

A Quasi-Periodicity in the Optical Polarization of PKS 2155-304



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OVERVIEW

AIM

Study low- and high-energy variability of PKS 2155-304

RESULTS

1. First quasi-periodic oscillation (QPO) detected in polarized flux
2. First simultaneous optical polarization and γ -ray observations during high-state

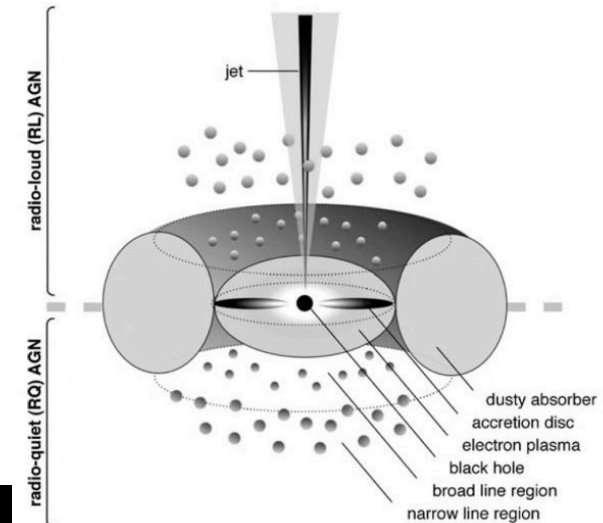
SOURCE

PKS 2155–304

Radio-loud AGN with jet aligned with observer's viewing angle, called *Blazar*

Properties

- Observed emission is highly luminous
- Variable from minutes to years ^{1,2}
- Broad-band, non-thermal continuum emission



Synchrotron Self Compton (SSC)

Low Energies

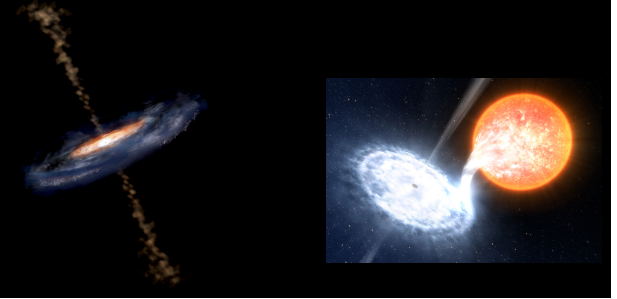
- Radio to optical to soft X-ray
- Synchrotron (sync) emission
- Polarization at radio & optical



High Energies

- Hard X-ray to γ -ray
- Inverse Compton emission

AGN and BHBs



Black Hole Binaries (BHBs)

- AGN & Galactic BHBs both powered by accretion onto black holes
- $10^8 M_{\odot}$ & $10 M_{\odot}$, respectively
- Mass-scaled analogies

BHBs

- QPOs in X-ray emission^{3,4}
- Important diagnostic tool, e.g. BH mass, discriminate between binary models

AGN

- QPOs rarely observed
- One reliable case: ~1 h X-ray QPO in REJ 1034+396⁵

A Polarized QPO in PKS 2155-304?

- One of few AGN for which QPO activity observed!
- ~4.6 h periodic component in *X*-ray light curve⁶
- Origin unclear

Intra-day Optical Polarization

- Source monitored intermittently between 2009 and 2012
- Results from 2009 observations

Outline:

- OBSERVATIONS
- DISCUSSION
- SUMMARY & CONCLUSIONS

OBSERVATIONS

Optical Polarization

- Recorded with the high-speed polarimeter HIPPO
- Mounted on 1.9 m Radcliffe telescope (SAAO)
- Intra-day variability (IDV) monitored from 25 to 27 July 2009
- 5 min temporal resolution (factor of 3 better ⁷)

Table 1. The mean daily optical polarization of PKS 2155–304 in July 2009.

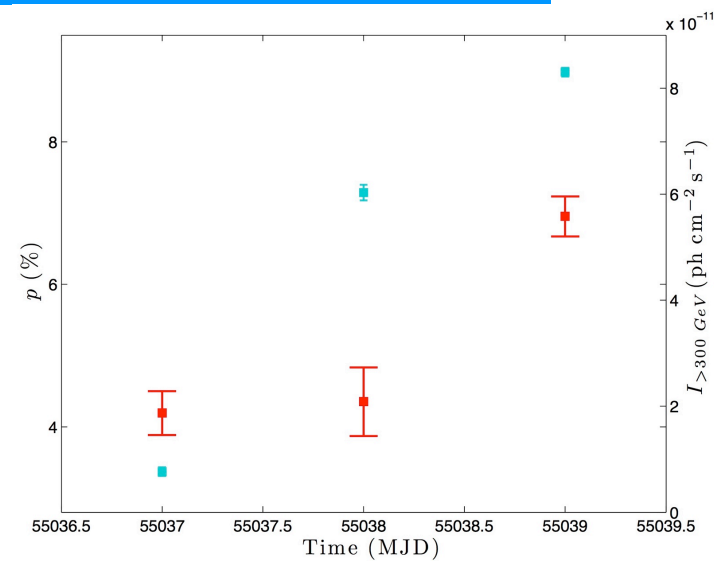
MJD	T_{obs} (min)	p (%)	θ (°)
55037	251	3.7 ± 0.3	88 ± 2.5
55038	105	7.0 ± 0.3	67 ± 1.0
55039	197	8.3 ± 0.7	68 ± 0.5

