# Wobbling jets Wobbling jets in active super-massive black holes -

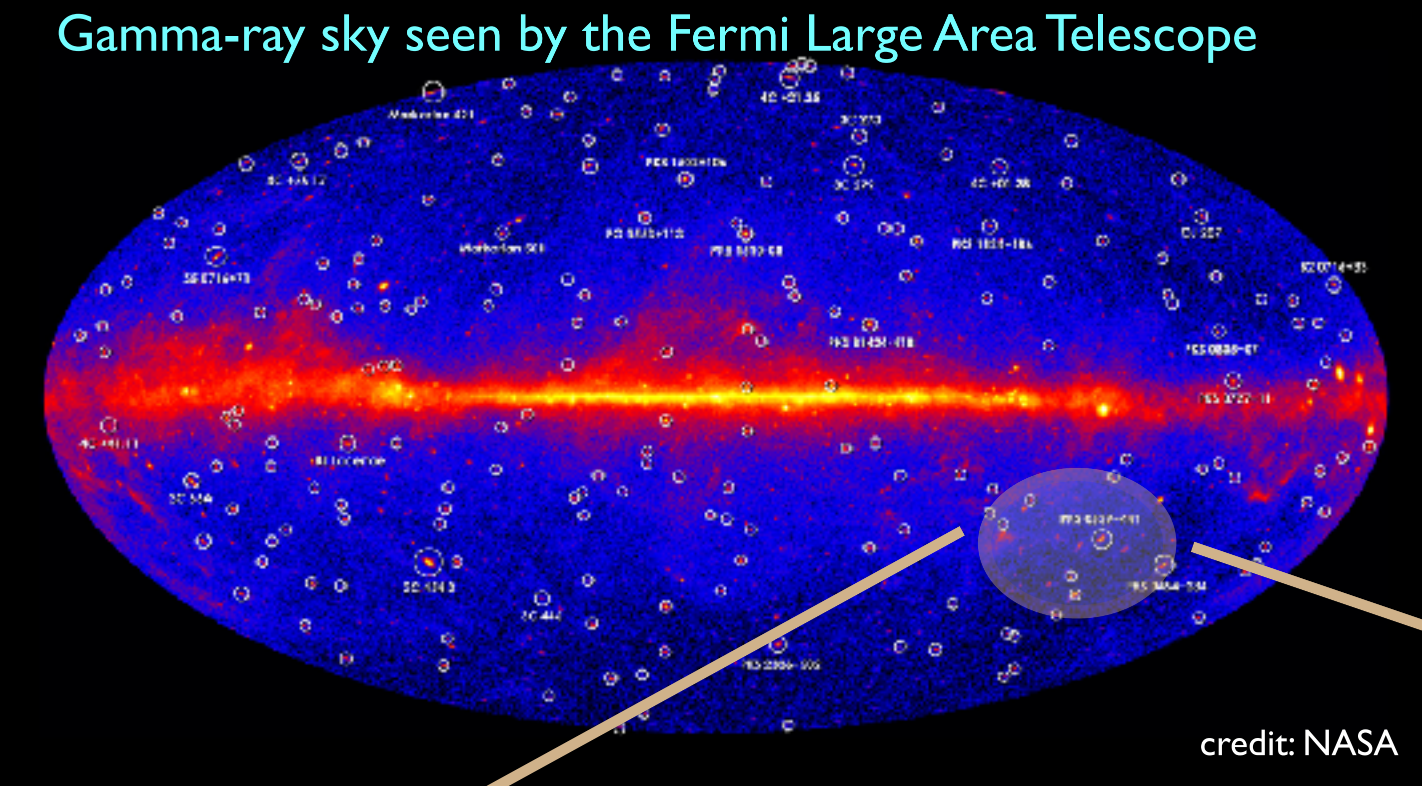
## a powerful tool to probe gamma-ray dissipation sites


**Bindu Rani,** NASA GSFC, USA

bindu.rani@nasa.gov

*On behalf of the Fermi-LAT collaboration*

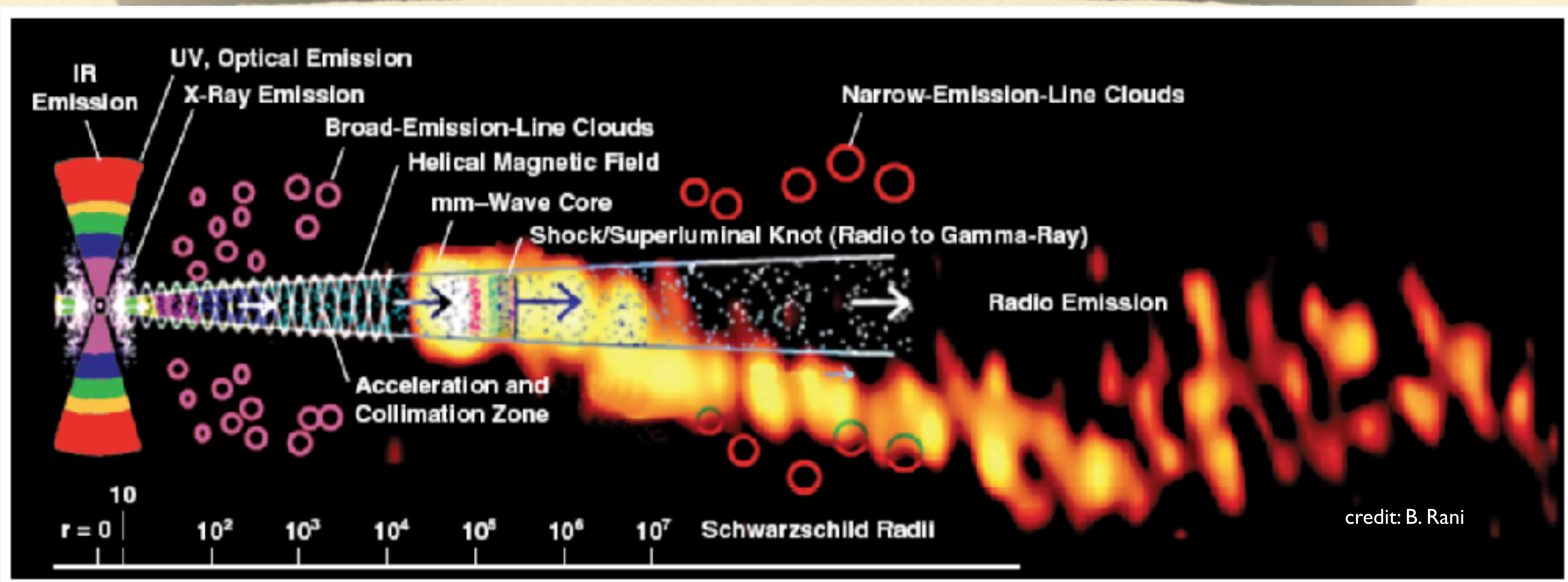
Scientific contributors:
T. P. Krichbaum, A. Zensus [MPIfR, Germany], J. Hodgson [KASI, S. Korea], A. Marscher, S. G. Jorstad [BU, USA]




