Magnetic fields in prestellar cores
A new perspective combining radio and infrared data

Dusting off the secrets of the Cosmos with PRIMA Space IR Telescope
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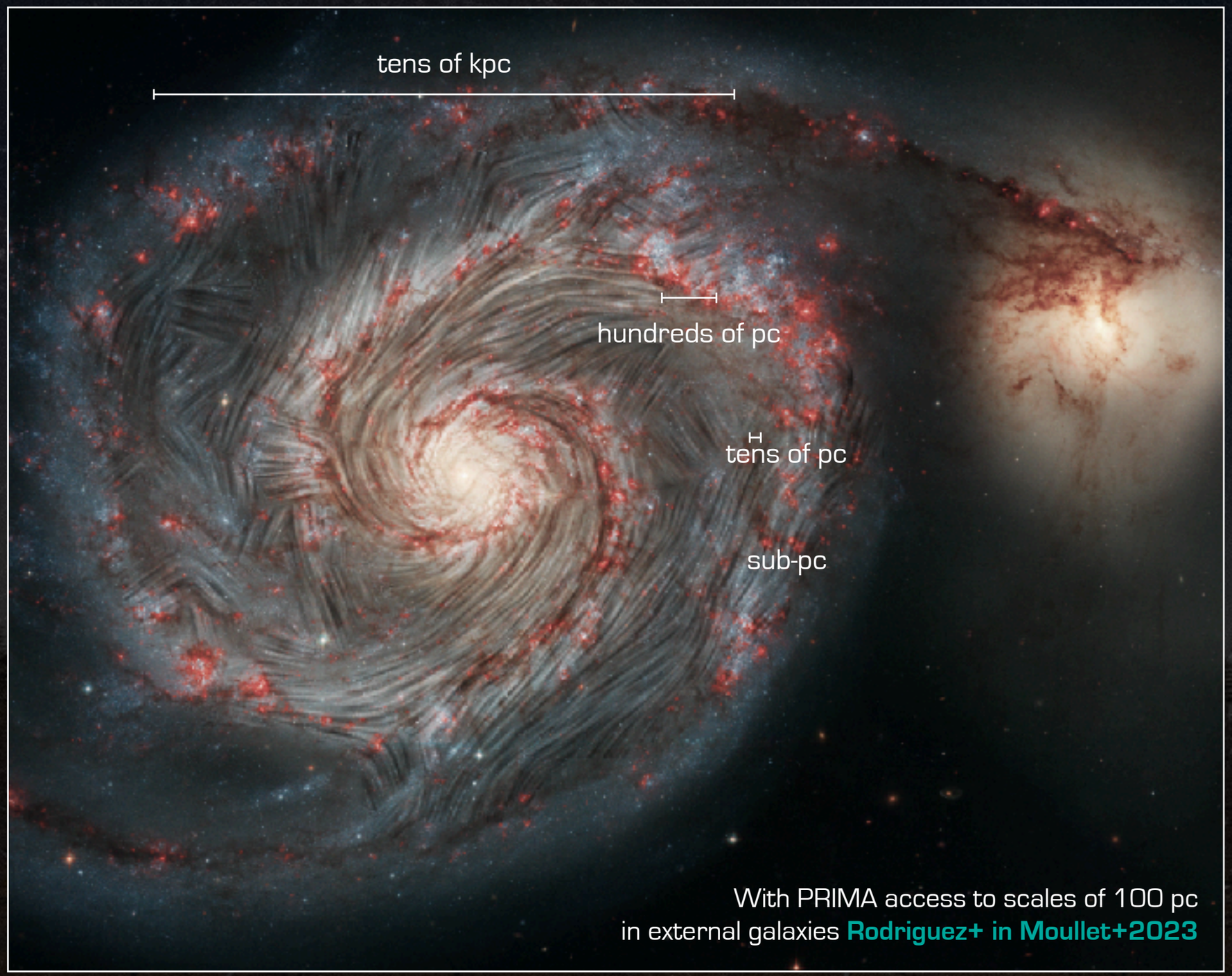
The magnetized interstellar medium (ISM) and star formation

Messier 51 (M51) galaxy - The Whirlpool galaxy - Hubble Space Telescope SOFIA 154um **(Borlaff+2021)**



Credits: NASA, ESA, S. Beckwith (STScI) and the Hubble Heritage Team (STScI/AURA)

