Total and Linearly Polarized Synchrotron Emission from Overpressured Magnetized Relativistic Jets

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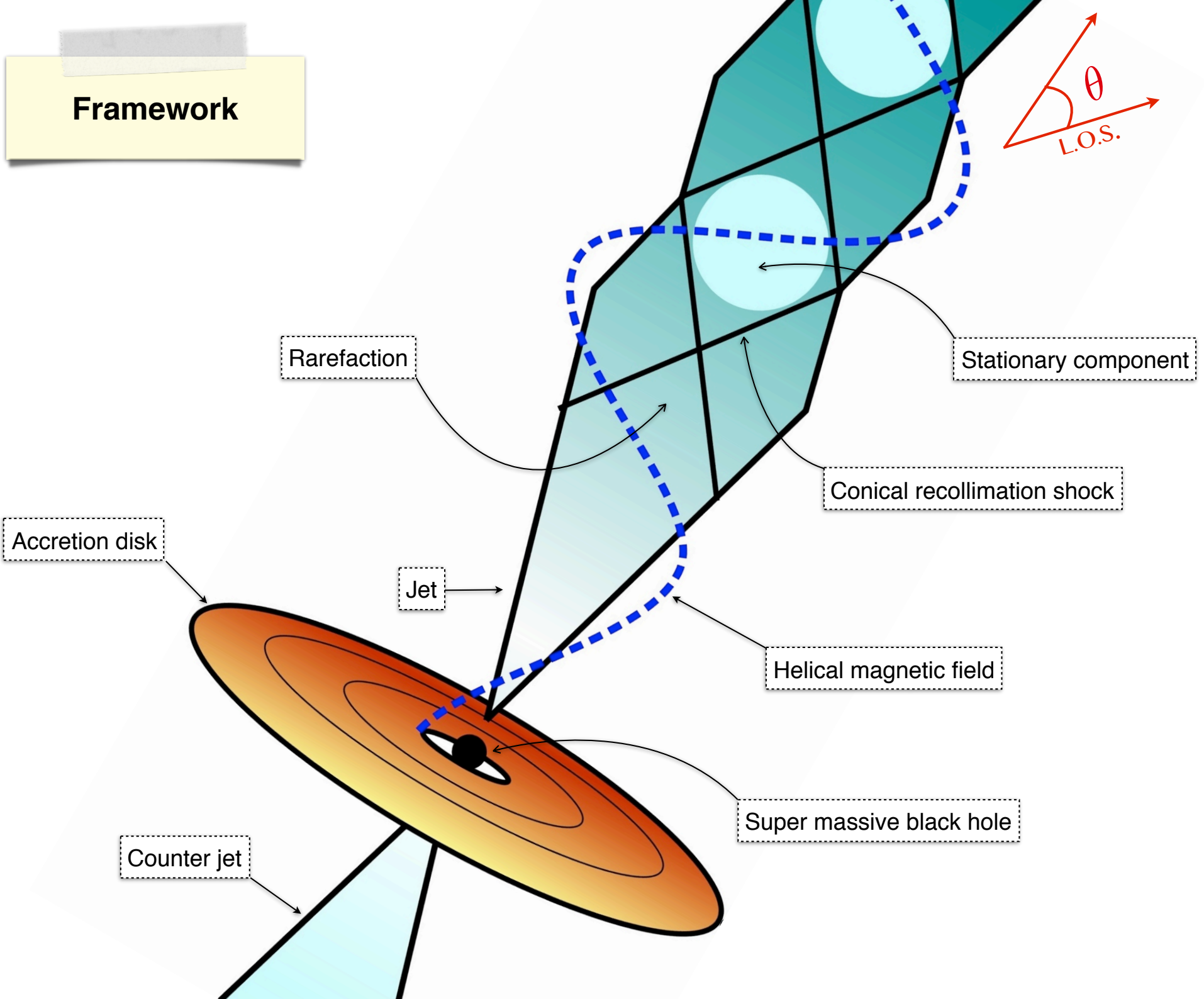
Based on
Fuentes et al. 2018, ApJ, in press

Framework


θ
L.O.S.
Rarefaction
Stationary component
Conical recollimation shock
Accretion disk
Jet
Helical magnetic field
Super massive black hole
Counter jet

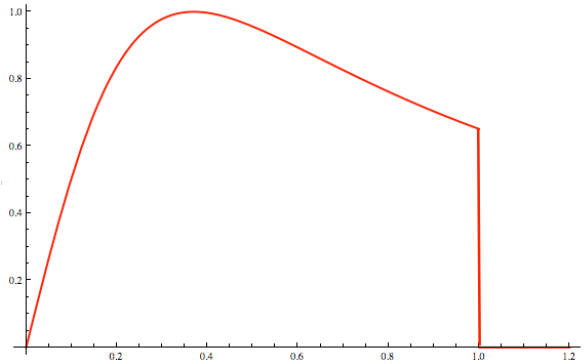
RMHD (I): Code characteristics

Solves the **(ideal) relativistic magneto-hydrodynamics equations** in conservation form for an **ideal gas equation of state**. **2.5D axially symmetric** (cylindrical coordinates)

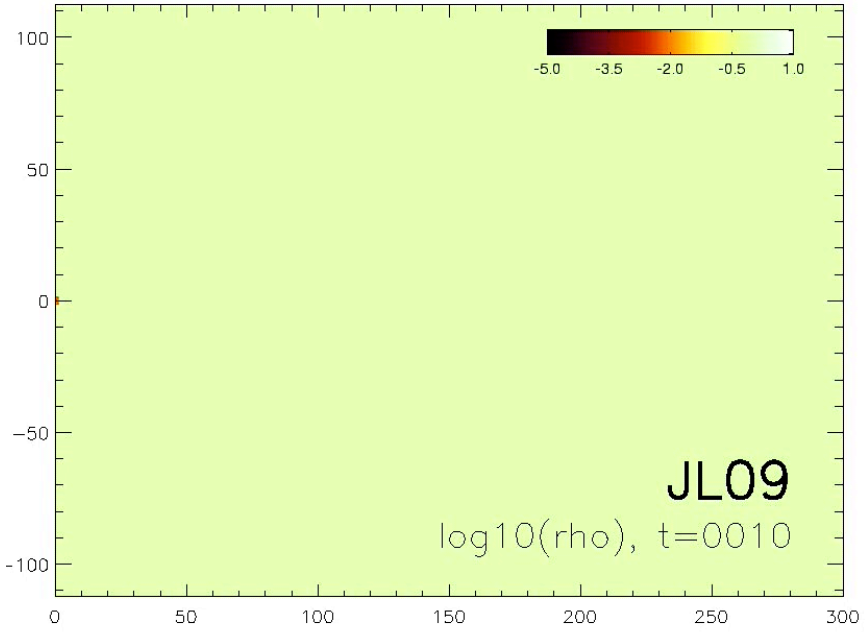
- Second-order
- Conservative
- Finite-volume
- High-resolution shock-capturing techniques: cell reconstruction, Riemann solvers, constrained transport scheme…

- **Top hat profiles** for: density, axial flow velocity and axial magnetic field
- **Toroidal component profile**:

$$B^{\phi}(r) = \begin{cases} \dfrac{2B^{\phi}_{j,\mathrm{m}}(r/R_{B^{\phi},\mathrm{m}})}{1+(r/R_{B^{\phi},\mathrm{m}})^2}, & 0 \leqslant r \leqslant 1 \\ 0, & r > 1. \end{cases}$$



Code and tests details: **Martí 2015a, 2015b**
Review on numerical RMHD: **Martí and Müller 2015**

