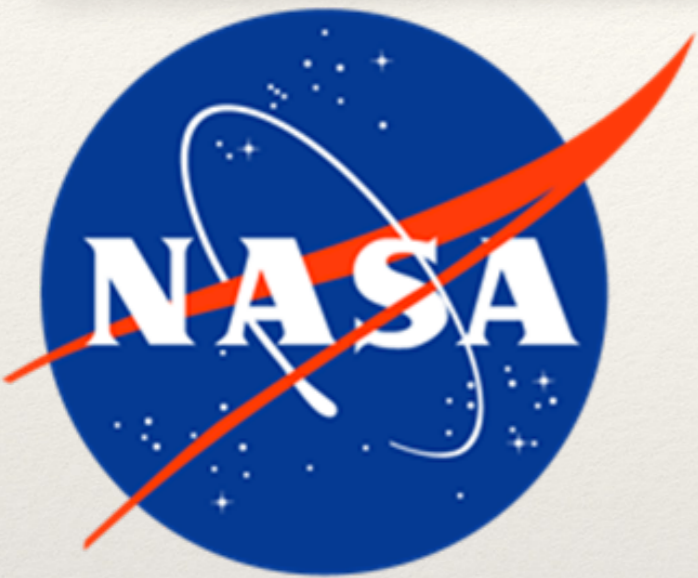


# High-frequency and high-energy polarization observations of Fermi blazars



Bindu Rani

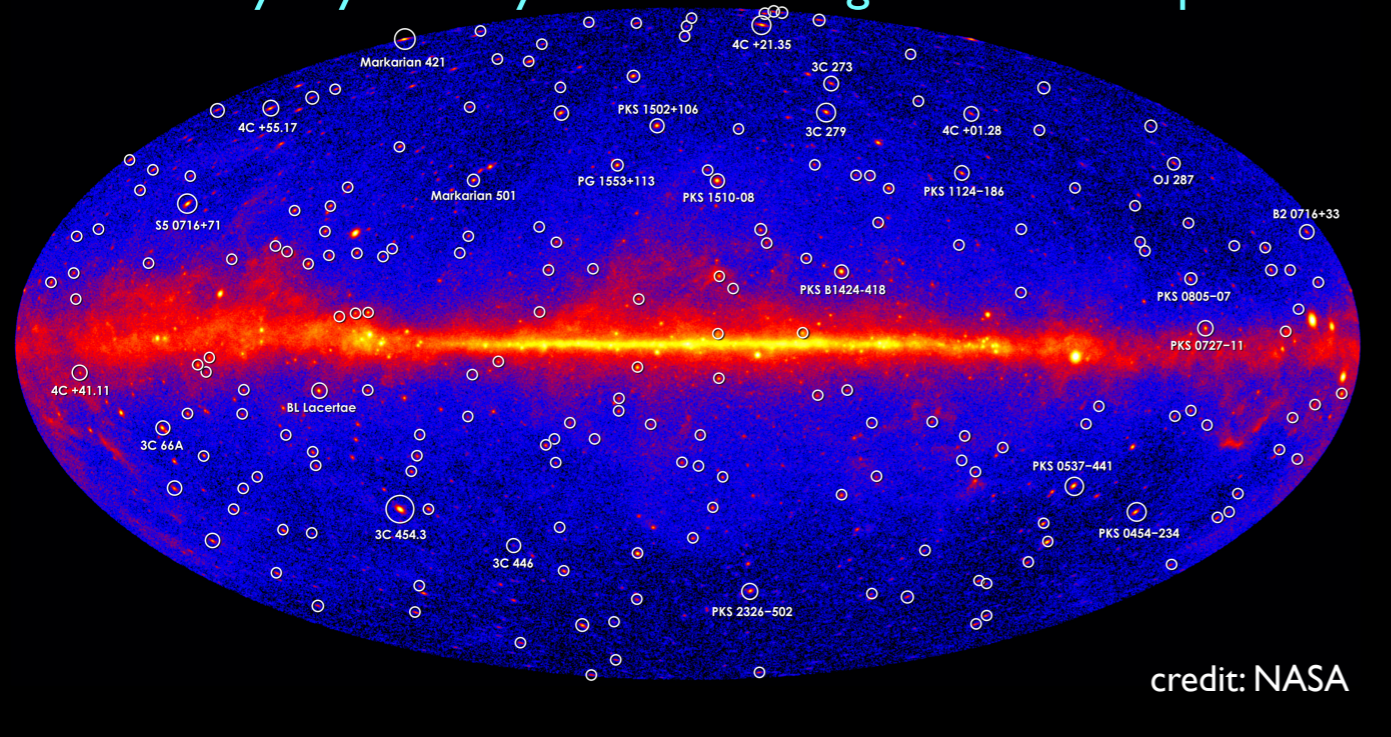
NPP Fellow

NASA GSFC, USA

*on behalf of the Fermi-LAT collaboration*

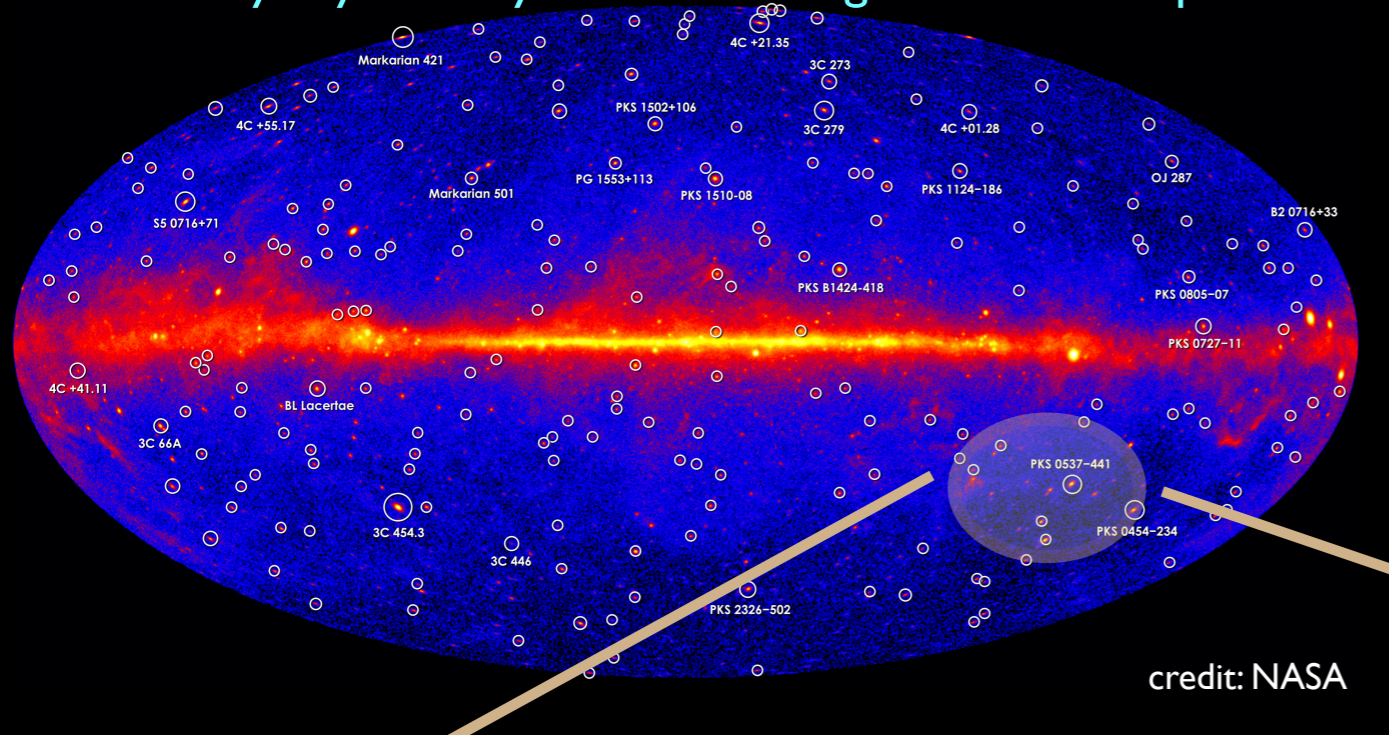
**Collaborators:** Thomas P. Krichbaum, Jeff A. Hodgson, Lars Fuhrmann, E. Angelakis, J. Anton Zensus [MPIfR, Bonn], Alan P. Marscher, Svetlana G. Jorstad [Boston University, USA], J. Hodgson, J. Oh [KASI]

