Spectral Evolution in Blazars
-Observation and Theory-

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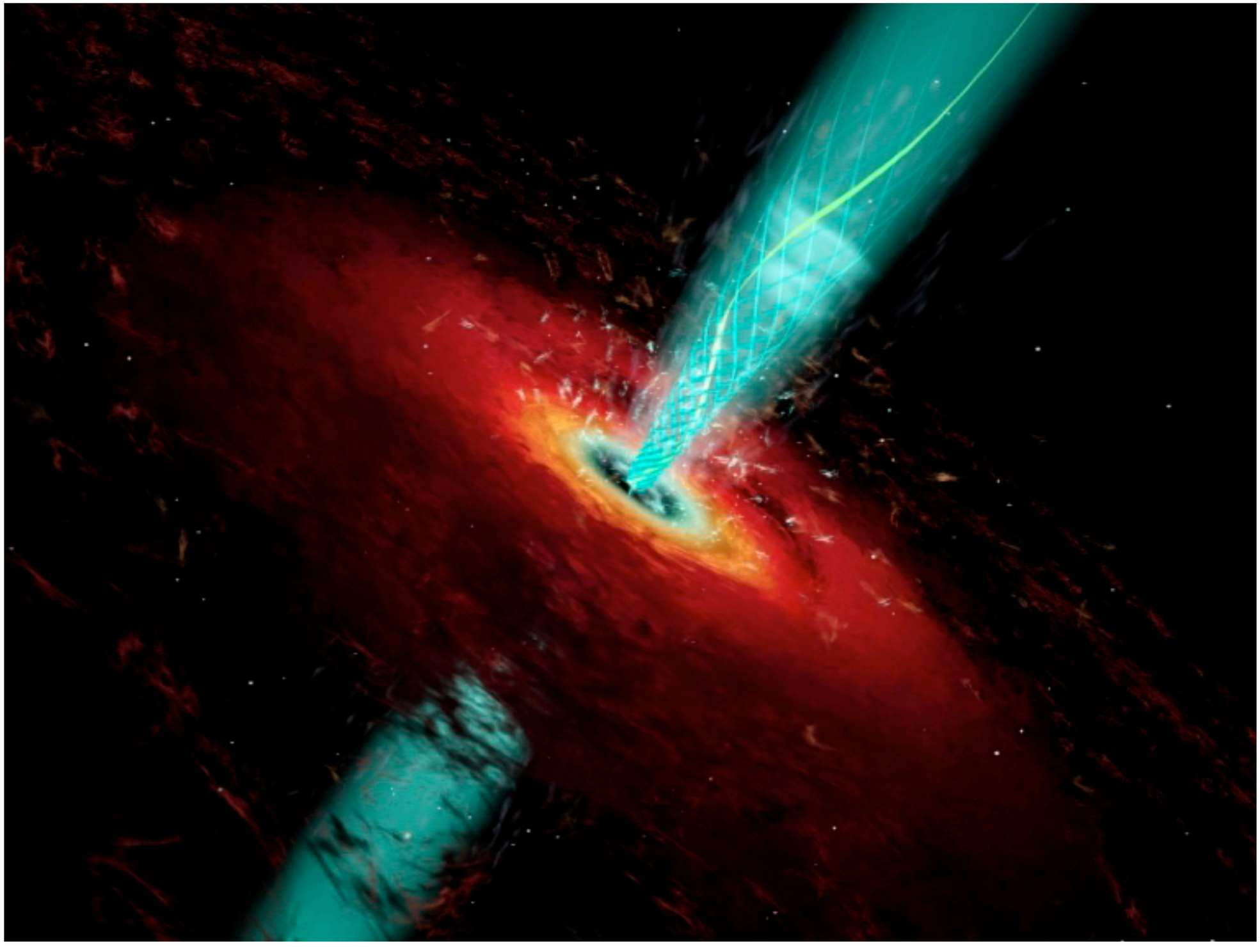
IMPRS astronomy & astrophysics Bonn and Cologne

Outline

- Motivation
- Observations
- RHD Simulations
- Summary

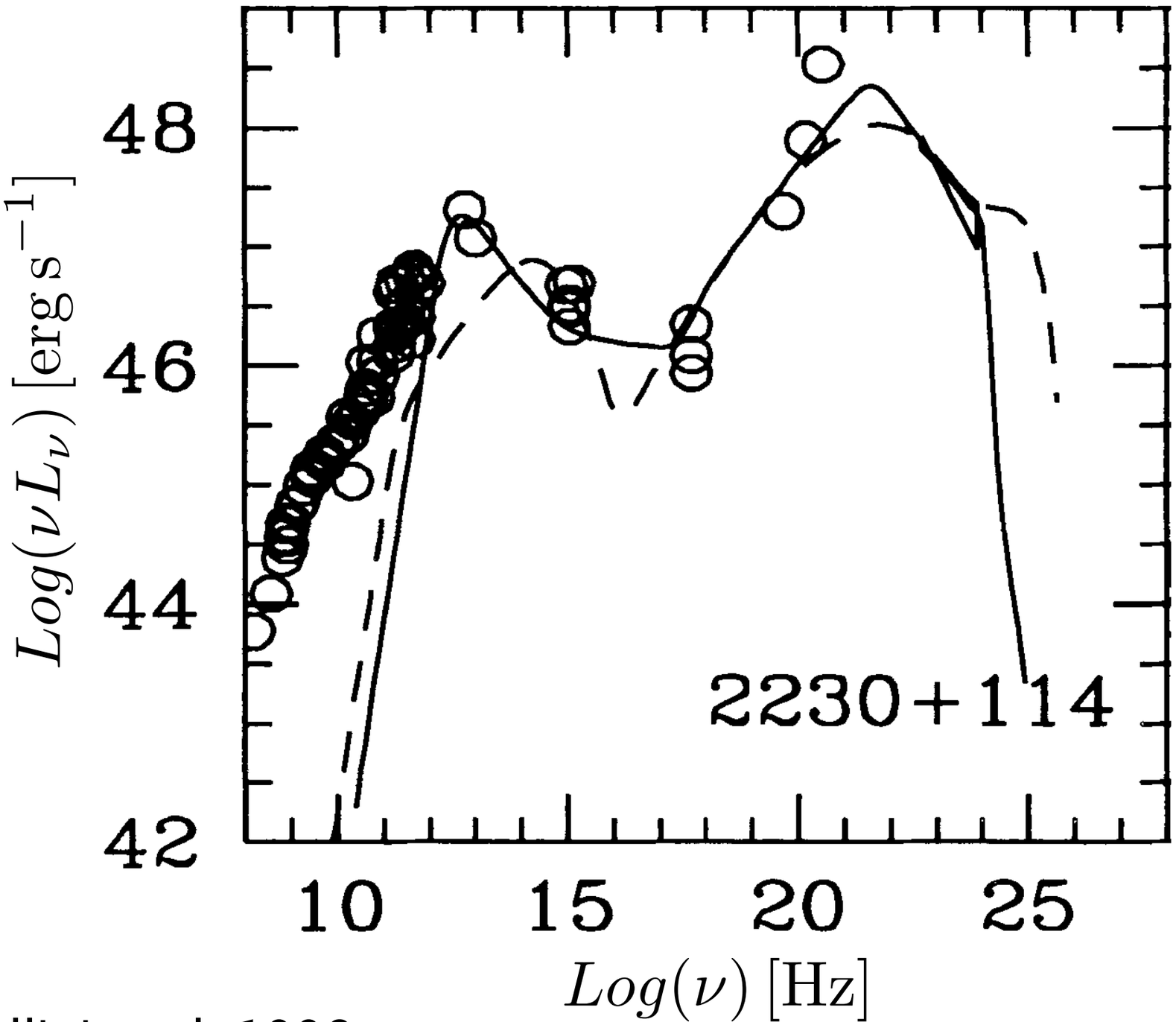
Active Galactic Nuclei



Ref: Steffen

Spectral Energy Distribution (SED)

Standard Model: Single zone model within cylindrical or conical jet



Ref: Ghisellini et al. 1998

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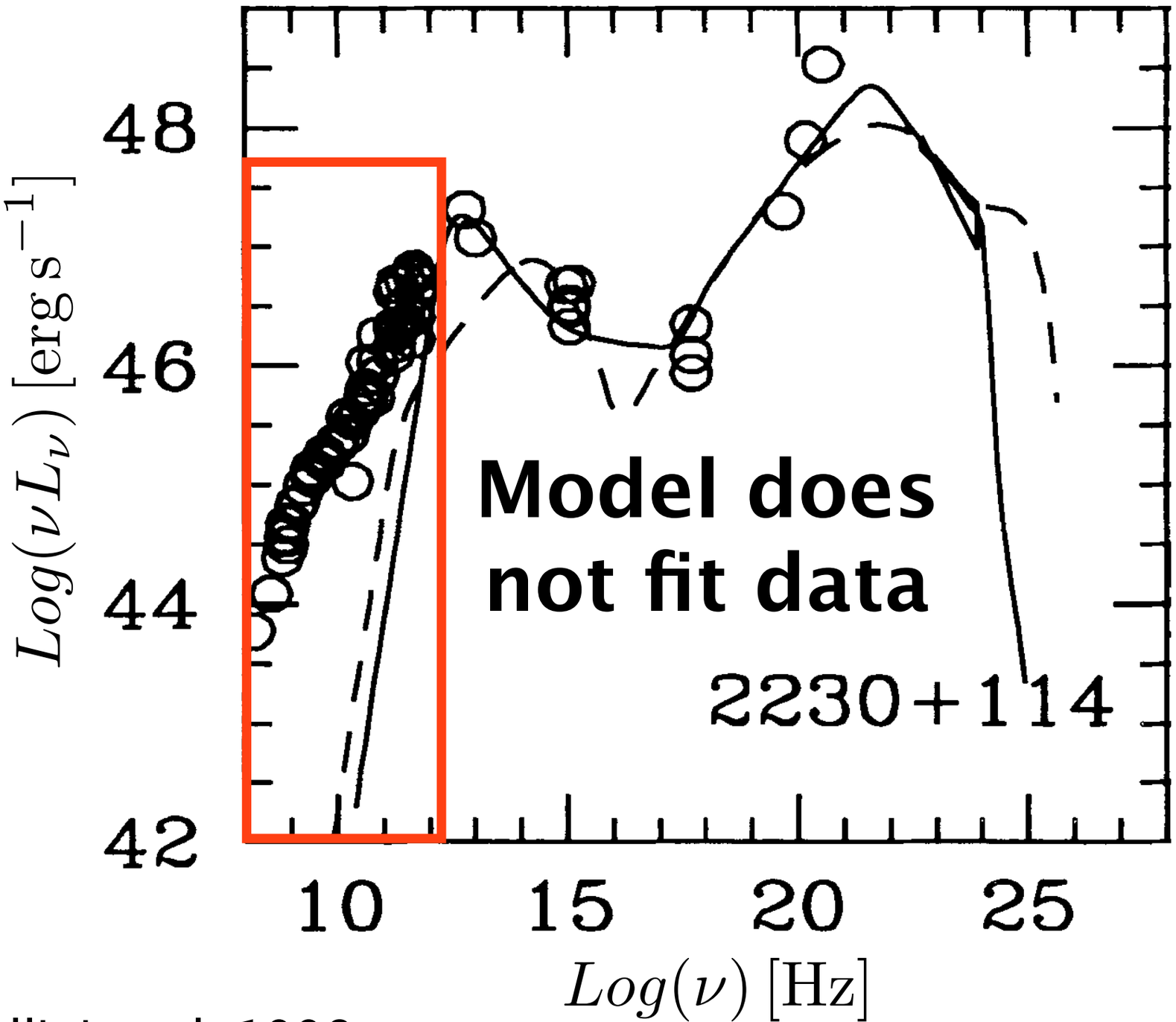


