

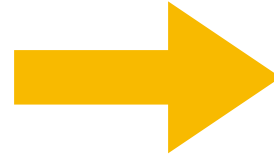
A vibrant, multi-colored jet of light from an active galactic nucleus (AGN) against a starry background. The jet is composed of several distinct lobes in shades of blue, purple, and white, radiating from a central bright point. The background is a dark, deep space filled with numerous small, distant stars.

# High-energy emission and particle acceleration in local radio-loud AGNs

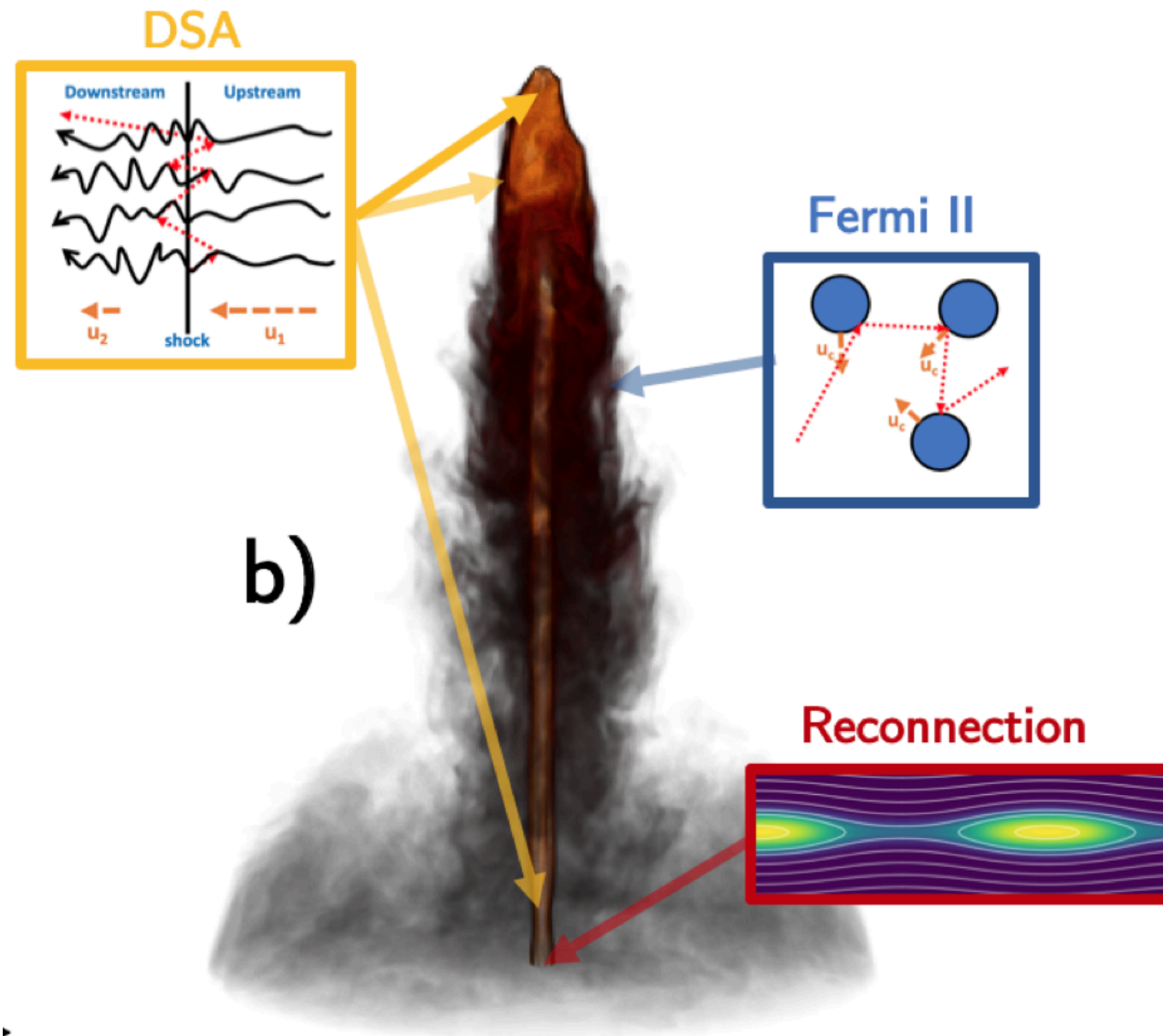
**Fabrizio Tavecchio**  
(INAF-OAB, Italy)



High energy emission



Particle acceleration



Matthews et al. 2020

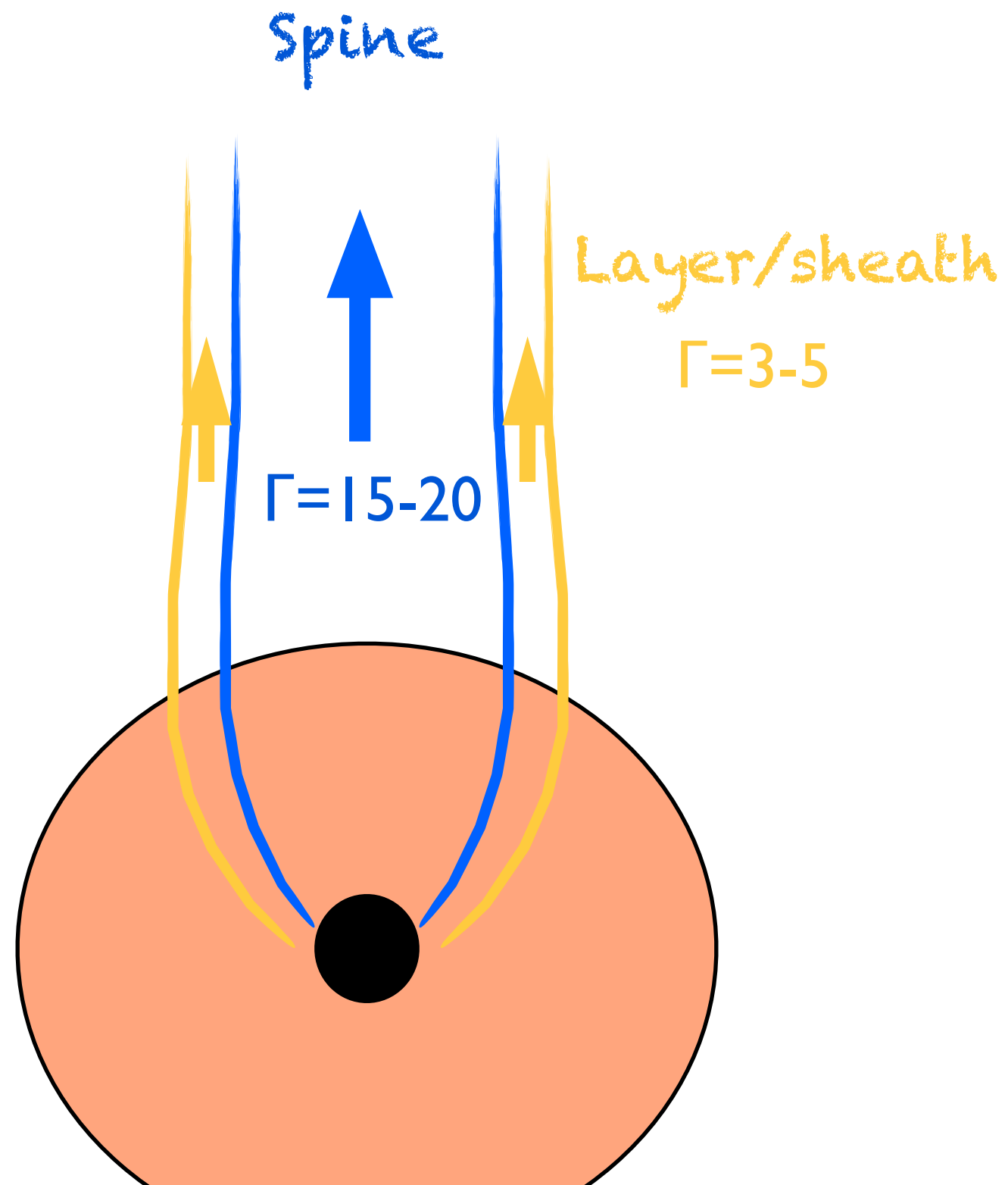
# Some novel ideas/results...

Radiogalaxies: spine-layer and shear acceleration

X-ray polarization of HBLs: stratified shocks?

Instabilities at recollimation shocks - extreme blazars

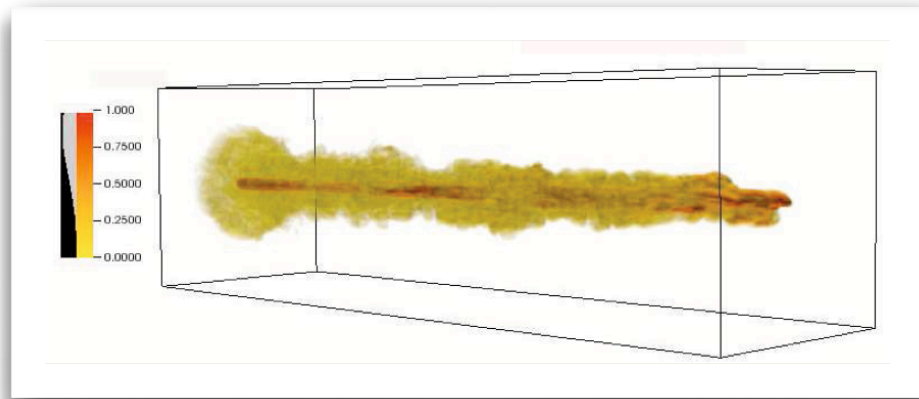
# Structured jets



Ghisellini, FT and Chiaberge 2005  
Tavecchio & Ghisellini 2008



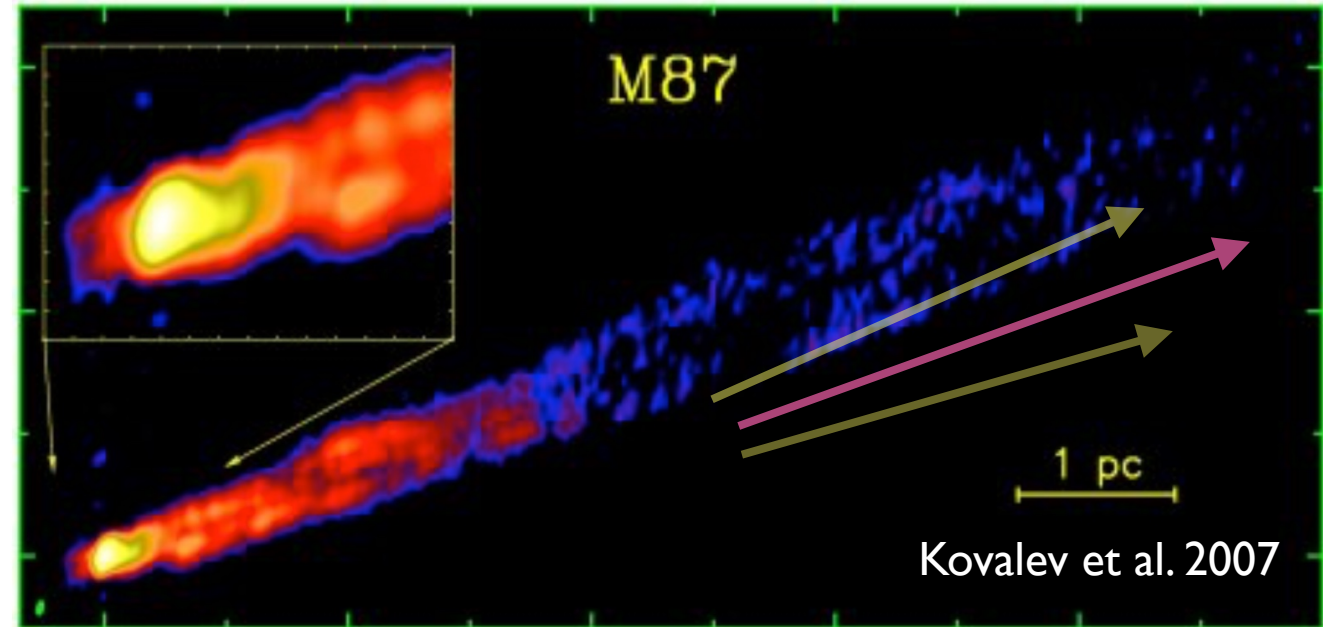
# Structured jets



**Simulations predict spine-layer structure**

**Entrainment/instabilities** e.g. Rossi et al. 2008

**Acceleration process** e.g. McKinney 2006



## Limb brightening

Mkn 501, Mkn 421, M87,  
NGC 1275

Laing 1996

Giroletti et al. 2004

Piner & Edwards 2014

Pushkarev et al. 2005

Clausen-Brown 2011

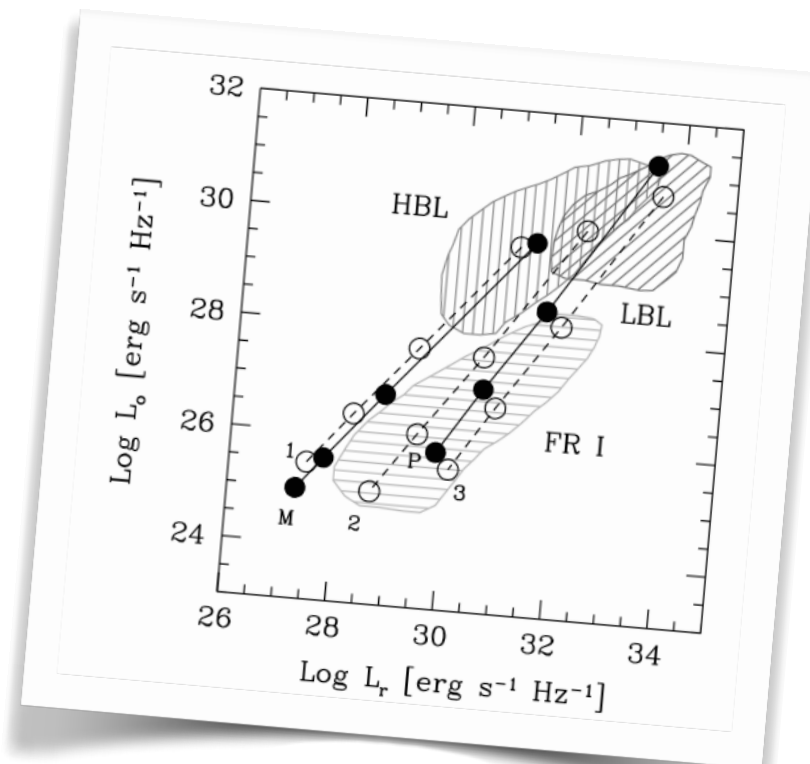
Murphy et al. 2013

## Unification requires velocity structures

Chiaberge et al. 2000

Meyer et al.