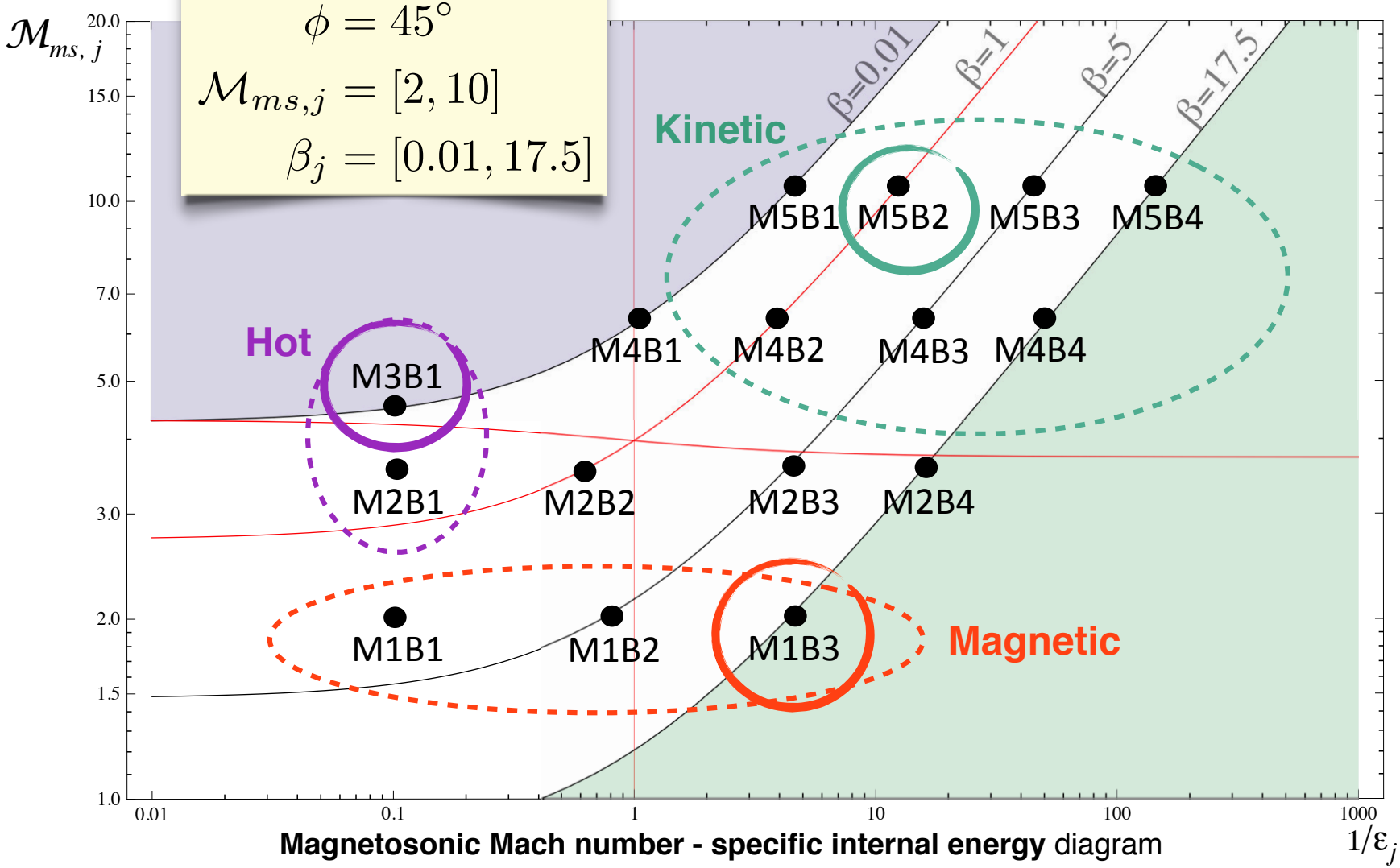


Quasi-one-dimensional approximation of the steady-state equations of RMHD (based on **Komissarov et al. 2015**)

RMHD (II): Parameter space

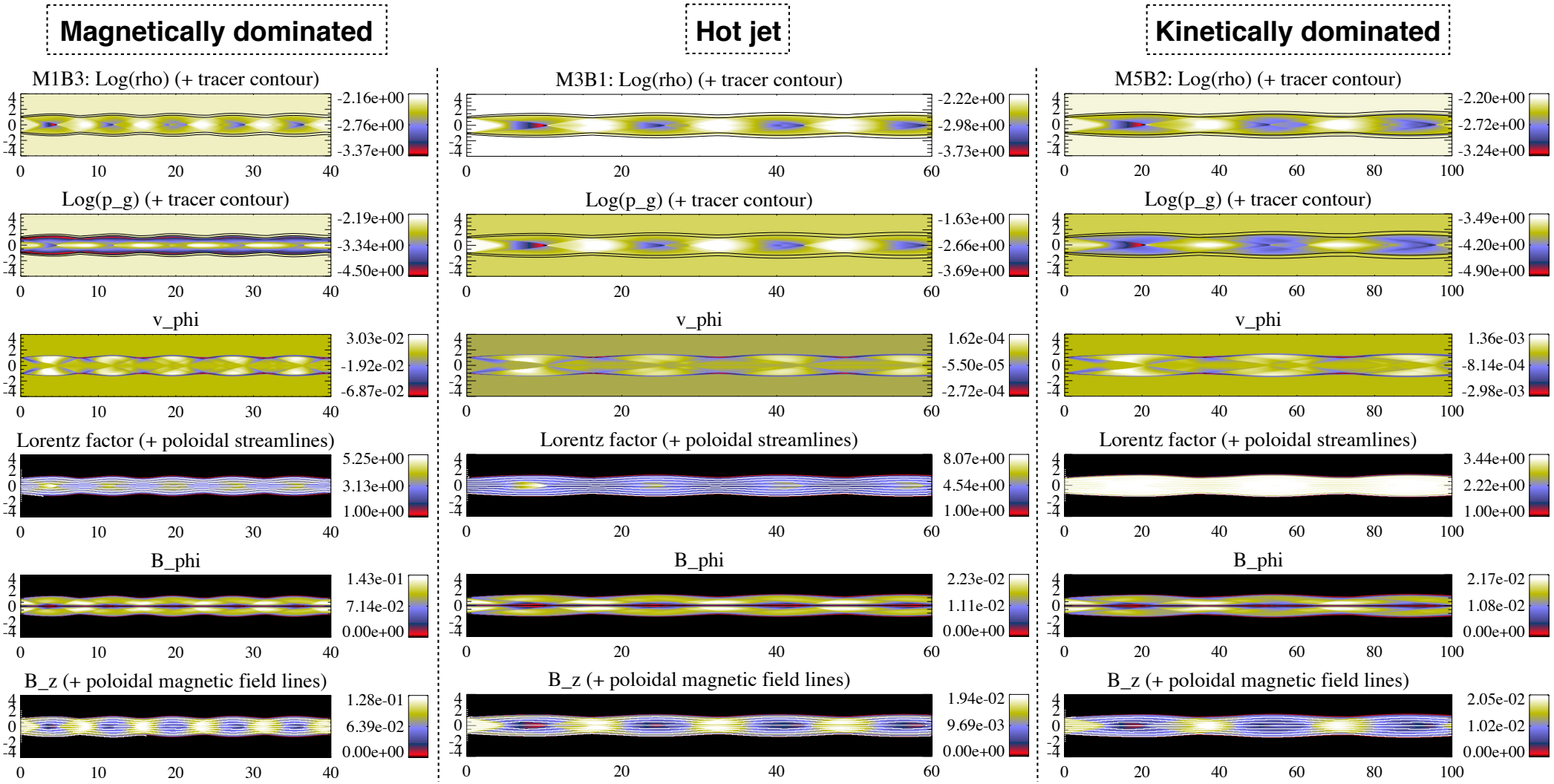
$$\rho_j = 0.005\rho_a$$
$$v_j = 0.95c$$
$$K = 2$$
$$\phi = 45°$$
$$\mathcal{M}_{ms,j} = [2, 10]$$
$$\beta_j = [0.01, 17.5]$$