Ref: Ghisellini et al. 1998

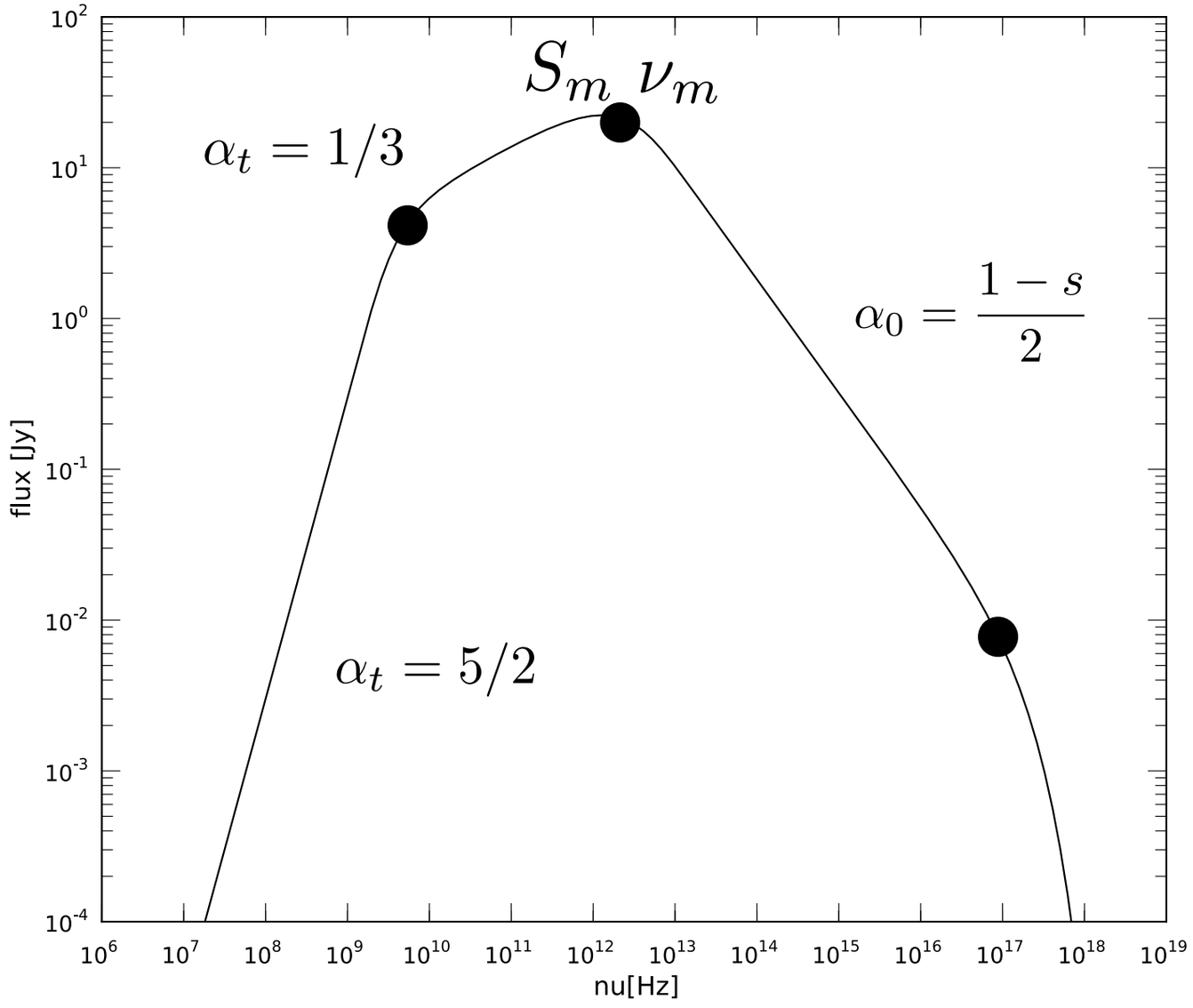
Synchrotron Radiation

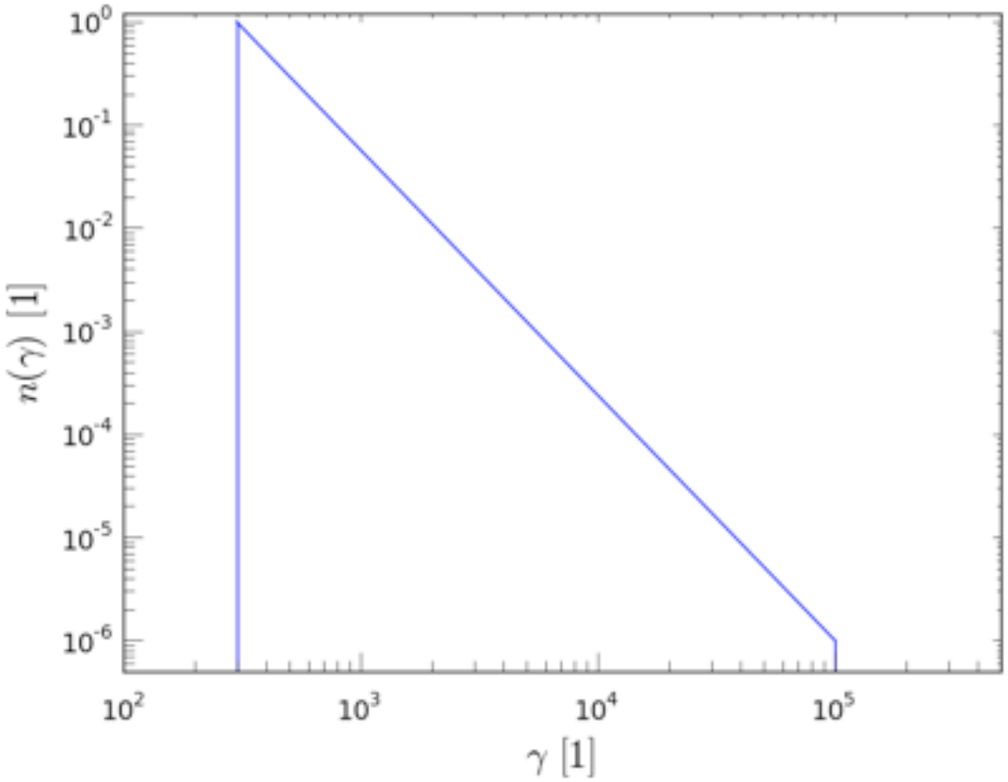
relativistic electrons:

$$N(\gamma) = K\gamma^{-s} \quad \gamma_{\min} < \gamma < \gamma_{\max}$$

magnetic field: B

Emission zone: R



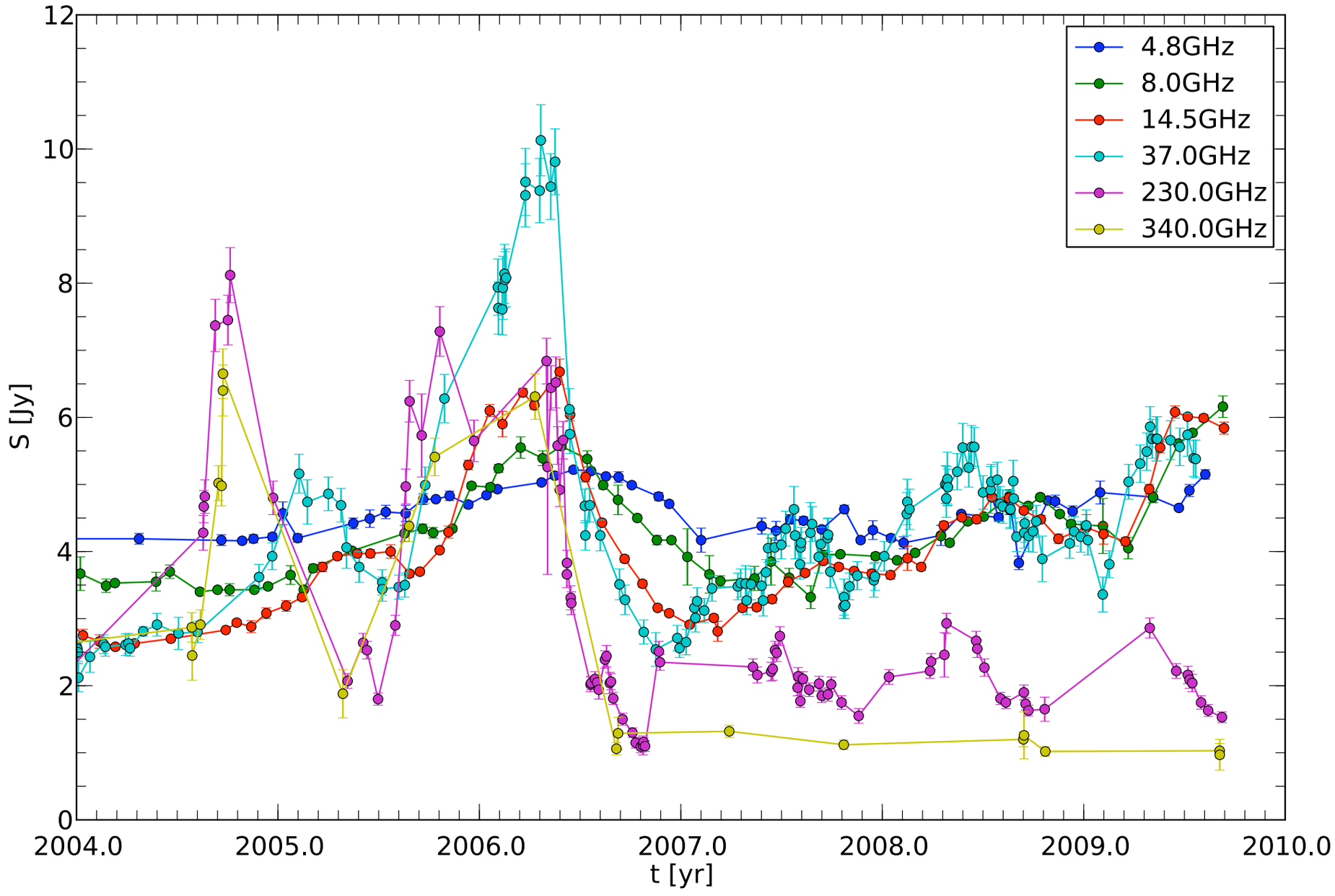


$$B \propto \nu_m^5 S_m^{-2}$$

$$N_0 \propto \nu_m^{-(2s+3)} S_m^{s+2}$$

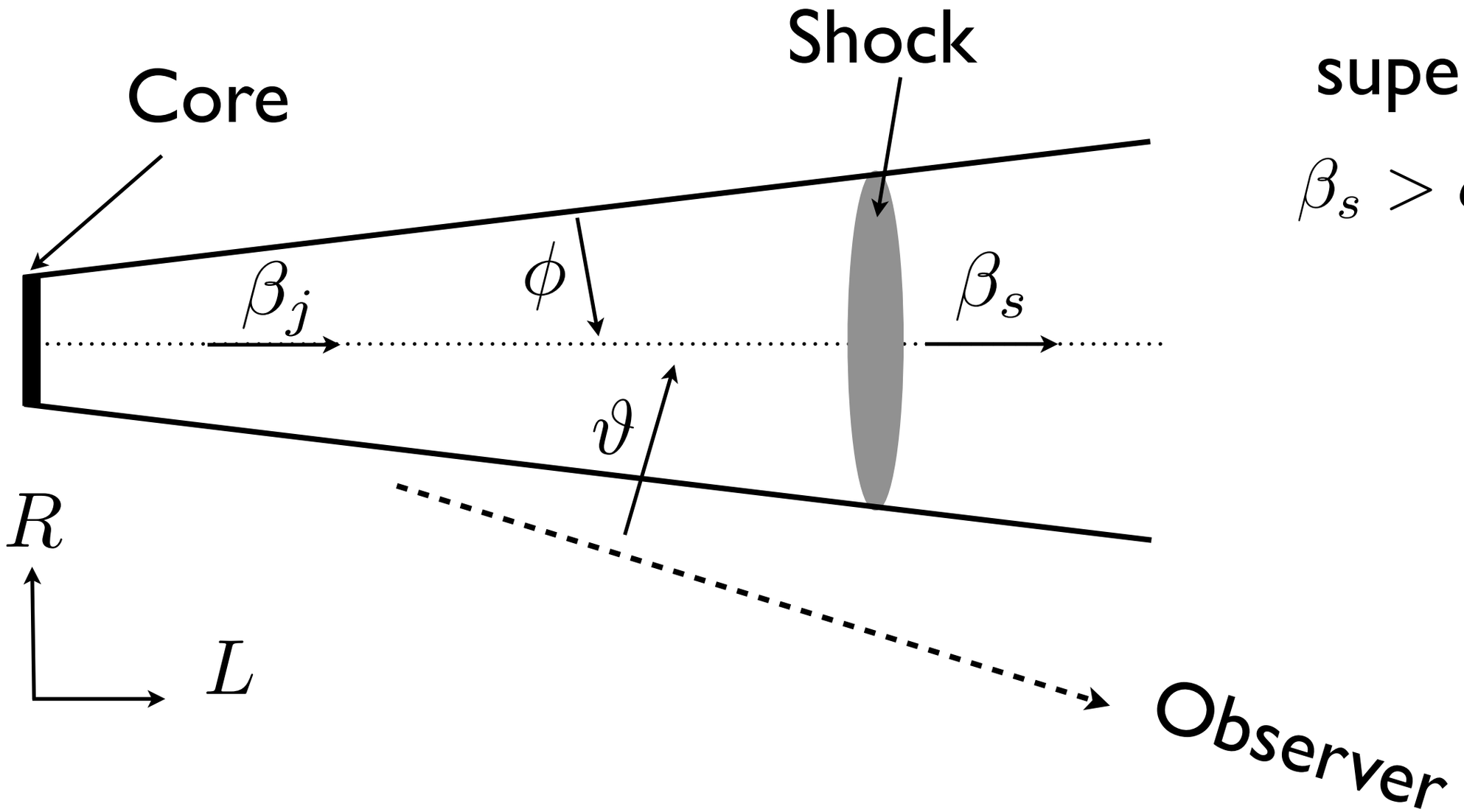
Single Dish

CTA 102 (2230+114) z=1.037



Ref: Fromm et al. 2011

Shock-in-Jet Model



$\beta_s > \beta_j$

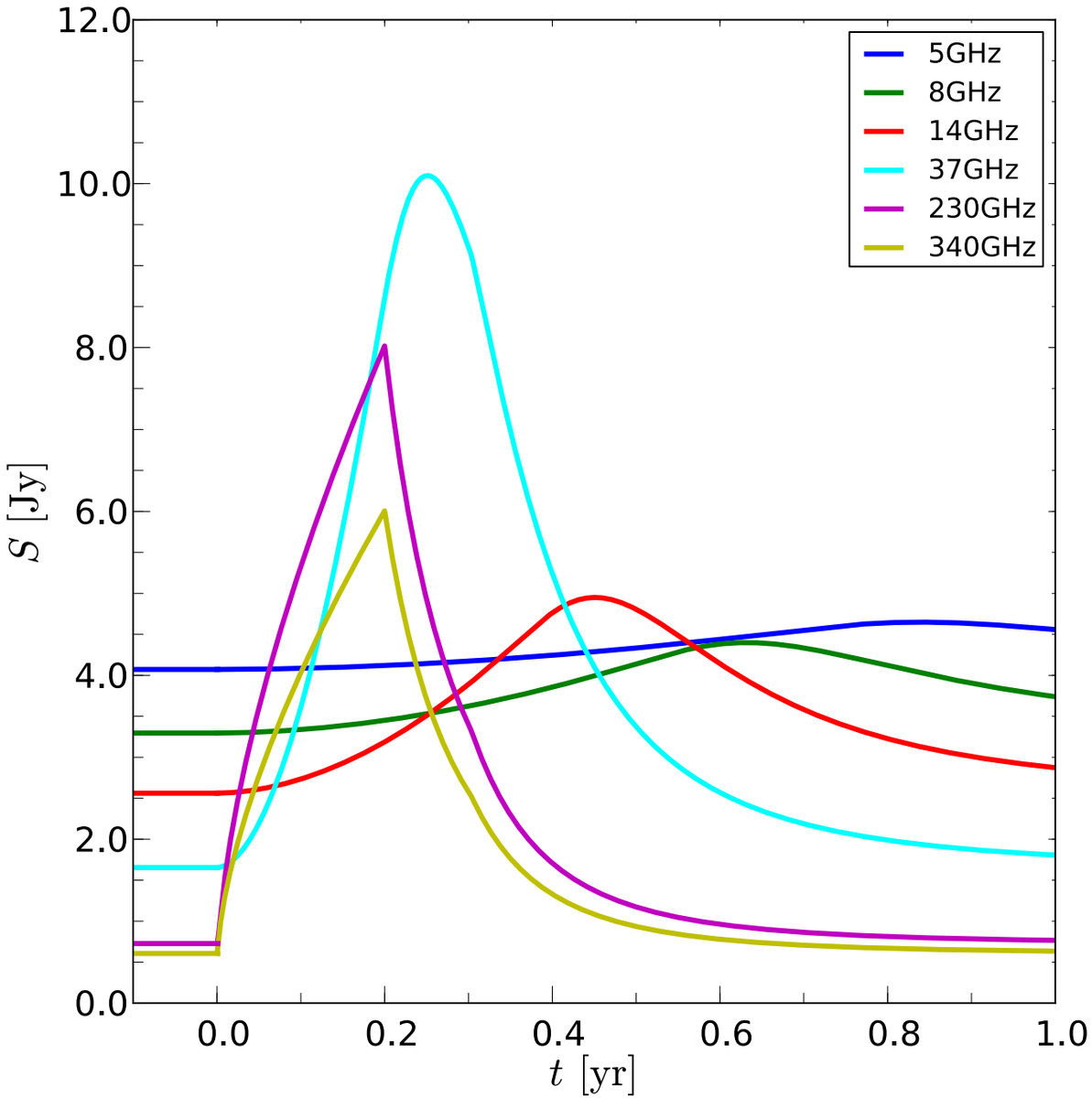
supersonic

$\beta_s > c_s$

Ref: Marscher & Gear (1985), Tuerler et al. (2000)

Single Dish

modeled light curve



observed light curve

Ref: Fromm et al. 2011

Single Dish

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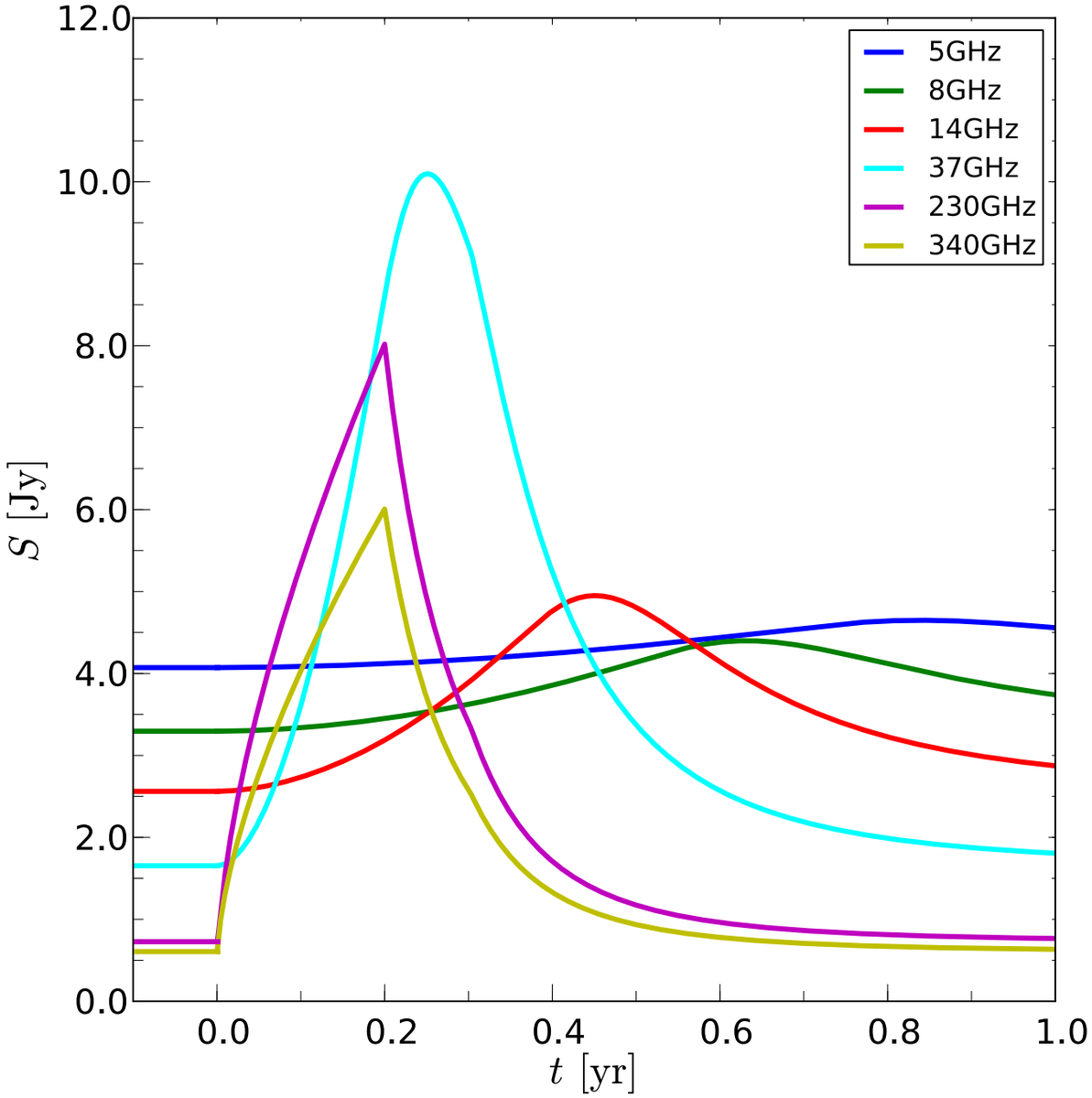