Keywords

STAR FORMATION

MAGNETIC FIELD vs MATTER COUPLING

IONIZATION

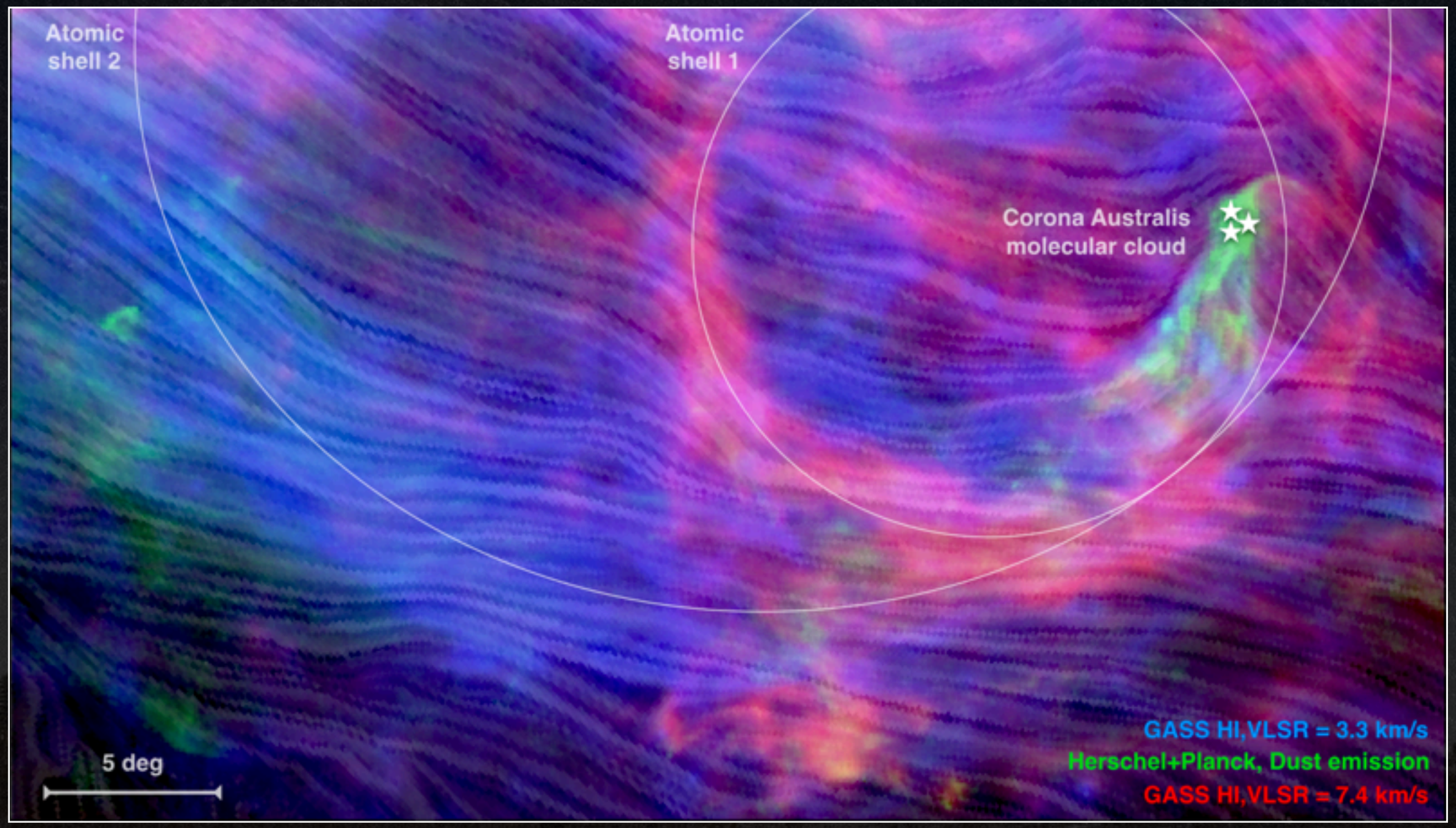
MULTIPHASE
interstellar medium (ISM)

MULTISCALE

GALACTIC LABORATORY

The Galactic laboratory at the scale of molecular clouds

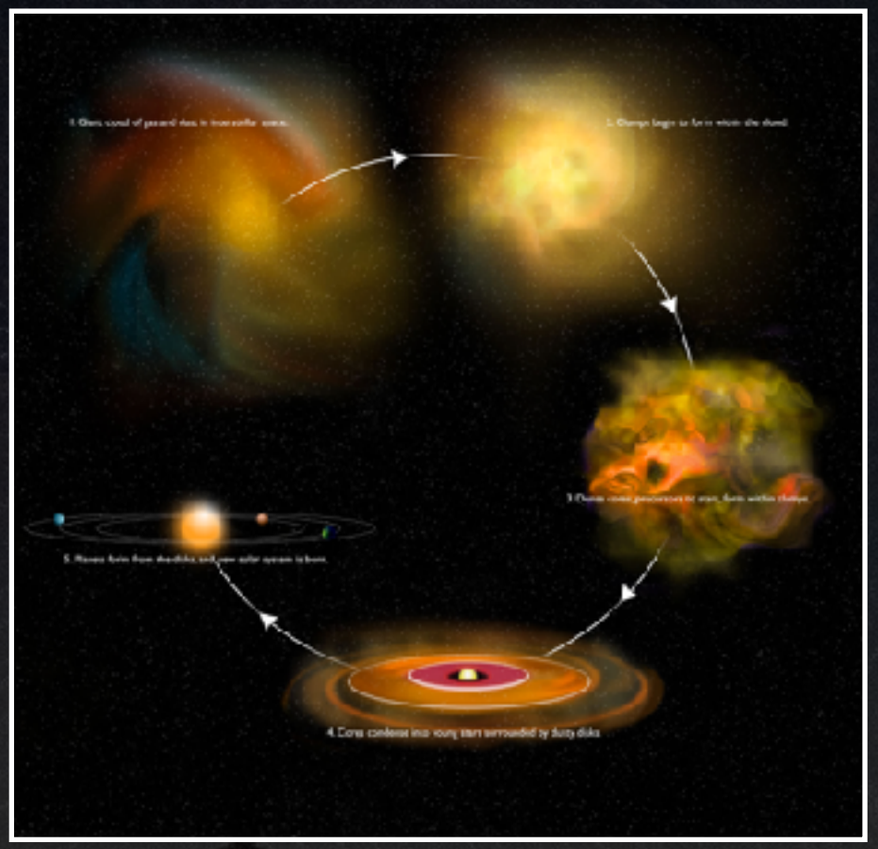
Star forming regions are anchored to the Galactic magnetic field that influences their dynamics



