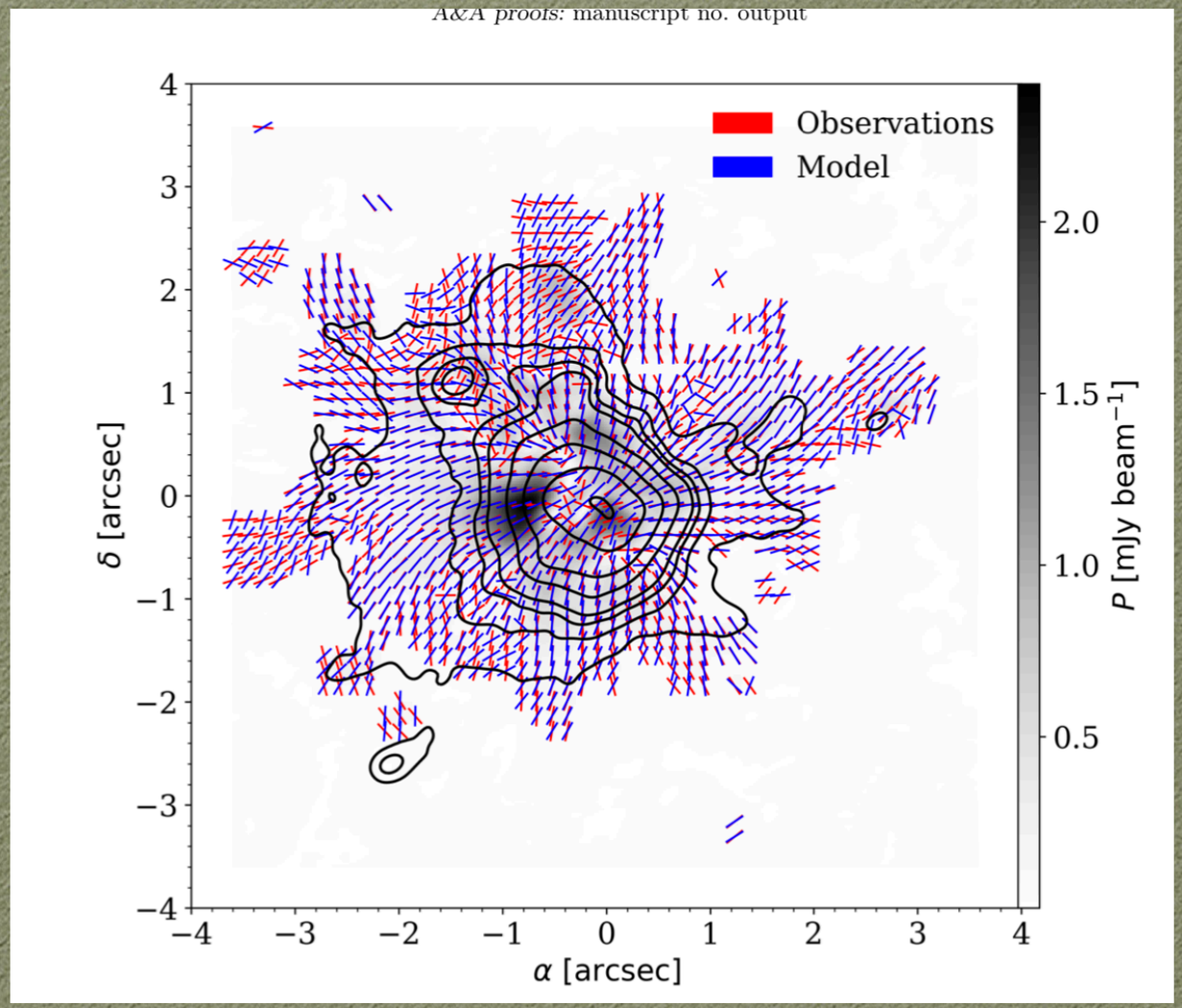
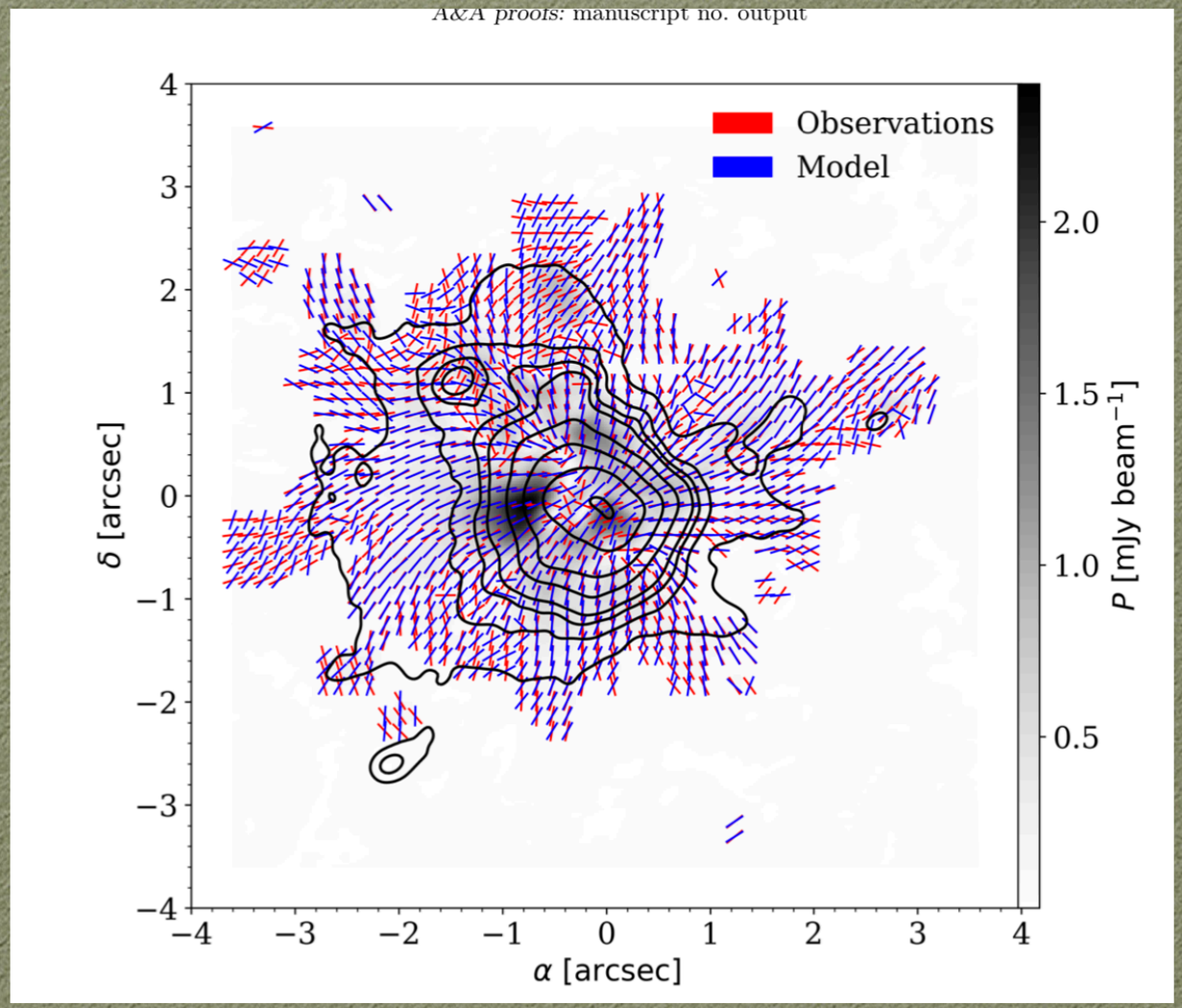
# G31.41 … what else?





Josep Miquel Girart
Institut de Ciències de l'Espai, CSIC & IEEC

# G31.41 … what else?





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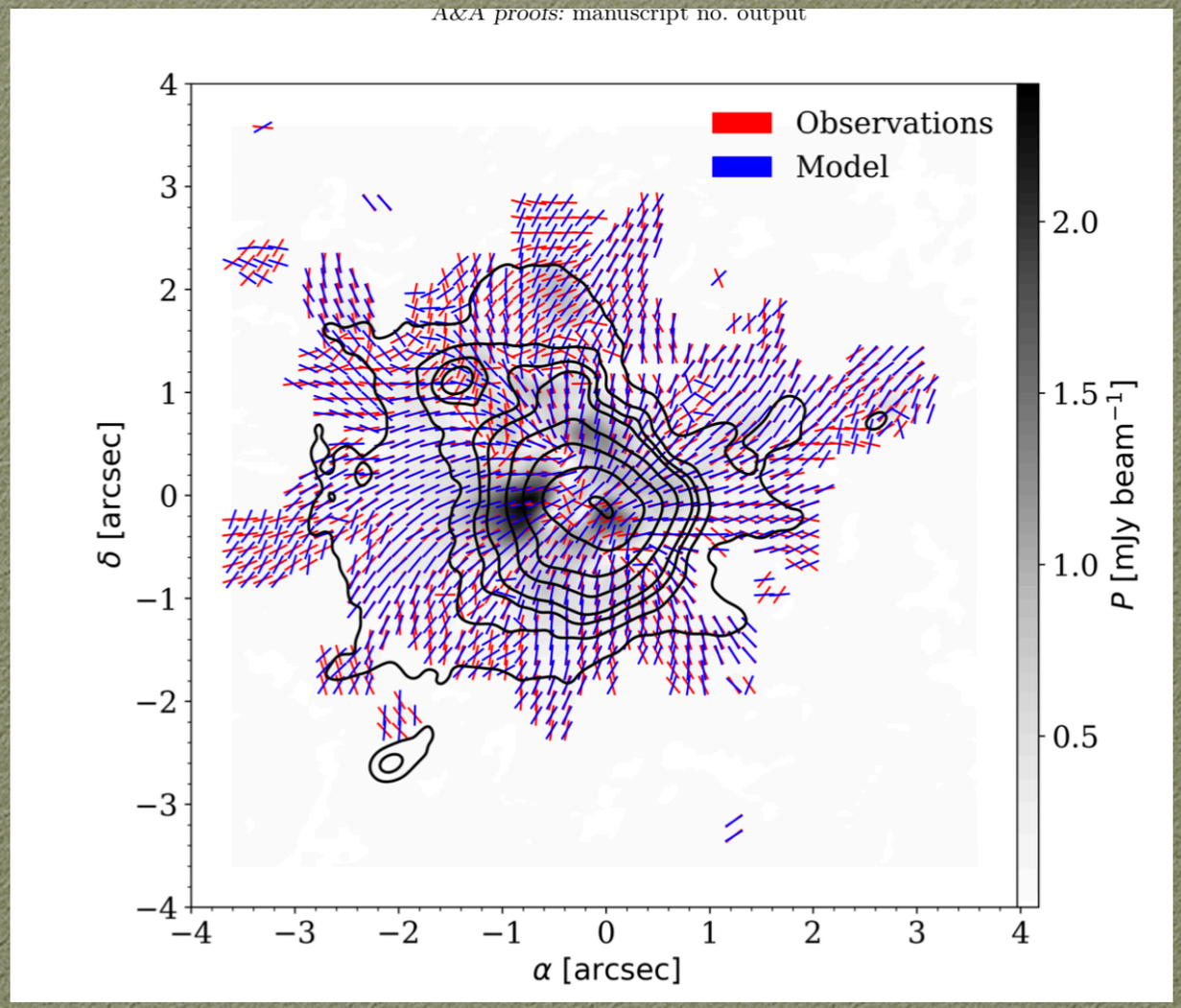
# G31.41 … what else?





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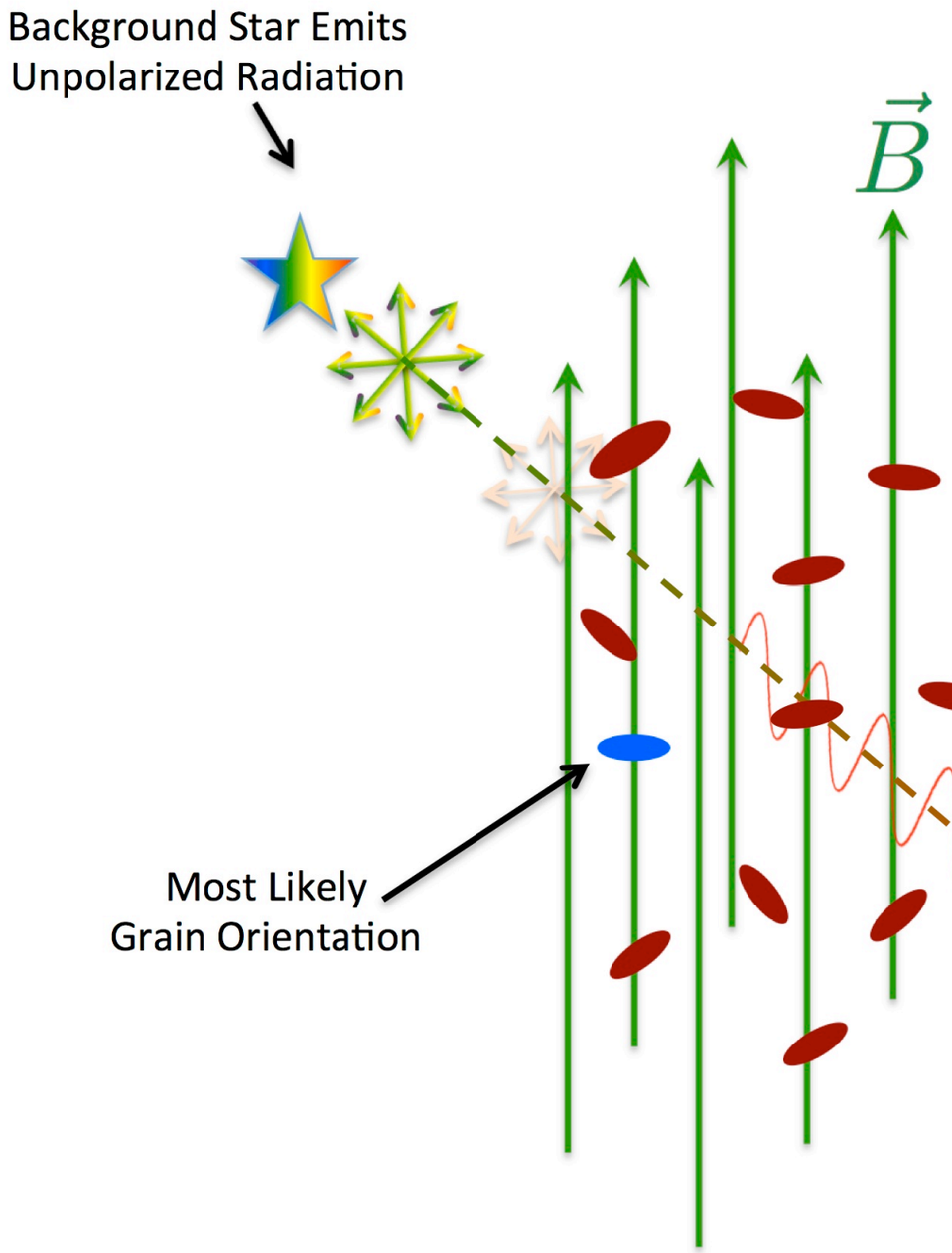
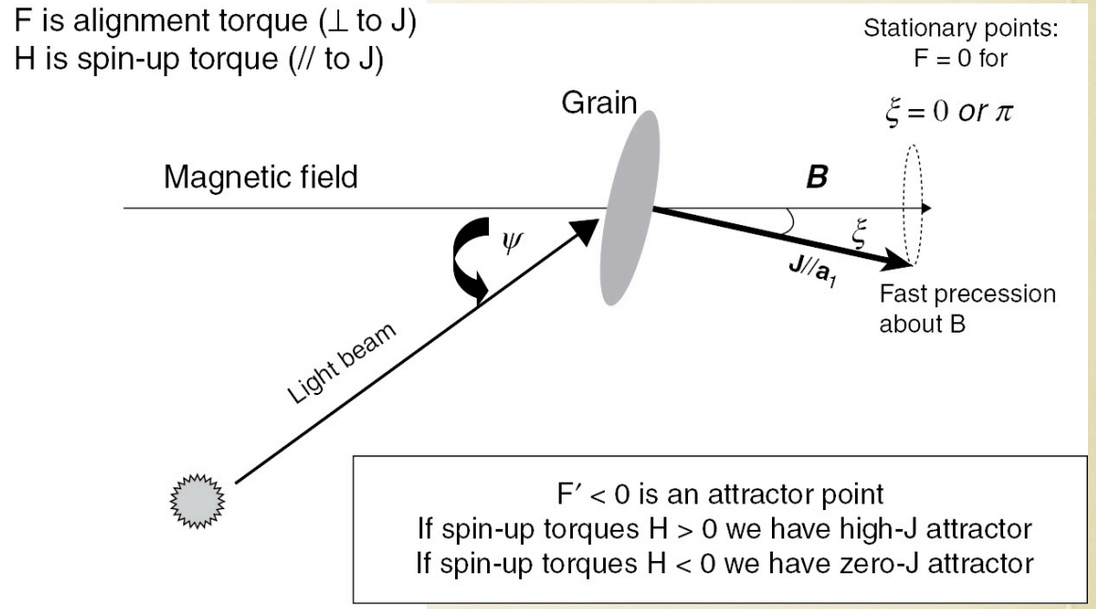
# Polarization at millimeter wavelengths from dust