# Key question:

- Location and origin of gamma-rays

## More than 60% objects seen by Fermi are blazars

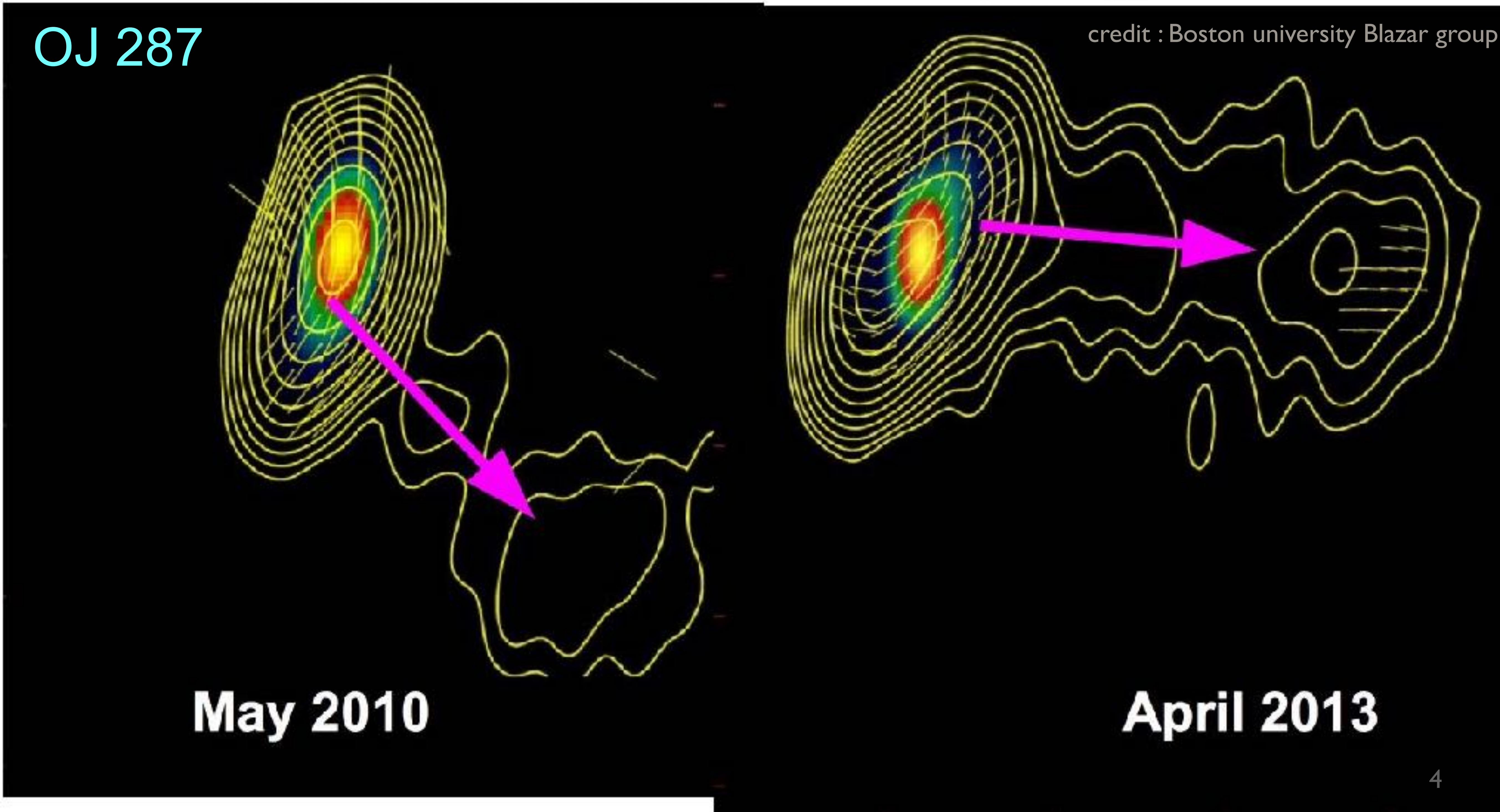


# JET WOBBLING

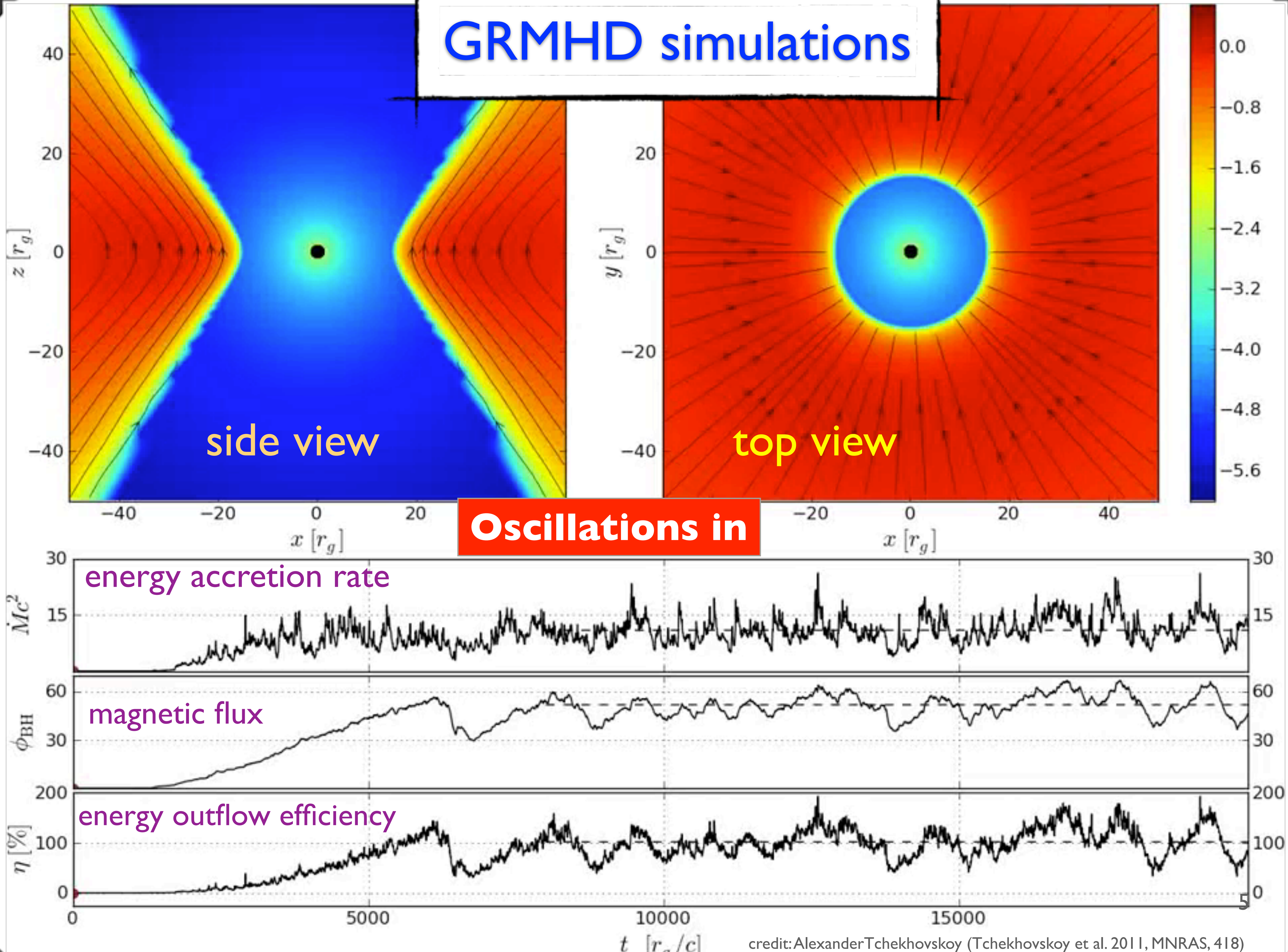
powerful probe of energy extraction from supermassive black holes

