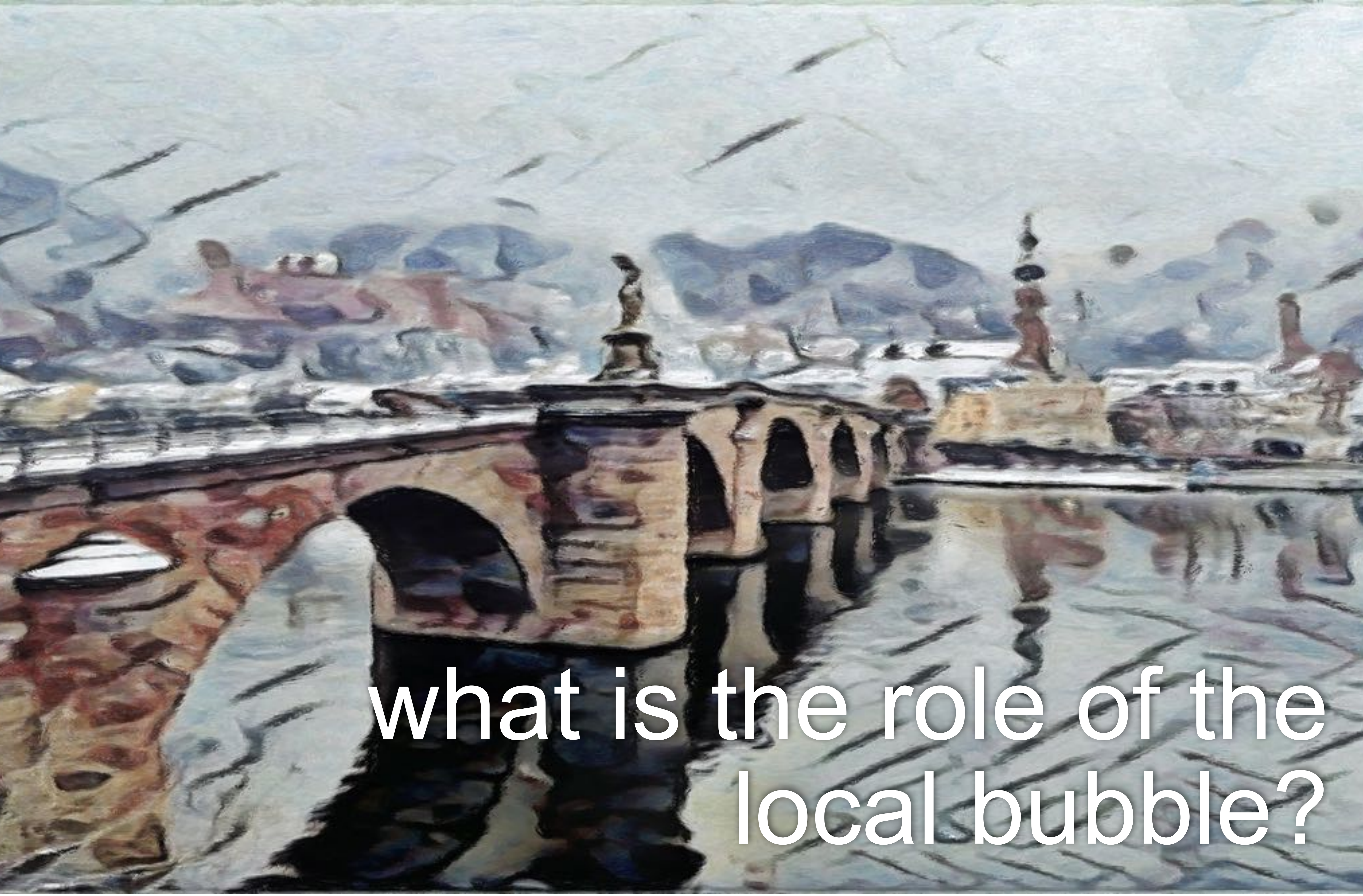

what is the role of the local bubble?

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dust polarization maps

can we fully understand this map?

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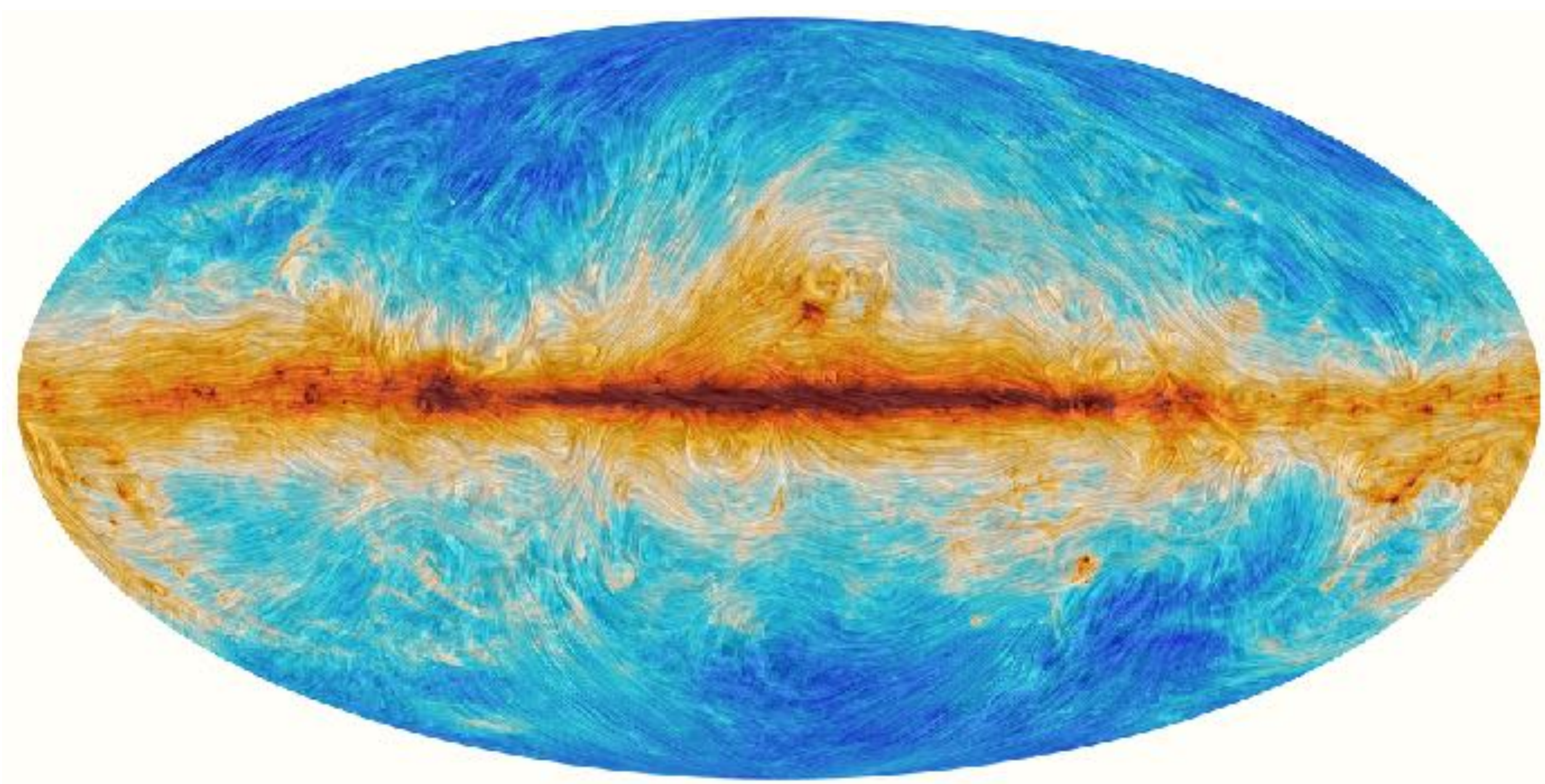

the sky as seen by Planck

can we fully understand this map?

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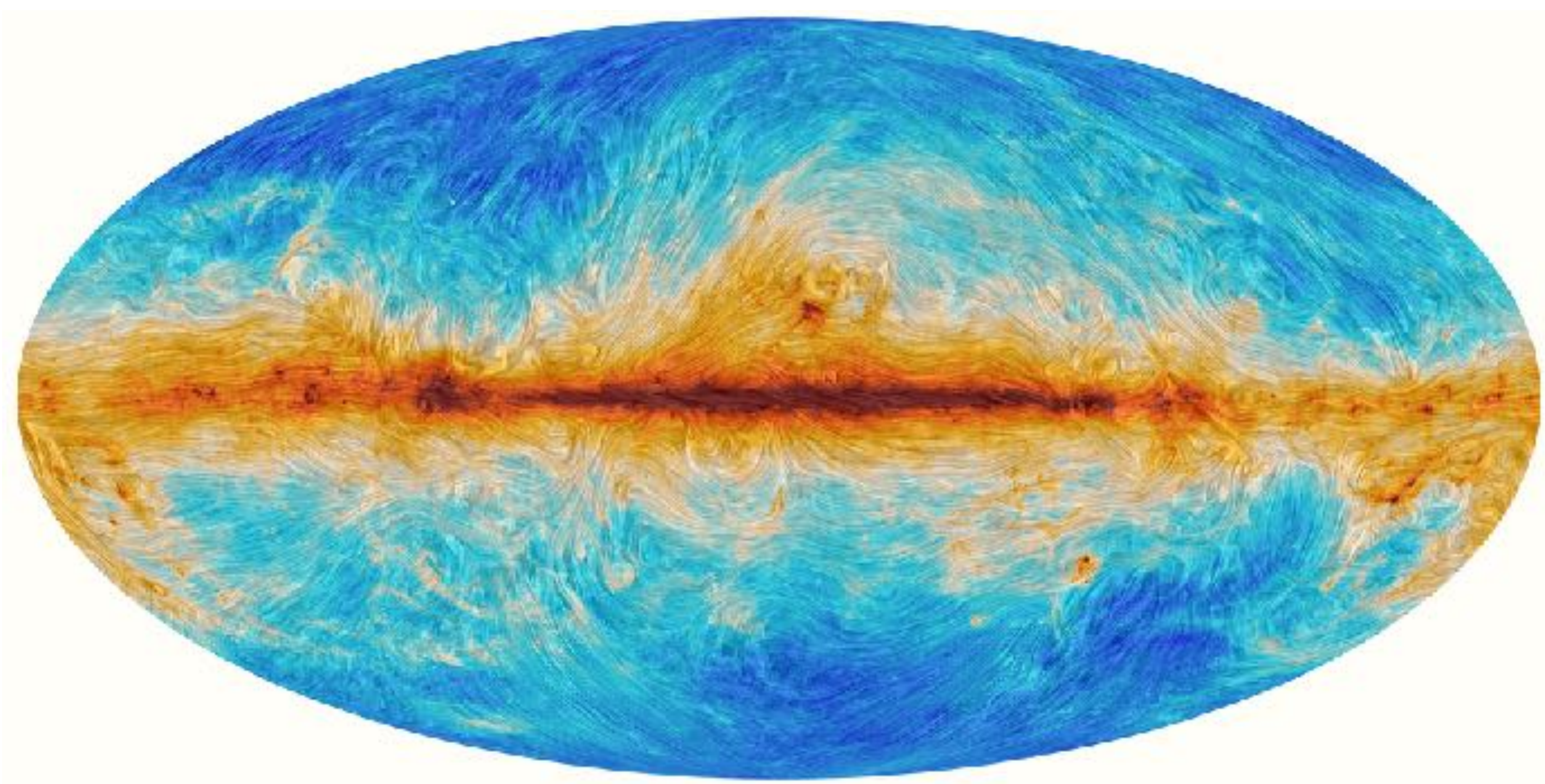

unfortunately we are far away from that still …

the sky as seen by Planck

synthetic maps with Polaris …

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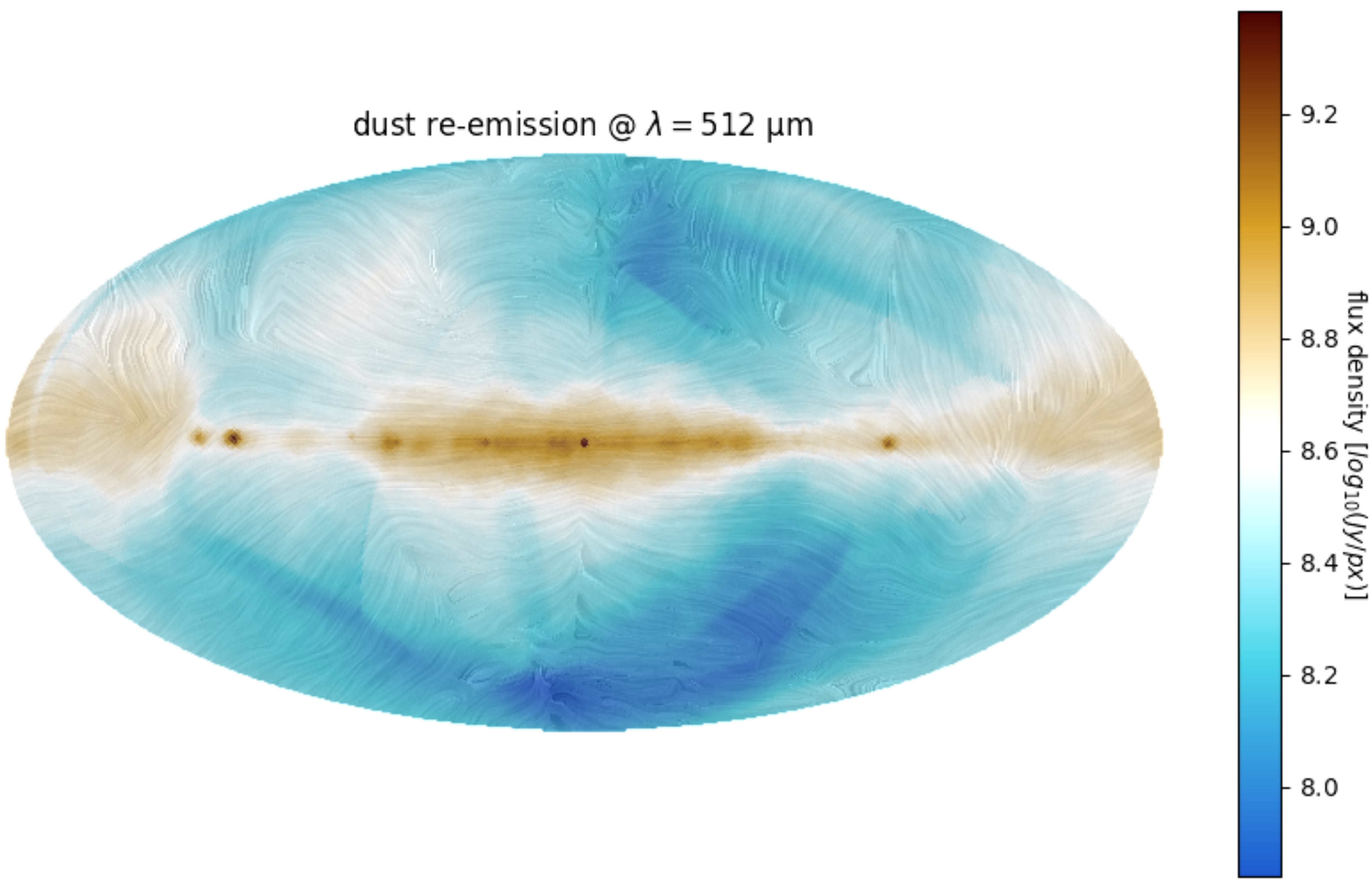