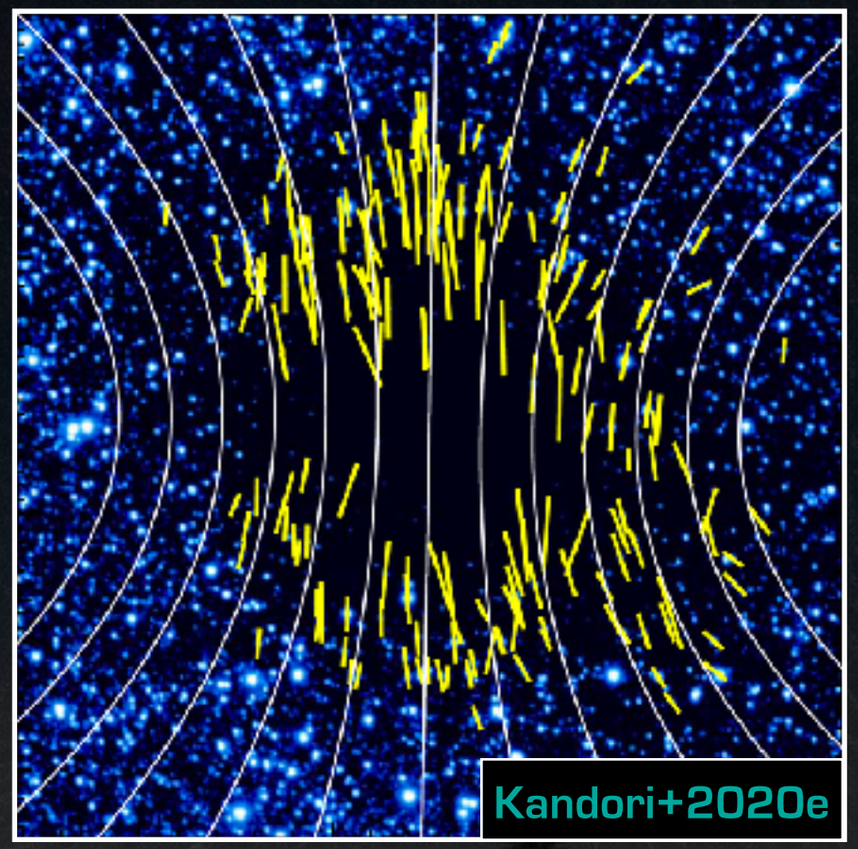
Corona Australis MC (150pc, **Bracco+2020c)**
See also **Planck int. results XXXII, XXXIII, XXXV 2016, Soler 2019**

What happens in molecular clouds closer to star formation?