# Wobbling Jets

Change in the Jet orientation with time

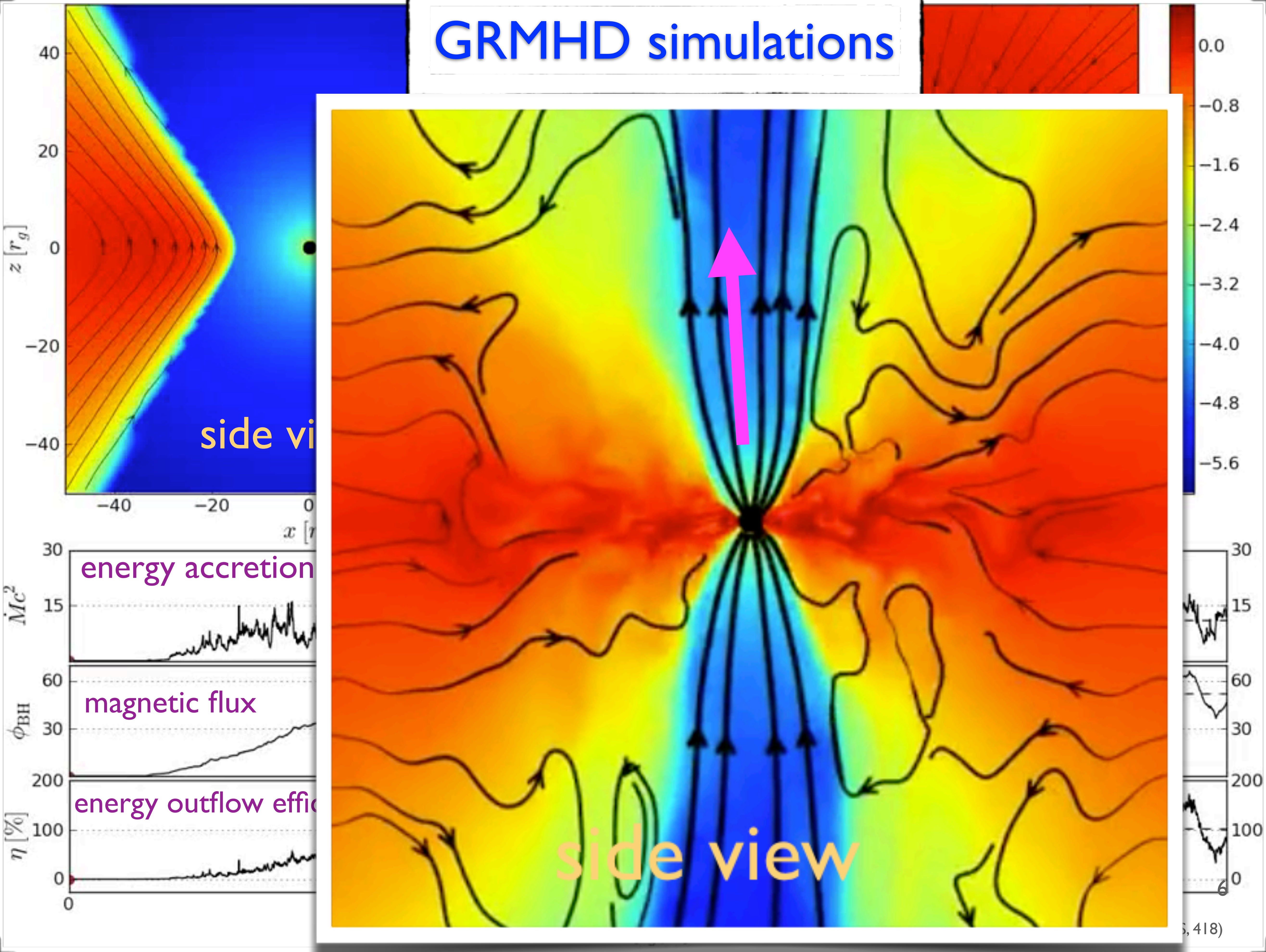


# GRMHD simulations




credit: Alexander Tchekhovskoy (Tchekhovskoy et al. 2011, MNRAS, 418)