Polaris
polarized radiative transfer

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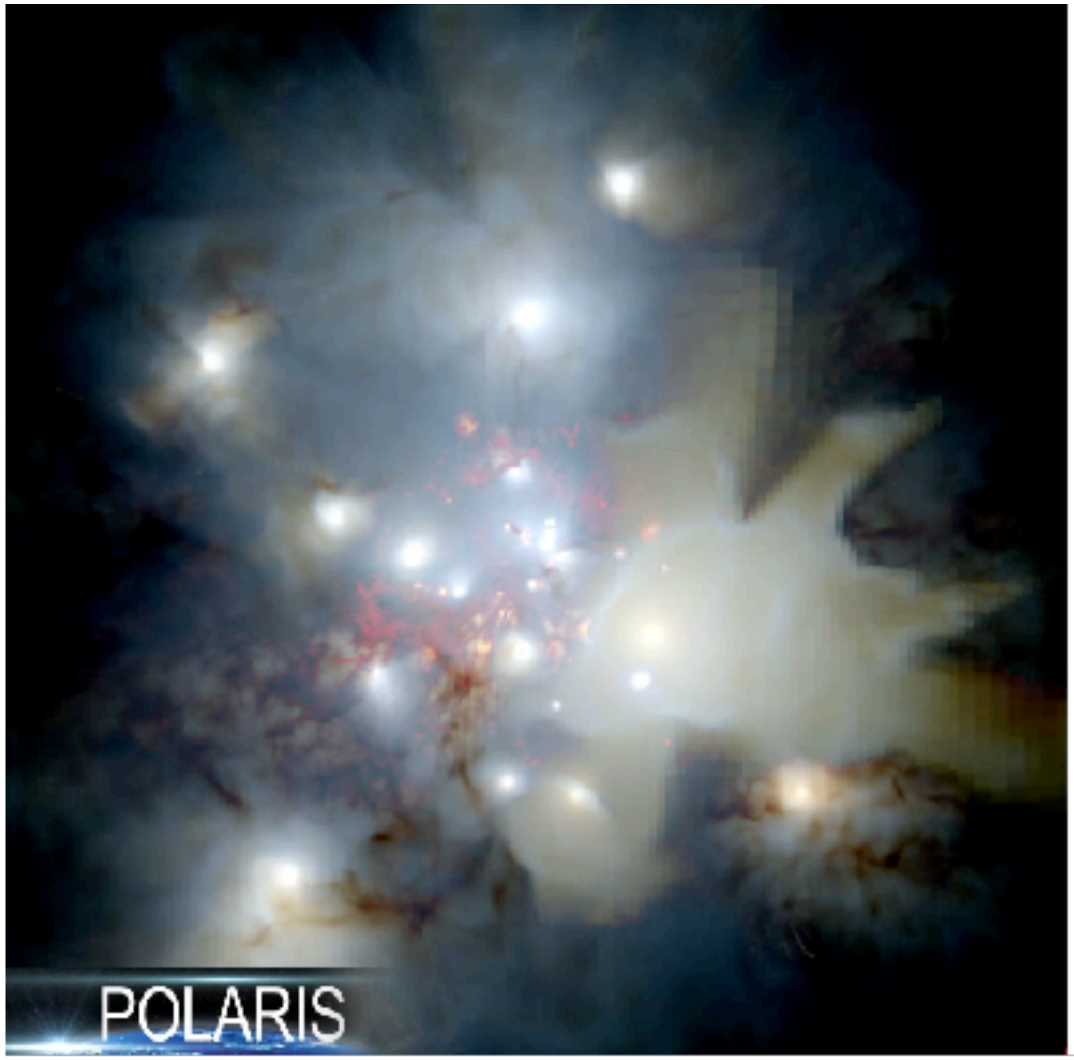
- MC dust heating: Combined heating algorithm of continuous absorption and immediate temperature correction
- grid: octree-grid with adaptive refinement
- polarization mechanism: Dichroic extinction, thermal reemission, and scattering
- dust grain alignment mechanisms:
  - Imperfect Davis-Greenstein (IDG)
  - Radiative torques (RAT)
  - Mechanical alignment (GOLD)
  - Imperfect internal alignement
  - Independent dust grain composition
- optimization: Enforced scattering, wavelength range selection, and modified random walk



Reissl et al. (2016, A&A, 593,87)
Reissl et al. (2019, ApJ, 885, 15)

Polaris website in Kiel: http://www1.astrophysik.uni-kiel.de/~polaris/

Polaris 1
modeling Faraday rotation

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Stokes formalism:

$$\vec{S} = (I, Q, U, V)^T$$

I = total intensity
Q,U = linear polarization
V = circular polarization

$$P_\mathrm{l} = \sqrt{\frac{U^2 + Q^2}{I^2}}\ .$$

fraction of linear polarization

$$p_\mathrm{t} = \sqrt{U^2 + Q^2 + V^2}$$

total polarization fraction

Equation of radiative transfer:

$$\frac{d}{d\ell}\vec{S} = -\hat{K}\vec{S} + \vec{J}\ .$$

K = 4x4 Müller matrix
J = emissivity

$$\frac{\mathrm{d}}{d\ell}\begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix} = \begin{pmatrix} j_\mathrm{I} \\ j_\mathrm{Q} \\ 0 \\ j_\mathrm{V} \end{pmatrix} - \begin{pmatrix} \alpha_\mathrm{I} & \alpha_\mathrm{Q} & 0 & \alpha_\mathrm{V} \\ \alpha_\mathrm{Q} & \alpha_\mathrm{I} & \kappa_\mathrm{V} & 0 \\ 0 & -\kappa_\mathrm{V} & \alpha_\mathrm{I} & \kappa_\mathrm{Q} \\ \alpha_\mathrm{V} & 0 & -\kappa_\mathrm{Q} & \alpha_\mathrm{I} \end{pmatrix} \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}\ .$$

with appropriate rotation of coordinate direction to simplify system in each cell

Reissl et al. (2019, ApJ, 885, 15)

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Polaris 2
modeling Faraday rotation

position angle:

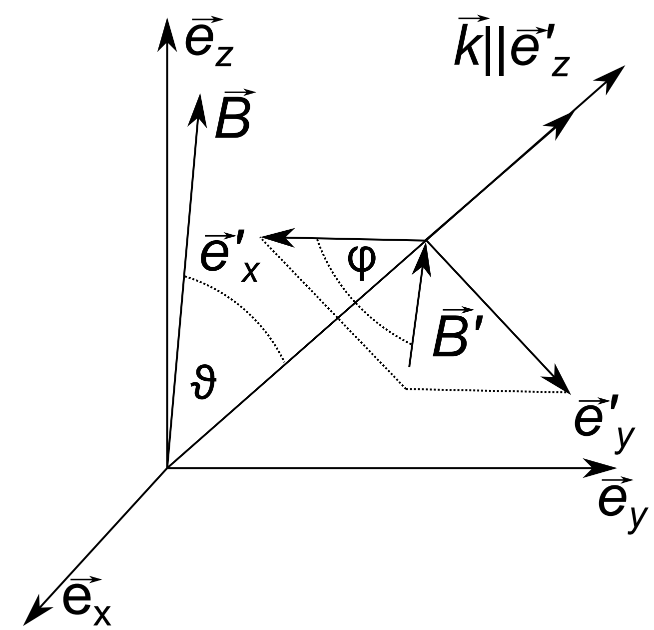
$$\chi = \frac{1}{2}\tan^{-1}\left(\frac{U}{Q}\right).$$

change of position angle:

$$\chi_{\rm obs} = \chi + \lambda^2 \times RM$$

with Faraday rotation measure

$$RM = \frac{1}{2\pi}\frac{n_{\rm th}e^2}{m_{\rm e}^2 c^4}\int n_{\rm th} B_{||} d\ell$$



Faraday depolarization

$$DP = \frac{I_{\lambda_1} \times P_{\rm l,\lambda_1}}{I_{\lambda_2} \times P_{\rm l,\lambda_2}}\left(\frac{\lambda_1}{\lambda_2}\right)^{\alpha}$$

Reissl et al. (2019, ApJ, 885, 15)

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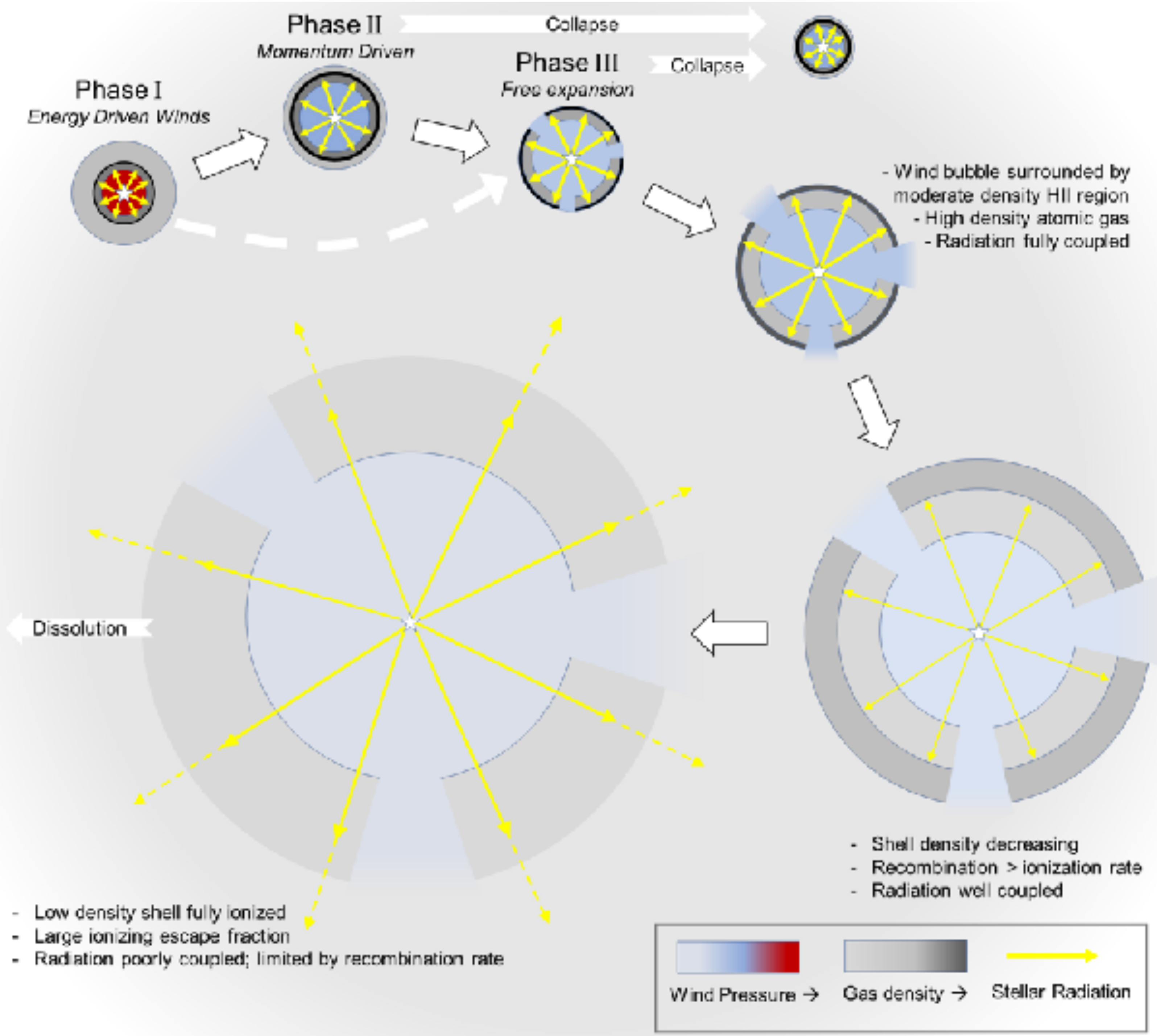
WARPFIELD
1D cloud/cluster model

WARPFIELD:

- 1D model of cluster embedded in spherical cloud
- starburst99 cluster evolution
- dynamics of think shell is calculated consistently
- with all relevant forms of stellar feedback
- fast, allowing for large parameter studies



Rahner et al. (2017, MNRAS, 470, 4453)
Rahner et al. (2019, MNRAS, 483, 2547)

WARPFIELD

WARPFIELD-EMP

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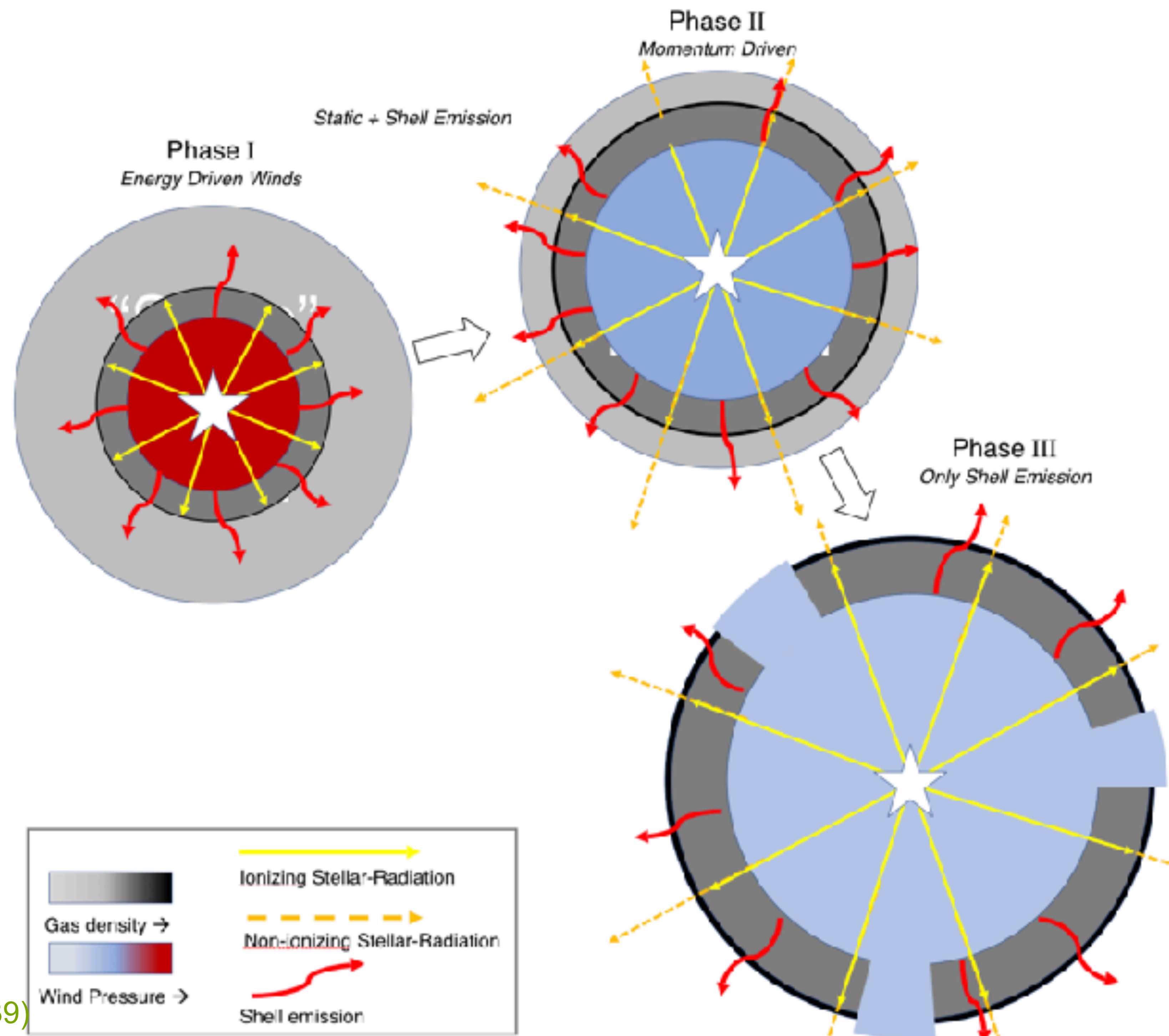
WARPFIELD-EMP emission predictor

WARPFIELD-EMP:

- 1D model of cluster embedded in spherical cloud
- starburst99 cluster evolution
- dynamics of think shell is calculated consistently
- with all relevant forms of stellar feedback
- fast, allowing for large parameter studies
- coupled to CLOUDY and 1D RT
- many different emission diagnostics



Pellegrini et al. (2020, MNRAS, 496, 339)

