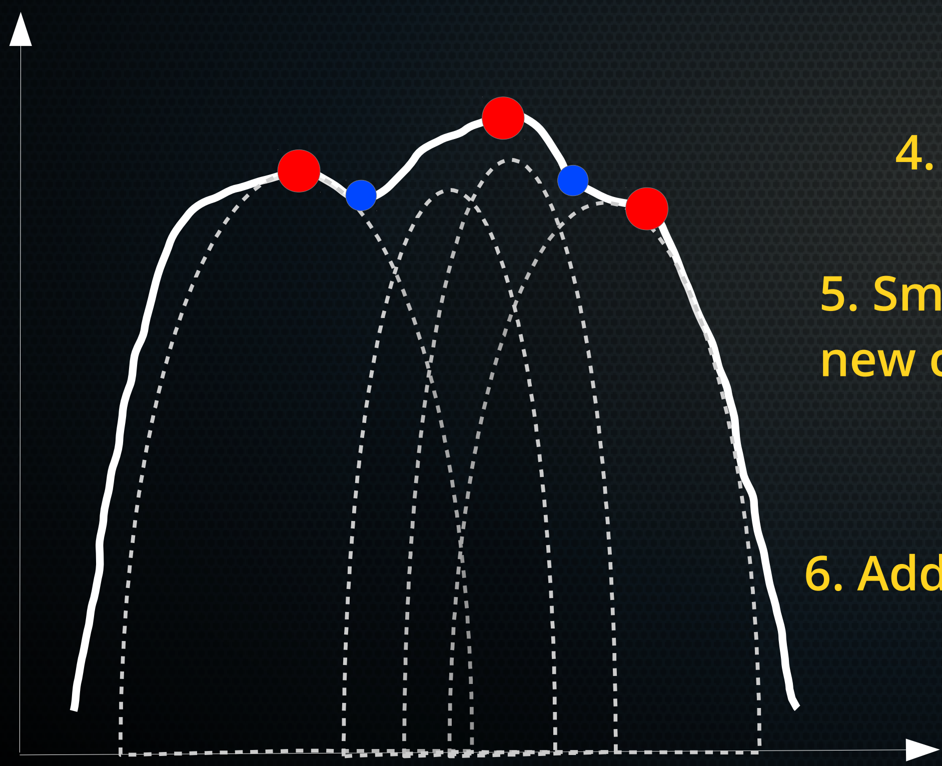
2. Fit distr. in close vicinities of the peaks: $N_i^{(1)}, \sigma_i^{(1)}, a_i^{(1)}$

3. Compose the total fitting function: $\sum_{i=1}^{m} \mathrm{lgn}_i$

4. Fit the whole distribution: $N_i^{(2)}, \sigma_i^{(2)}, a_i^{(2)}$

5. Small local peaks / inflexion points; Add new components. Repeat previous steps:

$N_i^{(3)}, \sigma_i^{(3)}, a_i^{(3)}$



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6. Add additional components (if needed)