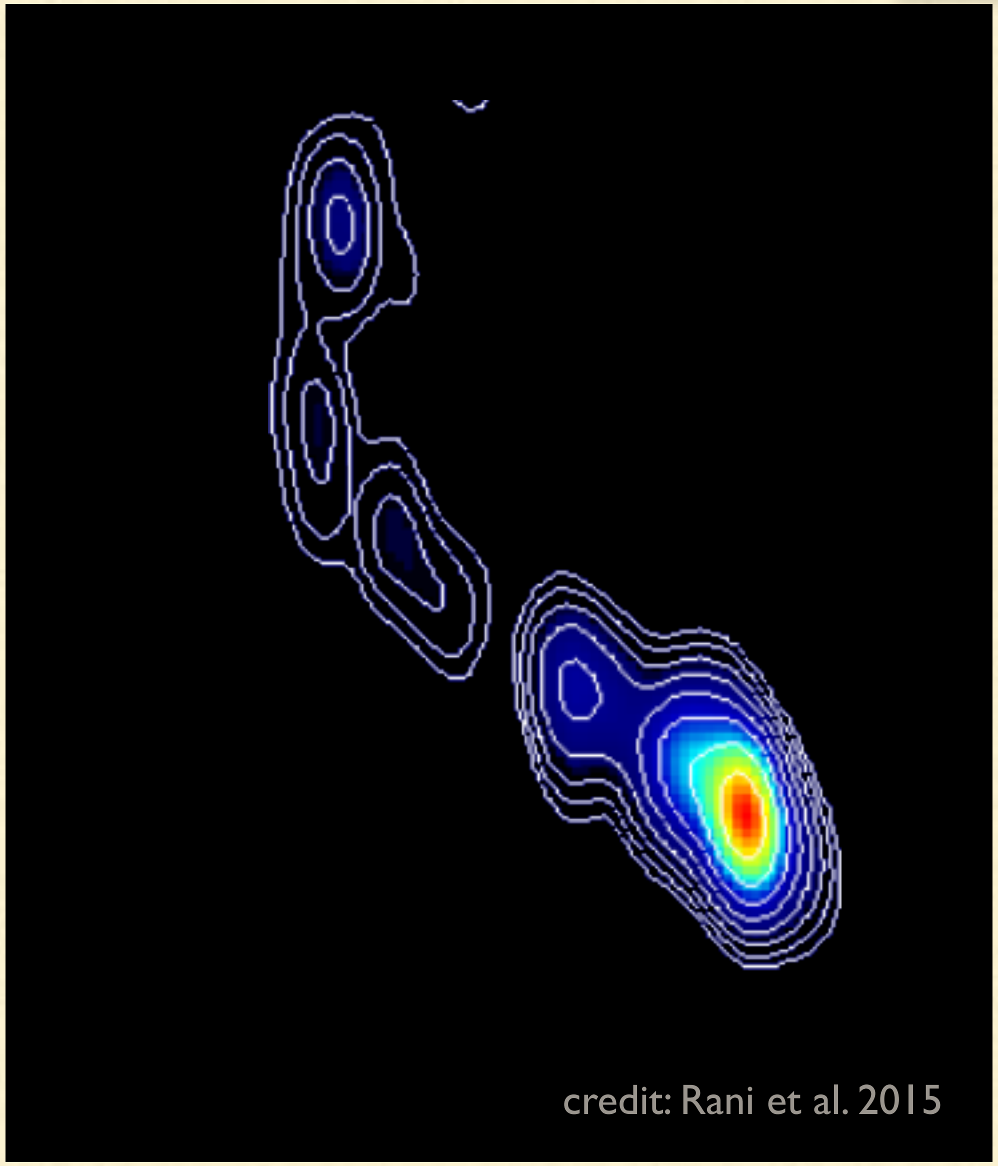
# GRMHD simulations



# Intensity and orientation variations

GMVA angular resolution: 50 micro-arcseconds

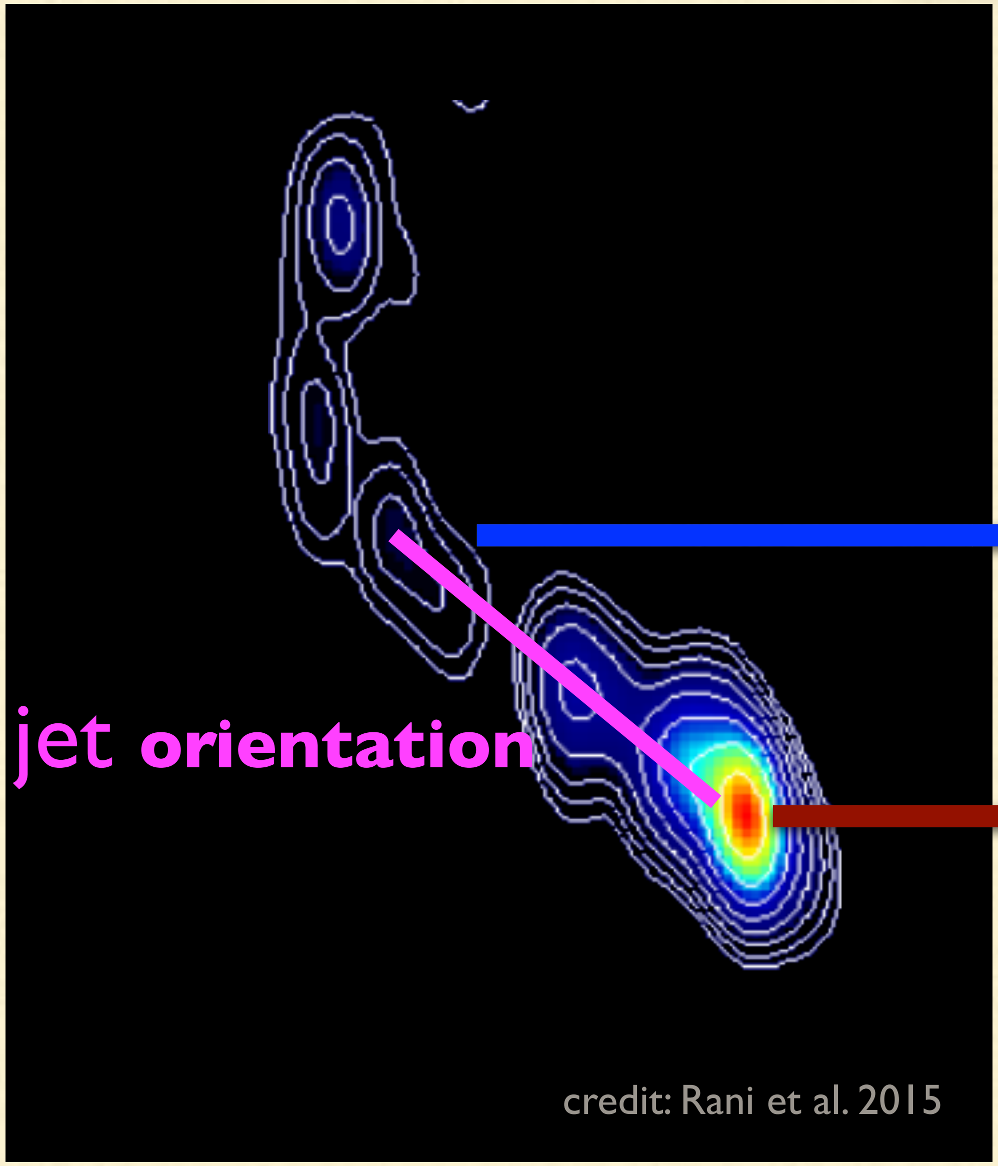
For a $10^9$ $M_\odot$ BH (z=0.1) = **450 $R_g$**



# Intensity and orientation variations

GMVA angular resolution: 50 micro-arcseconds

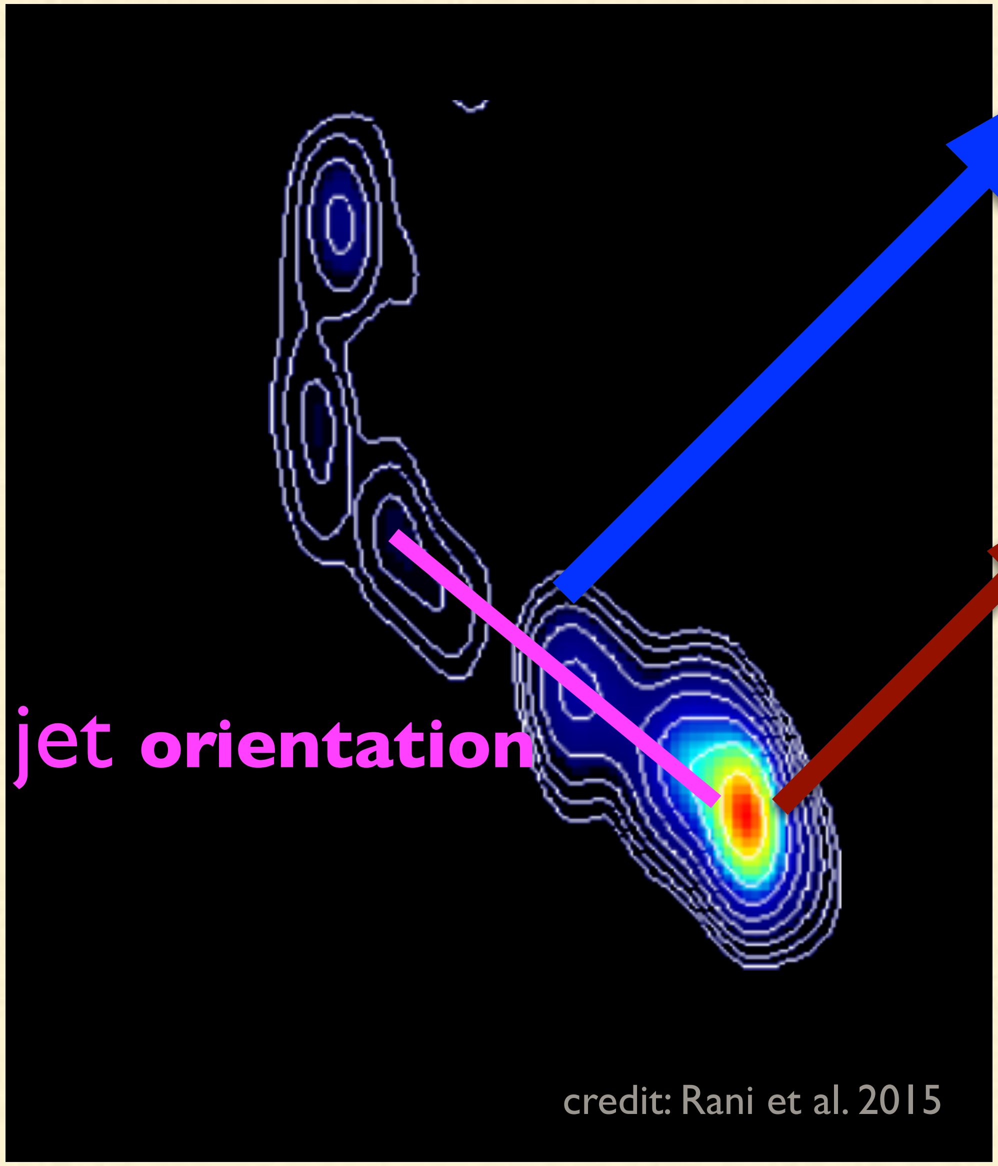
For a $10^9$ $M_\odot$ BH (z=0.1) = **450 $R_g$**