Parameters characterizing the models



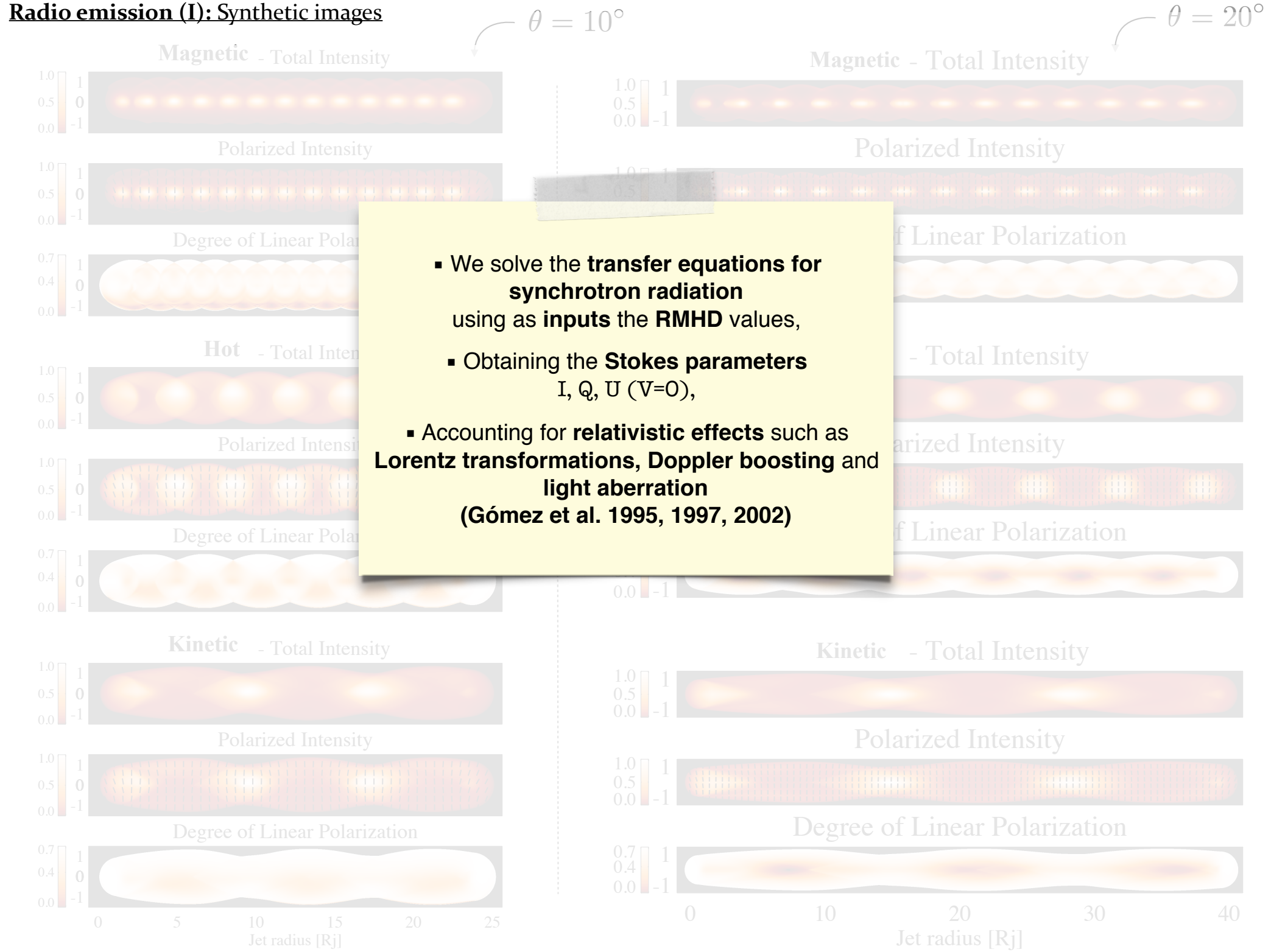
Magnetosonic Mach number - specific internal energy diagram