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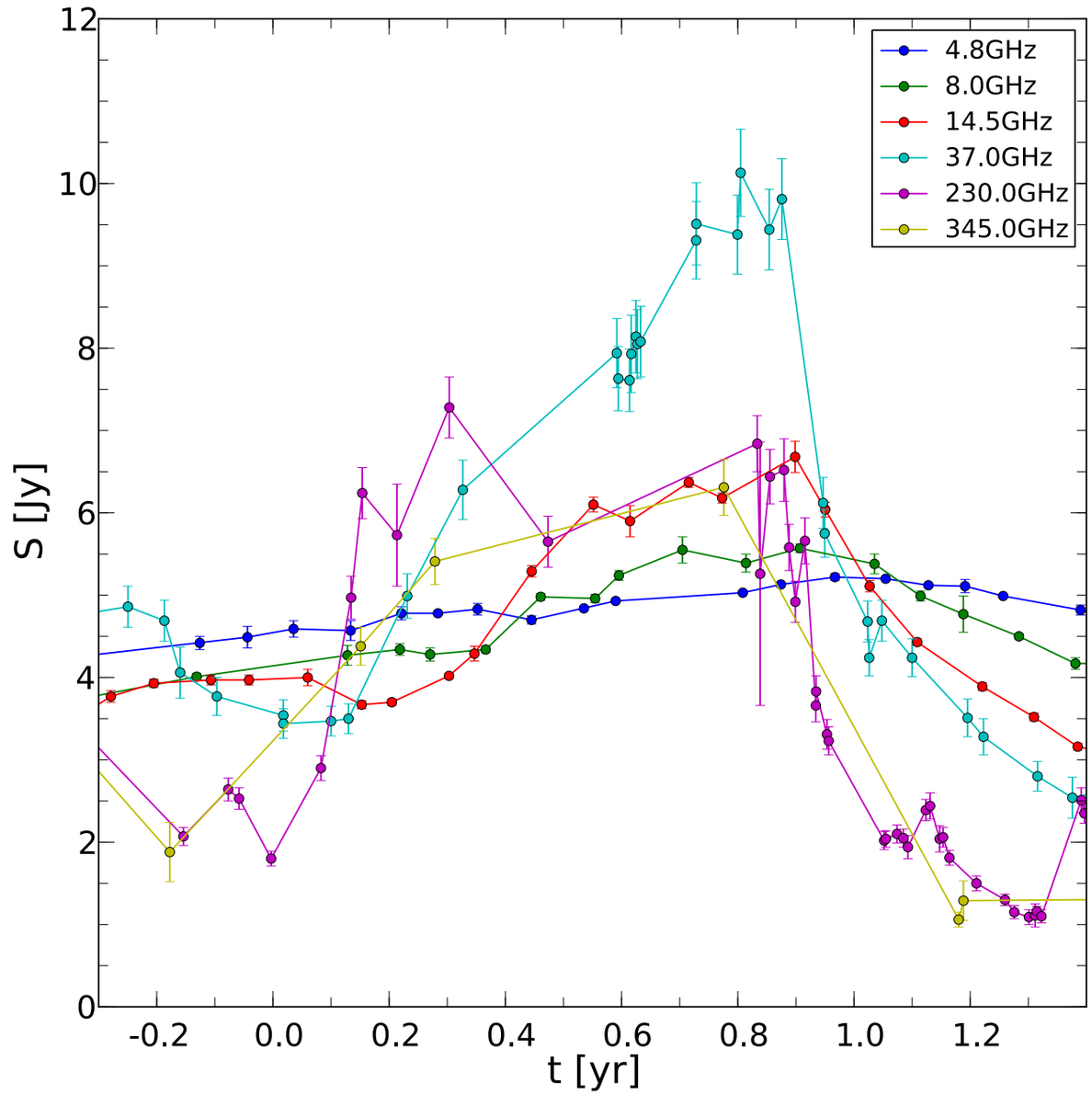

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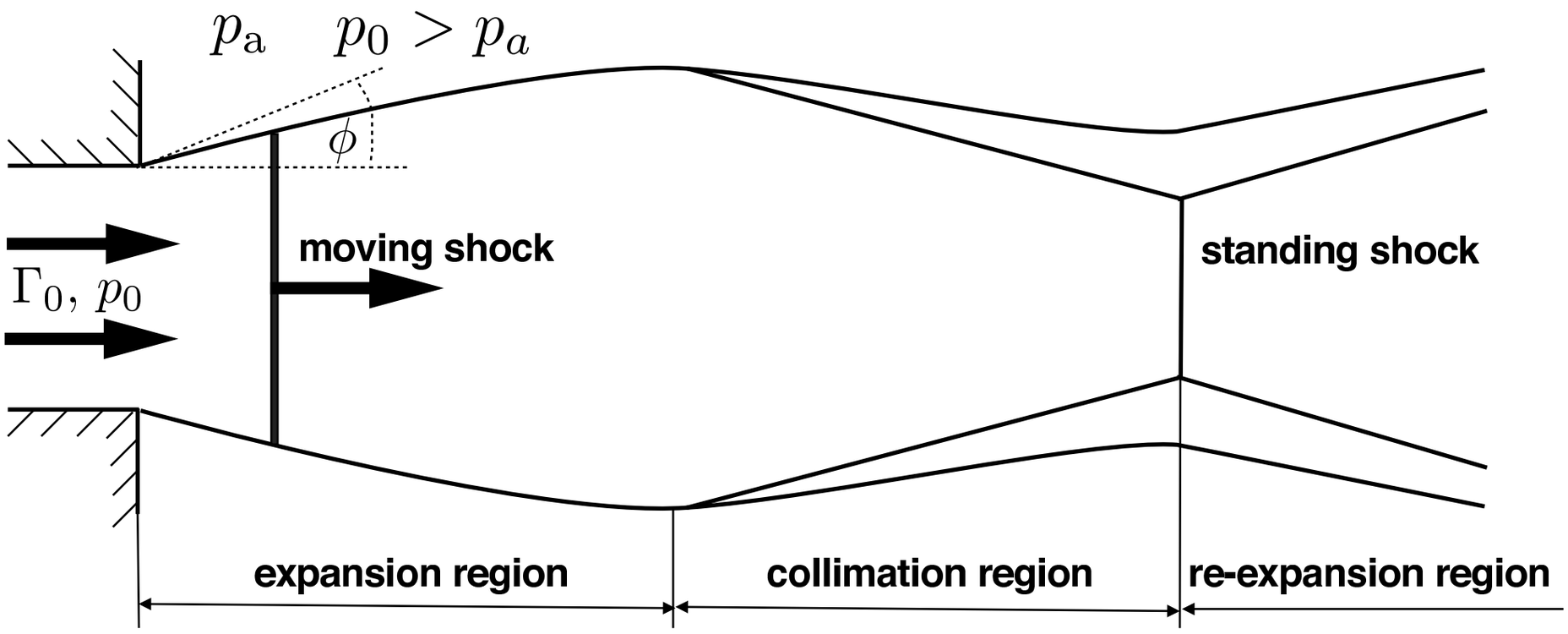
Modified Shock-in-Jet Model



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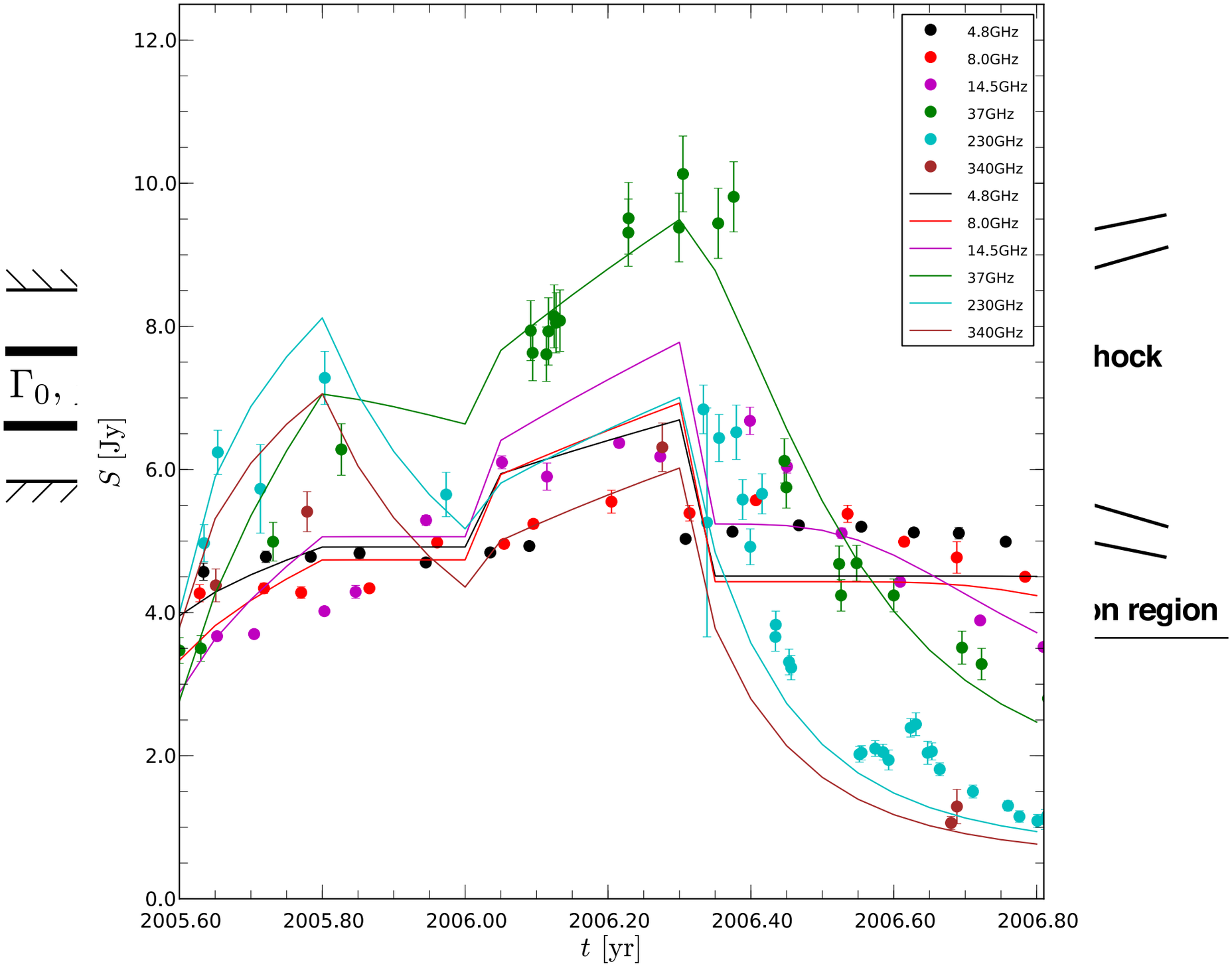