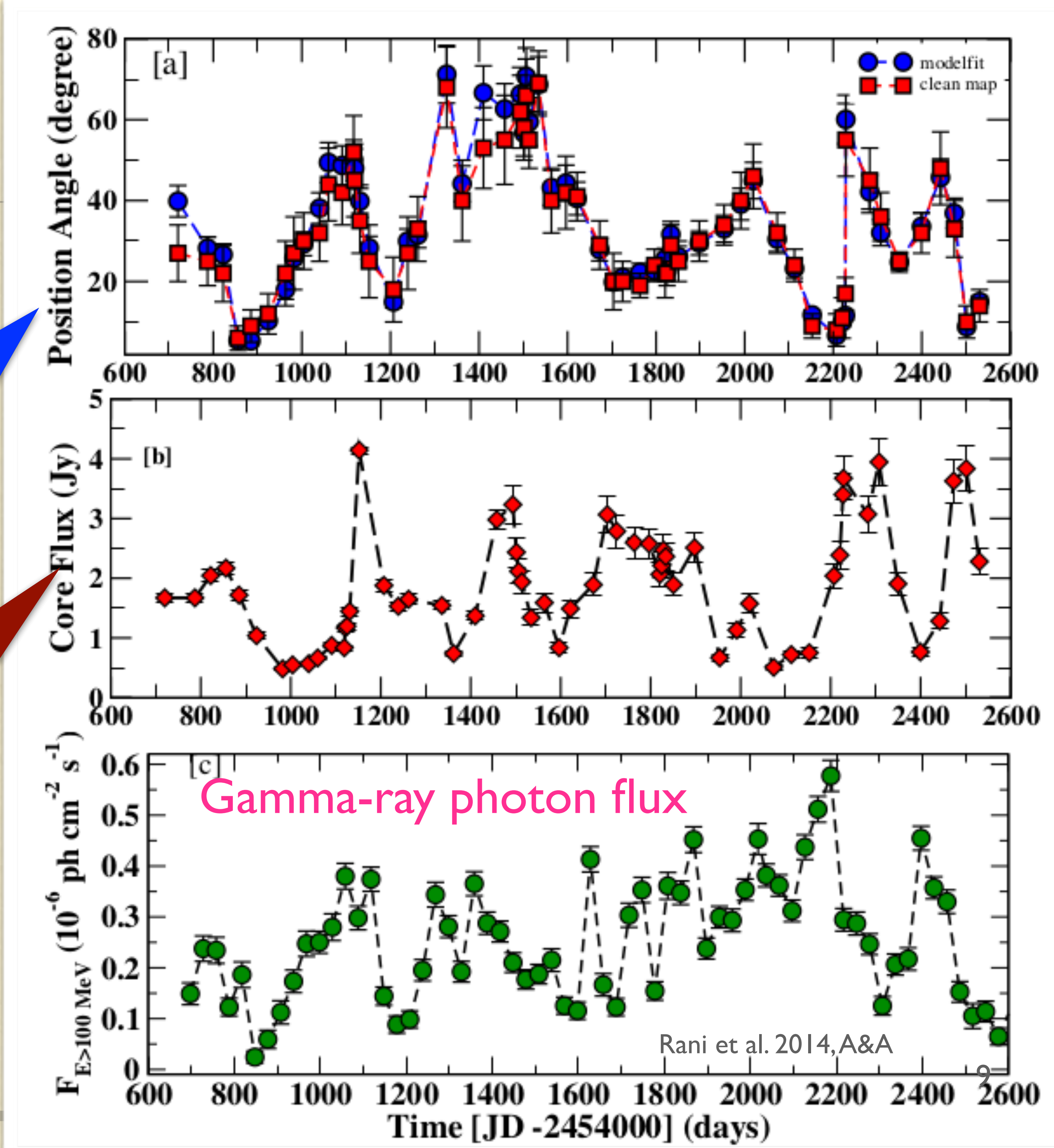



Jet outflow direction

Flux density of the most compact region close to the supermassive black hole

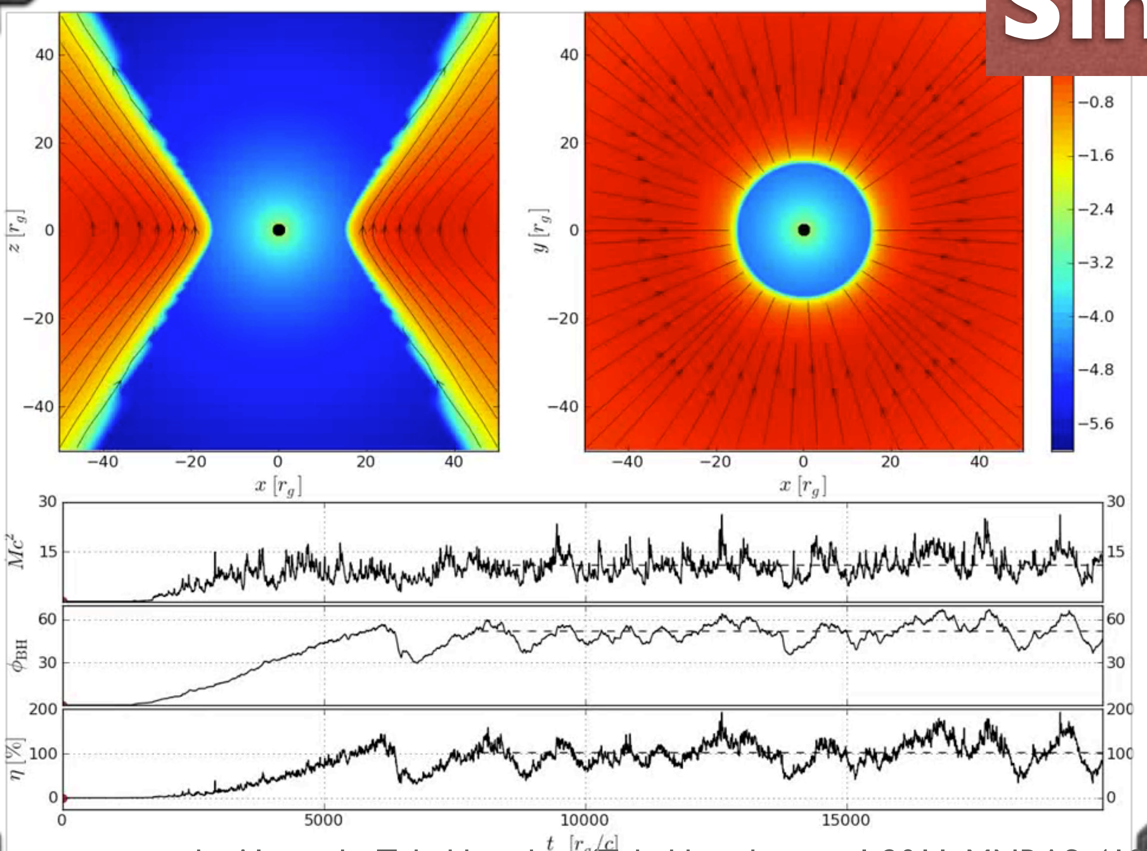
# Intensity and orientation variations



# Simulation versus observation

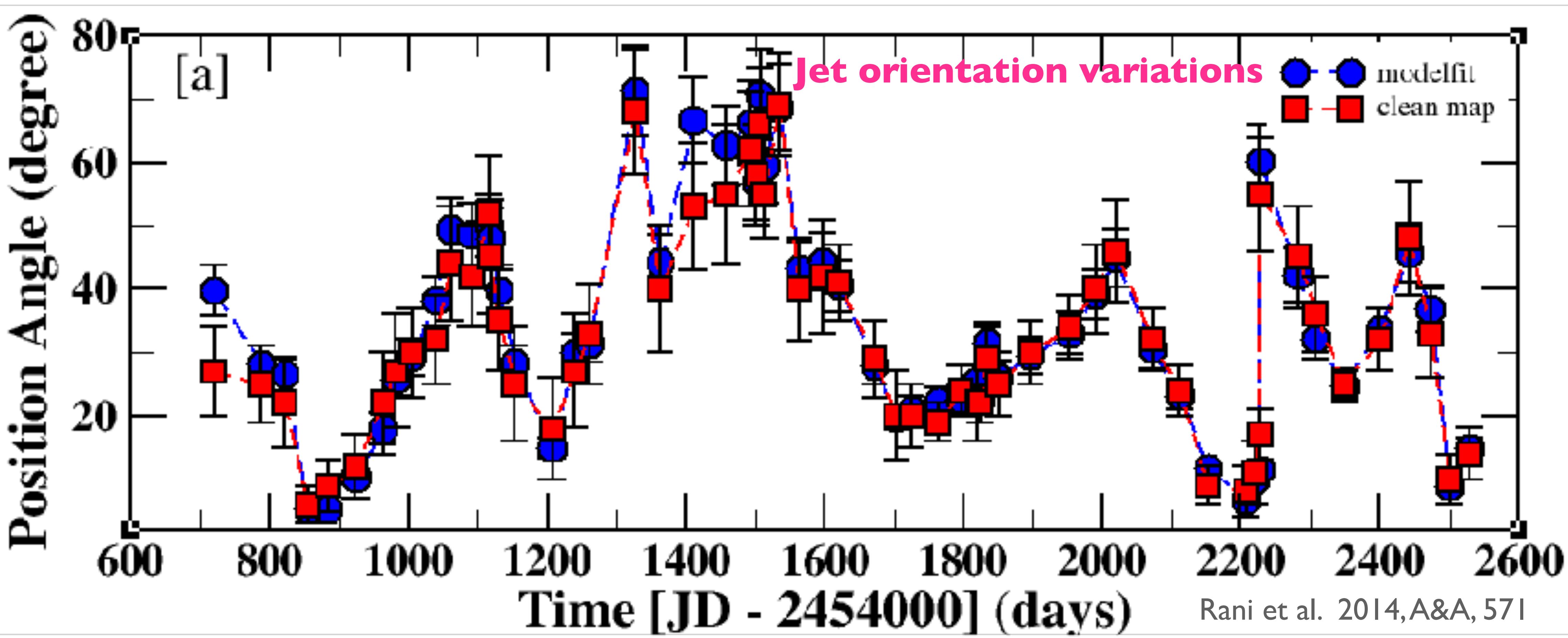
Jet orientation variations



credit: Alexander Tchekhovskoy (Tchekhovskoy et al. 2011, MNRAS, 418)