From clouds to stars: the role of prestellar dense cores

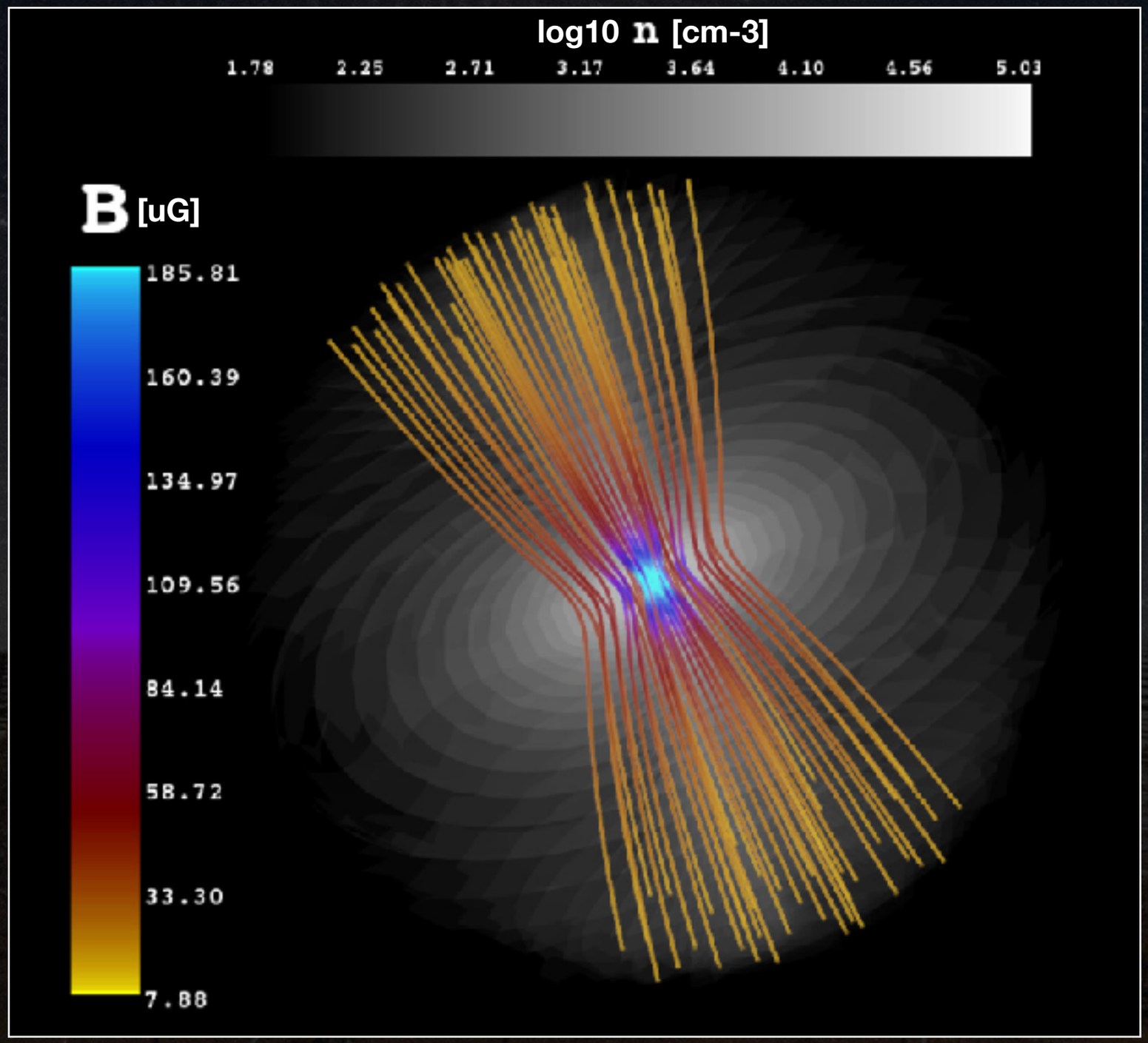


FeSt 1-457 in the Pipe Nebula, NIR data with SIRPOL



- First self-gravitating objects that undergo gravitational collapse in young stellar objects
- Dense, cold over-densities with low amount ionization, mostly from low energy cosmic rays (<1 GeV, **Padovani+2009, 2011**)
- What is the impact of the magnetic field in the evolution of dense/starless cores, often summarized by the mass-to-flux (magnetic) ratio?
- Measurements: Zeeman + dust polarization (NIR, mm) suggest field strengths spanning from tens to hundreds of uG (see reviews by **Pineda+2023** and **Pattle+2023**)
- Large uncertainties from **data** (e.g., Zeeman obs. are challenging), and **methods** (e.g., the use of dust polarization: 1 - Davis Chandrasekhar Fermi; 2 - Dust emissivity weighting !!! a key caveat for PRIMA !!!))

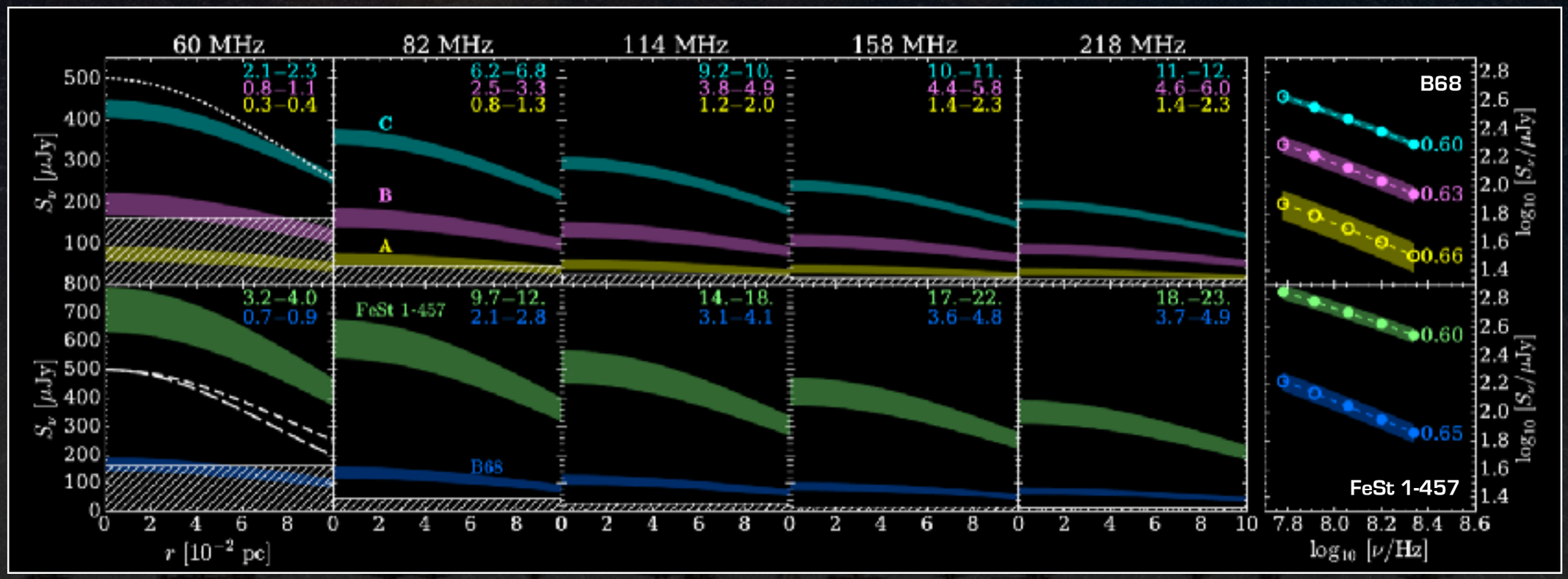
The radio window on magnetized prestellar cores



Padovani+2013

- Cosmic ray electrons (CRe) suffer energy losses only at $N_{\rm H} > 10^{25}\,{\rm cm}^{-2}$ (Padovani+2018)
- Given the Galactic CRe flux (e.g. Bracco+2024a) and the magnetic-field strengths (here ideal MHD applies), we expect non-thermal synchrotron radiation.
- This synchrotron emission is detectable at radio wavelength!

