Optical Polarimetry of PKS 2155-304

Constraints on Particle Acceleration and Source Structure

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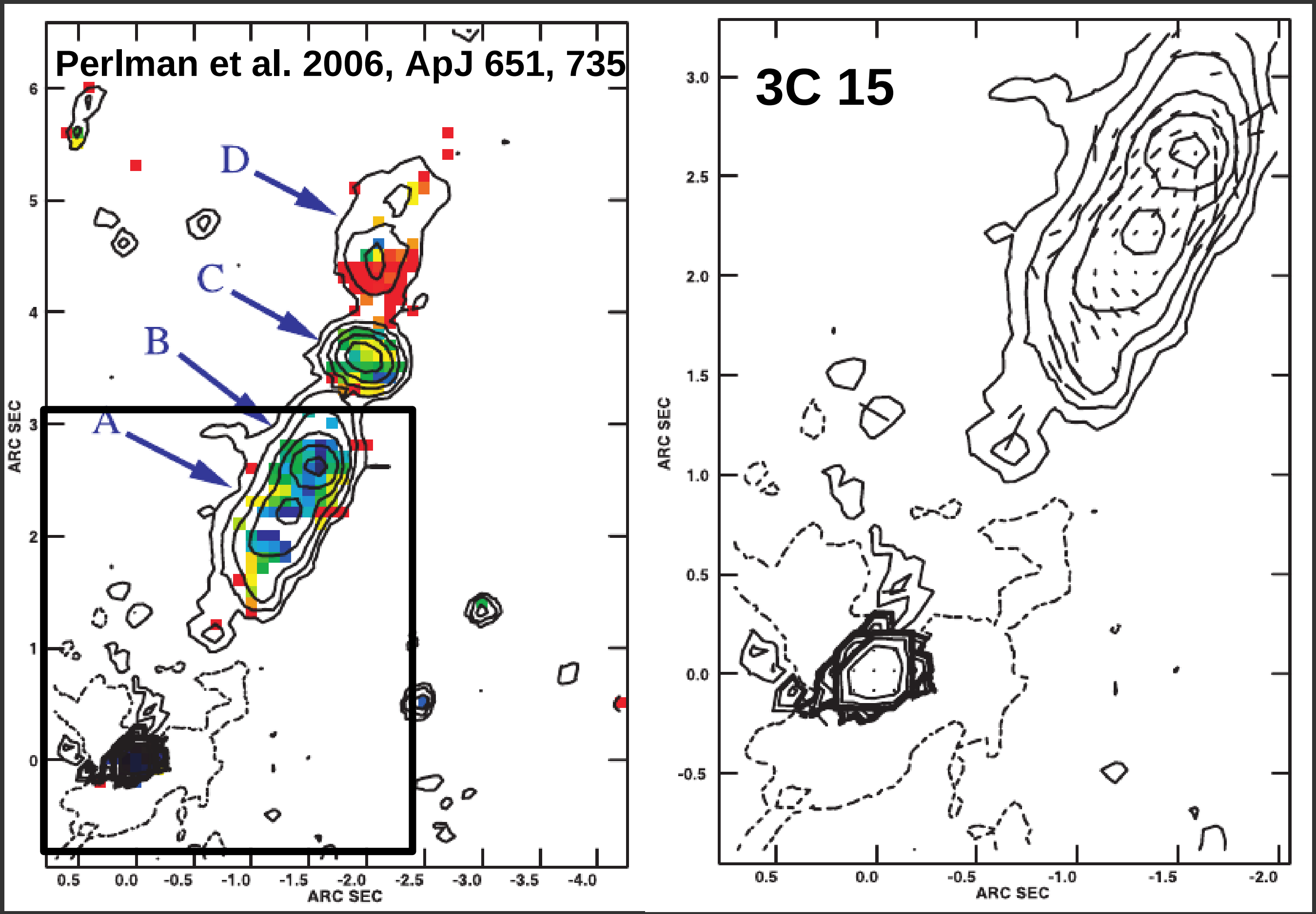
Time Variability at High Energies

Outline

- Scientific case for optical polarimetry
- Quiescent state of PKS 2155-304
- Results on PKS 2155-304
- Source structure
- Conclusions

Optical polarimetry?

- Jet non-thermal Sy emission is naturally polarised



Magnetic Field

Source Structure
beyond photometry

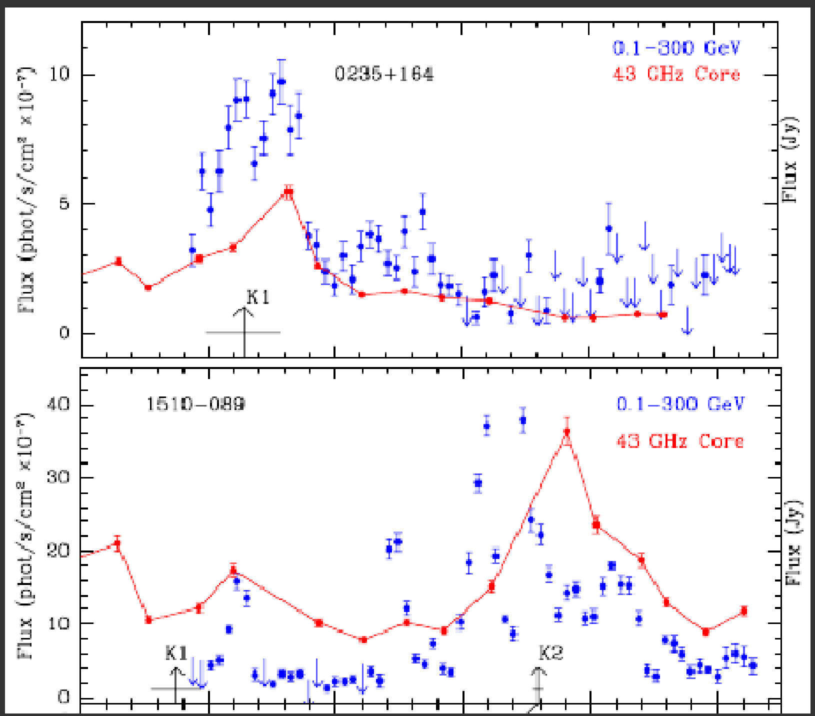
⇩

Mapping Location of Emission

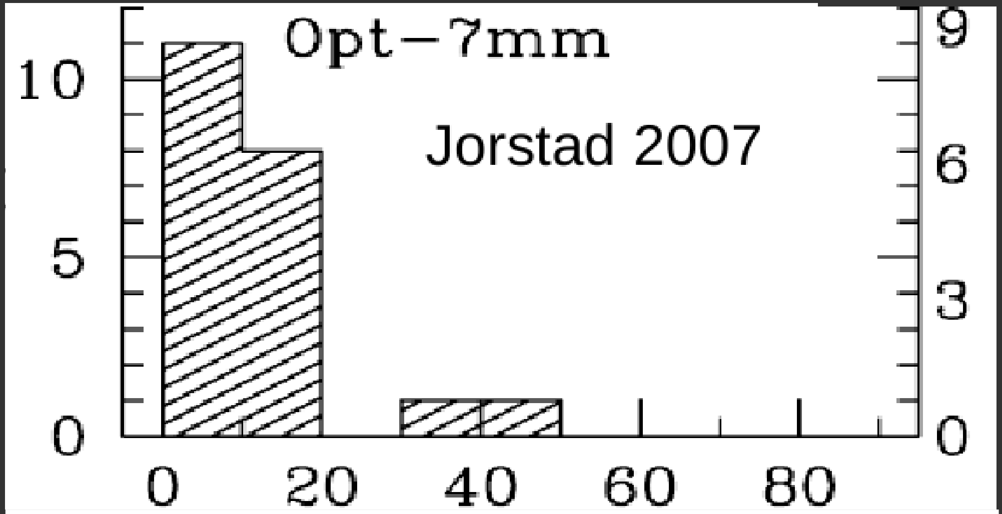
Optical polarimetry?

- Mapping of the emission regions via MWL correlations
  - Radio VLBI structures show correlation with VHE high states

Jorstad - *Fermi Symposium* 2009



HE to OPTICAL to RADIO MAPPING



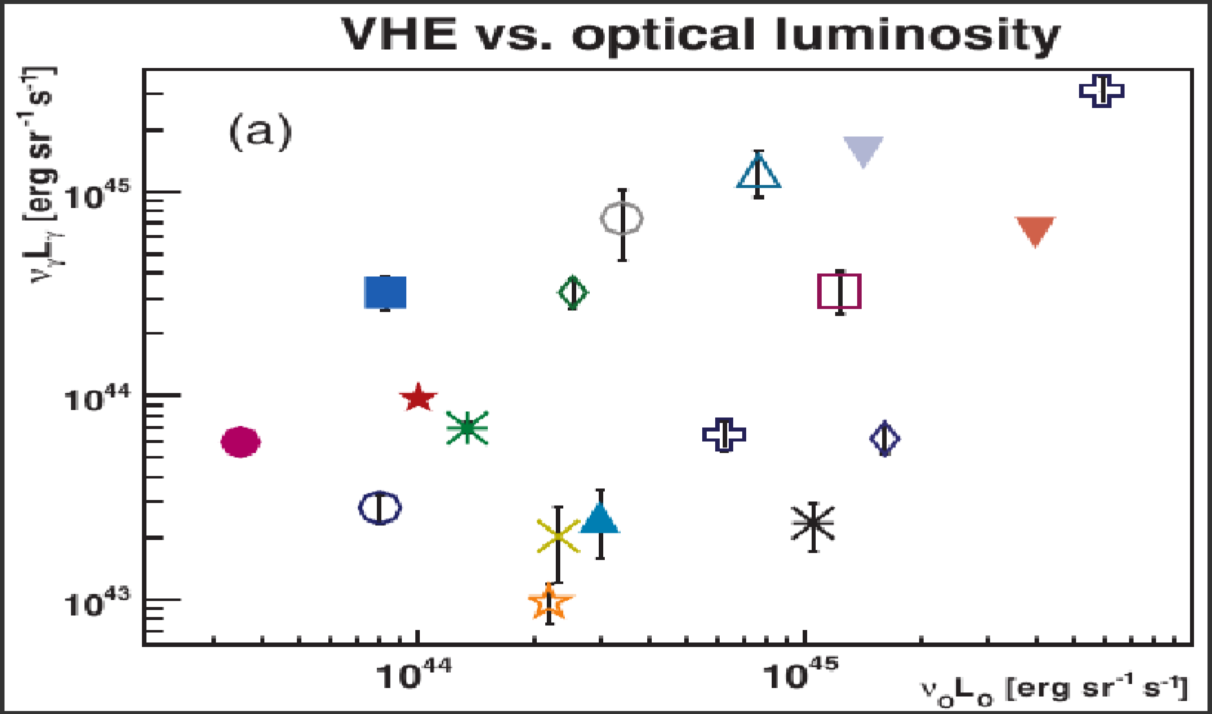
Poalrisation position angle difference

Durham University

Optical polarimetry?