# Gamma-ray sky seen by the Fermi Large Area Telescope

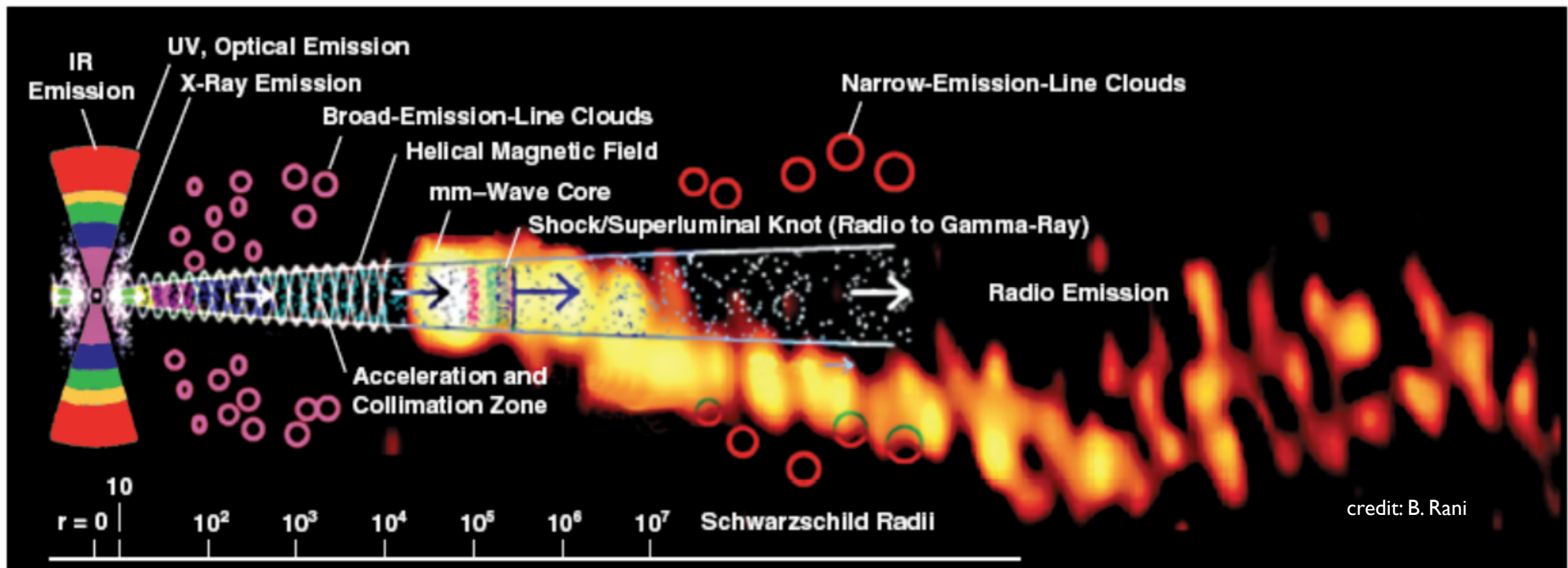


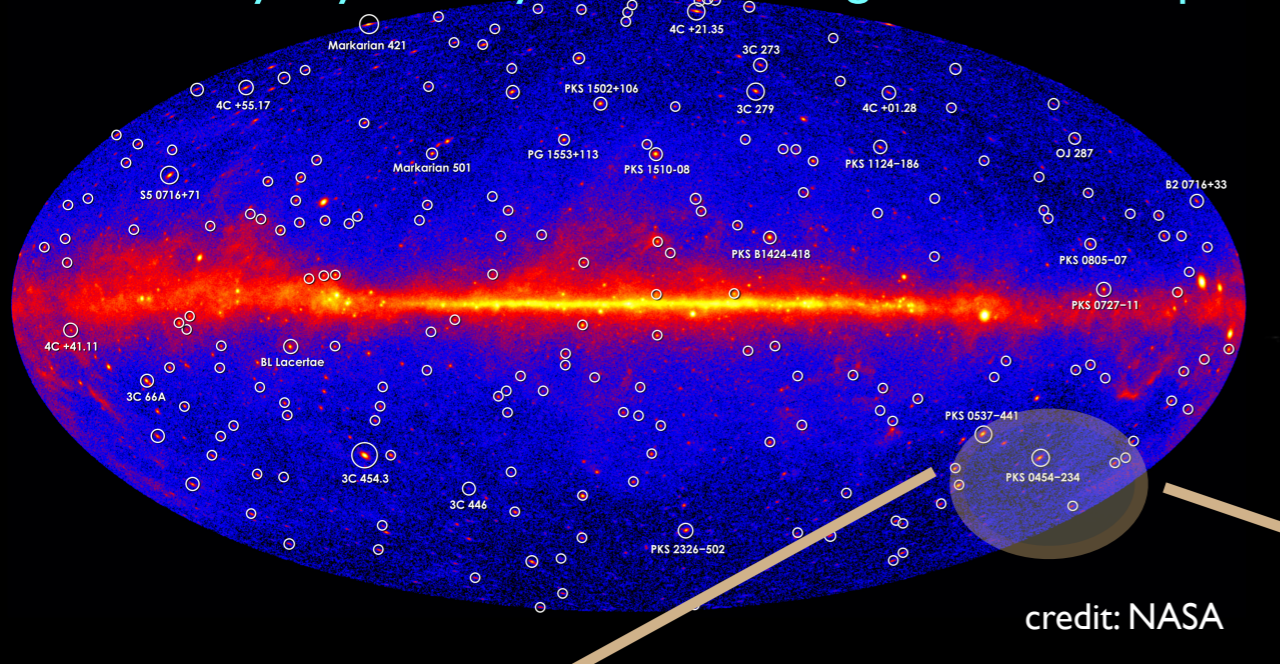
More than 60% objects seen by Fermi are blazars

# Gamma-ray sky seen by the Fermi Large Area Telescope



More than 60% objects seen by Fermi are blazars

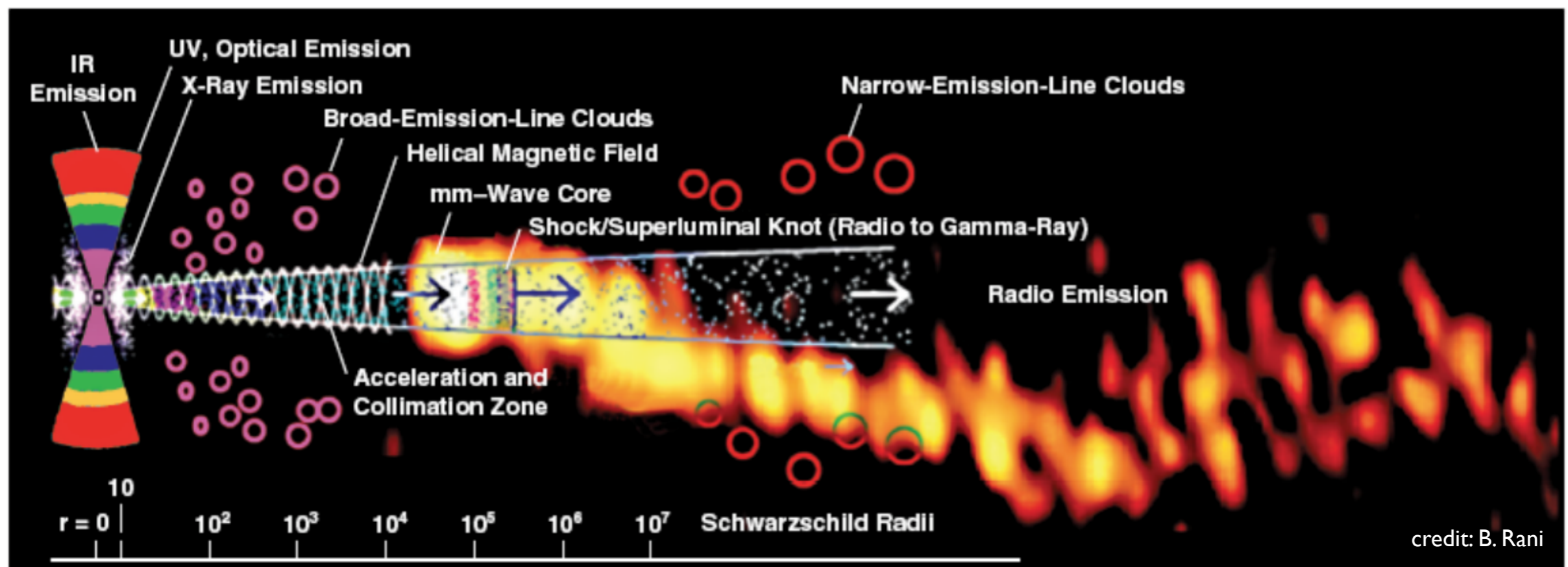




# Key questions:

- ❖ How are jets launched and confined?
- ❖ Where and how gamma-rays are produced?


More than 60% objects seen by Fermi are blazars



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# Key Questions

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- 
- ❖ How are jets made and confined?
  - ❖ How do relativistic outflows dissipate?