Sbarrato et al. 2014

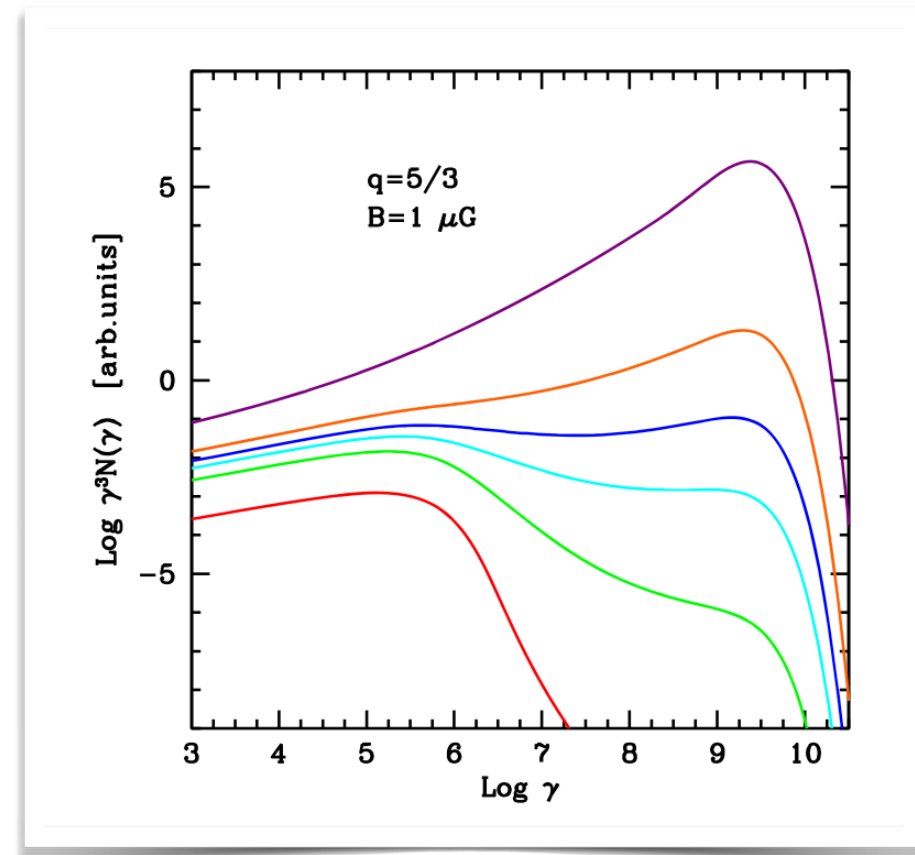
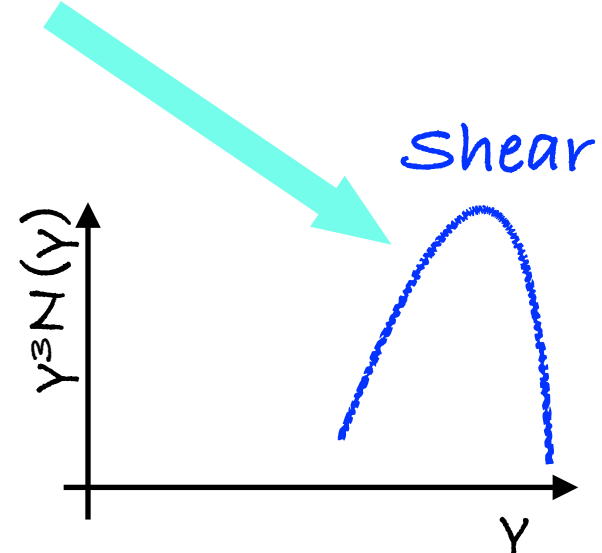
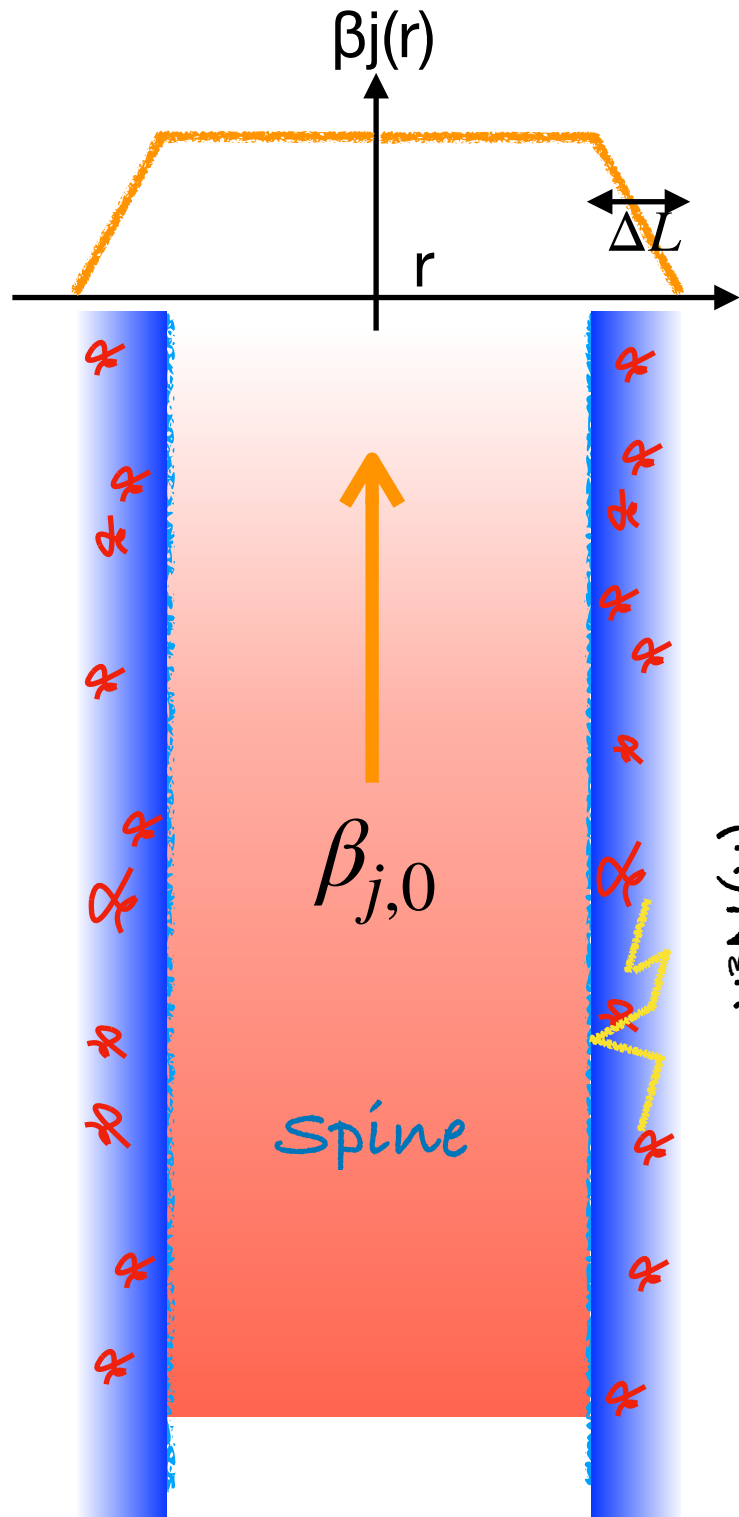


*similar suggestions for GRBs...*

# Shear acceleration

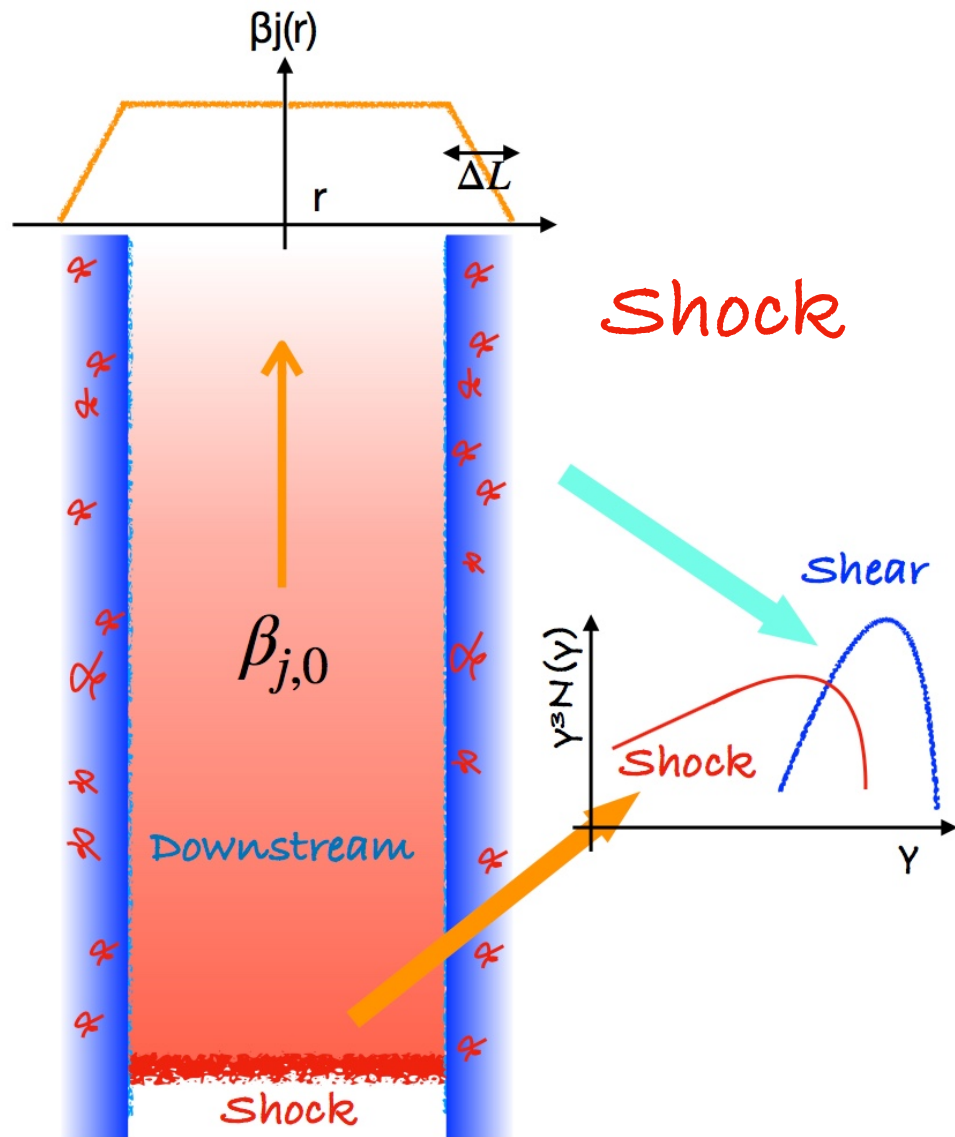
Rieger & Duffy 2004, 2019, 2021  
 Webb et al. 2018, 2020  
 Liu et al. 2017