- Mapping of the emission regions via MWL correlations

  Optical Photometry Correlations

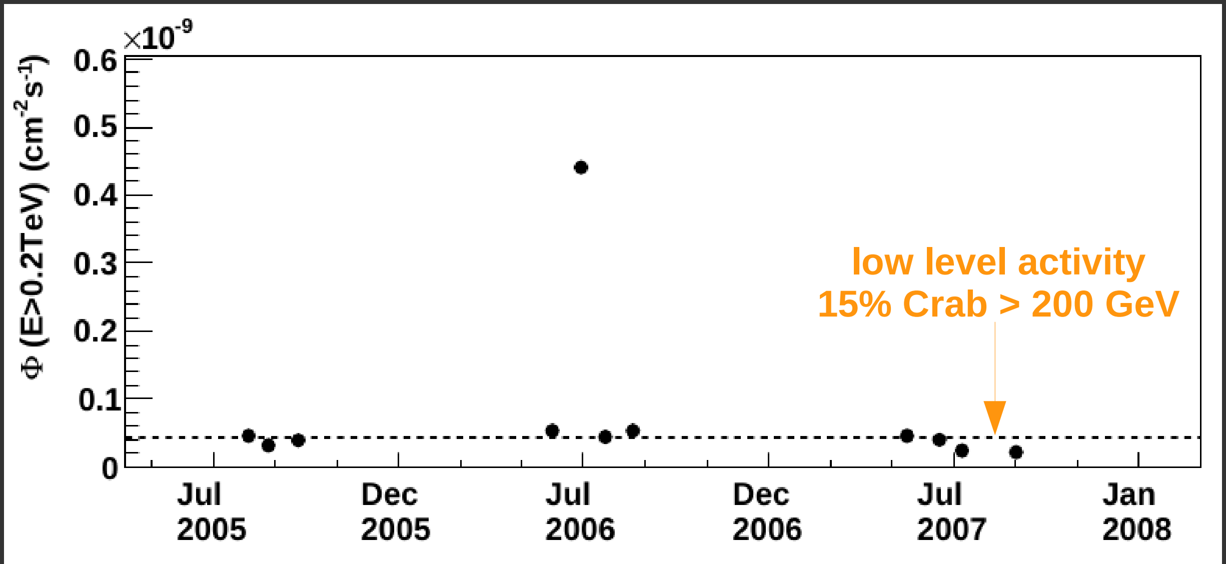


Wagner, R. 2008 MNRAS 385, 119

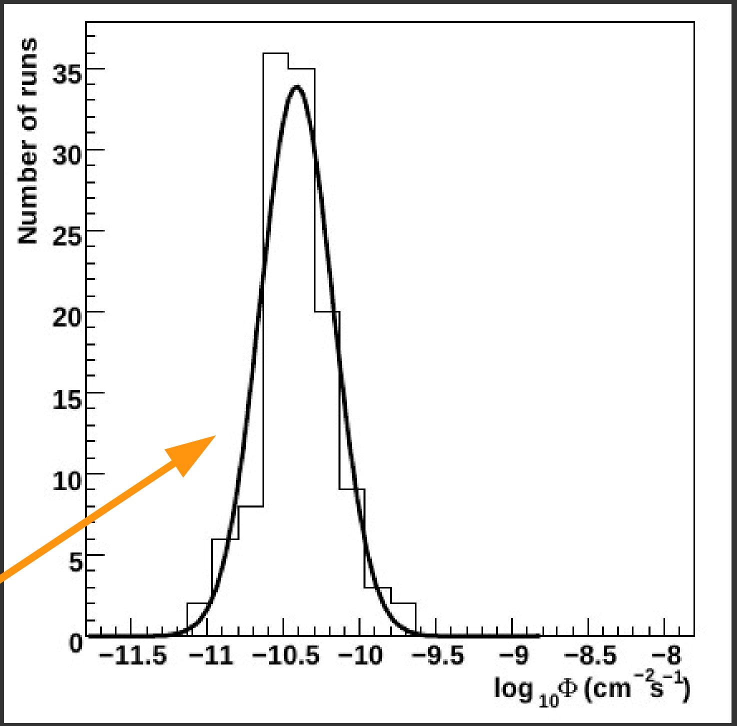
correlations between polarisation flares and high energy variability not systematically studied yet.

Quiescent State of PKS 2155-304

- Long-term constraints on “stable” low level of VHE emission



H.E.S.S. arXiv:10053702

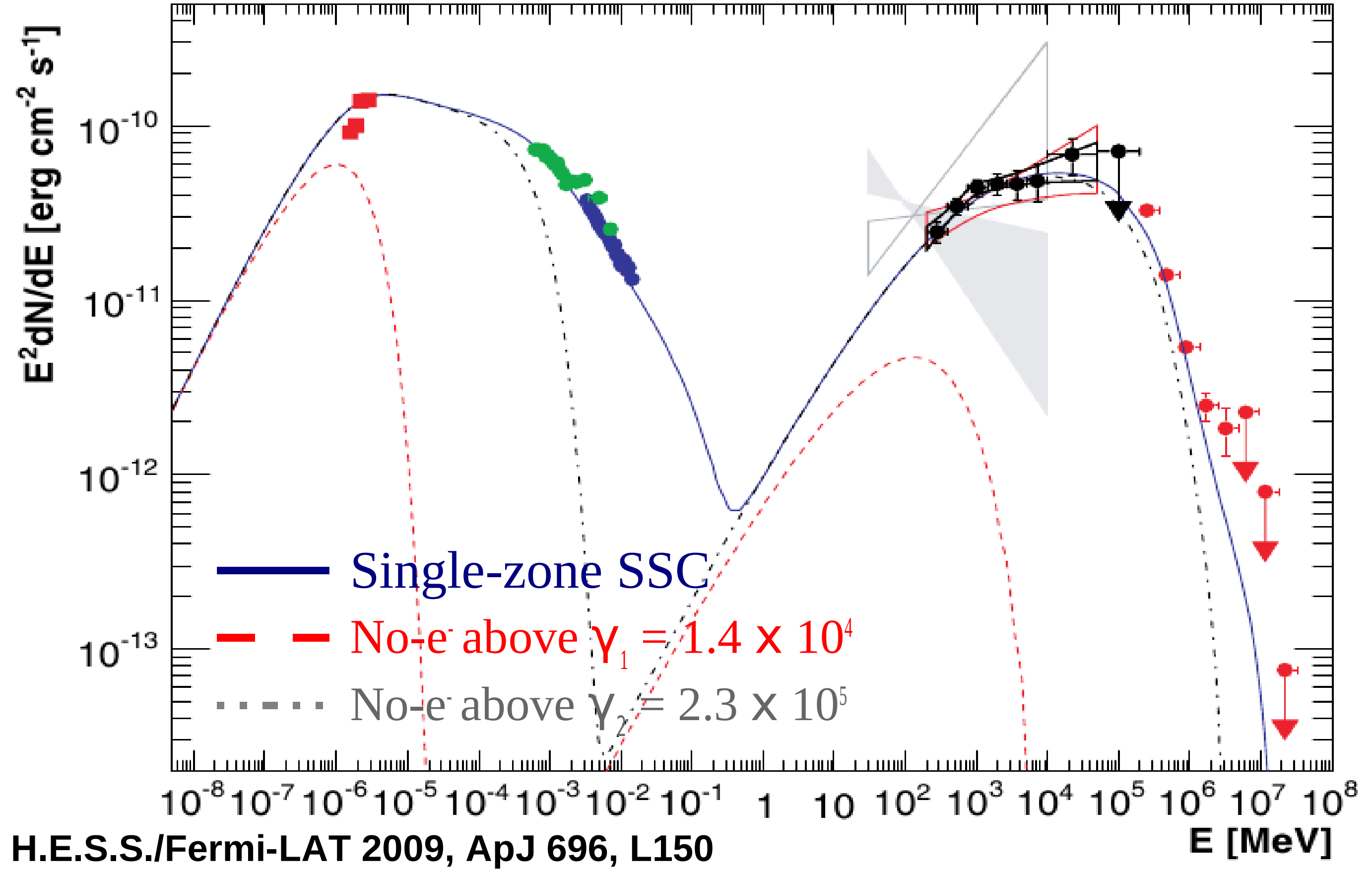


H.E.S.S. arXiv:10053702

width of distribution not compatible with random fluctuations ⇒ intrinsic variability at low state.

2008 MWL Campaign

- PKS 2155-304 observed in optical, X-rays, GeV (Fermi) and VHE (H.E.S.S.)



