HEPRO V
La Plata, Argentina
5-8 October 2015

# Spectral energy distribution, polarization, and synthetic radio maps of Cygnus X-1: a lepto-hadronic jet model

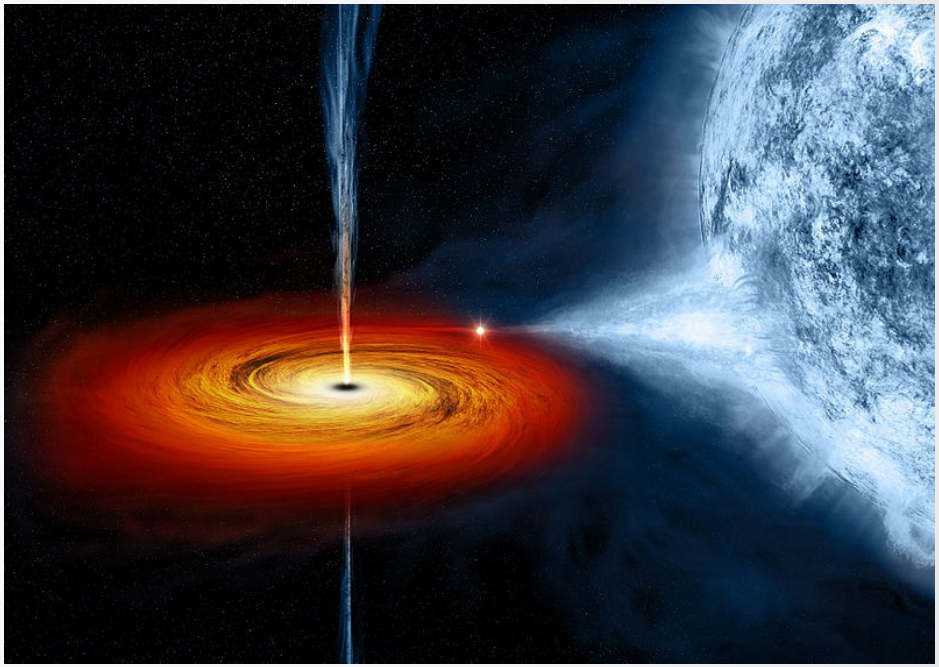
***Carolina Pepe***, Gabriela S. Vila & Gustavo E. Romero
Instituto Argentino de Radioastronomía

Relativistic Astrophysics and Radio Astronomy Group

# Starring: Cygnus X-1

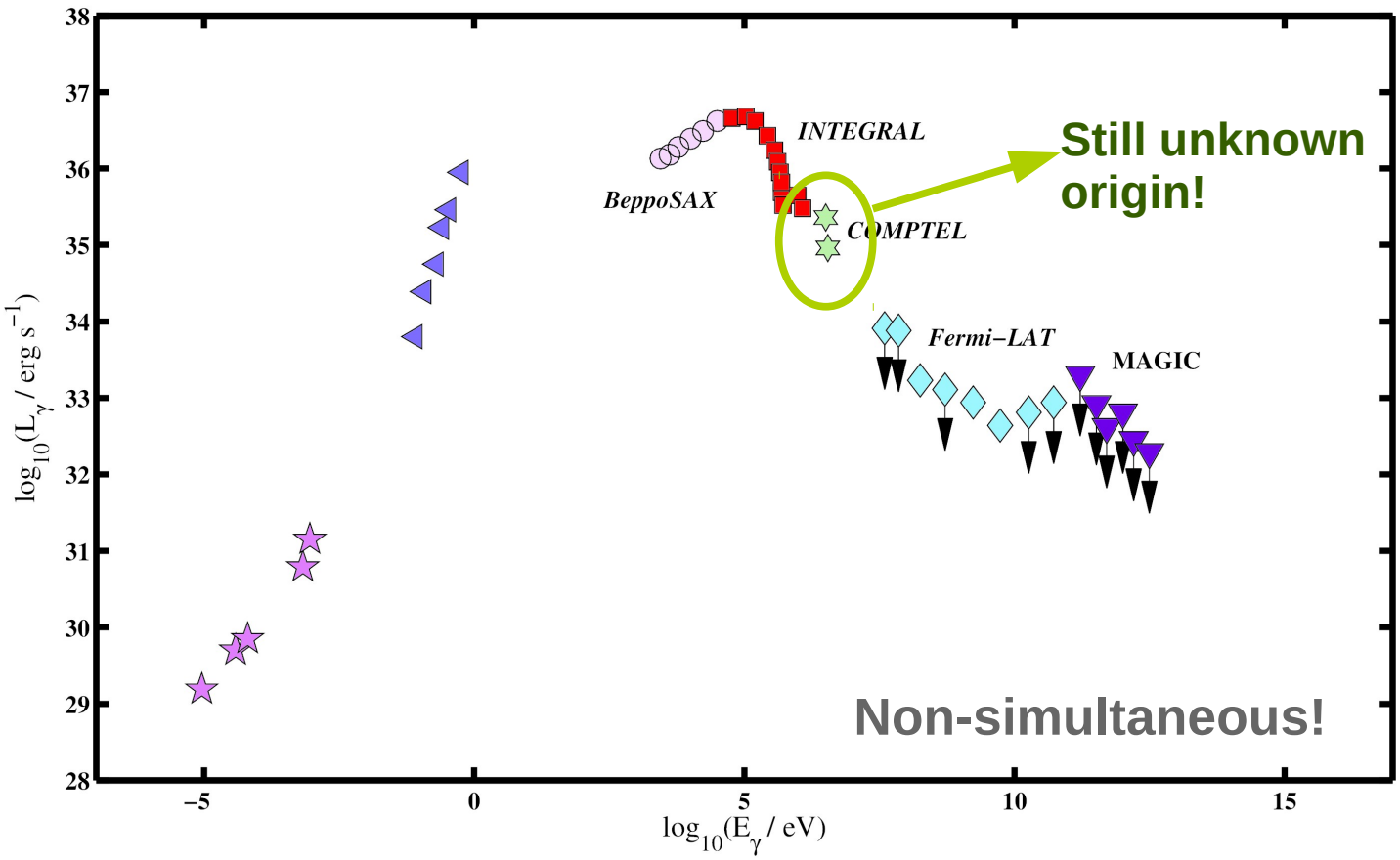
- Extensively-monitored HMXB in low/hard and high/soft states
- One of the two MQs confirmed as gamma-ray sources
- Resolved radio-jets
- Polarization detected