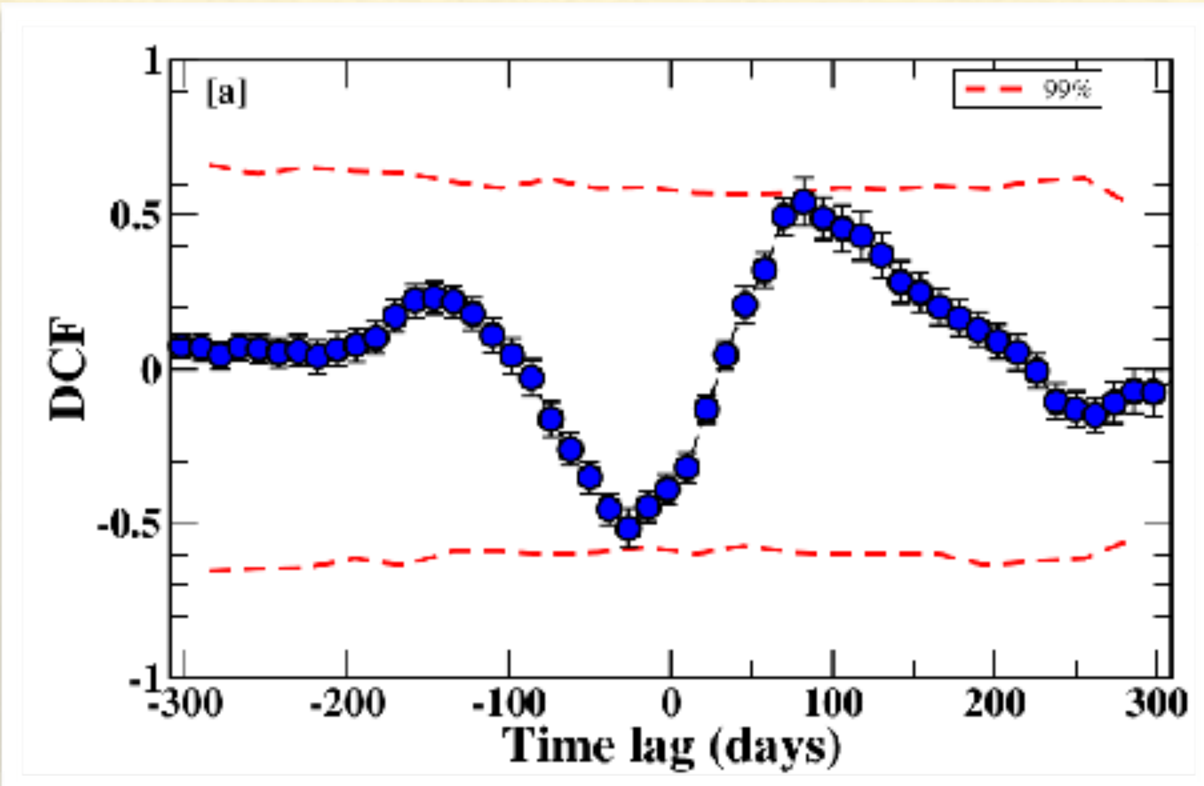
Simulations

Observations

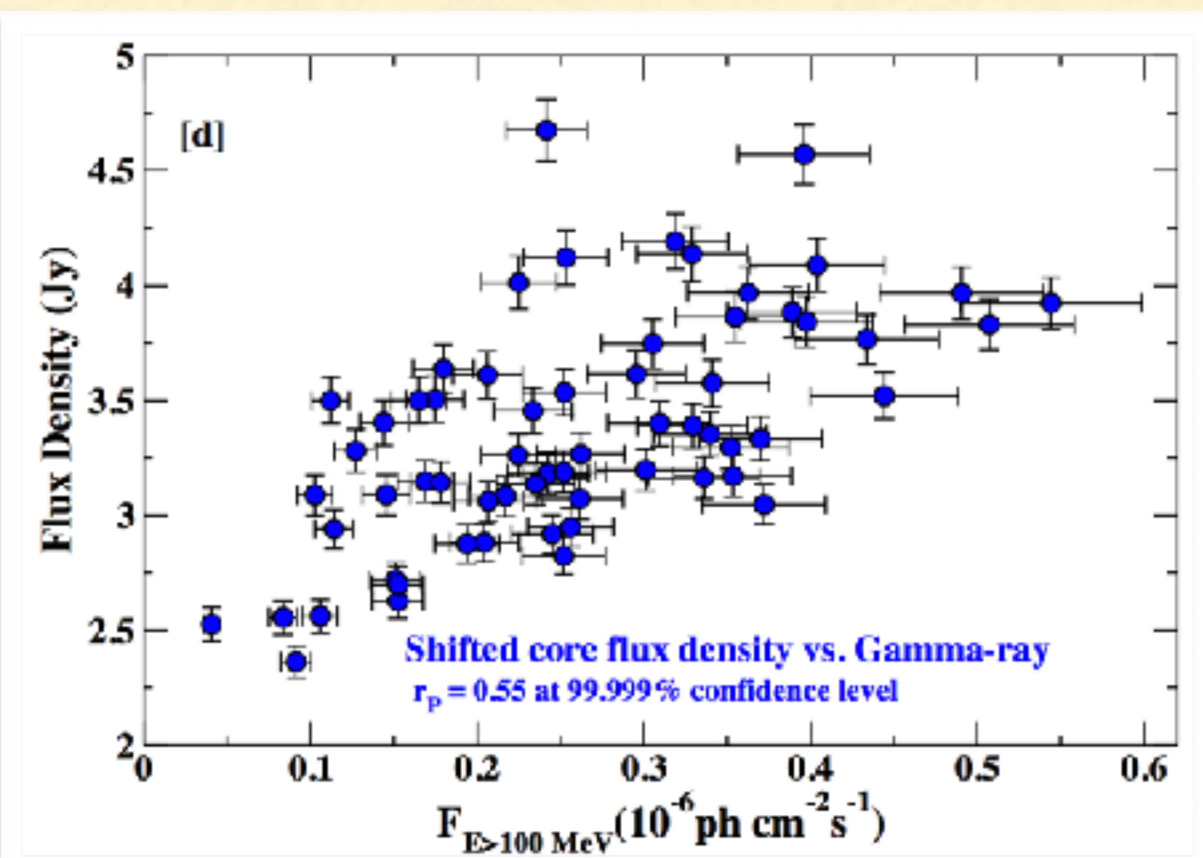



Rani et al. 2014, A&A, 571

# Gamma-ray and radio flux variations




Gamma-ray variations lead radio by ~80 days

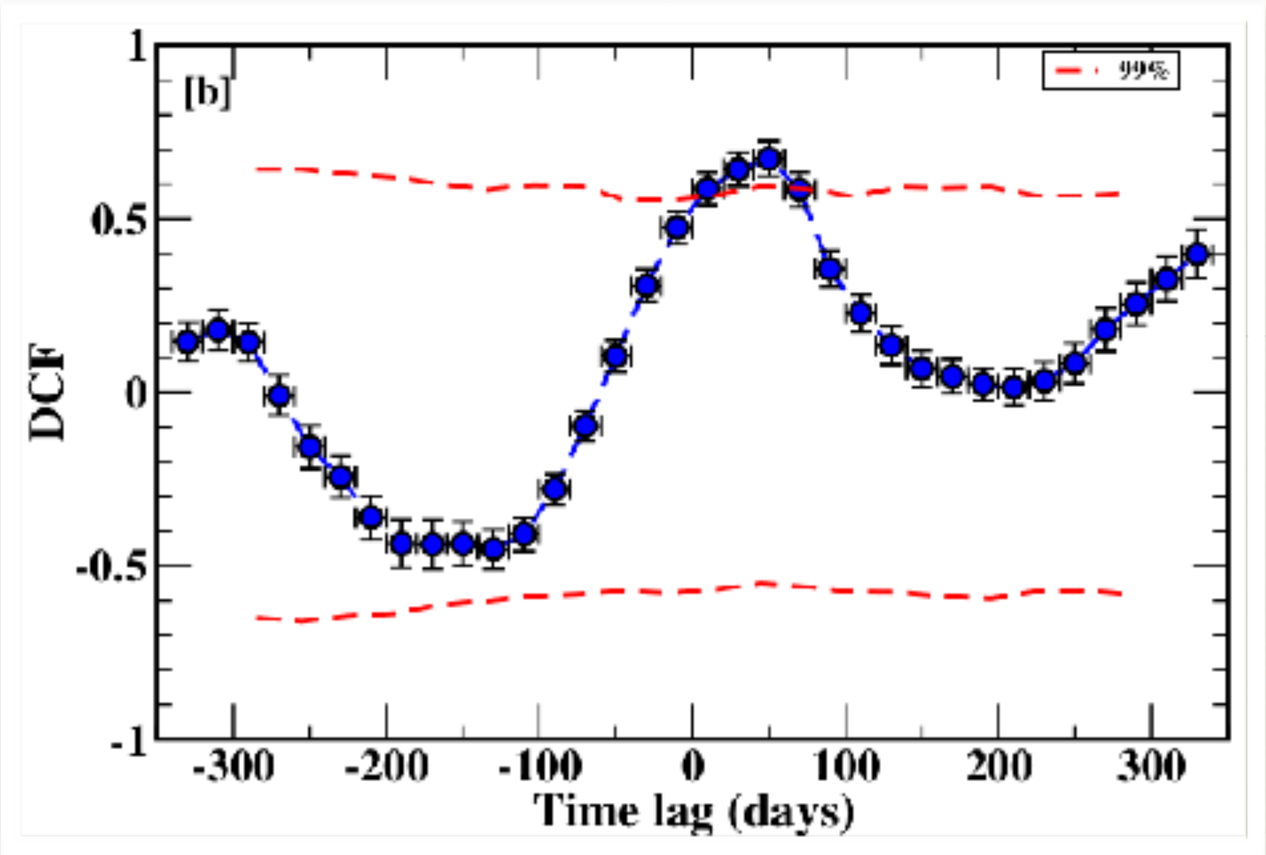


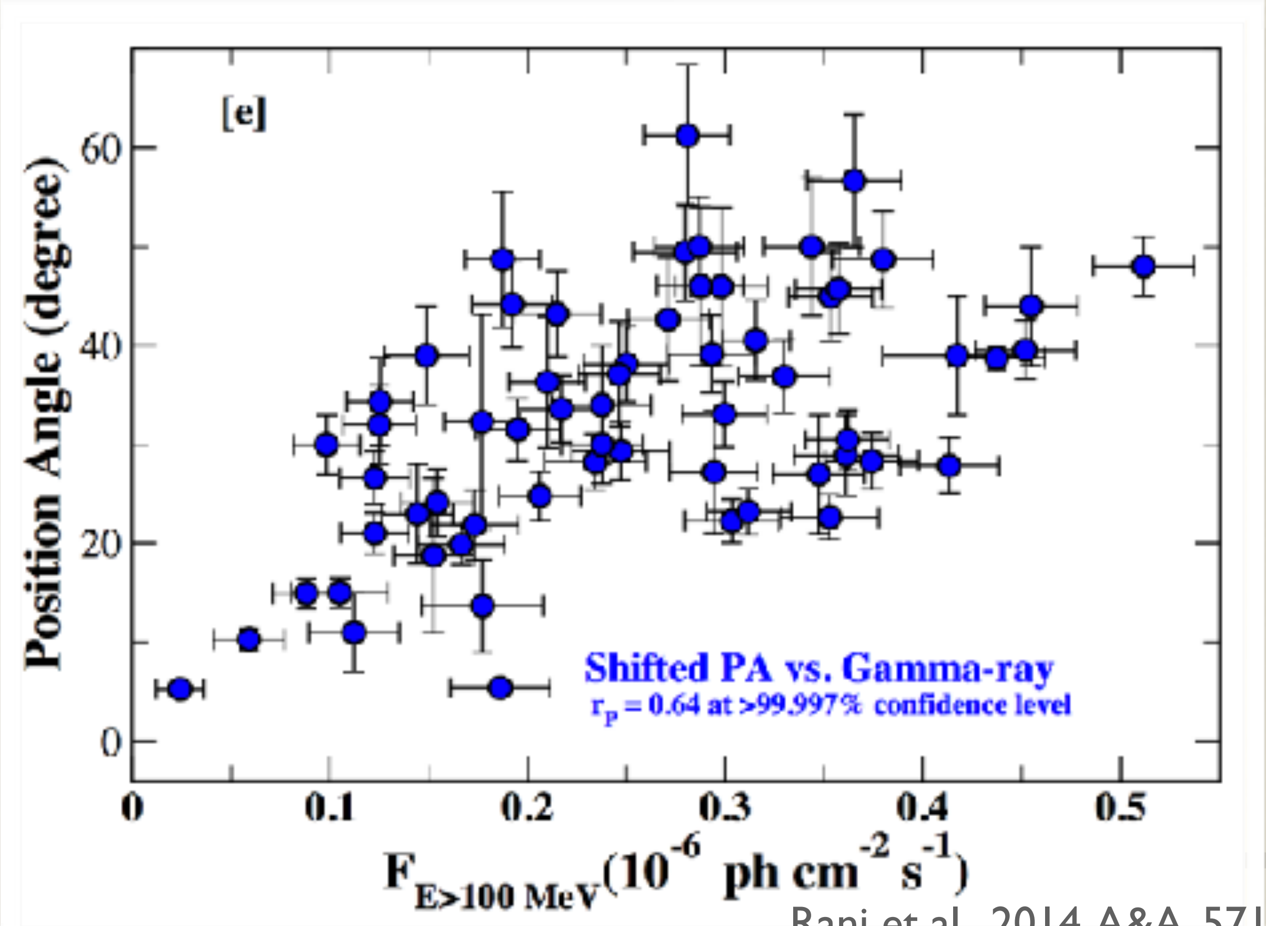

Separation between radio and gamma-ray emission regions is ~2.9 parsec



Rani et al. 2014, A&A, 571

# Gamma-ray and jet orientation variations

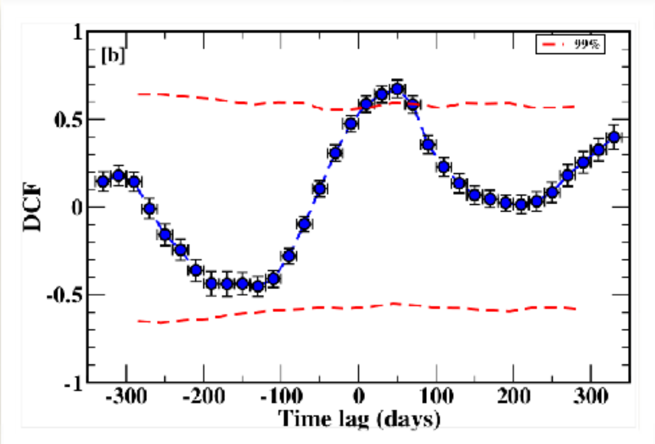


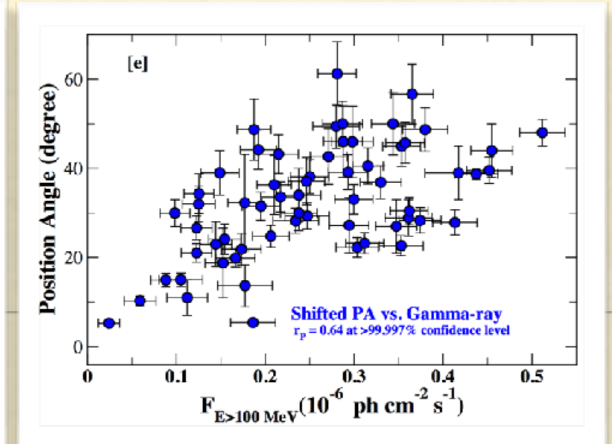




Rani et al. 2014, A&A, 571

Strong physical and causal connection between gamma-ray emission and the inner jet morphology in the source.