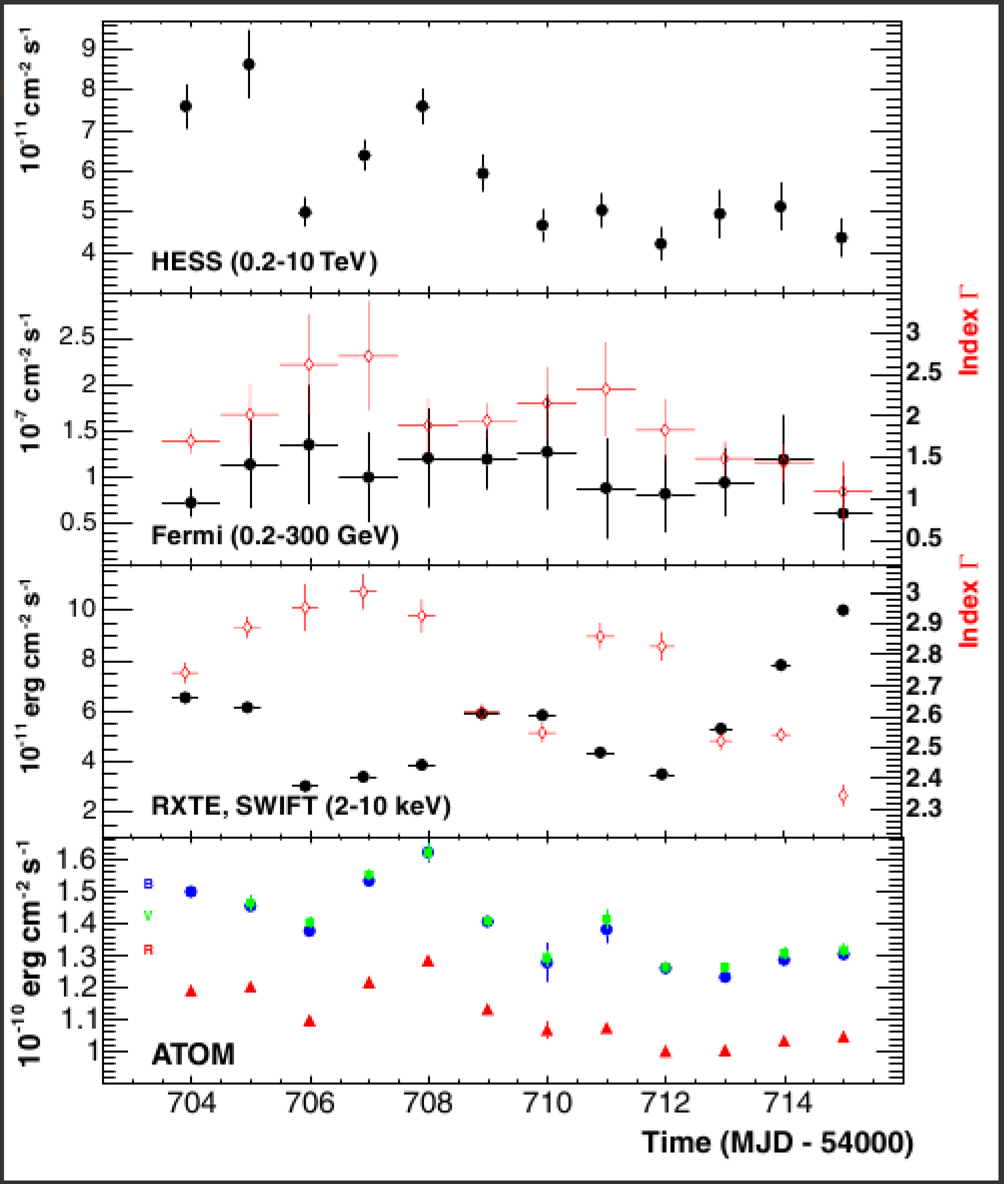
SSC model

"Blob" R ~10^{17} cm
Doppler factor Γ ~30
Field B ~ 0.02 G

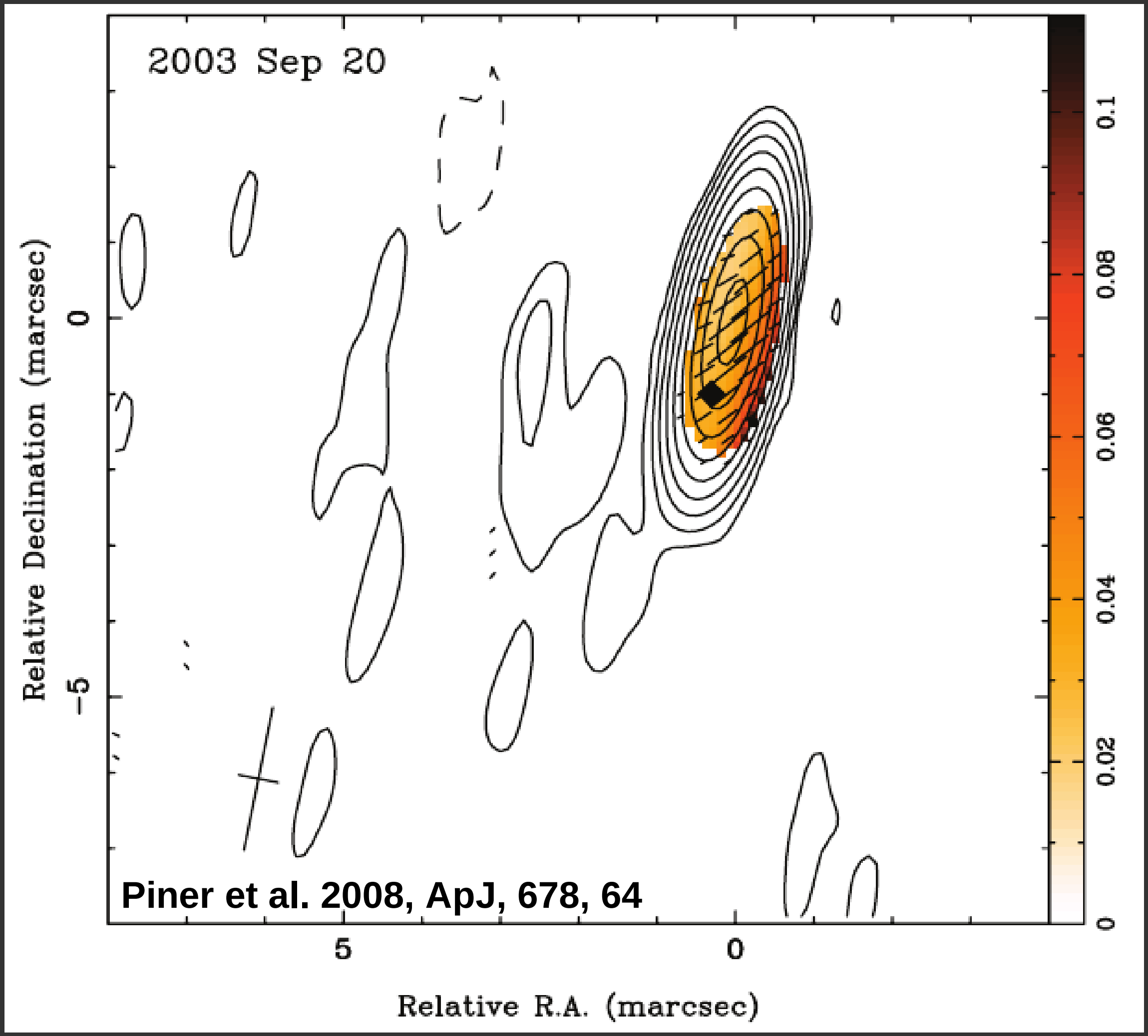
2008 MWL Campaign

- Variability disfavours a 1-zone scenario as shown in the time-averaged SSC modelling.

  - Optical emission correl. with TeV: Optical provides seed photons for IC?