**Cygnus X-1**



**Great for testing models!**

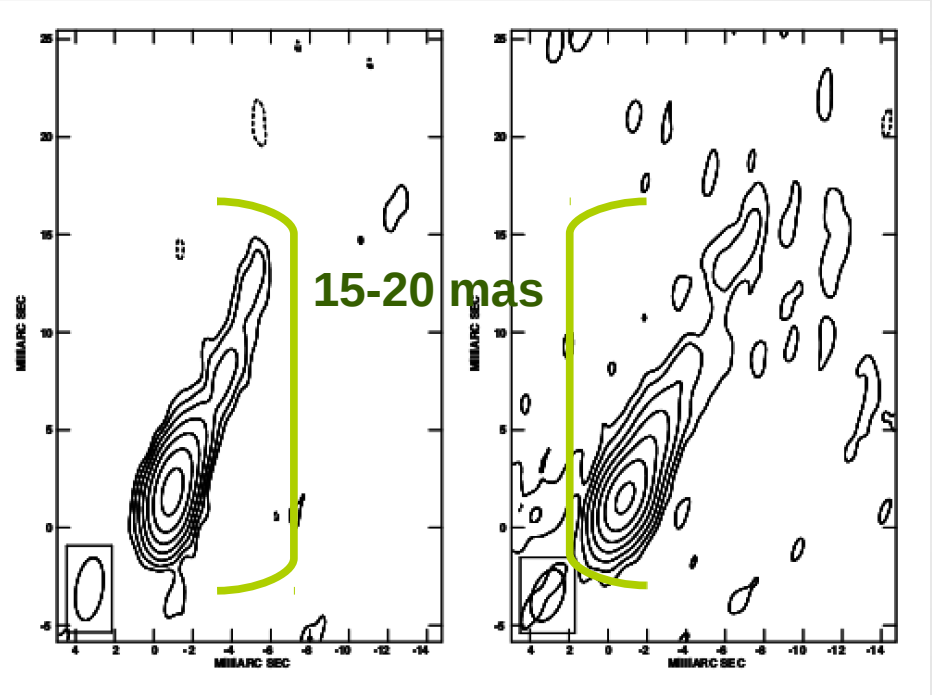
# Observations I




**Compilation taken from Zdziarski+2013**

# Observations II

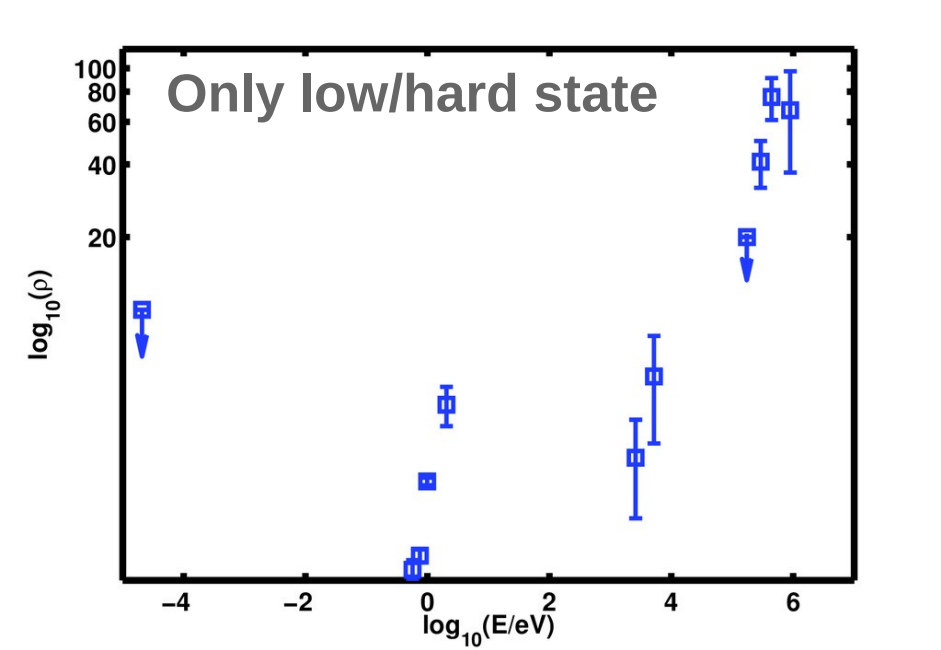
- Information about the emission/acceleration region
- Jet bending (2 days period).