WARPFIELD-EMP

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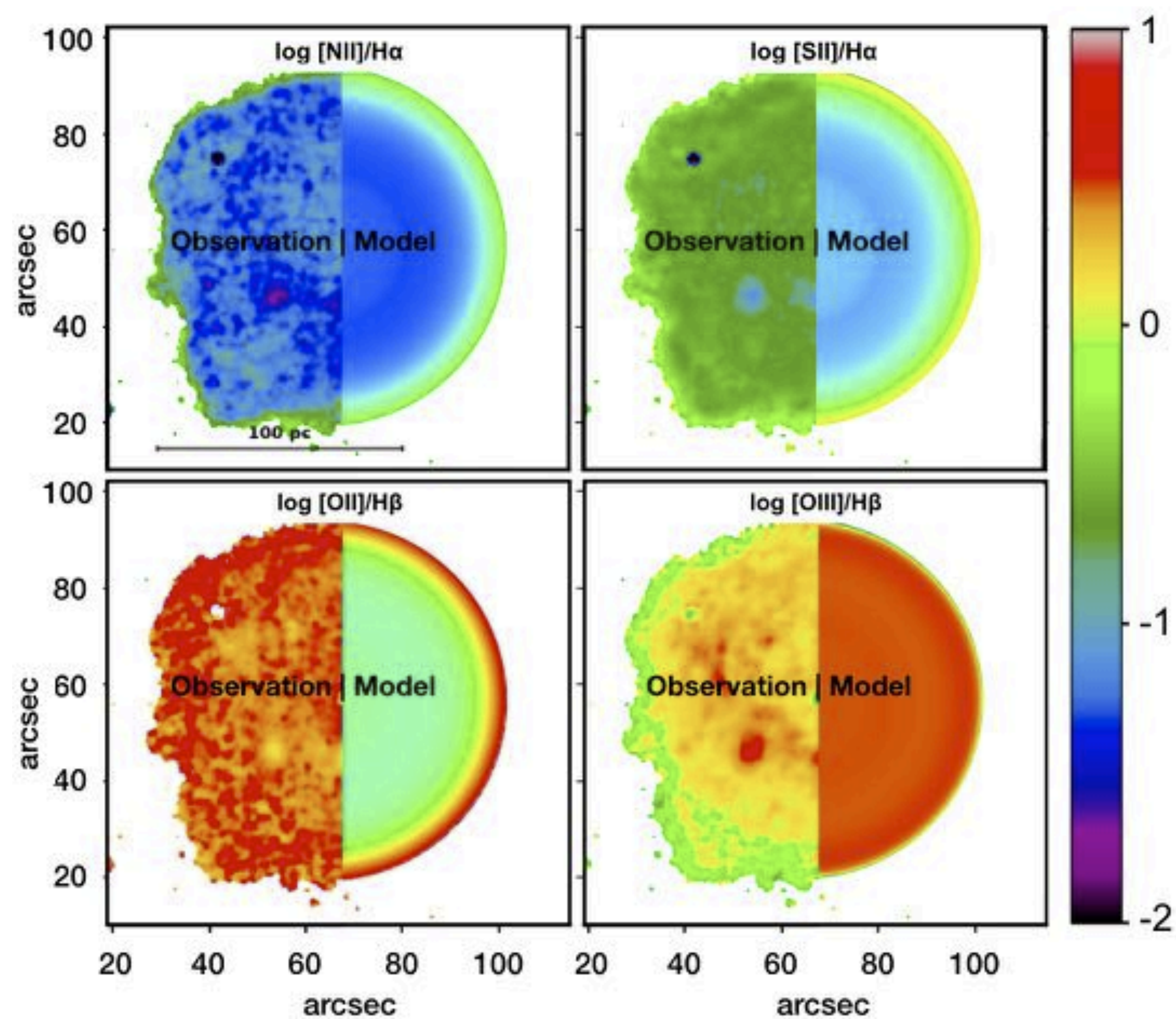

Pellegrini et al. (2020, MNRAS, 496, 339)

Polaris & WARPFIELD-POP dust polarization, synchrotron, Faraday rotation

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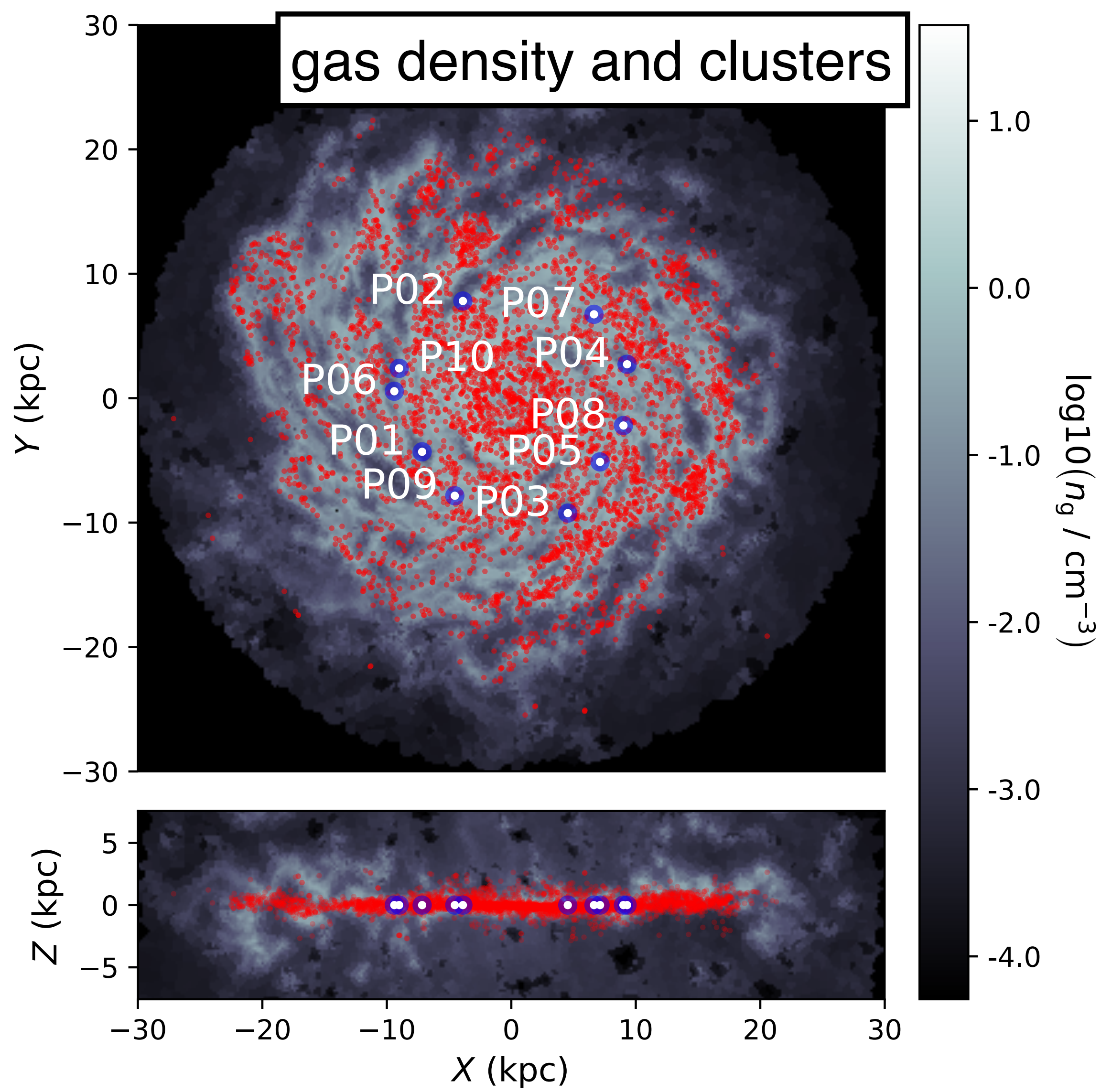

- take density and magnetic field configuration from theoretical or numerical model
- use KS relation to estimate star formation (or any other rule)
- sample star cluster mass function and merge with WARPFIELD
- use WARPFIELD-EMP with Polaris (CLOUDY) to construct the ISRF
- use Polaris again generate maps of the emission diagnostics of interest
- and to compute Faraday rotation measure (RM) maps

Pellegrini et al. (2020, MNRAS, 498, 3193)
Reissl et al. (in prep.)

Auriga 6 galaxy

Polaris & WARPFIED-POP modeling Faraday rotation

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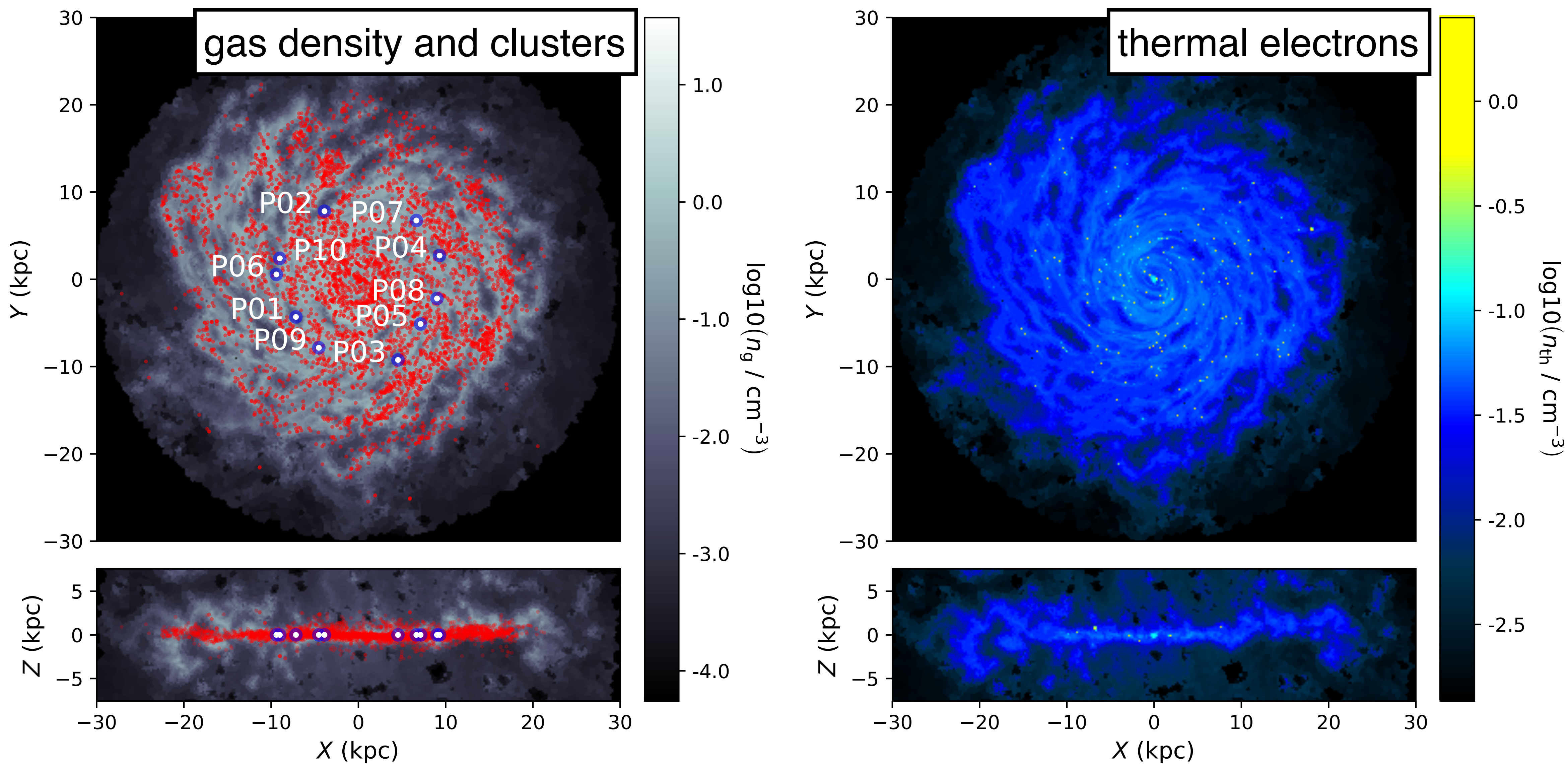

Reissl et al. (in prep.)

Auriga 6 galaxy

dust polarization maps

synthetic maps from Polaris & model galaxy

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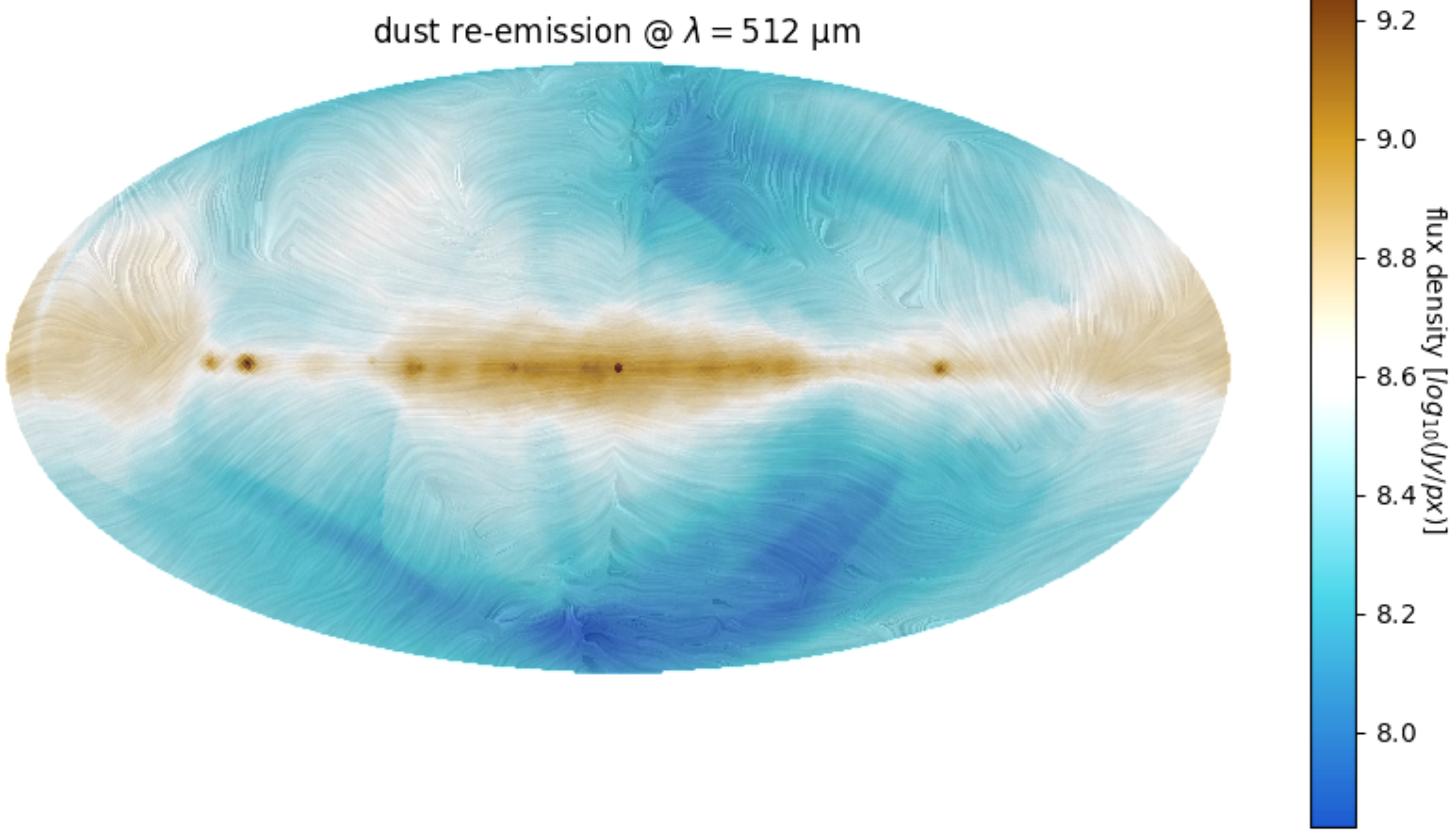

