# Magnetically regulated collapse in B335: The chemical perspective


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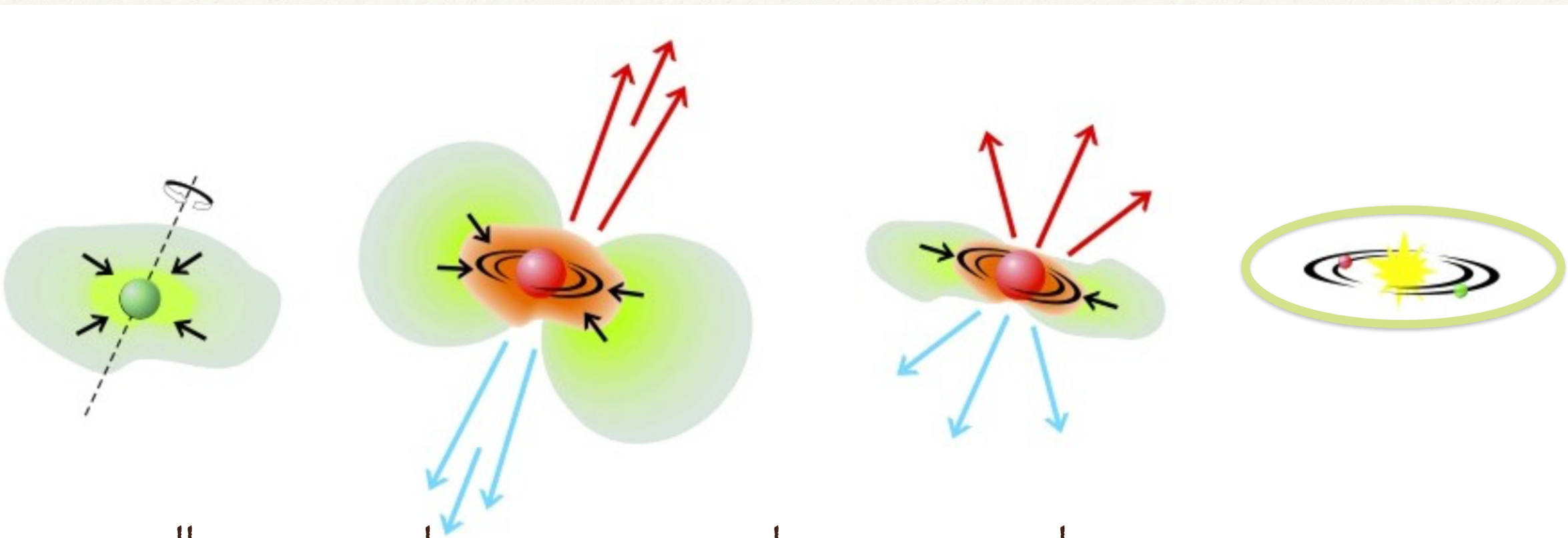
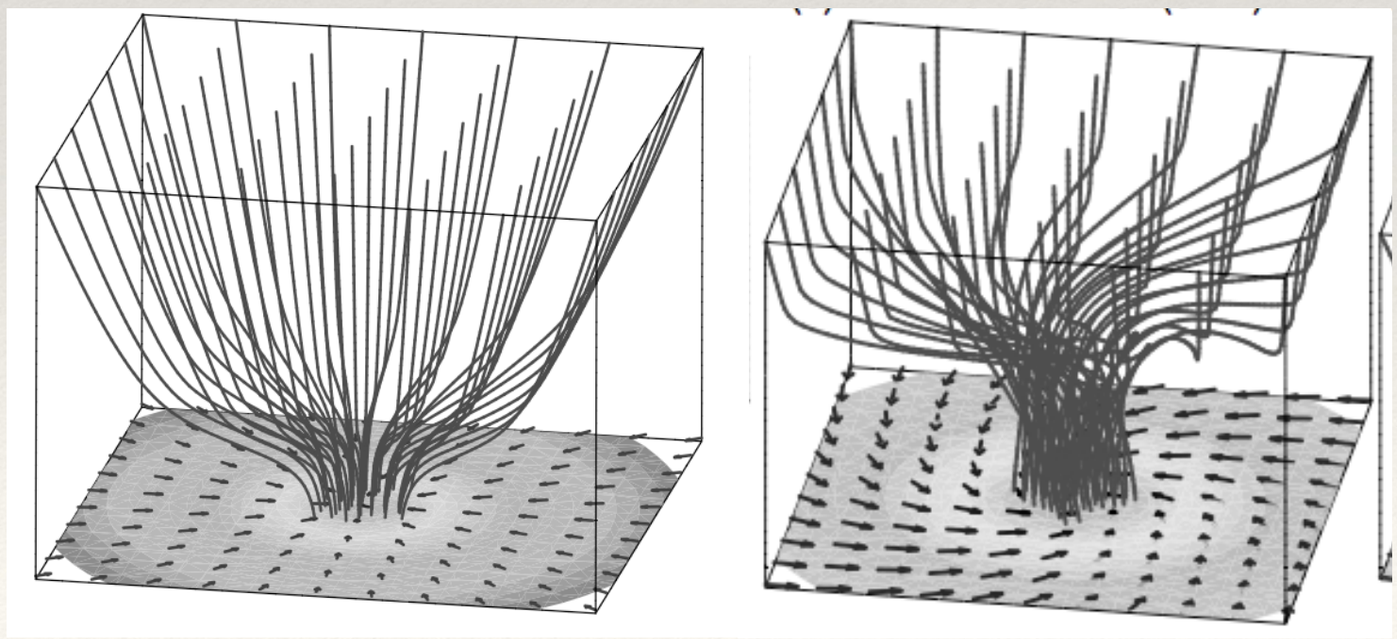
Cold Cores 2023 @ Barcelona

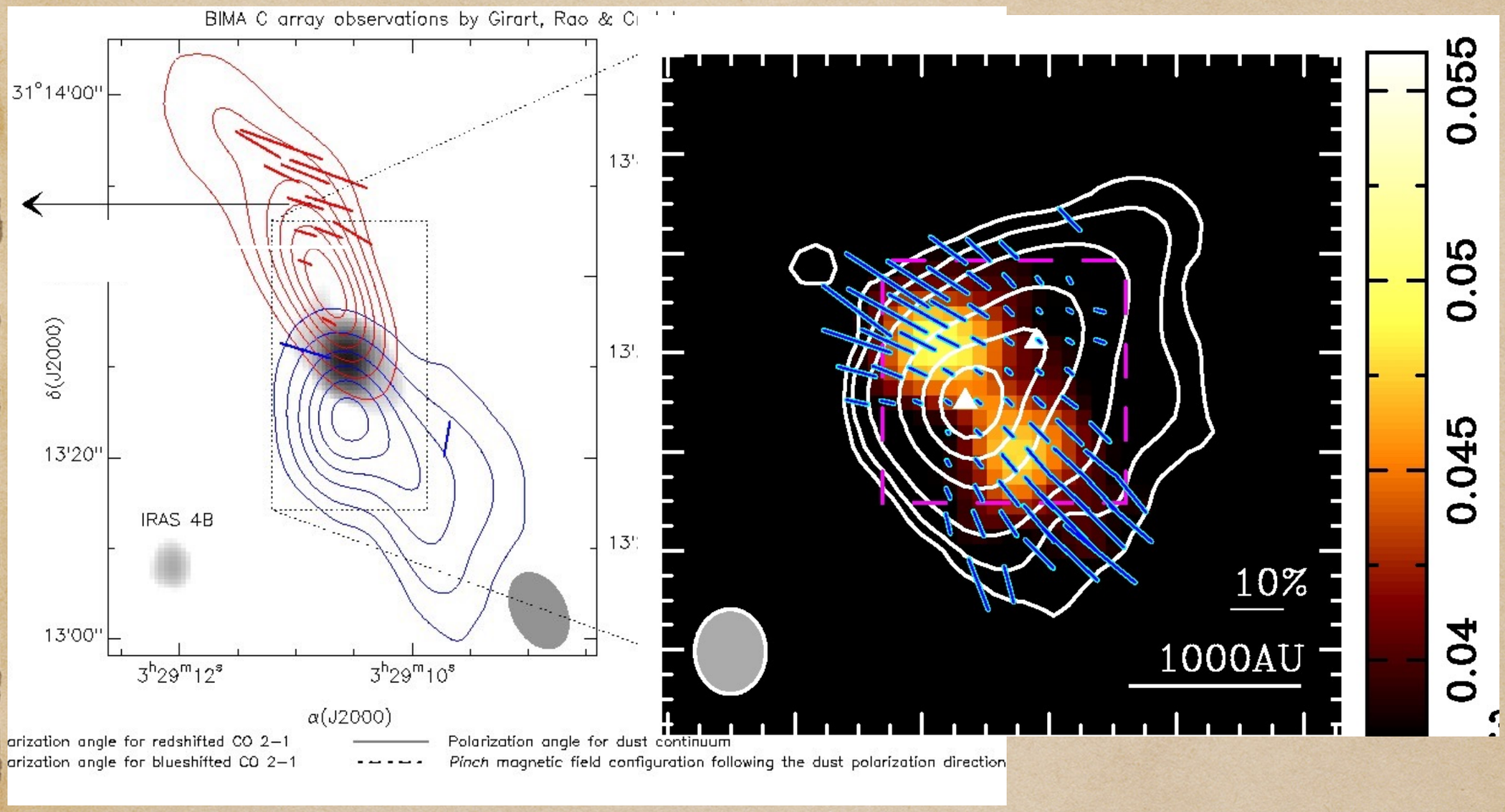
# The Star Formation Sequence for Low Mass Stars



Pre-stellar  Class 0  Class 1  Class 2  Pre-MS



# NGC 1333 IRASA: "textbook" case for low-mass star formation at core's scales



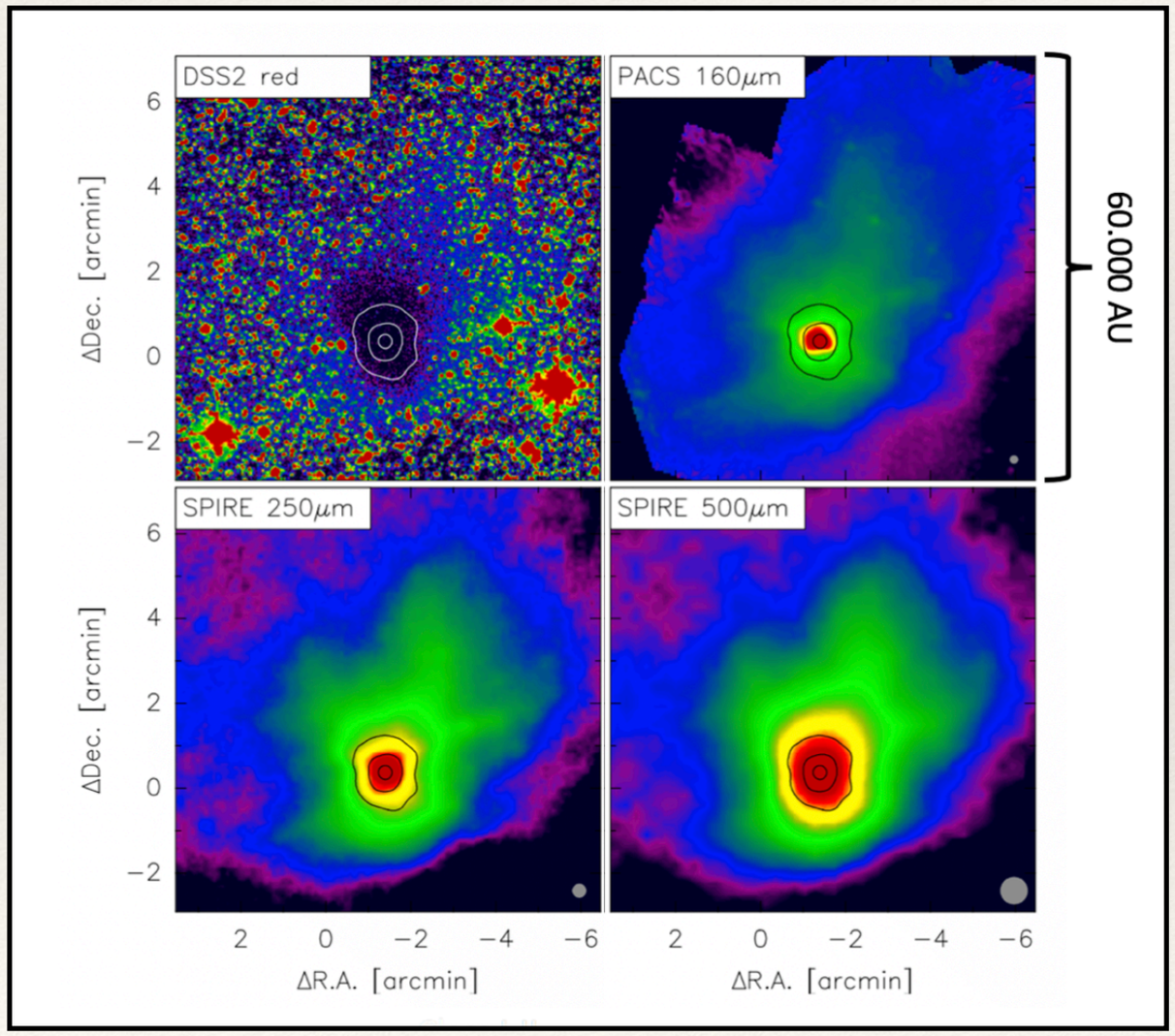

- IRAS 4A is a dense molecular core at **235 pc** Luminosity ~ **10 $L_{\odot}$**
- **$M_{core} \approx 1\ M_{\odot}$** $M_{acc}$ = **$3\times10^{-4}\ M_{\odot}$、 $yr^{-1}$**