Ref: Fromm et al. 2011

Very Long Base Line (VLBI)

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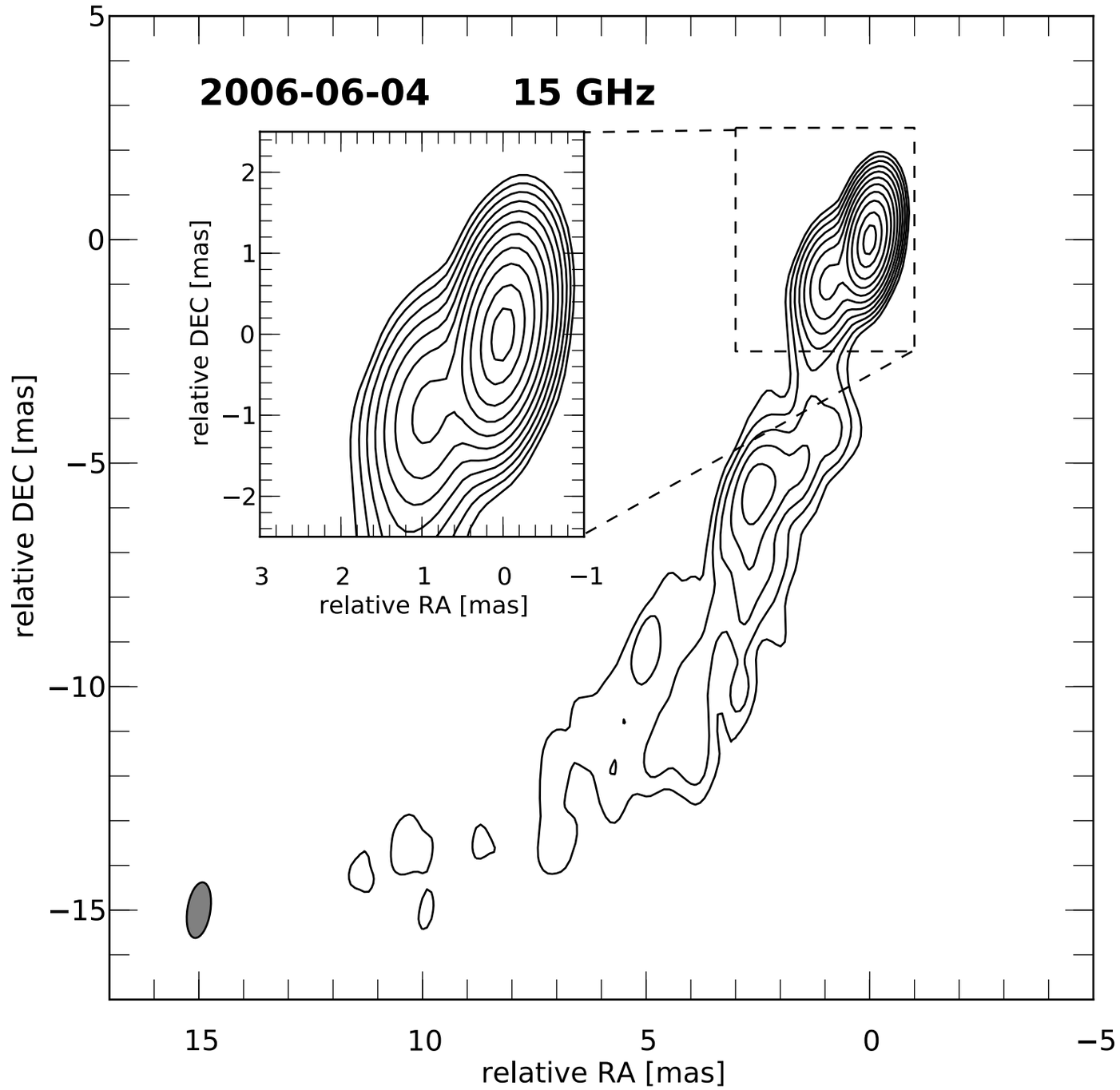
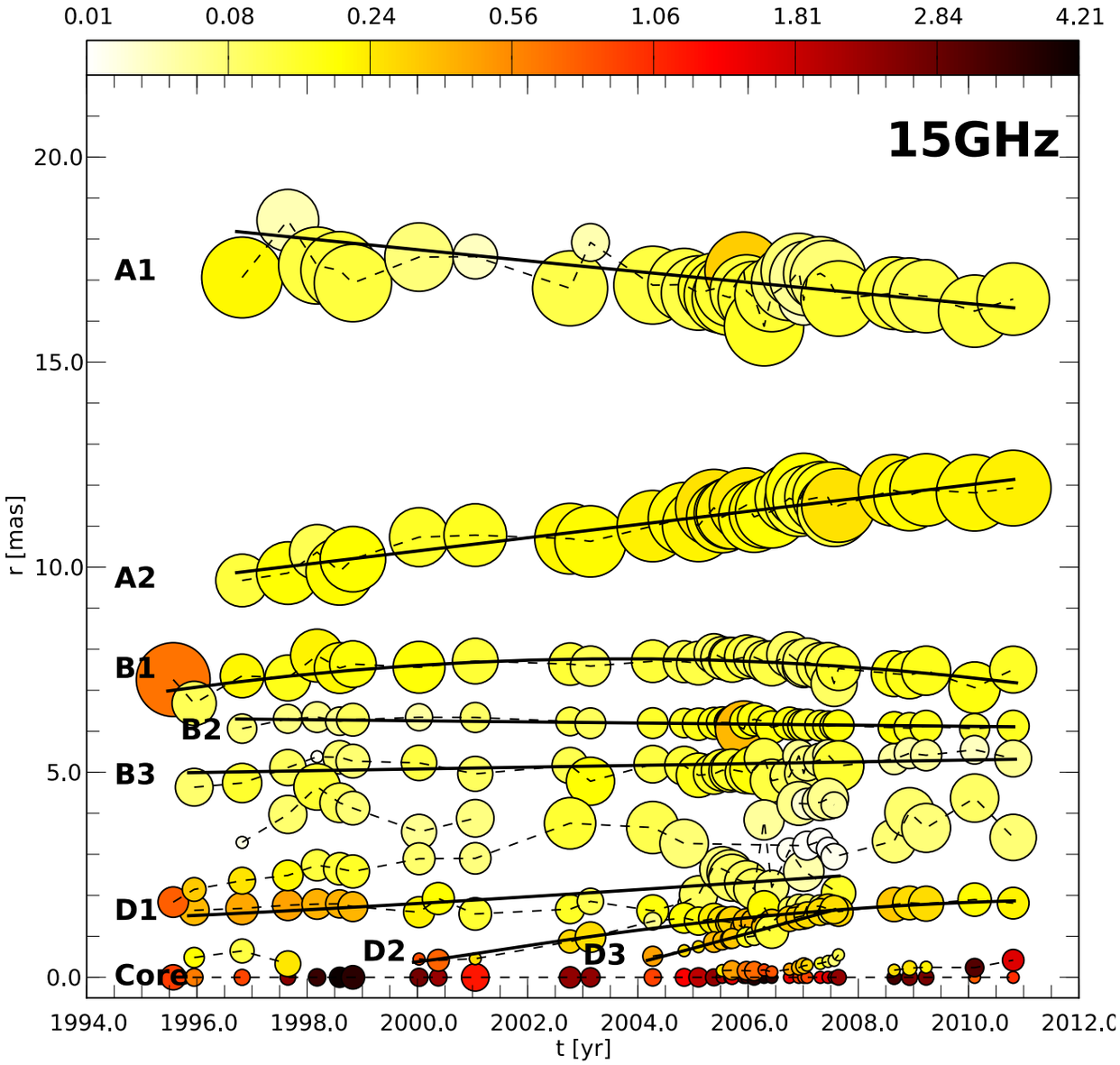


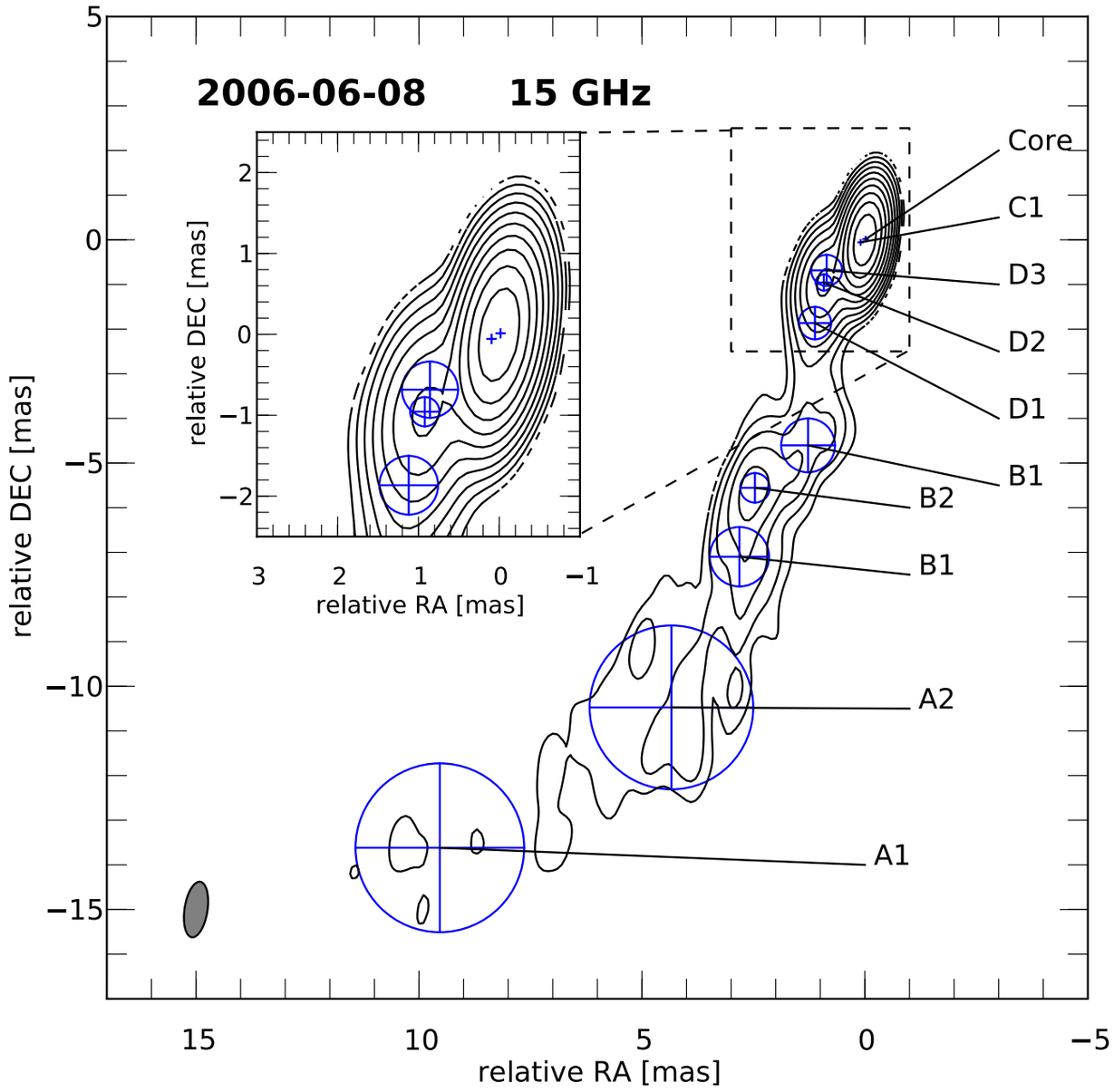
Ref: Fromm et al. 2012

VLBI Modeling

2D Gaussian Modeling: Position (x,y), Flux Density, (S) and Size (FWHM)