dust polarization maps

synthetic maps from Polaris & model galaxy

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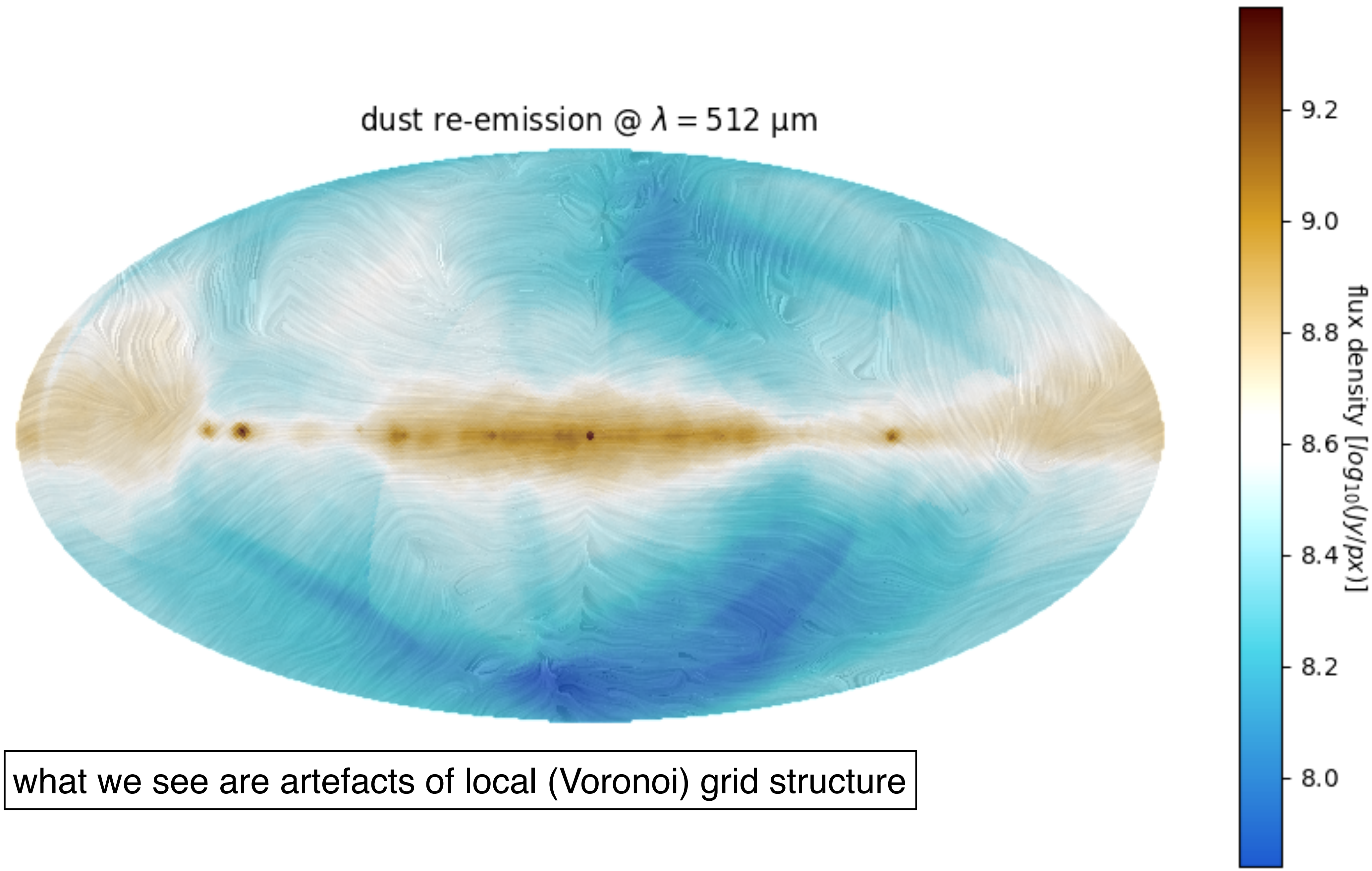

what we see are artefacts of local (Voronoi) grid structure some info on local bubble

importance of local bubble

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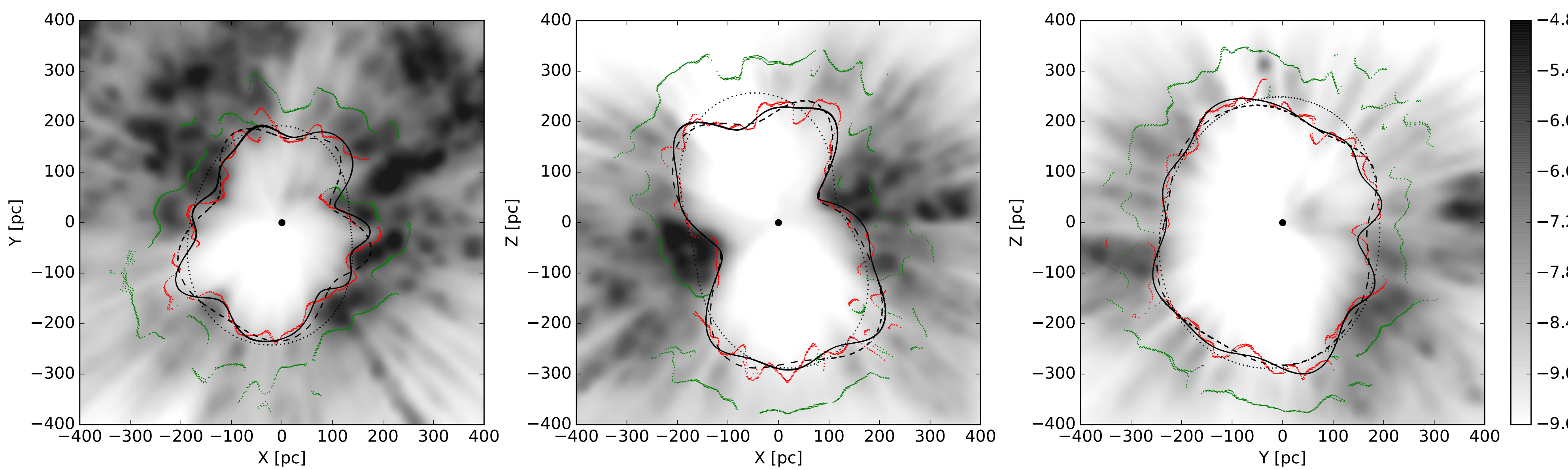
local bubble from dust extinction:



Pelgrims et al. (2020, A&A, 636, A17)

see also: Alves et al. (2018, A&A, 611, L5),
Marechal & Miville-Deschênes (2021, ApJ, 908, 186),
Krause & Hardcastle (2021, MNRAS, 502, 2807)

some info on local bubble

importance of local bubble

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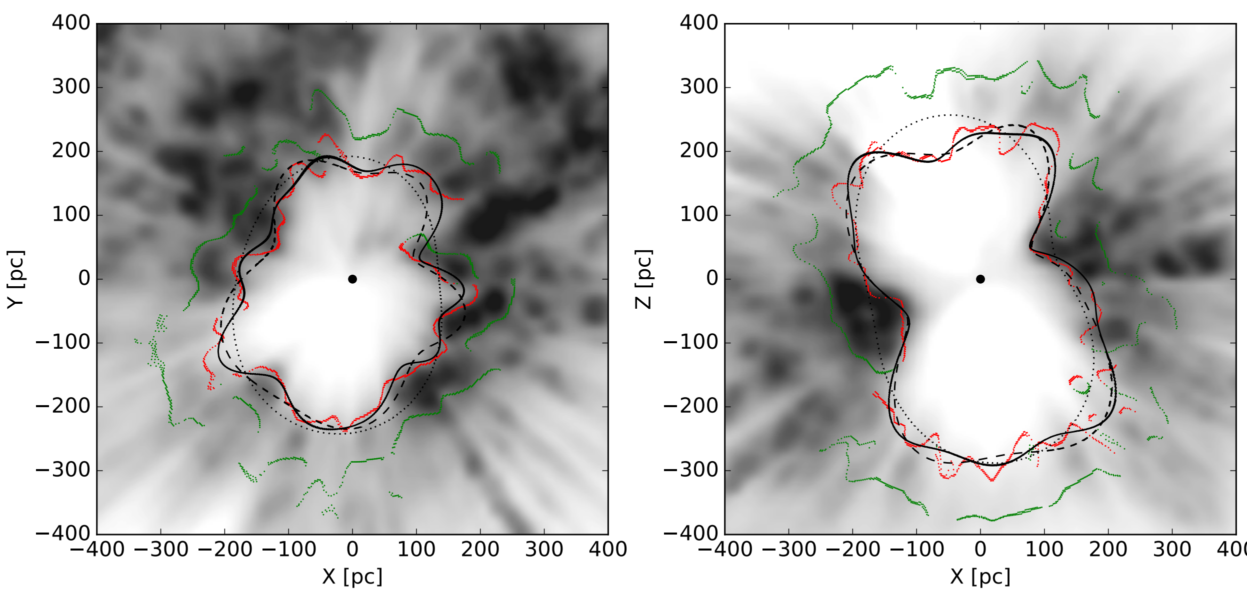
local bubble from dust extinction:



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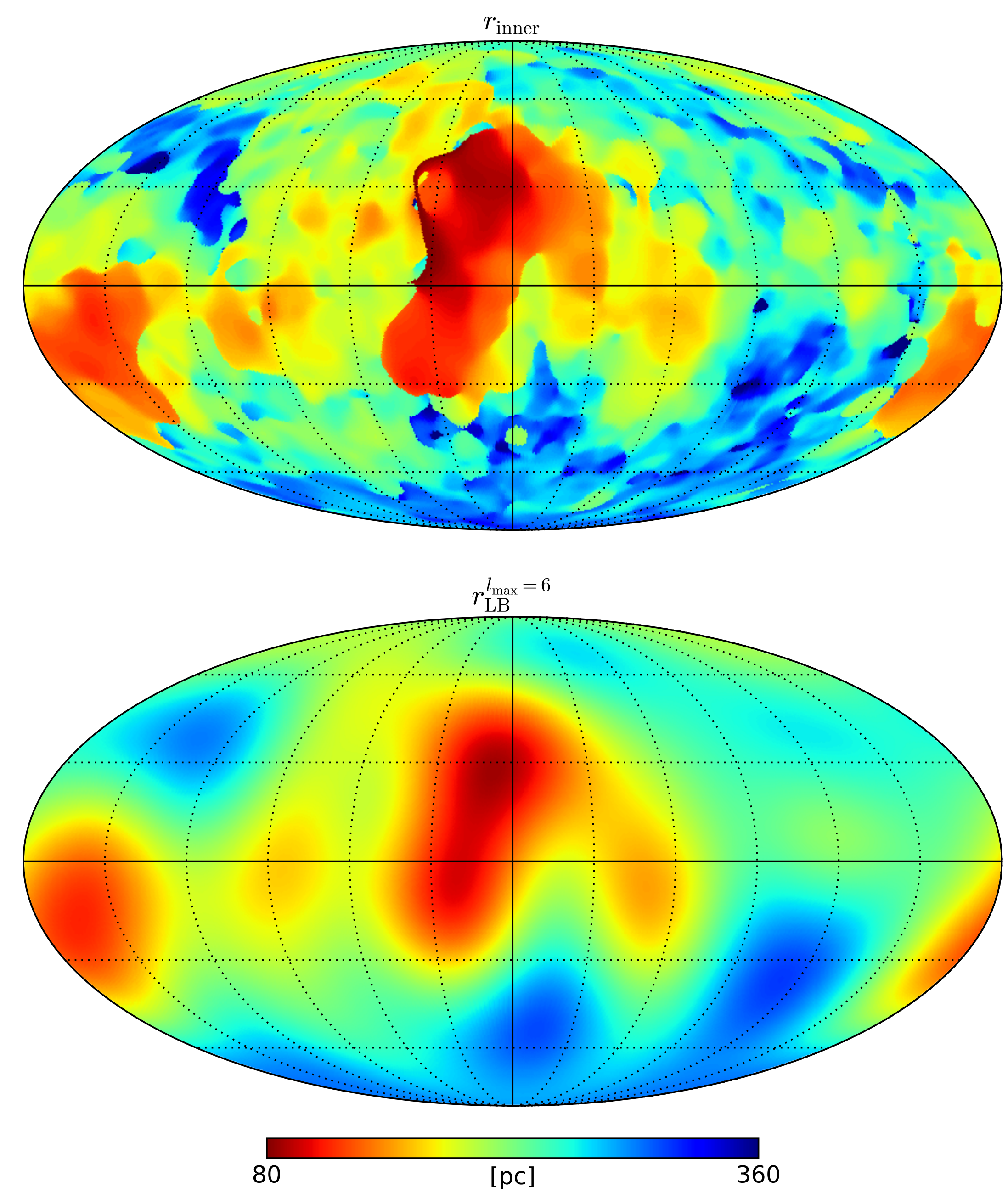
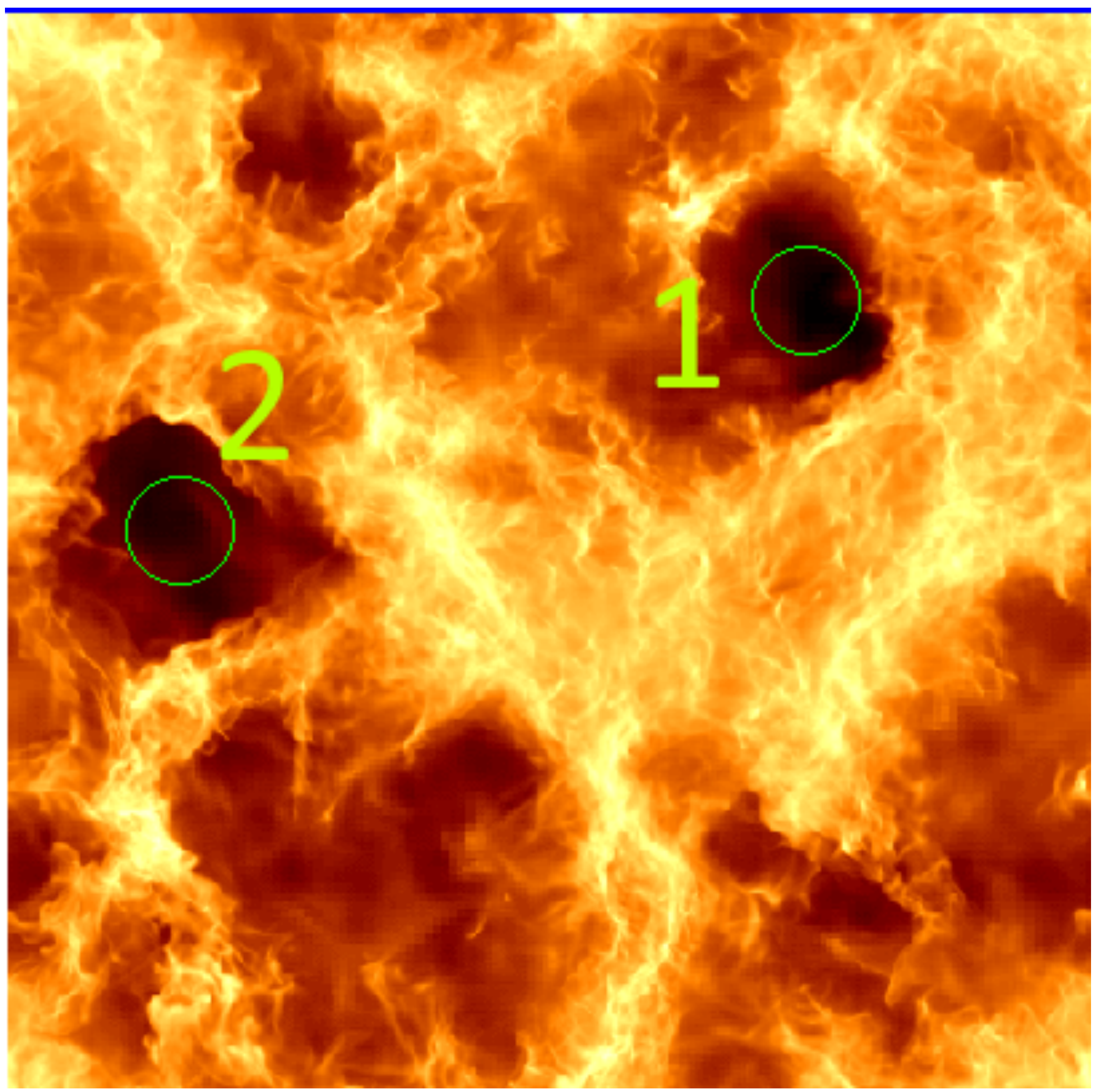


resulting full sky map of local bubble with distance color coded

Polaris
modeling local bubble



- very high resolution simulation from Philipp Girichidis
- models of magnetized bubbles