Fermi-II like process  
 Scattering on turbulence



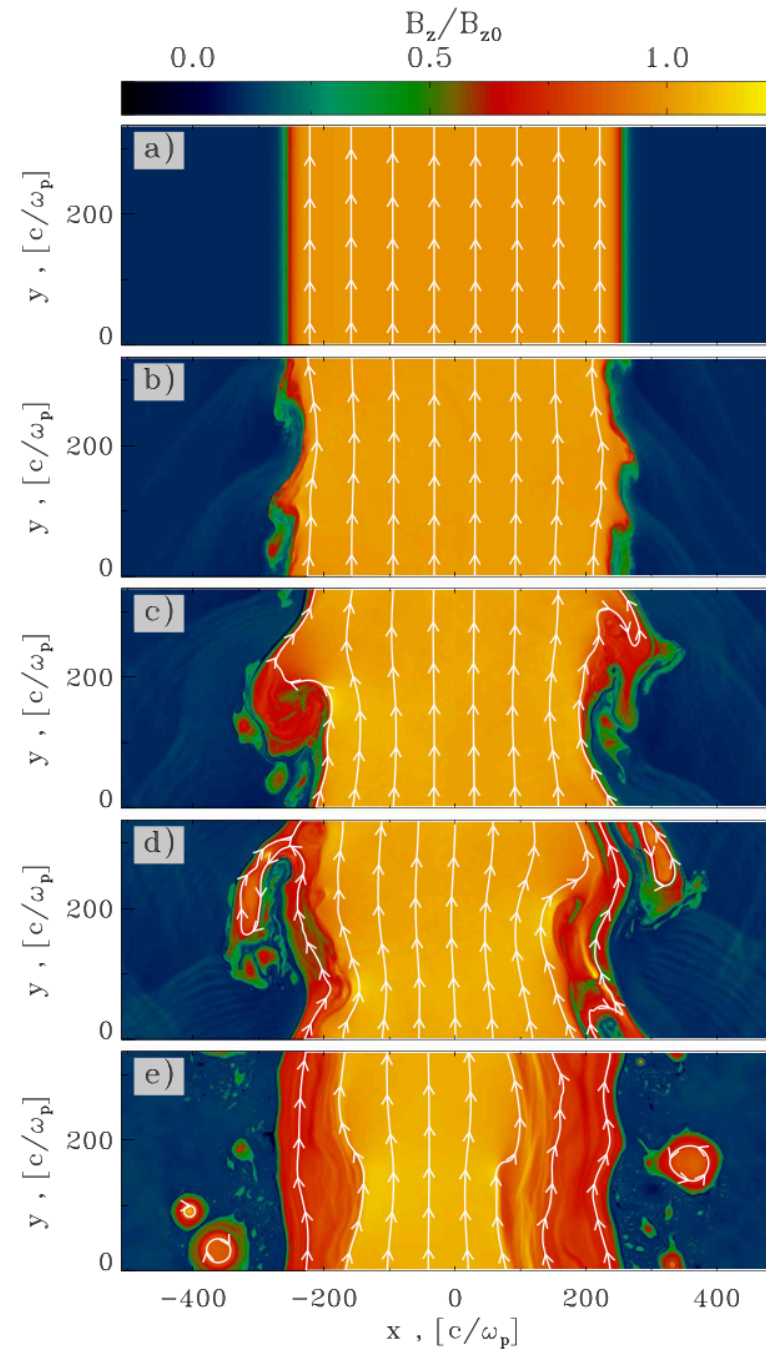
# Shear acceleration

Injection problem



Tavecchio 2021

Instabilities

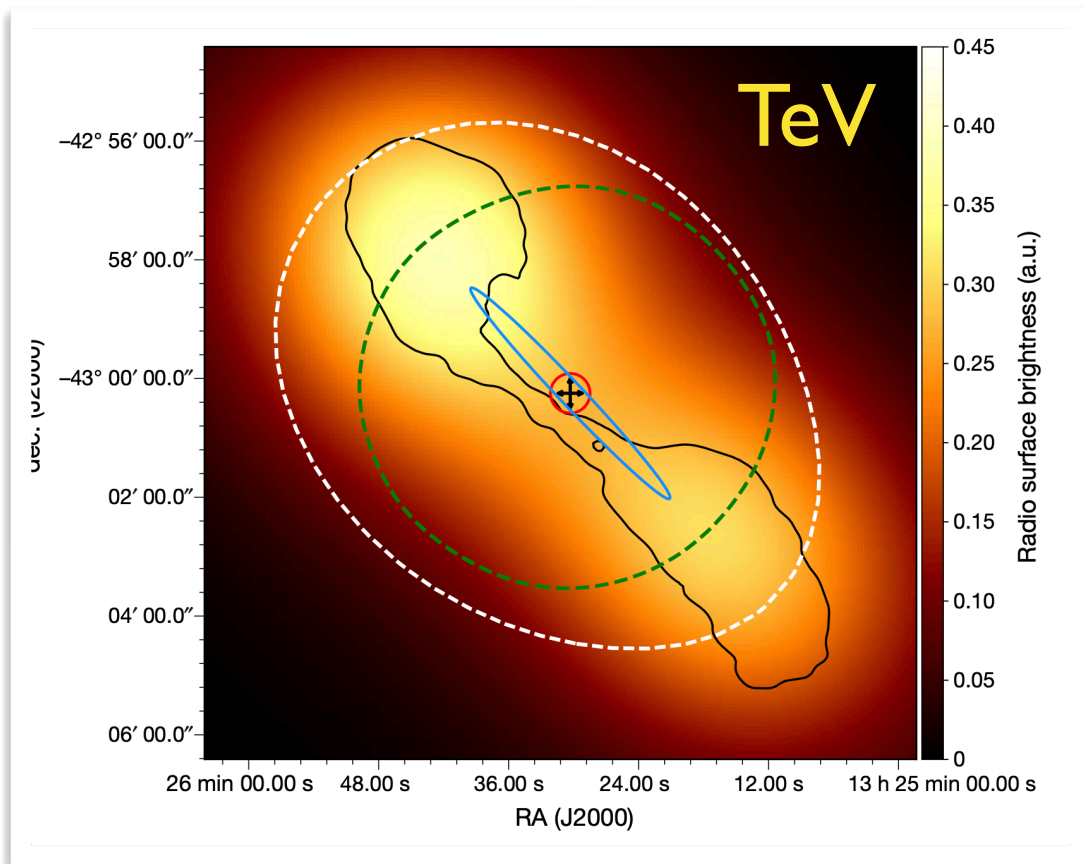


Sironi et al. 2021



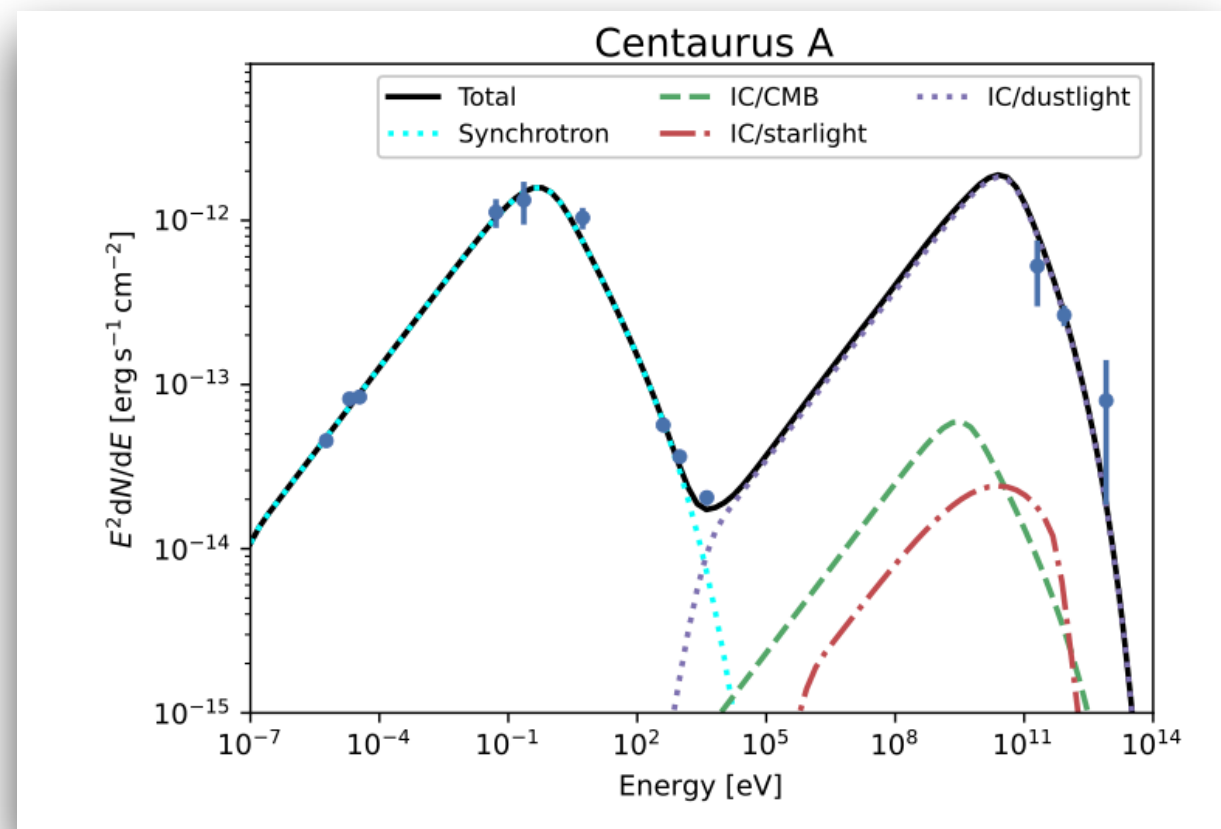
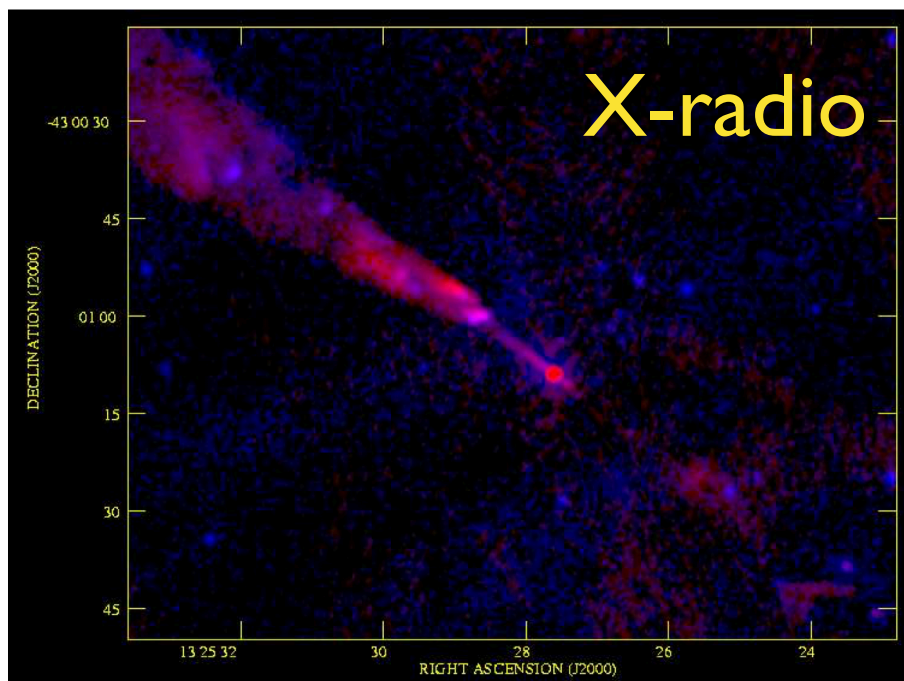
HESS Coll. 2020