**Girart, Crutcher & Rao1999, Lai 2001, Girart et al. 2006, Attard et al. 2009**

# B335: a "typical" isolated (magnetized) dense molecular core, harboring a low mass (Class 0) protostar

$1M_{\odot}$ , $2\ L_{\odot}$ , D=165 pc.

**Zhou et al. 1993**; Saito et al. 1999; Evans et al. 2005, 2015; Stutz et al. 2008; Yen et al. 2011, 2015, 2020; Kurono et al. 2013; Imai et al. 2016, 2019; Per Bjerkeli et al. 2019; Okoda et al. 2022



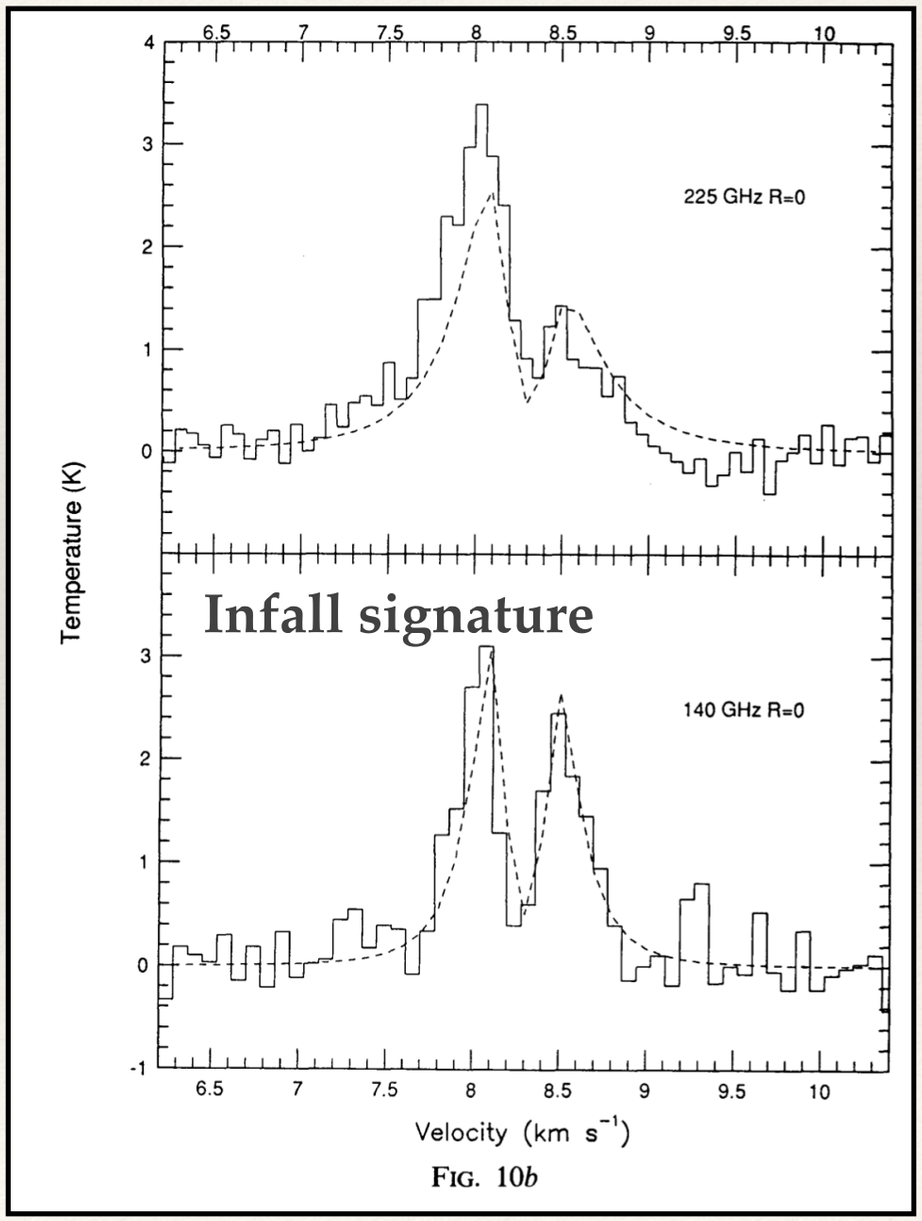




FIG. 10*b*

# Magnetically regulated collapse in B335: The chemical perspective

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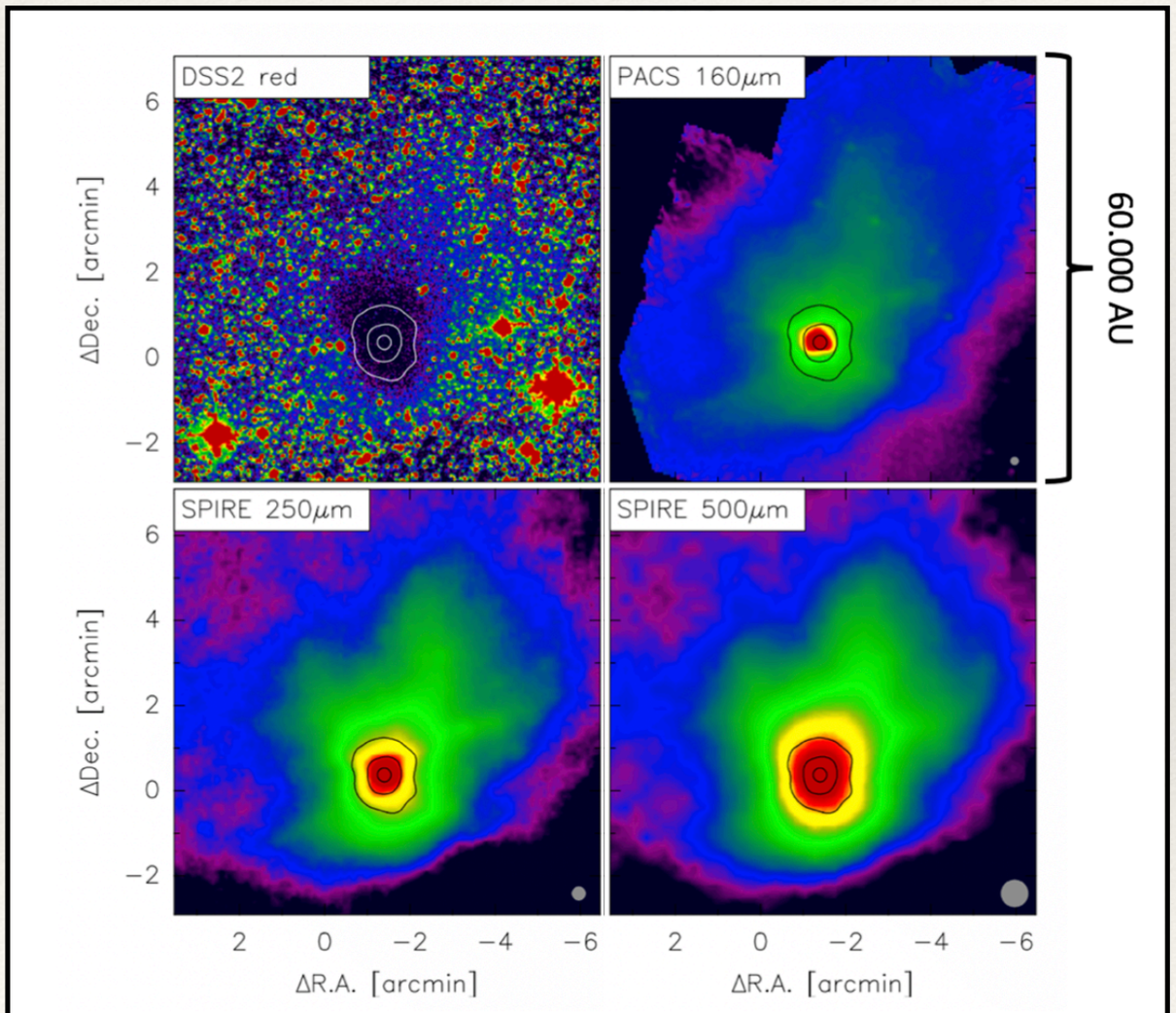