→ identify and trace features with time and frequency





Ref: Fromm et al. 2012

VLBI Modeling

steady state

speed of the components

viewing angle

size of the jet/emission region

magnetic field and its orientation

particle density and its evolution

$$\begin{aligned} \beta_{\mathrm{app}} &= 4 - 16\,\mathrm{c} \\ \delta_{\mathrm{max}} &= 8 - 21 \\ \vartheta_{\mathrm{max}} &= 2.6^{\circ} - 3.6^{\circ} \\ R &= 0.4 - 40\,\mathrm{pc} \\ B_{\mathrm{core}} &= 100\,\mathrm{mG} \\ N_{\mathrm{core}} &= 40\,\mathrm{cm}^{-3} \end{aligned}$$

during flares

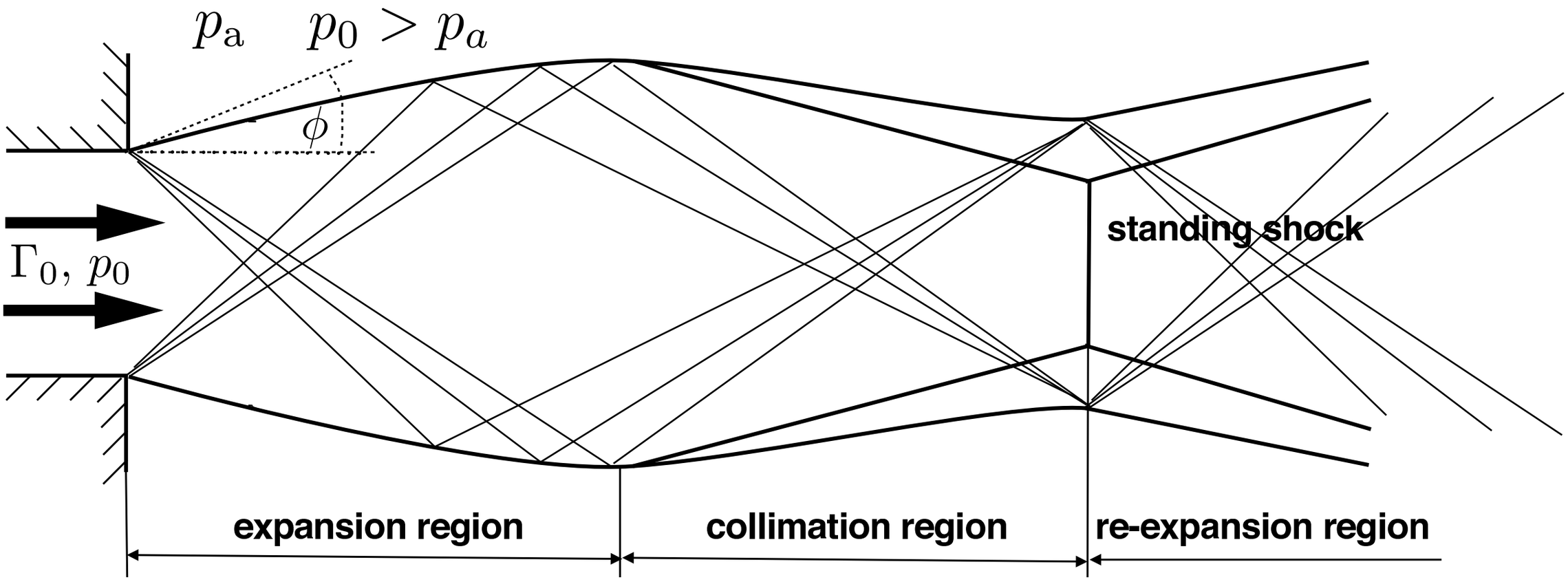
variation of the magnetic field

variation of the particle density

$$\begin{aligned} B_{\mathrm{core}} &= 100\,\mathrm{mG} \\ N_{\mathrm{core}} &= 100\,\mathrm{cm}^{-3} \end{aligned}$$

Ref: Fromm et al in prep.

Creation of standing features



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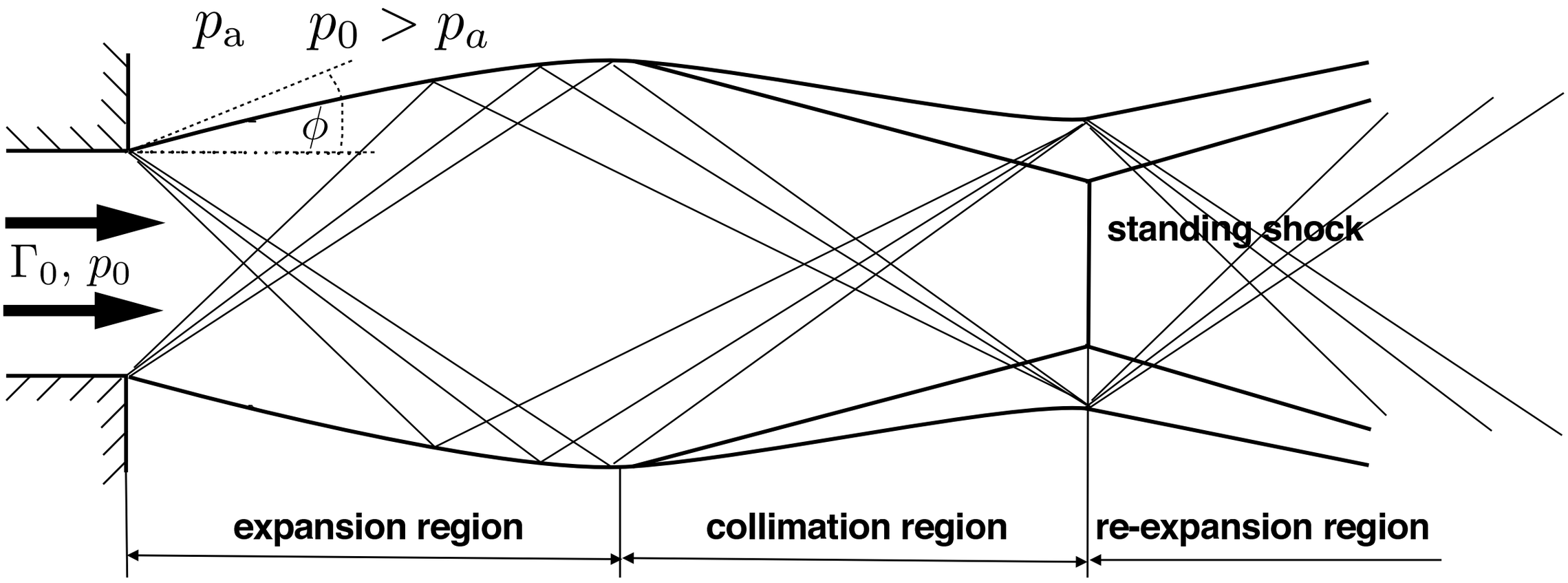


eR(M)HD Simulation

Using RATPENAT (Perucho et al. 2008) + LUXS(Fromm et al. 2012)

Parameters from observations:

$\Gamma = 17$

$\vartheta = 2.6°$

$v_b = 0.\bar{9}9827$

$z_{\mathrm{RC}} = 36\,\mathrm{pc}$

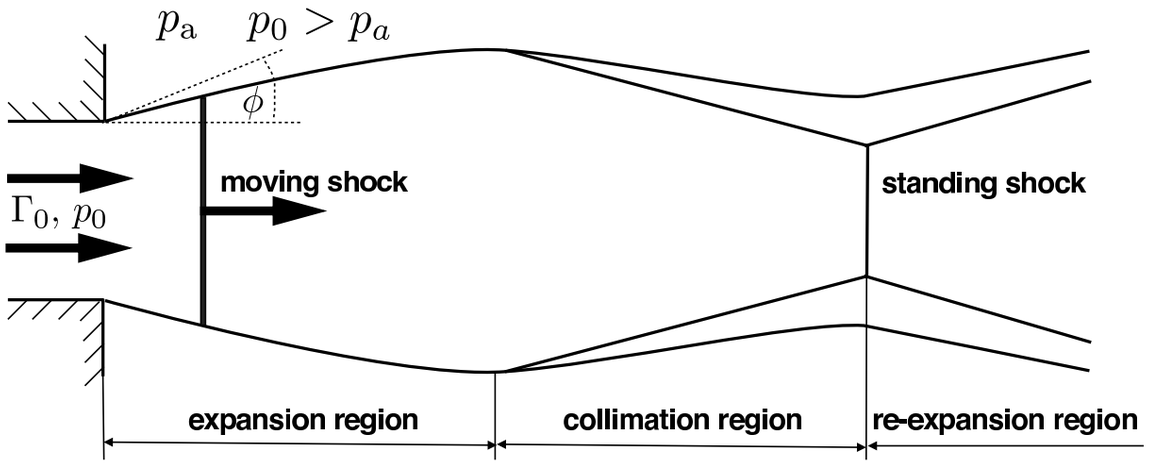
Assumptions: radiative & adiabatic losses