- The first mechanism: elongated dust grains aligned with B field



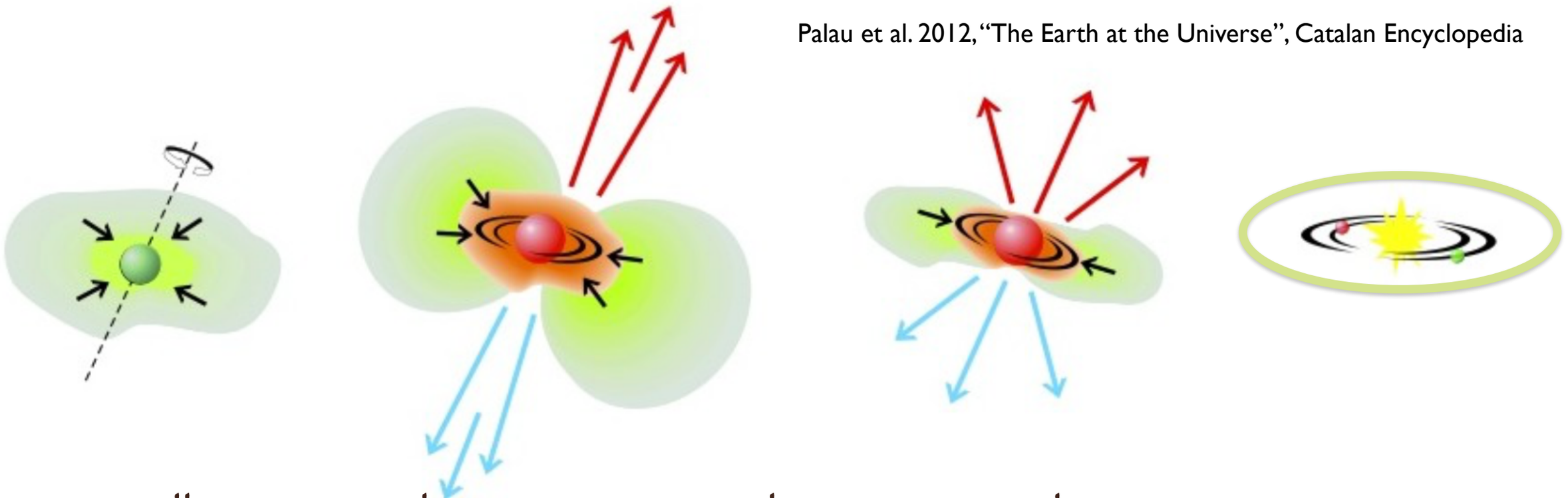

From B-G Anderson



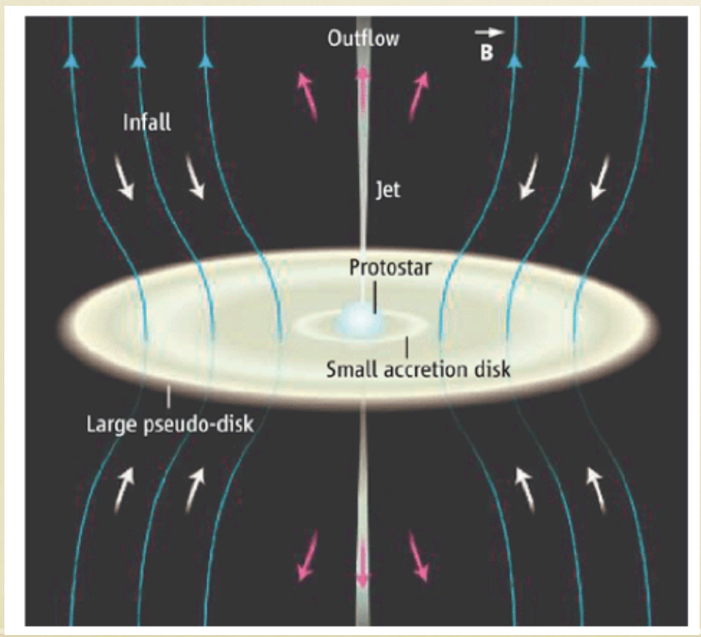

Lazarian, Andersson & Hoang 2015

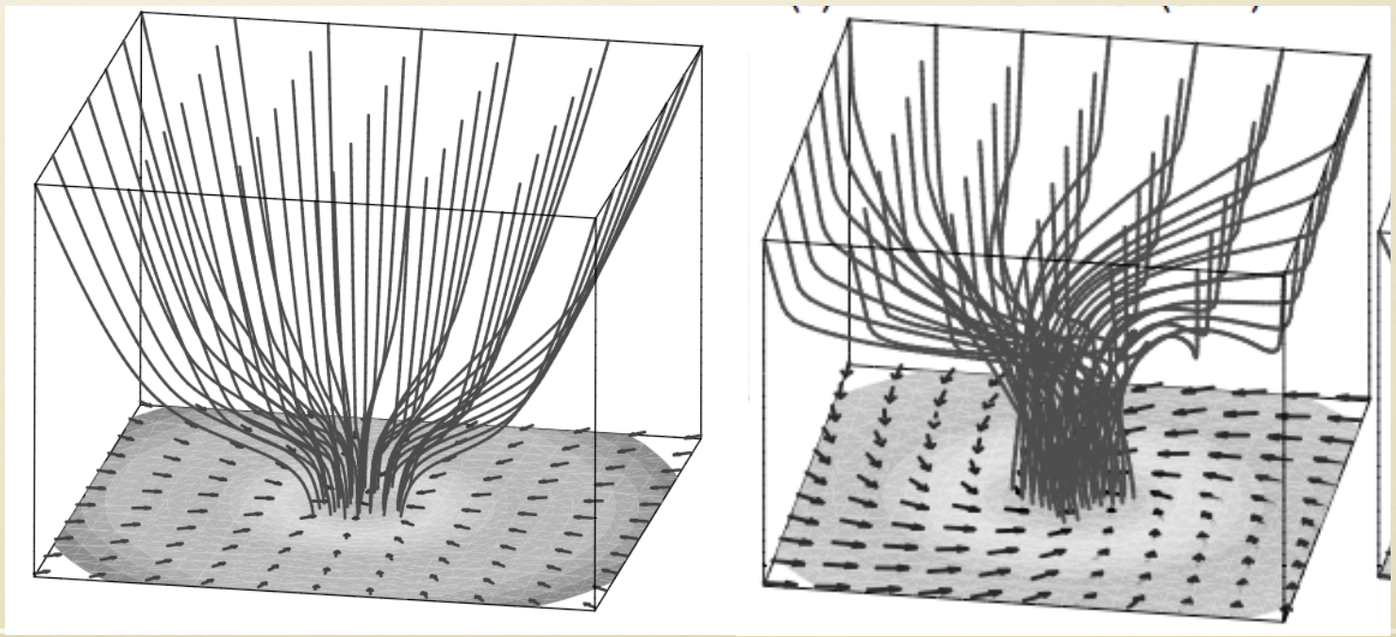
# The Star Formation Sequence for Low Mass Stars

Palau et al. 2012, "The Earth at the Universe", Catalan Encyclopedia

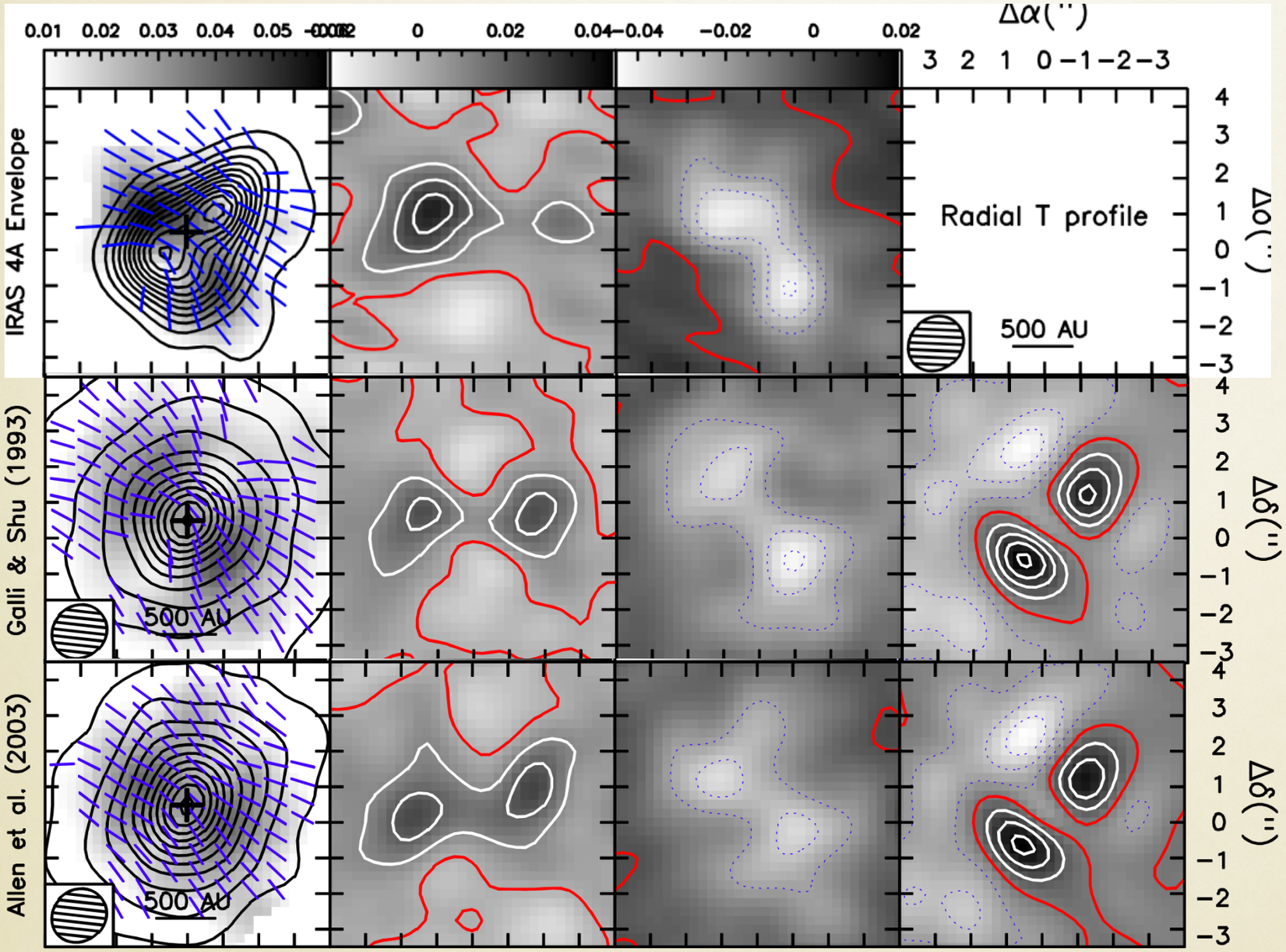


Pre-stellar → Class 0 → Class I → Class 2 → Pre-MS



# Protostellar phase: NGC 1333 IRASA, an "textbook" case?




• Galli Shu 1993. **Collapse of a singular isothermal sphere threaded by an initially uniform magnetic field**.