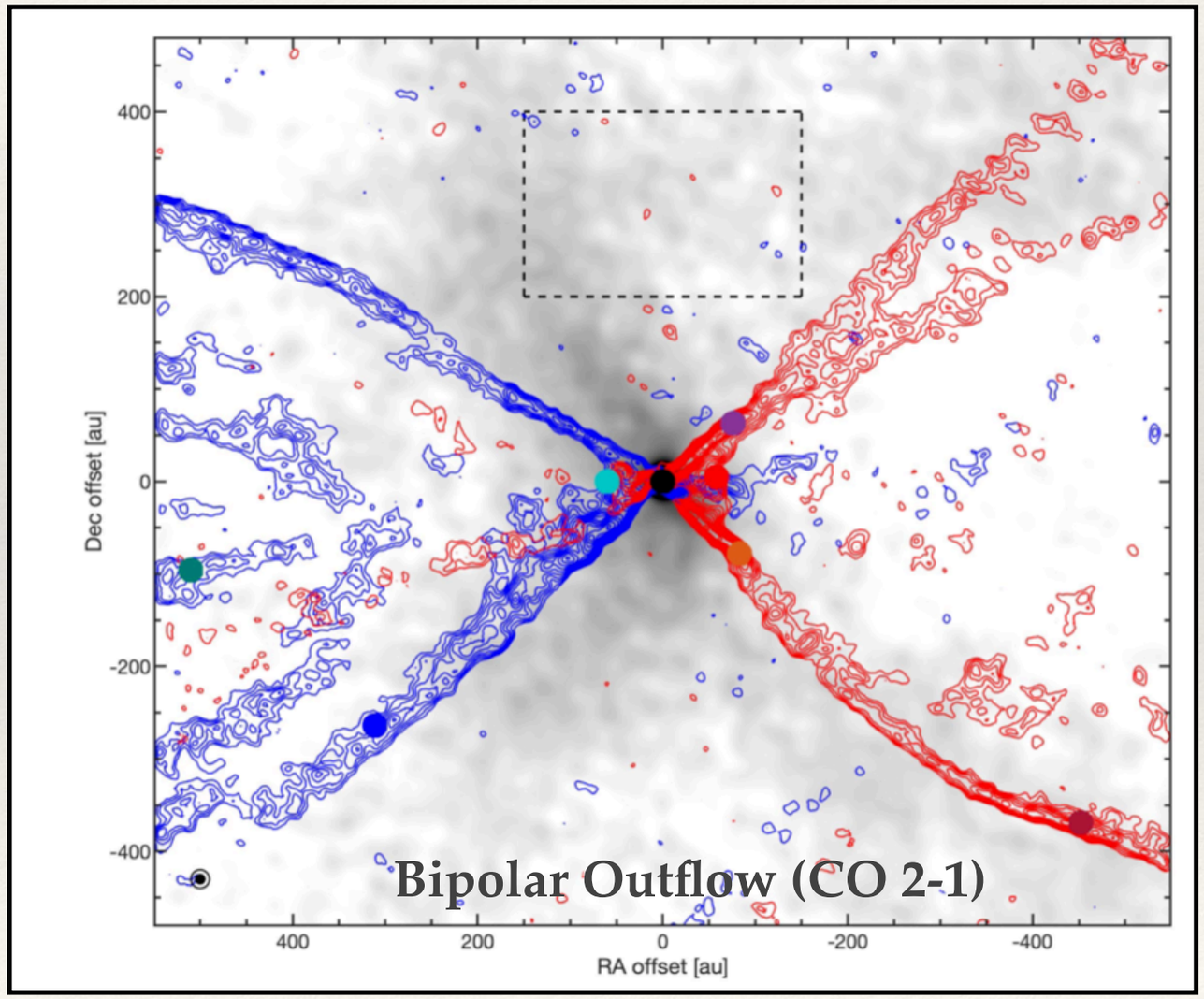

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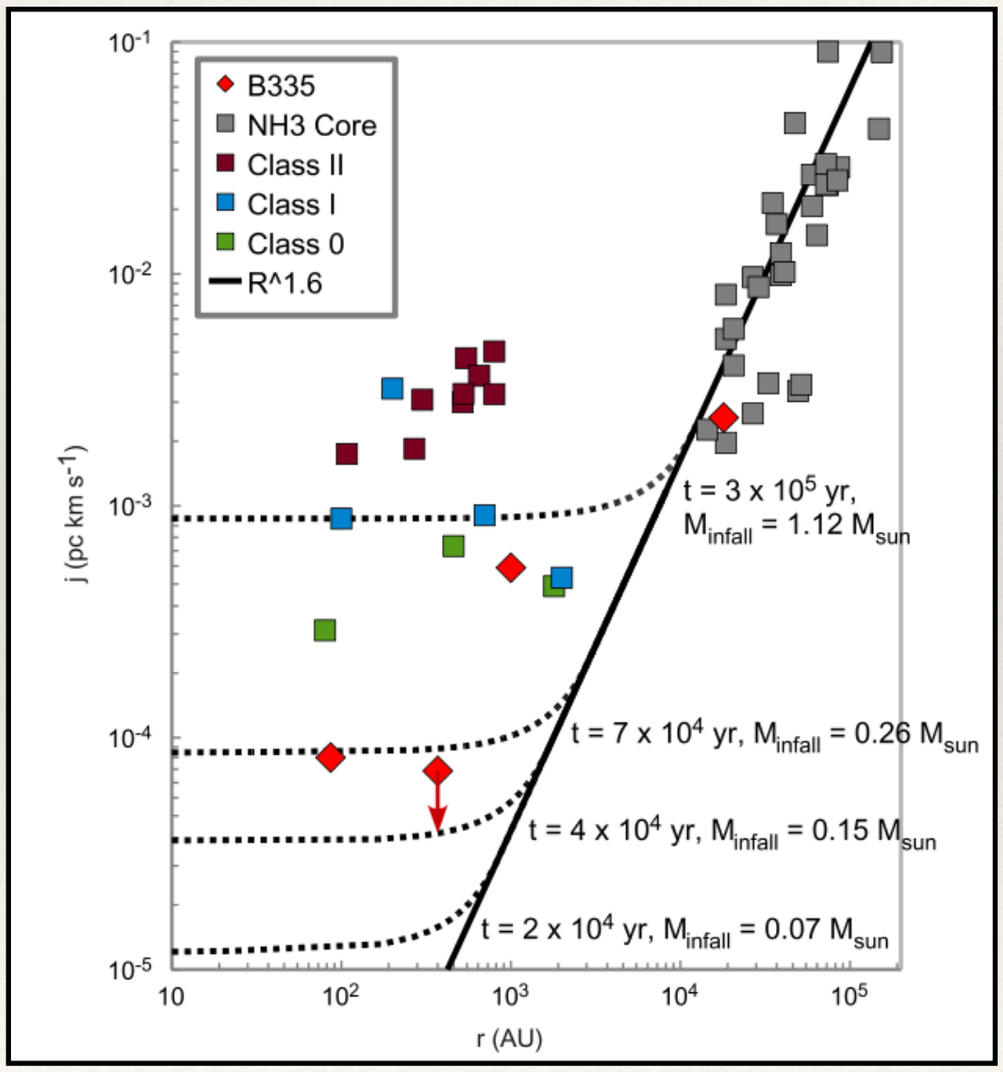


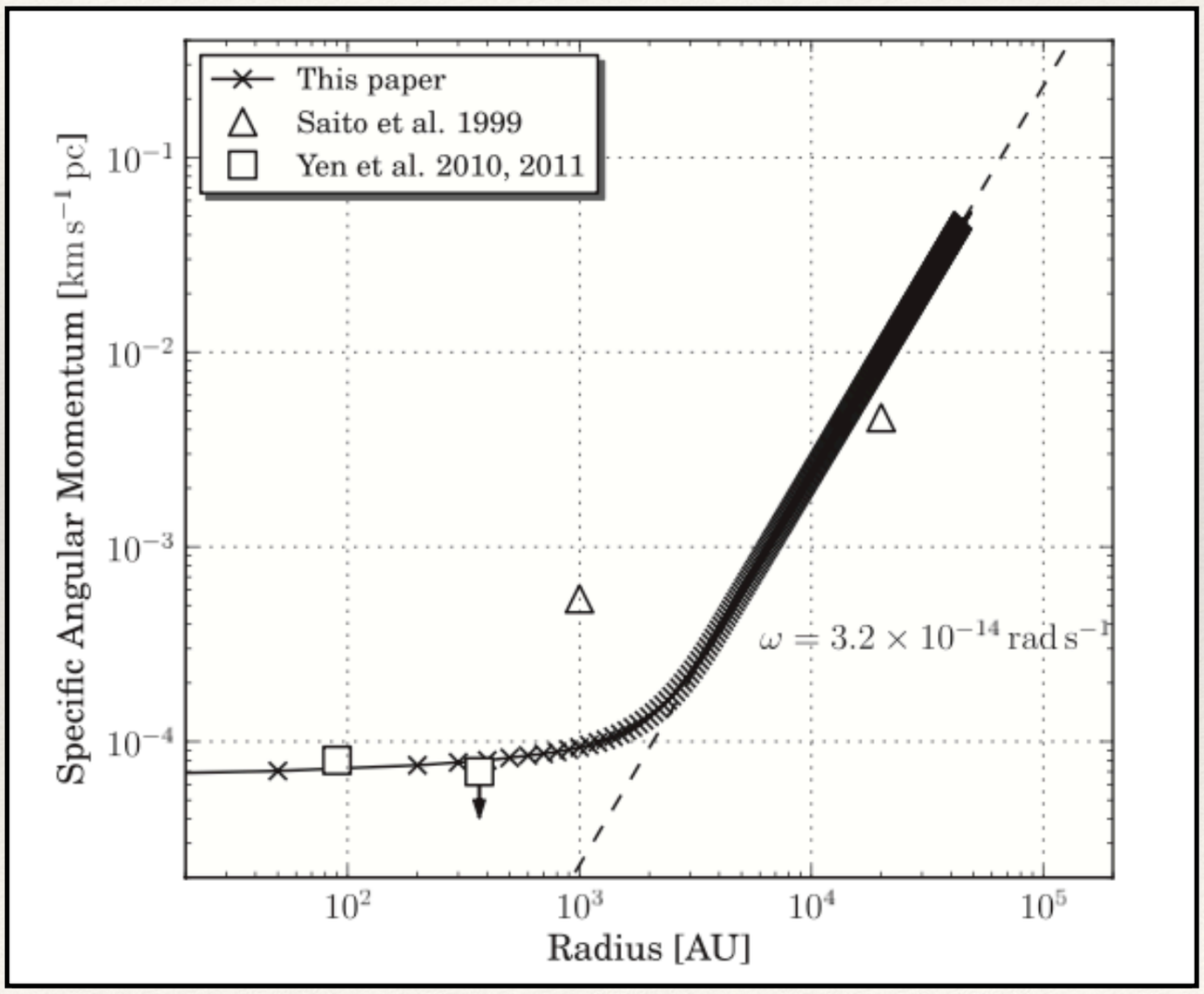


**Very low angular momentum at R<1000au, NO Keplerian disk at R>10au**

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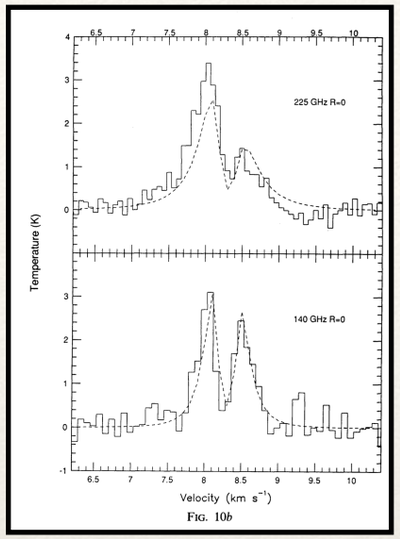
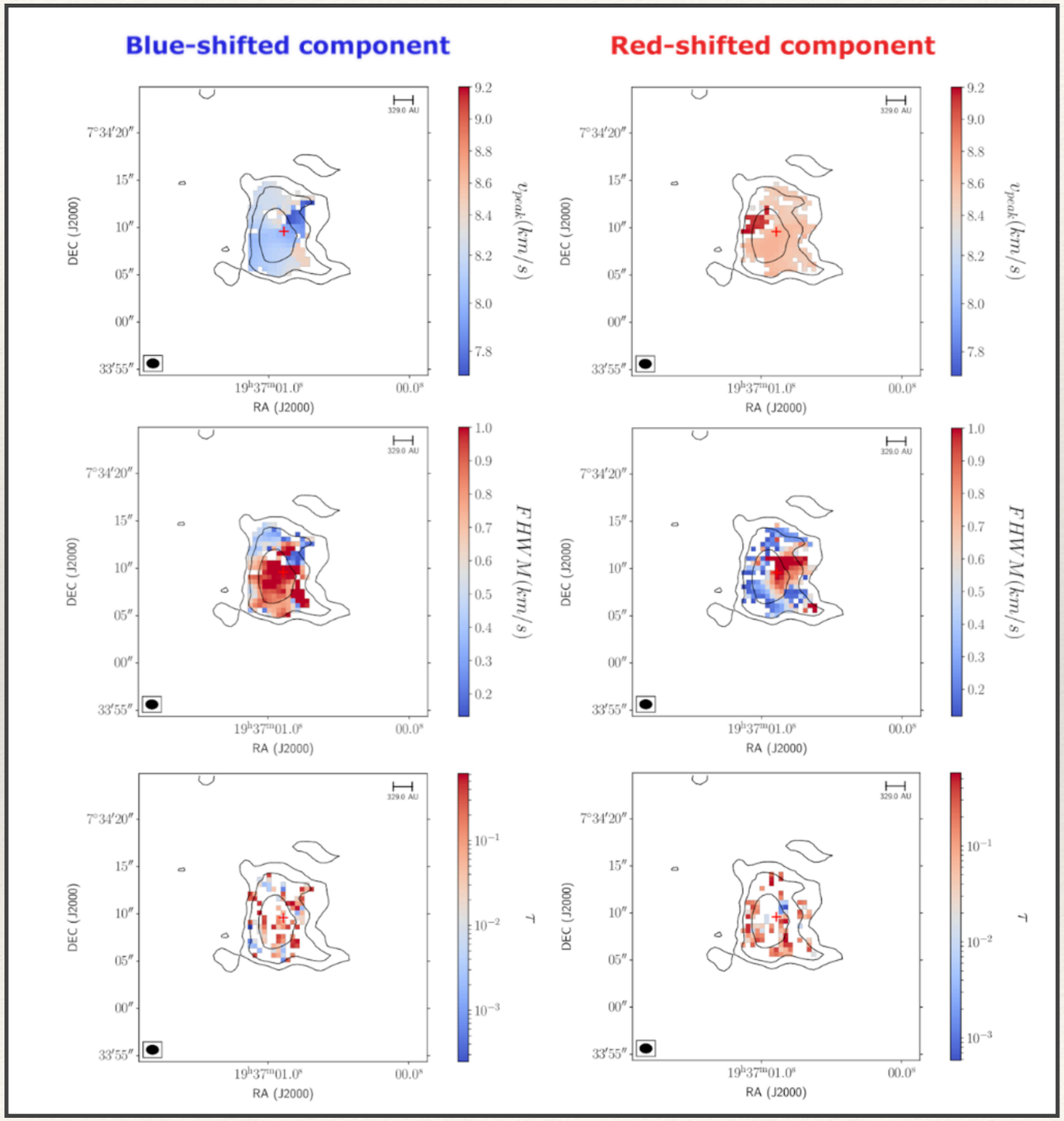