RMHD (III): Internal structure of the models



The overall **internal structure** is governed by the **Mach number**

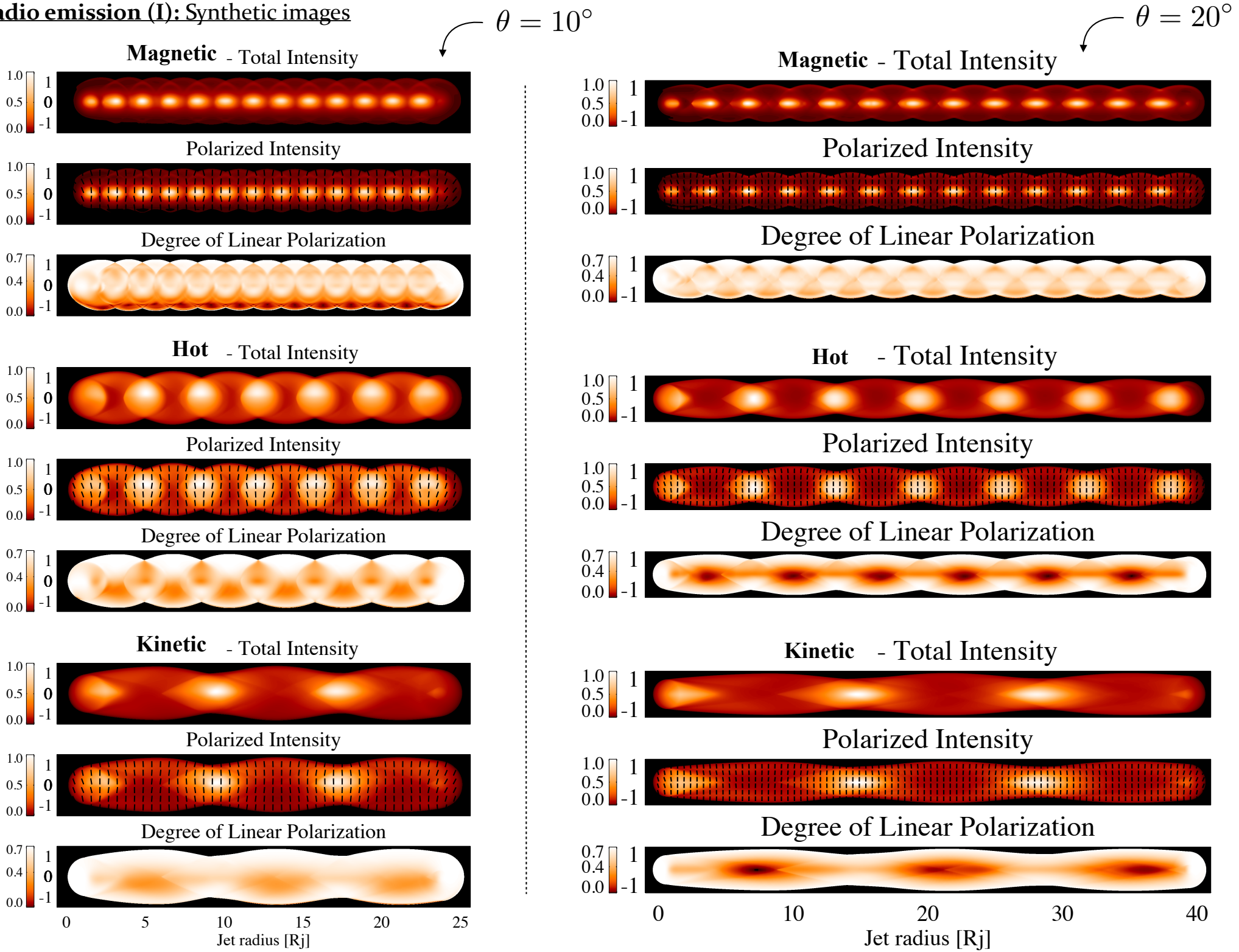
Radio emission (I): Synthetic images



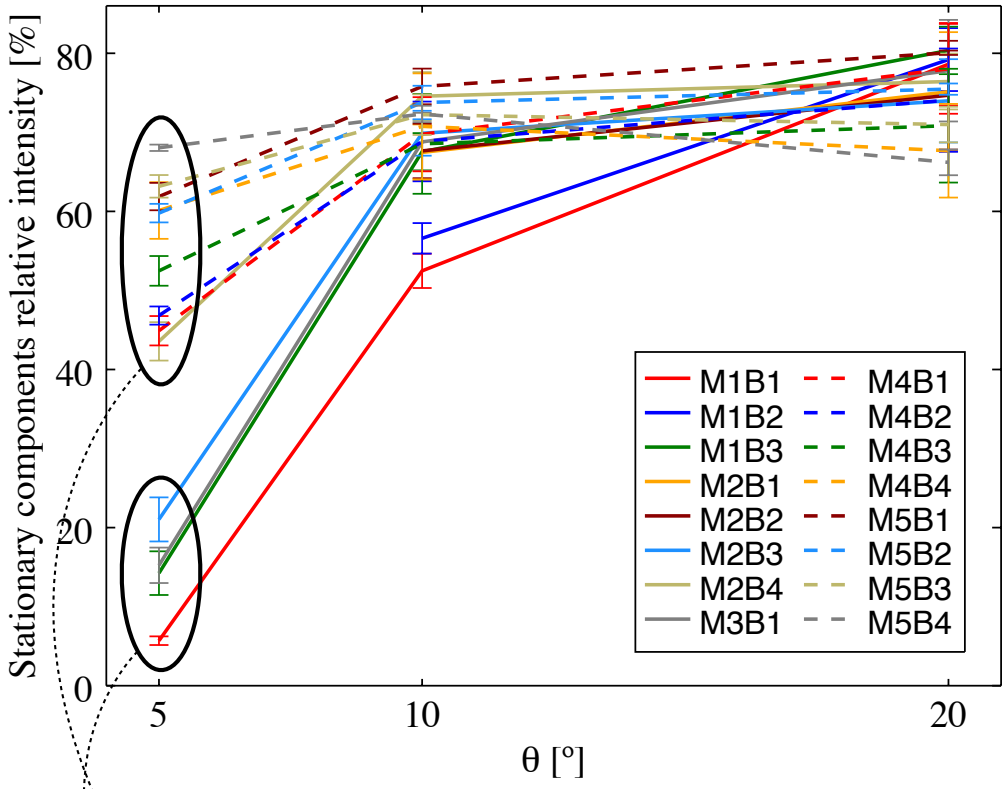
- We solve the **transfer equations for synchrotron radiation** using as **inputs** the **RMHD** values,
- Obtaining the **Stokes parameters** I, Q, U (V=0),
- Accounting for **relativistic effects** such as **Lorentz transformations, Doppler boosting** and **light aberration**

(Gómez et al. 1995, 1997, 2002)