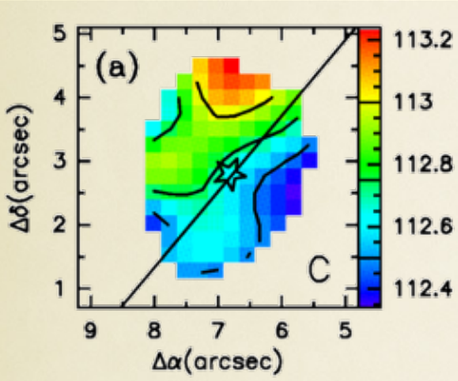
• Allen al 2003. Similar to Galli & Shu 1993 but numerical, taking into account rotation. Initially core already flattened

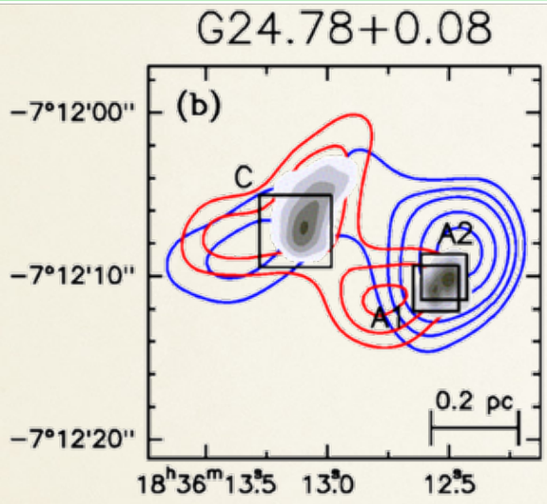
• $B_0$ = 0.4-0.9 mG

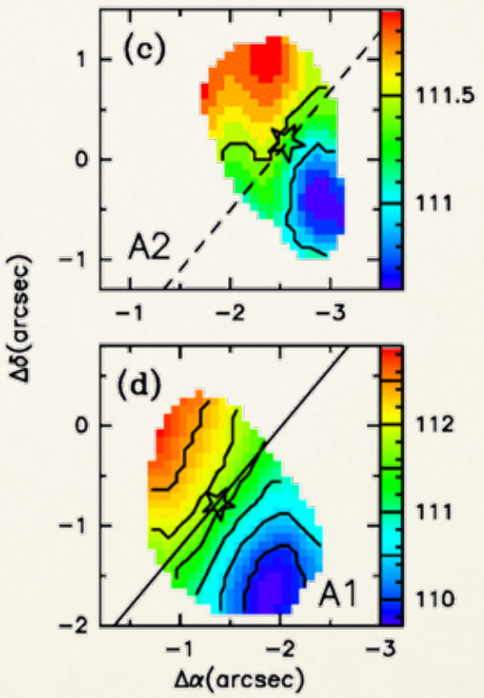
• $t$ = $10^4$ yr

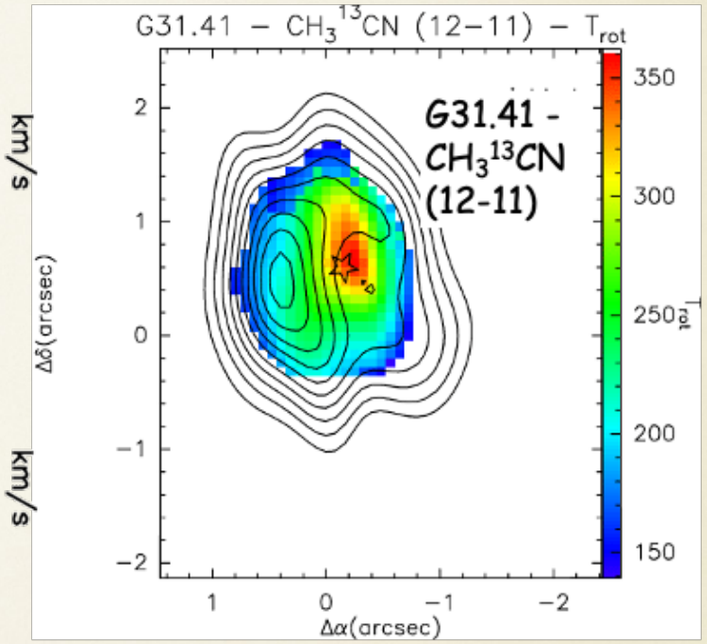
JMG, Rao & Marrone 2006, Sci; Frau, Galli, JMG 2011, A&A

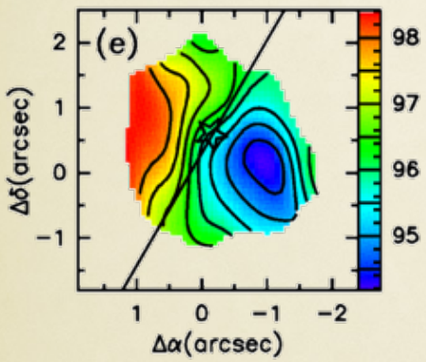
# Magnetic fields, rotation & infall towards G31.41+0.31

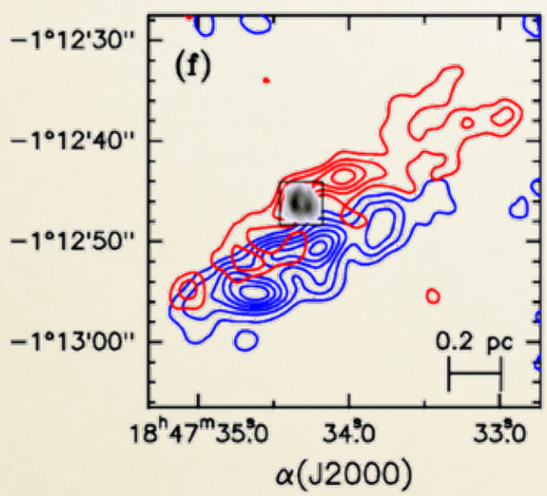


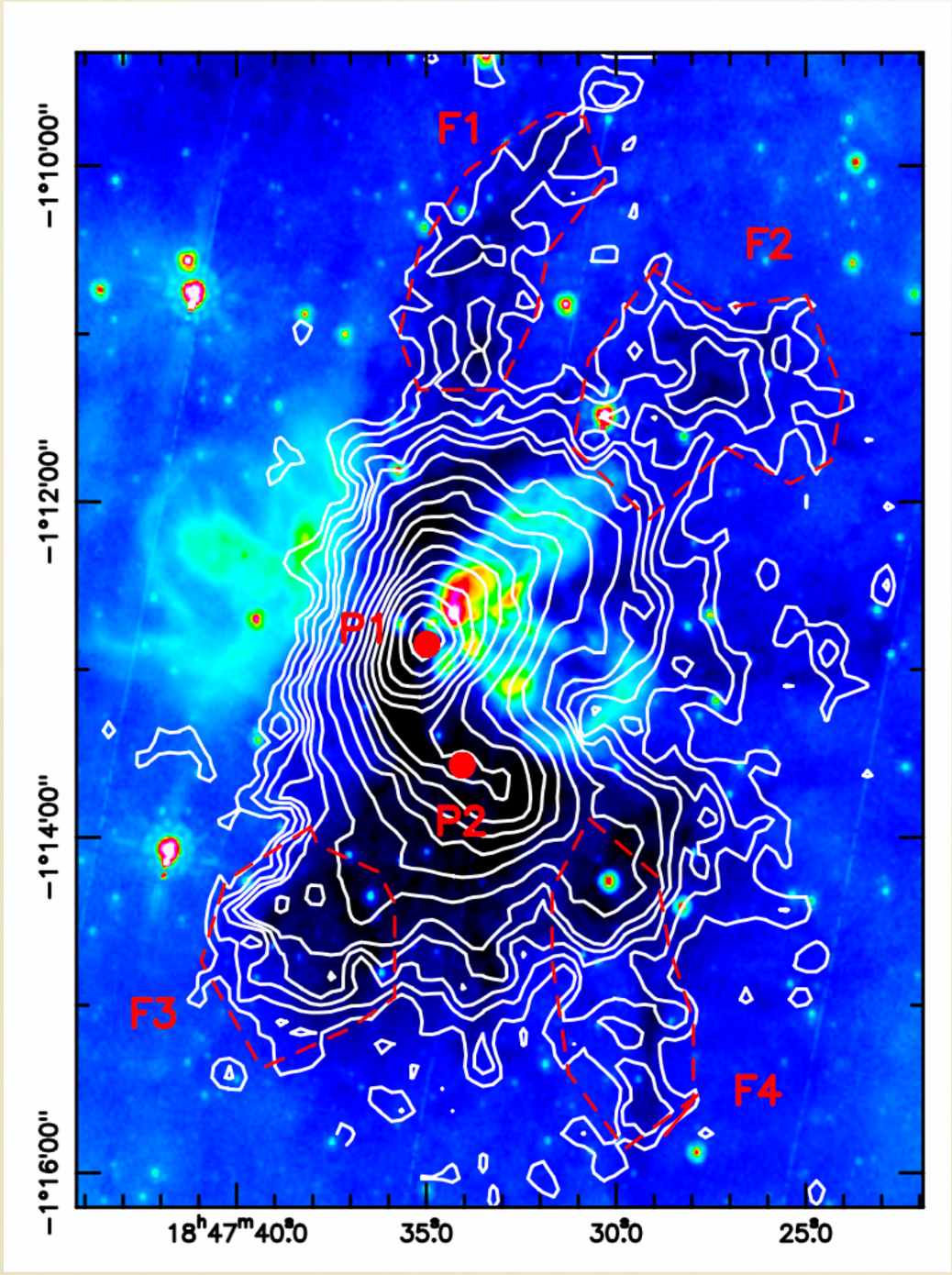



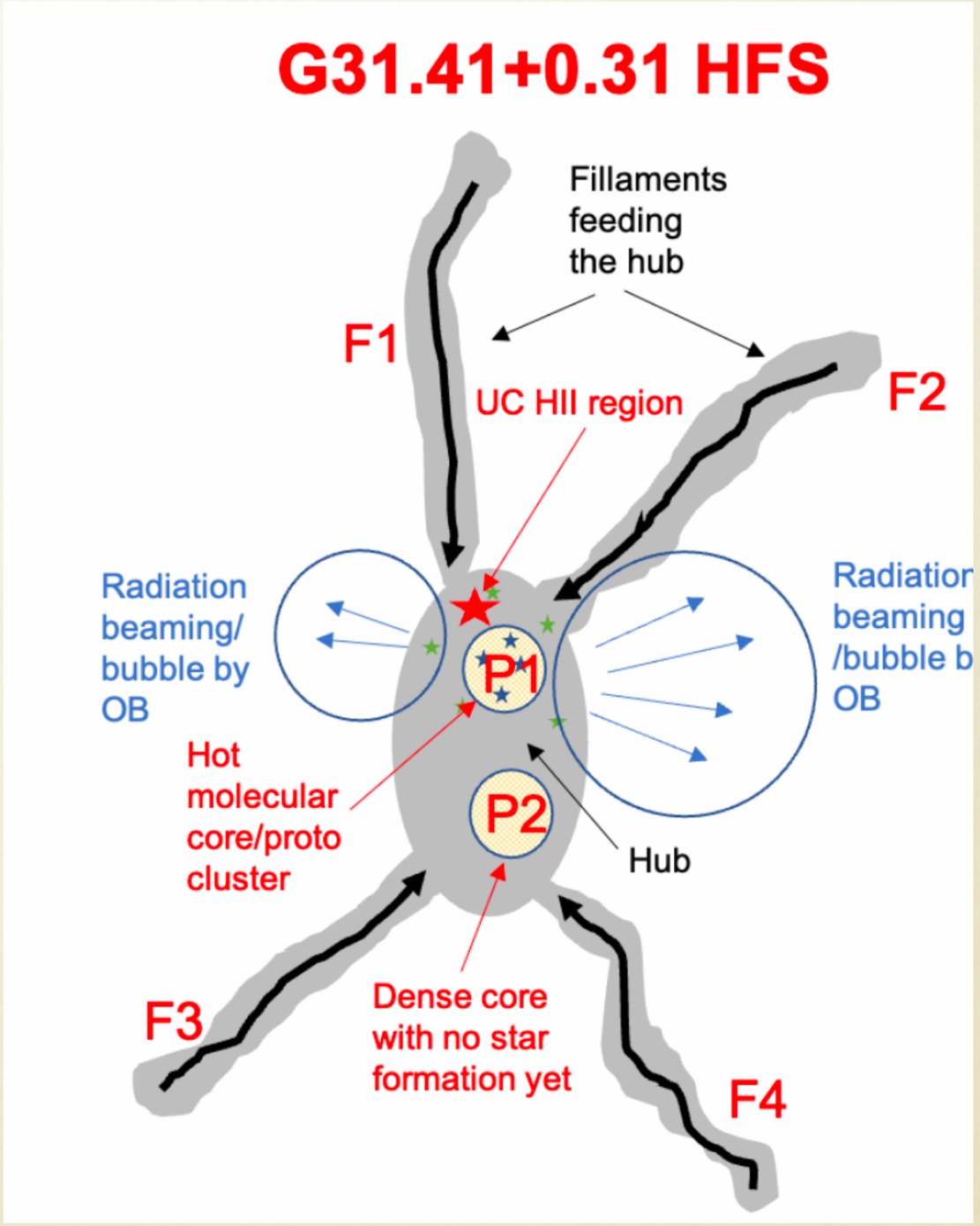




- G31.41 is a hot core (without UCHII) at a distance of **3.75 kpc**
- G31.41 luminosity, **5 $10^4$ $L_\odot$**, suggests that it harbors O7-O8 protostars
- Beltrán et al. 2004 detected a massive, dense and hot rotating “toroid”
- The presence of a bipolar molecular outflow is not well stablished