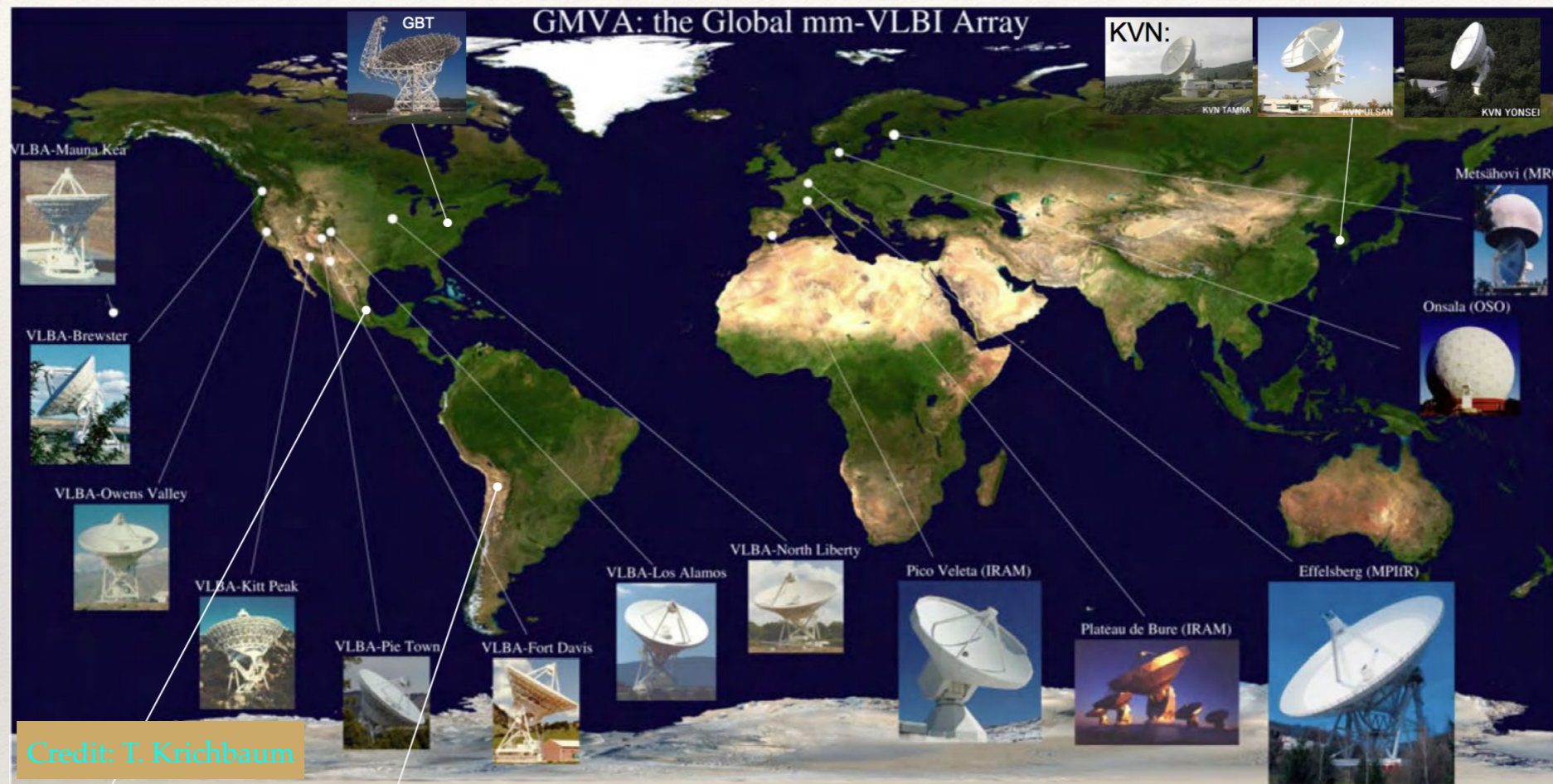


- High-resolution polarization imaging
- High-energy polarization observations

**Polarization observations :**  
magnetic field topology, configuration, order, strength

# High-resolution polarization observations

# High-resolution VLBI



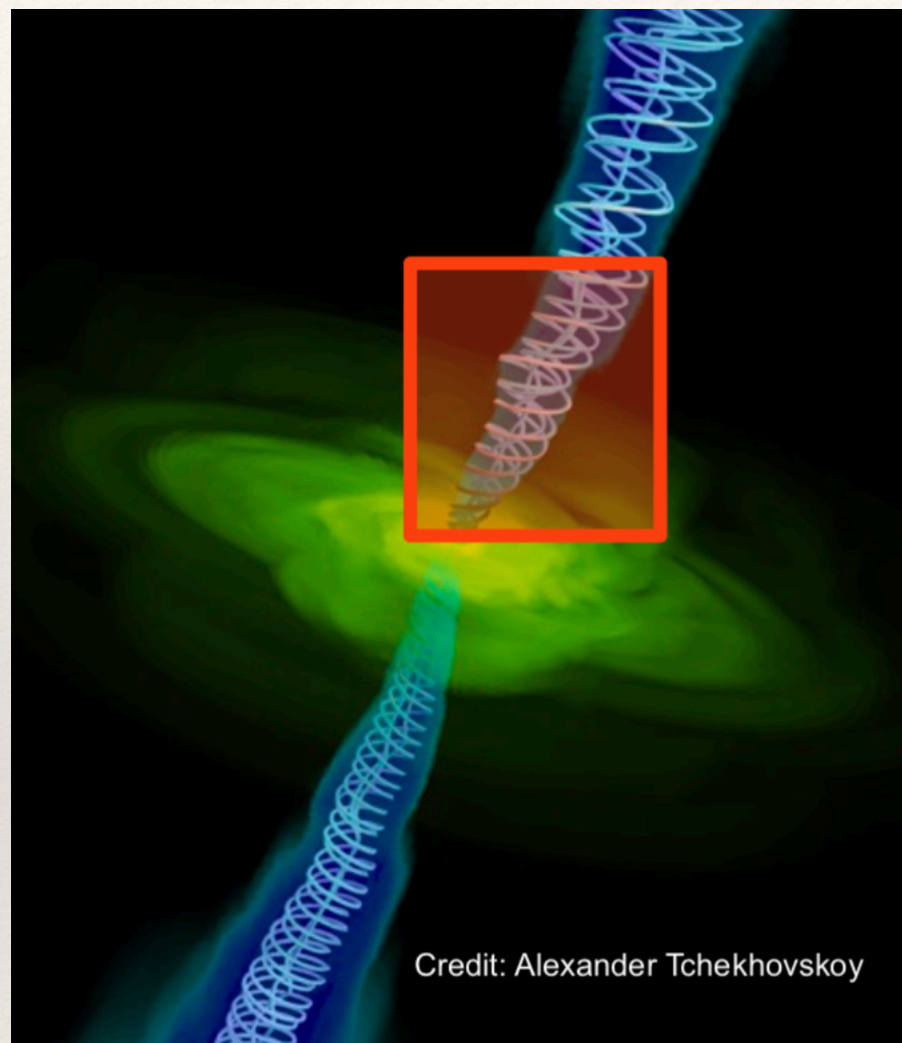
86 GHz

GMVA : High-frequency + high-resolution

# High-resolution VLBI



86 GHz



GMVA : High-frequency + high-resolution

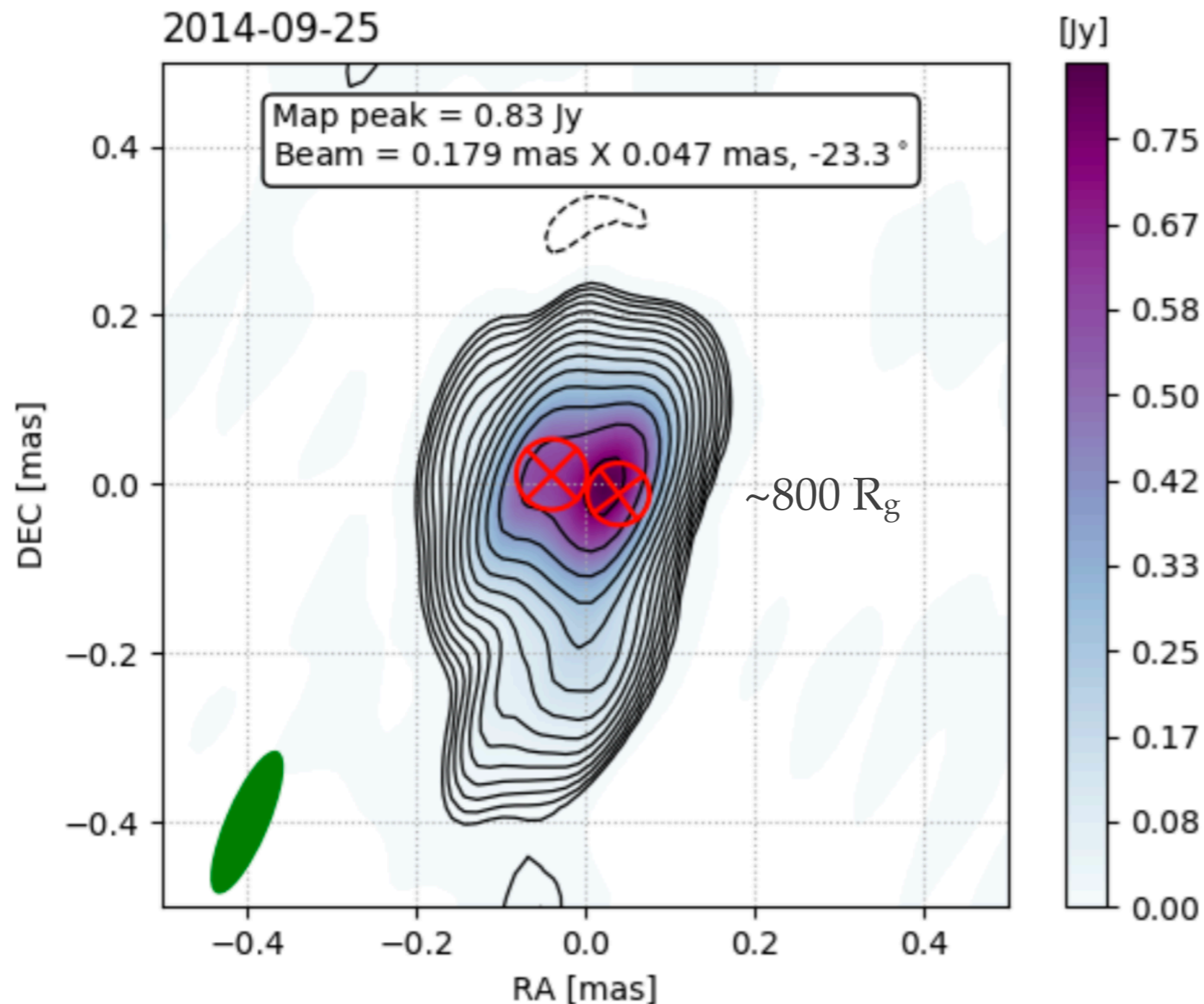
angular resolution: 50 micro-arcseconds

For a  $10^9 M_{\odot}$  BH ( $z=0.1$ ) = **450  $R_g$**



# Zooming into the jet launching region

## 86 GHz image of 3C 84

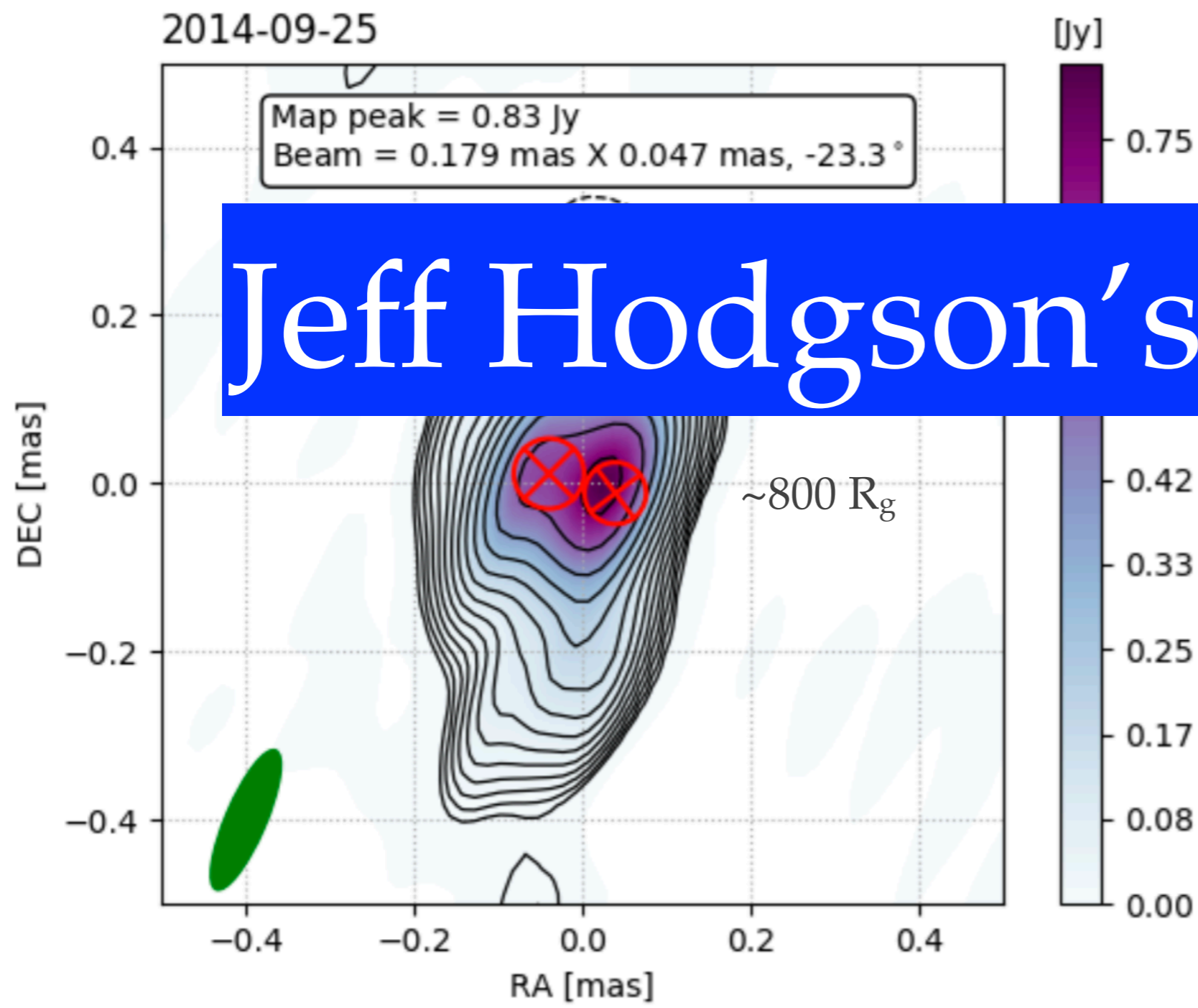


Discovered double  
nuclear structure in  
the core

credit: J. Oh, Hodgson J, B. Rani, et  
al. 2018, in preparation

# Zooming into the jet launching region

## 86 GHz image of 3C 84



Jeff Hodgson's poster

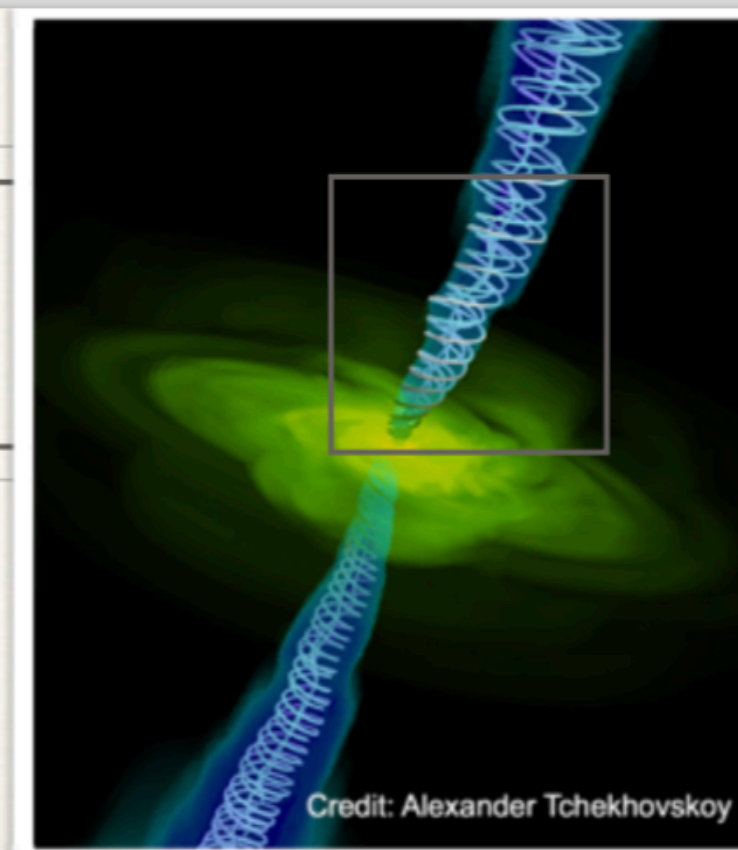
Discovered double nuclear structure in the core