Polaris for local bubble

Polaris
modeling local bubble

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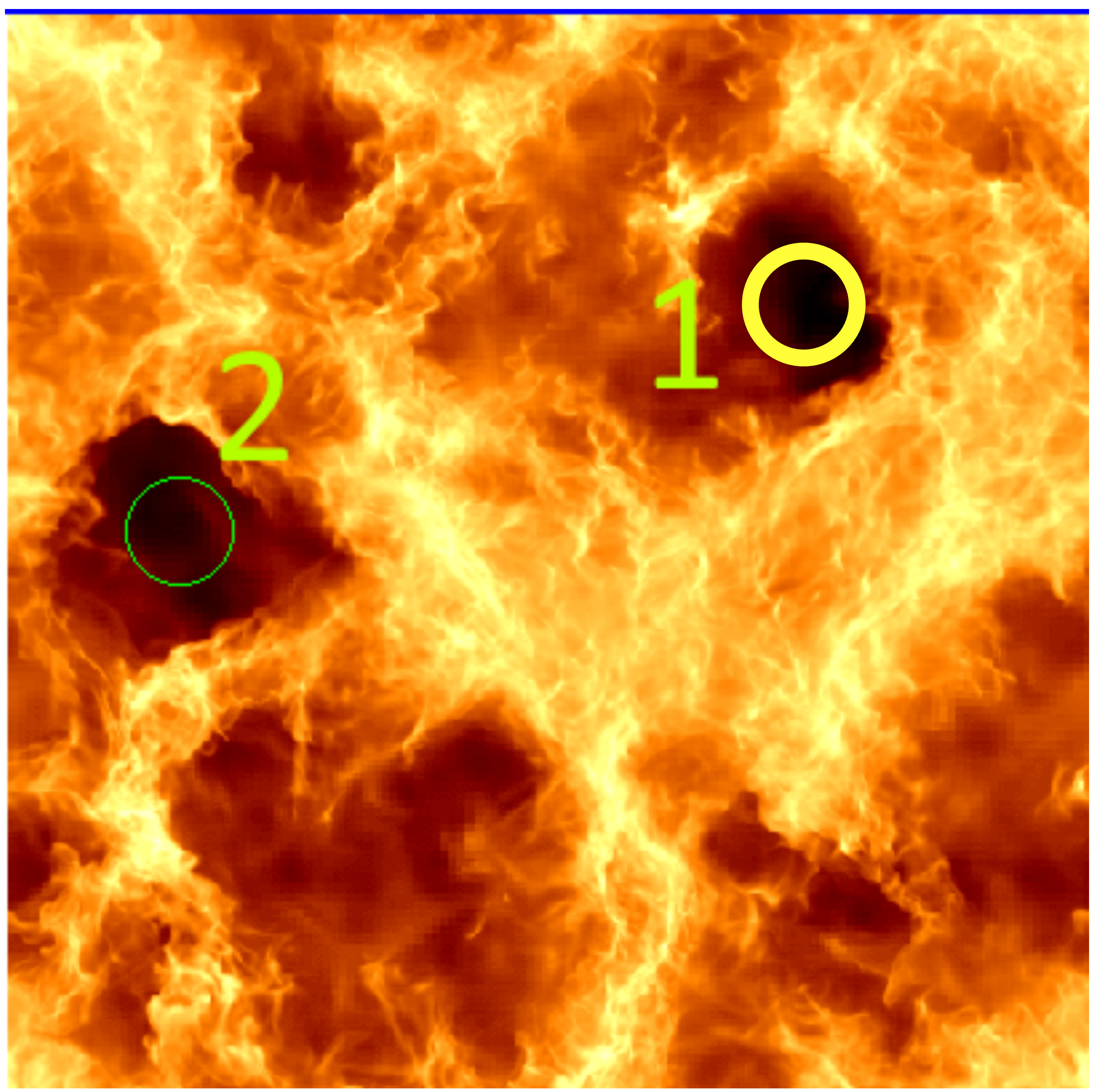

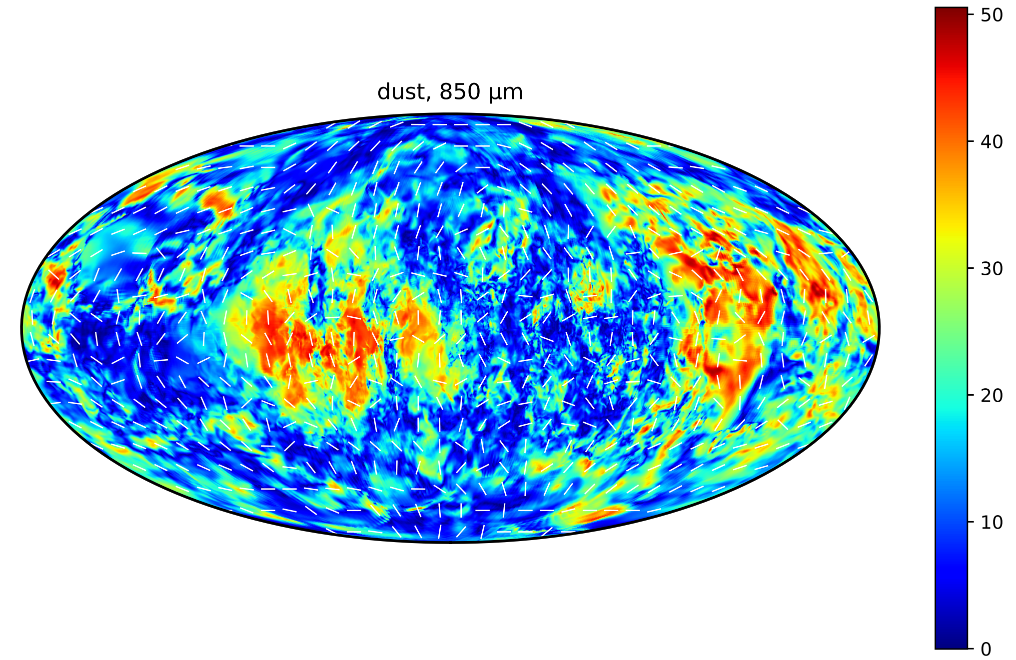

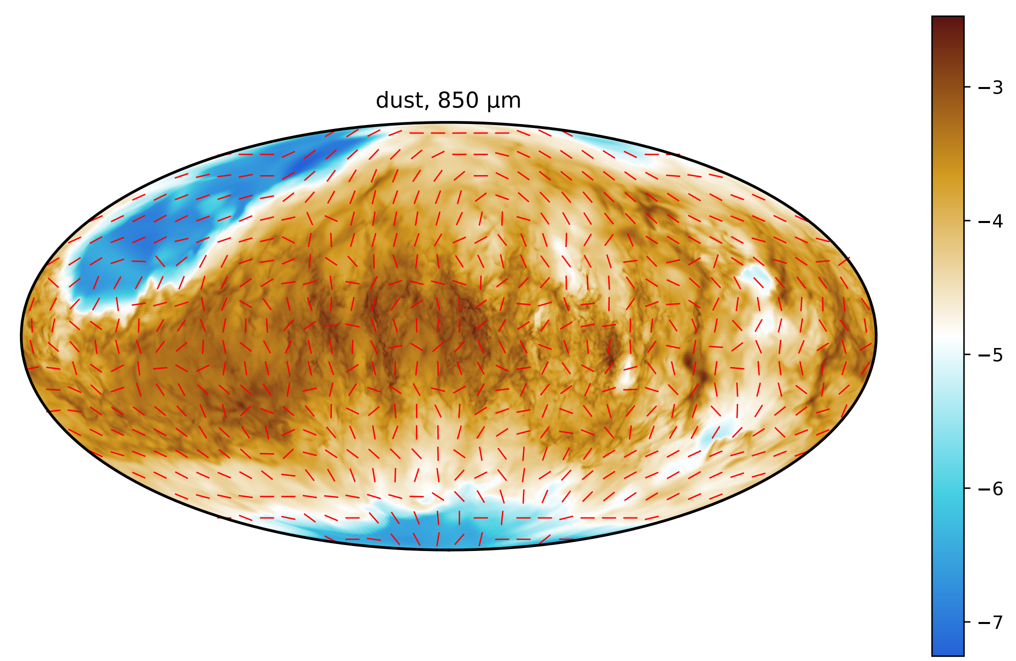

Polaris for local bubble

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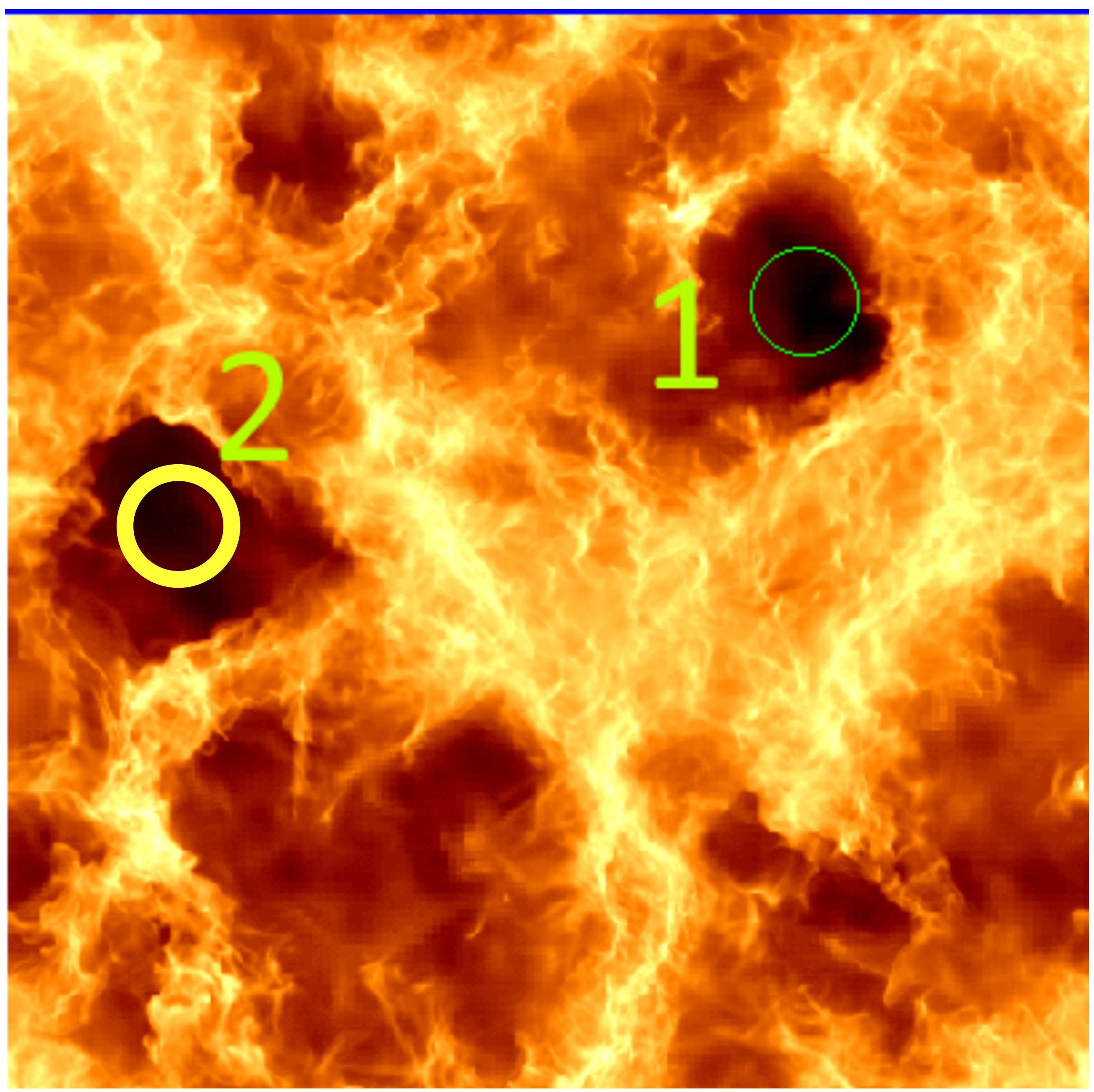
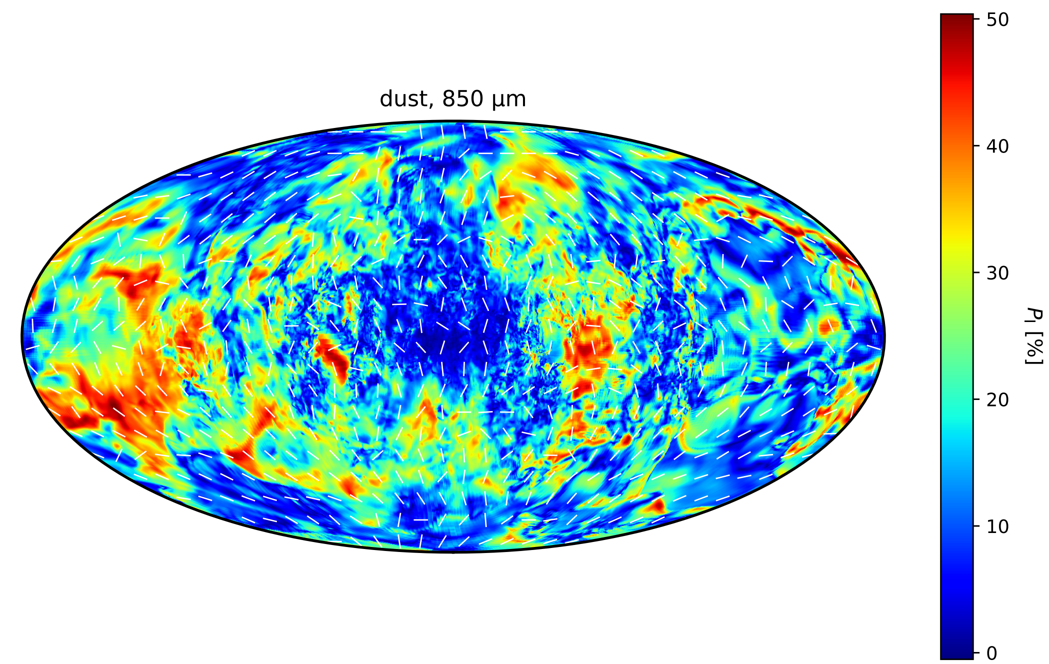
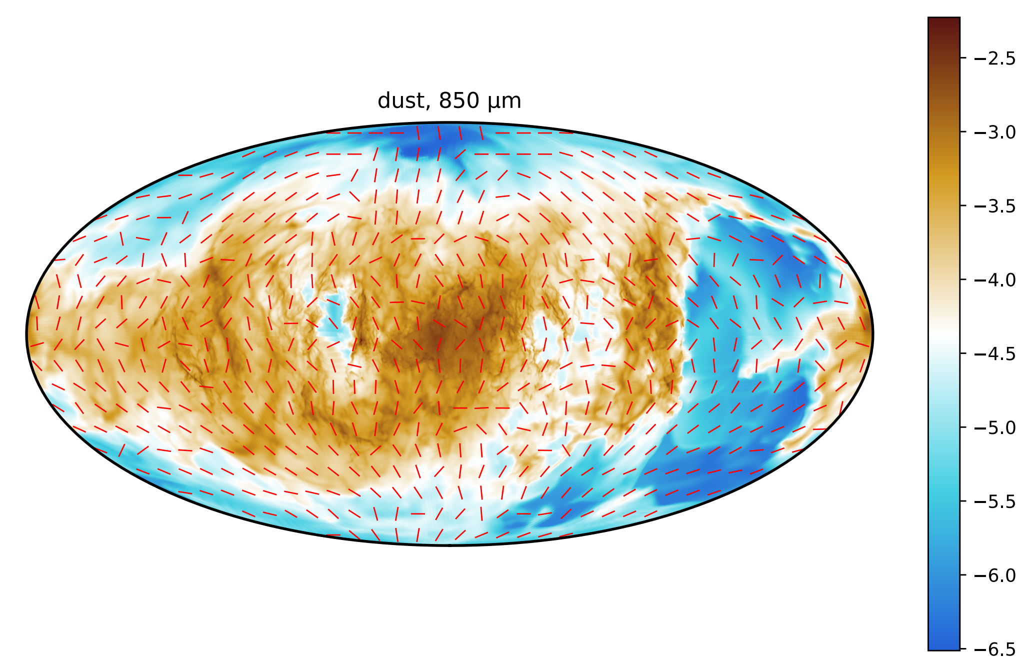
Polaris
modeling local bubble