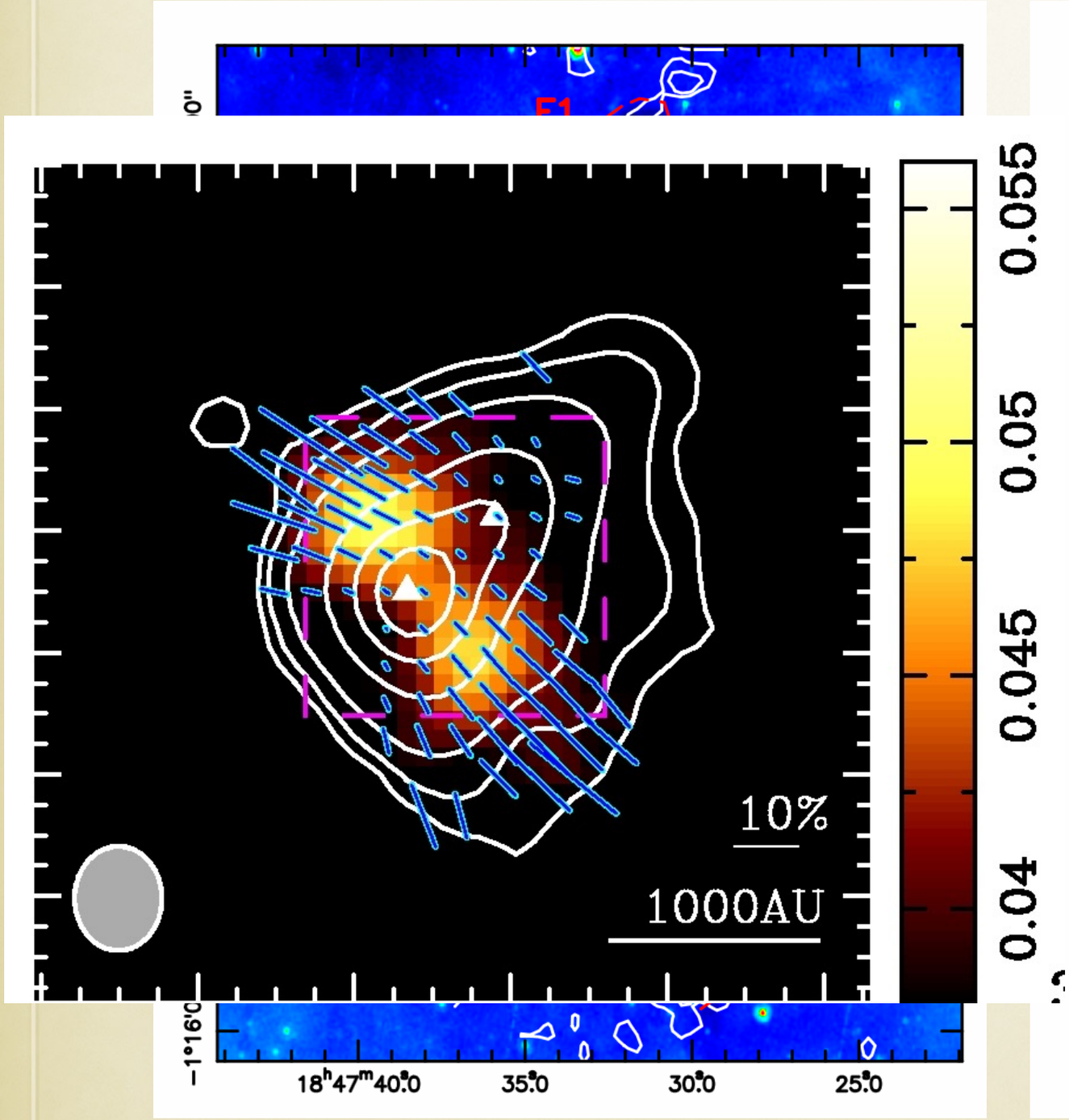
# G31.41- Filaments feading the beast



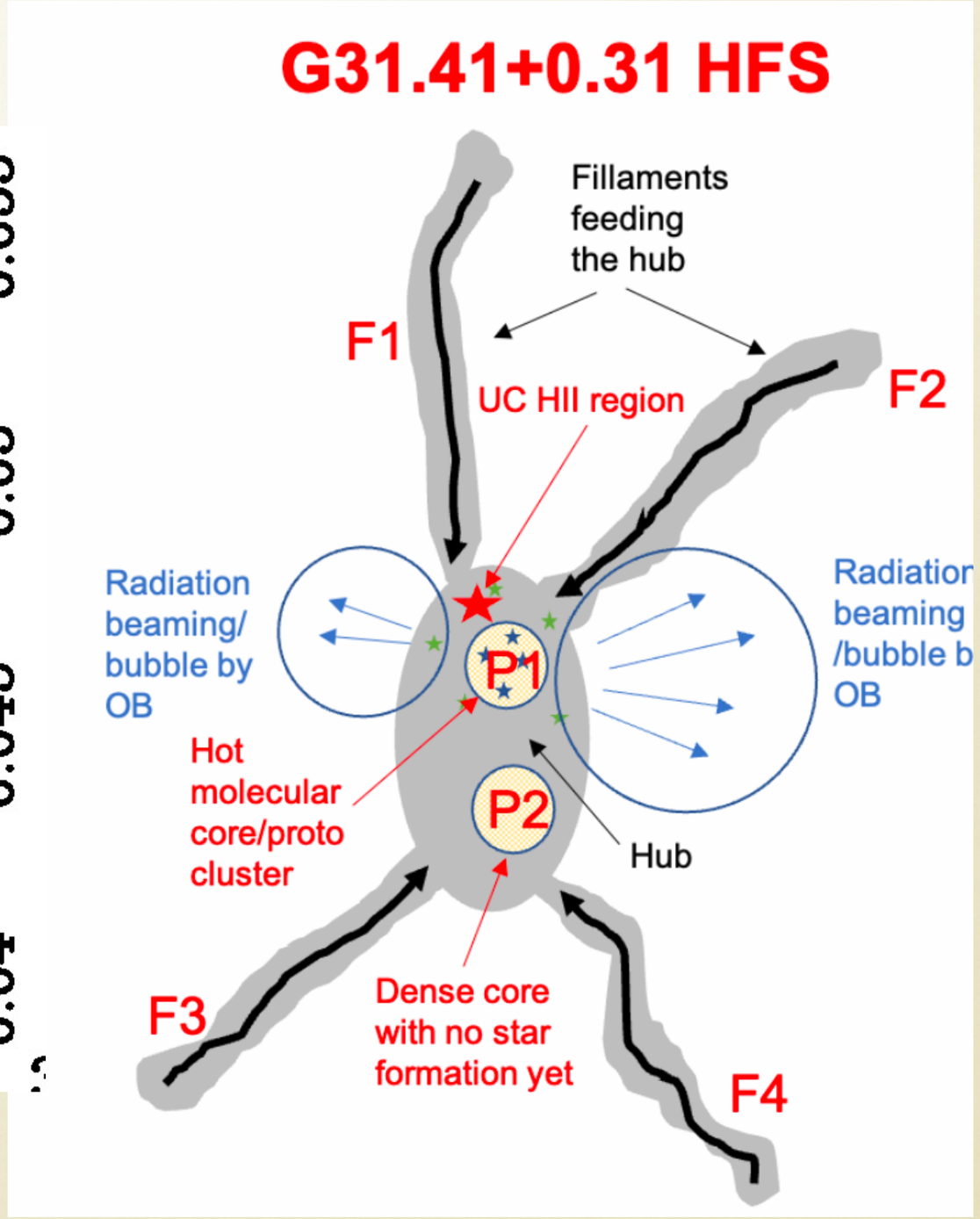




Beltran et al. (incl RC) 2022, A&A

# G31.41- What about magnetic fields?

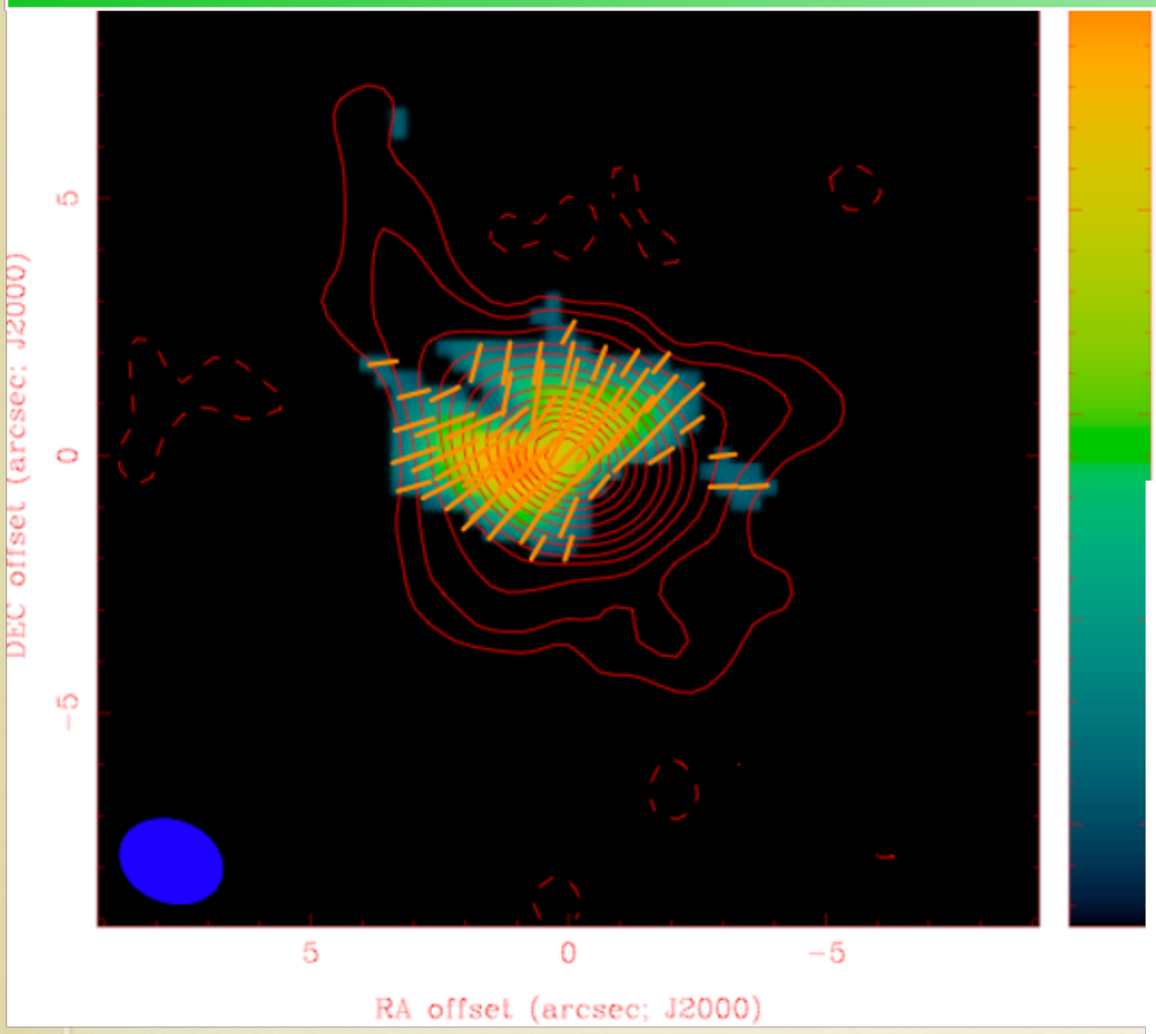



JMG, Rao & Marrone 2006, Sci

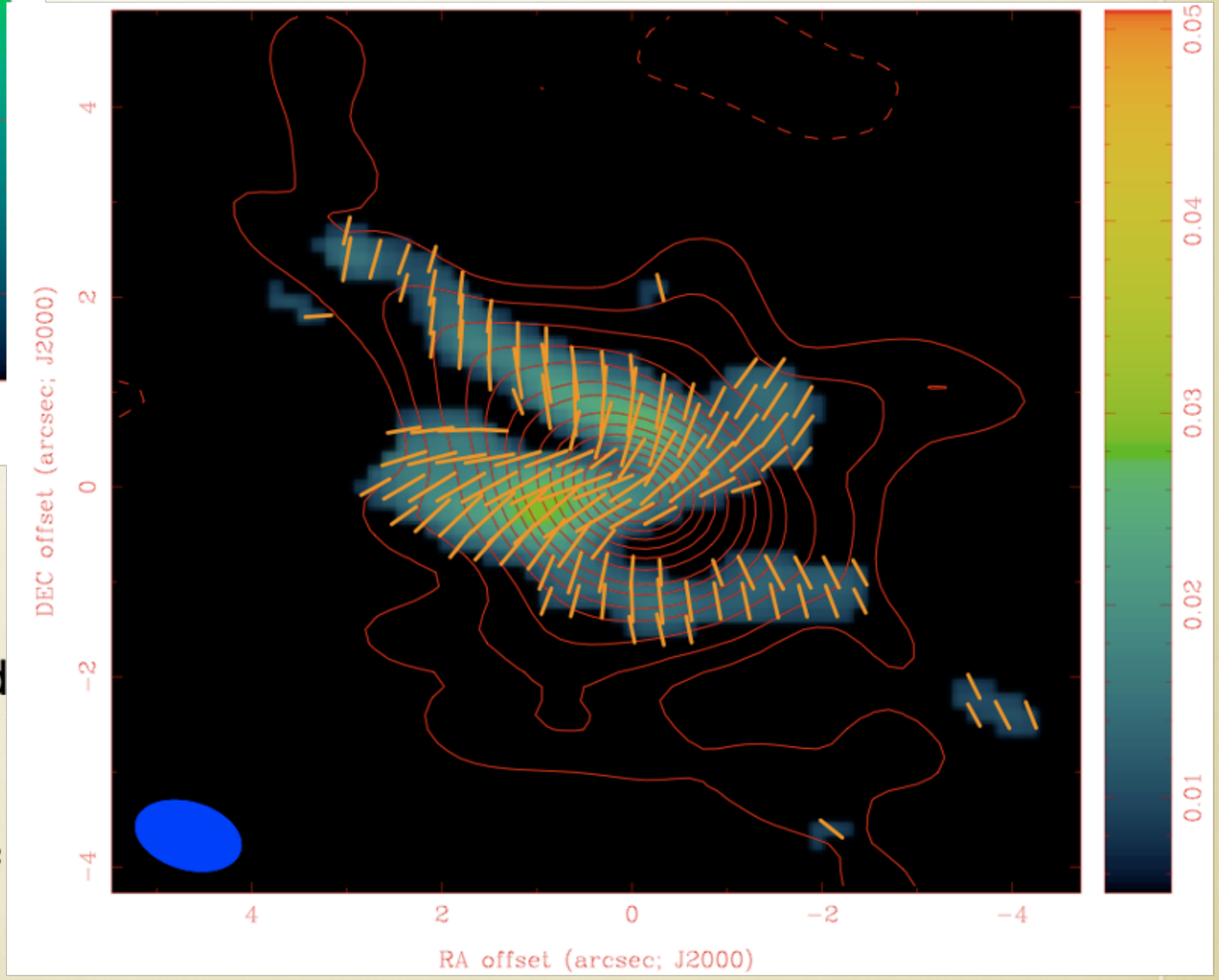



Beltran et al. (incl RC) 2022, A&A

# Magnetic fields towards G31.41+0.31




- Hot Core elongated in the NE-SW direction
- The gas mass associated with the dust core of $2\times10^4$ AU is $\mathbf{M_{core}\approx490M_{\odot}}$, and the volume density n(H2) $\approx4\times10^7$ cm$^{-3}$