Taken from Stirling+2001

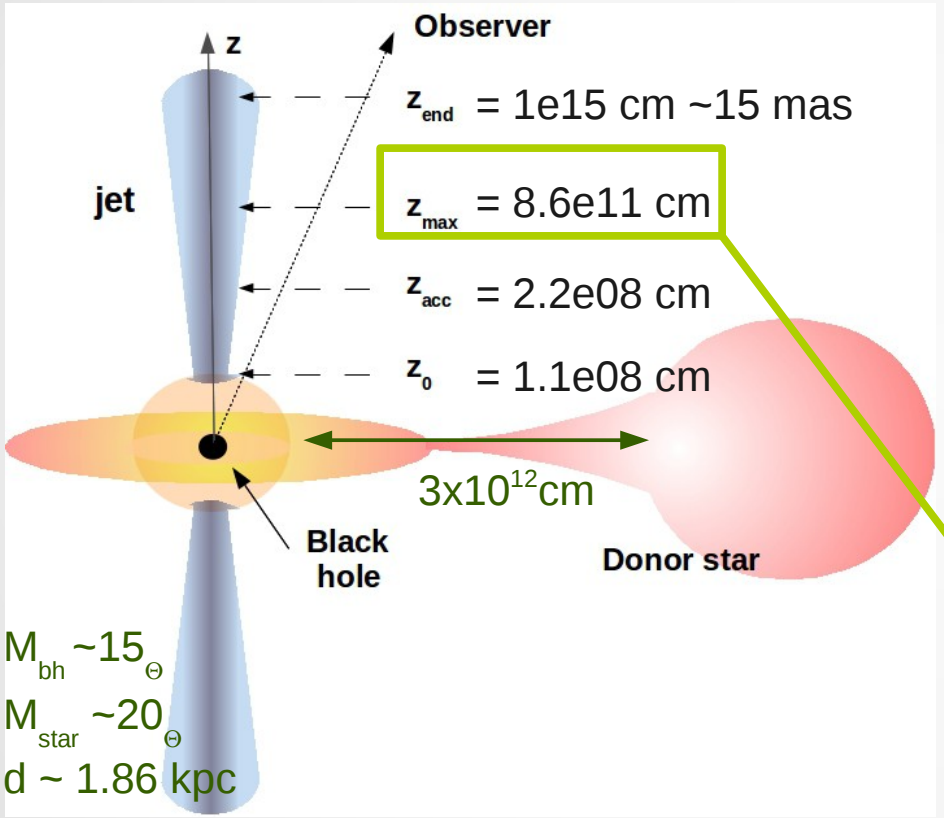
# Observations III

- Russell+2013 and Jourdain+2012,2014 proposed a jet origin.
- Alternatively, MeV polarization comes from the corona (Romero+2014)
- Polarization measurements can help to solve the MeV tail origin issue!