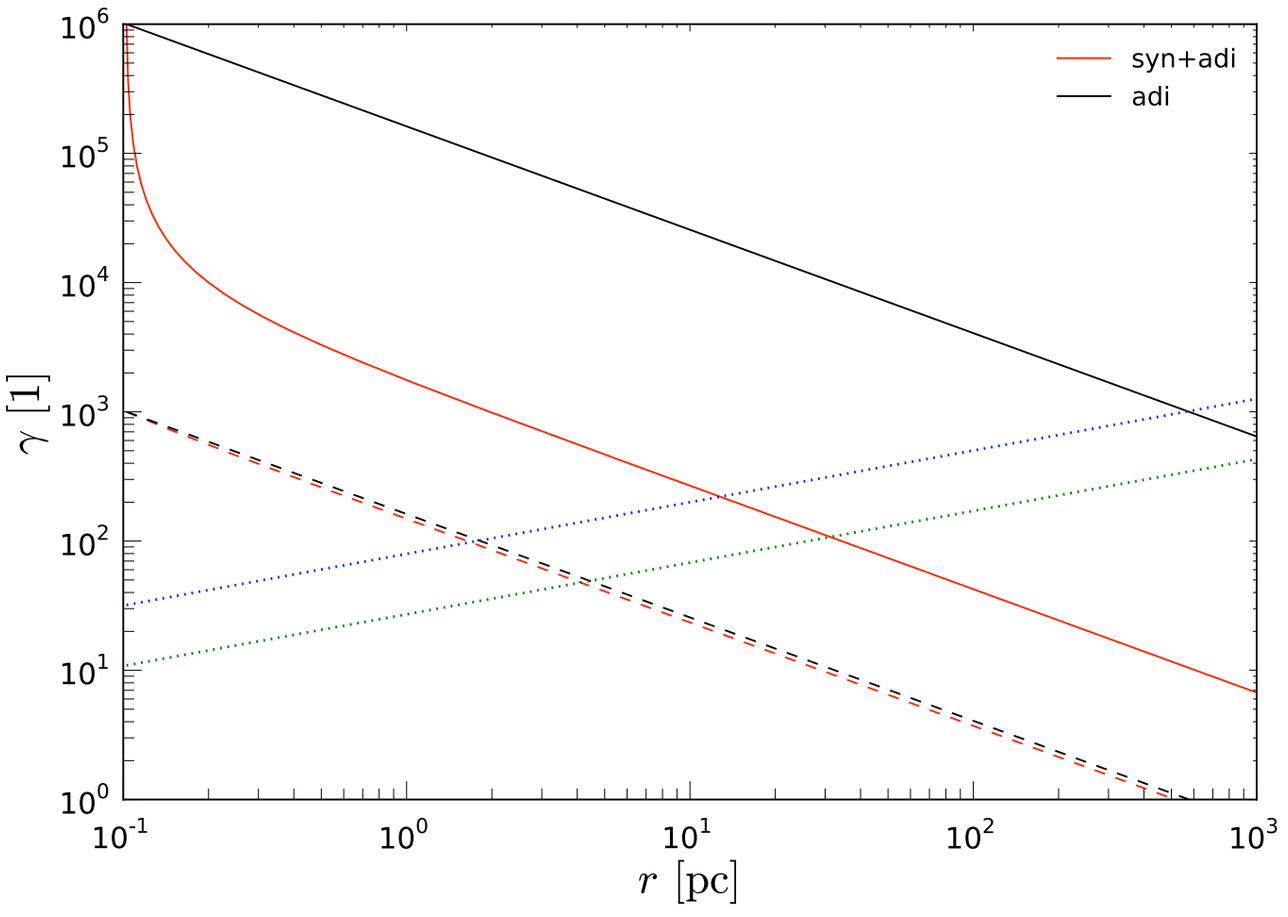
$d_k = 3$ over-pressure of jet

$\rho_b = 1.65 \cdot 10^{-27}$ g/cm^3

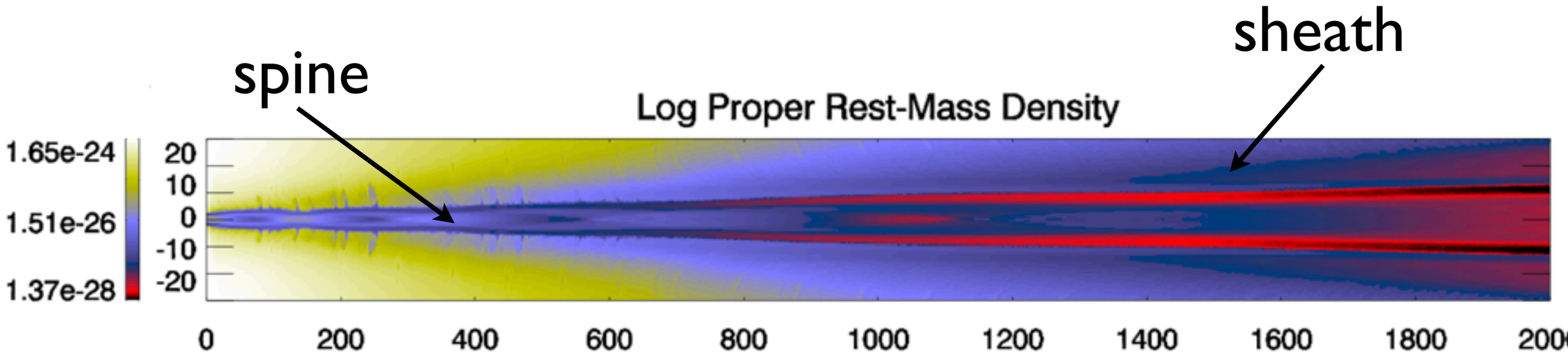
$M_a = 3$ Mach number

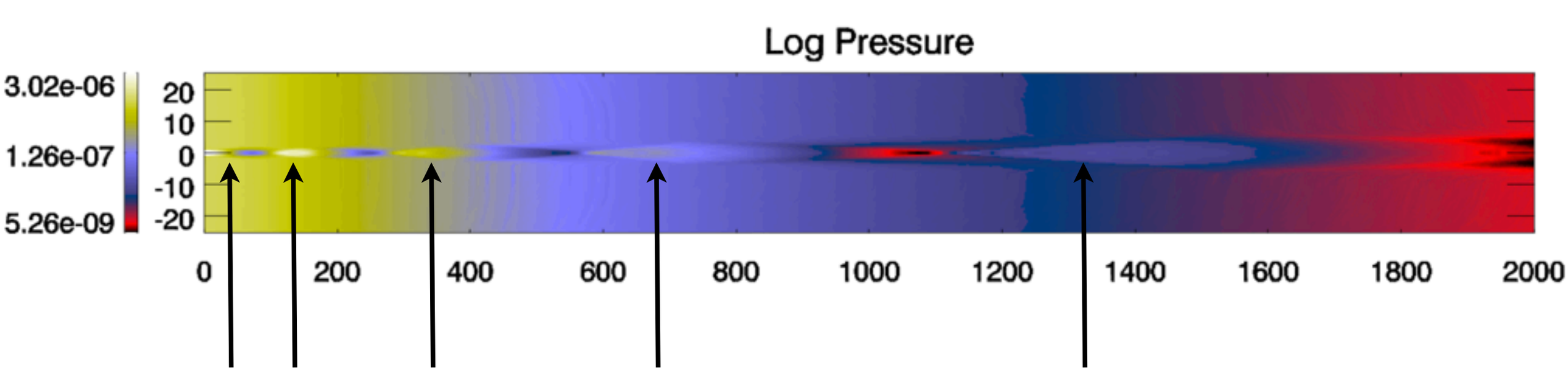
$\widehat{\gamma} = 14/9$ adiabatic index e-p+





eRHD Simulations (thermal particles)





standing shocks

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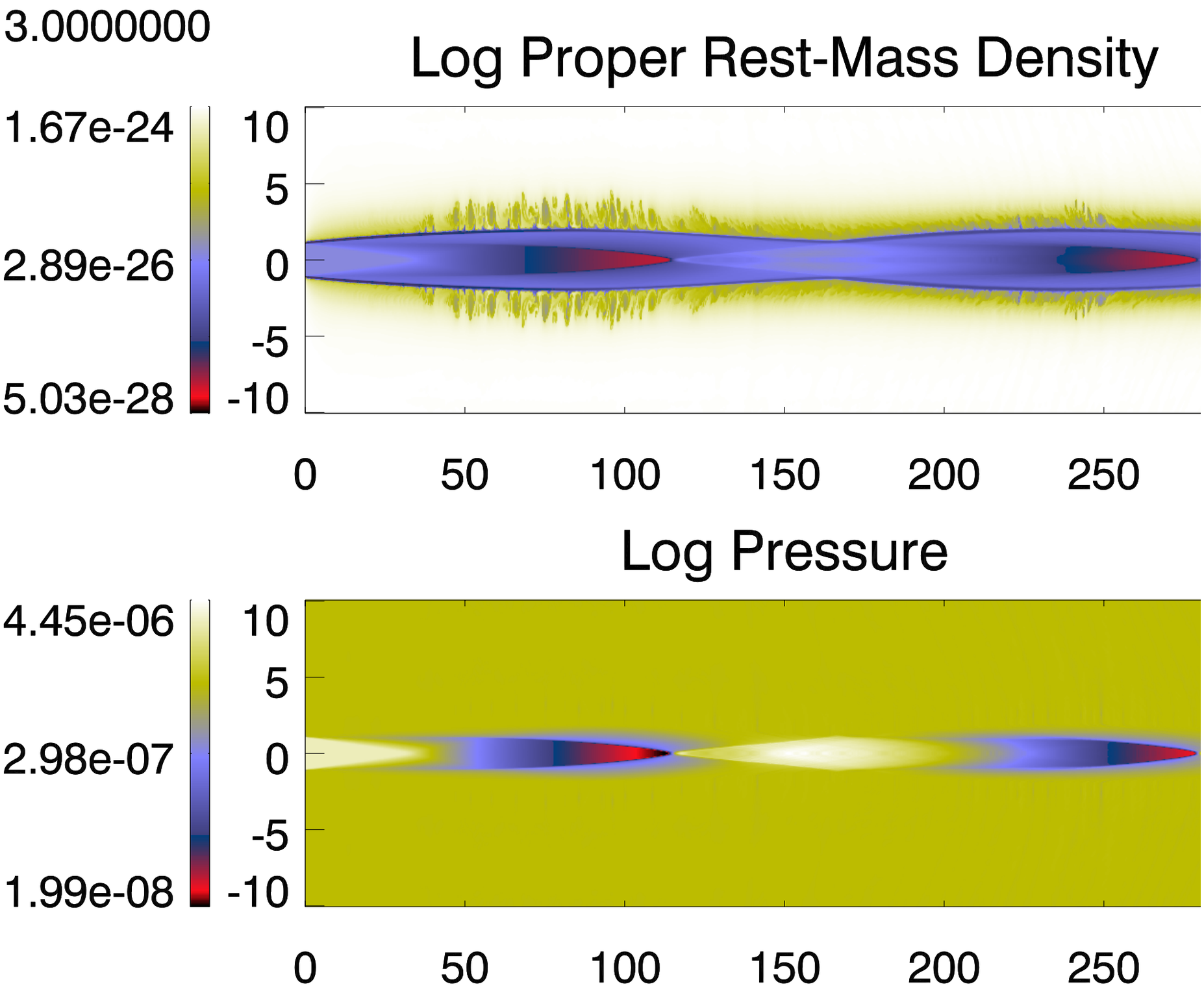