OBSERVATIONS

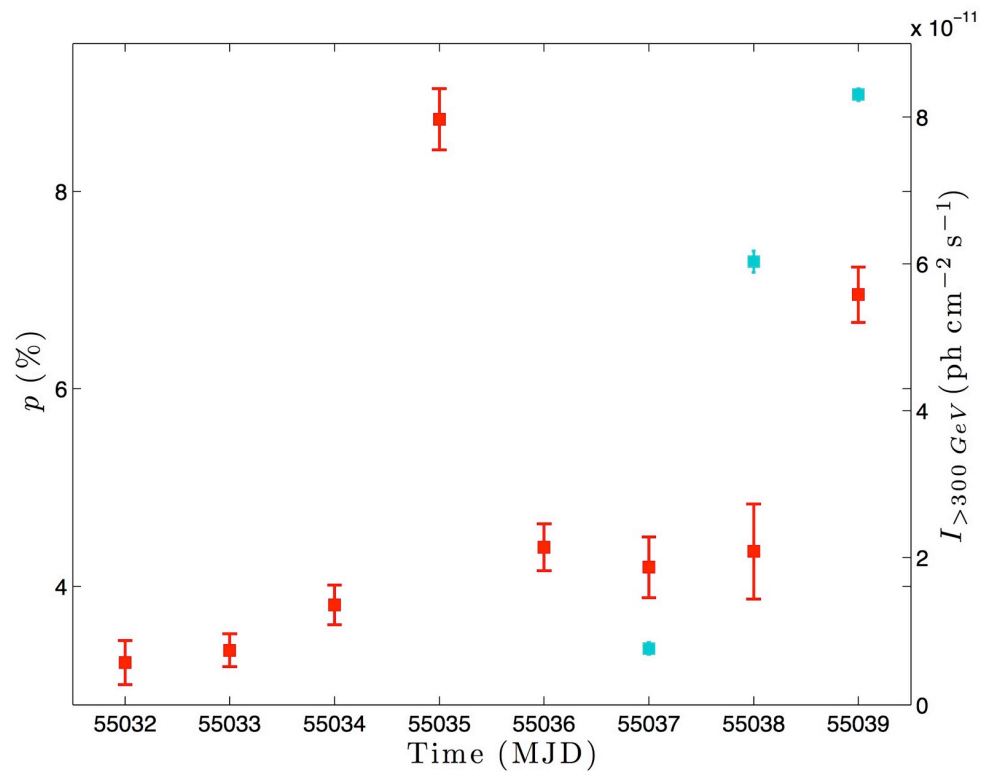
Very High Energy γ -rays

- Very high energy (VHE), photon energies > 300 GeV
- Recorded with the HESS, overlaps polarization observations
- Daily γ -variability monitored from 19 to 27 July 2009⁸,
- Simultaneous polarization & γ -ray observations for 3 days