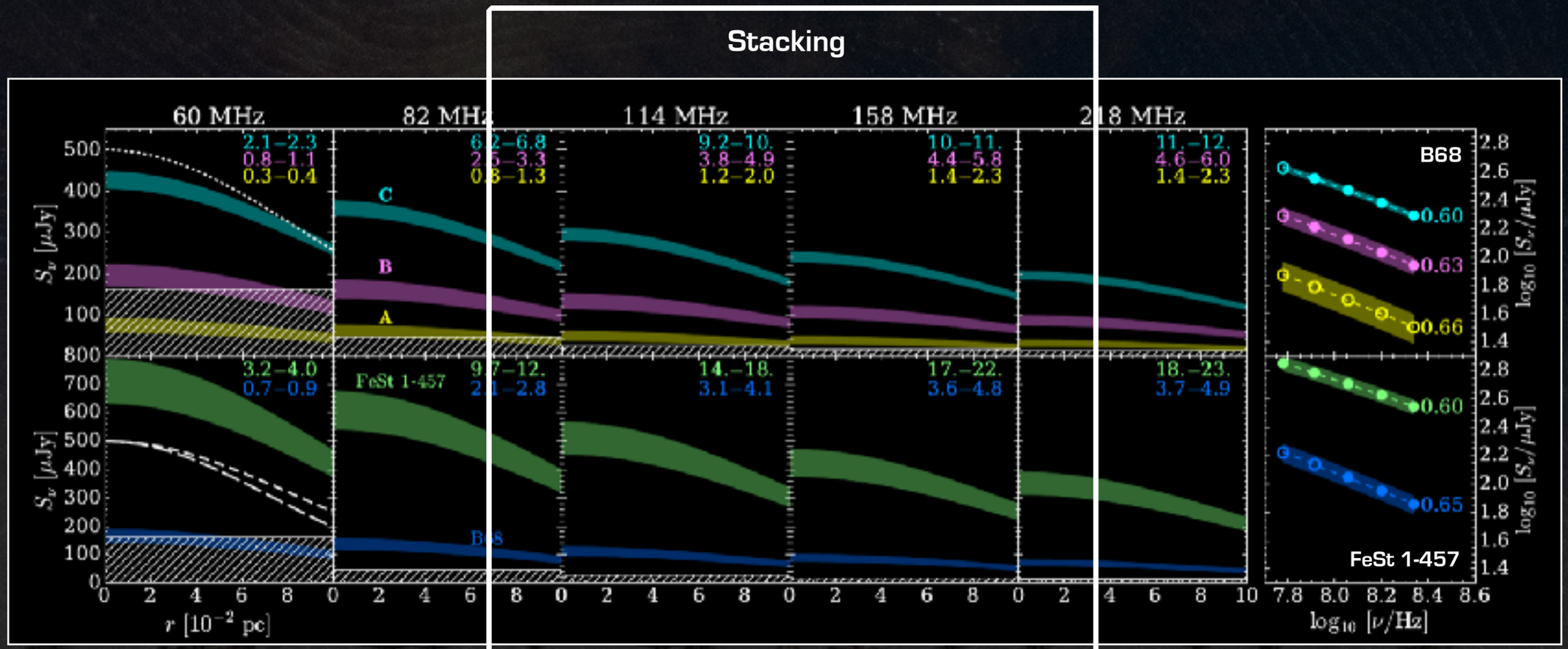
Synchrotron emission from dense cores before SKA prediction on single objects



Padovani & Galli 2018

Synchrotron emission from dense cores before SKA statistical approach

Stacking

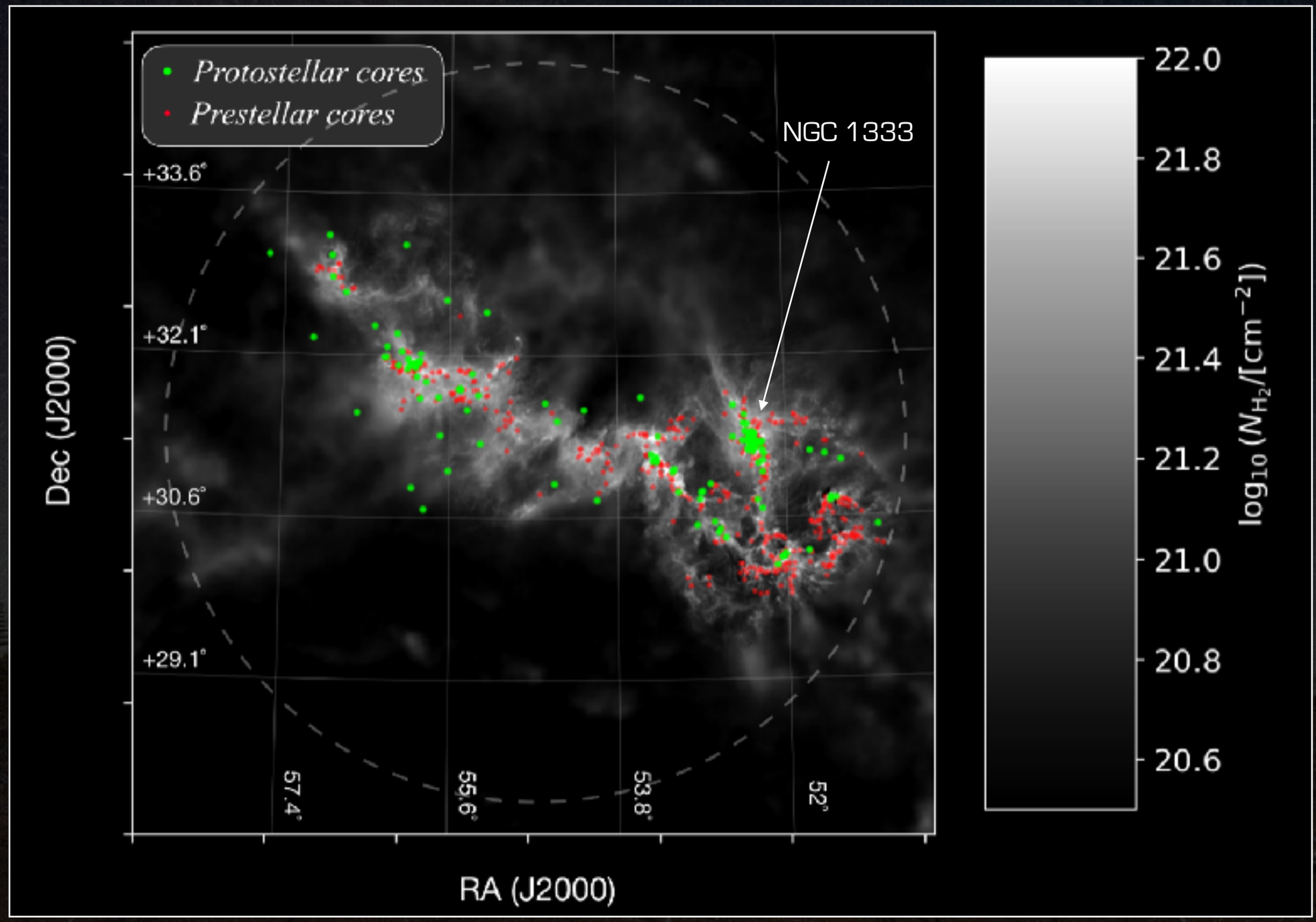


Padovani & Galli 2018

LOFAR, 144 MHz (Shimwell+2022)