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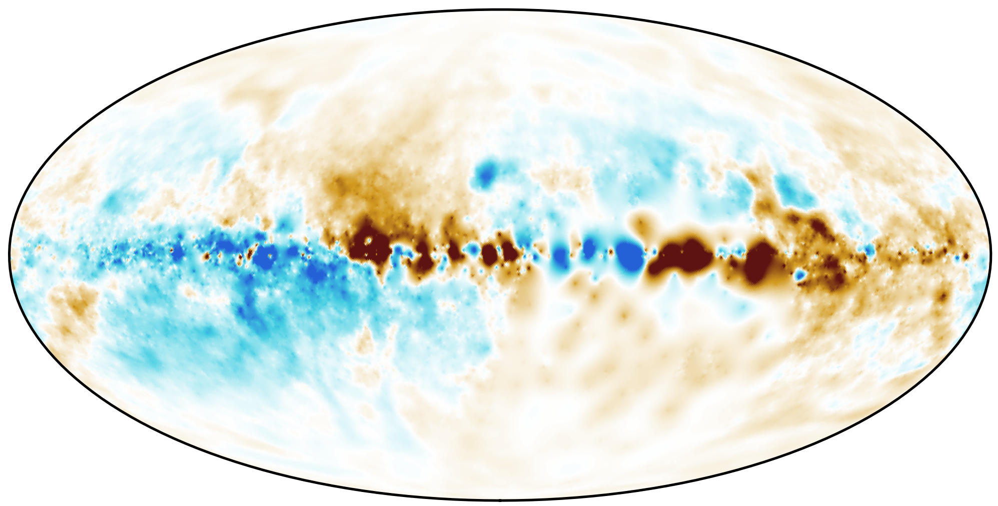
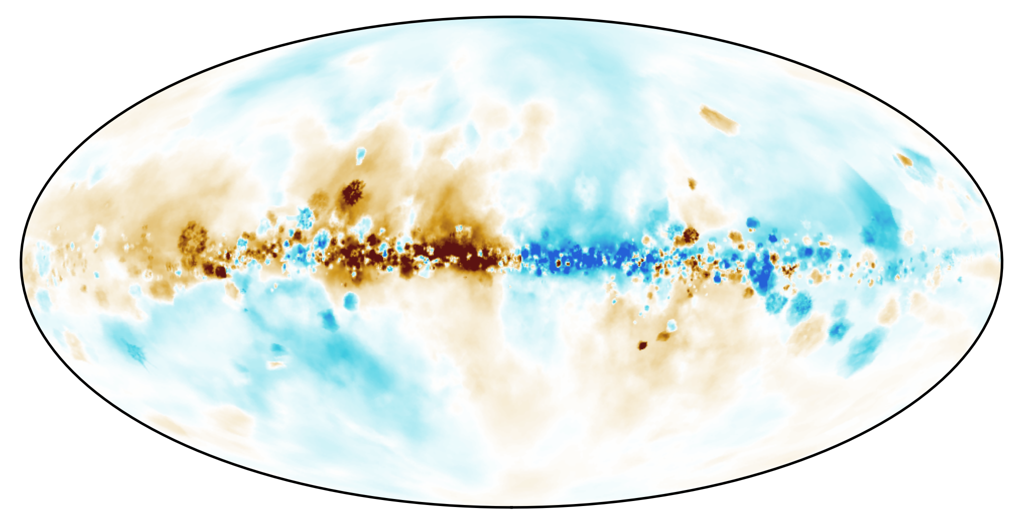
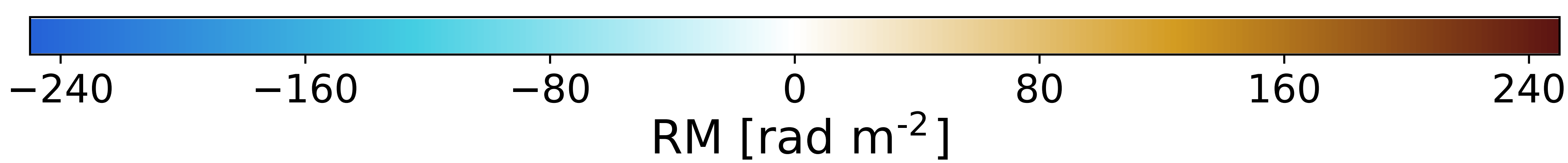
modeling Faraday rotation all-sky maps



quiz...





Reissl et al. (in prep.)

Faraday rotation map

modeling Faraday rotation all-sky maps

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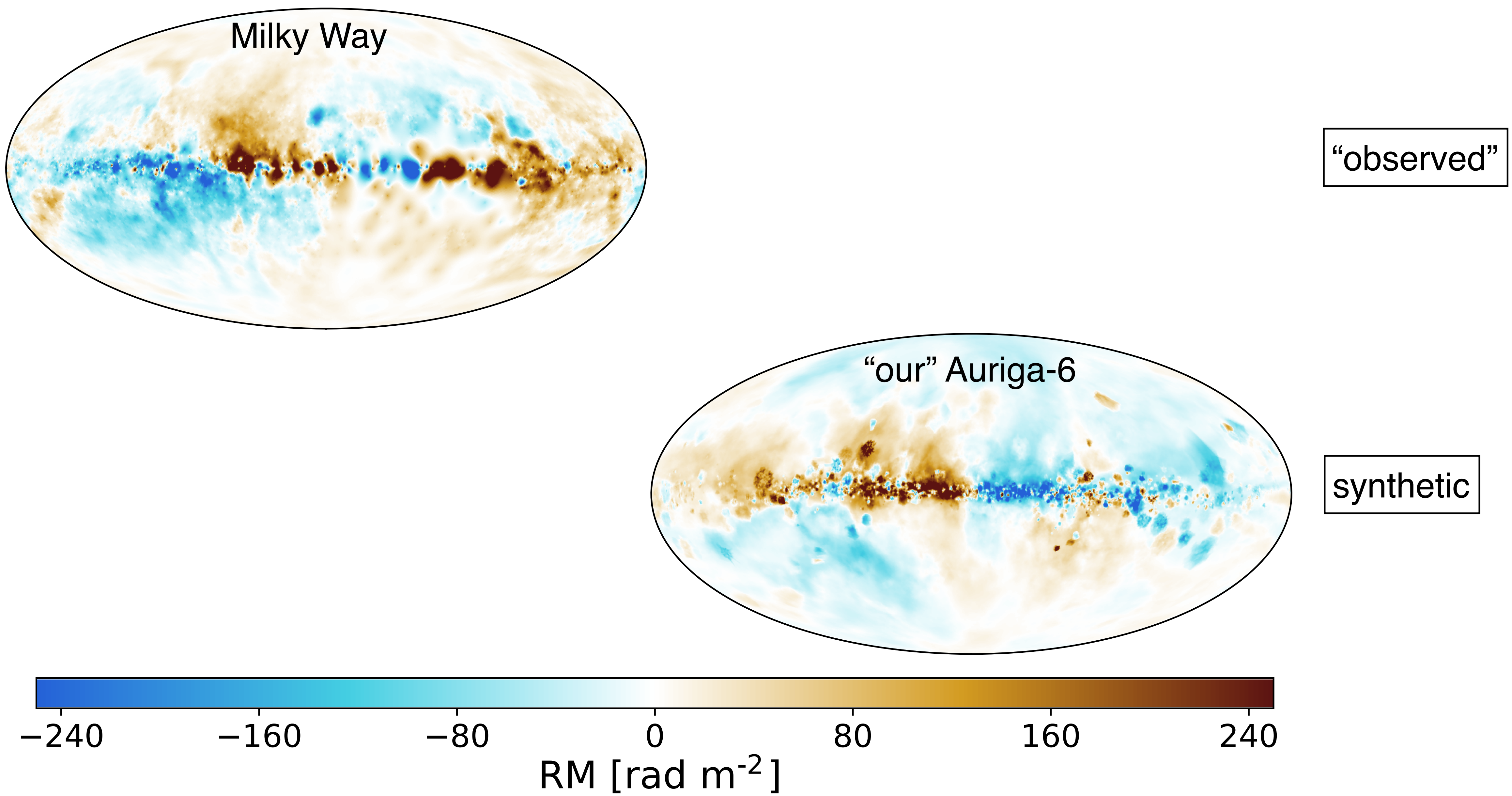

Reissl et al. (in prep.)
Oppermann et al. (2012, A&A, 542, A93)

Faraday rotation map

modeling Faraday rotation all-sky maps

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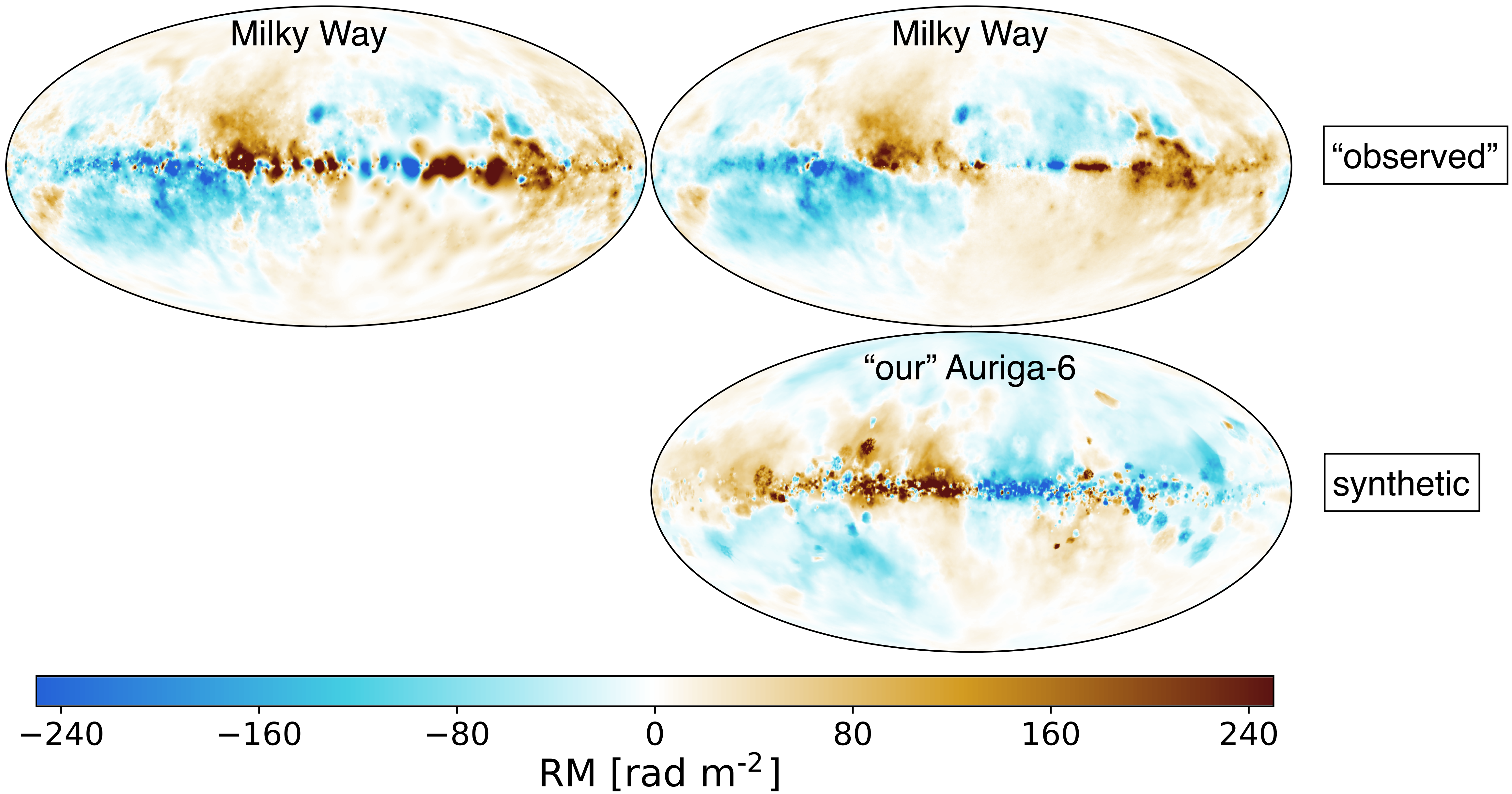

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Faraday rotation map

modeling Faraday rotation all-sky maps

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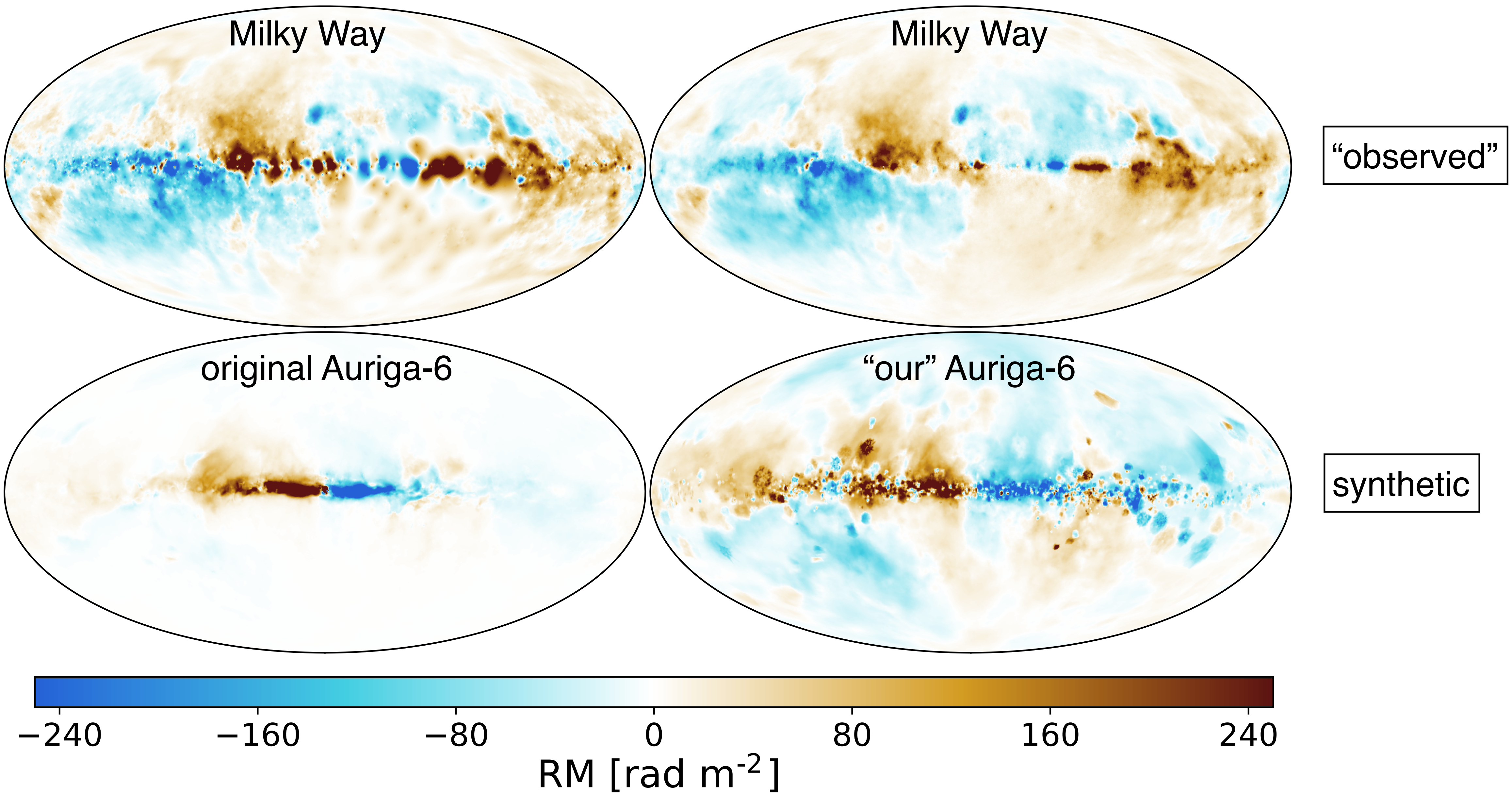

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Oppermann et al. (2012, A&A, 542, A93), Hutschenreuther & Enßlin, 2020, A&A, 633, A150), Pakmor et al. (2018, ApJ, 783, L20)

Faraday rotation map

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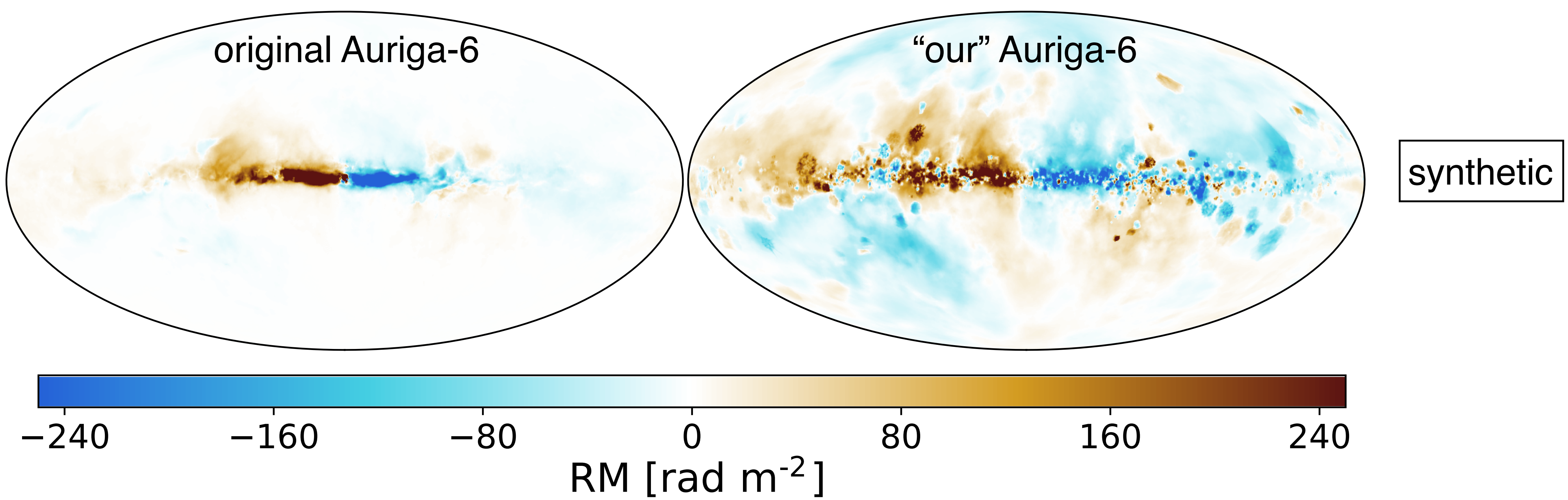
modeling Faraday rotation all-sky maps