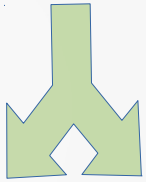

**Compilation taken from Russell+2014**

# Radiative model (I). Big picture.




## Jet energetics

$$L_{rel} = q_{rel}\, L_{jet};\quad q_{rel} < 1$$



**0.07**

**=**

$$L_e \qquad L_p = a\, L_e$$

Equipartition at jet base:

$$U_{mag}(z_0) = U_{kin}(z_0)$$

Magnetic field intensity:

$$B(z) = B_0 \left( \frac{z_0}{z} \right)^{m=1}$$

$E_{min}$ = 120 $m_0$

$\eta_{accel}$ = 3x10$^{-3}$

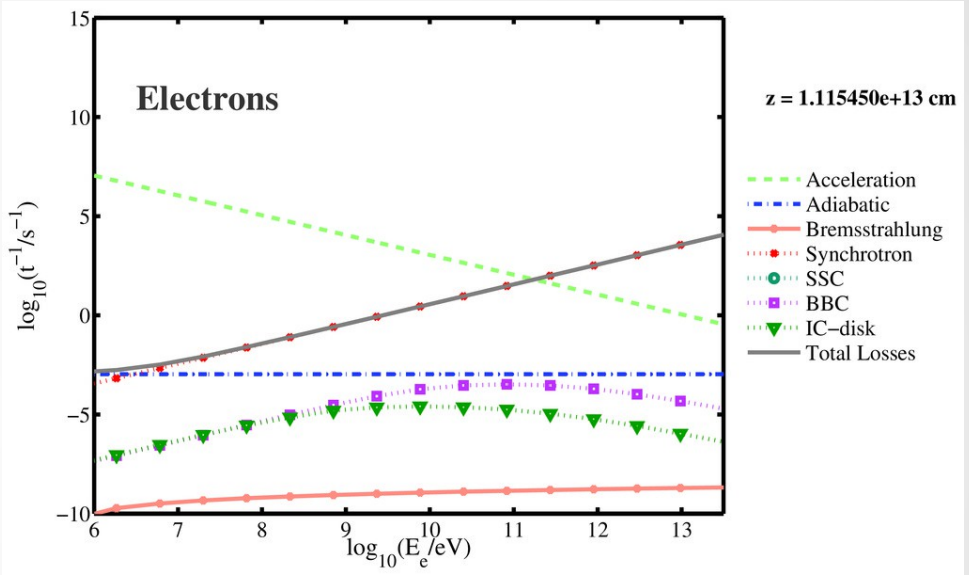
→ **Free parameters!**

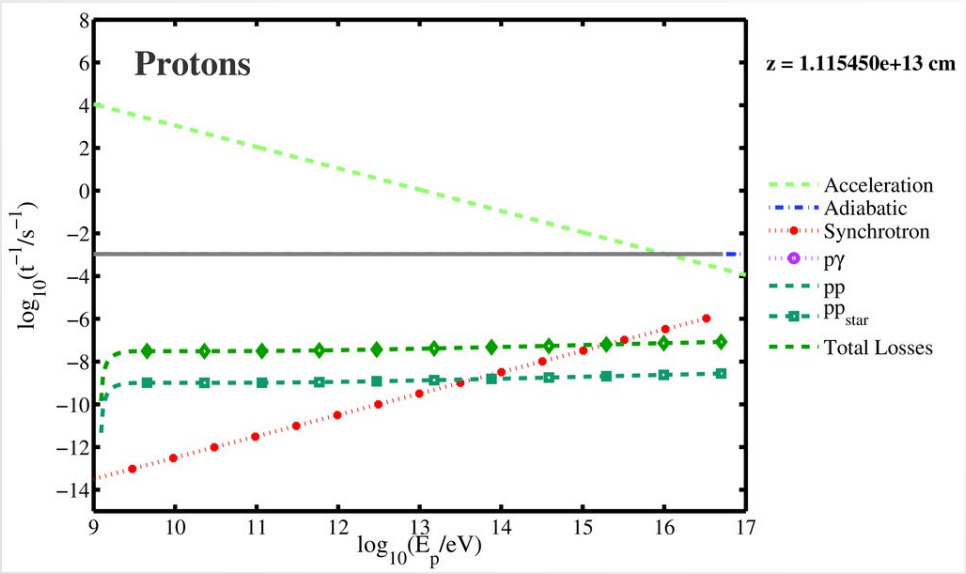
# Radiative model (II). Cooling processes.

- Radiative cooling is calculated for primary and secondary particles

**Leptons**

- Synchroton
- Relativistic Brehmstrahlung
- Inverse Compton (SSC, BBC, IC-disk)