credit: J. Oh, Hodgson J, B. Rani, et al. 2018, in preparation

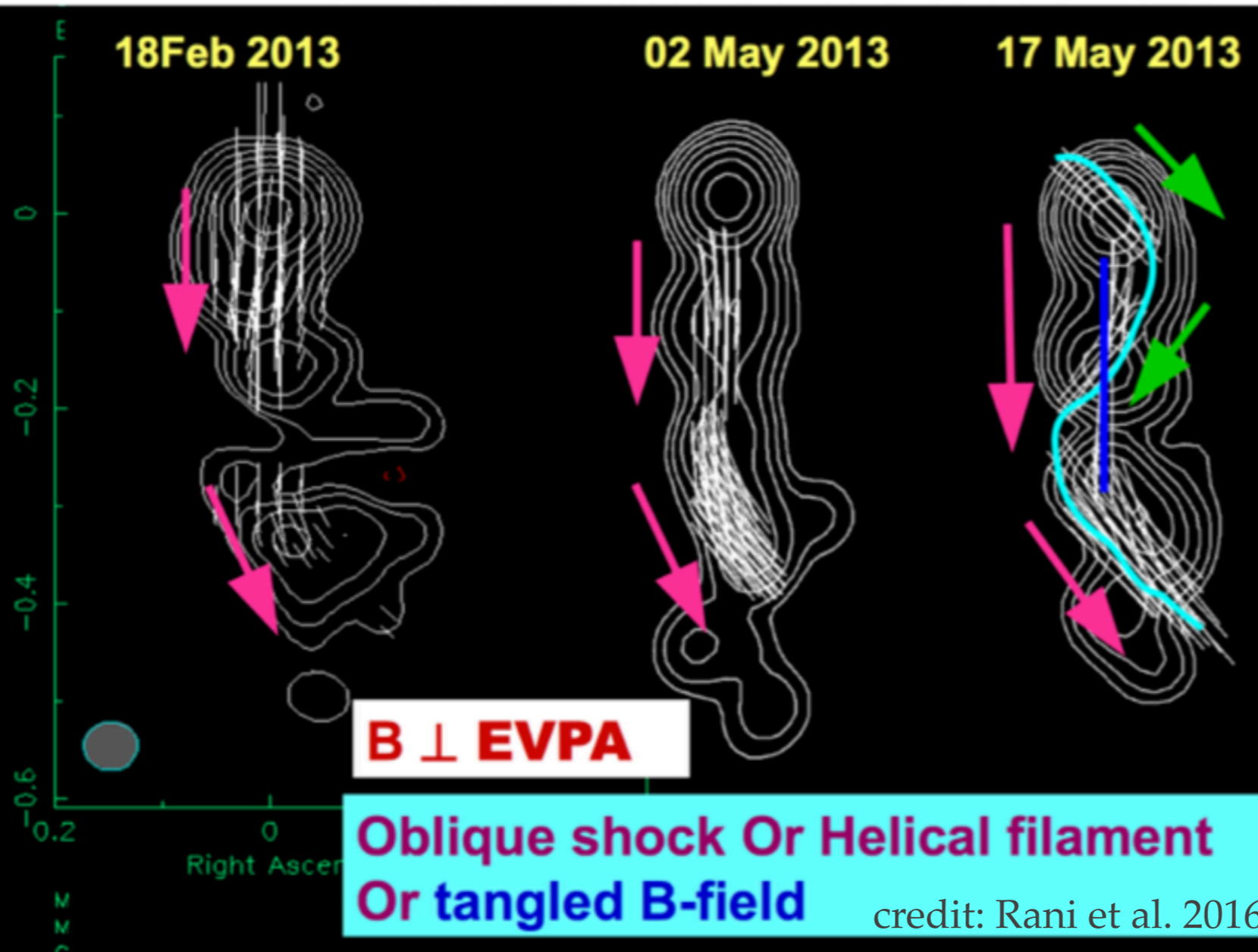
# Jet Launching

Global mm-VLBI, angular resolution: 50 micro-arcseconds

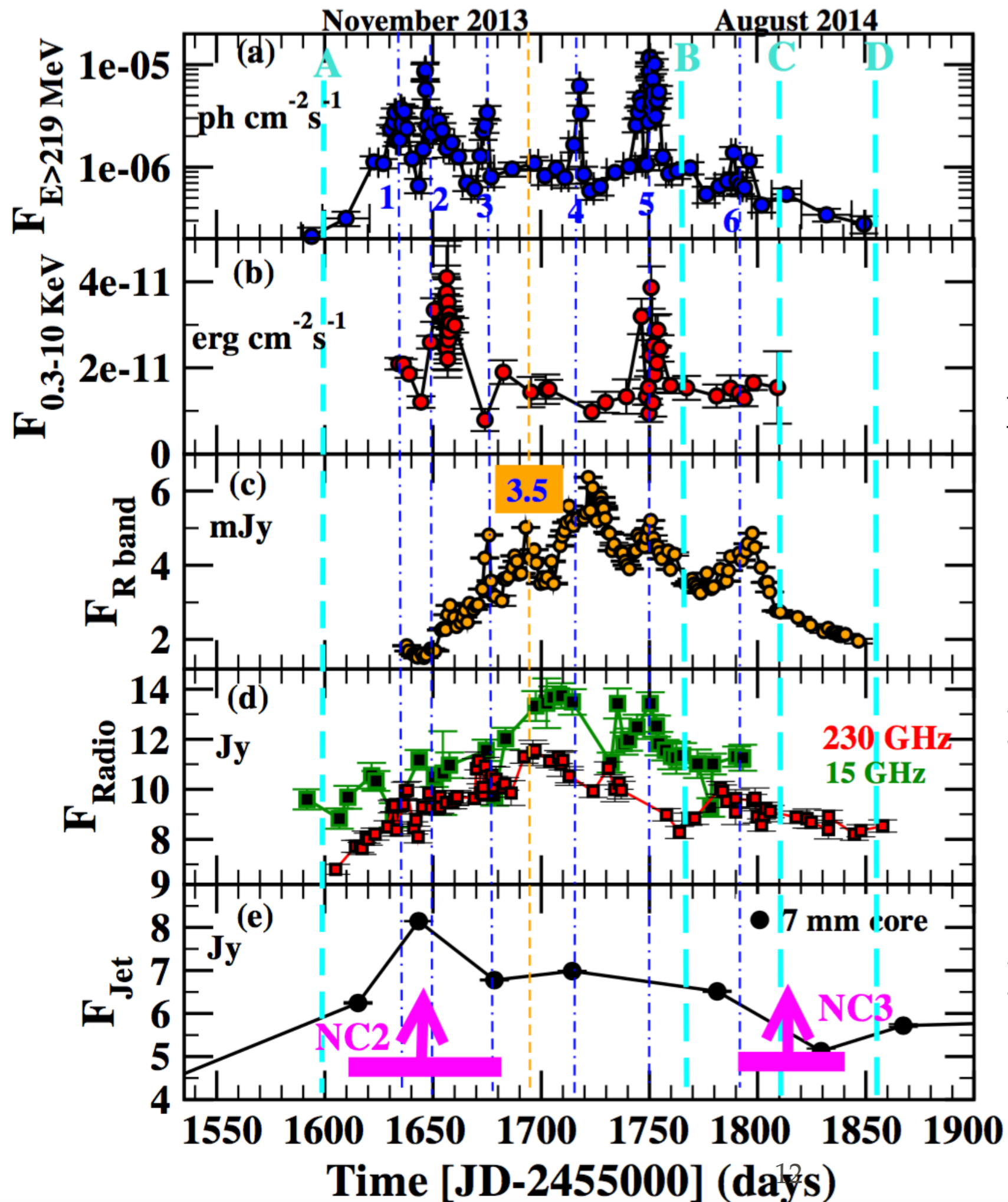
For a  $10^9 M_{\odot}$  BH, one could scale down up to  $\sim 450 R_g$  at  $z=0.1$