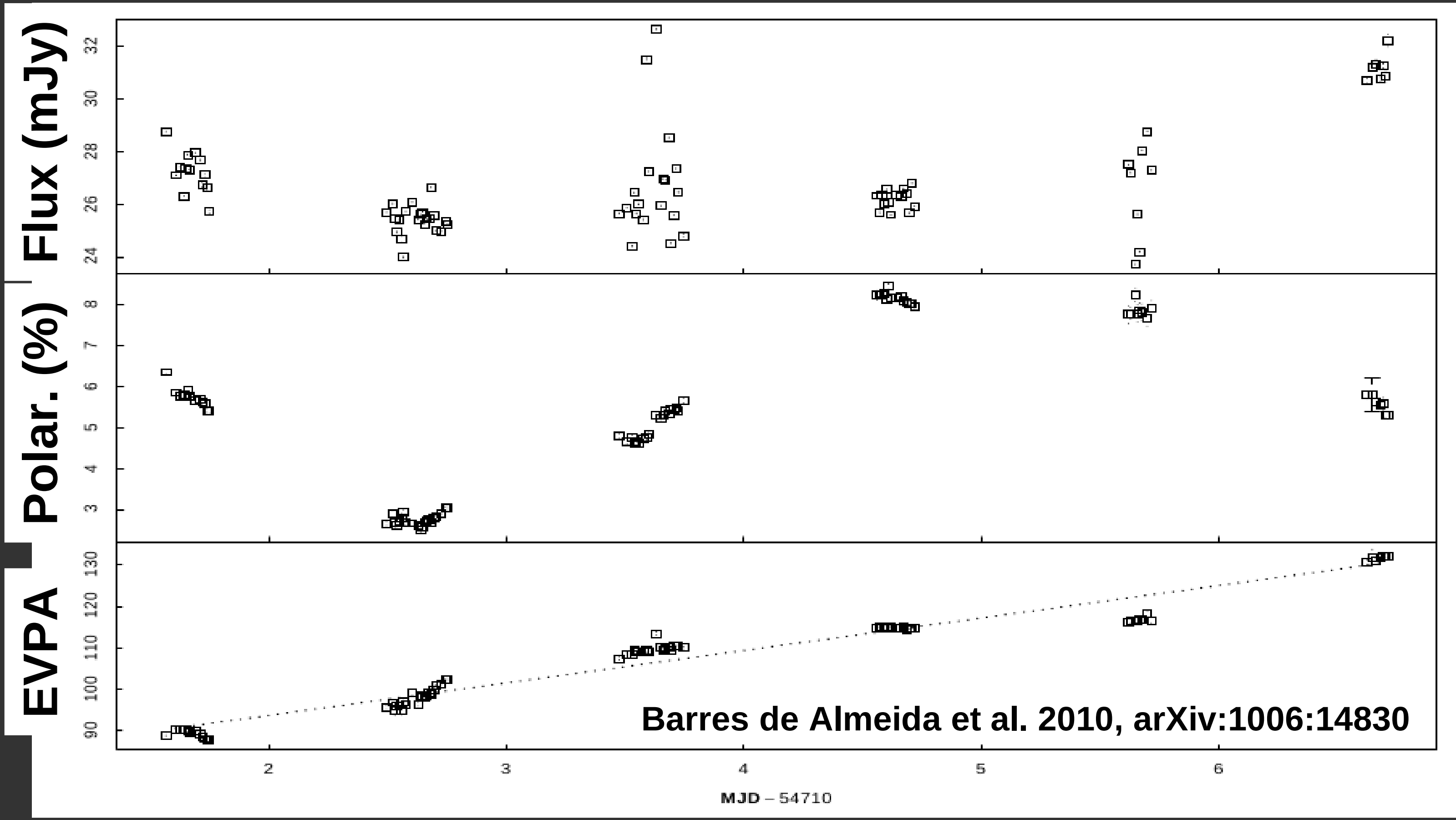
Source Structure and Emission Site



- 43 GHz radio images of jet show polarisation from core alone
  - range of P ~ 3-8%
  - EVPA ~ 140º-160º, in close alignment with jet P.A.
- Long term optical polarised emission similar to radio ones.
  - suggests low state optical polarised emission originates at GHz radio core

Optical Polarimetric Observations

- Polarimetric campaign conducted at the 1.6-m LNA telescope in Brazil is part of a 3-yr monitoring programme of VHE blazars with IAGPOL



Optical Polarimetric Observations

- Photometric variability – microvariability (hour timescale)

  - accompanied by variation on the spectral index variation

$$t_{\rm acc} < t_{\rm sync}$$

$$\approx 1.1 \times 10^4 \left(\frac{1+z}{\delta \nu_{GHz} B_G^3} \right)^{1/2} \text{hours}$$

$B \lesssim 0.5$ G

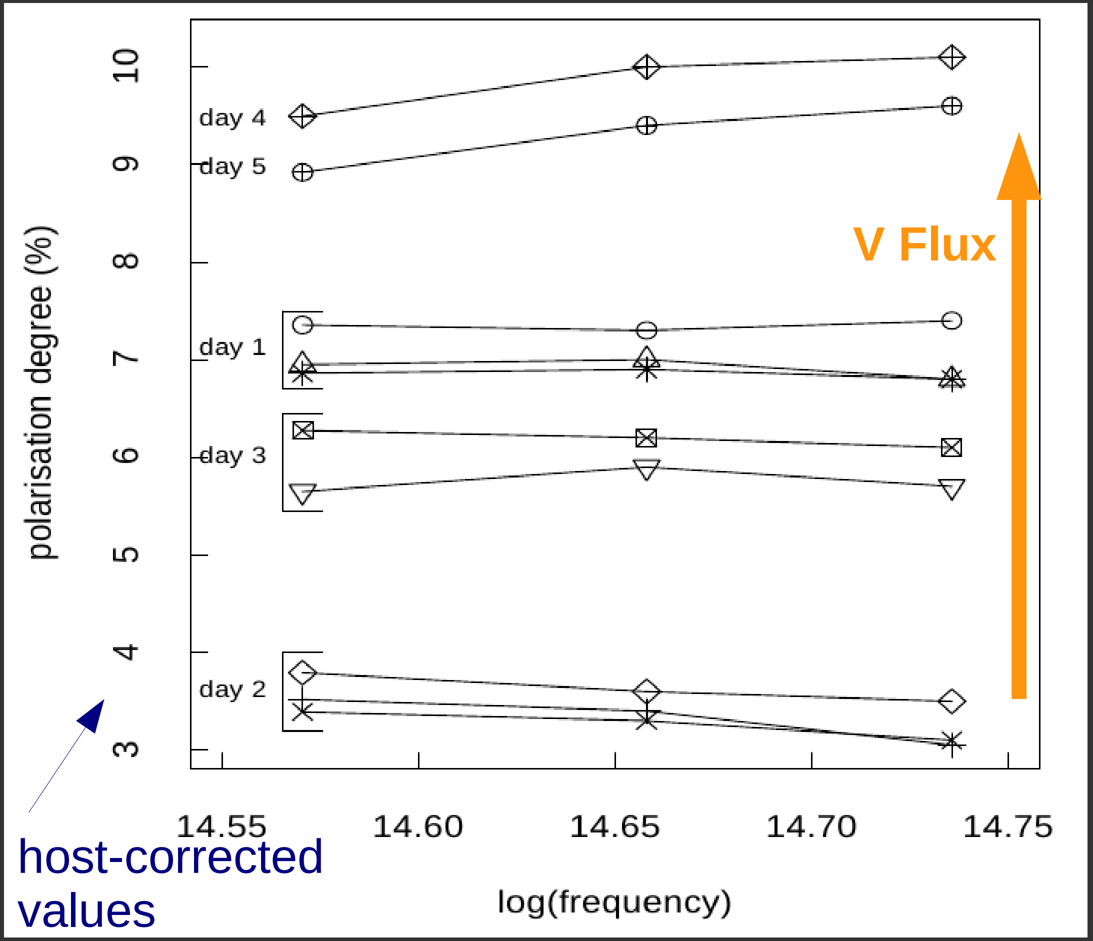
$$r_{\rm s} < \delta t_{\rm sync} c/(1+z)$$

$$\sim 5 \times 10^{-3} \text{pc}$$

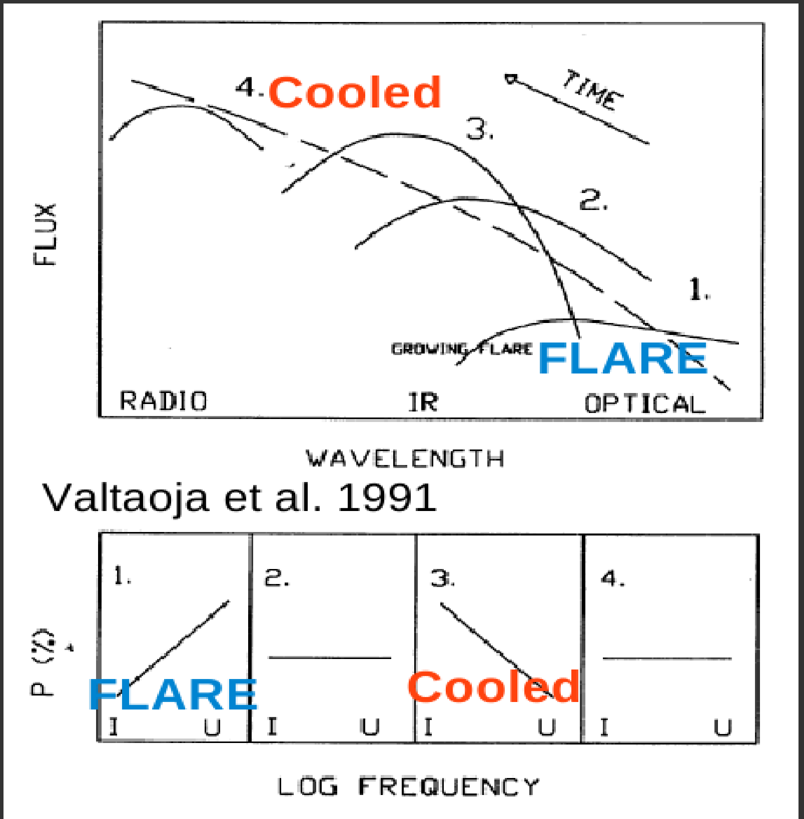
EMISSION AT SHOCK FRONT

Optical Polarimetric Observations

- Frequency dependence of the polarisation parameters.