FIG. 10*b*

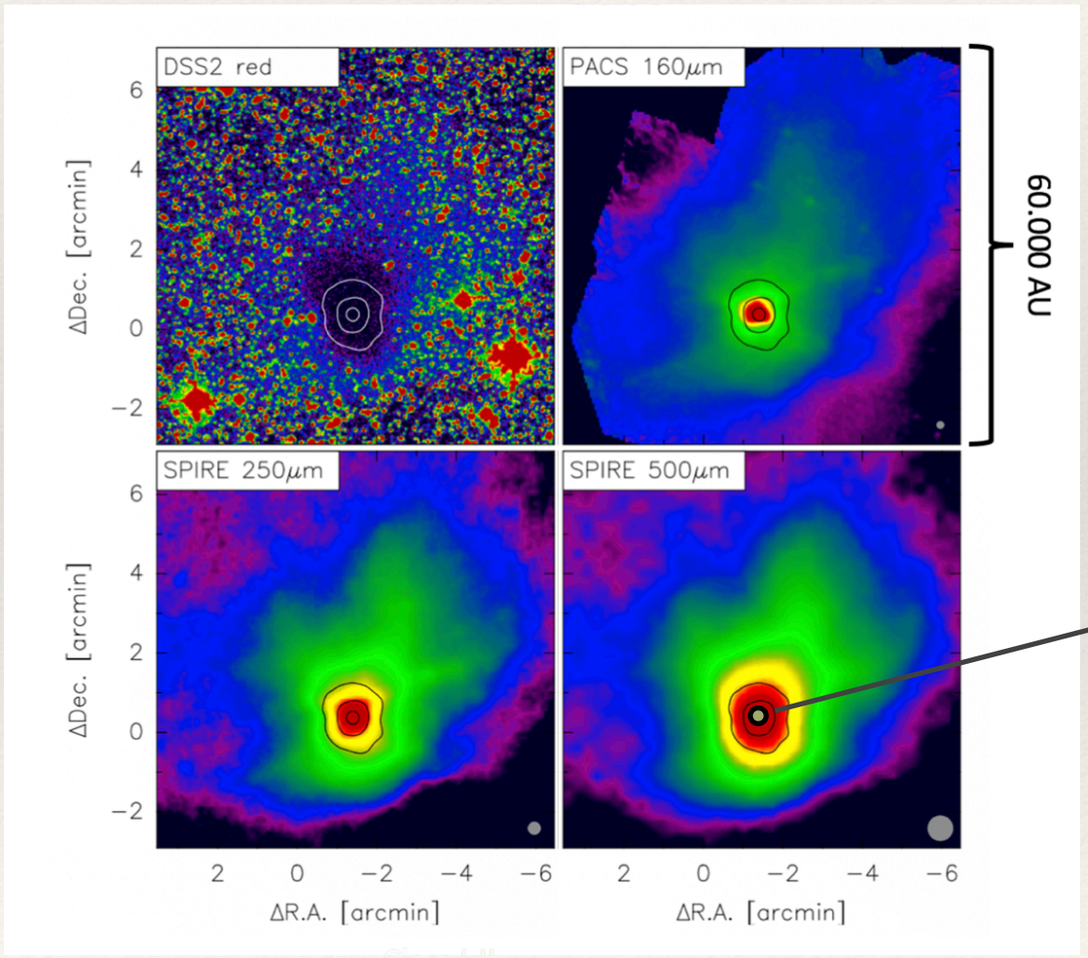
- $C^{17}O$ 1-0 traces two velocity components and is optically thin
- Classical spherical infall doesn't work
- **Non-isotropic accretion from the envelope into the central source along the outflow cavity walls** ?

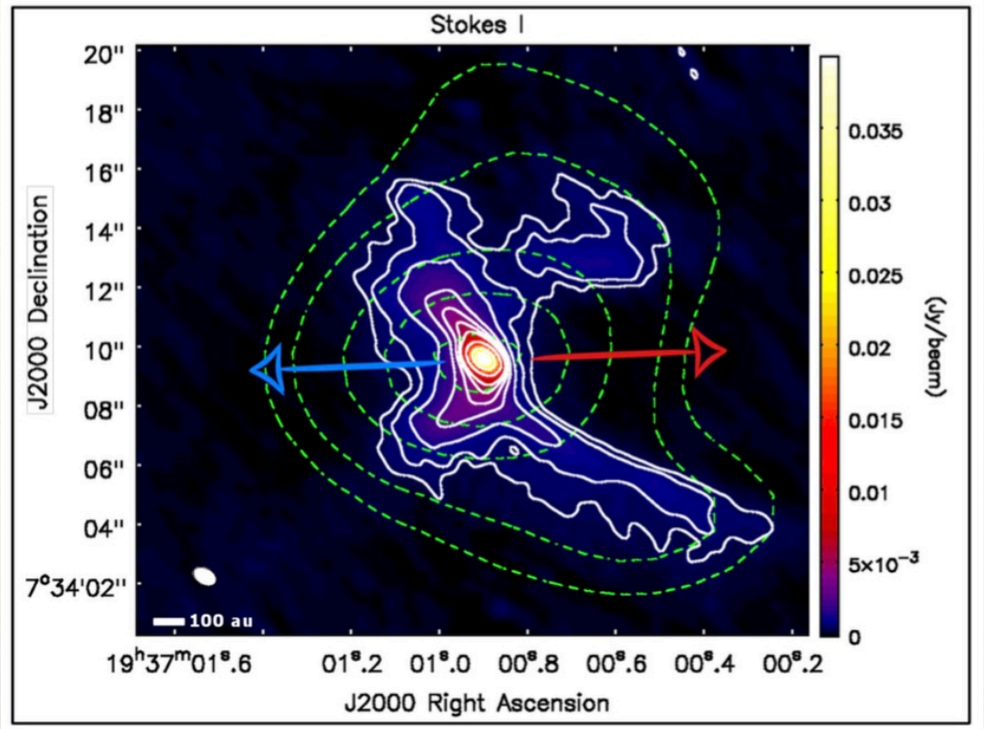


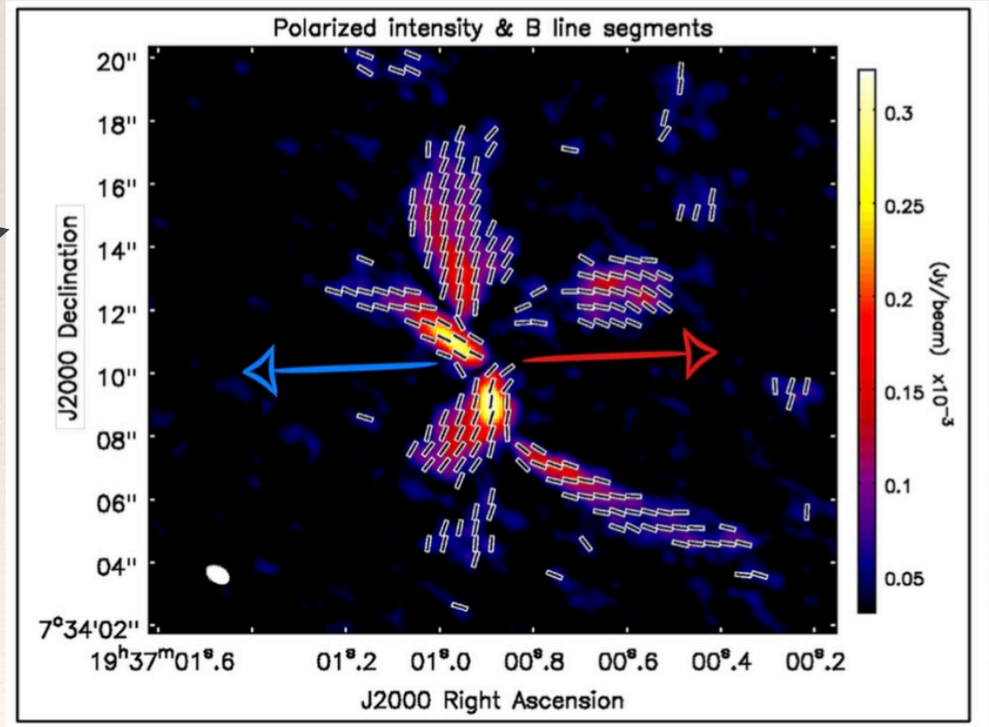

Cabedo et al. 2021, A&A

# B335: a "typical" isolated (magnetized) dense molecular core, harboring a low mass (Class 0) protostar

Magnetic fields derived from the linear polarization of the 1.3 mm dust continuum at scales 60-1000 au