Simulations



Observations



**Broadband observations of 3C 279**

GeV

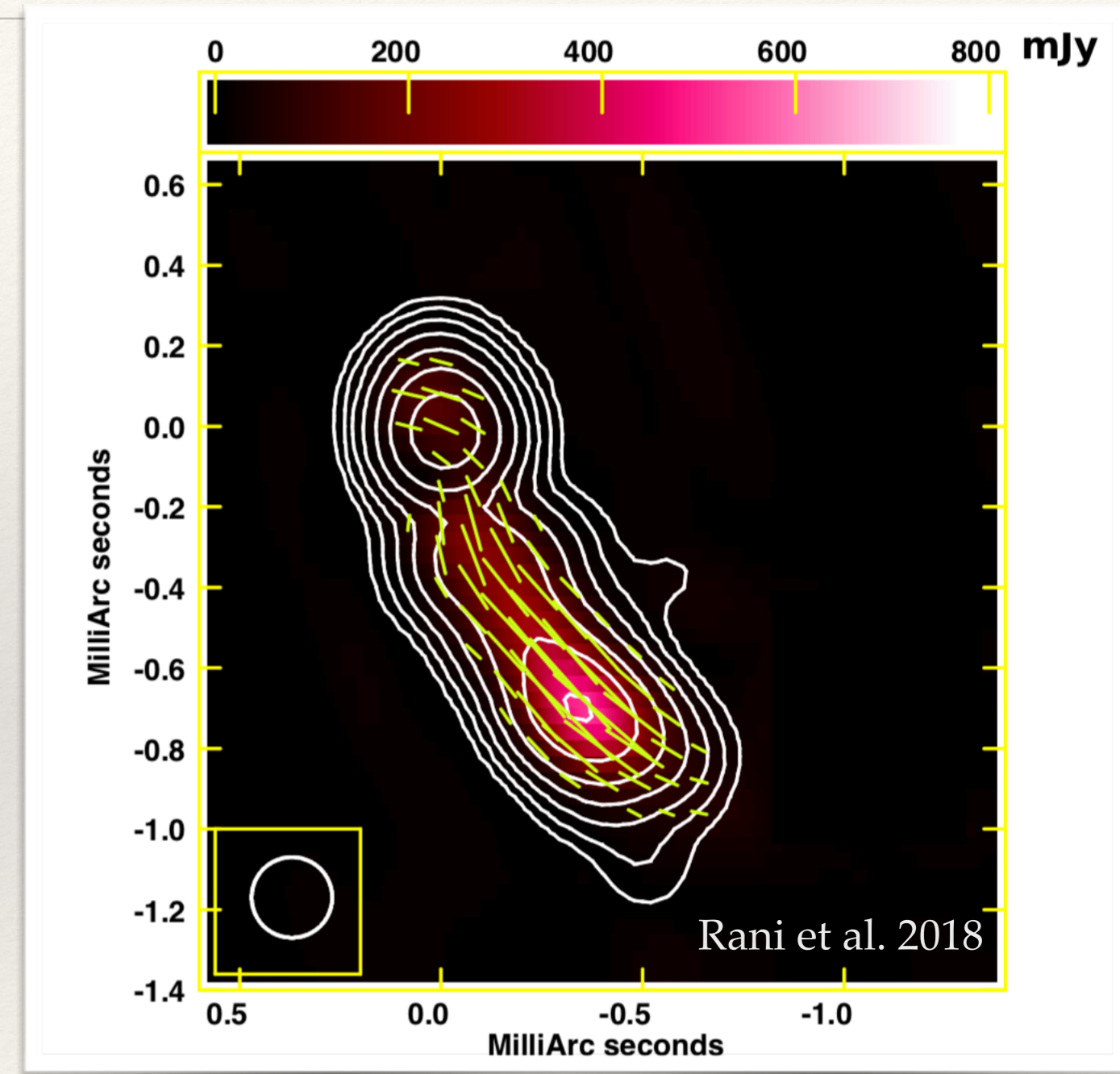
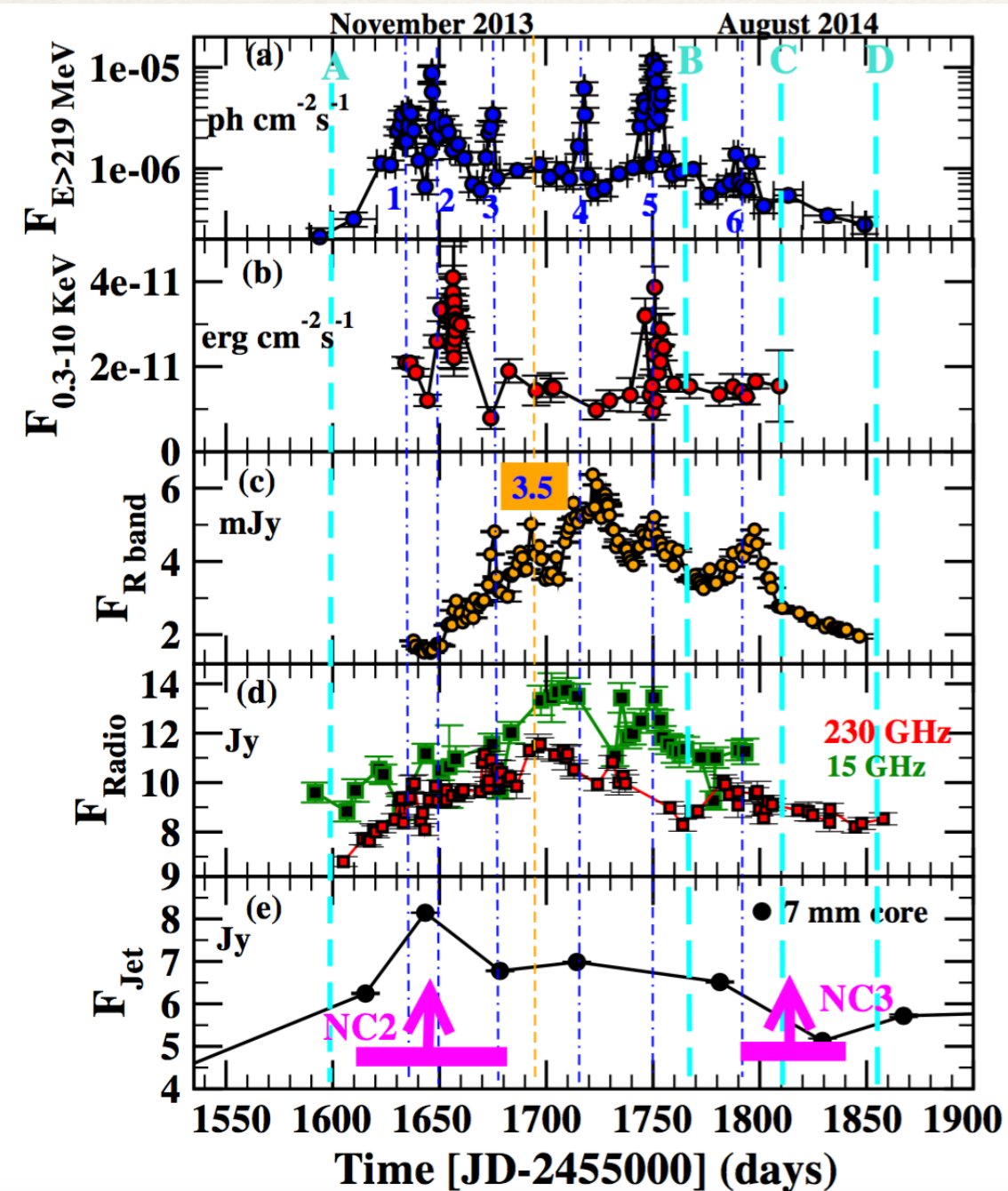
X-ray