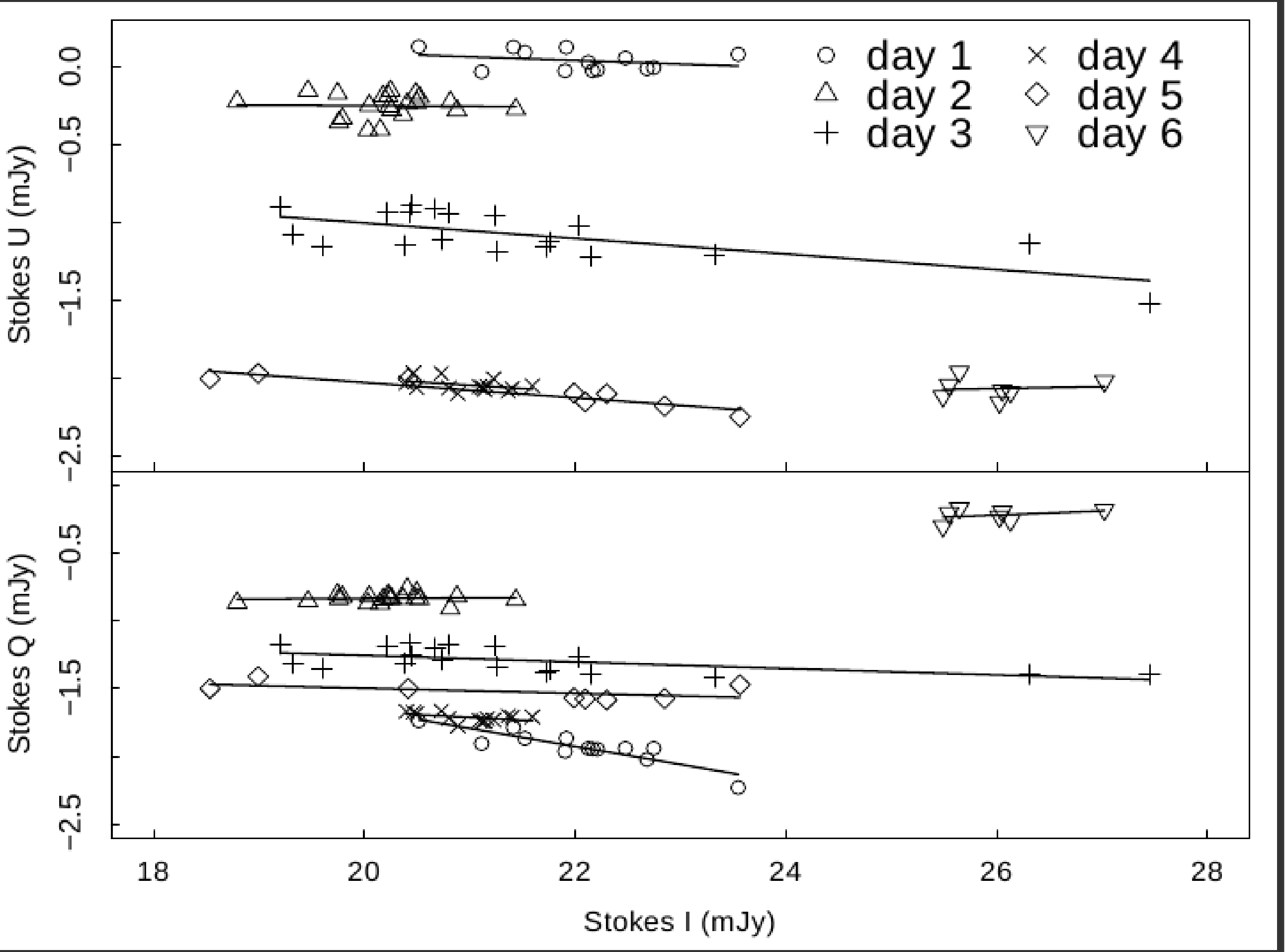
- evolving FDP is observed in the data



Valtaoja et al. 1991

Optical Polarimetric Observations

- Intranight variability happens with unvariable Stokes parameters



- parameters of variable comp. used to model polarised emission

$$p^2 = \frac{p_{\rm cons}^2 + p_{\rm var}^2\ I_{\rm v/c}^2 + 2\ p_{\rm cons}\ p_{\rm var}\ I_{\rm v/c} \cos 2\xi}{(1 + I_{\rm v/c})^2}$$

$$\tan 2\theta = \frac{p_{\rm cons}\ \sin 2\theta_{\rm cons} + p_{\rm var}\ I_{\rm v/c}\ \sin 2\theta_{\rm var}}{p_{\rm cons}\ \cos 2\theta_{\rm cons} + p_{\rm var}\ I_{\rm v/c}\ \cos 2\theta_{\rm var}}$$

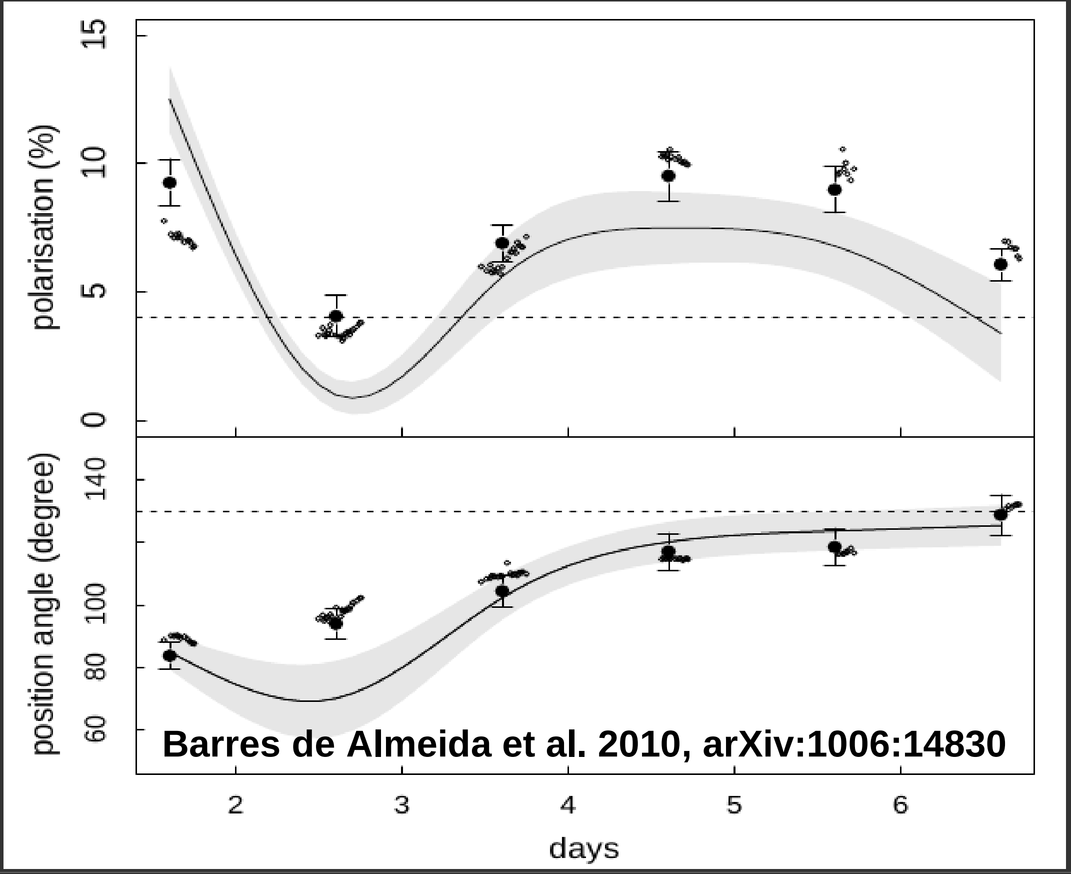
Optical Polarimetric Observations

- Polarimetric behaviour can be explained by superposition of a variable (shock) + an extended (underlying jet) component.

- variable component more polarised but contributes to ≤ 30% of the total flux.

Table 1. Polarisation parameters of variable component.

MJD	$p_{\rm var}$ (%)	$\theta_{\rm var}$ (°)	$I_{\rm var}$ (mJy)
54711	12.5 ± 1.3	84.9 ± 5.6	2.3 ± 0.6
54712	1.0 ± 0.6	70.0 ± 12.0	2.0 ± 0.2
54713	5.6 ± 1.4	102.2 ± 7.0	3.8 ± 0.6
54714	7.5 ± 1.4	120.1 ± 6.4	1.8 ± 0.8
54715	6.8 ± 1.3	123.6 ± 6.2	5.8 ± 0.8
54716	3.4 ± 1.9	125.4 ± 6.5	7.5 ± 1.0



Barres de Almeida et al. 2010, arXiv:1006:14830

Optical Polarimetric Observations

- Polarimetric Variability – inter-day timescales

  - lack of correlation with total flux variability points to a different physical mechanism
  - timescale of changes can be related to propagation of a shock through jet with changing properties and magnetic field

$$\Delta t = \left(\frac{D(1+z)}{c\beta_s \delta_s \Gamma_s} \right)$$

VARIATION FROM SHOCK PROPAGATION

← **D ≈ 0.3 pc**

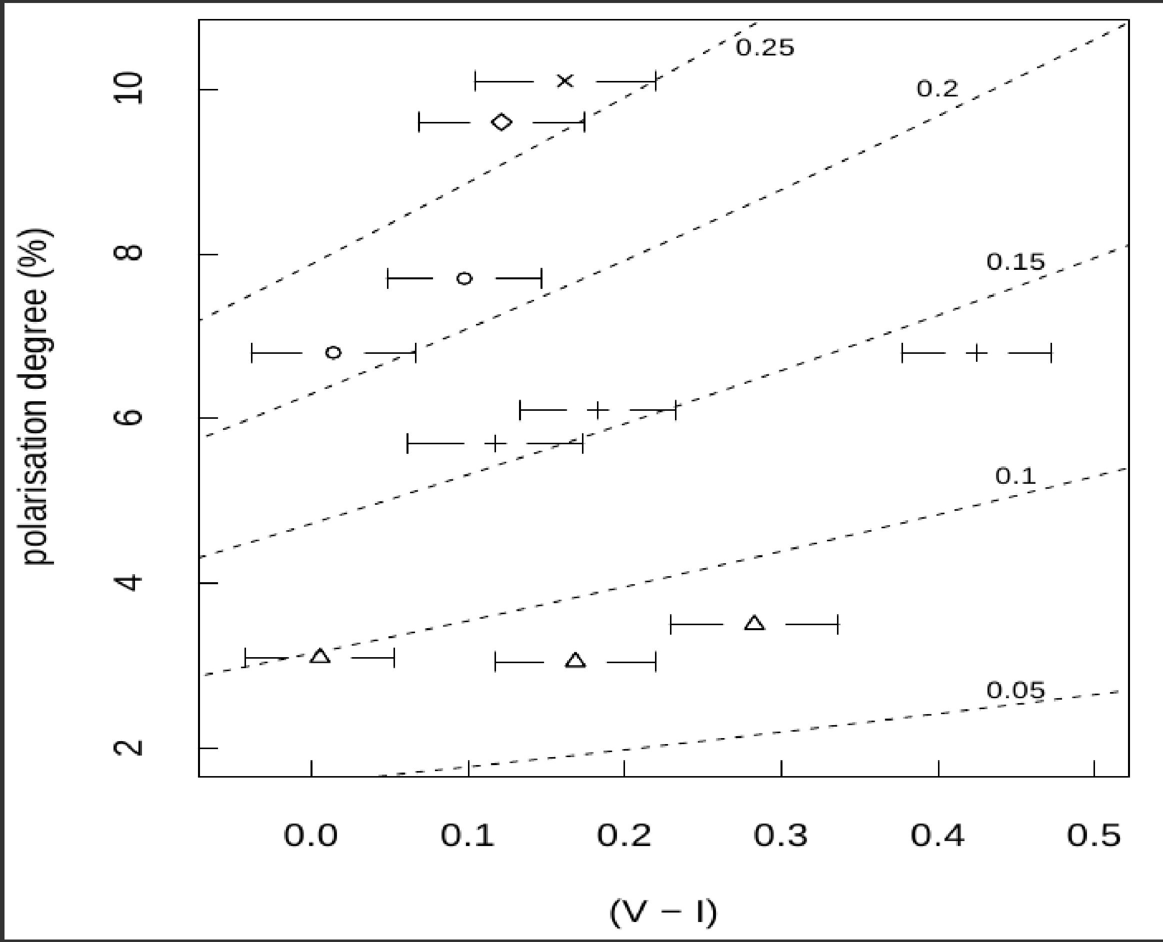
Field coherence length?