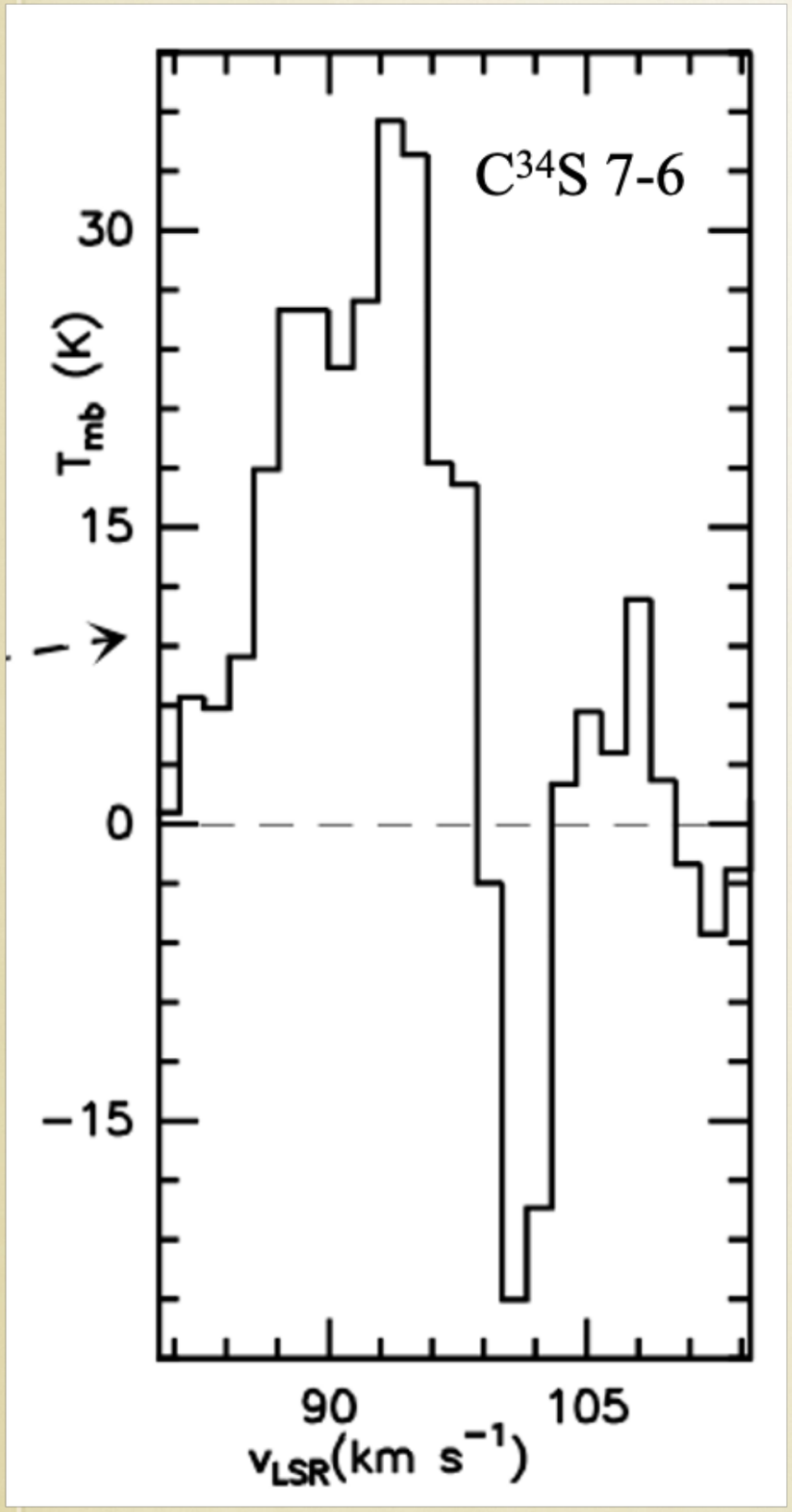


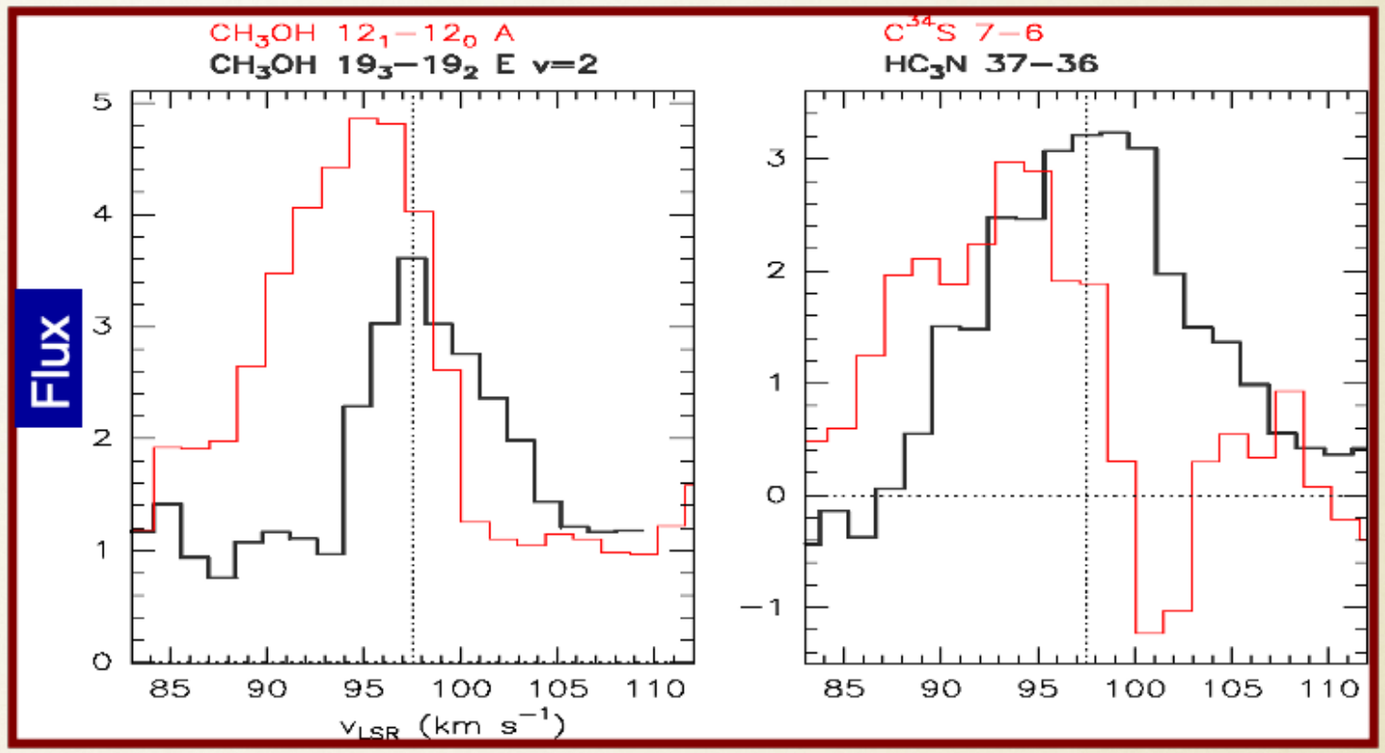

- The dust polarization patter suggests an **hourglass shape morphology**, similar to the one found in IRAS4A but the scale and mass involved are much larger

- B lines perpendicular to the major axis of the hot core

JMG et al. (incl RC) 2009, Sci

# Infall towards G31.41+0.31.



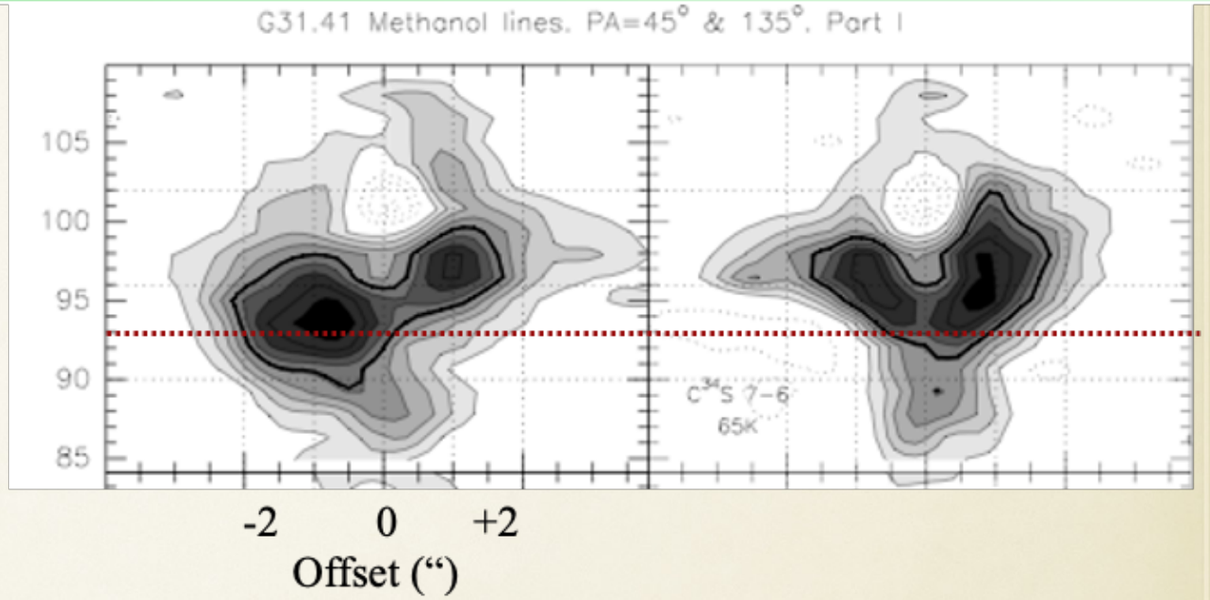

JMG et al. (incl RC) 2009, Sci

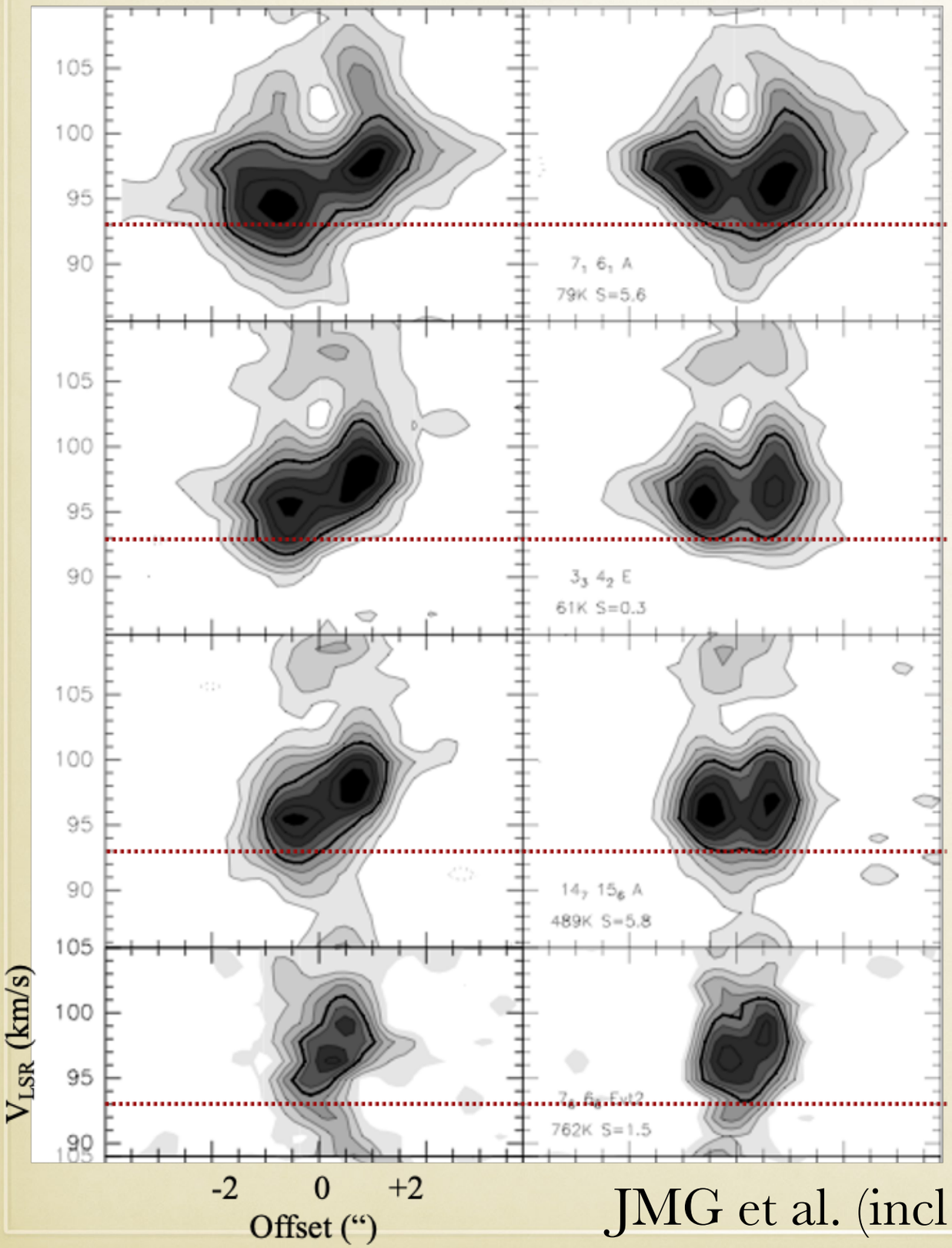
• There is a clear inverse P-Cygni in C34S 7-6 profile that suggests infalling gas.

• The signature is well seen in low energy transitions (<100K) and is probably due to a very hot compact dust component around the massive (proto)stars.