Optical

Radio

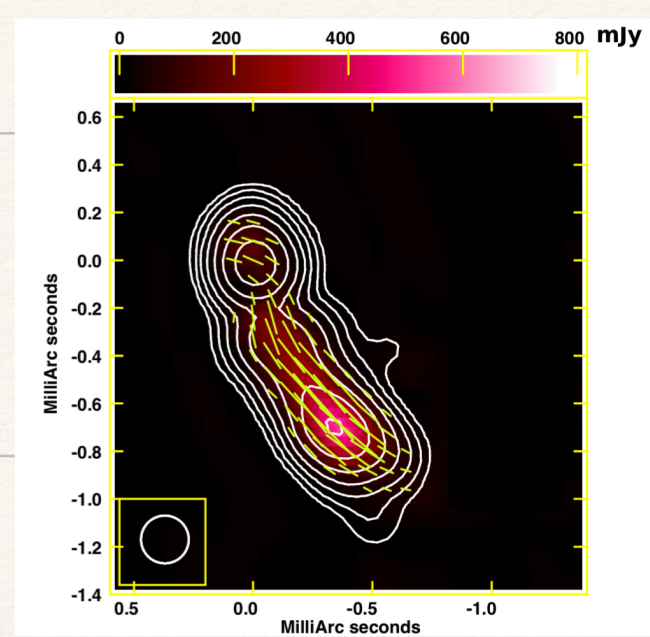
Radio - VLBI

# Broadband observations of 3C 279

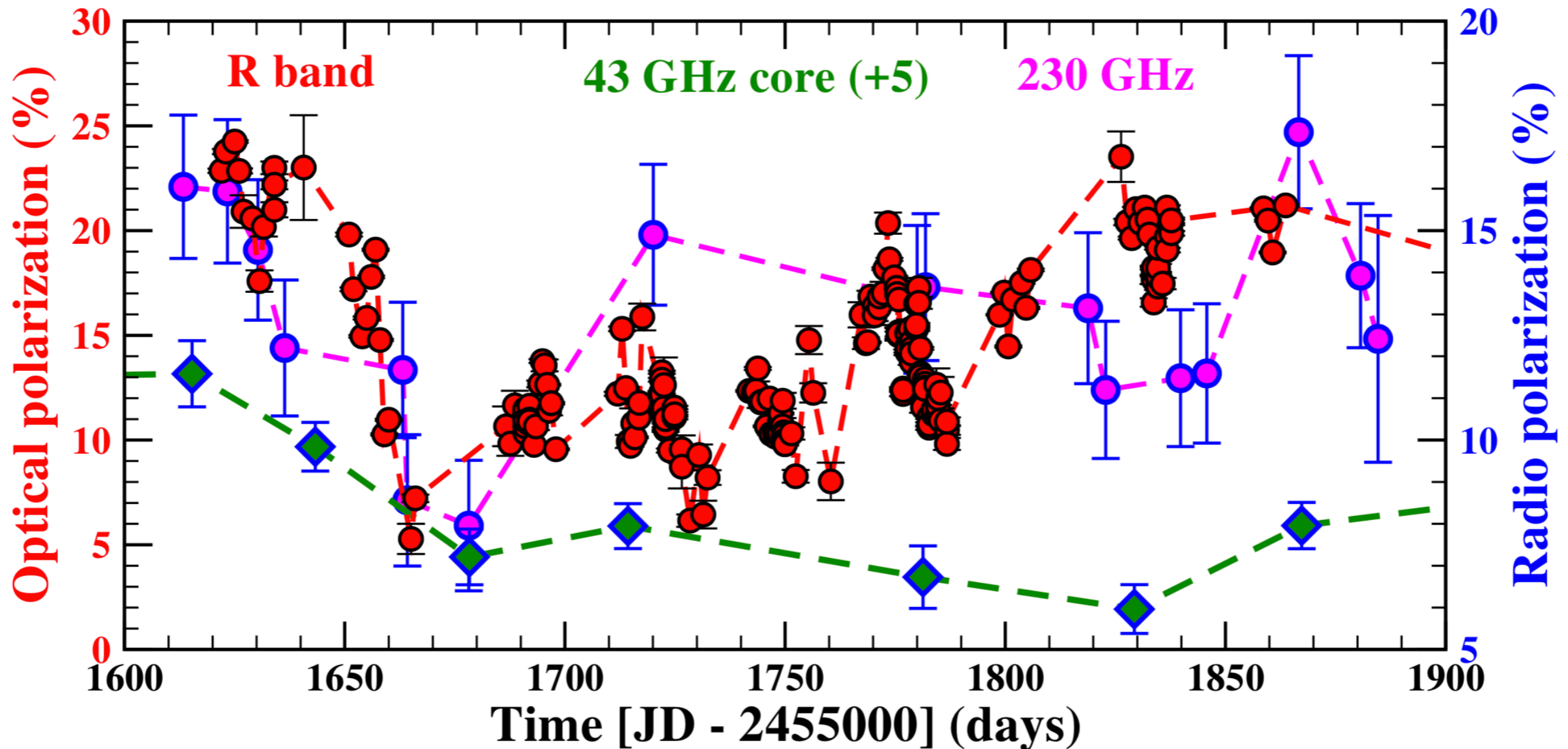


Radio image of 3C 279 jet

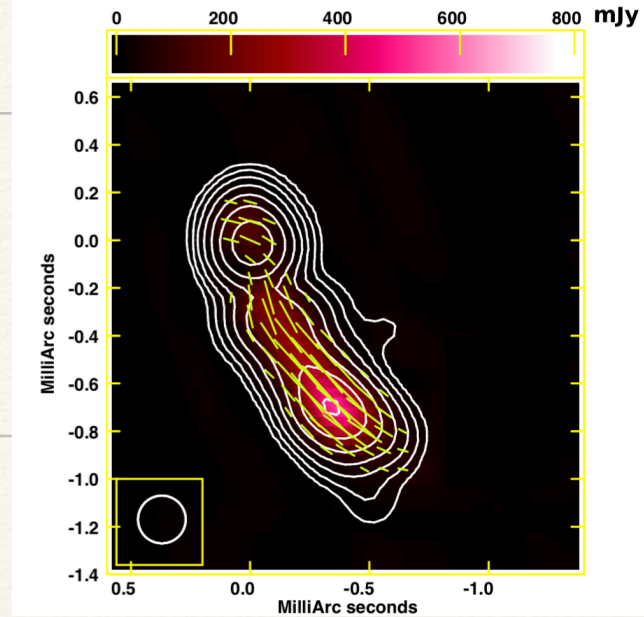
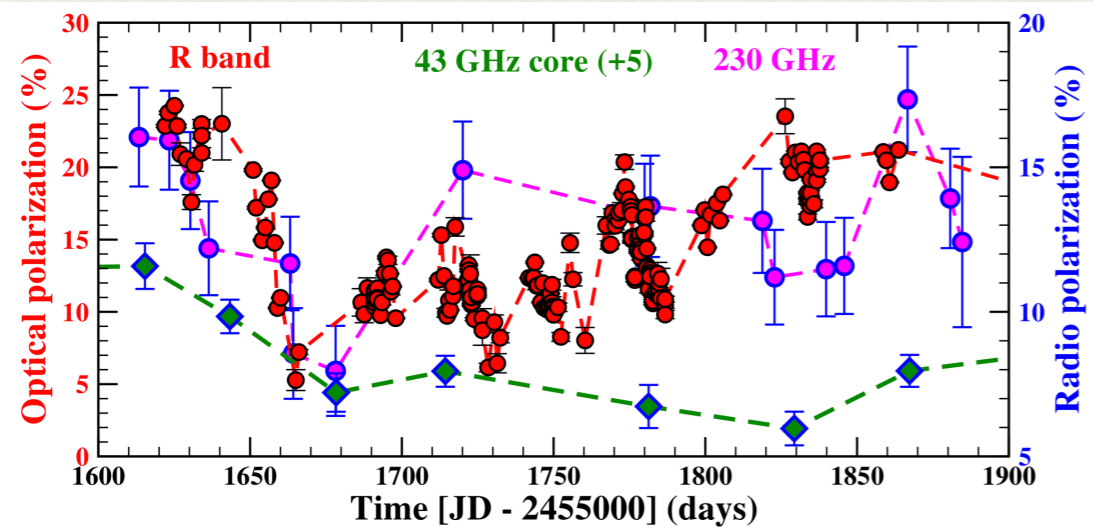
# Broadband observations of 3C 279



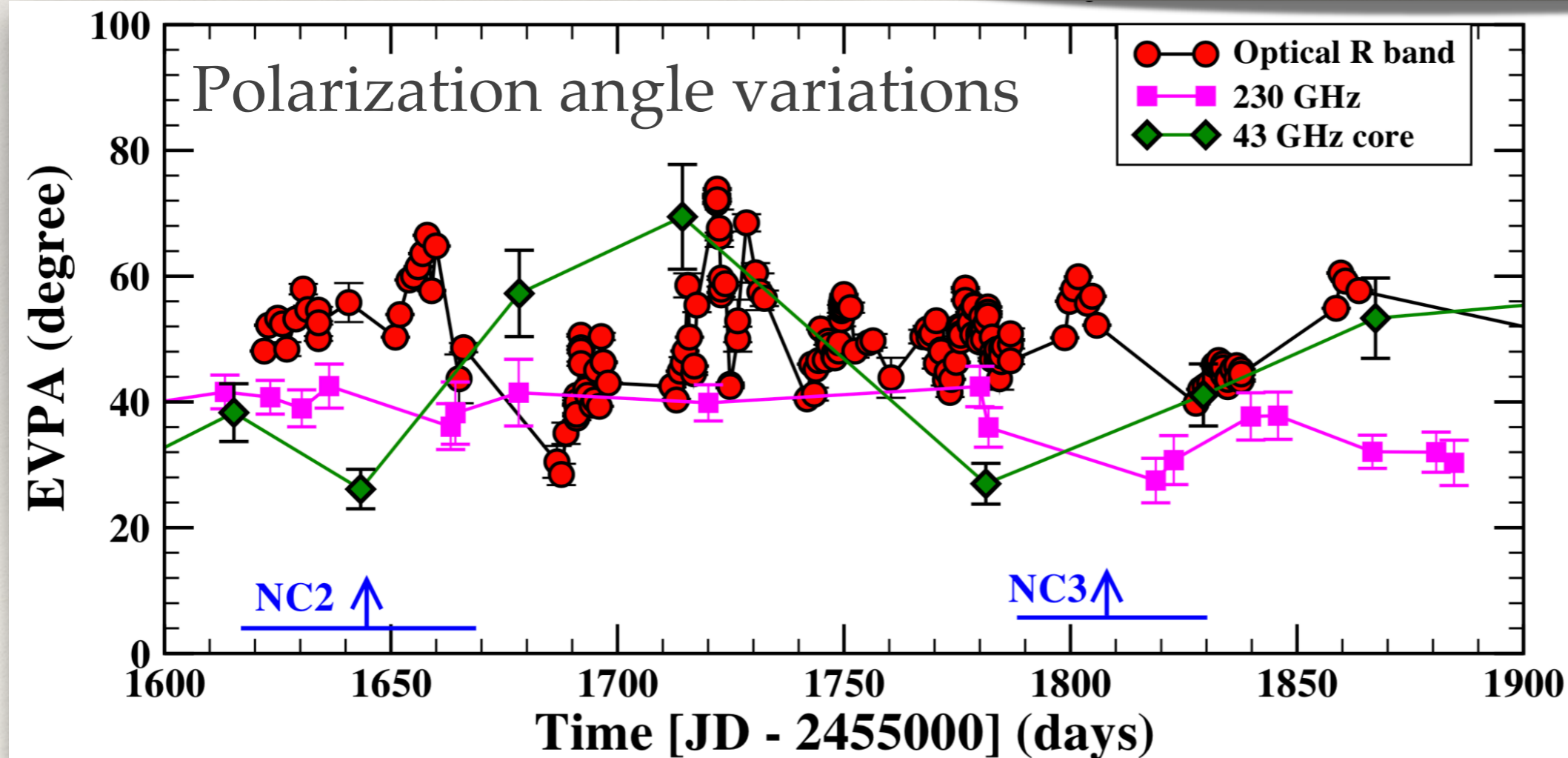
## Polarization variations



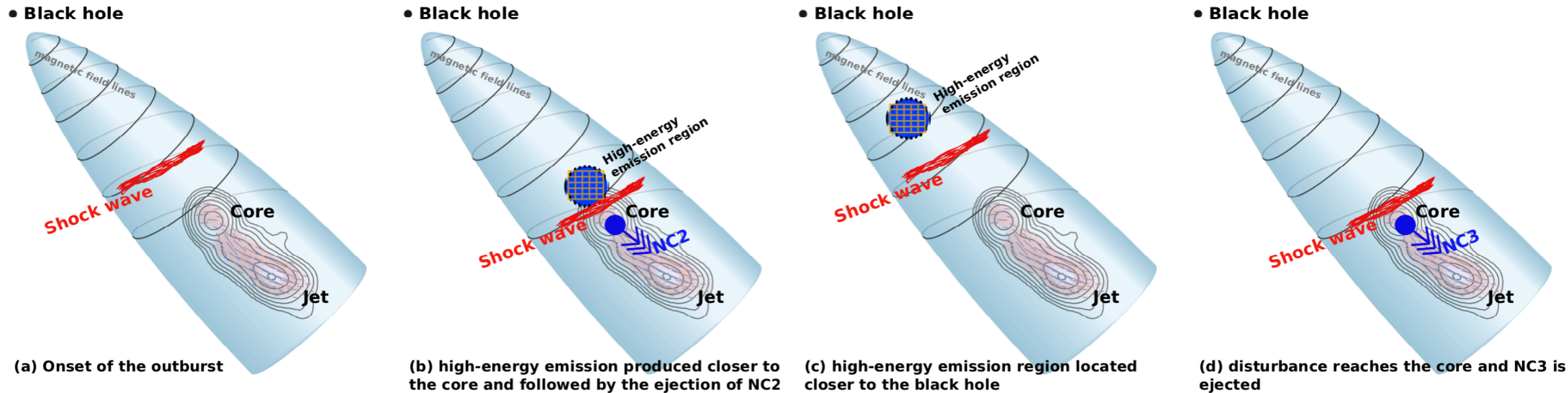
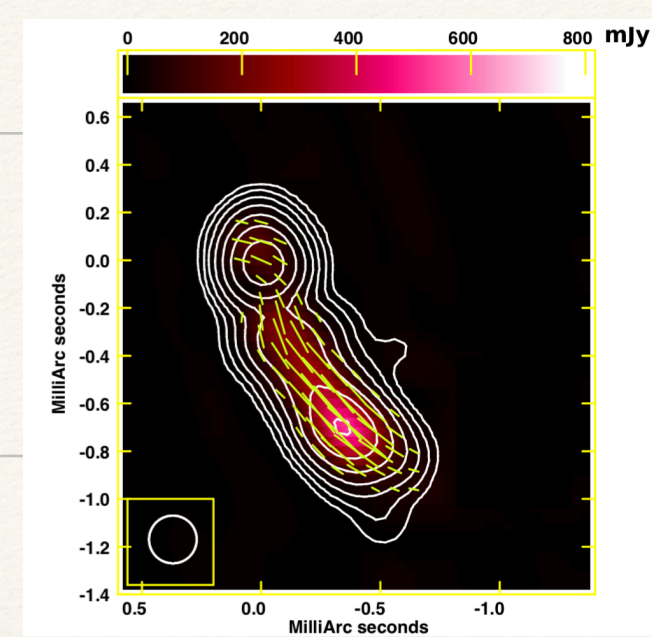
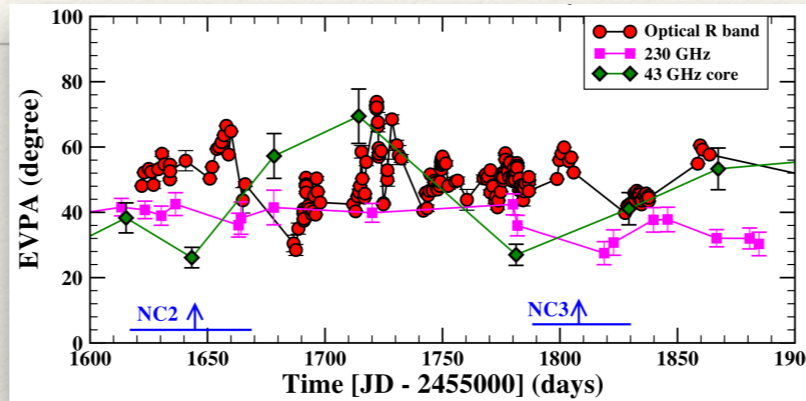
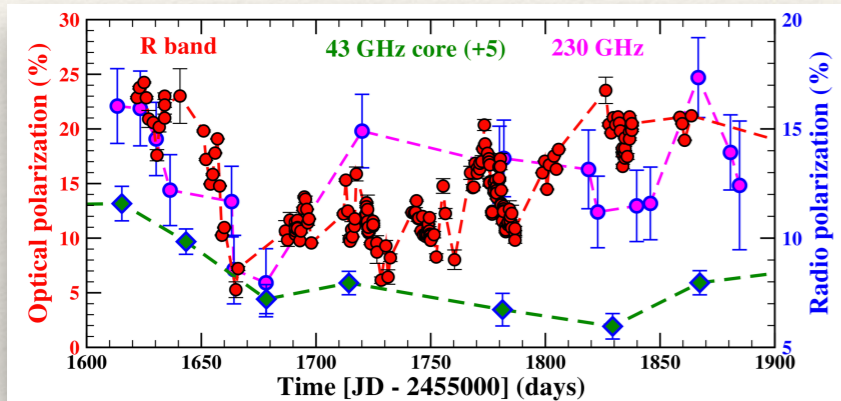
# Broadband observations of 3C 279