Radio emission (I): Synthetic images



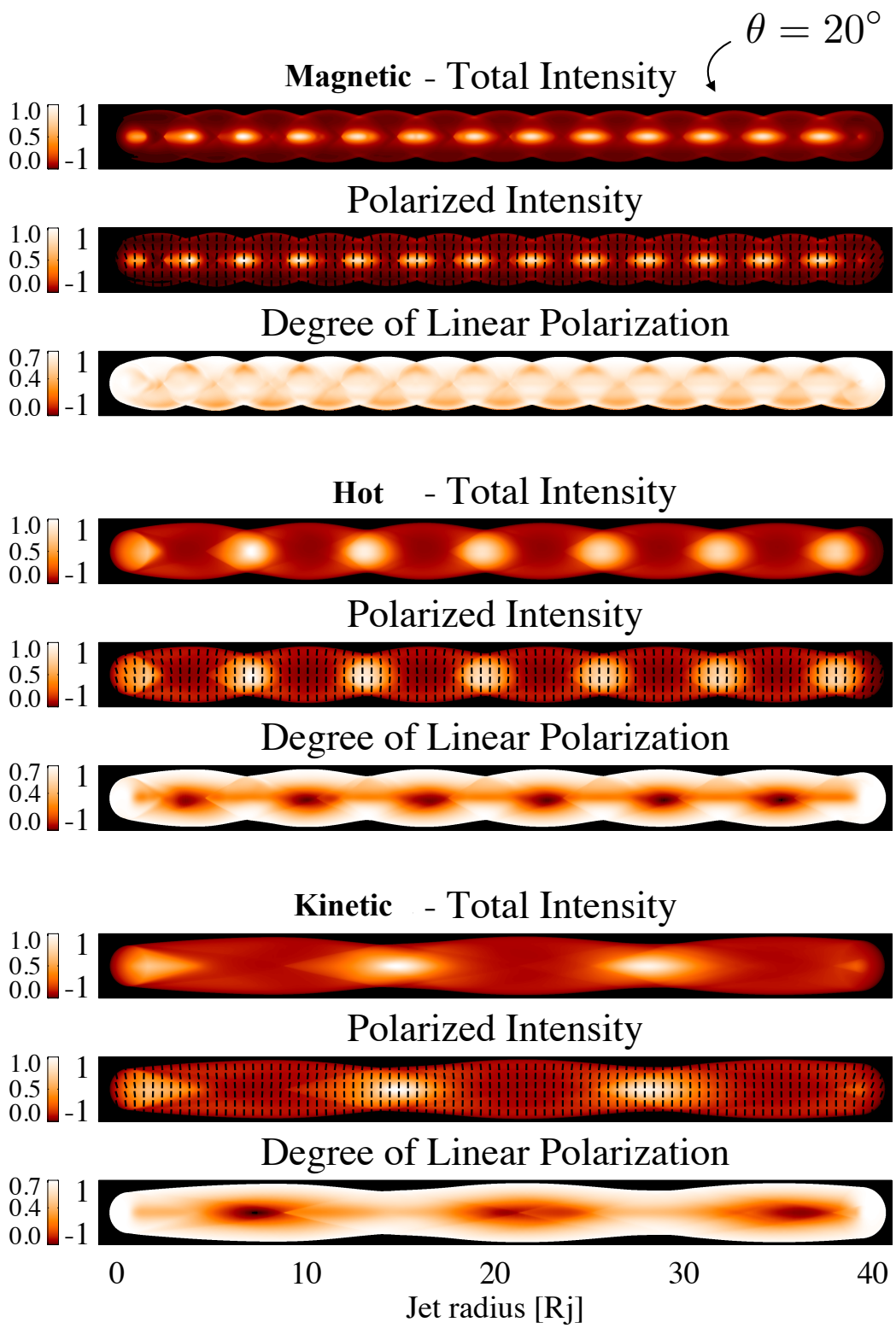
Radio emission (II): Knots intensity



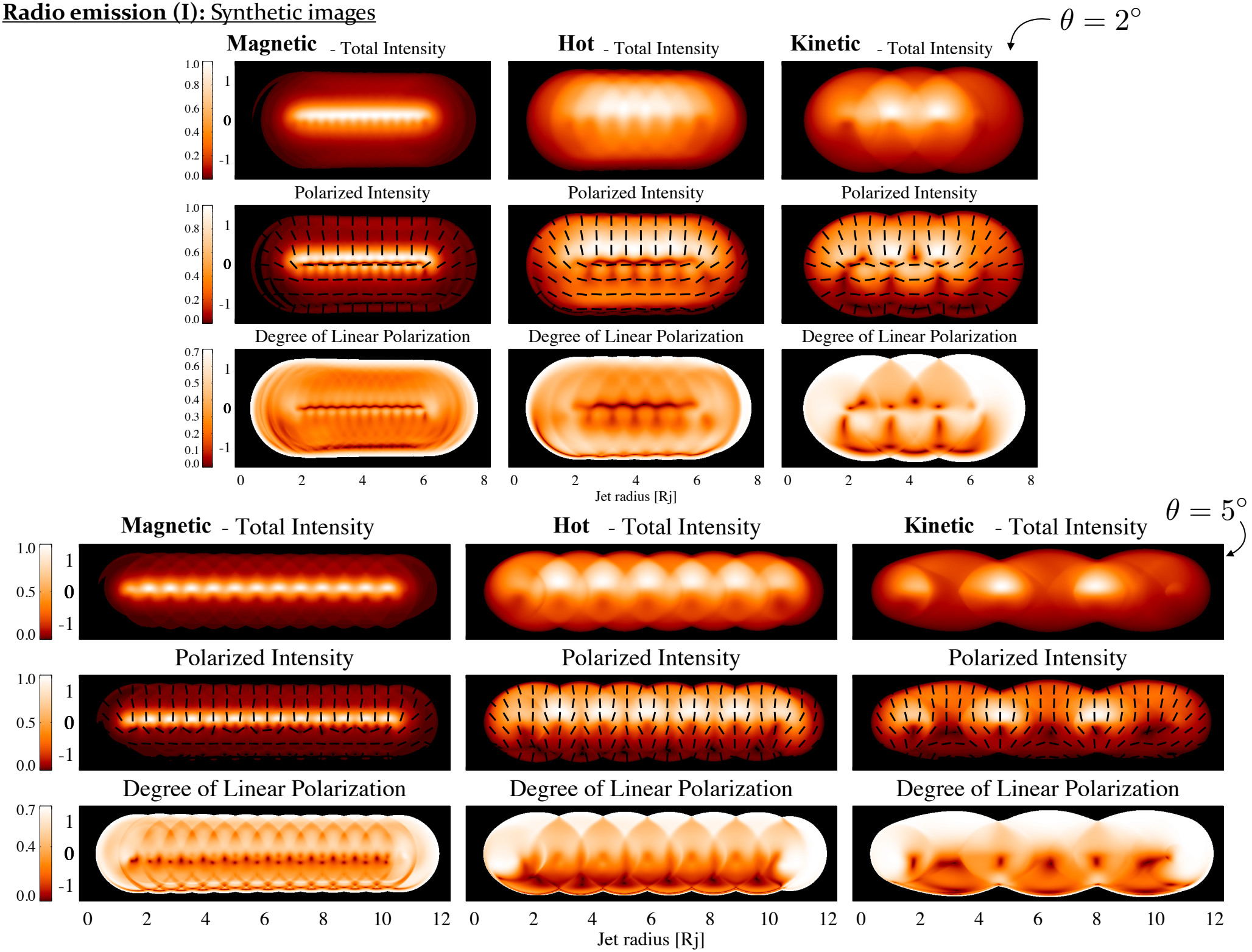
- **Kinetically** dominated models (colder jets)
- **Hot and magnetically** dominated models

Due to:

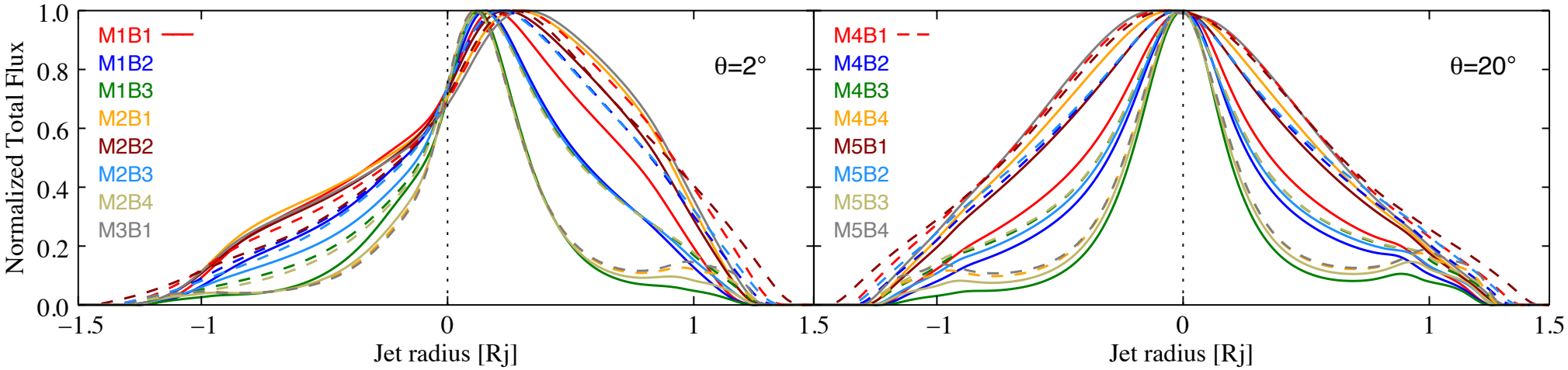
1. Projection effects
2. **Doppler boosting** greater in **rarefactions** for 5º and greater in **recollimation shocks** for 20º