Synchrotron emission from dense cores before SKA the Perseus case: a statistical approach

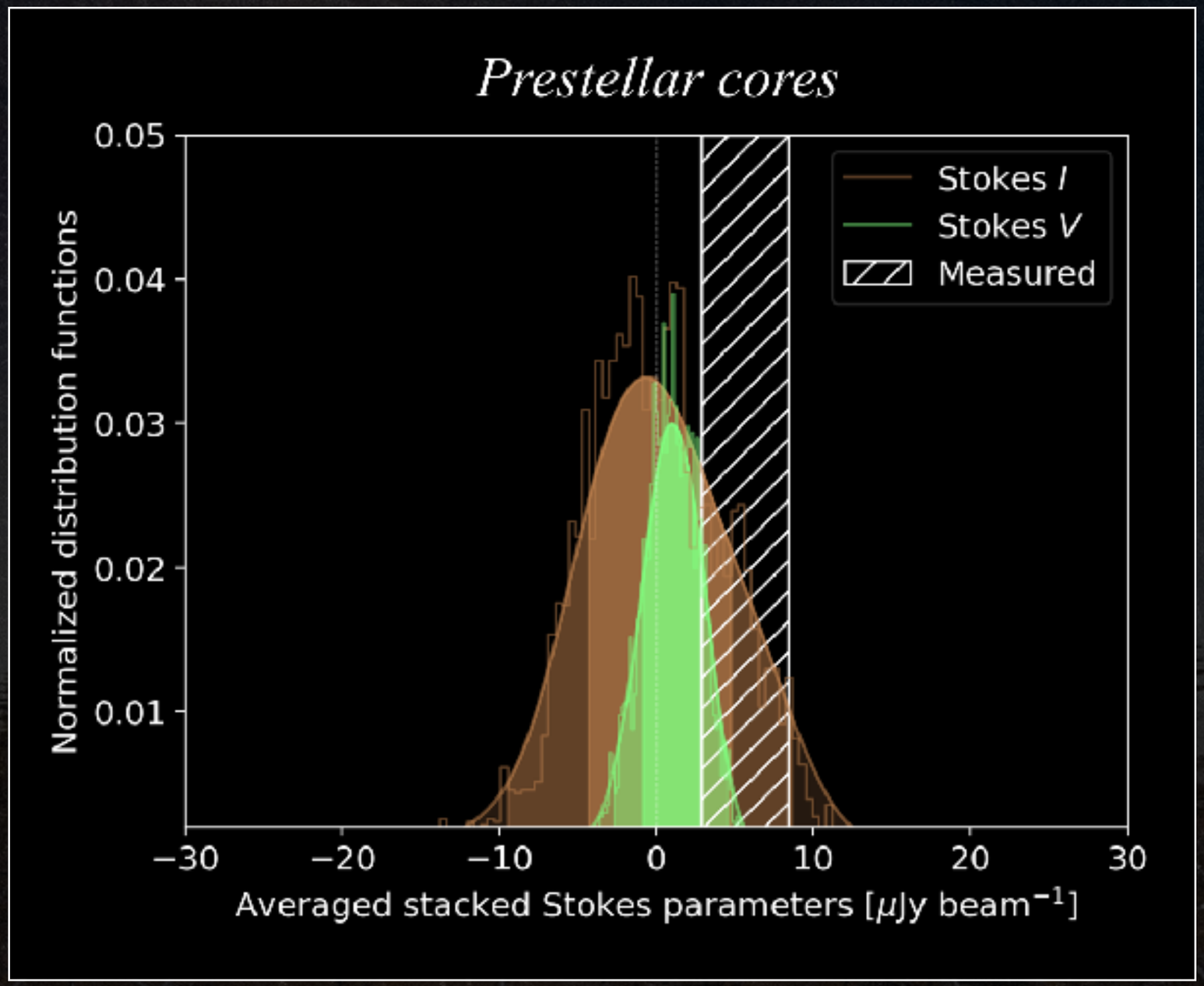
Dust thermal emission of Perseus (300 pc), Herschel and Planck combined **(Bracco+2020b)**



Bracco+2025, Pezzuto+2021: **353 prestellar, 132 protostellar**

Synchrotron emission from dense cores before SKA the Perseus case: a statistical approach

Quantifying the non detection through boot-strapping (5000 samples)



*No detection at a level of 5 uJy/beam

Bracco+2025

Synchrotron emission from dense cores before SKA the Perseus case: a statistical approach