Optical Polarimetric Observations

- Modeling of the magnetic field evolution and structure

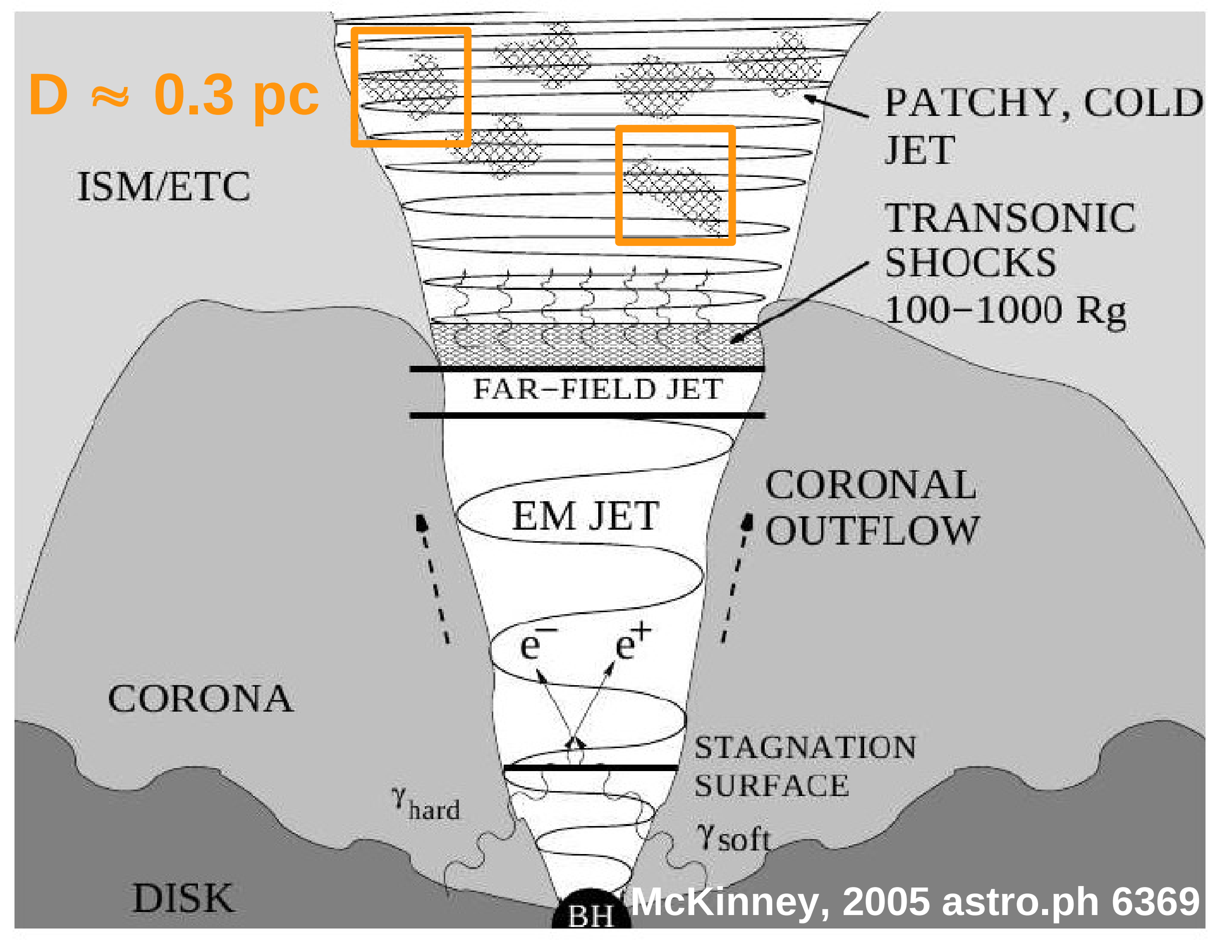
- changing in polarisation linked to variations on the magnetic field degree of ordering