- faithful reproduction of the Milky Way measurements requires knowledge of local star forming regions
- we need to combine galaxy formation simulations with population synthesis models



Reissl et al. (in prep.)
Pakmor et al. (2018, ApJ, 783, L20)

THOR
Faraday sky

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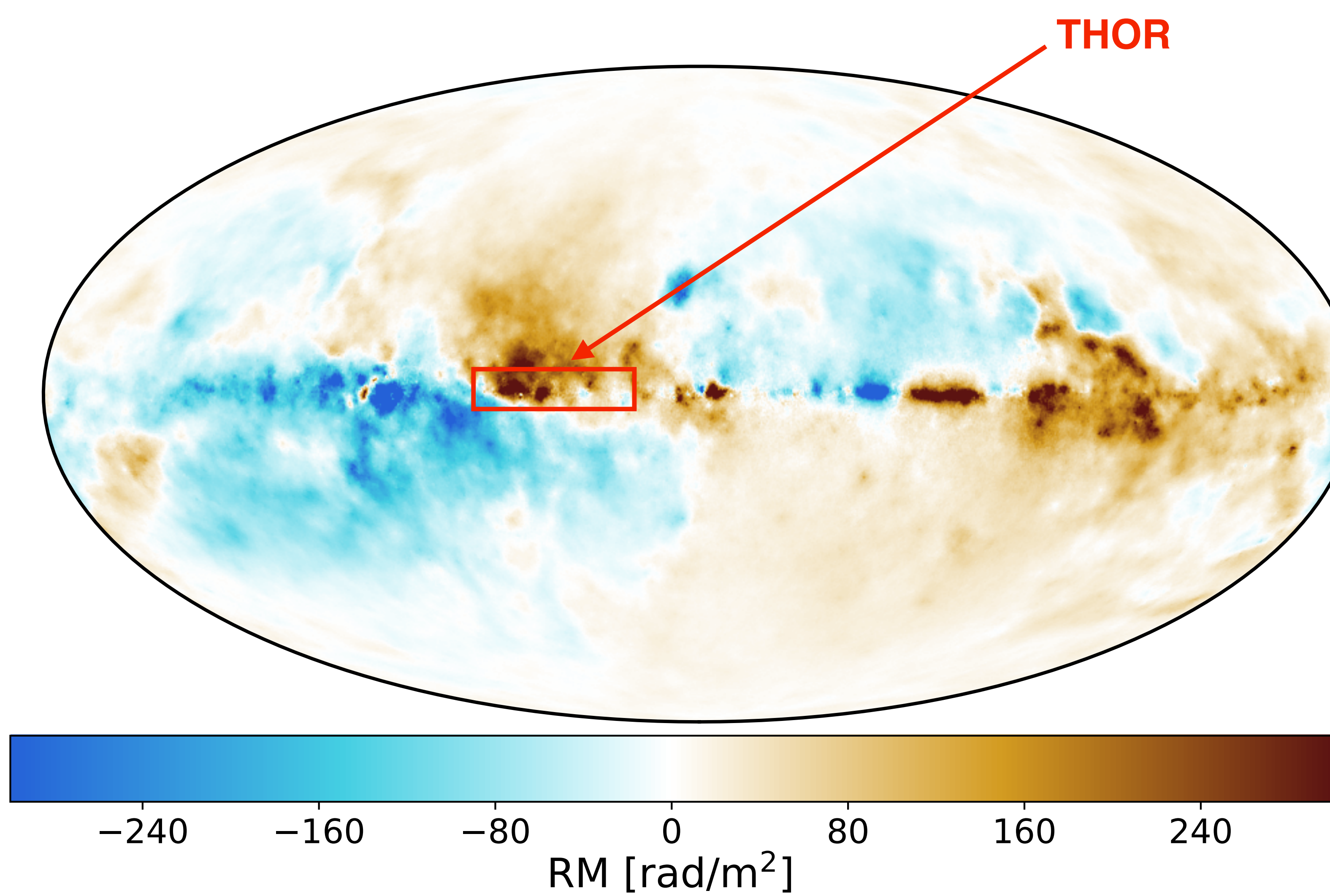
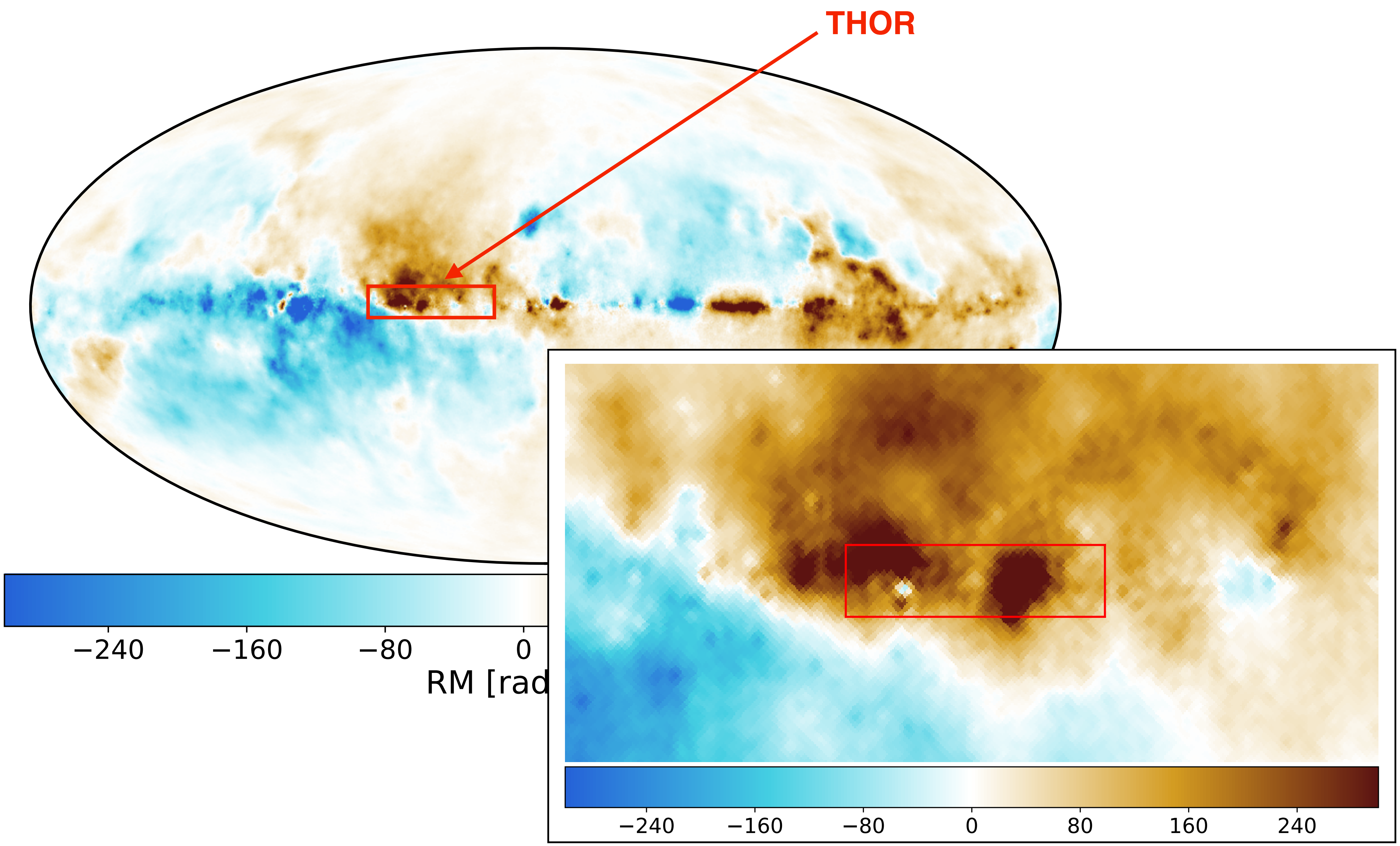


Hutschenreuther & Ensslin (2020, A&A, 633, A150)

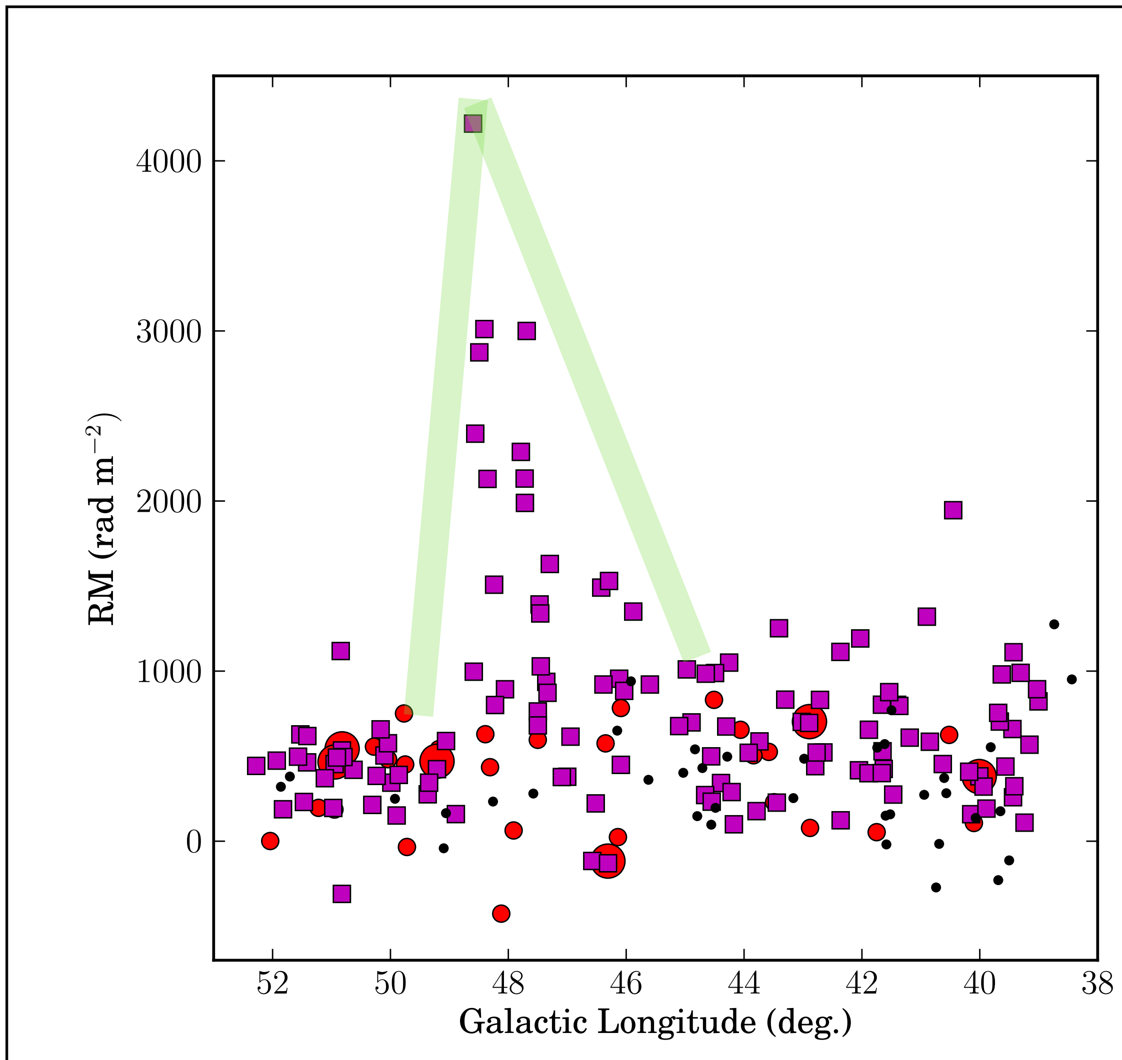
THOR
Faraday sky



Hutschenreuther & Ensslin (2020, A&A, 633, A150)

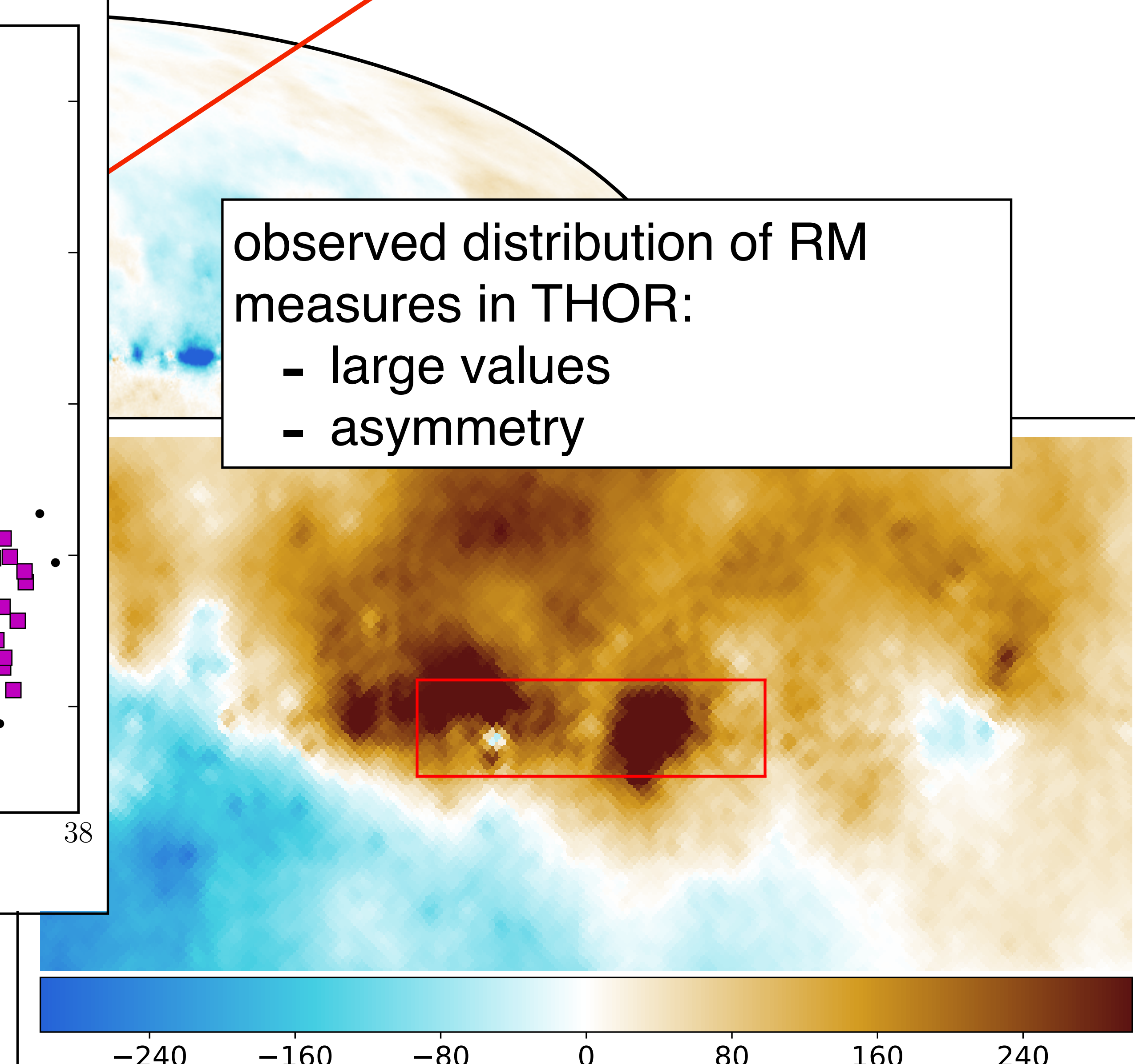
Polaris for all-sky maps

THOR
Faraday sky



Shanahan et al. (2019, ApJ, 887, L7)
Reissl et al. (2020, A&A, 642, A201)

THOR



observed distribution of RM measures in THOR:
- large values
- asymmetry

Hutschenreuther & Ensslin (2020, A&A, 633, A150)