# Gamma-ray and jet orientation variations



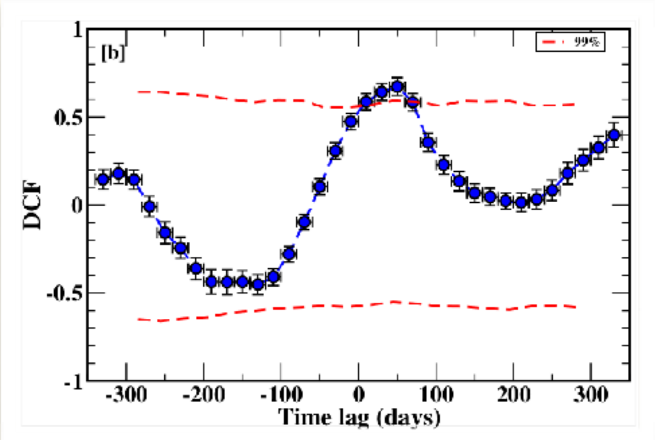



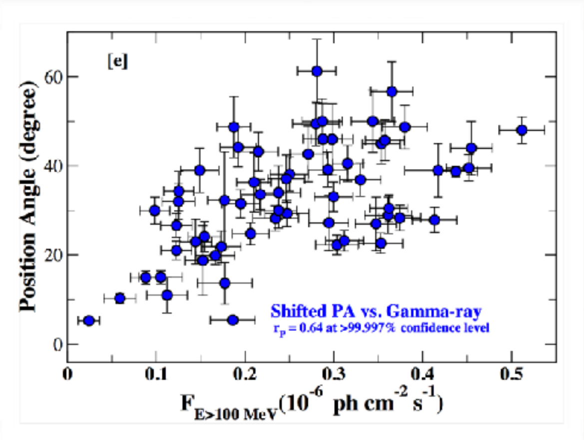

- High-energy dissipation sites

- Strong casual connection between the inner jet morphology and high-energy emission in blazar S5 0716+714

- Gamma-ray emission is associated with bends in the jet, possibly indicating energy dissipation due to magnetic instabilities or reconnection.

# Gamma-ray and jet orientation variations




An excellent tool to probe high-energy dissipation **sites** and **conditions**

- Strong casual connection between the inner jet morphology and high-energy emission in blazar S5 0716+714