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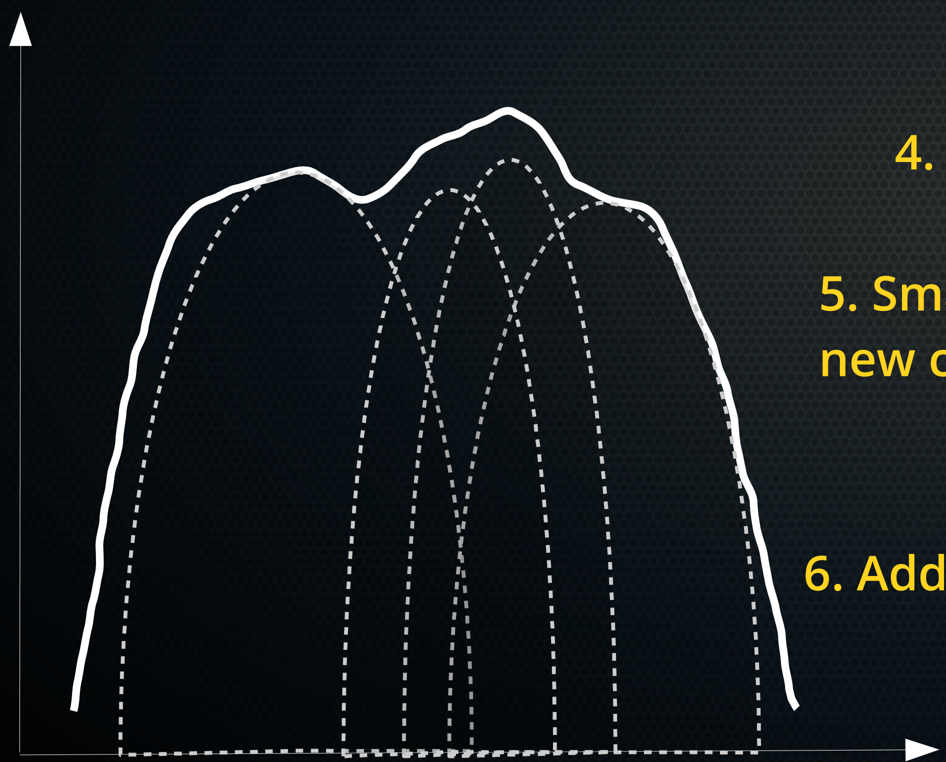
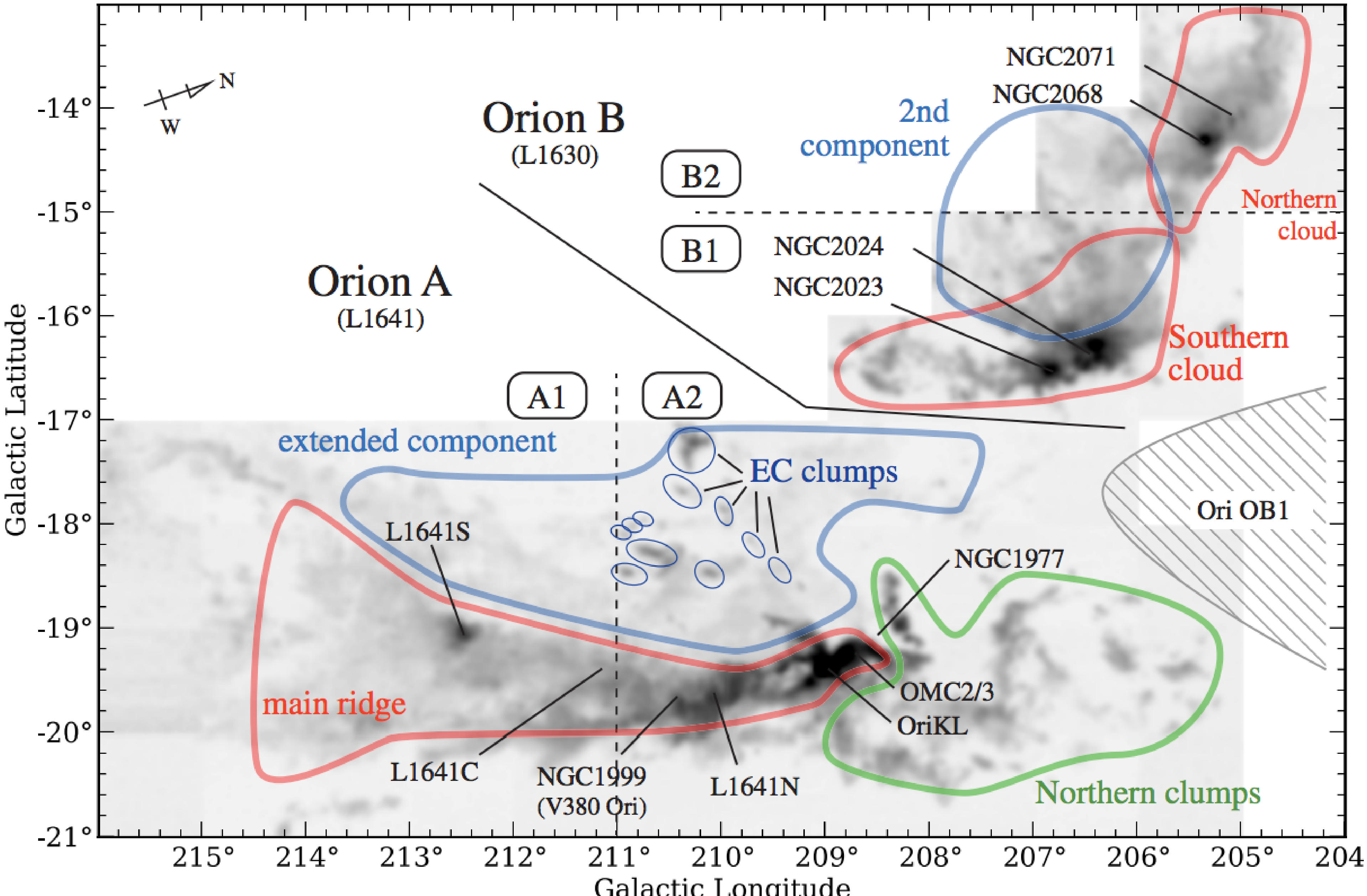


7. Fit the total fitting function: $(N_i, \sigma_i, a_i)(i = 1, \cdots, m)$



N
W
Orion B
(L1630)
B2
B1
2nd
component
NGC2071
NGC2068
Northern
cloud
NGC2024
NGC2023
Southern
cloud
Orion A
(L1641)
A1
A2
extended component
EC clumps
Ori OB1
L1641S
NGC1977
OMC2/3
OriKL
main ridge
L1641C
NGC1999
(V380 Ori)
L1641N
Northern clumps
-14°
-15°
-16°
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Galactic Latitude
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