• Medium enery transitions also show partial redshifted absorption

# Rotation towards G31.41+0.31



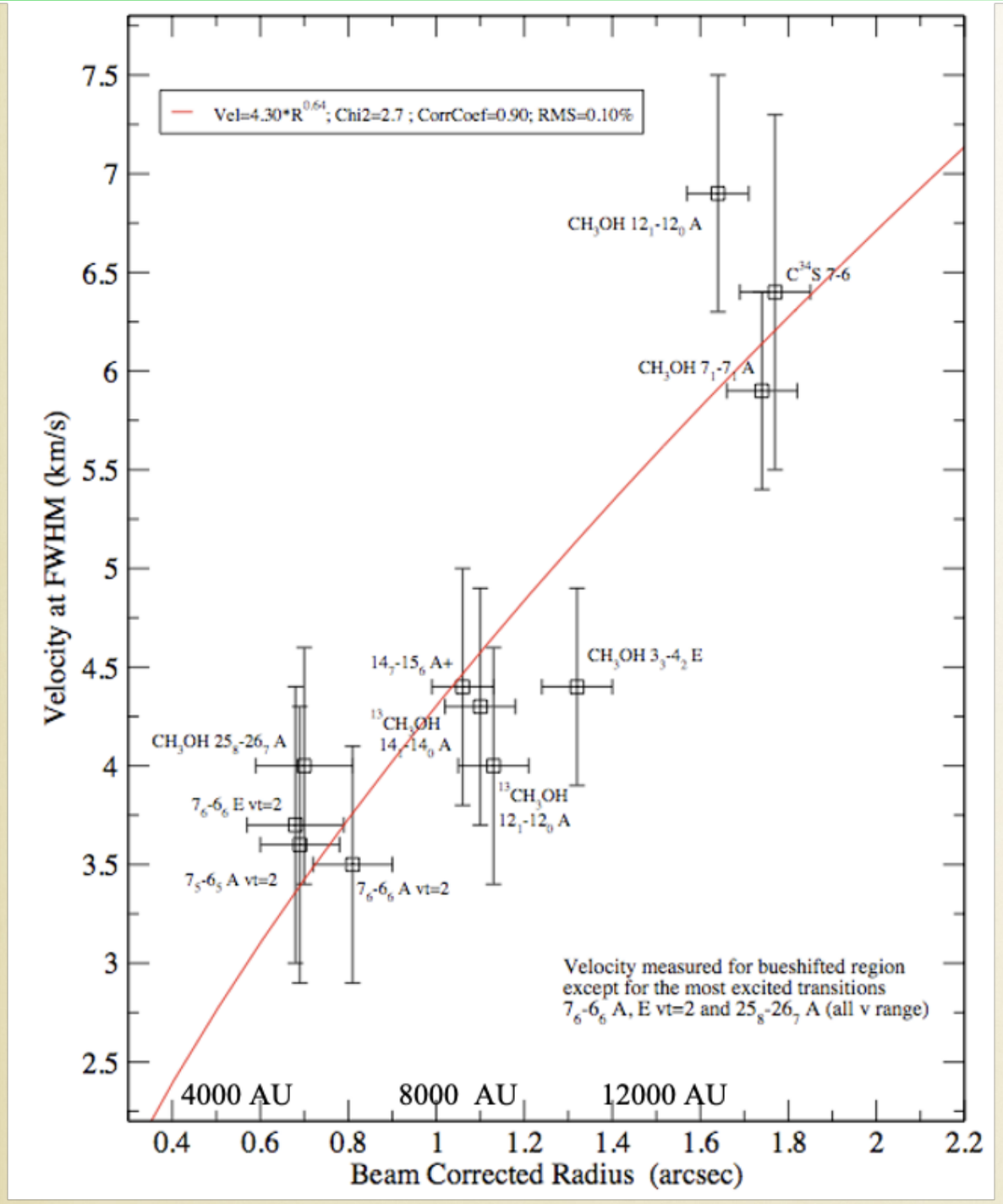

The position-velocity plots of the methanol lines along the major and minor axis show interesting features:

- A quasi inverse P Cygni profile is observed in some of the lowest energy transitions of the methanol

- The more compact transitions show a shorther velocity range, that is a smaller rotation velocity

JMG et al. (incl RC) 2009, Sci

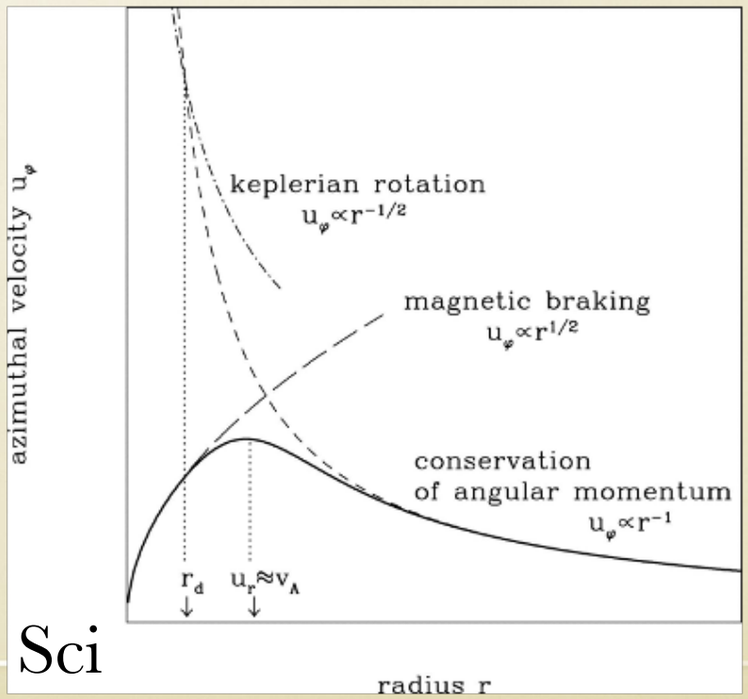
# Magnetic Braking towards G31.41+0.31 ?!




- "mean" rotation or spin velocity and radius has been measured from the Half Maximum contour of different methanol transitions in the P-V plots.

- The measured spin velocity of the hot core decreases with decreasing radius, a rough fit to the data shows that

- Therefore the angular momentum is not conserved: **Magnetic braking**

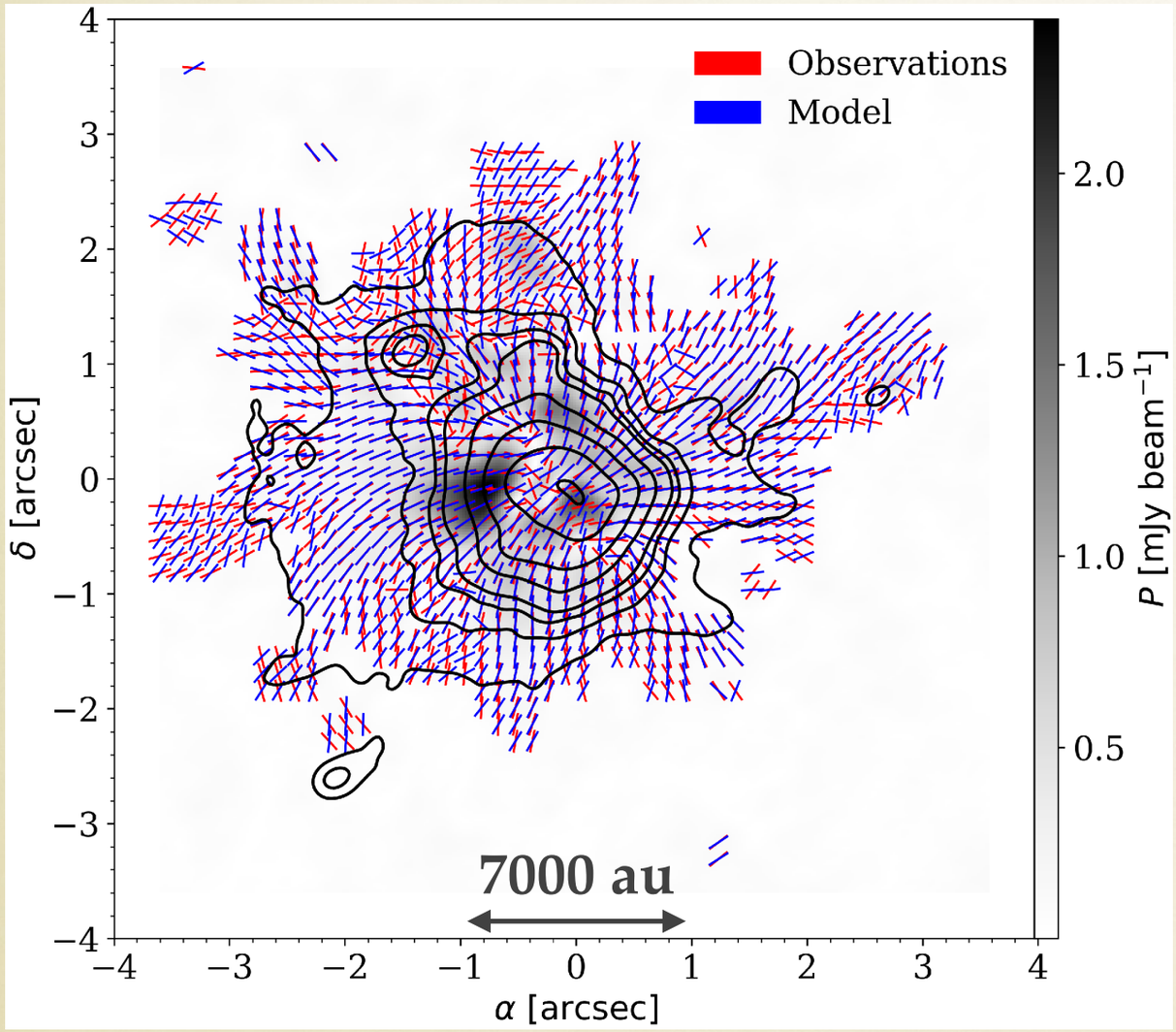


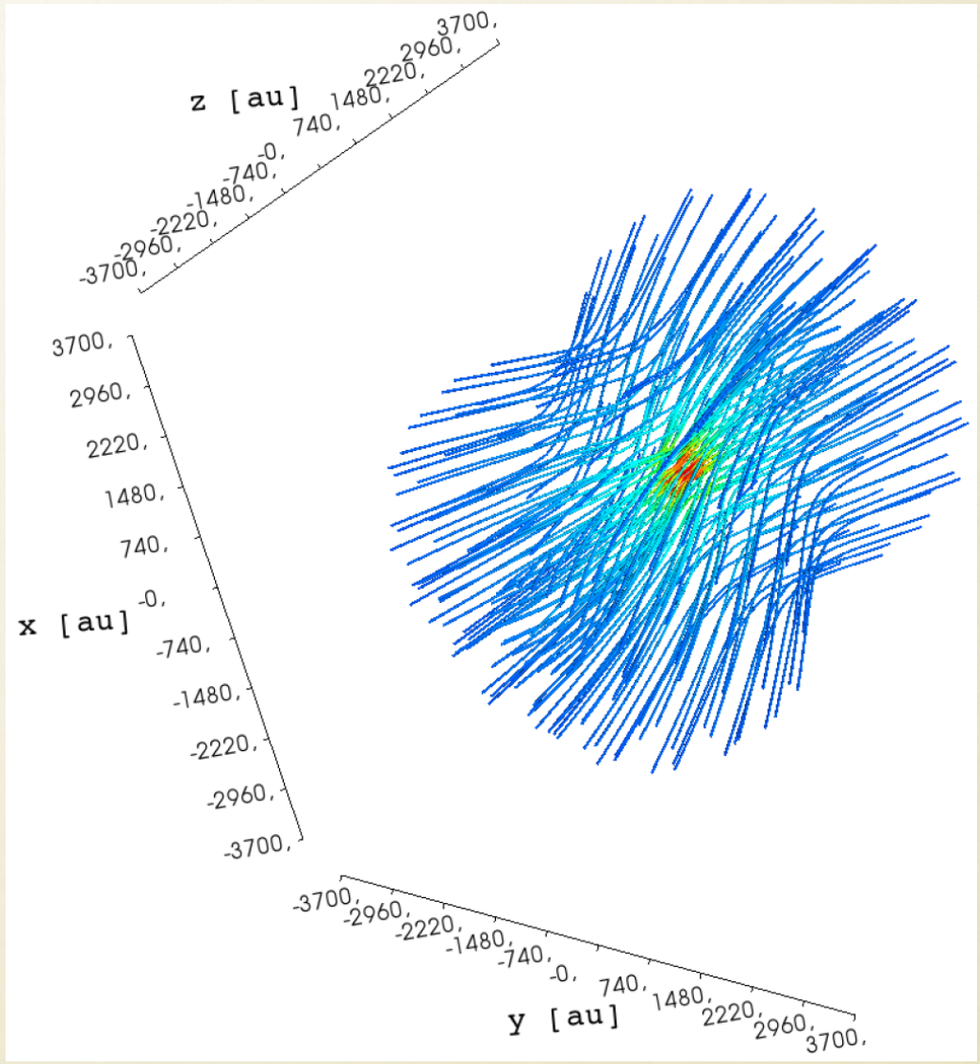

- Galli et al. 2006 predicts that when magnetic braking occurs then:

JMG et al. (incl RC) 2009, Sci

# G31.41- the ALMA

## G31: B field hourglass confirmed

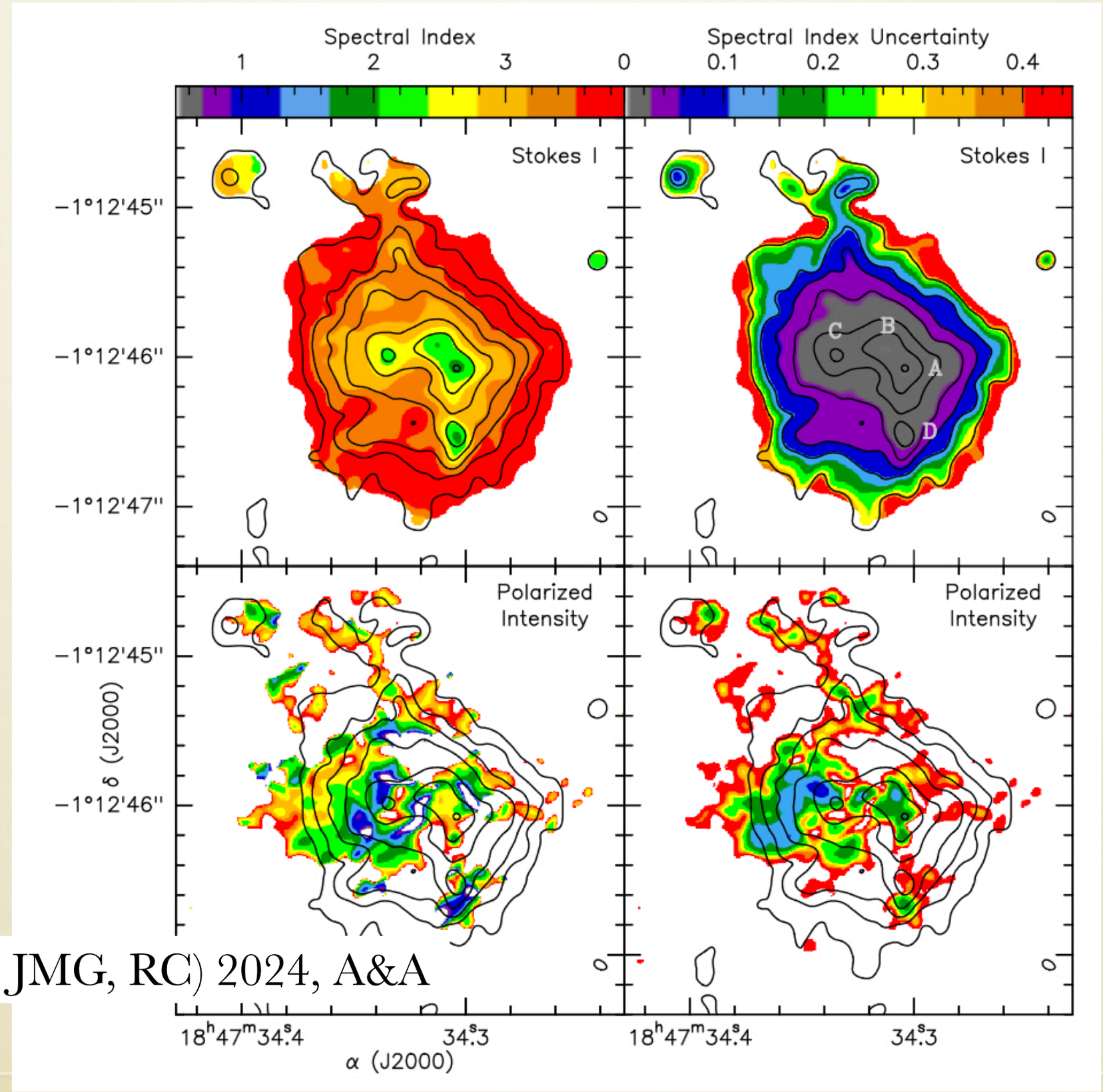



- B field of ~10 mG. Mass-to-flux ratio: **slightly supercritical**
- **Toroidal component** of the B field: **10% of the poloidal component**