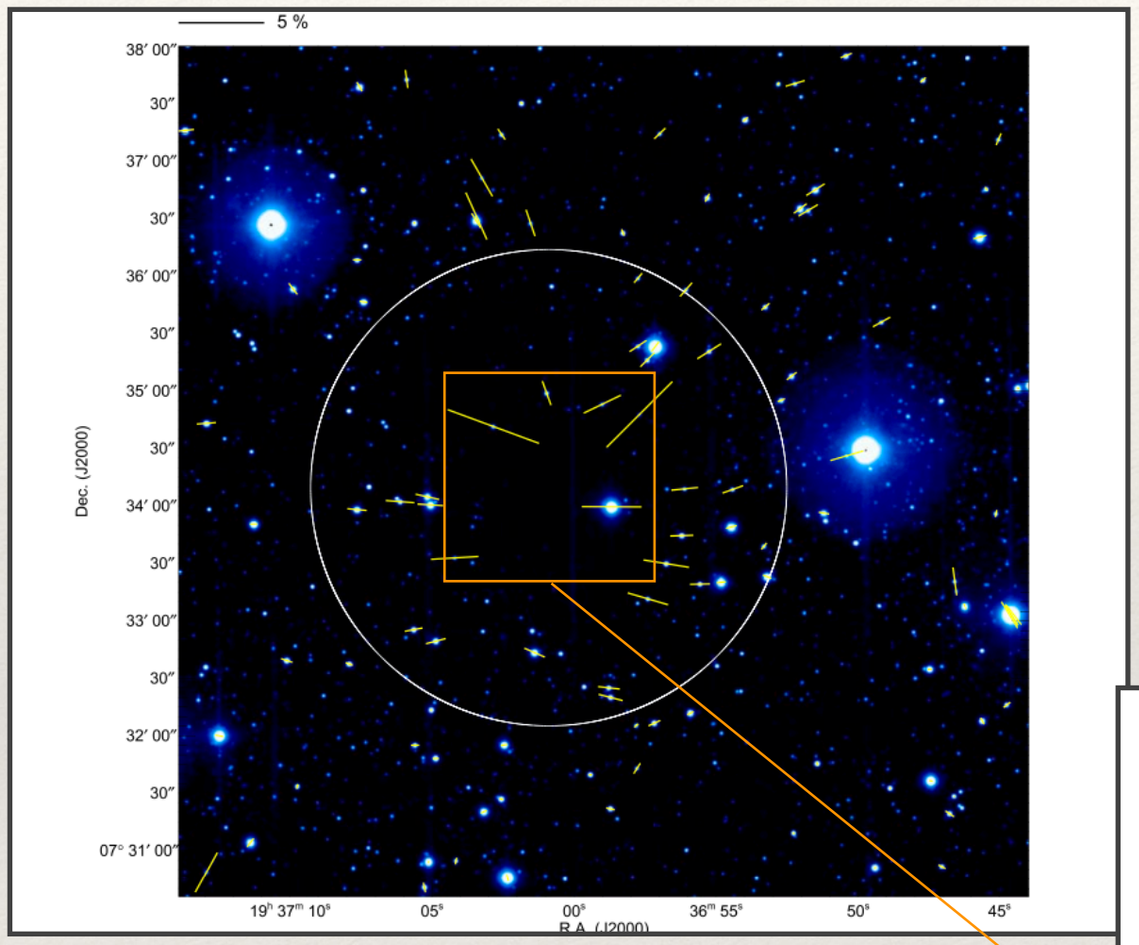



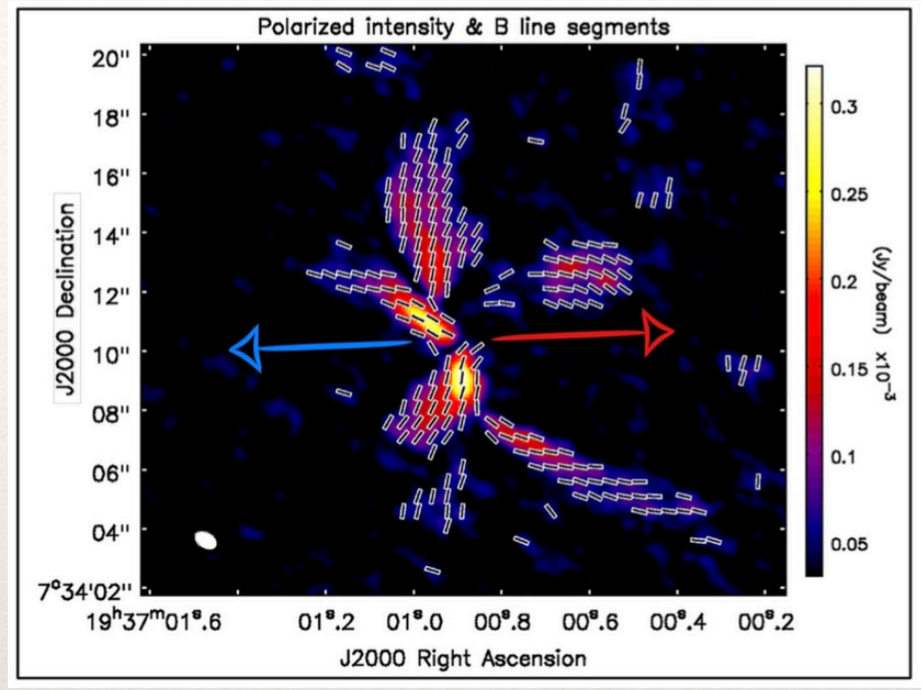

Maury, JMG et al. 2018, MNRAS

# Magnetically regulated collapse in B335: The chemical perspective

## B335: a "typical" isolated (magnetized) dense molecular core, harboring a low mass (Class 0) protostar

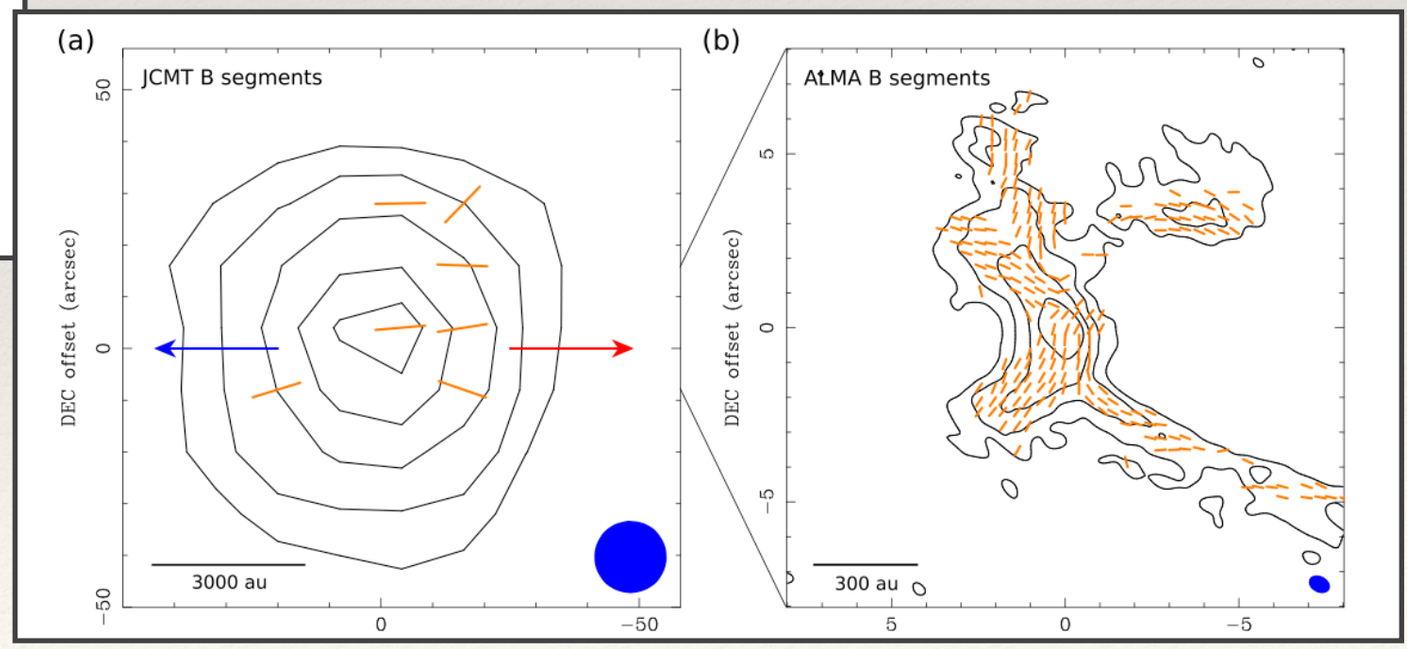
Kandori et al. 2020




Maury, JMG et al. 2018, MNRAS

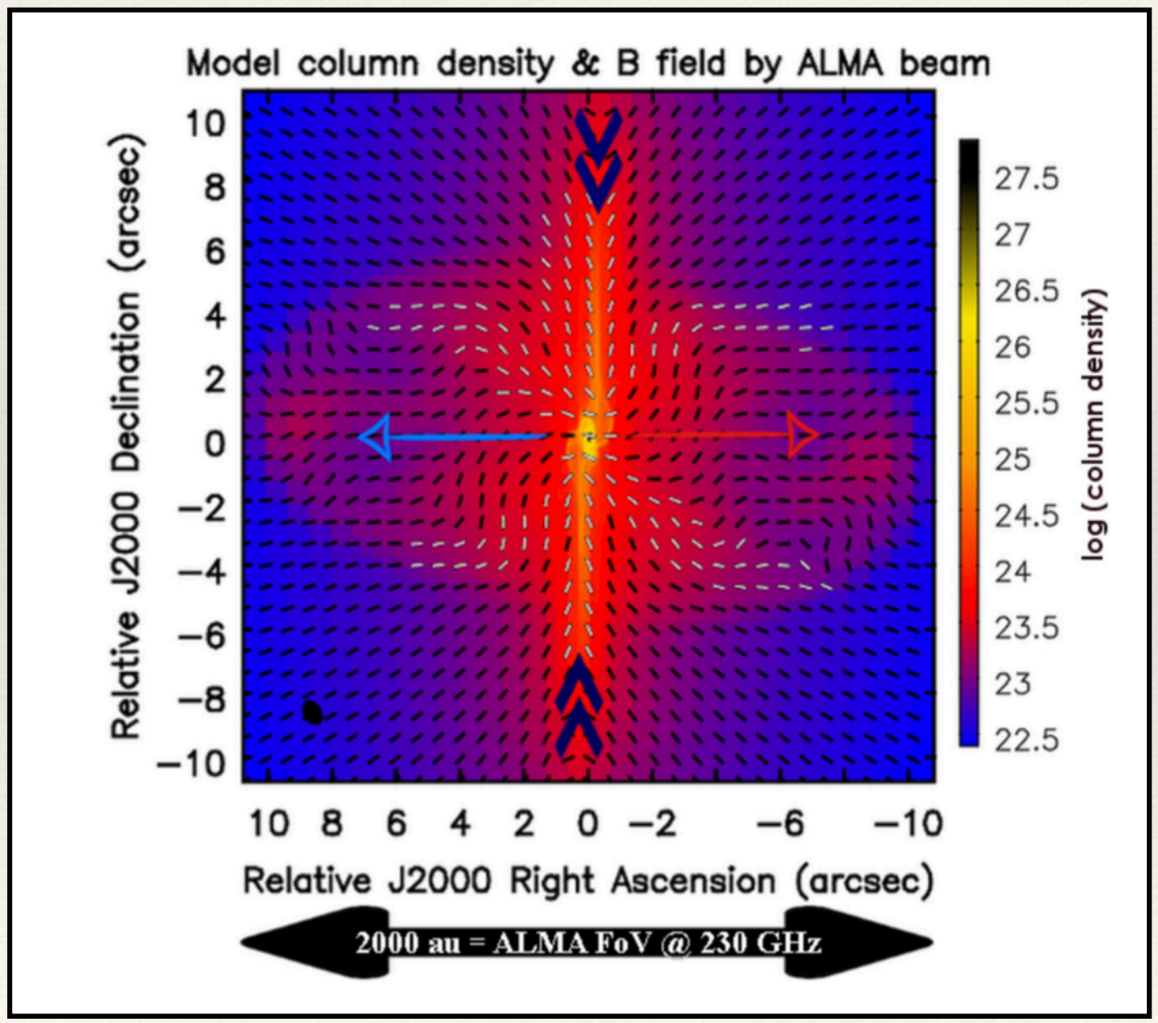
Magnetic fields maintains coherences from 0.1 pc to 100 au



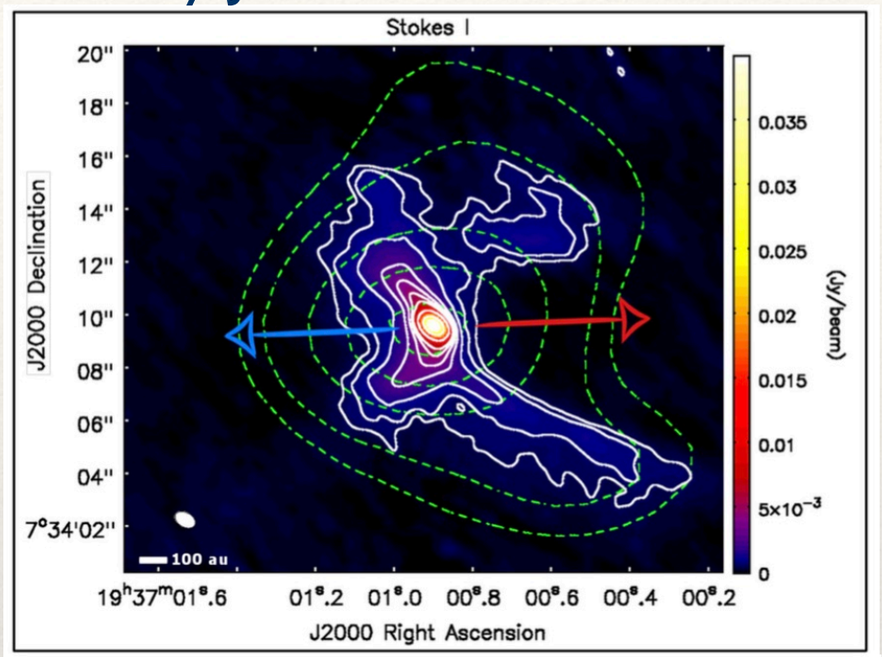

Yen et al. 2019

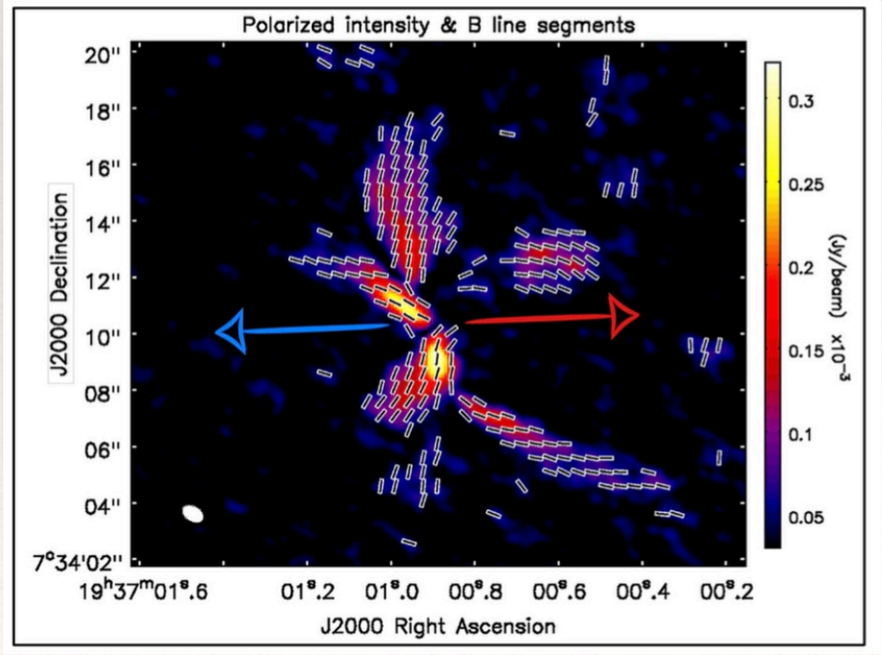
# B335: a "typical" isolated (magnetized) dense molecular core, harboring a low mass (Class 0) protostar