- Gamma-ray emission is associated with bends in the jet, possibly indicating energy dissipation due to magnetic instabilities or 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) will offer an angular resolution of ~10 micro arcseconds

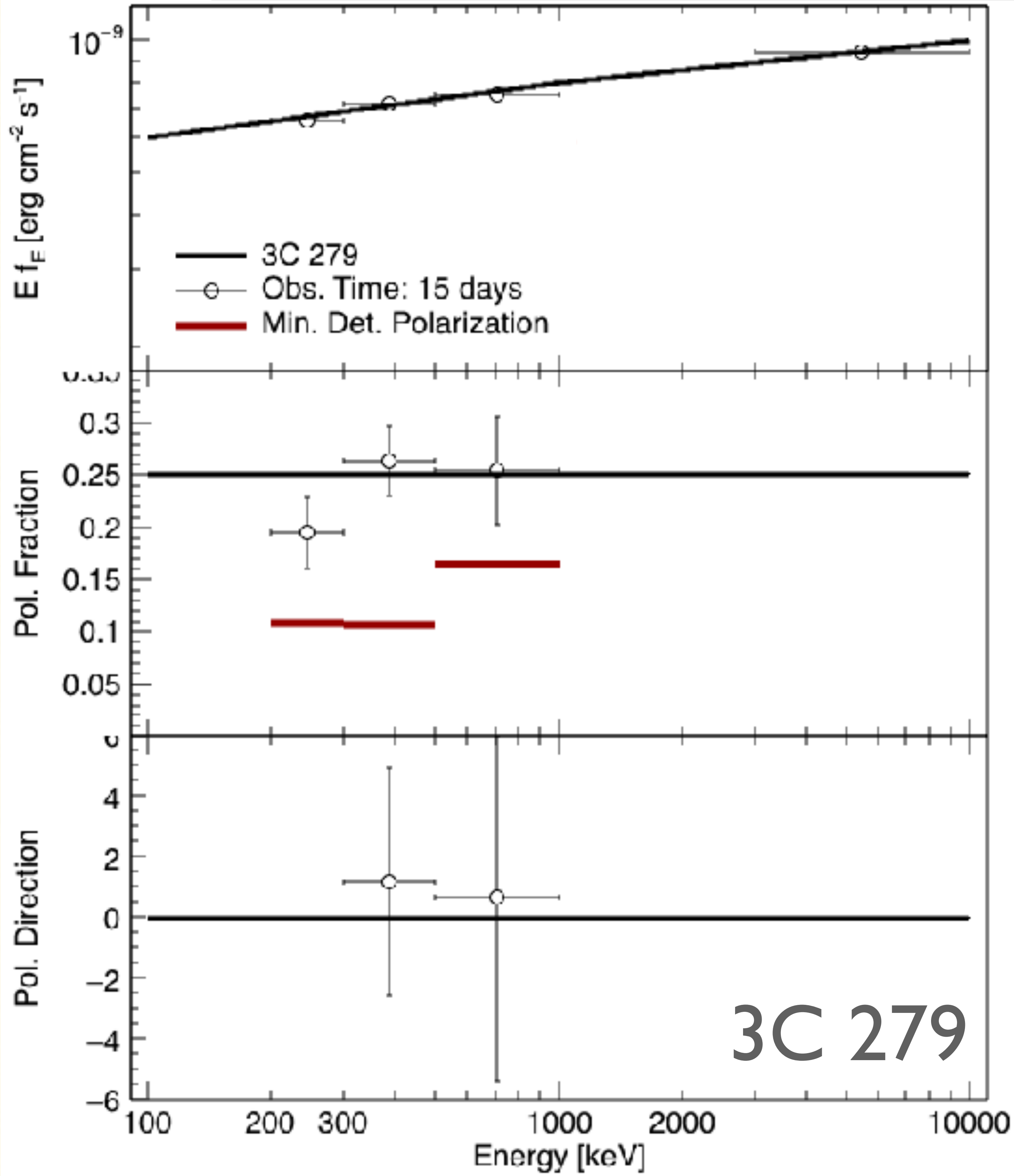
Participation of ALMA will probably bring a new era

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

IXPE, **AMEGO**, etc.

# AMEGO polarization detection capability

All-sky Medium Energy Gamma-ray Observatory




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

15-20% polarized low synchrotron blazars like 3C 279 will be detectable

*On behalf of the AMEGO team*

Thanks for your attention