$$p = f(\gamma)\beta^2 = \frac{(\gamma+3)(\gamma+5)}{32}\,\Pi_0\,\beta^2$$



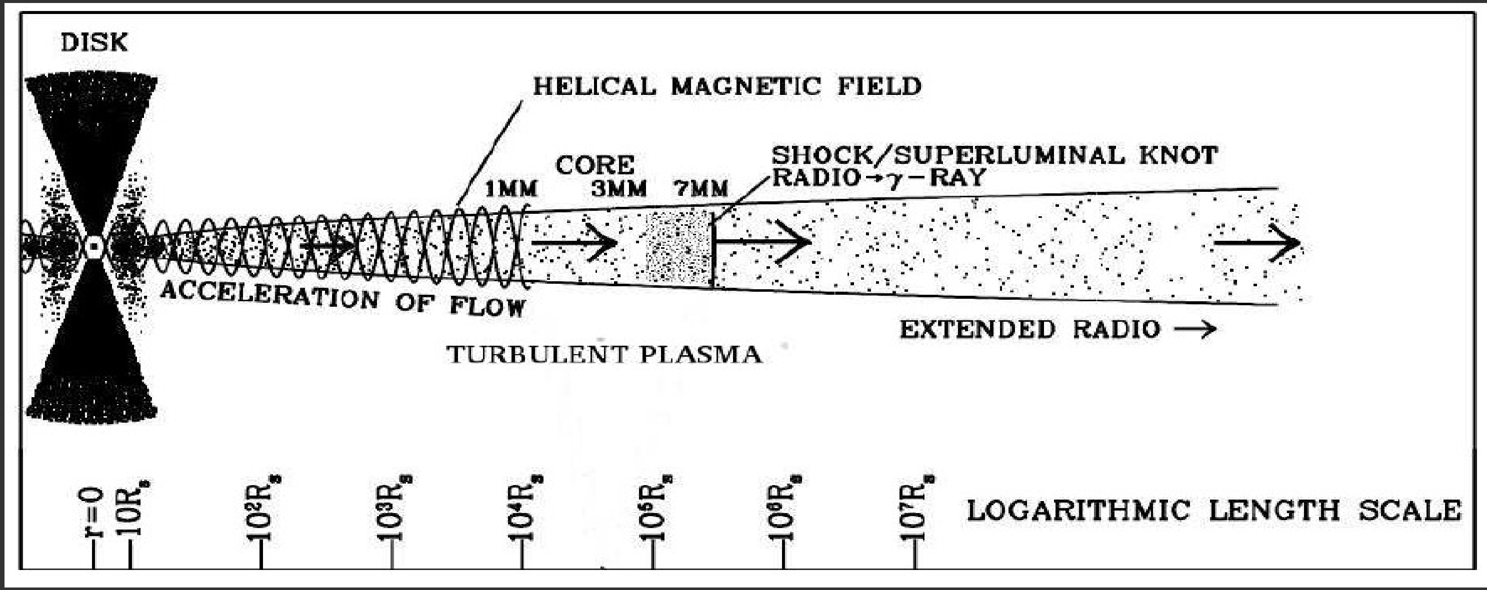
Source Structure and Emission Site

- Modeling of the magnetic field evolution and structure



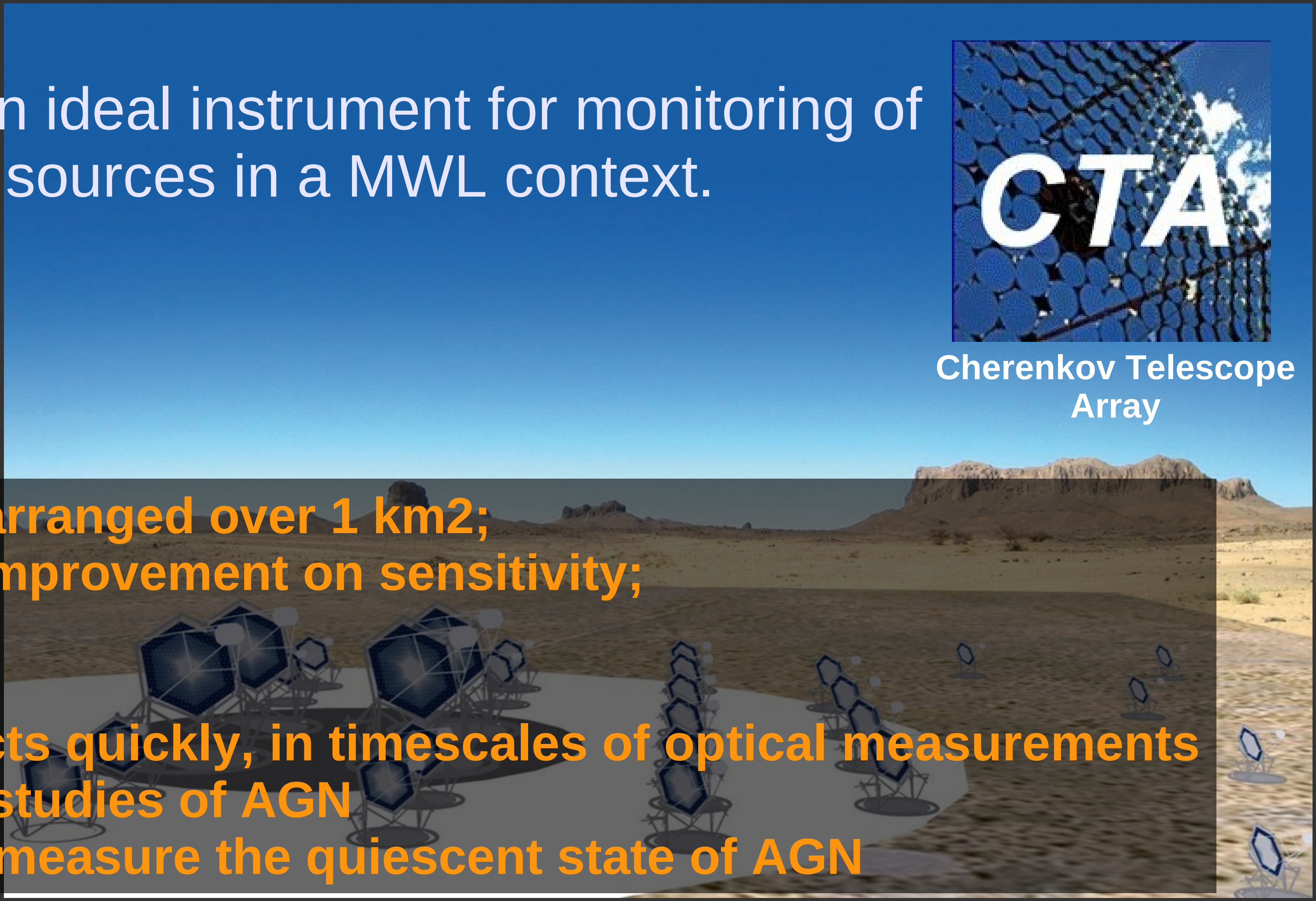
Conclusions

- PKS 2155-304:
  - polarisation modeled by superposition of a two Sy components;
  - inhomogeneous source structure explains the lack of correlation between polarimetric and photometric flux.
  - MWL DATA: correlations favour nested jet emission models.



Future: Polarimetry and CTA

- CTA will be an ideal instrument for monitoring of Xgal variable sources in a MWL context.



Cherenkov Telescope Array

• 50-100 IACTs arranged over 1 km2;
• order of mag improvement on sensitivity;

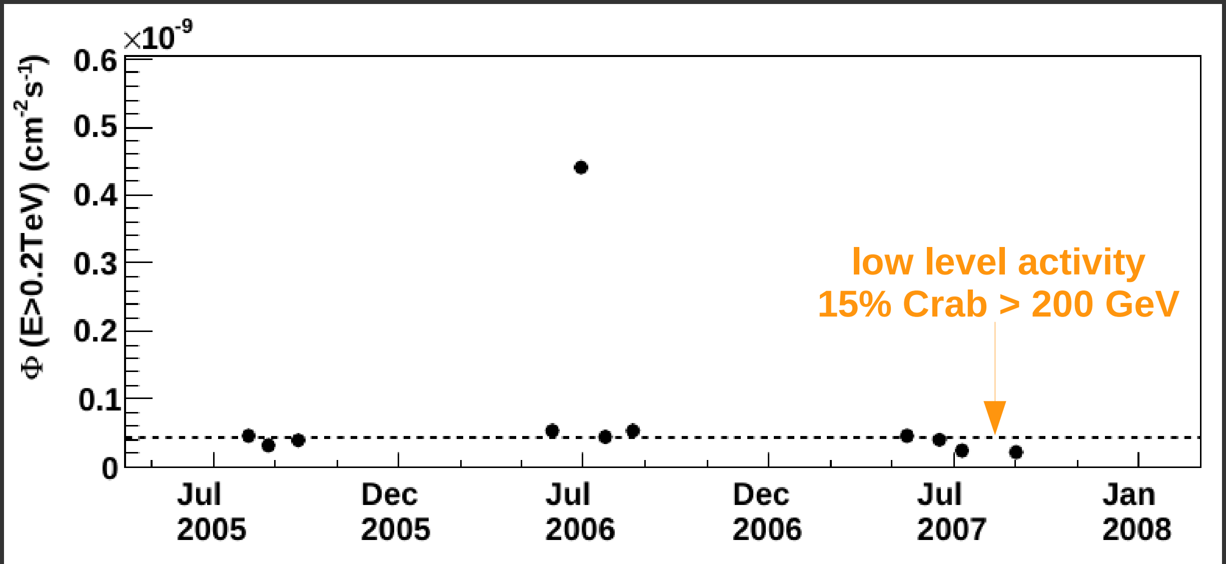
This will allow:

- follow objects quickly, in timescales of optical measurements
- population studies of AGN
- capacity to measure the quiescent state of AGN

EXTRA SLIDES

Quiescent State of PKS 2155-304

- Long-term constraints on “stable” low level of VHE emission



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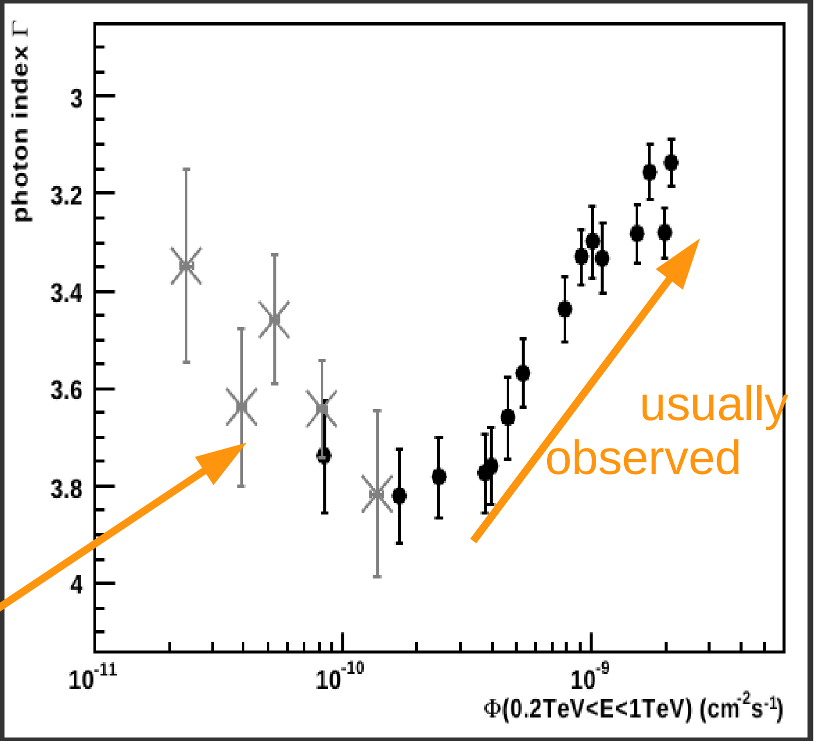
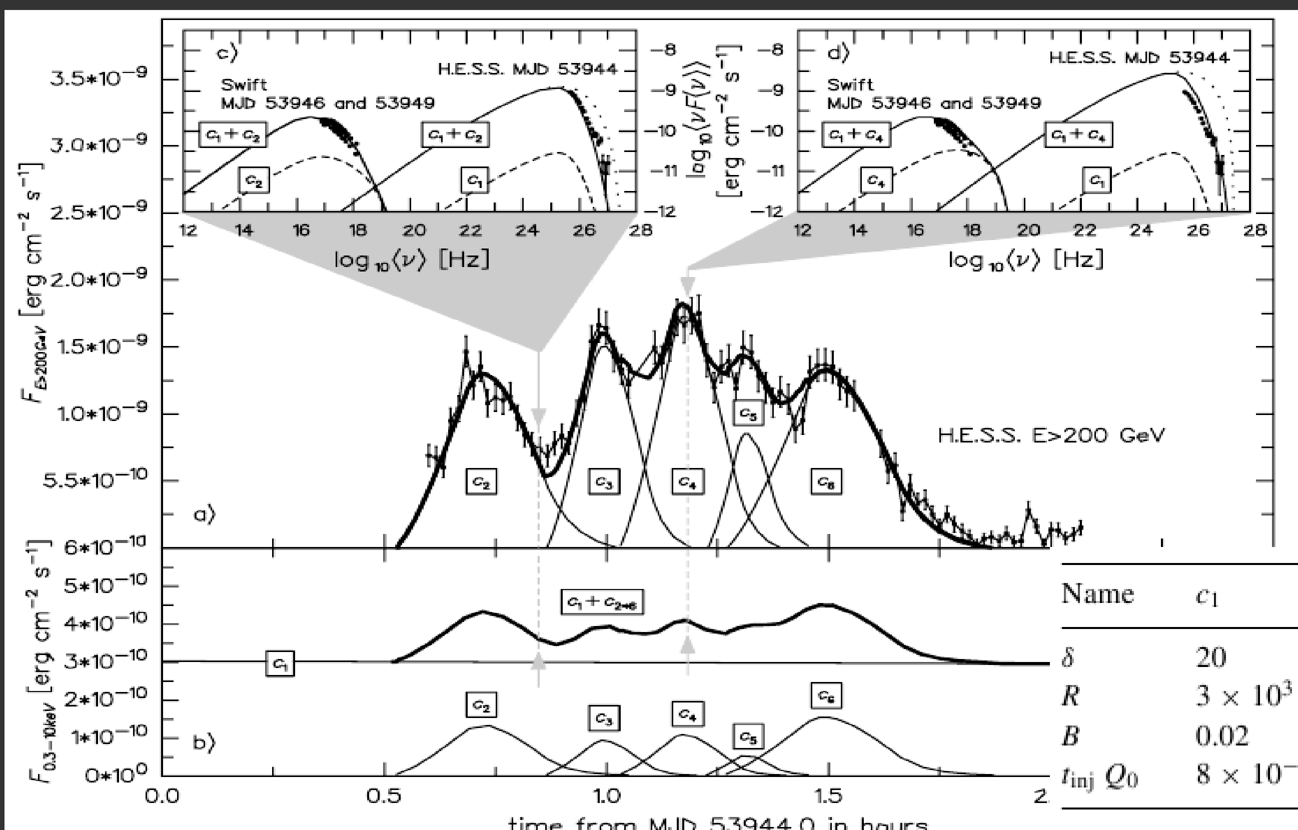


H.E.S.S. arXiv:10053702

Observation of spectral softening
with flux increase at low state.