Non-ideal MHD Model can qualitatively reproduce the observations for a mass-to-flux ratio of 6 and β of 0.001




Maury, JMG et al. 2018, MNRAS



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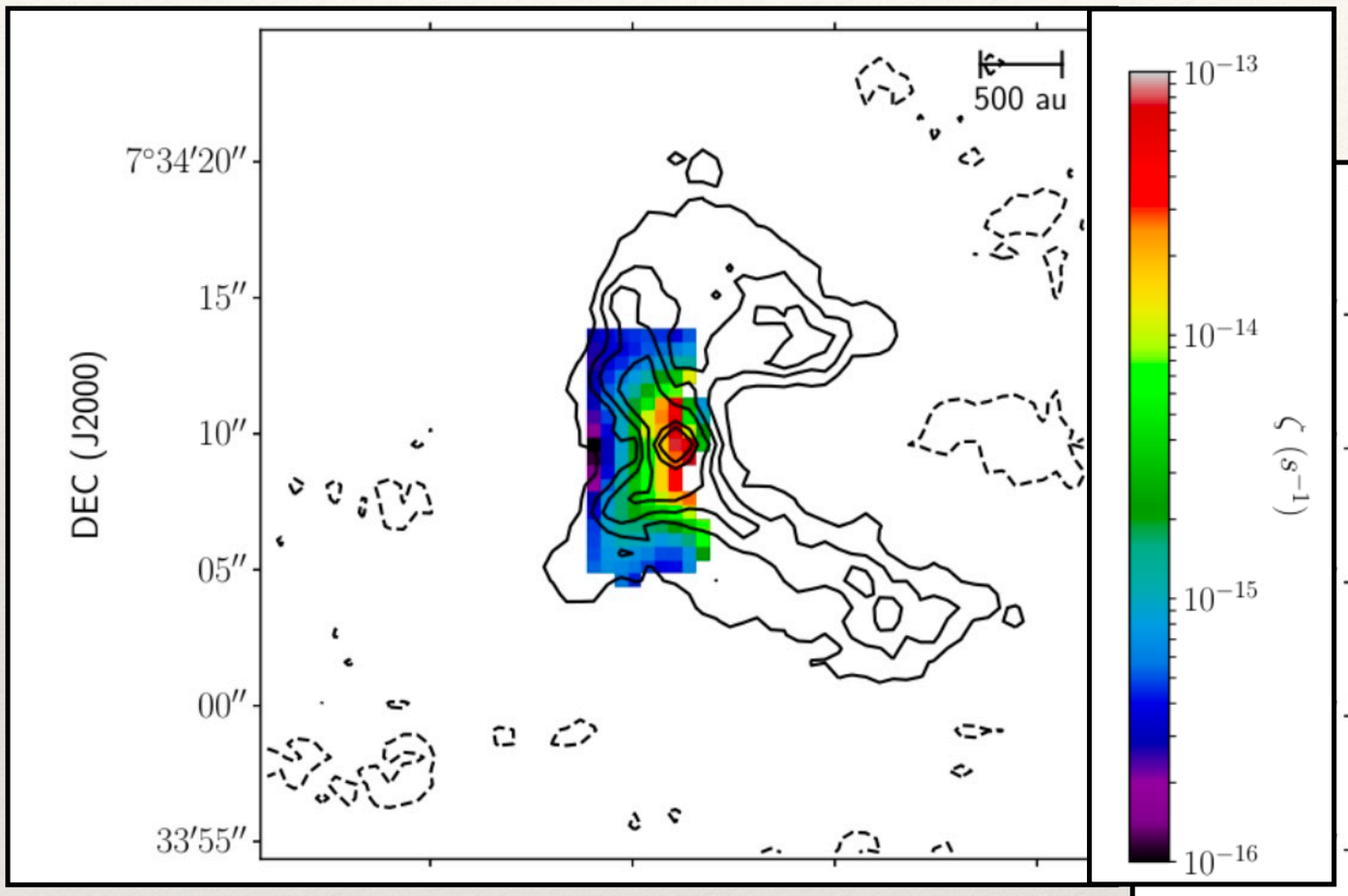


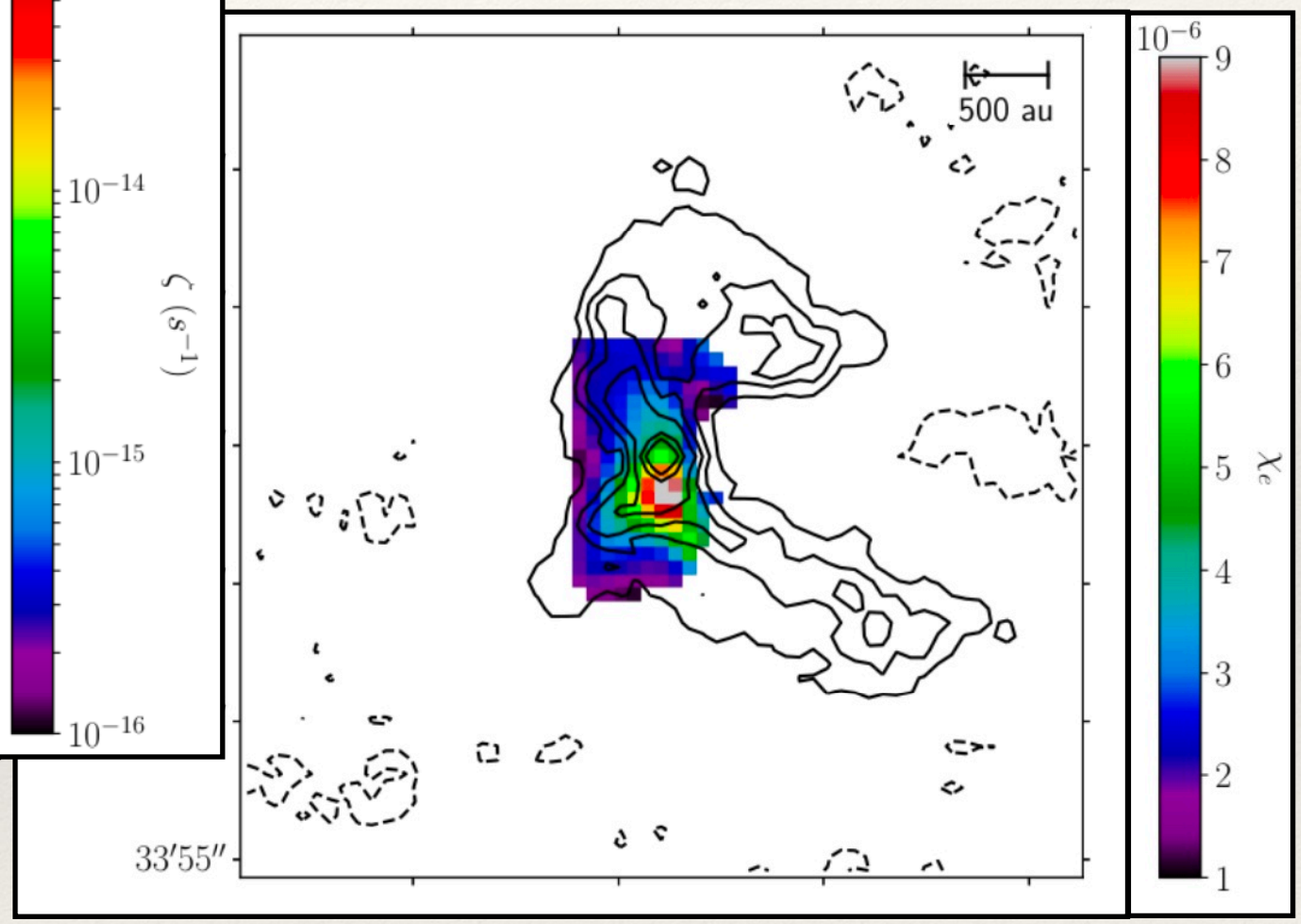


Using ALMA observations we have been able to infer the ionization fraction and ionization rate