Radio emission (I): Synthetic images

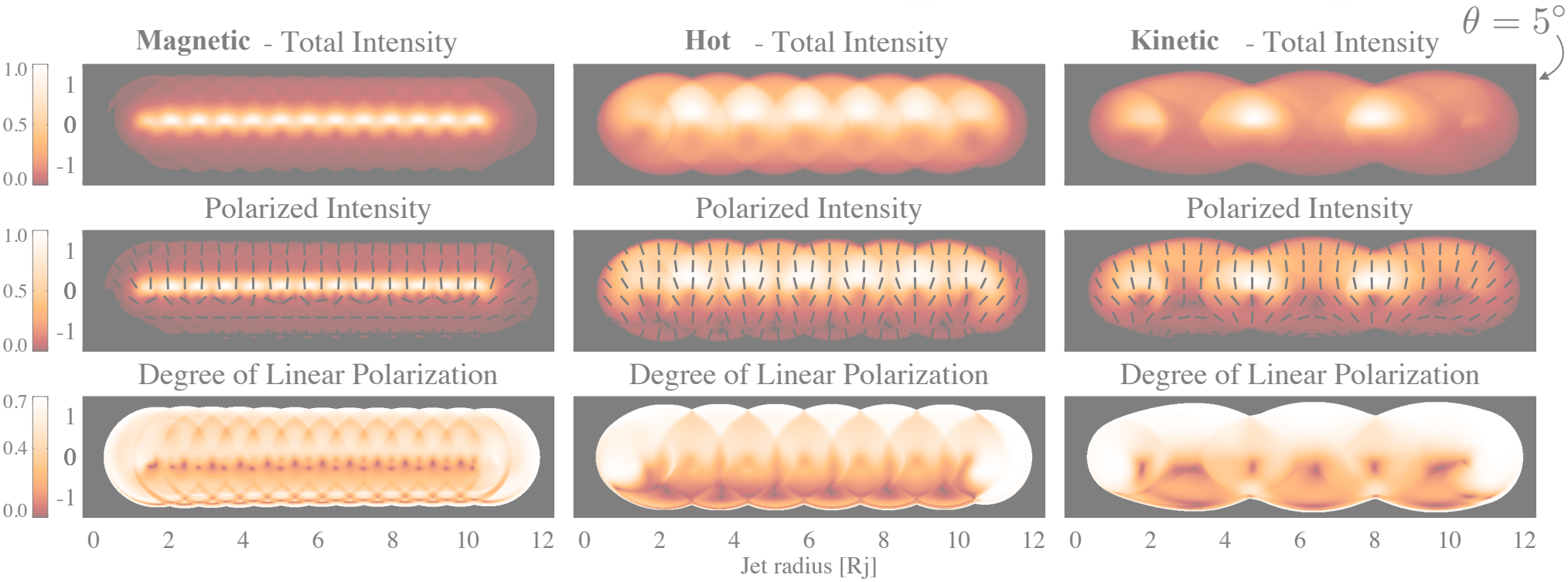


Radio emission (III): Emission asymmetry and spine brightening



Top-down emission **asymmetry** due to **helical magnetic field**

Spine brightening due to large **magnetic pressure** gradient and **magnetic tension**

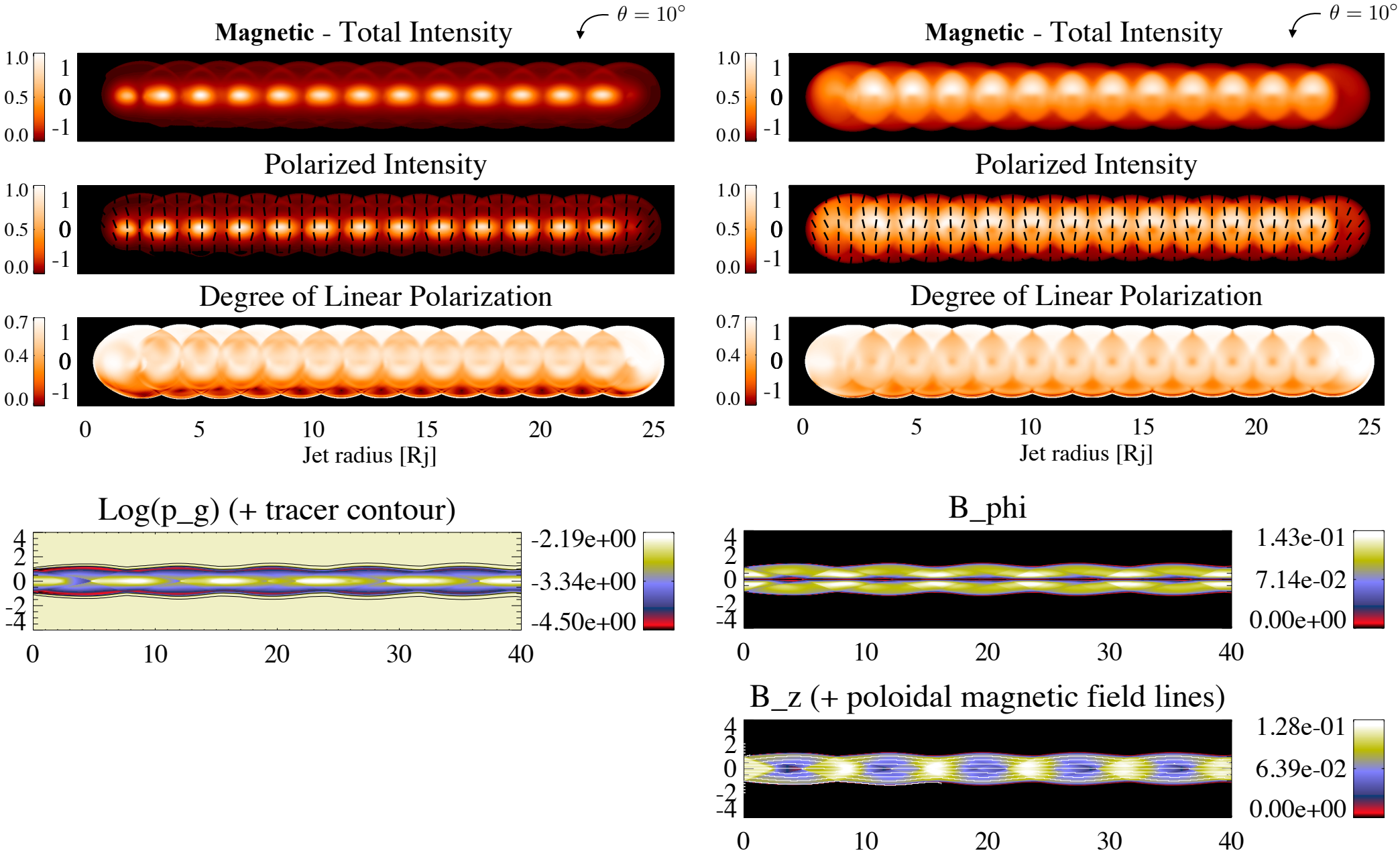


Radio emission (IV): Particle injection

$$N(E)dE = N_0 E^{-\gamma} dE$$

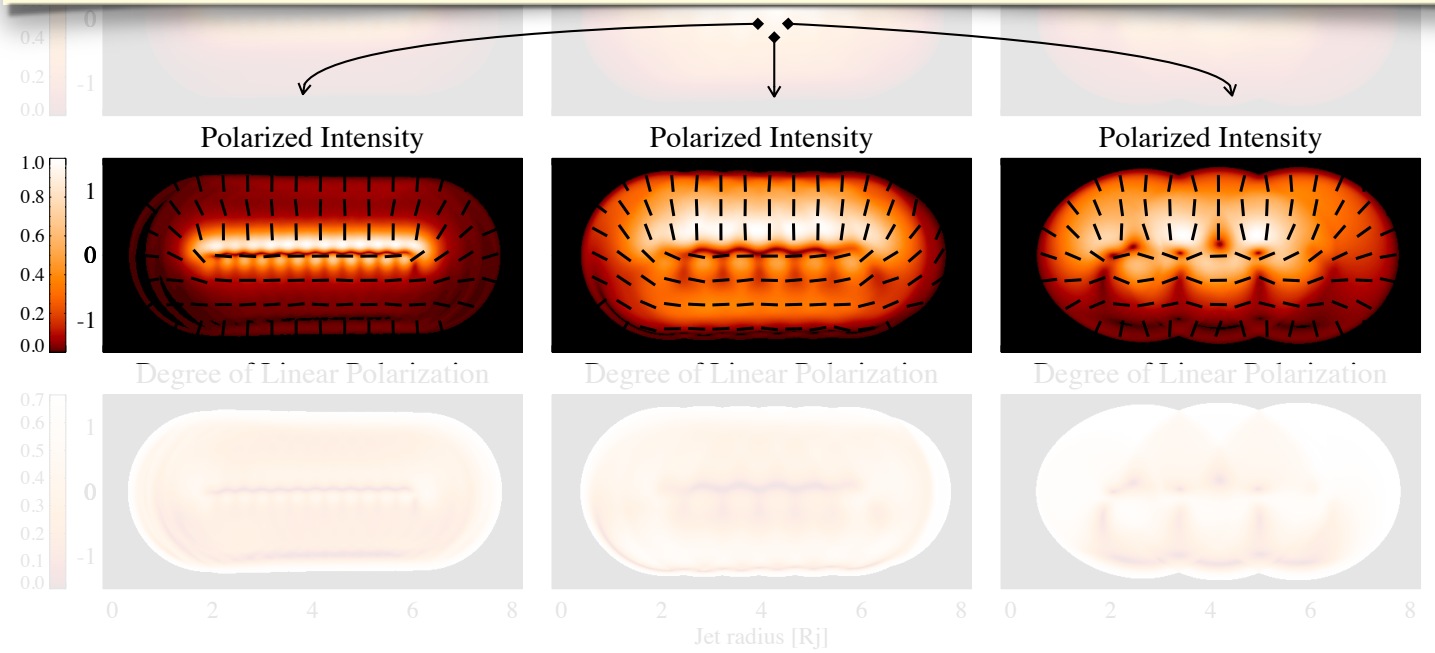
$N_0 \propto U$

$N_0 \propto B'^2$



Radio emission (V): Polarization

Bimodal distribution of the **EVPAs** at small viewing angles due to **helical magnetic field**