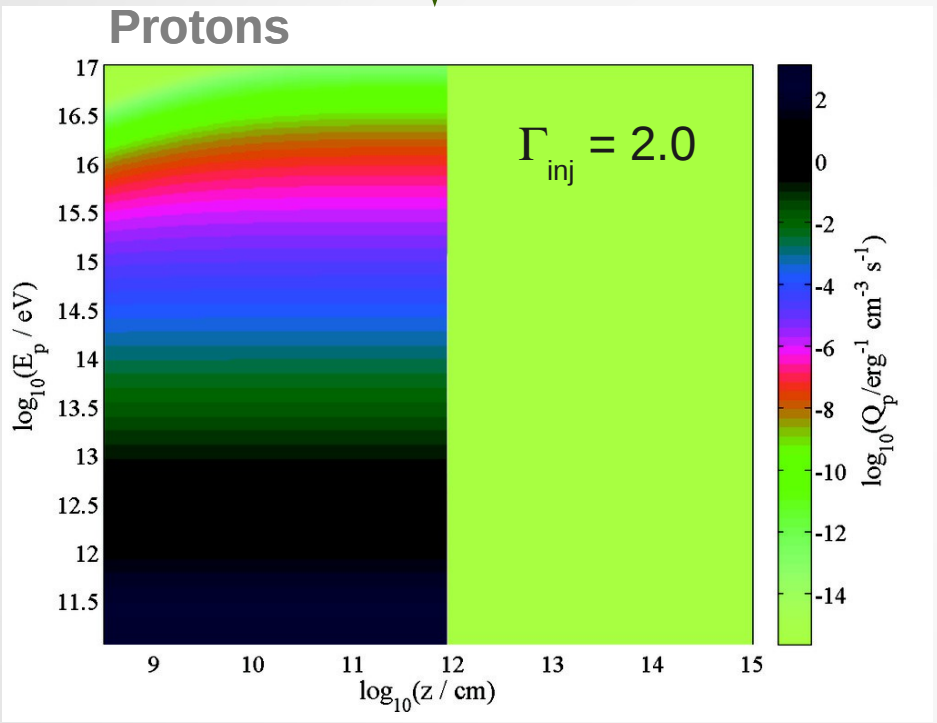



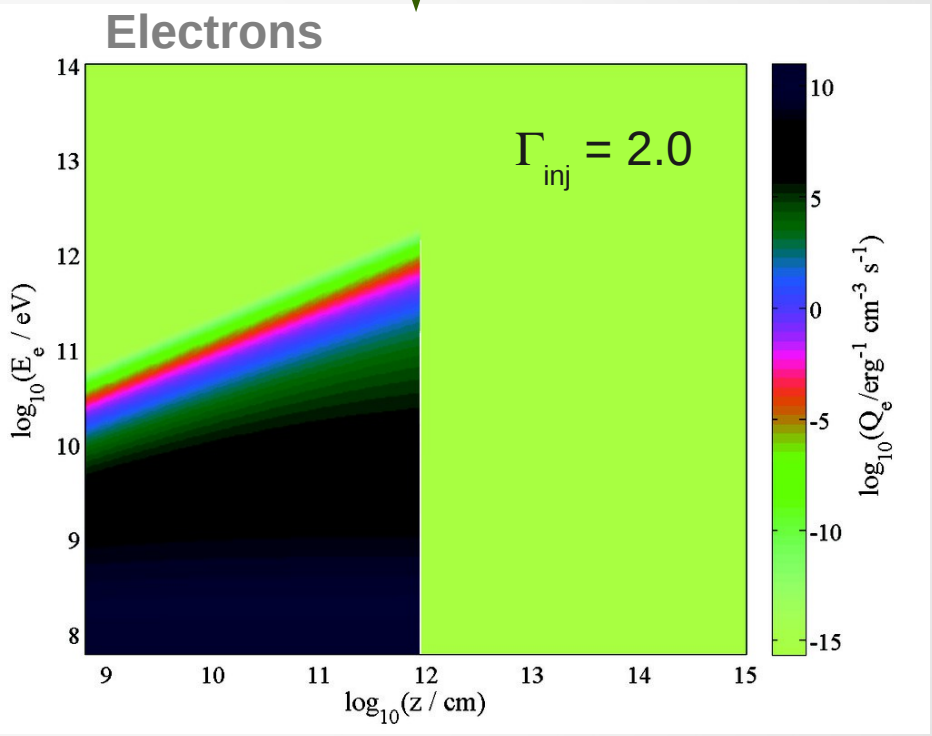

**Protons**

- Synchroton
- pp (internal and star)
- pγ (internal and star)