Cabedo, Maury, Girart et al. arXiv:2204.10043

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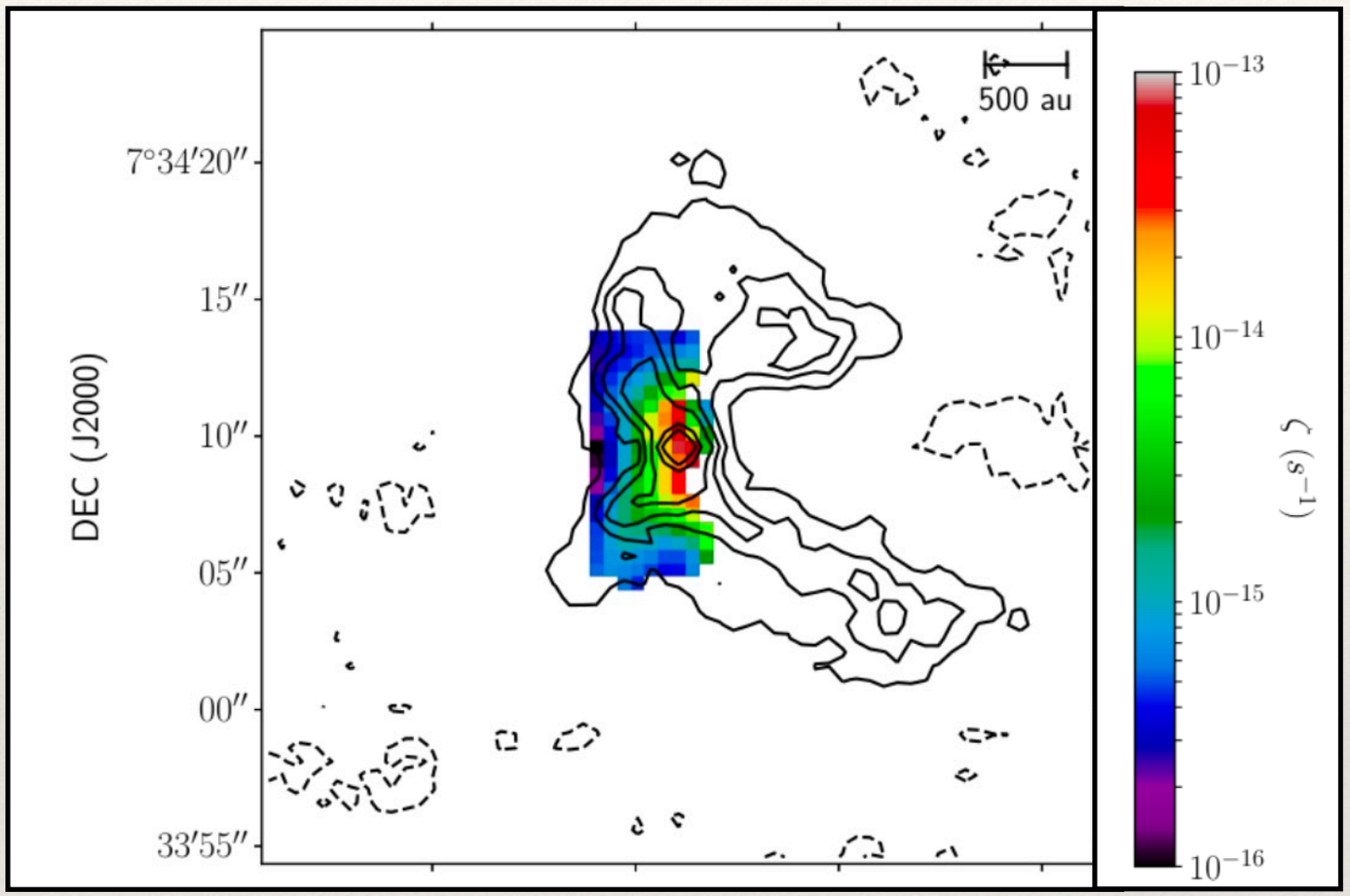
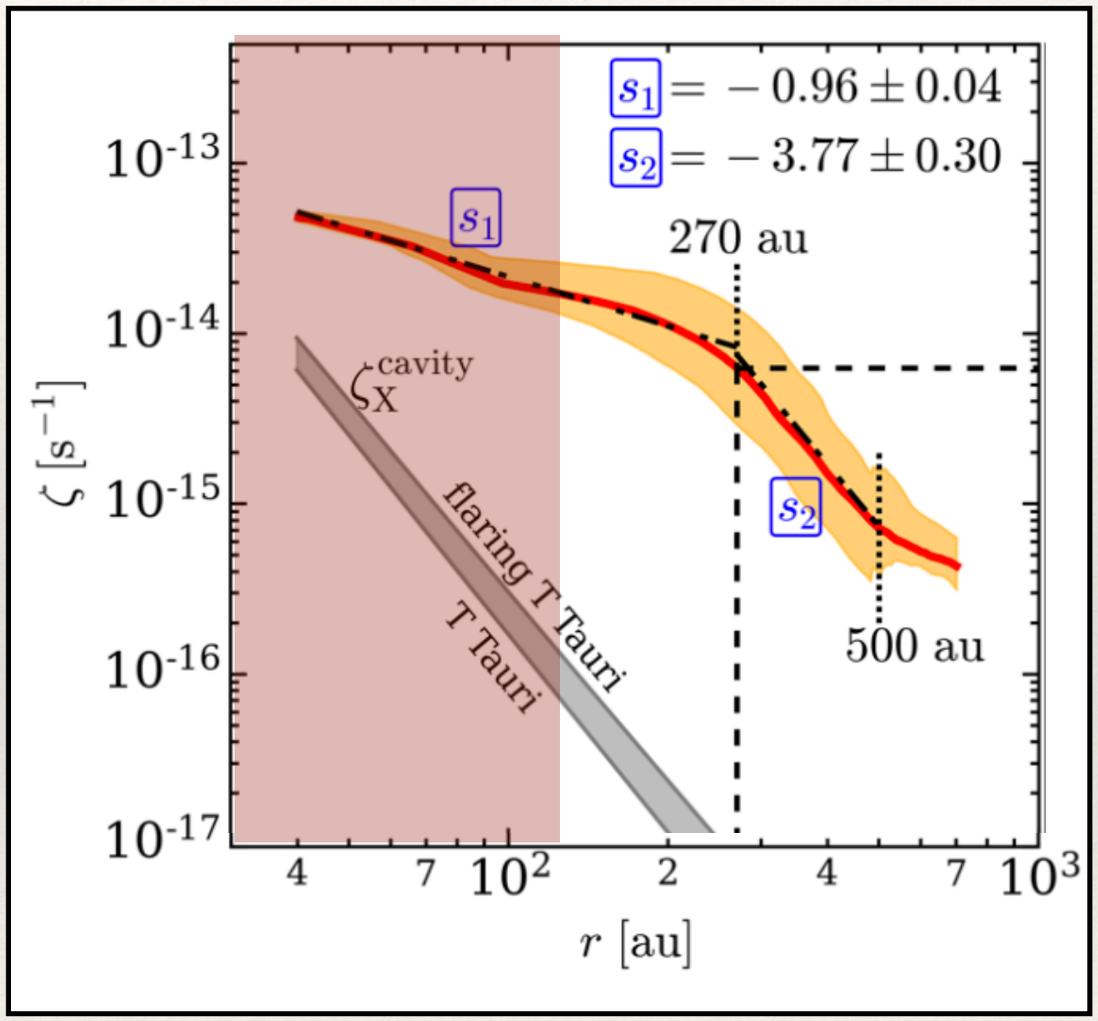



For R<1000 au

local acceleration of CRs

(and not the penetration of interstellar CRs)

may be responsible for the gas ionization




Cabedo, Maury, Girart et al. arXiv:2204.10043

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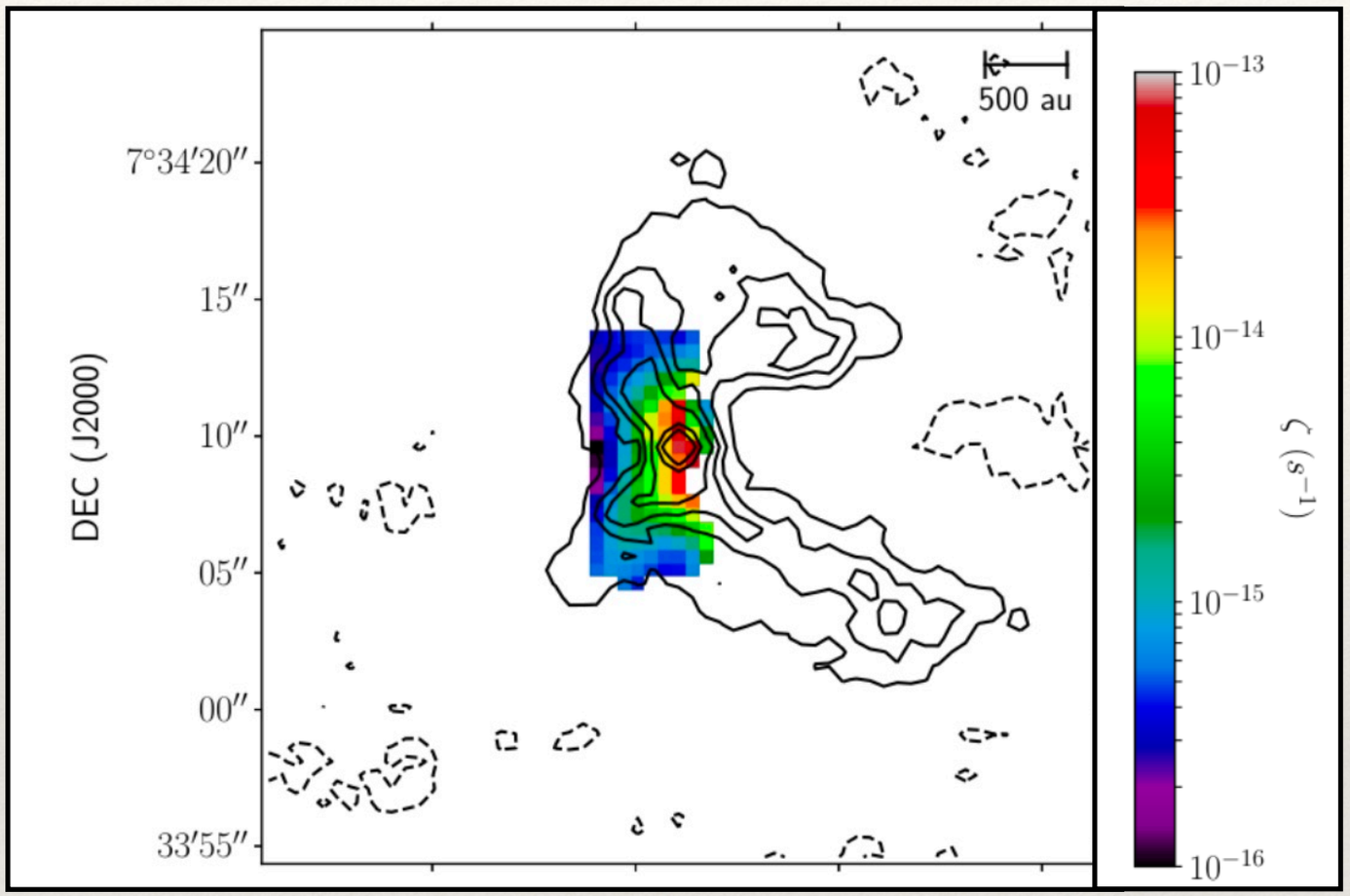
**(I) Local production of CR: is it episodic?**

**(II) Efficient coupling between the magnetic field and the gas in the inner envelope of B335**

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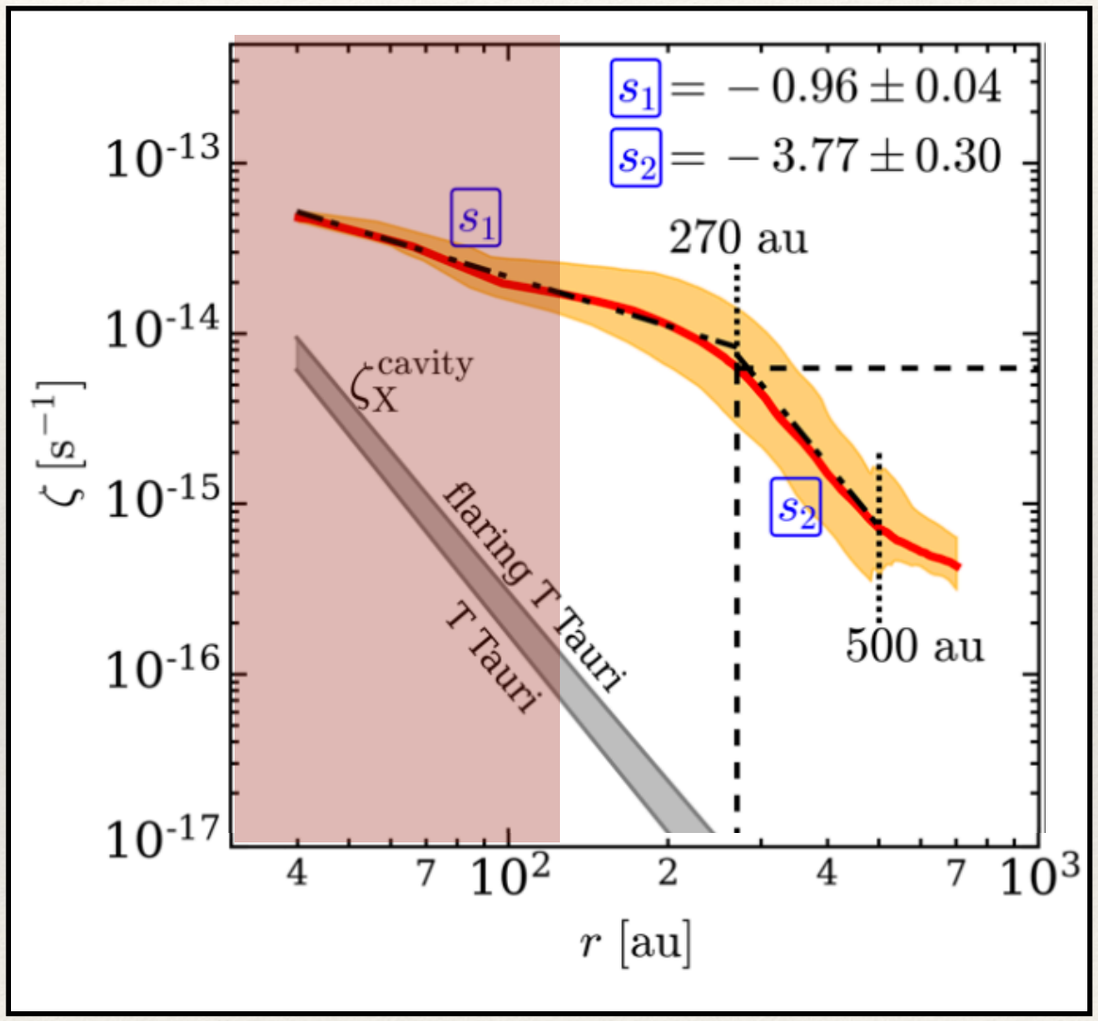


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# HOW?