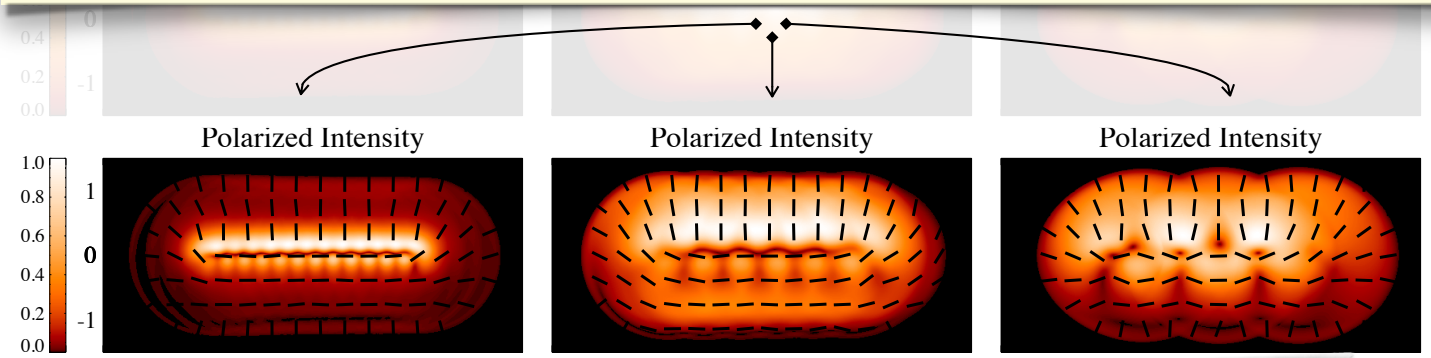


$\theta = 2°$

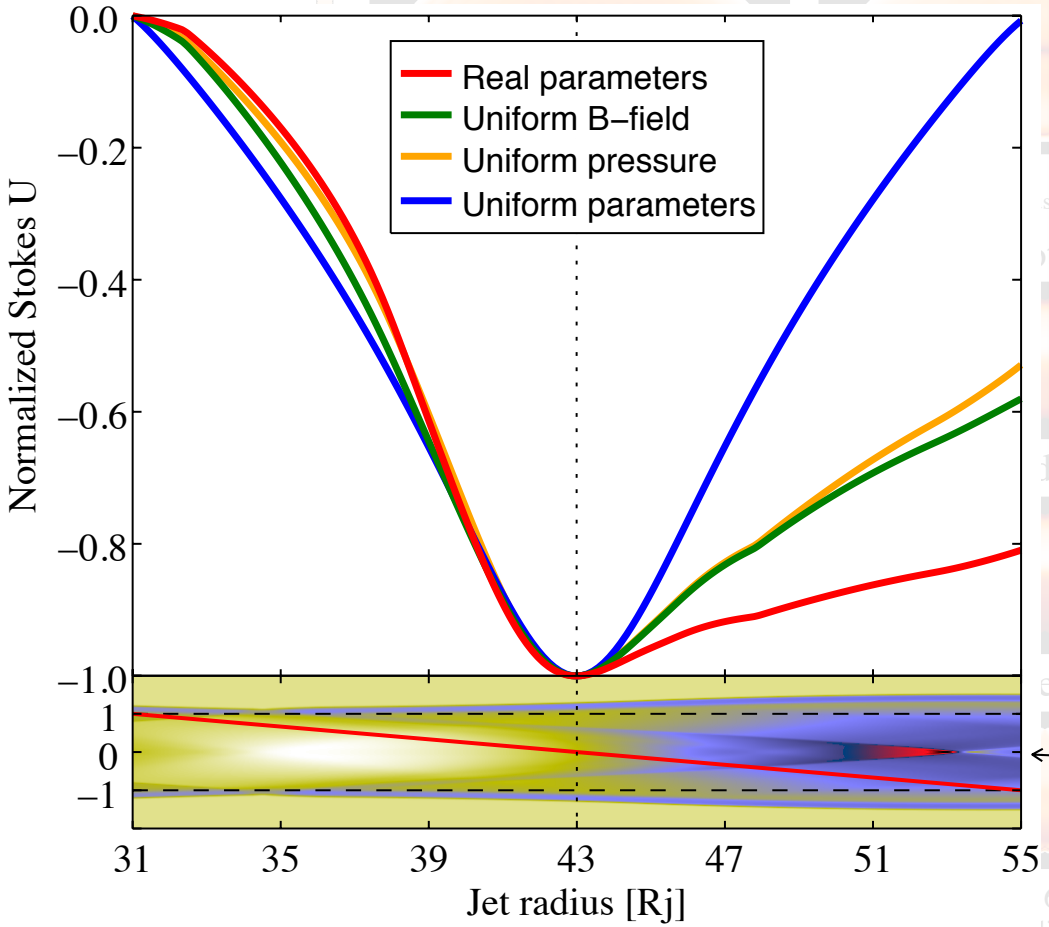
$\theta = 5°$

Radio emission (V): Polarization

Bimodal distribution of the **EVPAs** at small viewing angles due to **helical magnetic field**