# Cen A

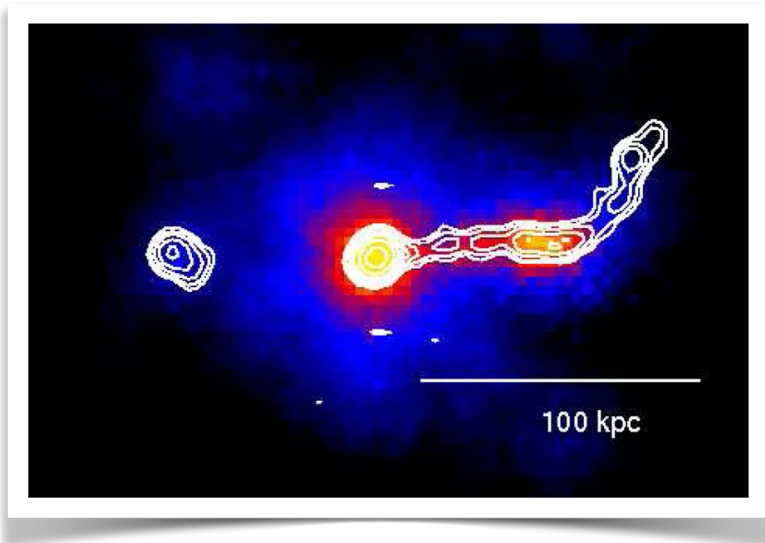


*Mildly relativistic jet*

Wang et al. 2021

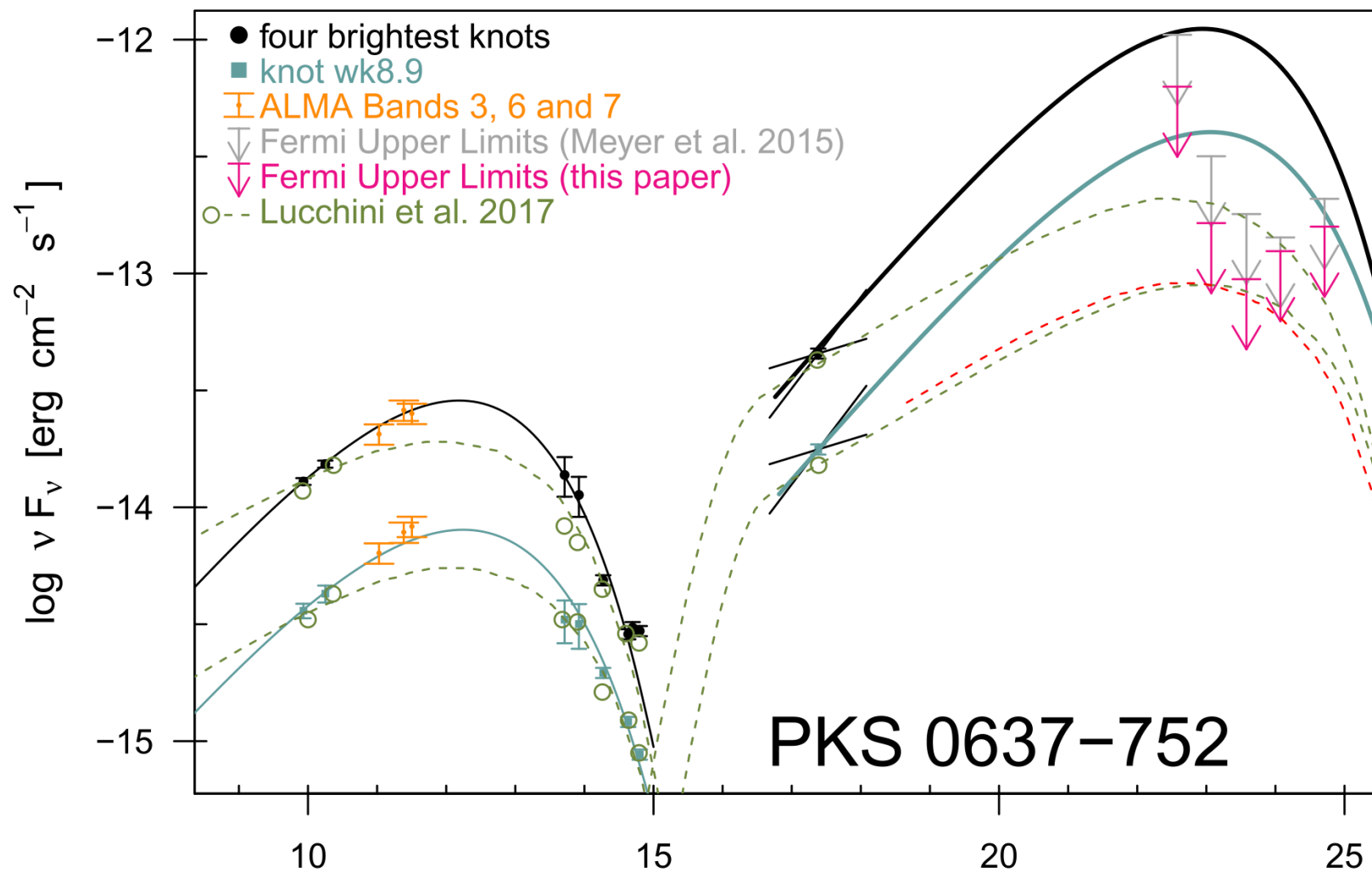


Hardcastle et al. 2003



# PKS 0637-752

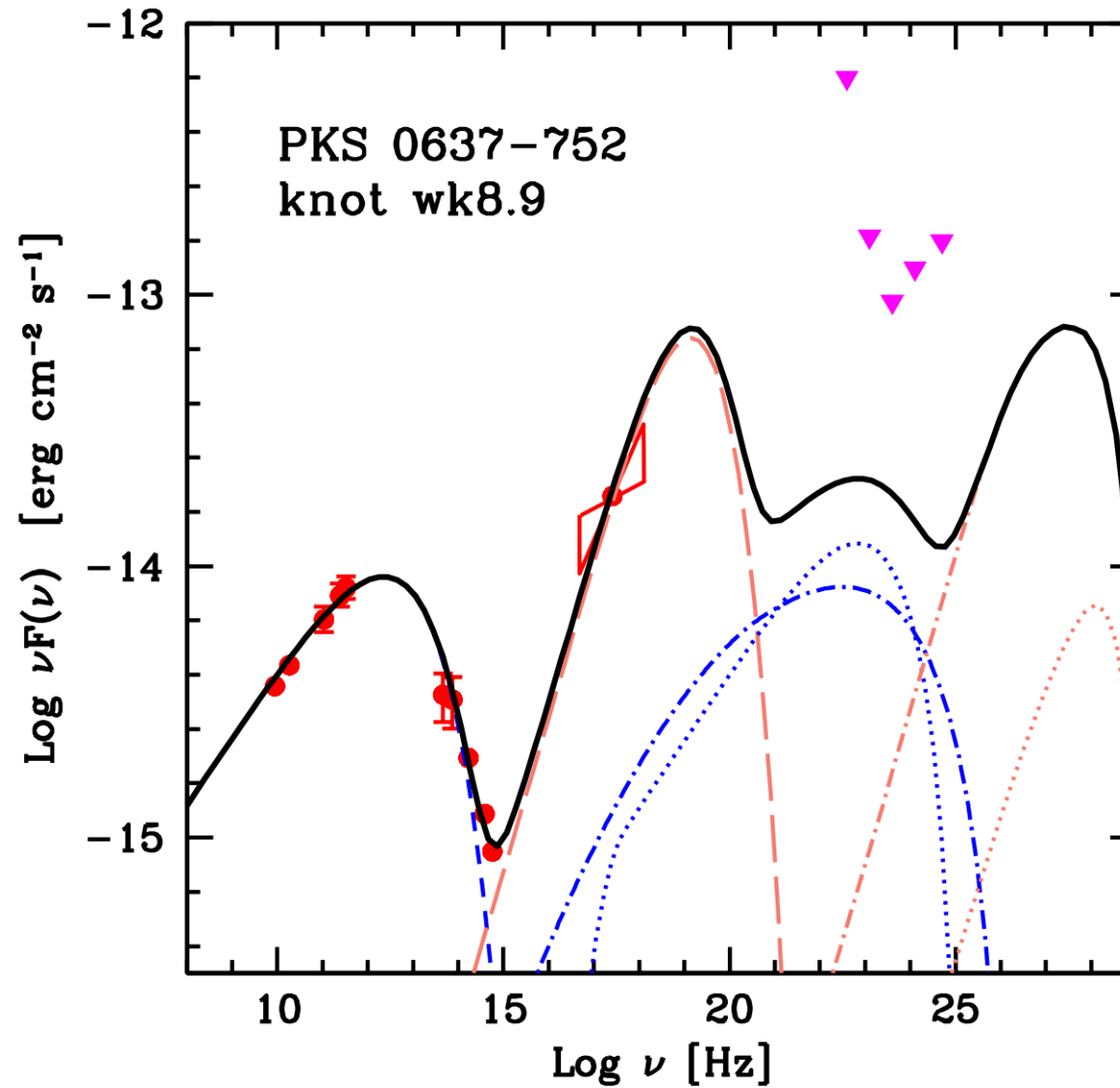
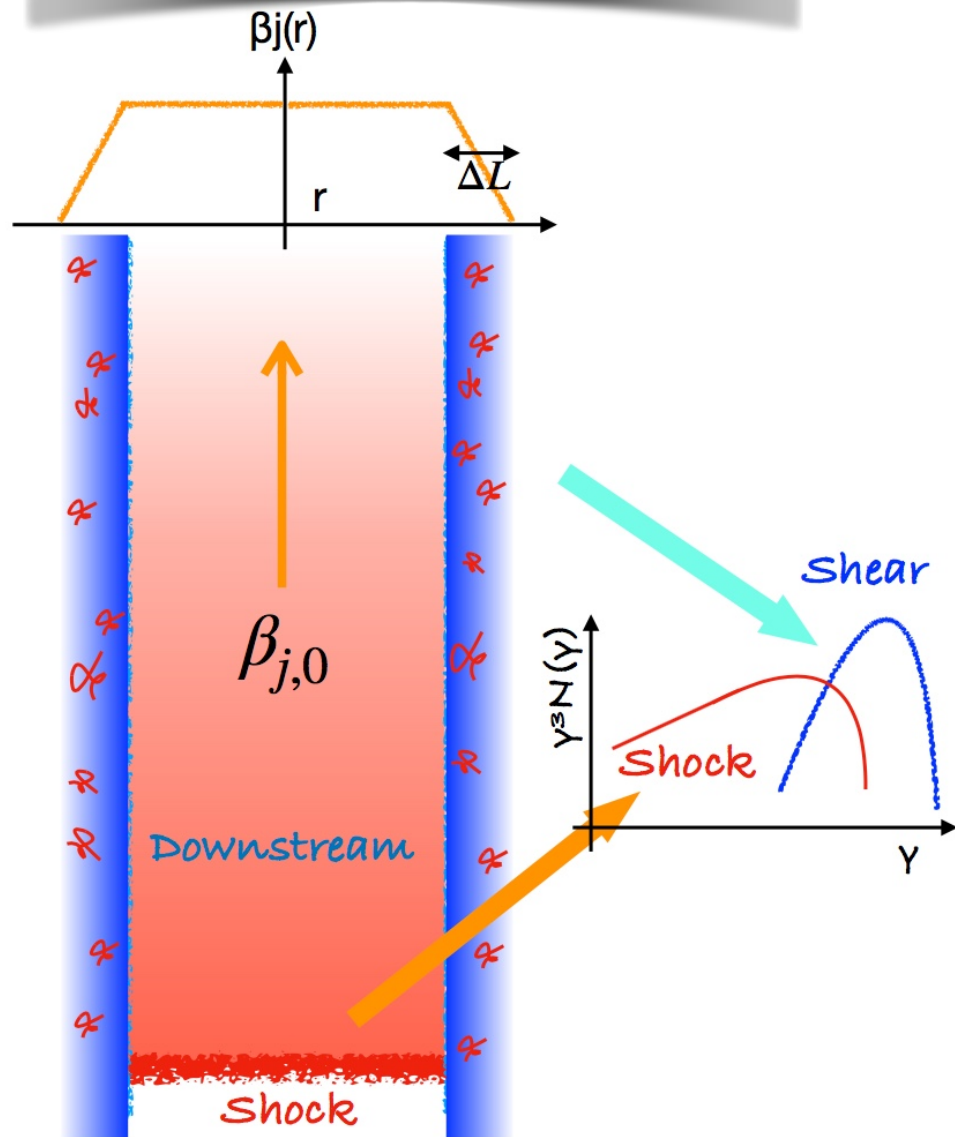
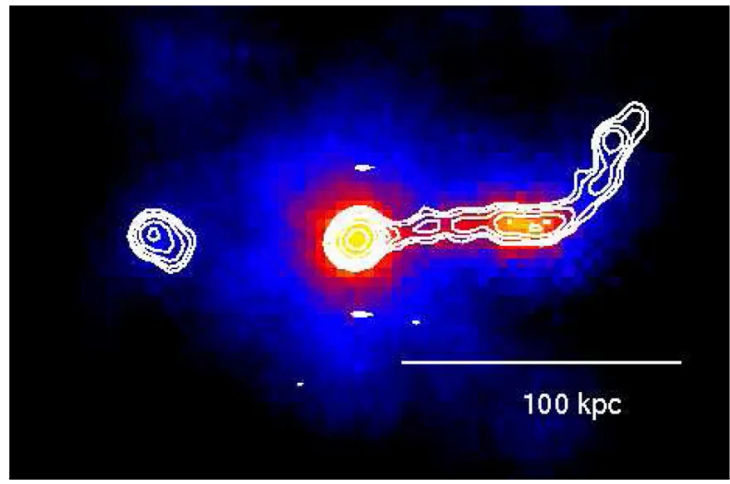
The classical IC/CMB model is ruled out



But still valid for high-z sources, Ighina et al. 2022

# PKS 0637-752

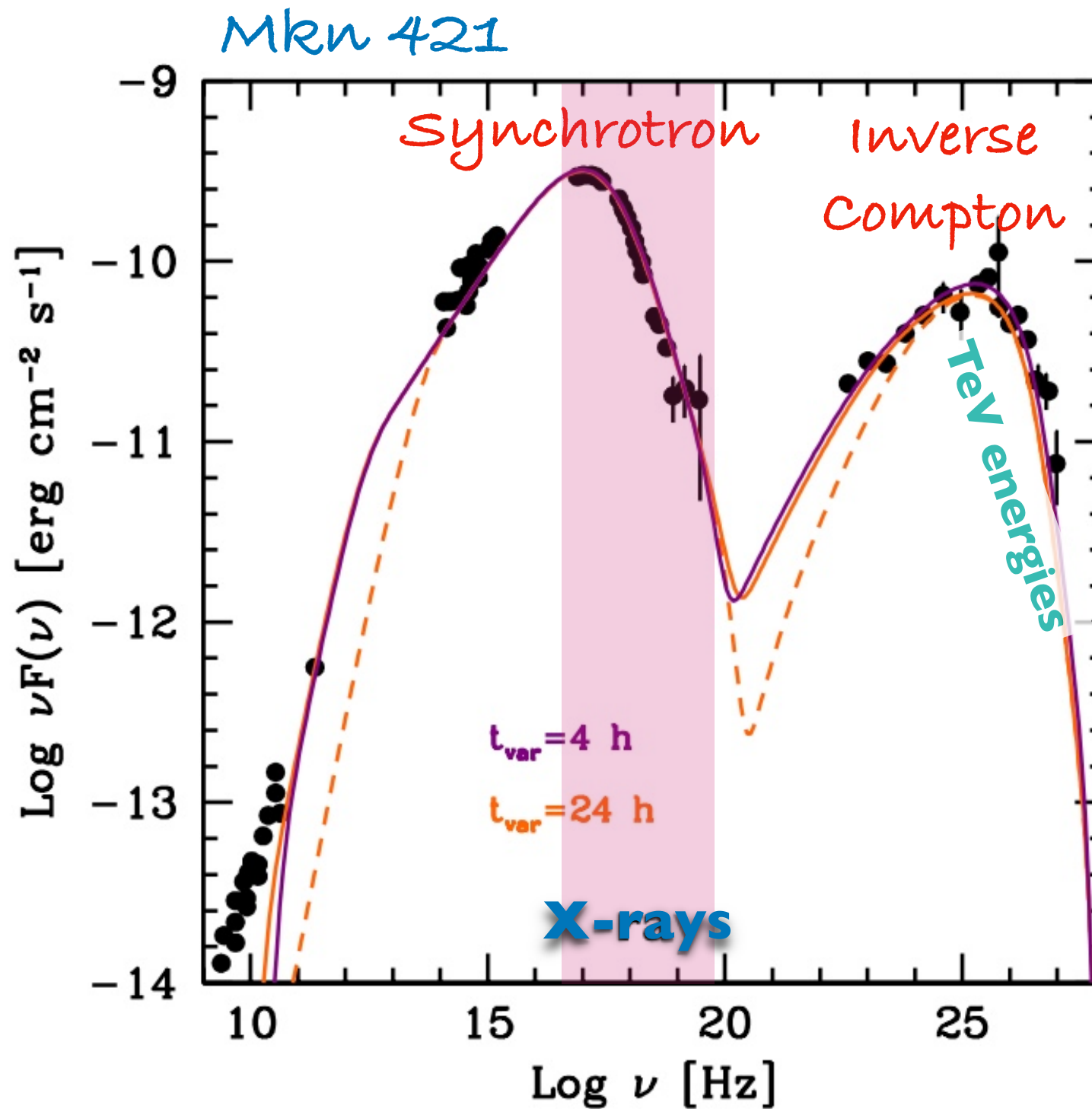
$\Gamma_j = 1.7$   
 $B = 10 \mu\text{G}$   
 $\Delta L = 0.15 R_j$



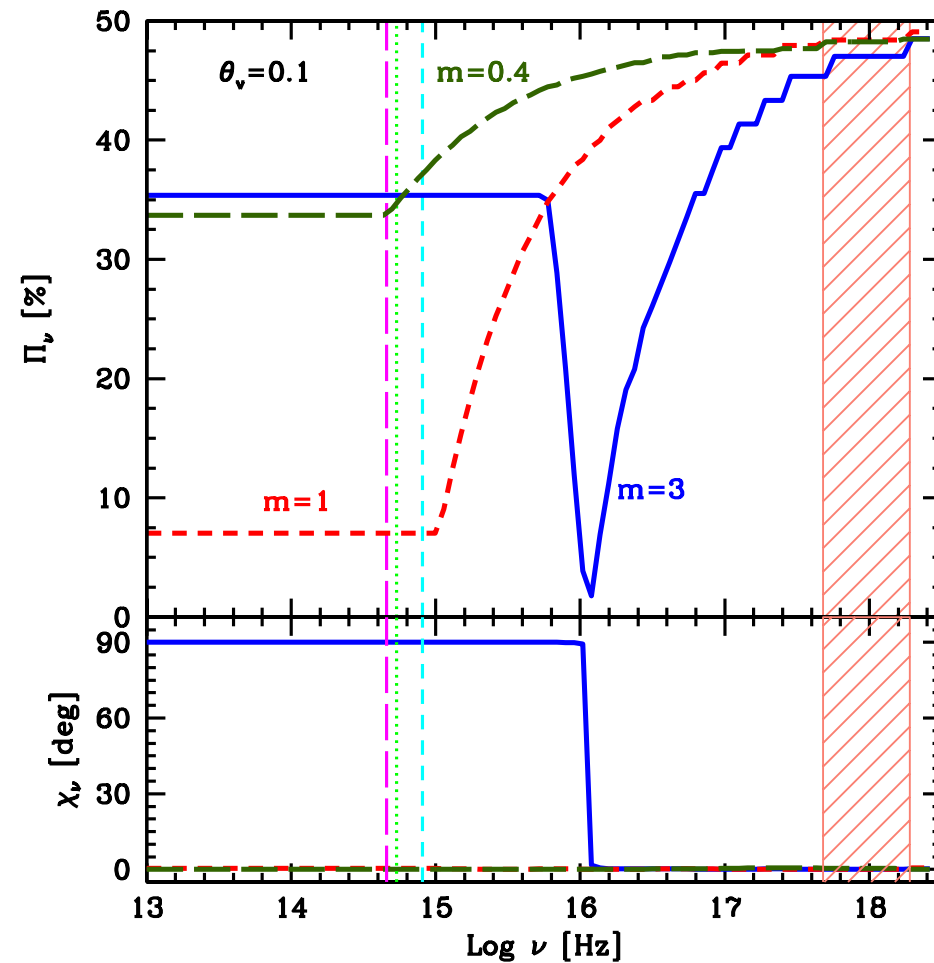
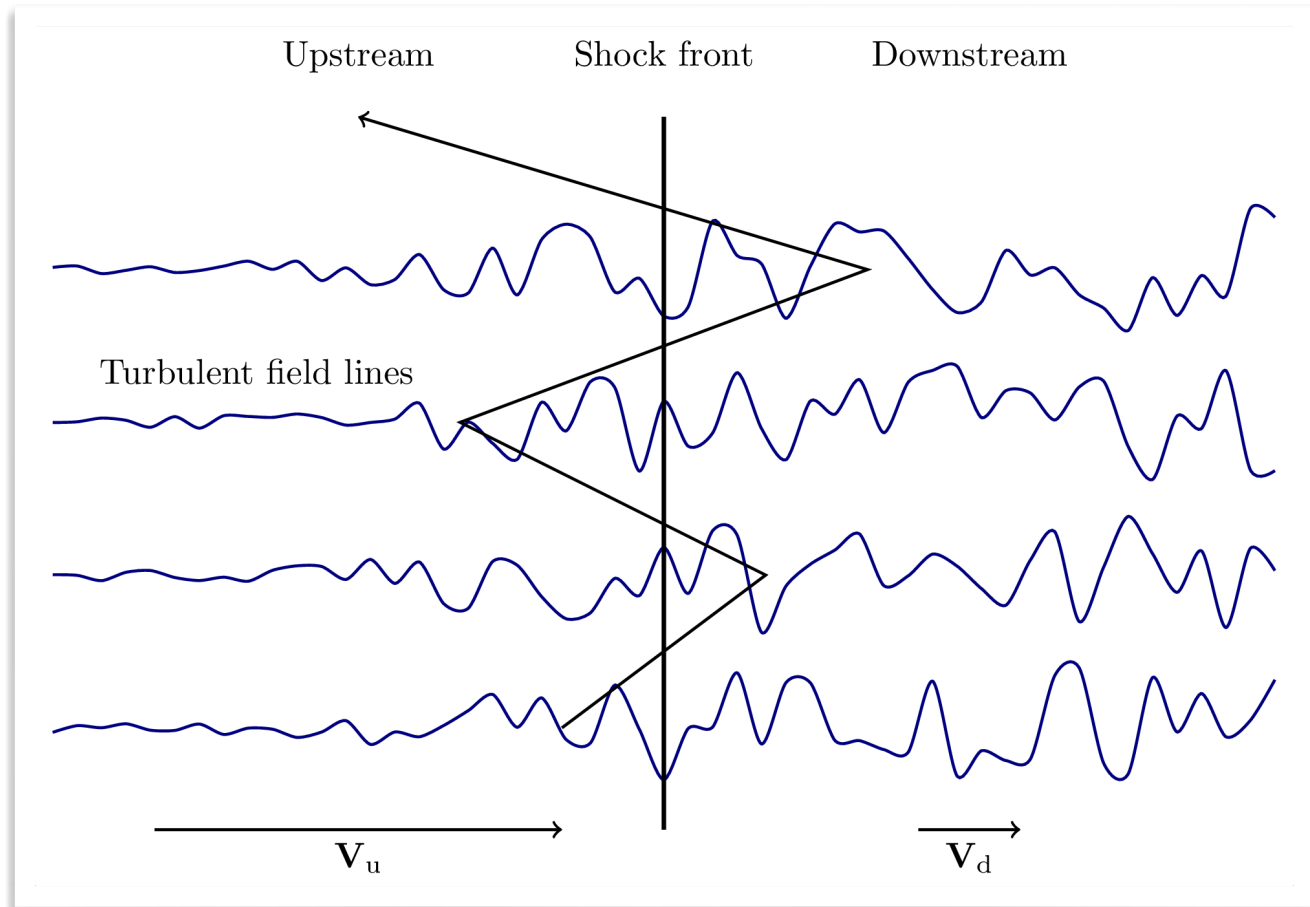
But caveats (see e.g. Breiding et al. 2022)  
 X ray emission narrower than radio...  
 see Paola's talk ( $\gamma = 10^{10}$  on the axis!)