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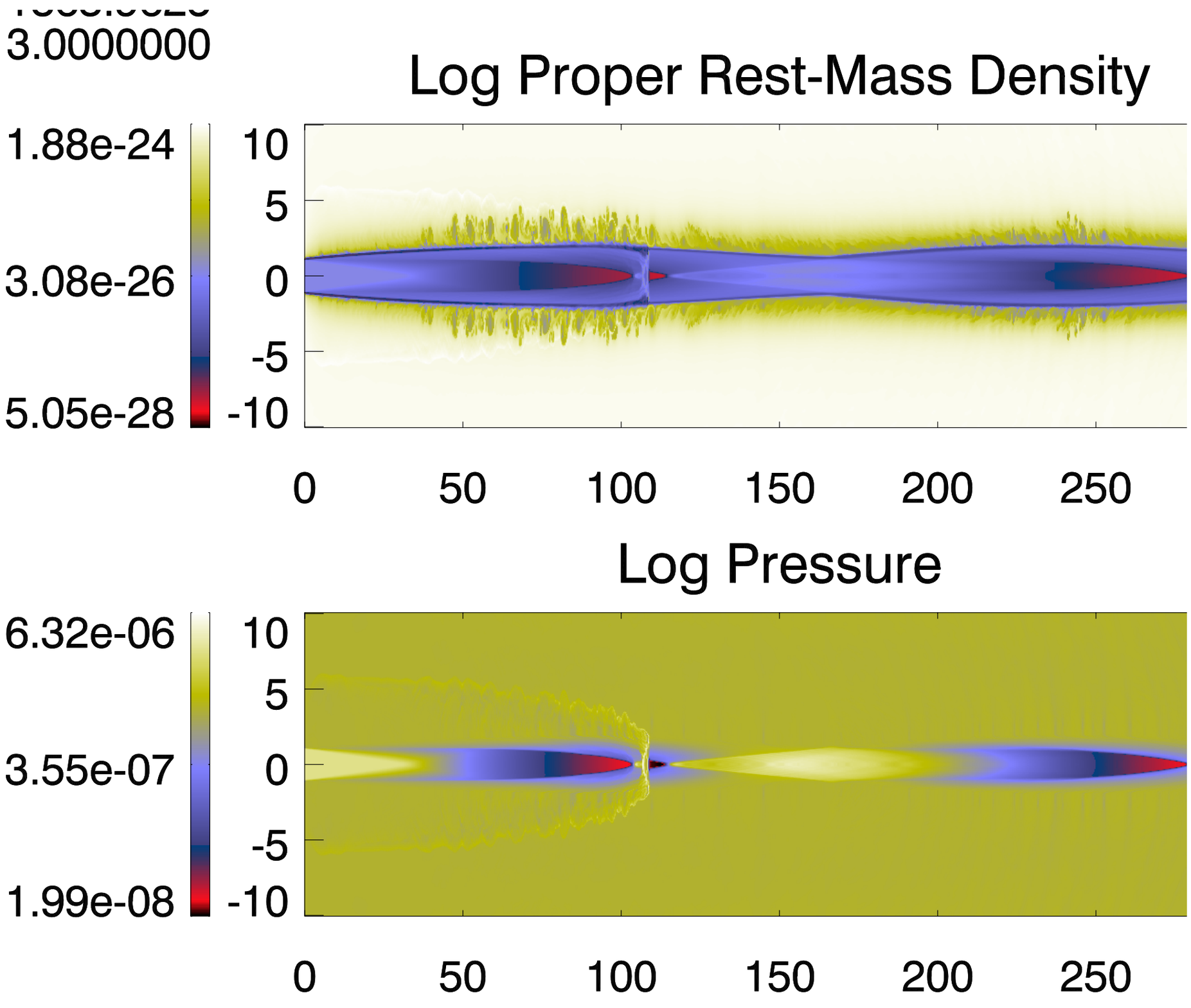

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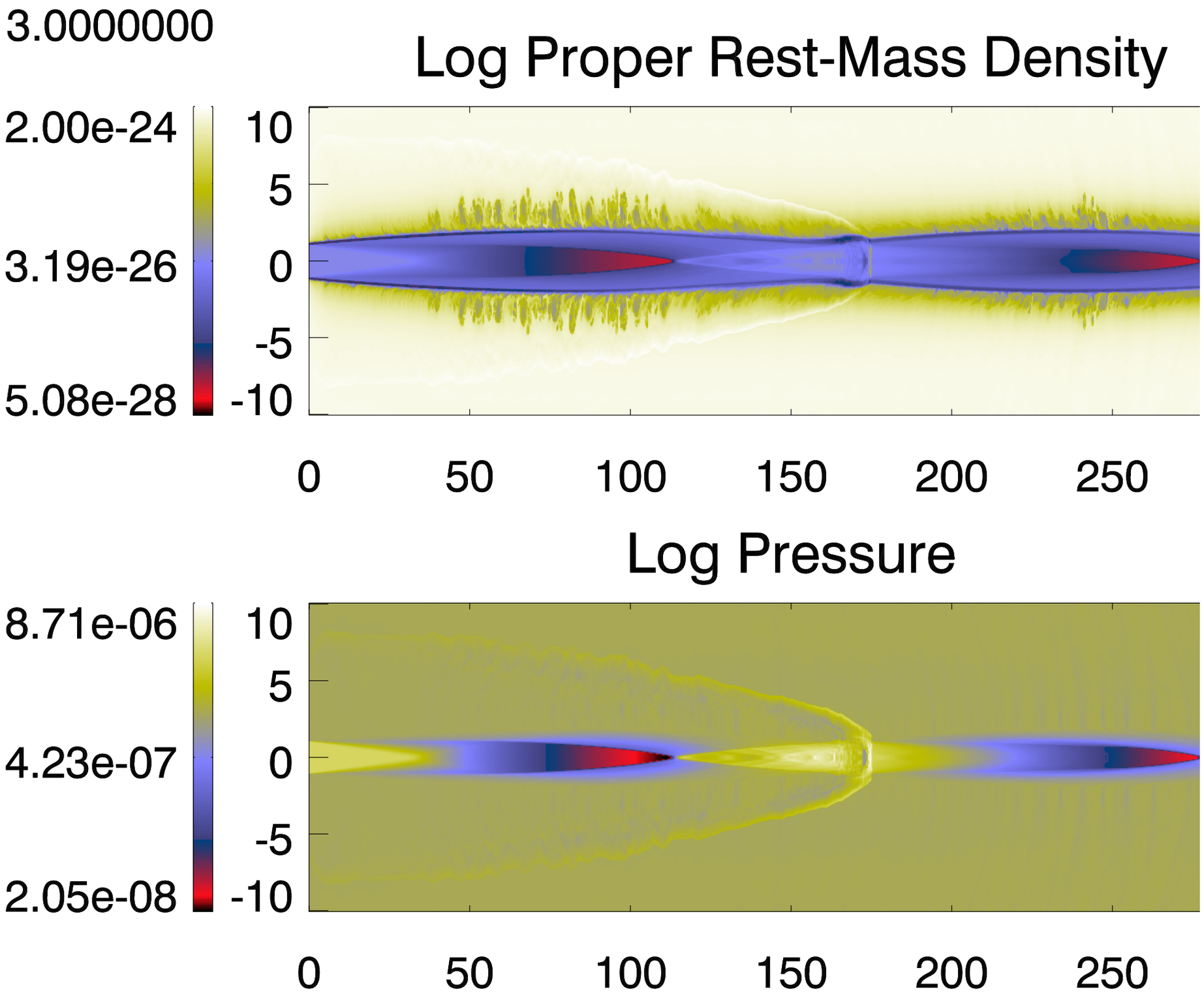
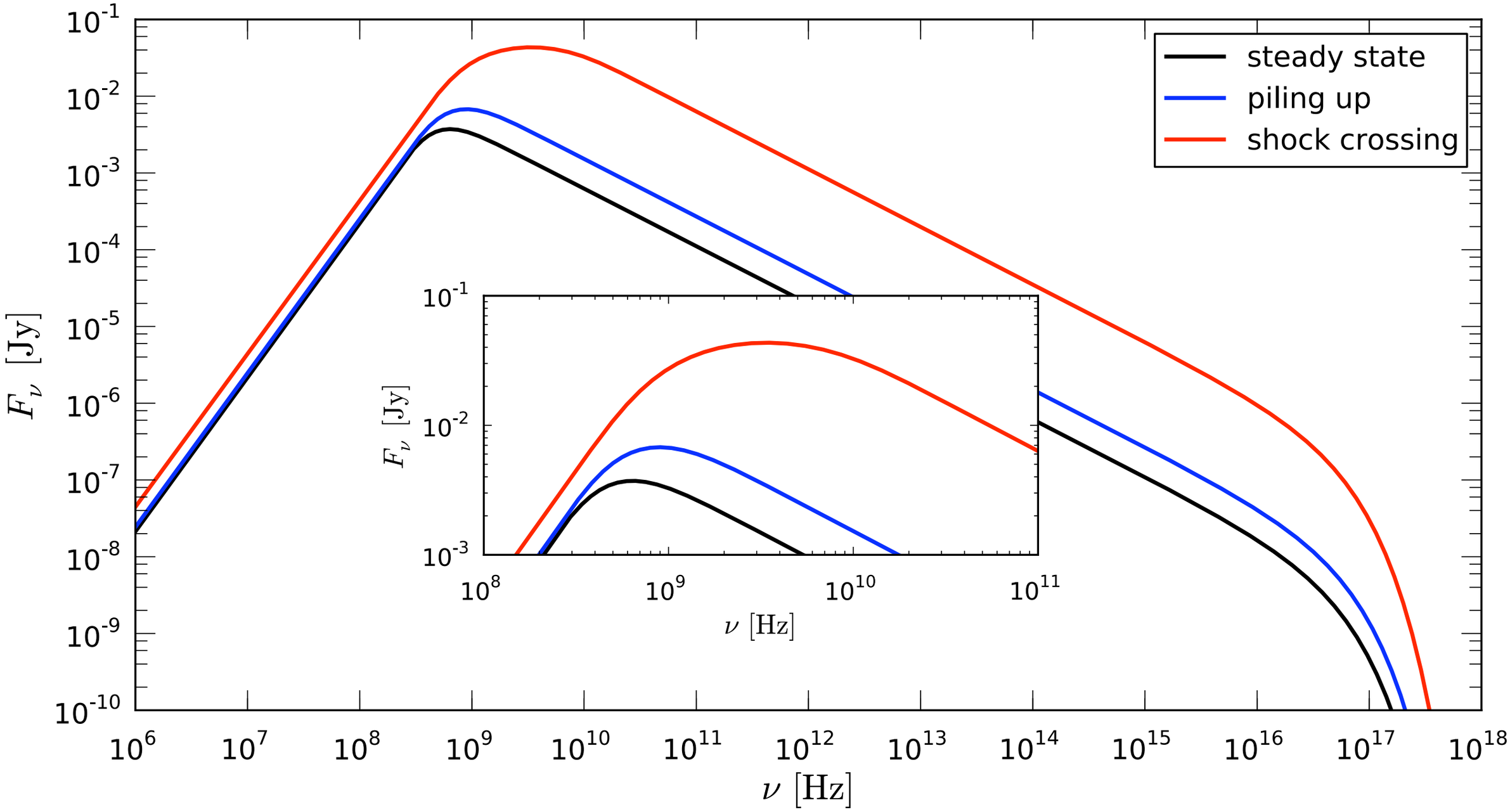


eRHD Simulations (Emission)



Summary

- intrinsic parameters from observations
- internal structure of the jet is important
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to be done

- application to other blazars
- modify the radiative transfer code (2D ray tracing)
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Questions/Suggestions