# Radiative Model (III). Particle distributions

**End of acceleration region**



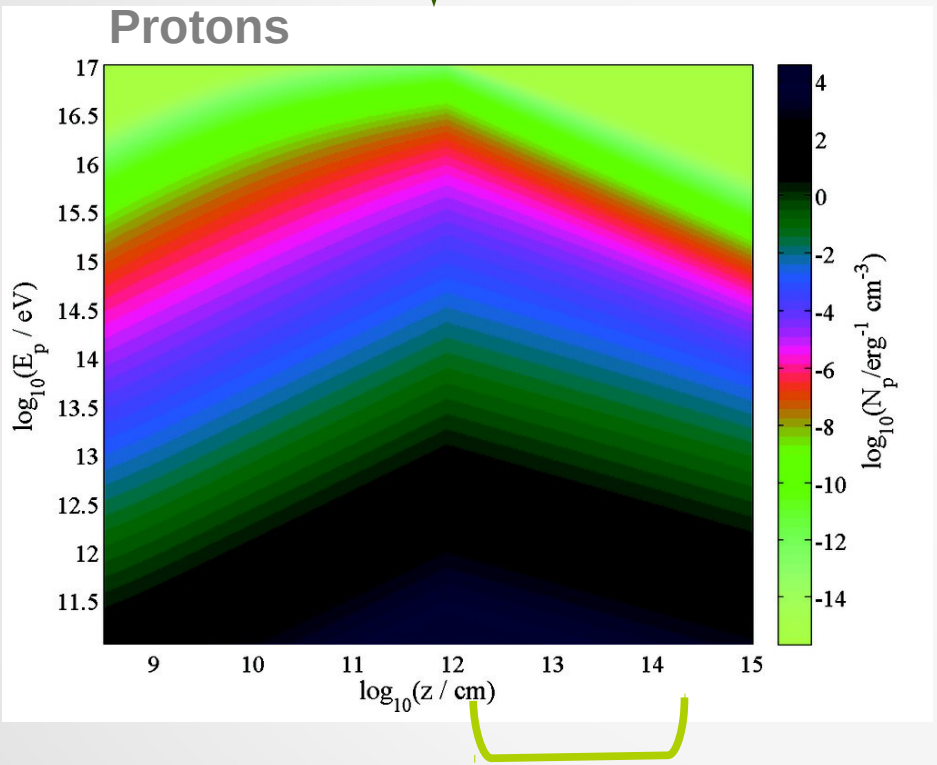




$$v_{conv}\frac{\partial N}{\partial z}+\frac{\partial}{\partial E}\left(\frac{dE}{dt}N\right)+\frac{N}{\tau_{dec}(E)}=Q(E,z)$$

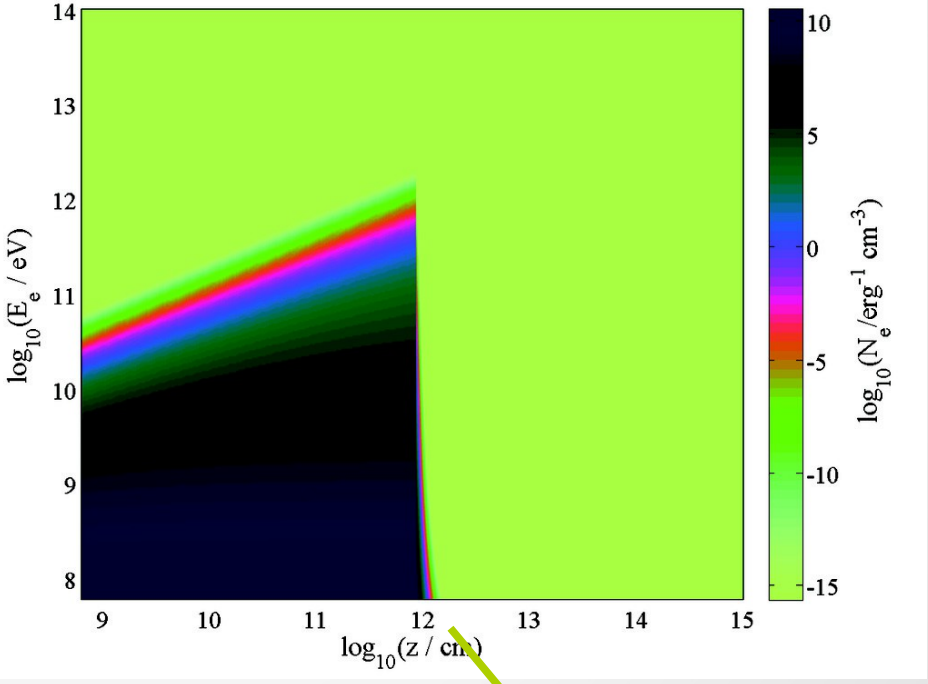
# Radiative Model (III). Particle distributions