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Polaris for all-sky maps

Polaris for all-sky maps

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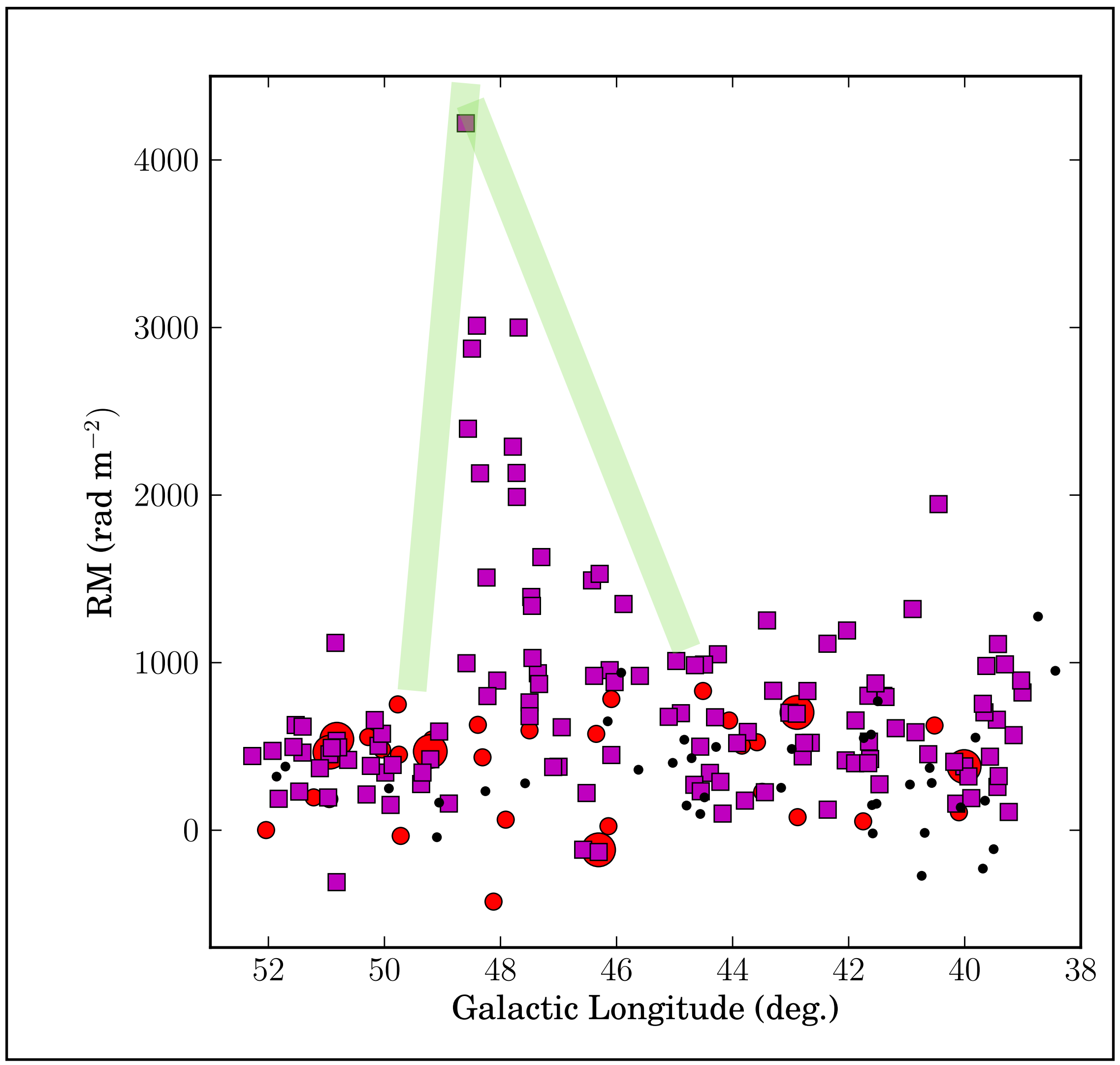
THOR + Polaris Faraday sky



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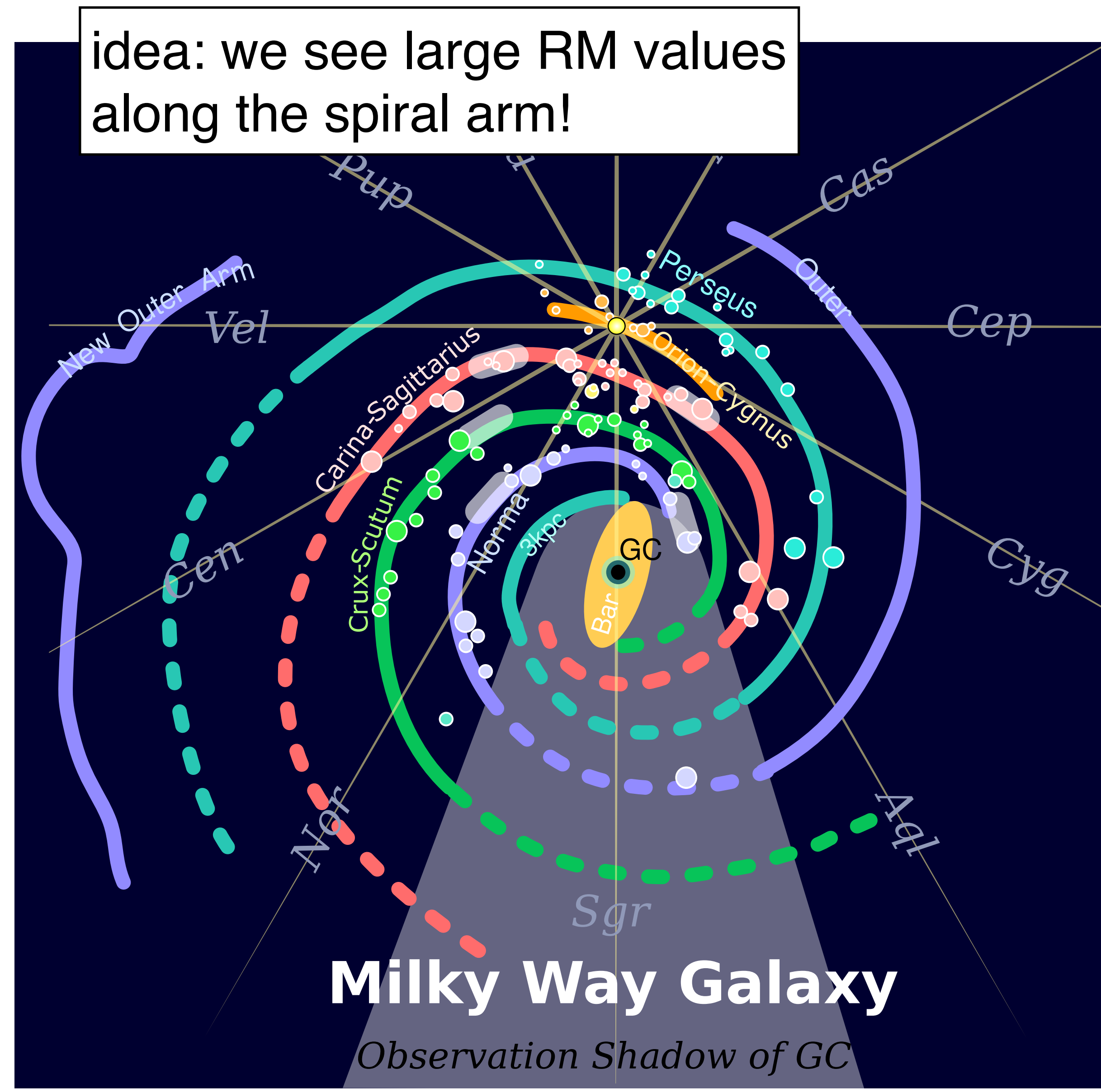

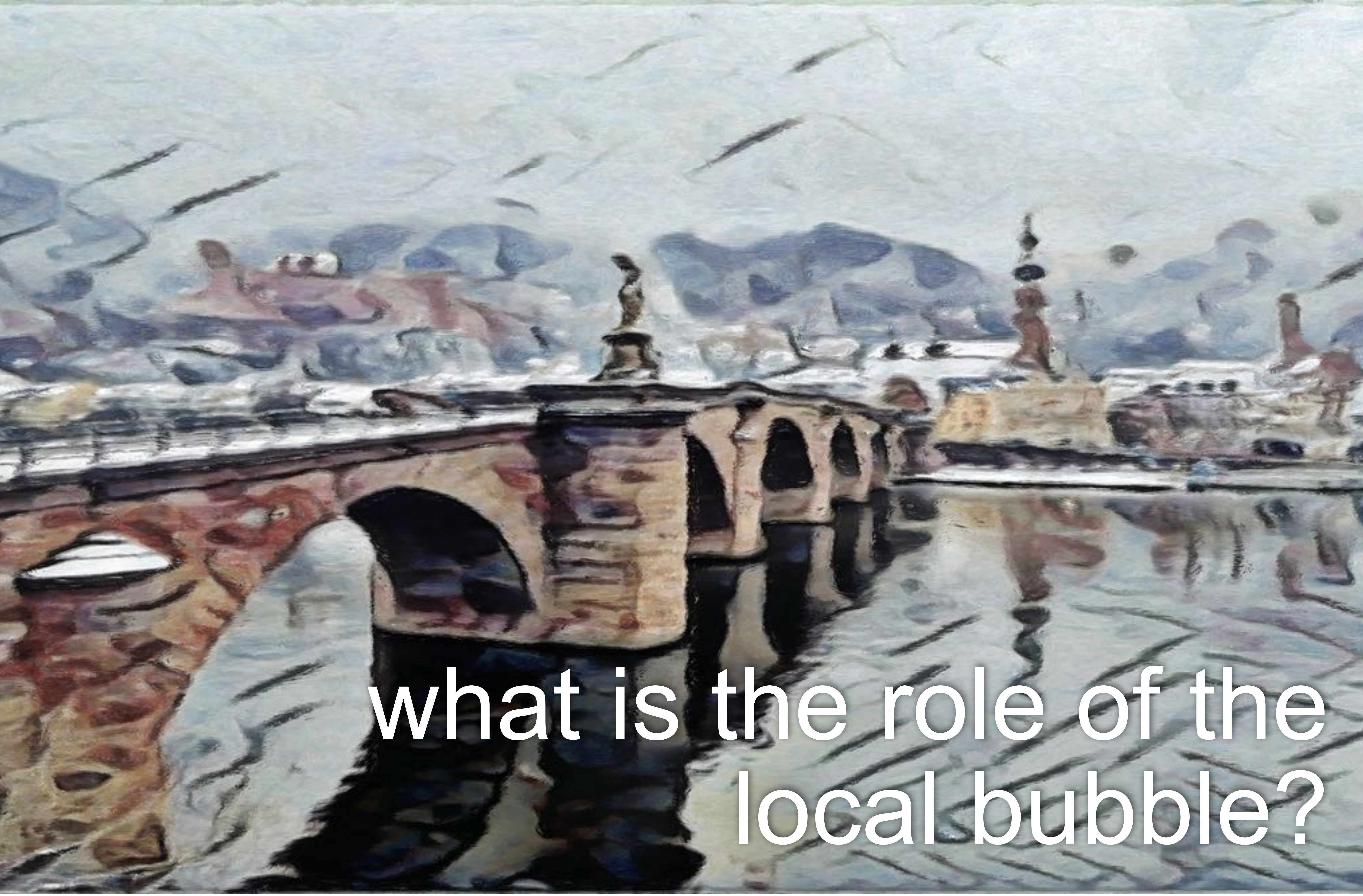

what is the role of the local bubble?

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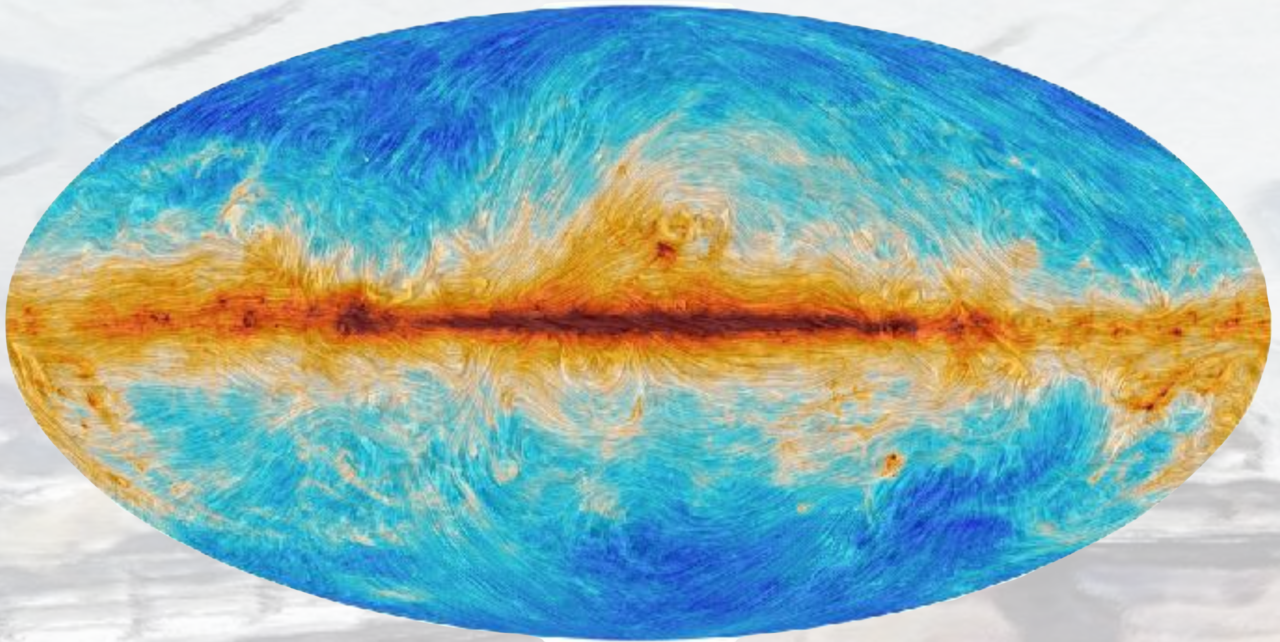

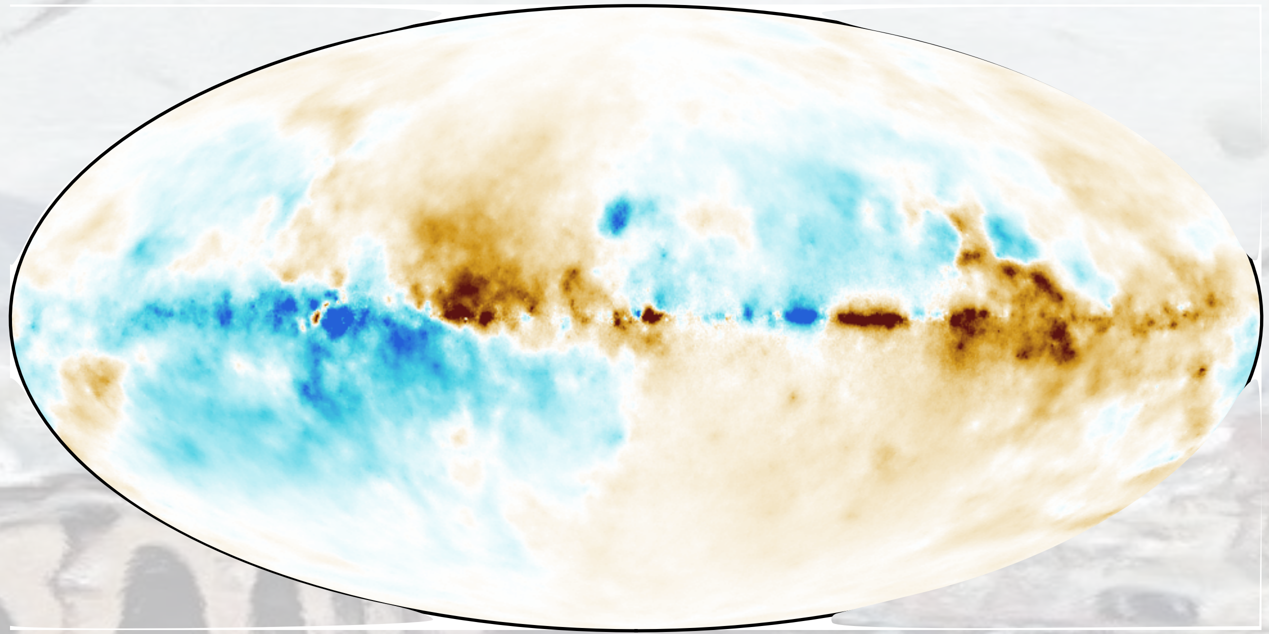

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