# HBLs: The most extreme accelerators



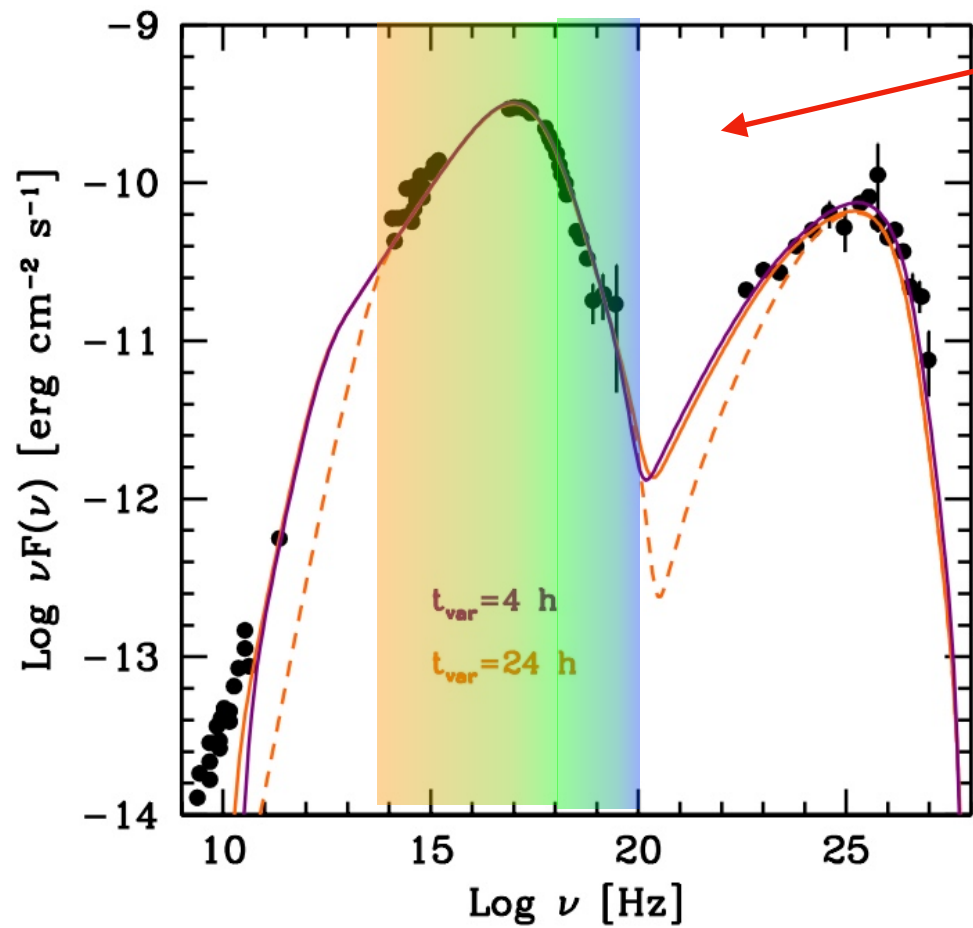
# Particle acceleration at shocks



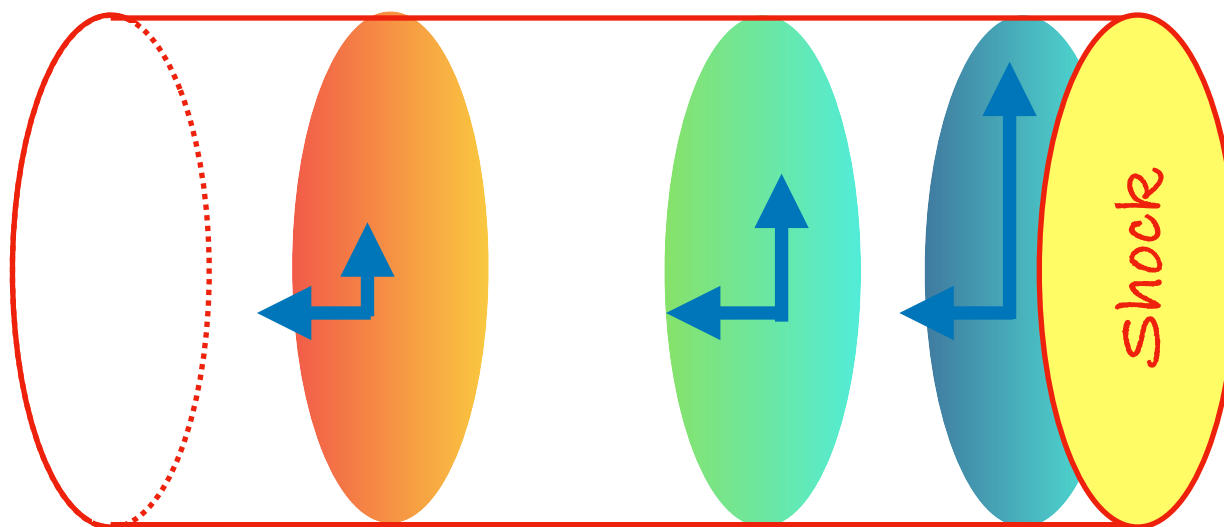
Efficient acceleration requires  
(self-produced)  
magnetic fields close to the  
front

Signature: high  
polarization in X-rays,  
lower at low frequency

Tavecchio et al. 2018, 2020



$$\nu_s \propto \gamma^2 B$$

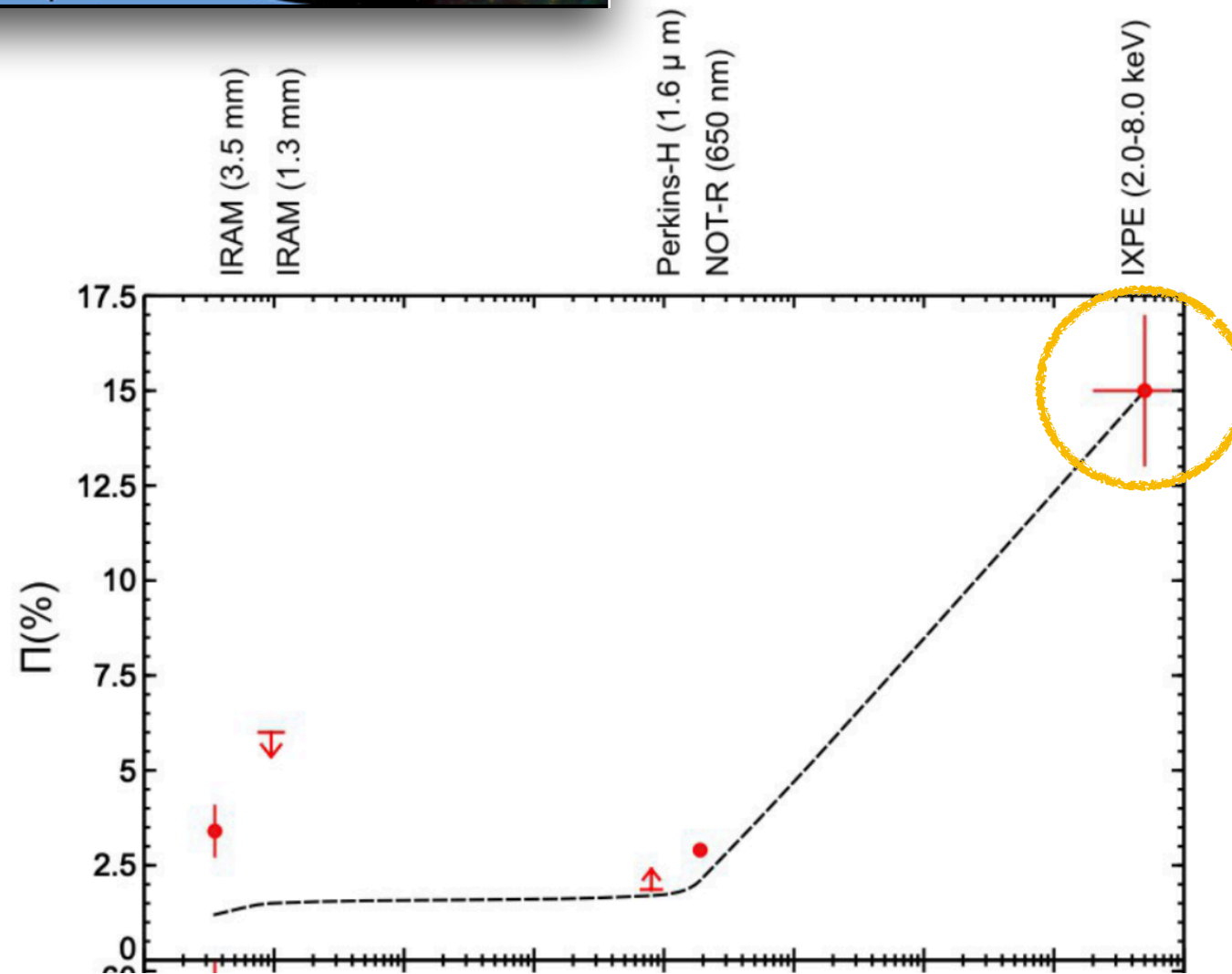




# Hints from IXPE



Di Gesu (+Tavecchio) et al. 2022



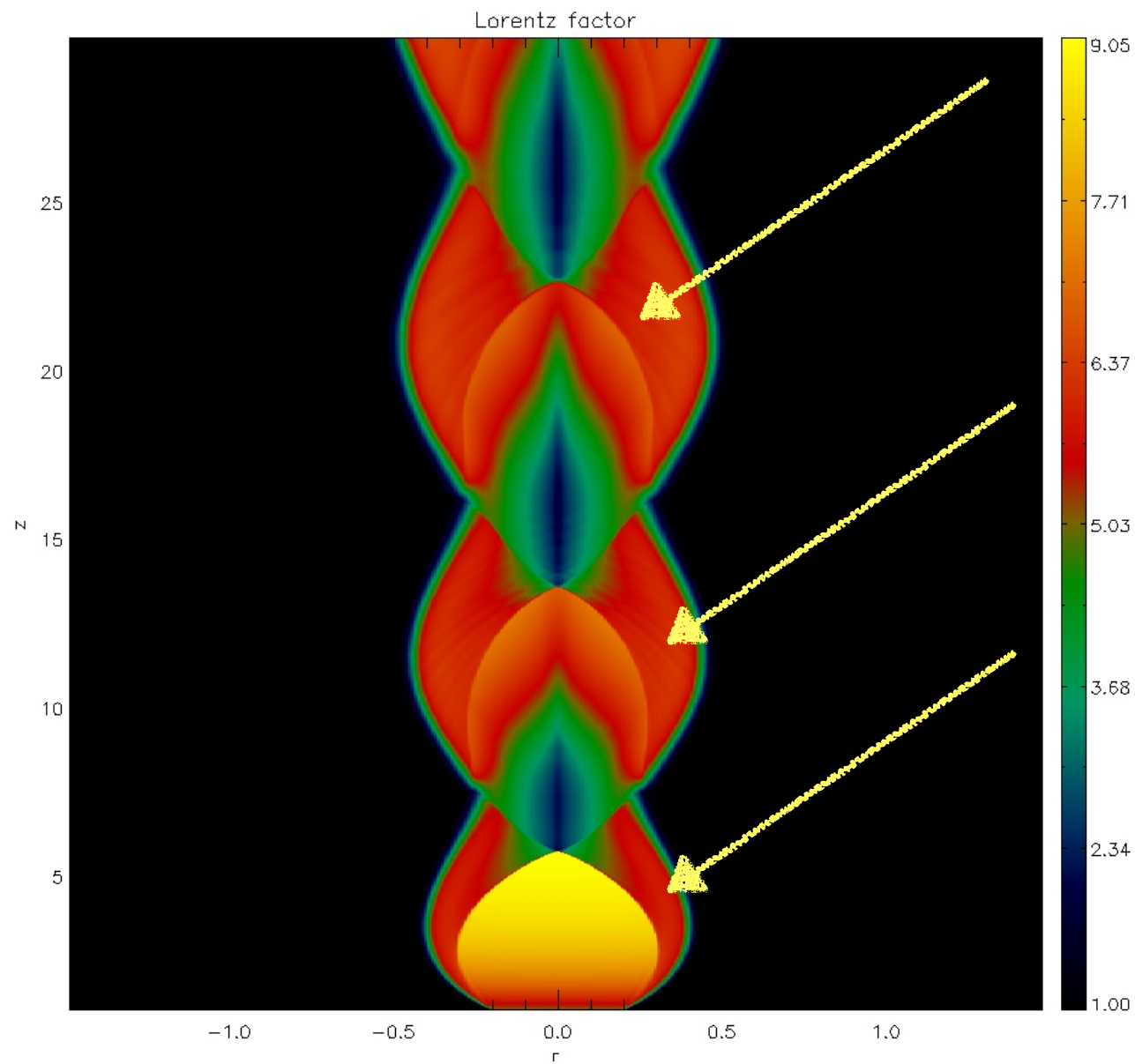
First IXPE observation of Mkn 421 in April 2022

Similar results for Mkn 501 (Liodakis et al. 2022)

Stratified shock?