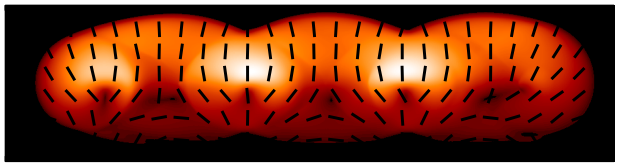


$\theta = 2°$

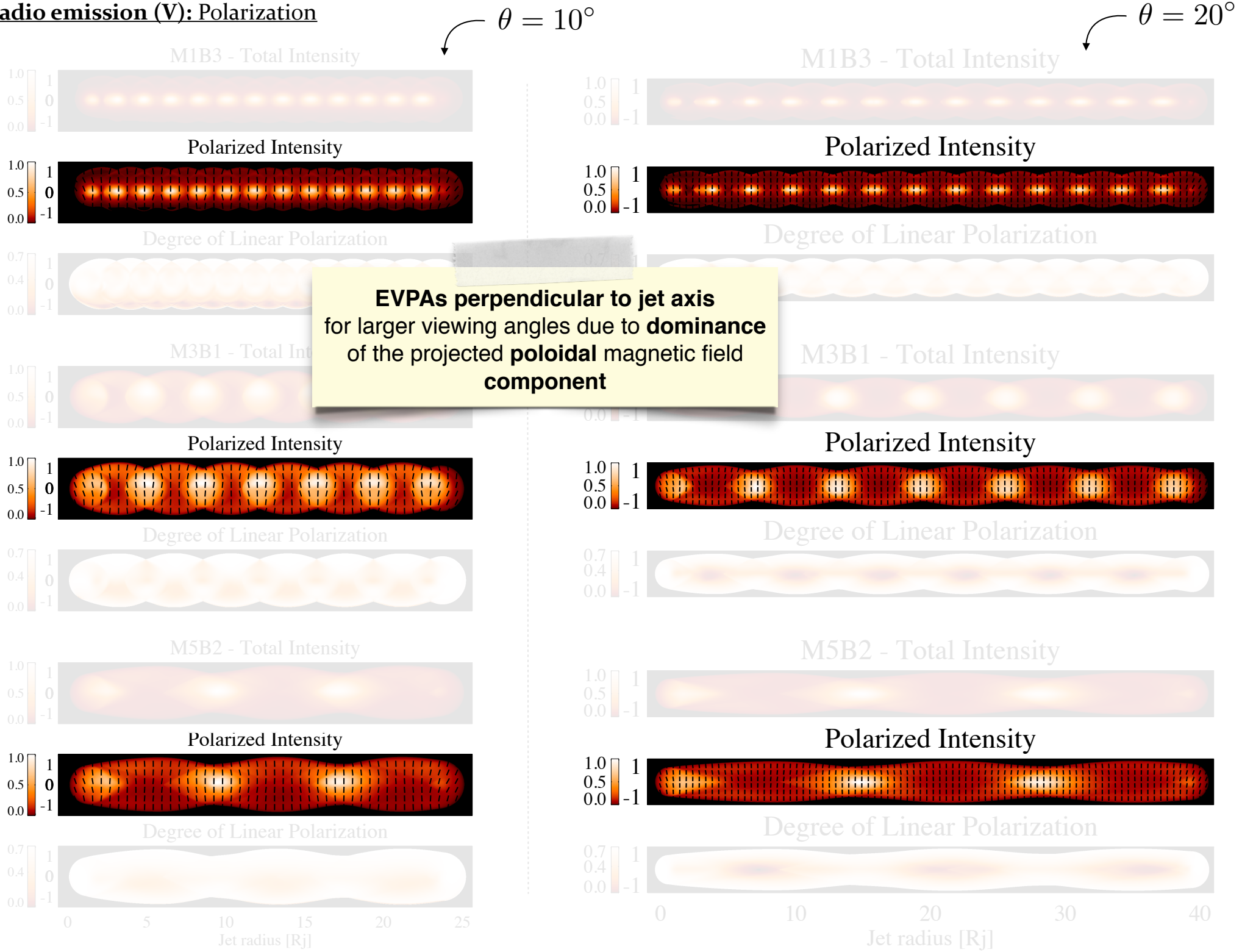


- **Small variations** in the **polarization angle** of up to **~26°** observed around **stationary components**,
- Due to a break of the **Stokes U symmetry**,
- Independently of the viewing angle,
- As a consequence of the presence of several **recollimation shocks.**

$\theta = 5°$

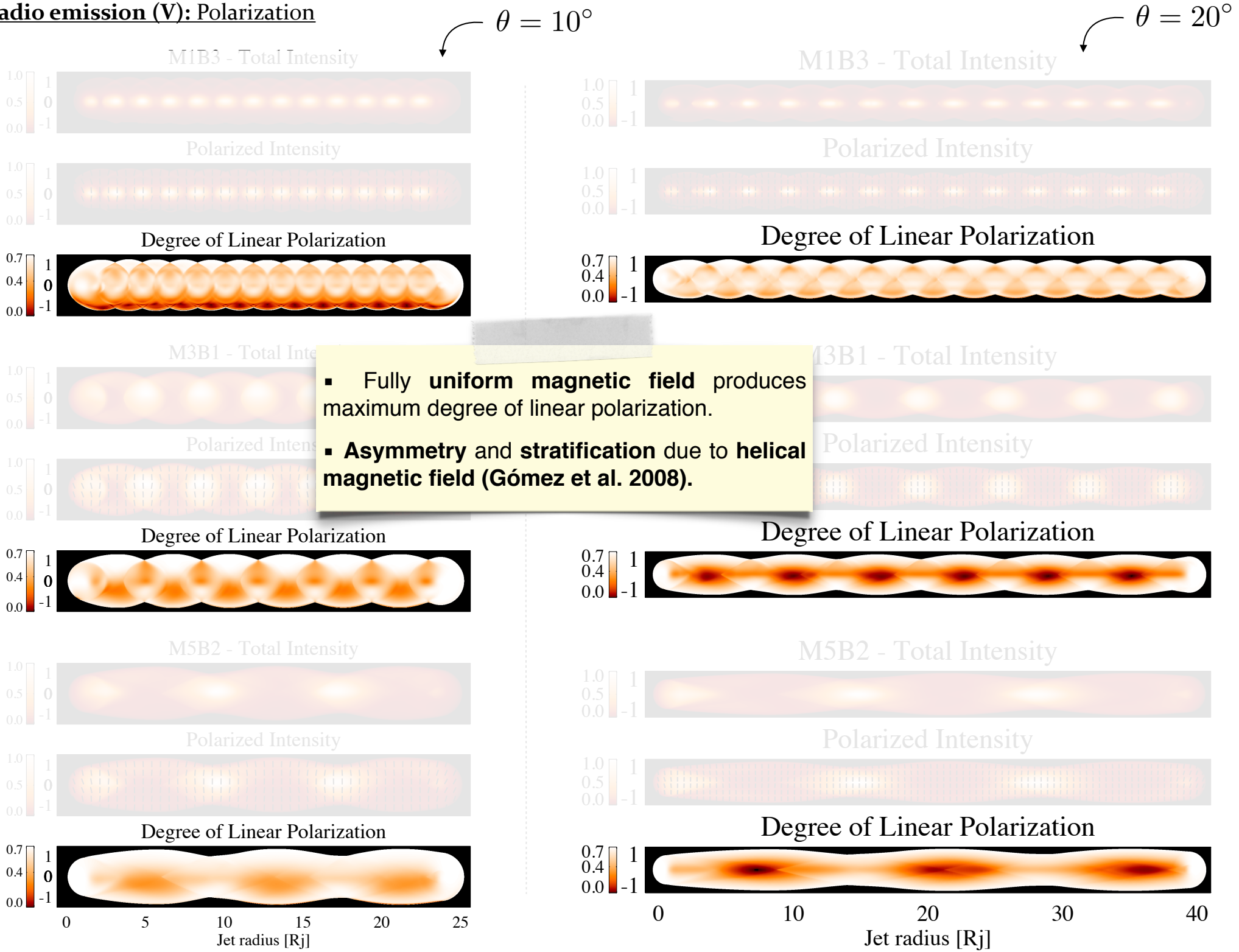


Radio emission (V): Polarization



EVPAs perpendicular to jet axis
for larger viewing angles due to **dominance** of the projected **poloidal** magnetic field **component**

Radio emission (V): Polarization



- Fully **uniform magnetic field** produces maximum degree of linear polarization.
- **Asymmetry** and **stratification** due to **helical magnetic field (Gómez et al. 2008).**

Summary

- We have performed **RMHD simulations** as well as **total and polarized radio emission** of multiple jet models threaded by a **helical magnetic field**, attending to their dominant type of energy: **internal, kinetic** or **magnetic**.

- The **internal structure** of the models is determined by the **Mach number,** the **internal energy** and the **magnetization**.

- **Recollimation shocks** produce **bright stationary components** whose emission gets **confined** in a jet spine as the **magnetization increases** and the **non-thermal particle population** is considered to be a **fraction of the thermal** one.

- **Kinetic** models show **more intense knots** at **small viewing angles**, while **hot and magnetically** dominated jets present **more intense knots** at **larger viewing angles** due to **Doppler boosting.**

- **Lower viewing angles** show a **bimodal distribution of the EVPAs**, being either perpendicular or aligned with the jet axis. Small **variations in the EVPAs (~26º)** are observed in **recollimation shocks**. The **degree of polarization** presents an **asymmetric** and **stratified** structure due to the **helical magnetic field.**