- ALMA data cubes of
  - $C^{17}O$ & $H^{13}CO^+$ 1-0 : $f_D$
  - $DCO^+$ & $H^{13}CO^+$ 3-2 : $R_D$
    - Dust emission at 2.7 mm : $N(H_2)$
- Derived using Caselli+1998 recipe
  - $$\chi_e = \frac{2.7 \times 10^{-8}}{R_D} - \frac{1.2 \times 10^{-6}}{f_D},$$
  - $$\zeta = \left[7.5 \times 10^{-4} \chi_e + \frac{4.6 \times 10^{-10}}{f_D}\right] \chi_e n_{H_2} R_H,$$

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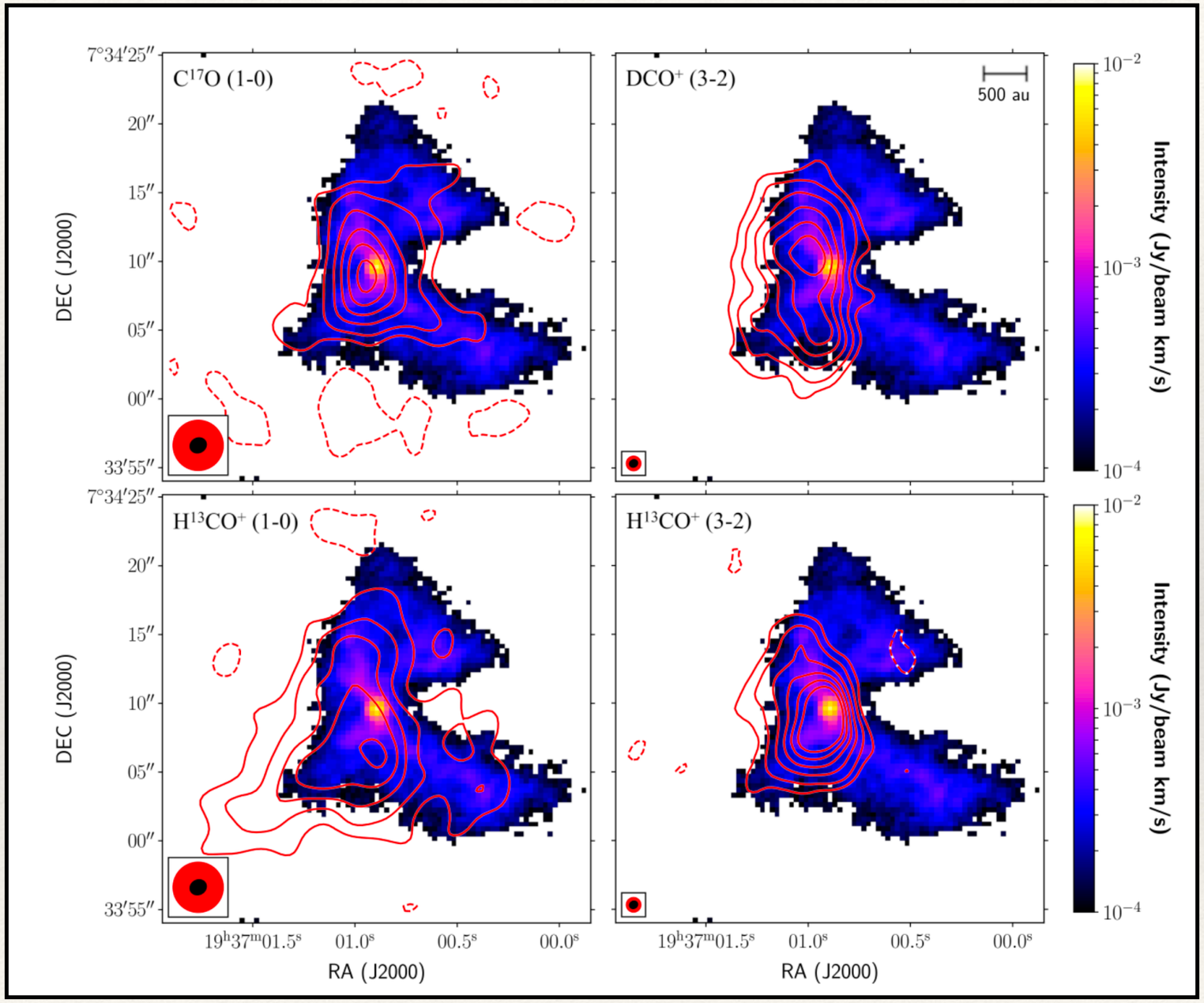
# HOW?



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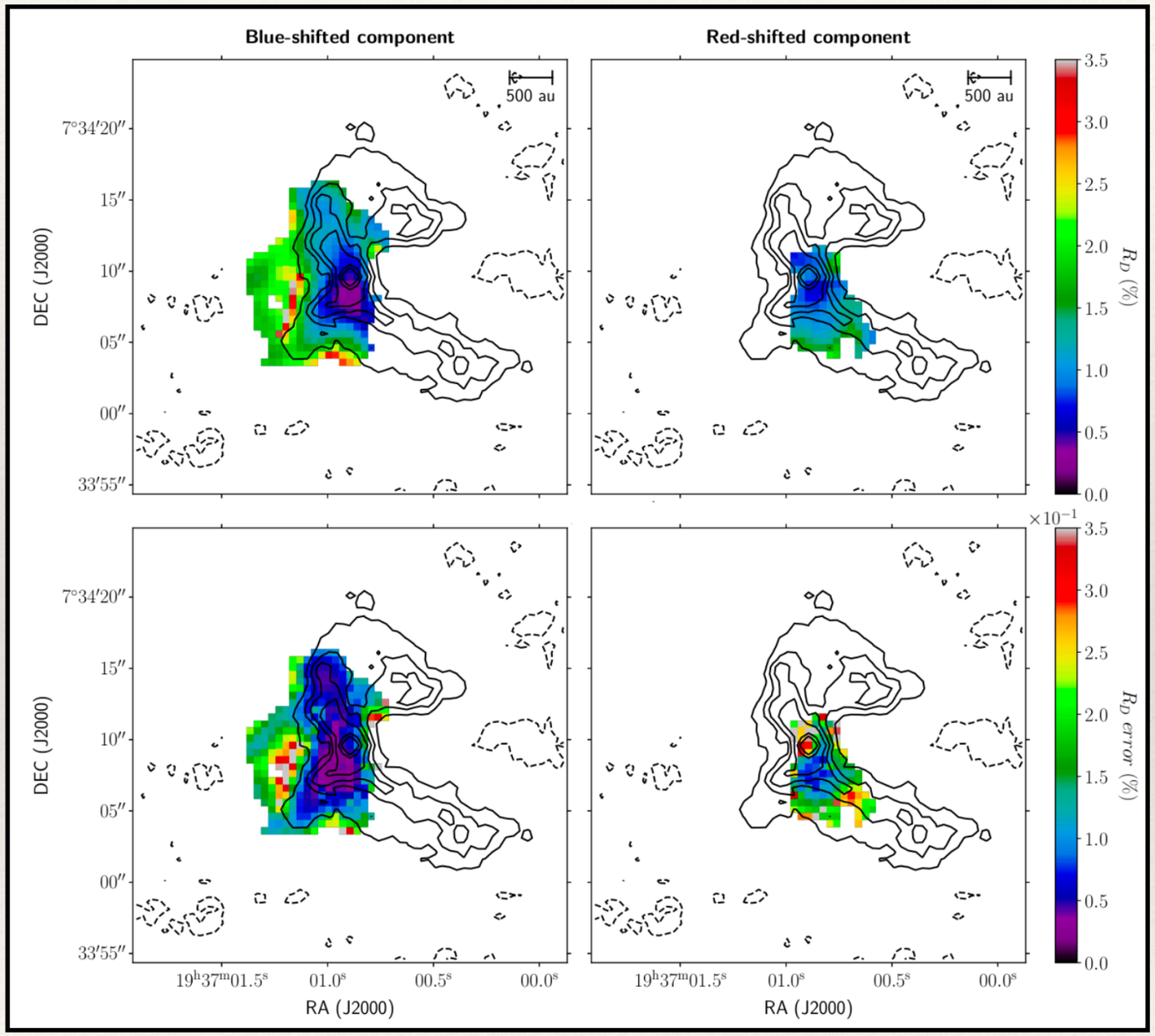


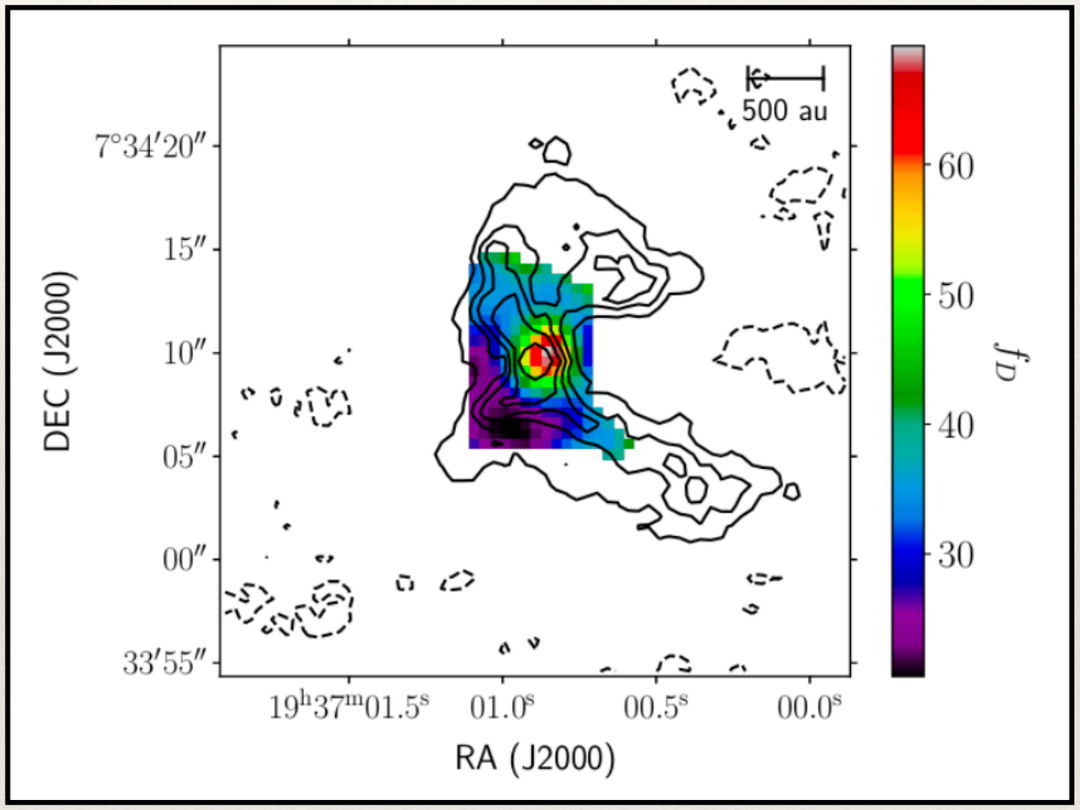

# SUMMARY

- ALMA observations of B335 have been used to study the magnetic field and derive the ionization fraction and the ionization rate
- The magnetic field is coherent at different scales but
- Significantly dragged by the gravitational collapse
- We found high values of Xe, increasing toward the YSO
- **Local Cosmic Rays** are necessary to explain the observed ionization rate pattern
- Local production of CR: is it episodic?
- The results suggests **an efficient coupling between the magnetic field and the gas** in the inner envelope of B335
- *NEXT*: Is this a peculiar source? $\Longrightarrow$ **We need a statistical sample with updated chemical models and RT analysis**