optical and radio polarization angles are roughly parallel to the jet direction



# Broadband observations of 3C 279



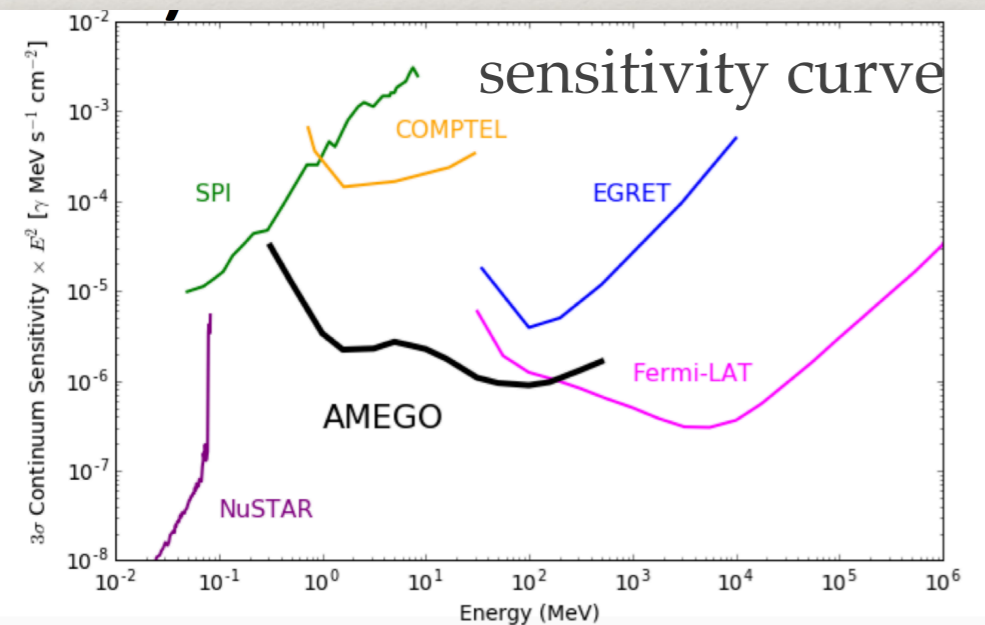
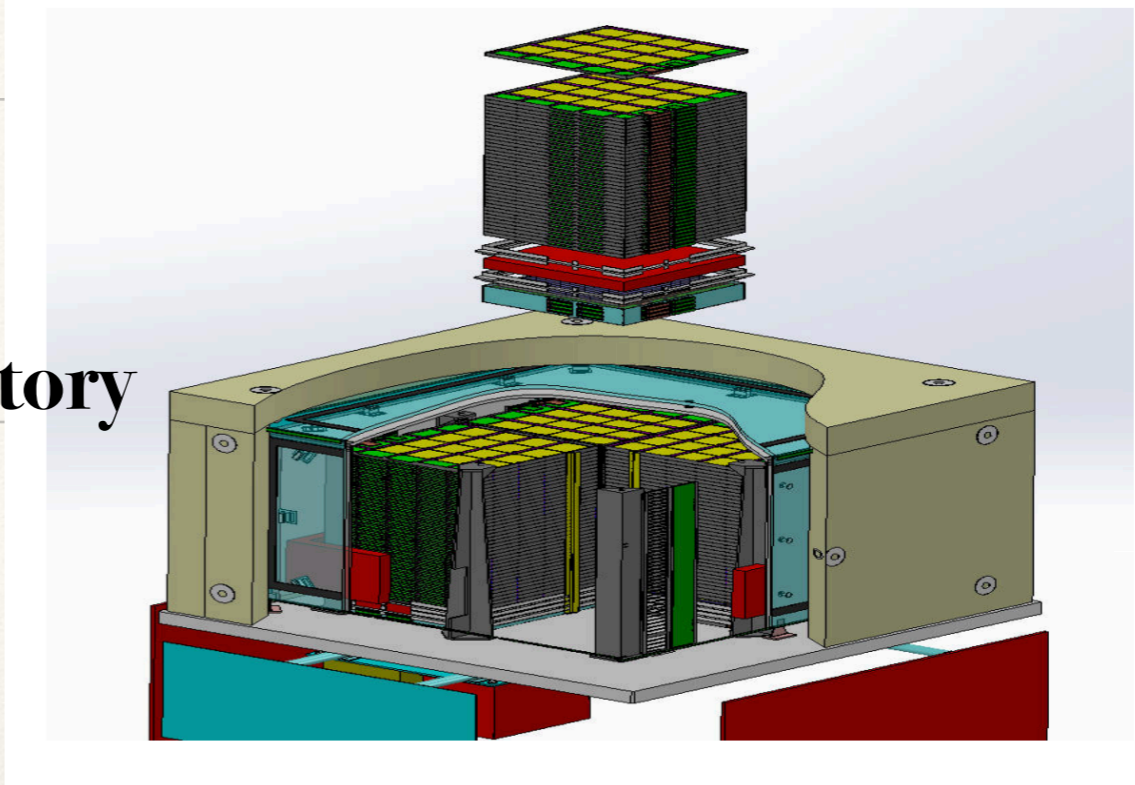
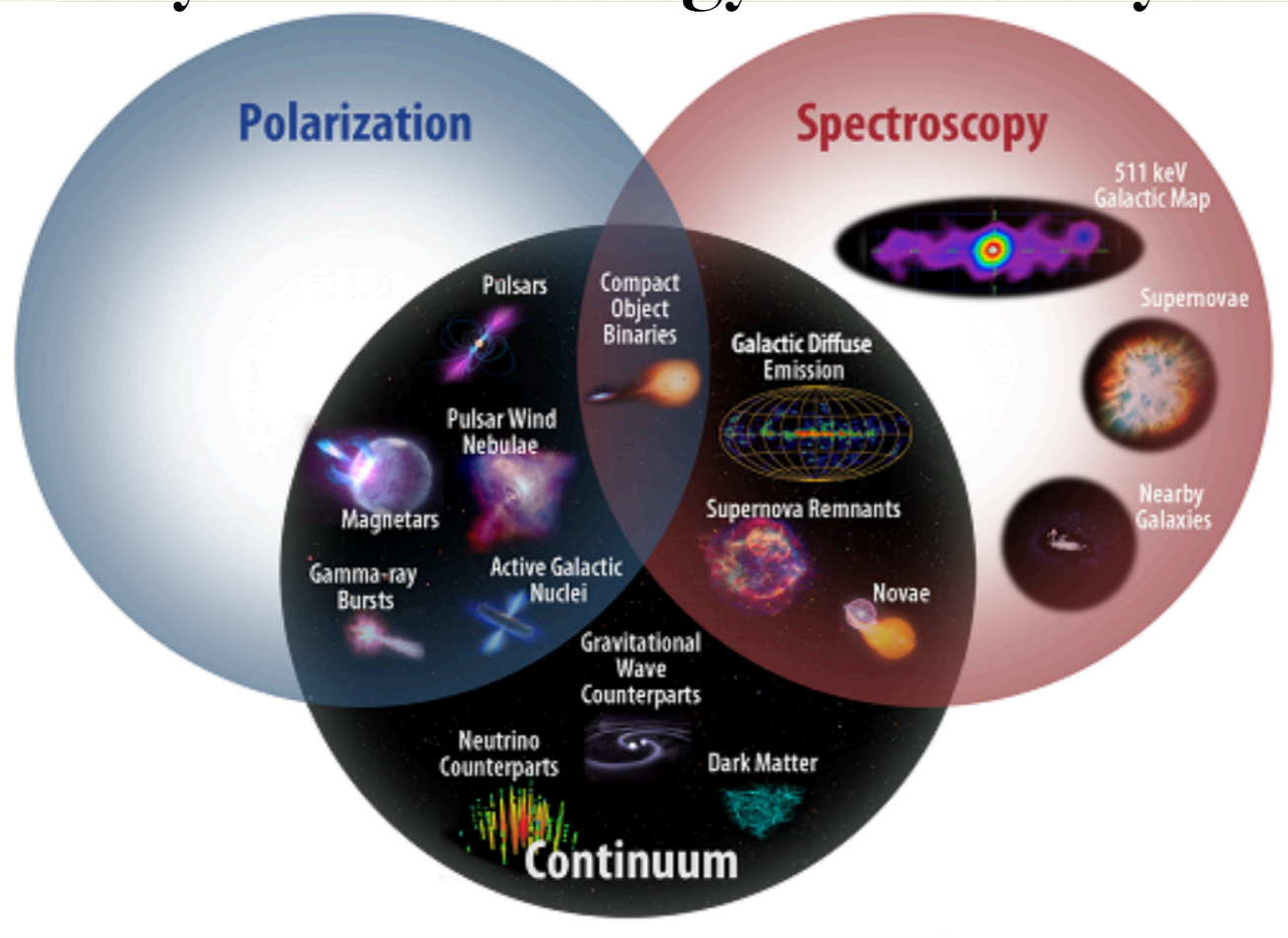
Multiple gamma-ray emitting sites in 3C 279