**End of acceleration region**

Protons



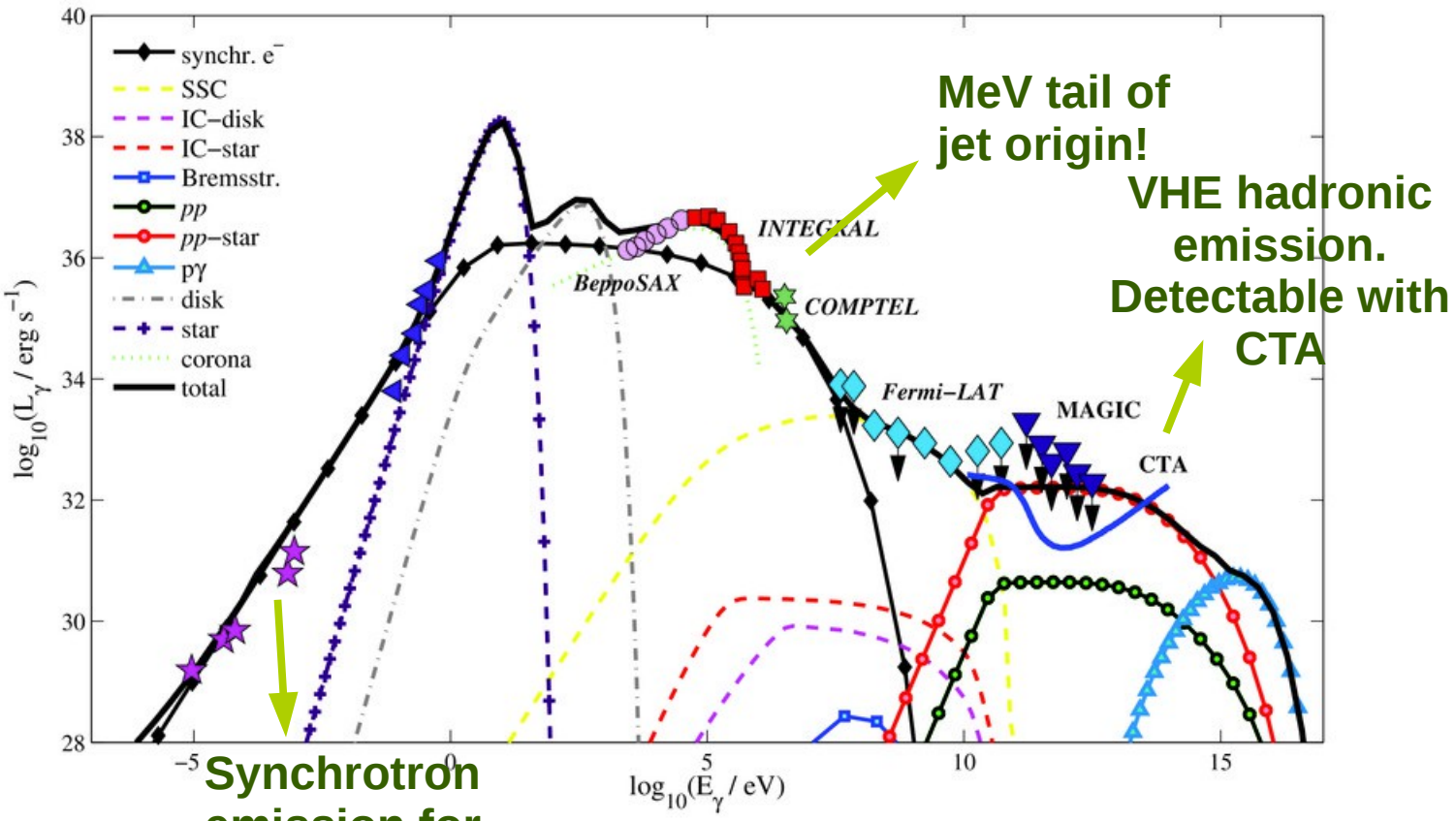

Electrons




**Transport of particles!**

**The magnetic field still operating**
**Cools electrons completely**

# Radiative model (IV). SED




**MeV tail of jet origin!**

**VHE hadronic emission. Detectable with CTA**

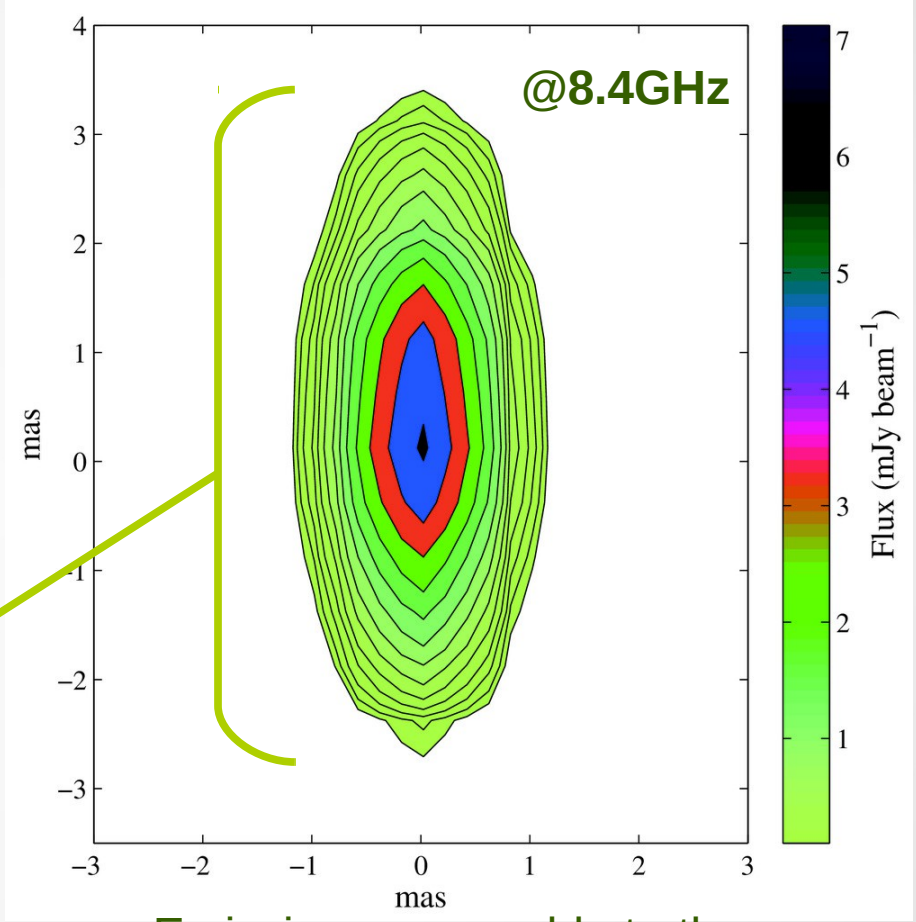
**Synchrotron emission for radio-map modelling**

# Radio maps

- Convolved with Gaussian FWHM of 2.25 × 0.86 mas[2]
- separation between “pointings”:one beam radius in each direction

Extension smaller than observed: hint about extension/location of acceleration region and/or magnetic field morphology?

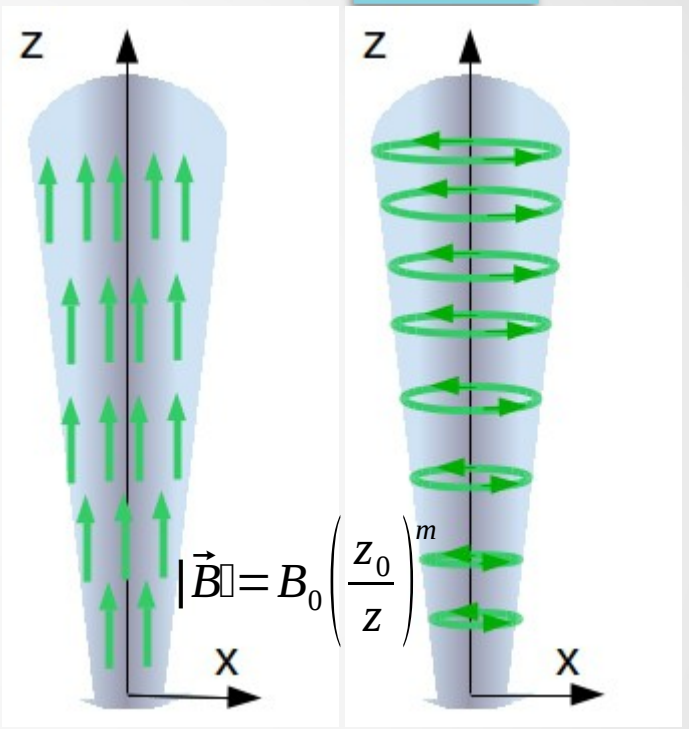
**Let's explore polarization studies!**




Emission comparable to the observations taken with VLBA, VLA (8 mJy beam$^{-1}$,Stirling+2001), GMRT (10.4 mJy beam$^{-1}$,Pandey+2006) and MERLIN (8 mJy beam$^{-1}$, Fender+2006)

# Synchrotron polarization. First steps.

- Stokes parameters from first principles: no simplifications made (Korchakov+1962)
- Full freedom about the magnetic field geometry and particle distribution
- $\rho^{obs}_{\sim 0.5MeV} = 76\% \pm 15\%$
  $\rho^{obs}_{\sim 1.2MeV} = 67\% \pm 30\%$




$\rho_{MeV}$ ~80%  $\rho_{MeV}$ ~75%

**Next step: more complex magnetic field geometries**

# Concluding remarks and prospect work

- VHE emission dominated by hadronic processes
- MeV tail from jet origin
- Flux of synchrotron radio emission consistent with observations. Acceleration region and/or magnetic field needs to be improved.
- Polarization studies are used to test the magnetic field geometry.
- More complex geometries will be considered. SED from the radiative model can then be tested according to the new magnetic field.


**For details see Pepe, Vila & Romero 2015:**
**http://arxiv.org/abs/1509.08514**
**(accepted in A&A)**