# Recollimation shocks

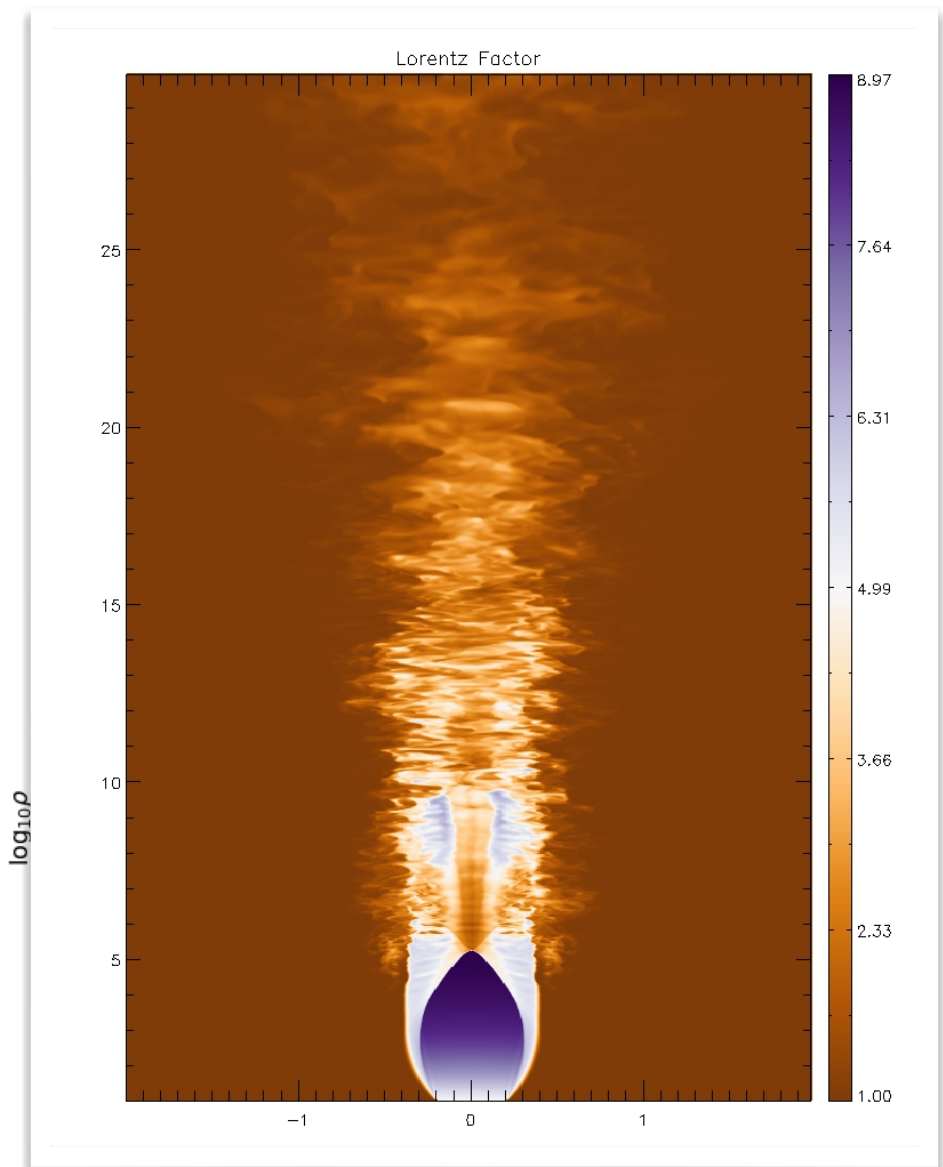
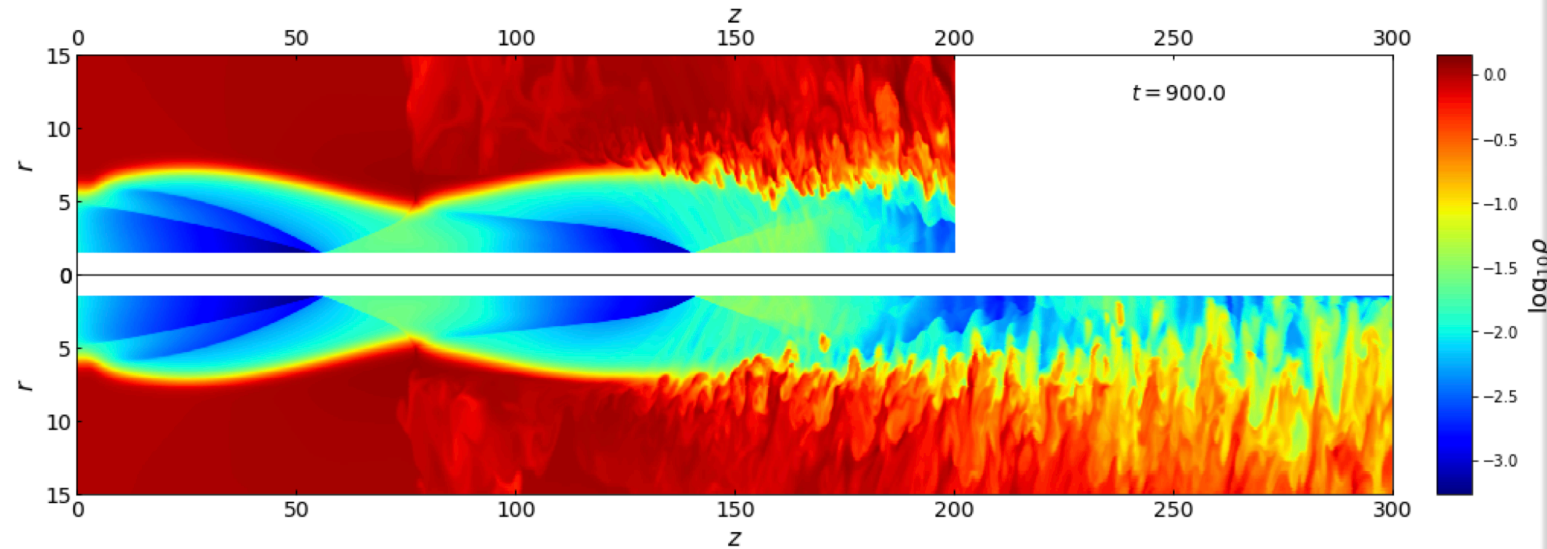
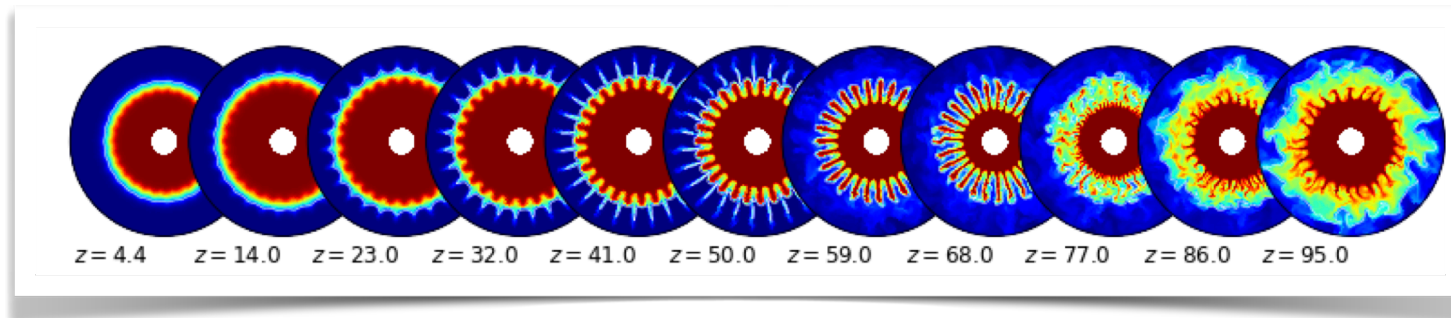
*2D simulations*  
*Chain of recollimation shocks*



# (3D) Instabilities and recollimation

Abolmasov & Bromberg 2023

HD jet



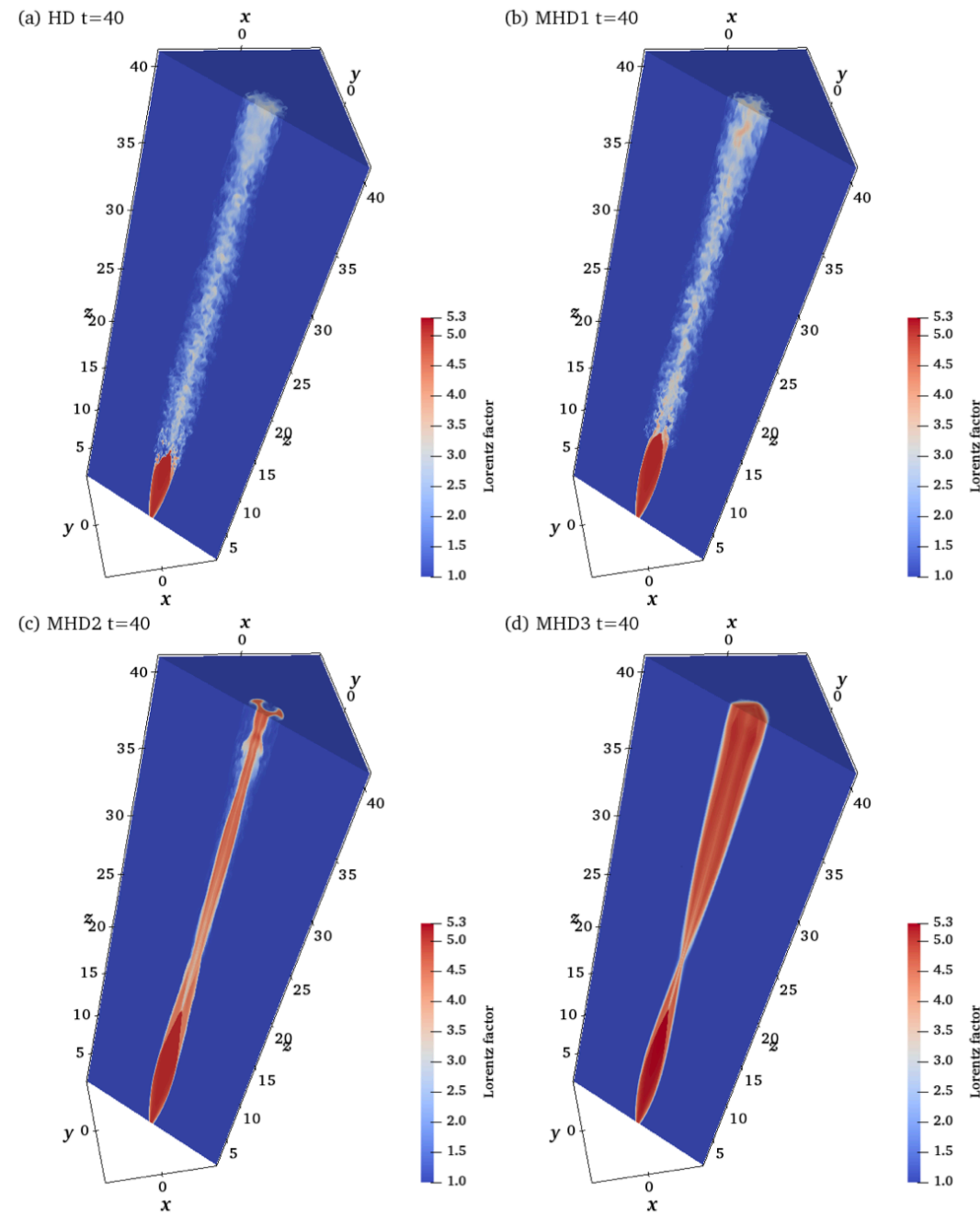
Costa et al. in prep

Rayleigh-Taylor/centrifugal instability



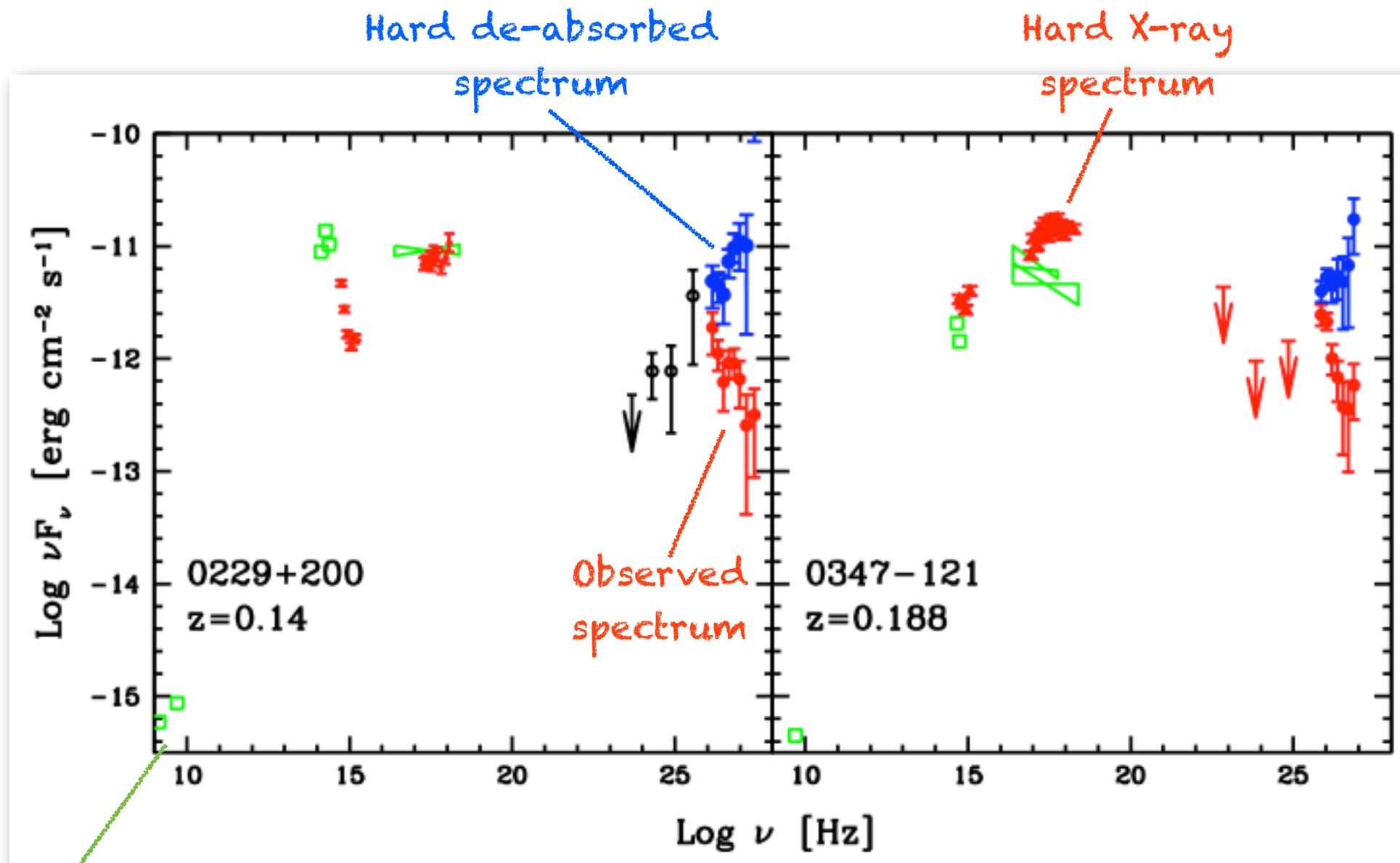
# (3D) Instabilities and recollimation

Low magn.