# High-energy polarization observations

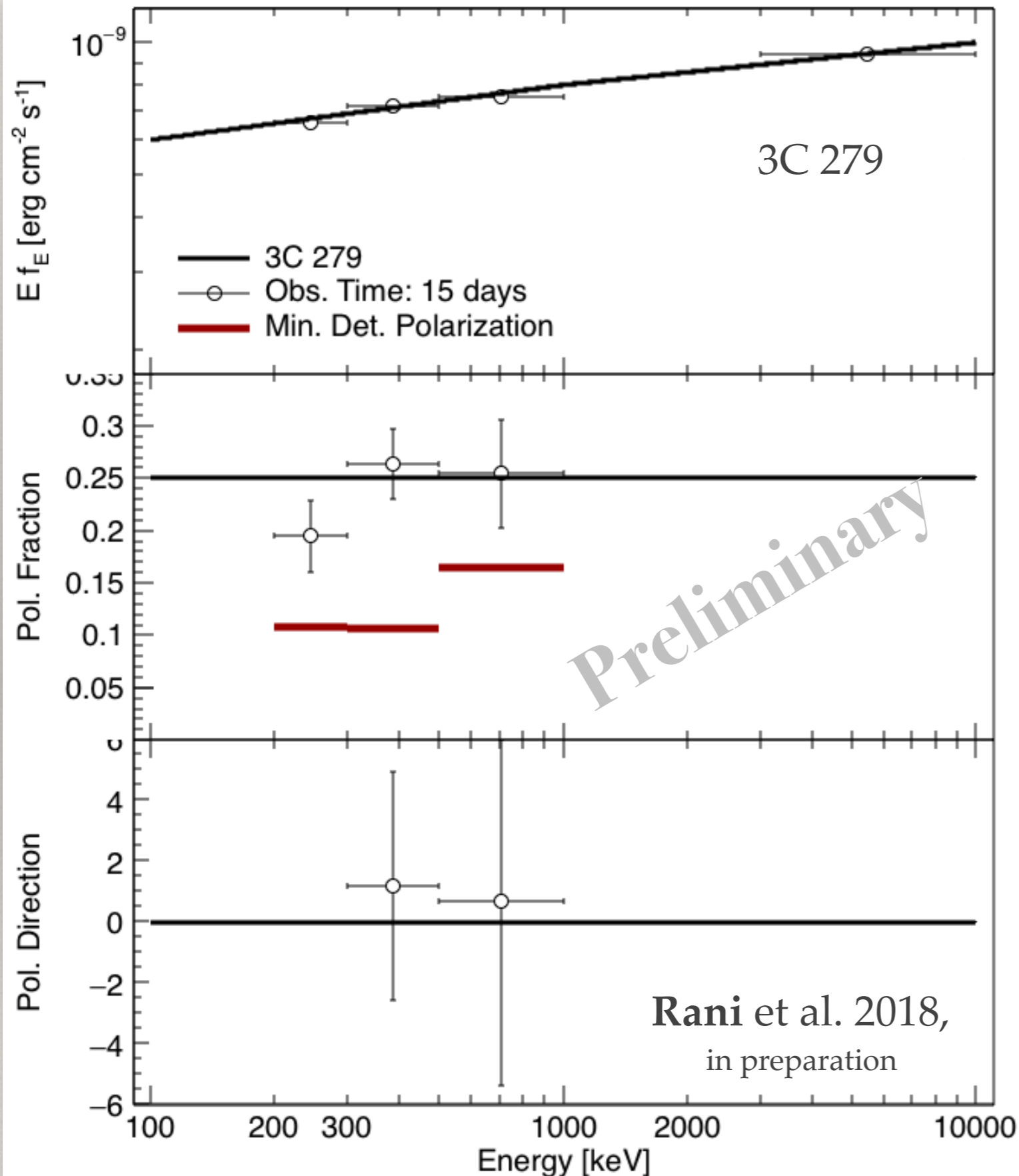
# AMEGO

## All-sky Medium Energy Gamma-ray Observatory



- ❖ Energy range: 200 keV – >10 GeV;
- ❖ <2% energy resolution below 5 MeV
- ❖ Angular resolution: 3 deg (1 MeV), 10deg (10 MeV), 1.5deg (100 MeV)
- ❖ Field of View: ~2.5 sr
- ❖ Survey mode, view 80% of the sky per orbit

# AMEGO - polarization simulations

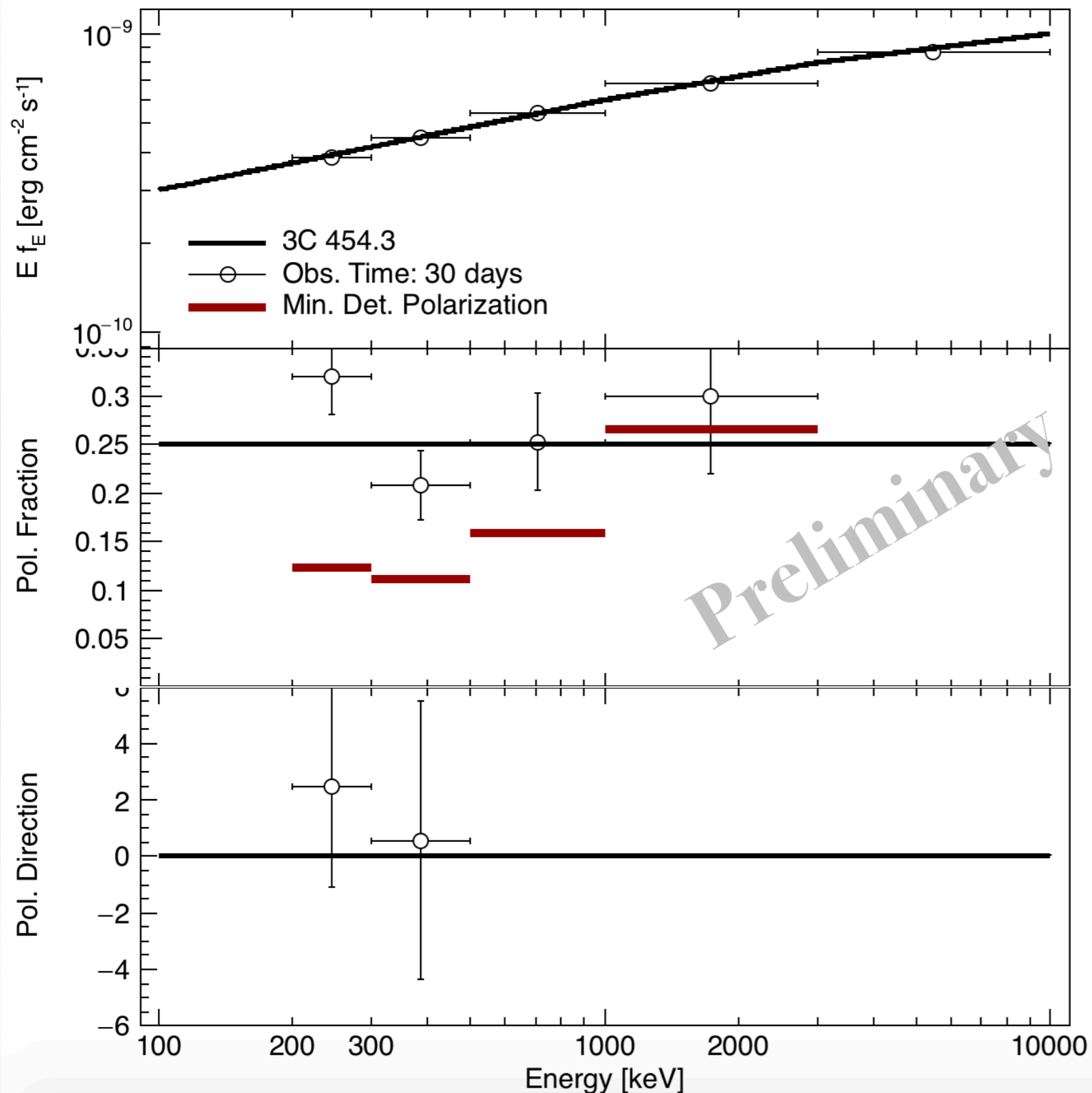


On-time = 0.1

Observation time: 15 days  
Fractional polarization : 25%  
Polarization angle = 0 degree

>(15-20)% polarized  
LSPs will be detectable

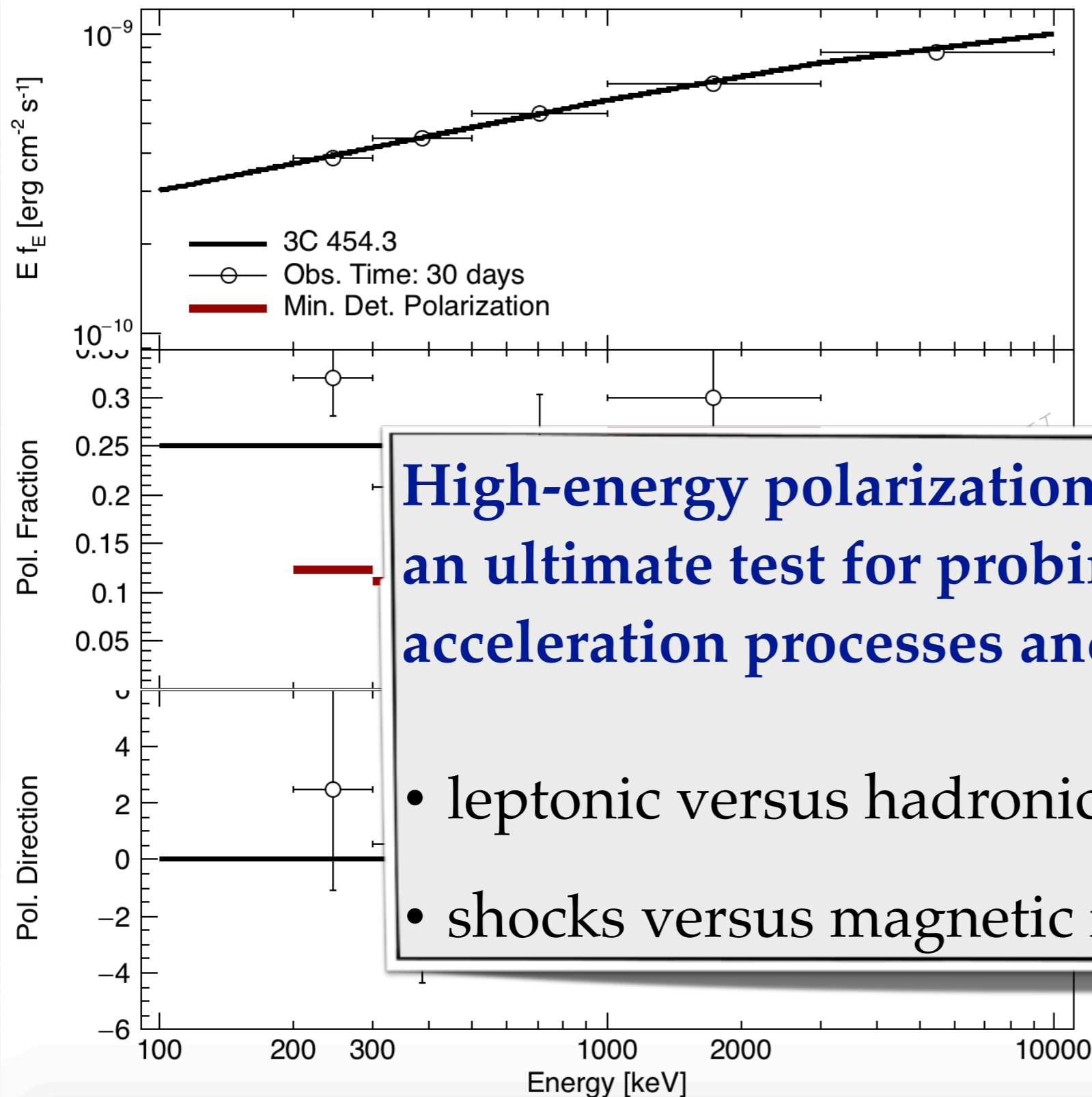
# A few more LSPs: 3C 454.3



Observation time: 30 days  
Fractional polarization : **25%**  
Polarization angle = 0 degree

**>(15-20)% polarized LSPs will  
be detectable**

# A few more LSPs: 3C 454.3



Observation time: 30 days  
Fractional polarization : **25%**  
Polarization angle = 0 degree

**High-energy polarization observations will deliver an ultimate test for probing the energetic particle-acceleration processes and emission mechanisms:**

- leptonic versus hadronic models and
- shocks versus magnetic reconnection

# Future Prospectives

- **Fermi is doing great –**

>3000 Fermi-LAT sources (c.f. ~300 GeV sources prior to Fermi)

Many discoveries, many new source classes, many surprises

Pass8 data release June 2015– improved systematics and an extension of the energy reach for the photon analysis below 100 MeV and above a few hundred GeV

- **The future of high-resolution VLBI is also very bright and rich –**

The event horizon telescope (EHT) offers an angular resolution of ~10 micro arcseconds

Participation of ALMA brought a new era

- **The high-energy polarization missions are also on their way –**

Imaging X-ray Polarimetry Explorer (**IXPE**), All-sky Medium Energy Gamma-ray Observatory (**AMEGO**), etc.

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**thanks for your attention**