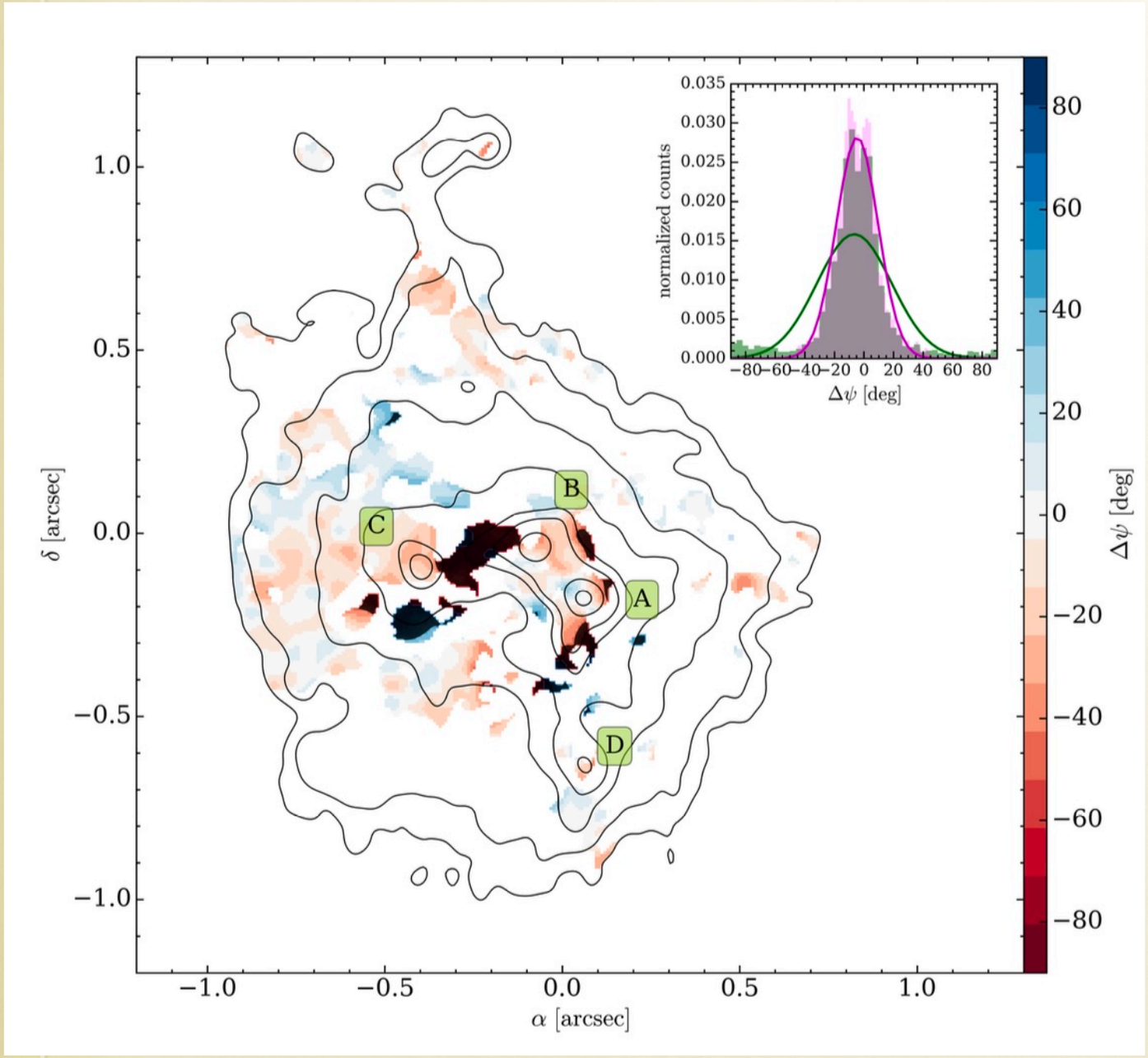
**Beltran et al. 2019, ApJ**

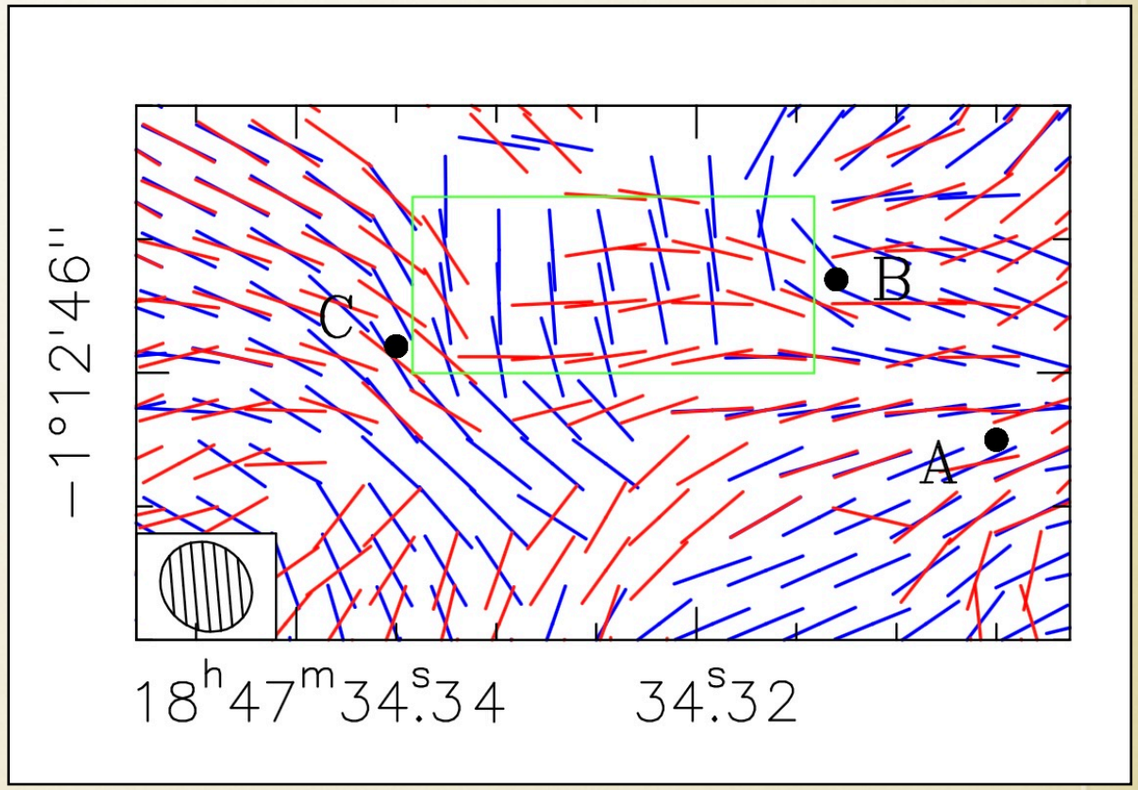
# G31.41- Polarization Spectral index




Beltran et al. (incl JMG, RC) 2024, A&A

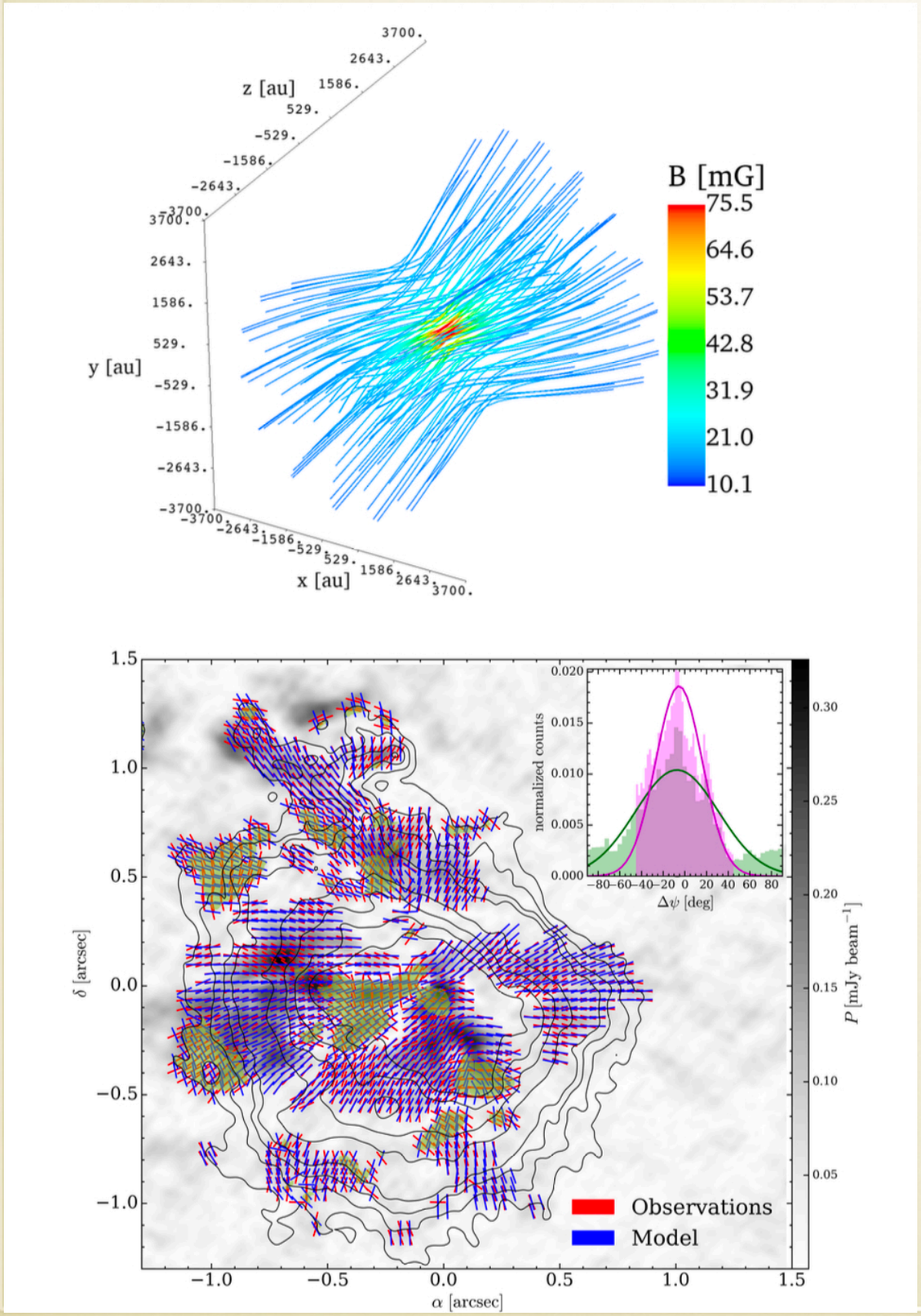
# G31.41- Angle difference between 3 and 1.3 mm