High magn.

# Extreme BL Lacs

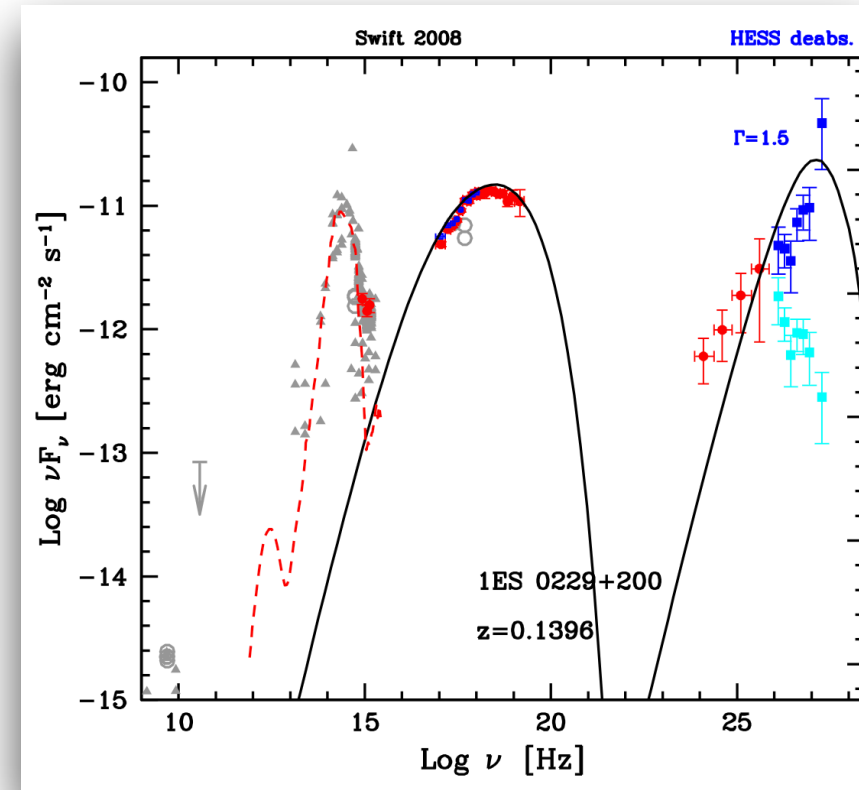
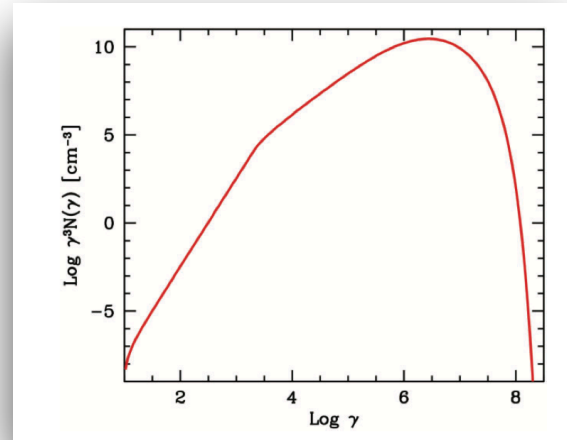
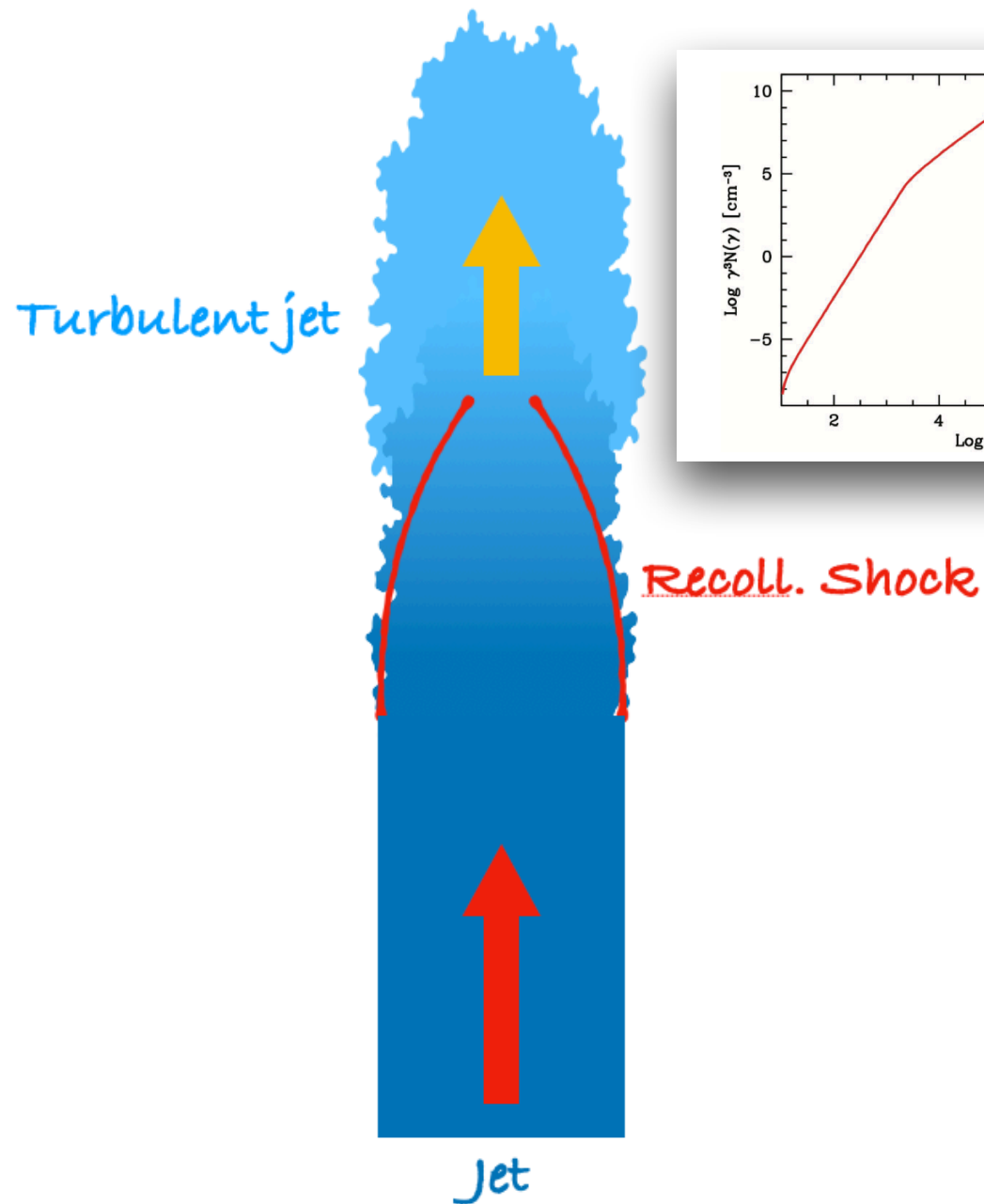


Small radio flux

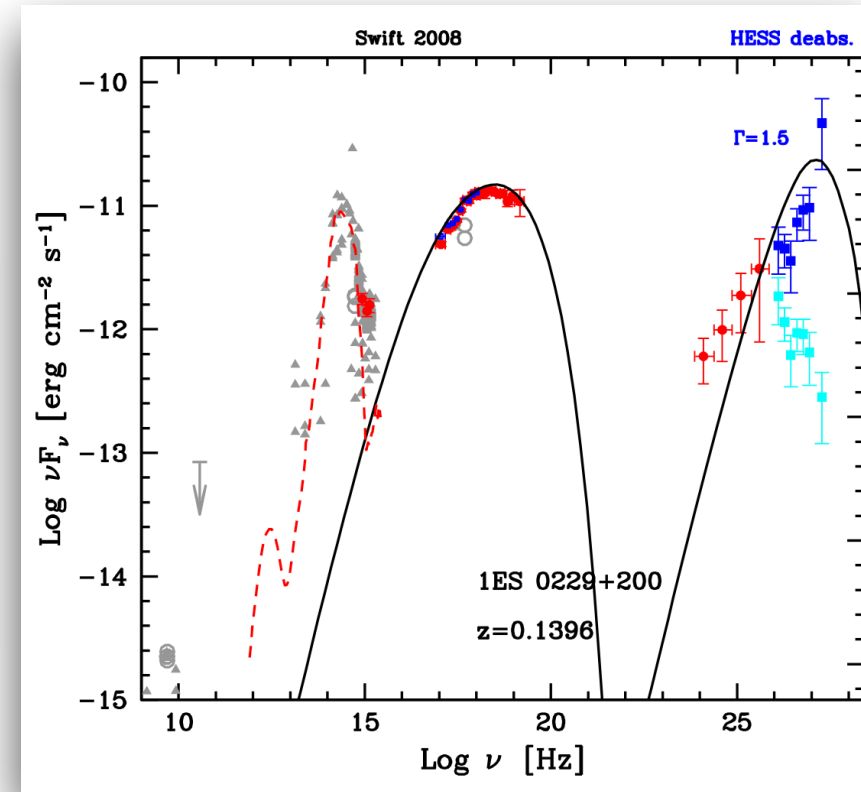
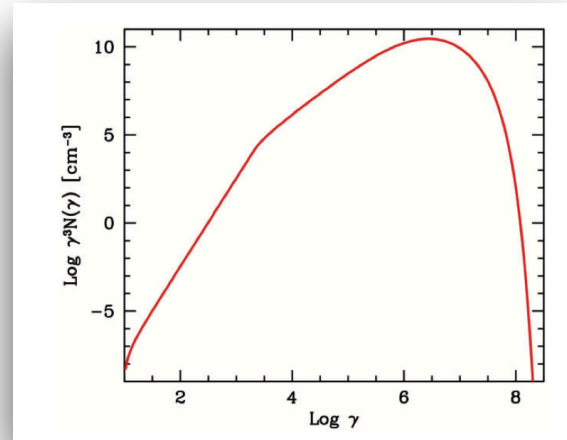
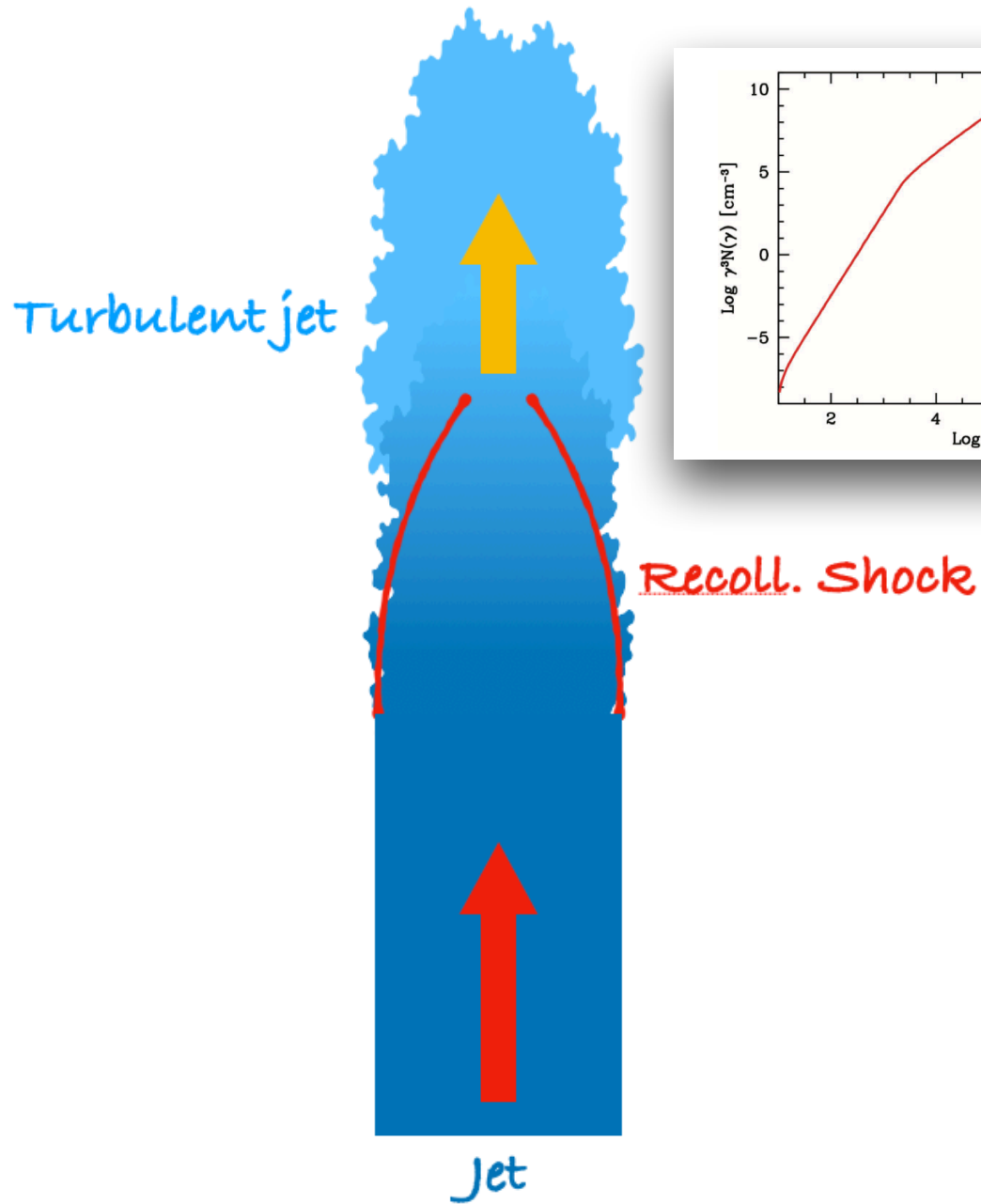
Bonnoli et al. 2015

after Costamante et al. 2001

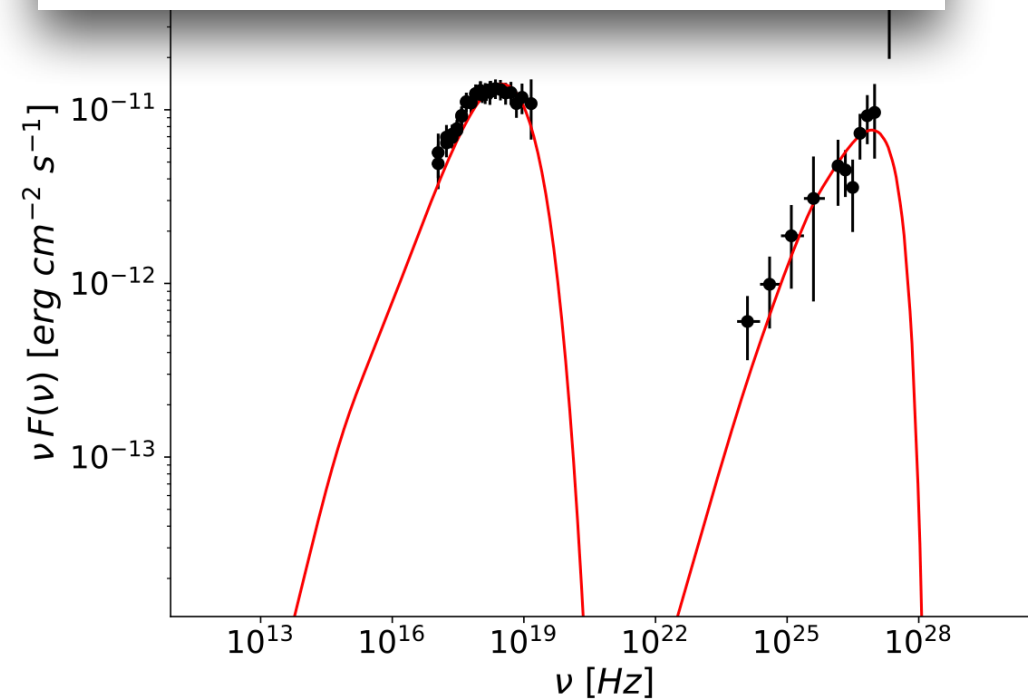
# Extreme BL Lacs: low $\sigma$ , unstable jets?