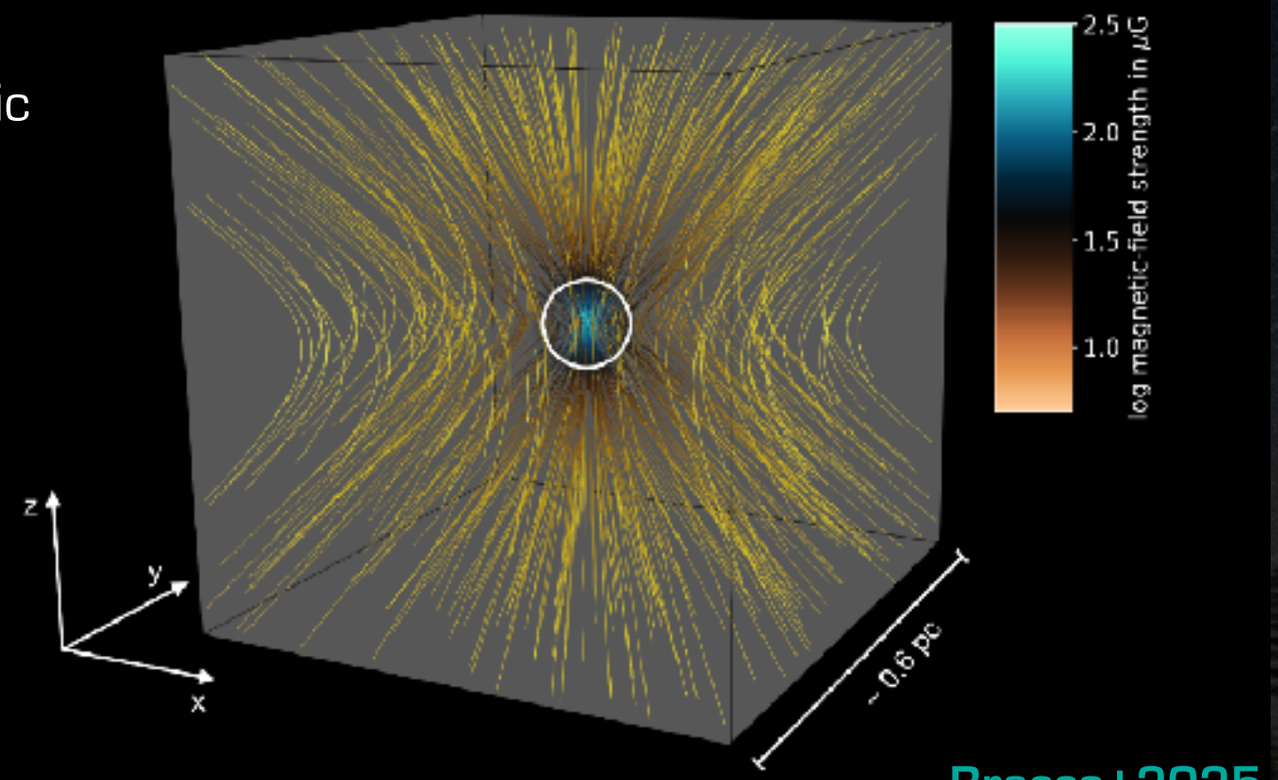
Interpreting the non detection with mock data from analytical magnetic-field models of molecular-cloud cores
Li & Shu 1996, Galli+1999, Padovani & Galli 2011, Padovani+2013

*Magneto-static, isothermal, self-gravitating, and axisymmetric cores supported by hourglass magnetic fields. Two parameters:

1) effective sound speed (turbulent+thermal) [0.17 - 0.5 km/s] **Crutcher+2012**

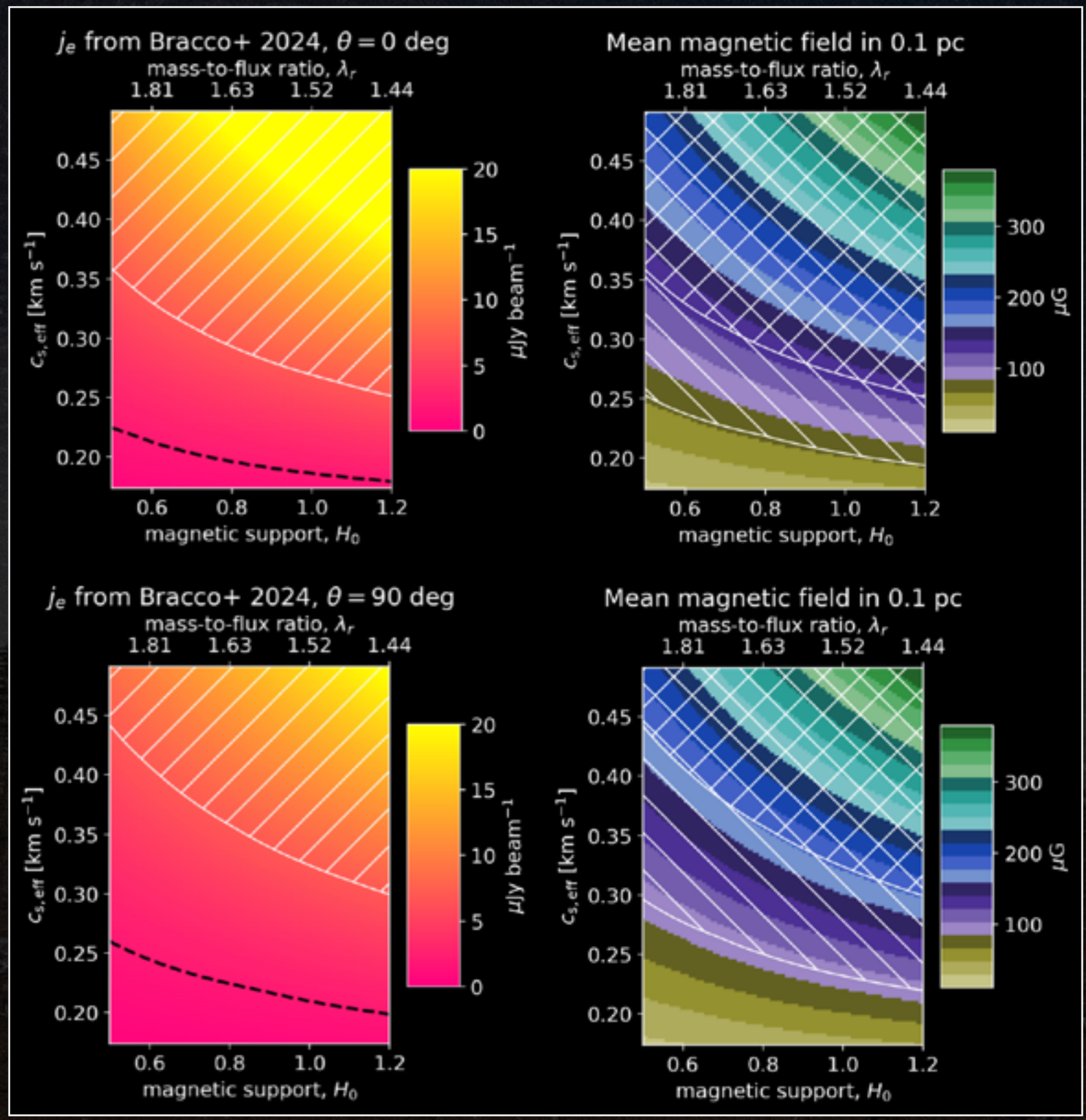
2) mass-to-flux ratio, Lr, which determines the magnetic support to gravity, Ho **(Li & Shu 1996)** [1.44, 2] **Crutcher+2012**