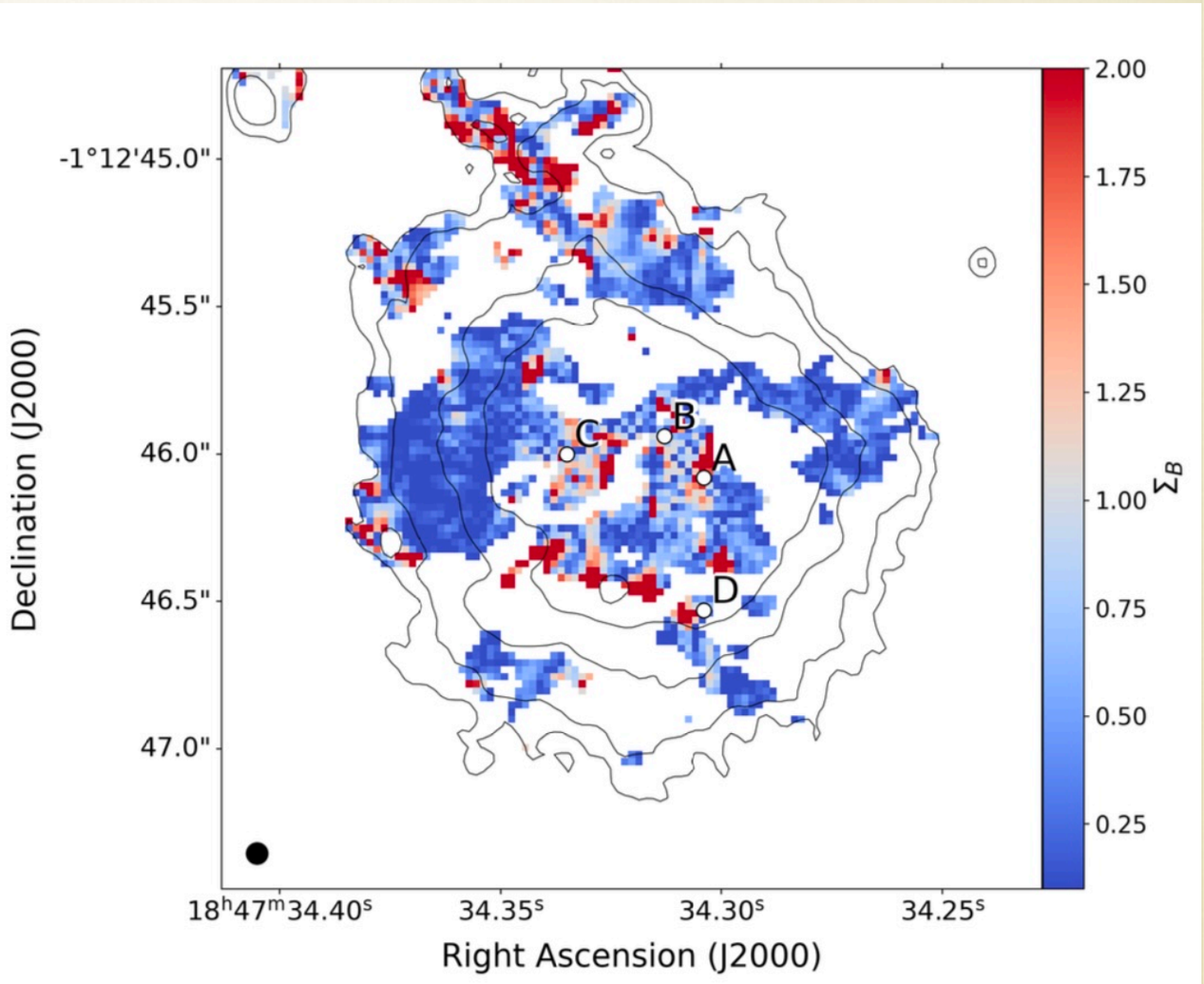



Beltran et al. (incl JMG, RC) 2024, A&A

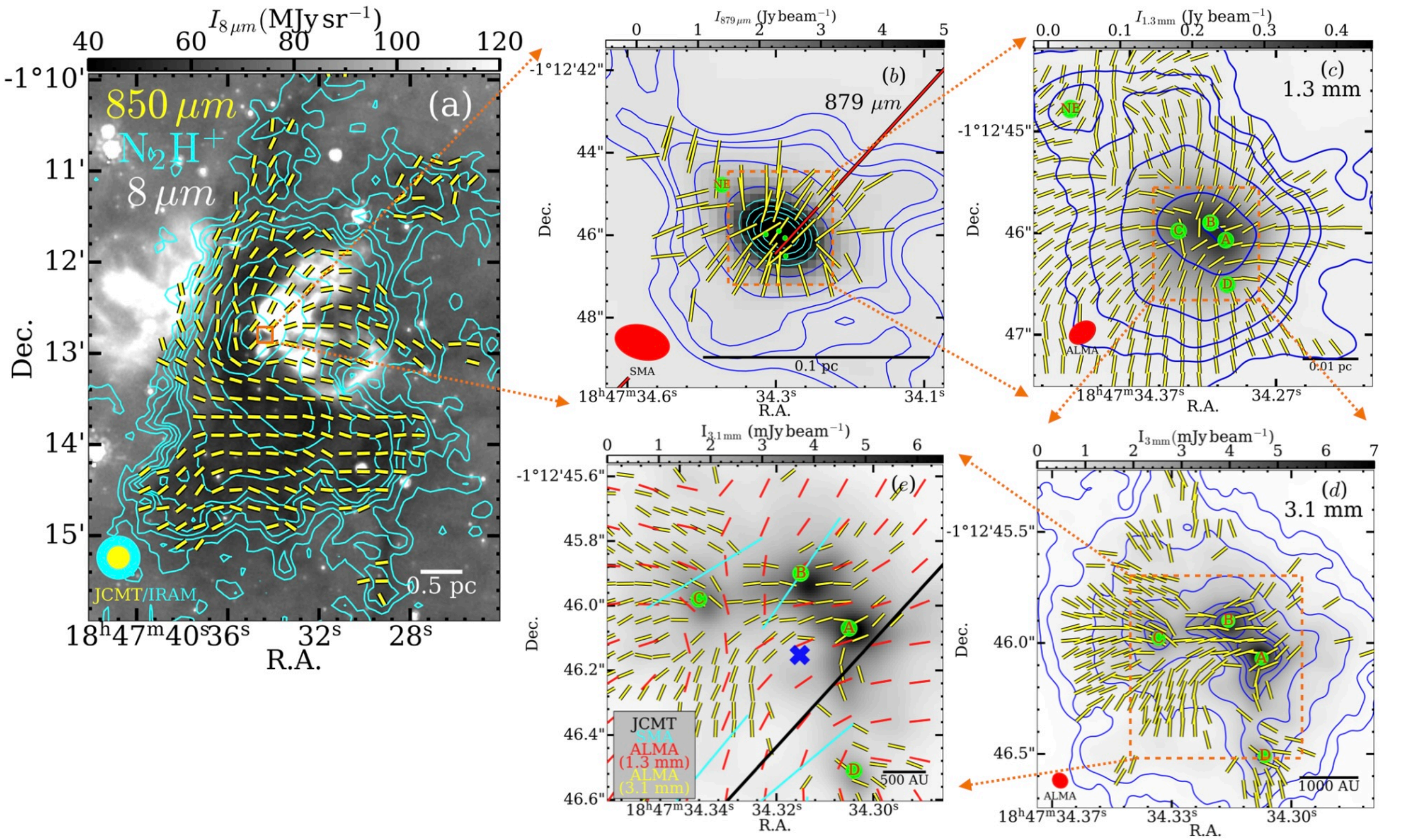
# G31.41- B field properties



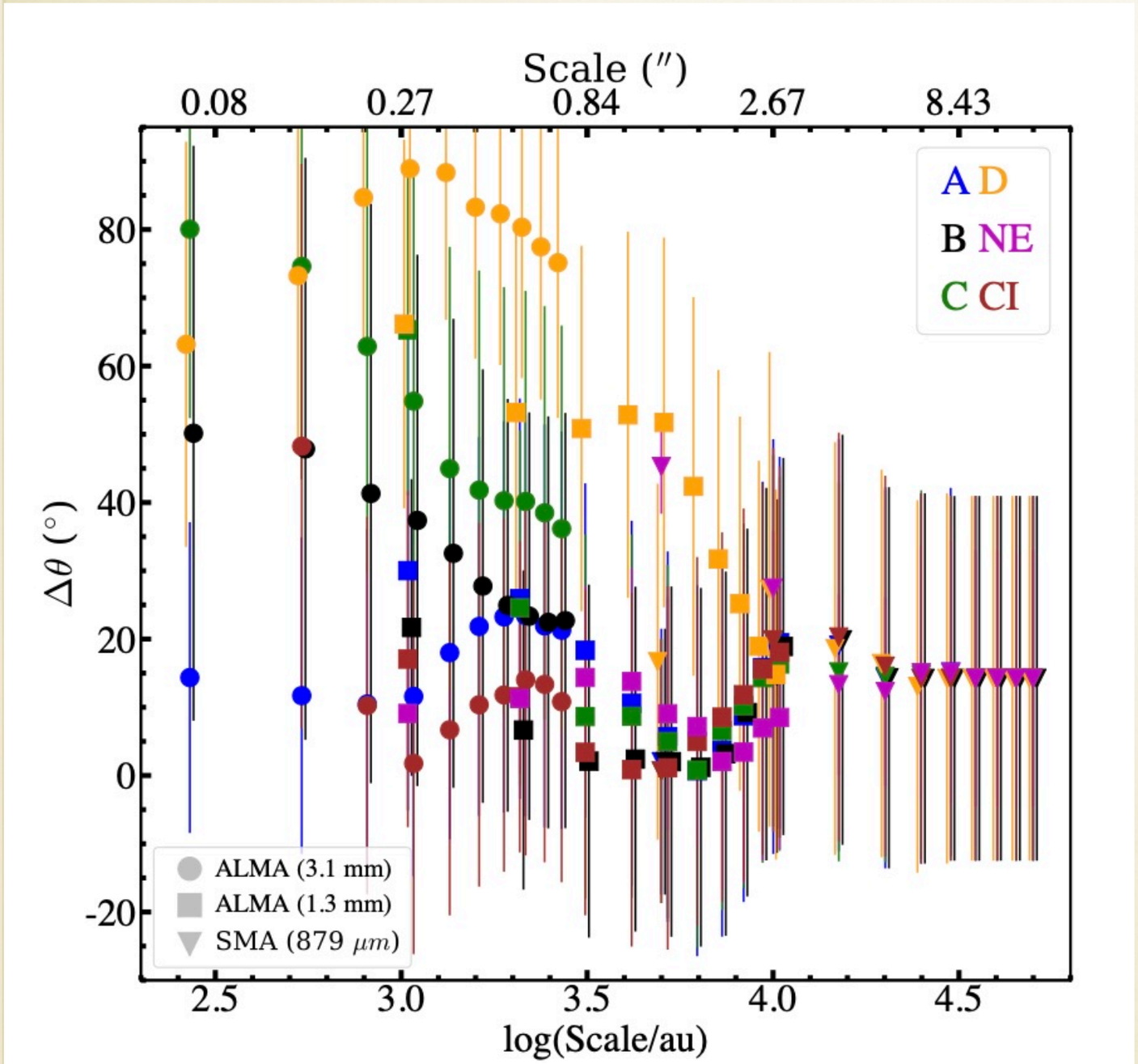

Beltran et al. (incl JMG, RC) 2024, A&A

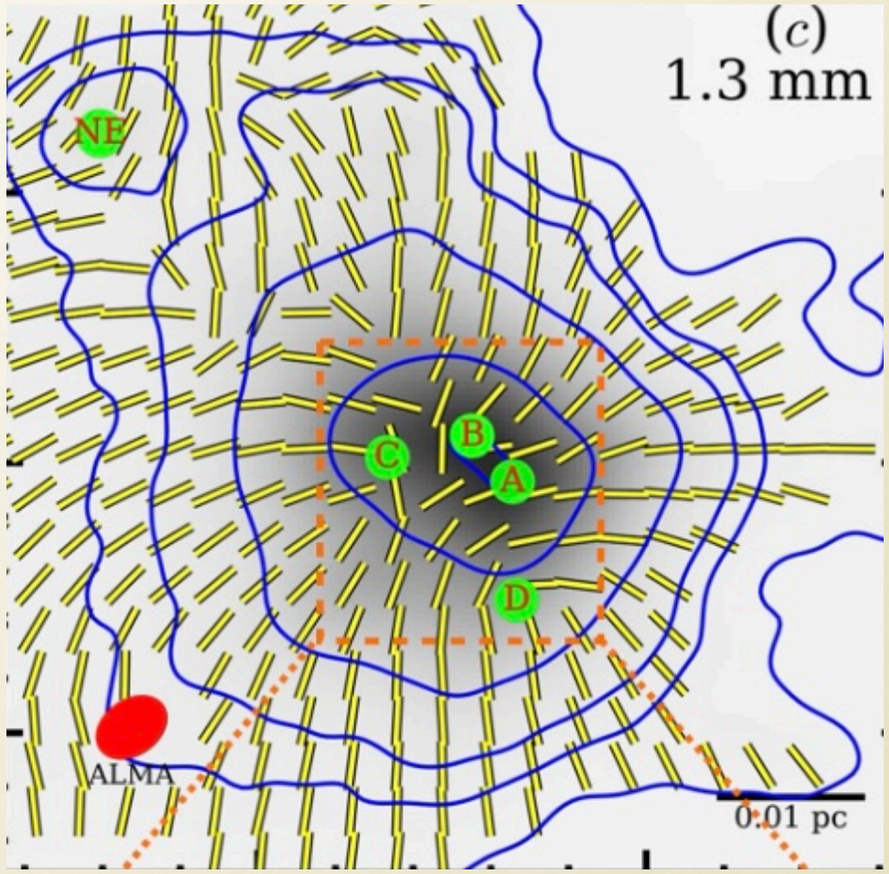
# G31.41- Multiscale comparison




Law et al. (incl JMG, RC) 2025, A&A

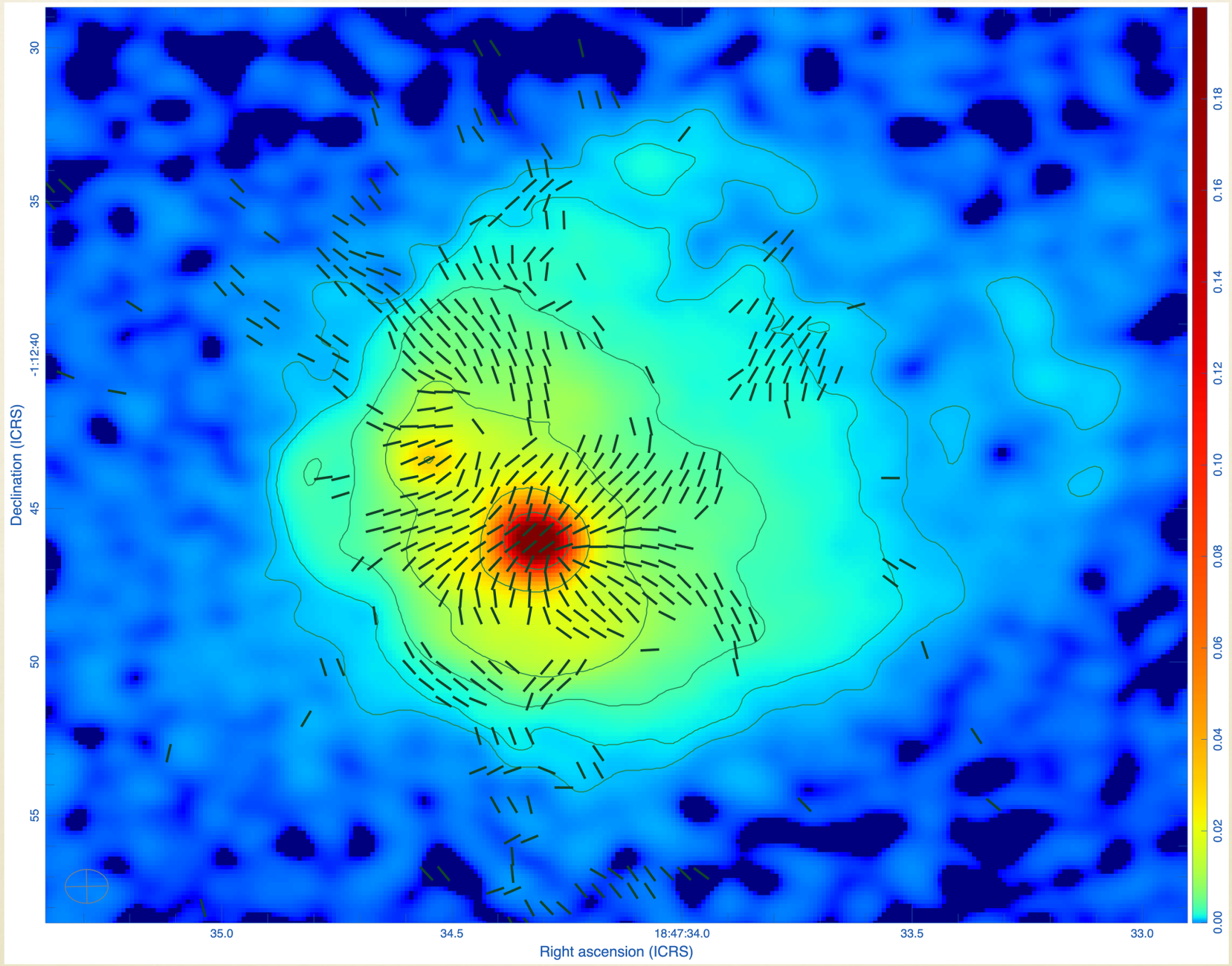
# G31.41- Multi scale B field




Law et al. (incl JMG, RC) 2025, A&A

# G31.41- What's next?




New ALMA 3mm data …

# G31.41 … what else?

G31.41 is an excellent target to better understand the role of magnetic fields:

- Magnetic fields regulates the collapse in this massive dense molecular core, in a "monolithic"-type of collapse
- Yet, there is moderate levels of fragmentation at scales
- Is non-isotropic accretion (through filaments) the responsible of fragmentation?
- Be aware of having a polarized view … things may not be as you think