# Extreme BL Lacs: low $\sigma$ , unstable jets?

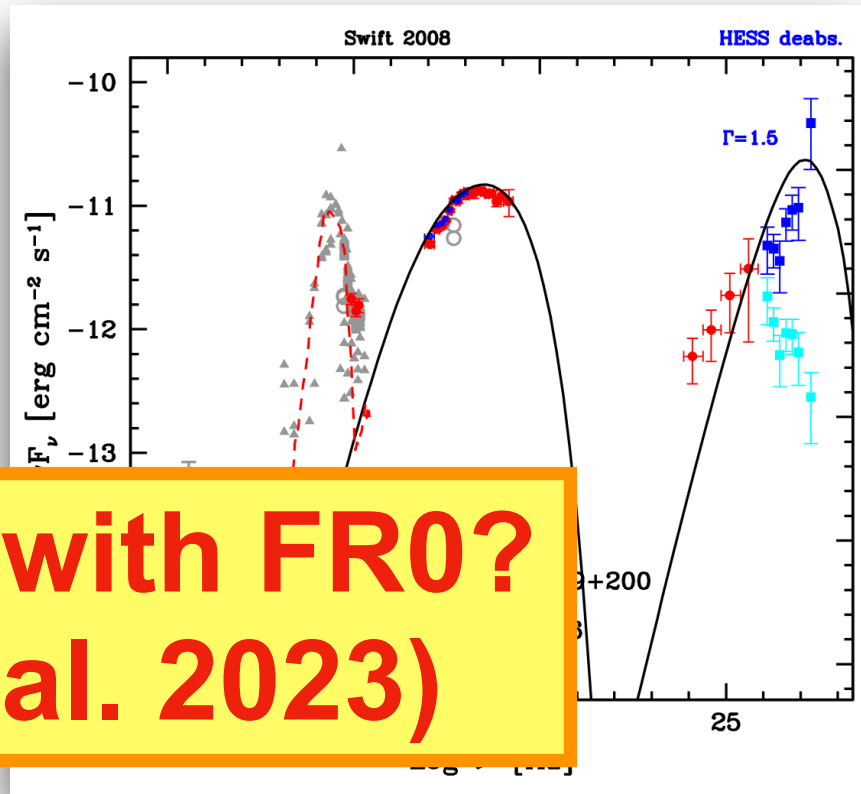
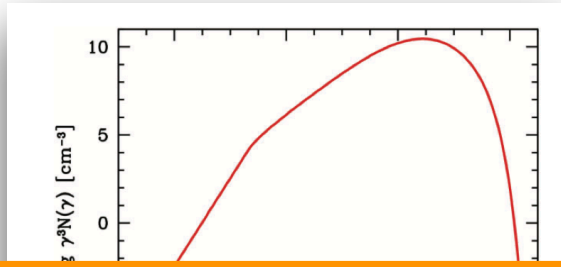


Including turbulence damping



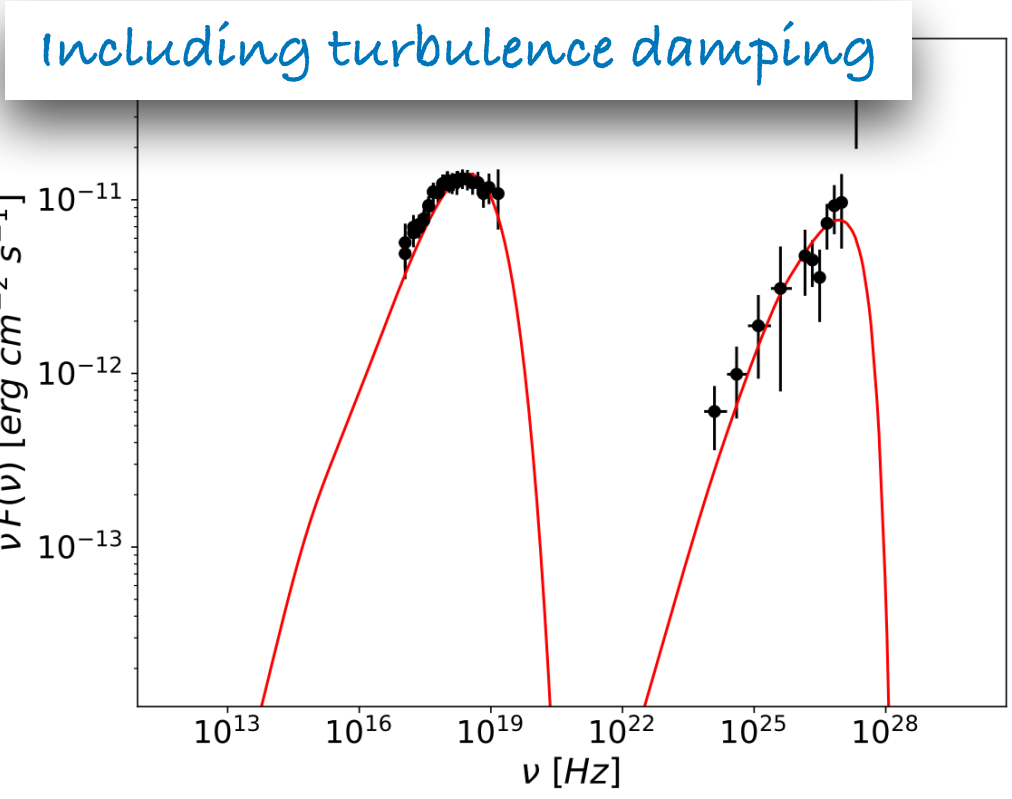


# Extreme BL Lacs: low $\sigma$ , unstable jets?



**Any connection with FR0?  
(Giovannini et al. 2023)**

*Recoil. Shock*



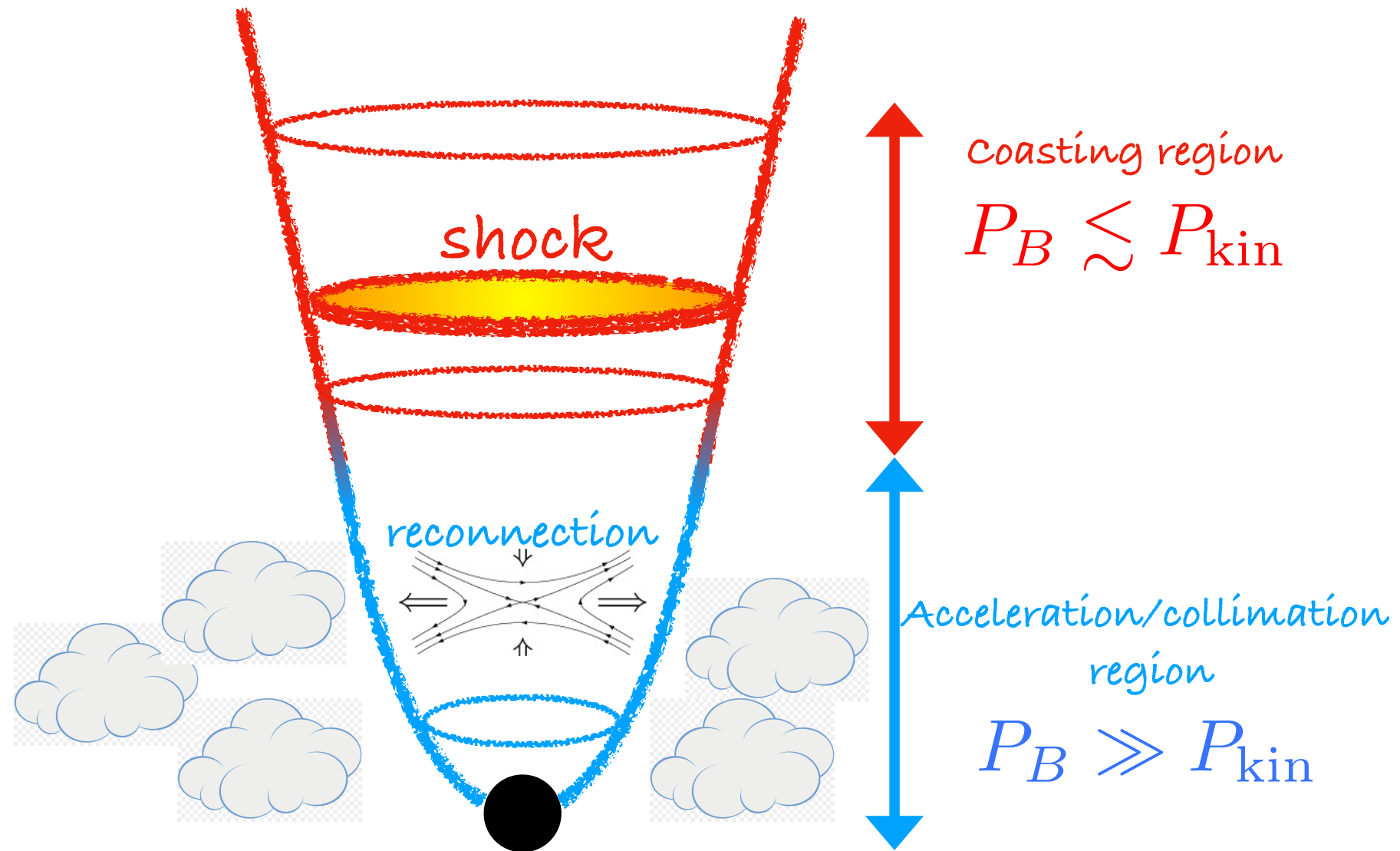


A space-themed background featuring a large, bright starburst or comet tail in shades of blue, purple, and white, set against a dark grey space filled with numerous small white stars. The text "THANK YOU!" is written in a bold, black, hand-drawn font across the center of the starburst.

THANK YOU!



# Energizing the particles



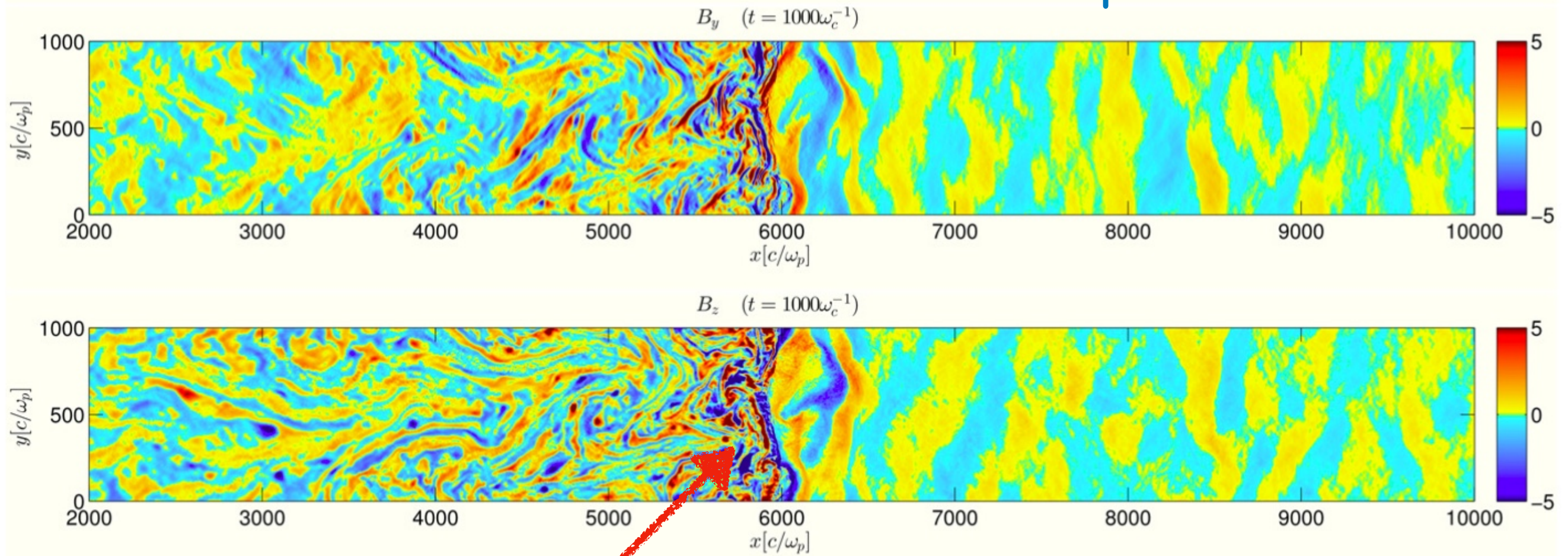
Contopoulos 1994  
Komissarov et al. 2009  
Tchekhovskoy et al. 2009

# Magnetic field generation at shocks

Downstream



Upstream



*Compressed (circularly polarized)  
Alfvén waves self-generated  
by accelerated protons streaming upstream*



# Magnetic field generation at shocks

*Trans-relativistic, nearly parallel, low  $\sigma$  shock*