Quiescent State of PKS 2155-304

- Detailed modeling of flaring state reveals a complex Multi-component source structure (e.g. Katarzynski et al. 08)



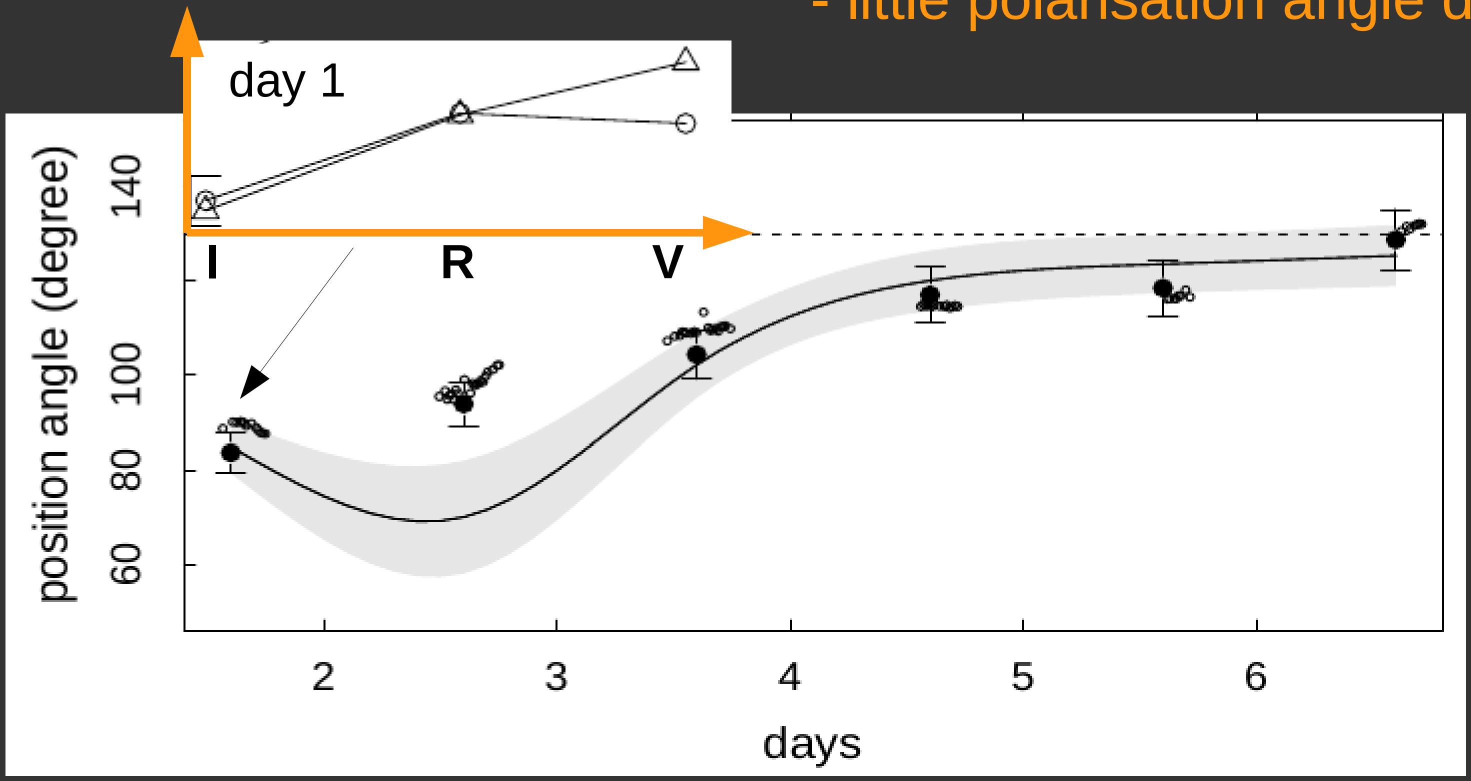
An extended component (jet) is necessary to explain the MWL Emission but is not expected to contribute to VHE flux.

Name	c_1	c_2	c_3	c_4	c_5	c_6	Unit
δ	20	30	30	30	30	30	
R	3×10^3	5.2	3.5	4	2.3	6	10^{14} cm
B	0.02	0.1	0.1	0.1	0.1	0.1	G
$t_{inj}\ Q_0$	8×10^{-6}	3.2	7.95	6.8	12	2.45	10^7 cm^{-3}

Optical Polarimetric Observations

- Frequency dependence of the polarisation properties.

- little polarisation angle dependency



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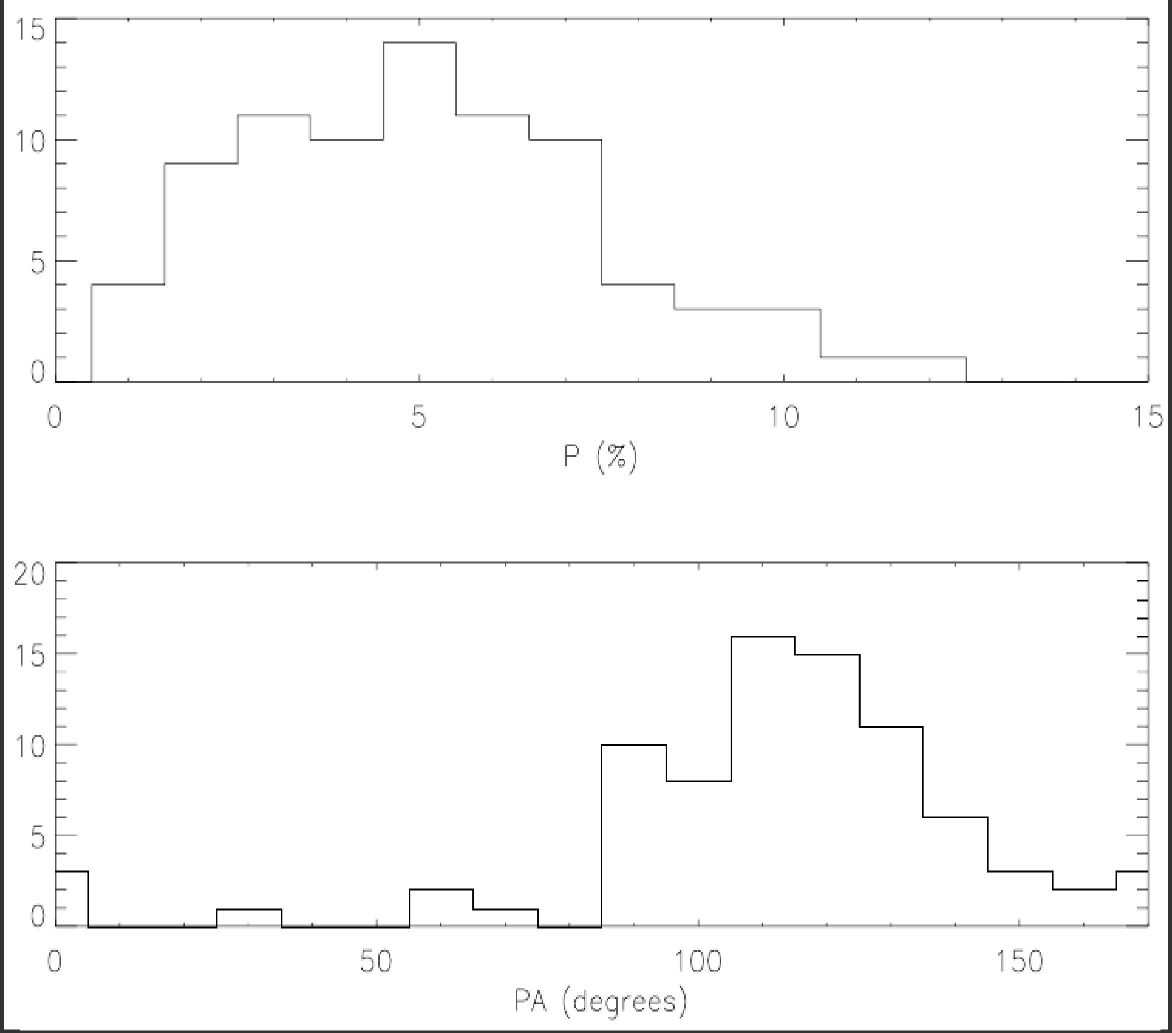

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Polarimetry: Essential ingredient in HE obs.

- Optical (and radio) polarimetry are essential ingredients in MWL campaigns, and can be key to revealing the sites of gamma-ray emission.

  - We have an ongoing, long-term project at the LNA observatory in Brazil for the continual monitoring in optical polarimetry of VHE sources.

  - We are currently using the imaging capabilities of the fast RINGO-II polarimeter at the Liverpool robotic telescope to follow the polarisation evolution of the jet of M 87 with arcsec resolution in weekly timescales, as part of a radio, X-ray and VHE MWL campaign.

Conclusions -II

- Additional info provided by polarisaton allowed to put further constraints on the site and structure of the sites of VHE emission:

  - emission most likely originates in compact shocked component within the radio core, similar to propositions made for the X-ray quiescent flux (e.g. Giebels et al. 2002);
  - favouring nested jet emission models.