* CRe models from **Bracco+2024**



Bracco+2025

Synchrotron emission from dense cores before SKA the Perseus case: a statistical approach



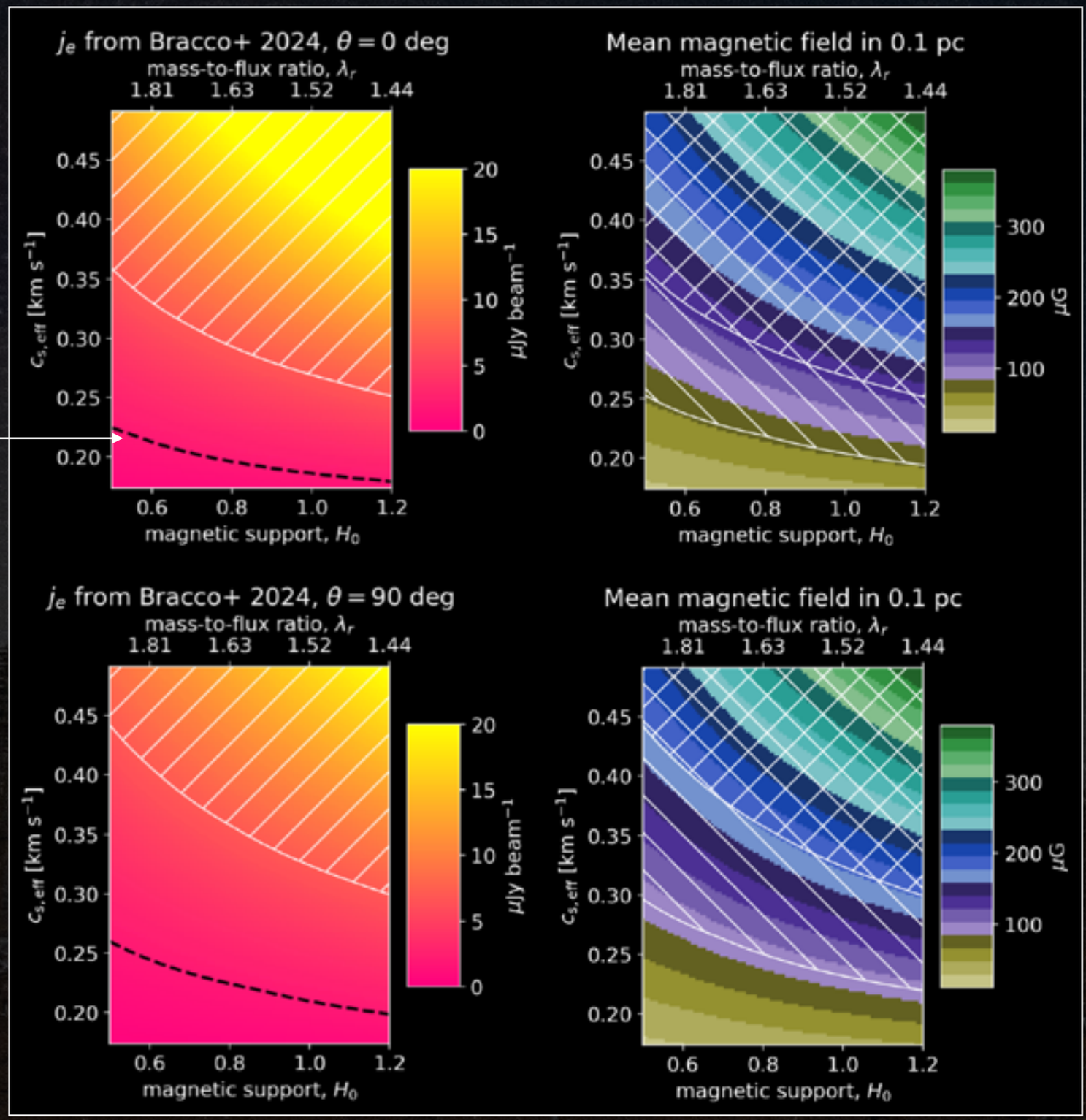
Bracco+2025

Synchrotron emission from dense cores with SKA the Perseus case: a statistical approach

SKA-Low

2 uJy/beam
9 hours with AA*
4 hours with AA4

Sokolowski+2022



Bracco+2025

Summary

- The IR and radio windows will be essential tools to probe the multiscale magnetized universe towards star formation
- I have shown one application to the case of prestellar cores with LOFAR+Herschel (Bracco+2025)
- The radio perspective, bright with the SKAO, can help put constraints on the magnetic-field strength of prestellar cores and refine IR methods to estimate the magnetization of dense cores.
- Wait for the upcoming SKA Science Book 2025 (expected at the end of the year)

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