- Correlated behaviour
- Consistent with SSC emission from same evolving region

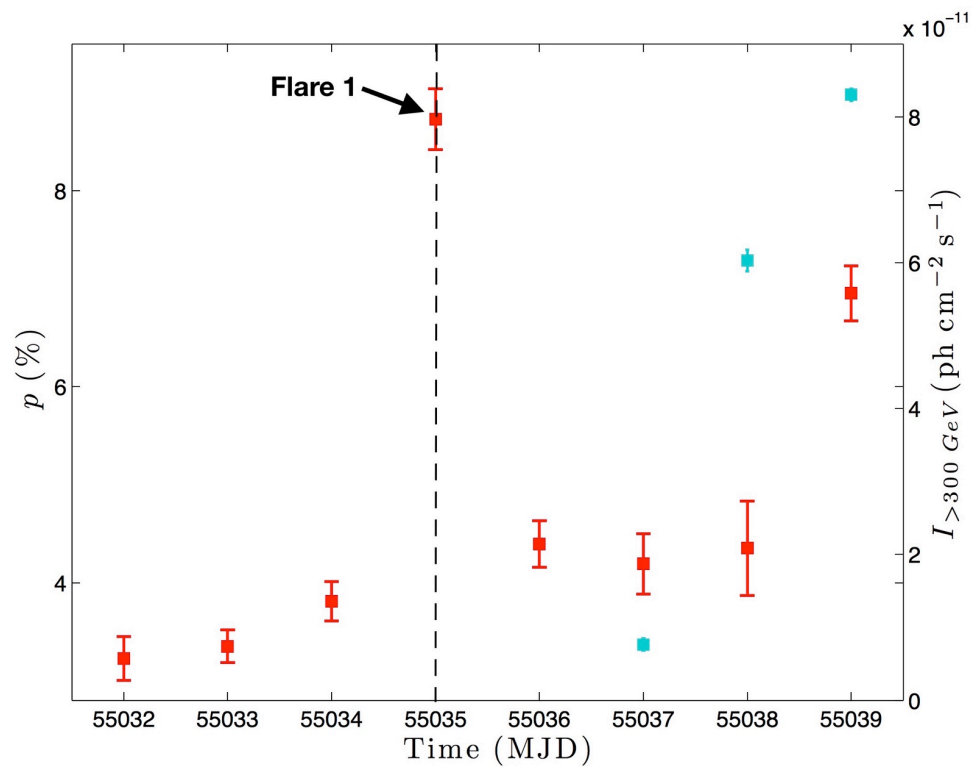


OBSERVATIONS



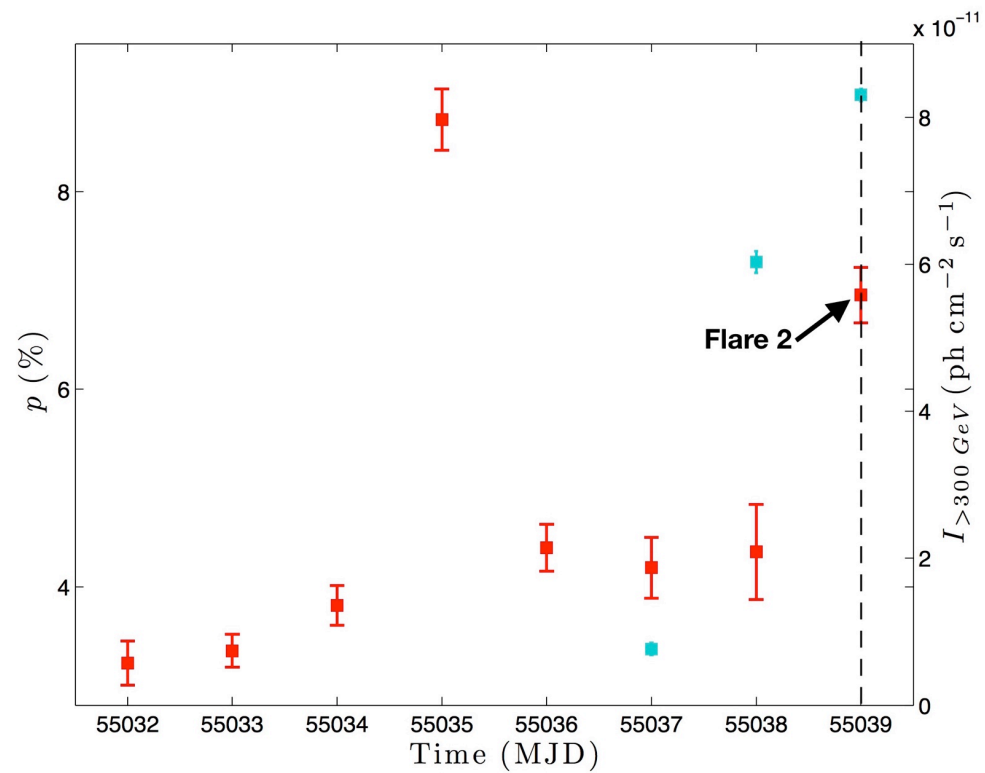
- 2009 VHE light curve
- Detect two γ -ray flares
- First simultaneous polarization & γ -ray obs. in high-state!

OBSERVATIONS



- Flare 1
- Peaks on 23 July 2009
- Lasts 4 days

OBSERVATIONS



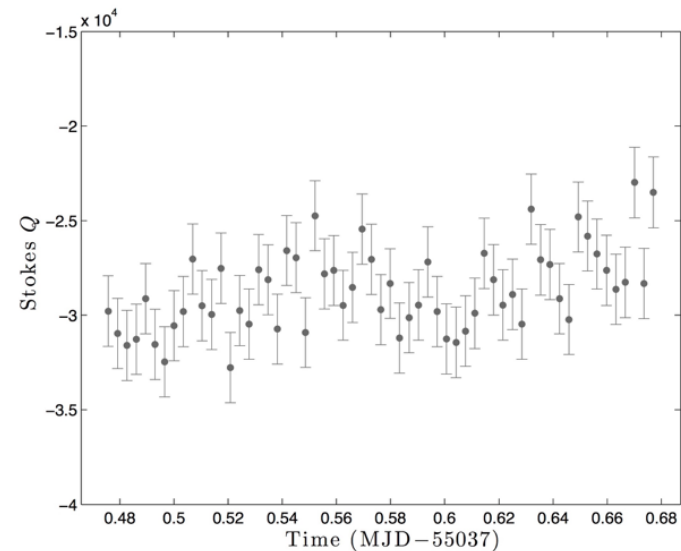
- Flare 2
- Developing flare
- 3 days from 25 – 27 July

A QPO IN POLARIZED FLUX?

Intra-day Variability

- At onset of Flare 2 (25 July 2009)
- Possible amplitude modulation
- Appears to cycle every 30 min
- ~4 h observation run

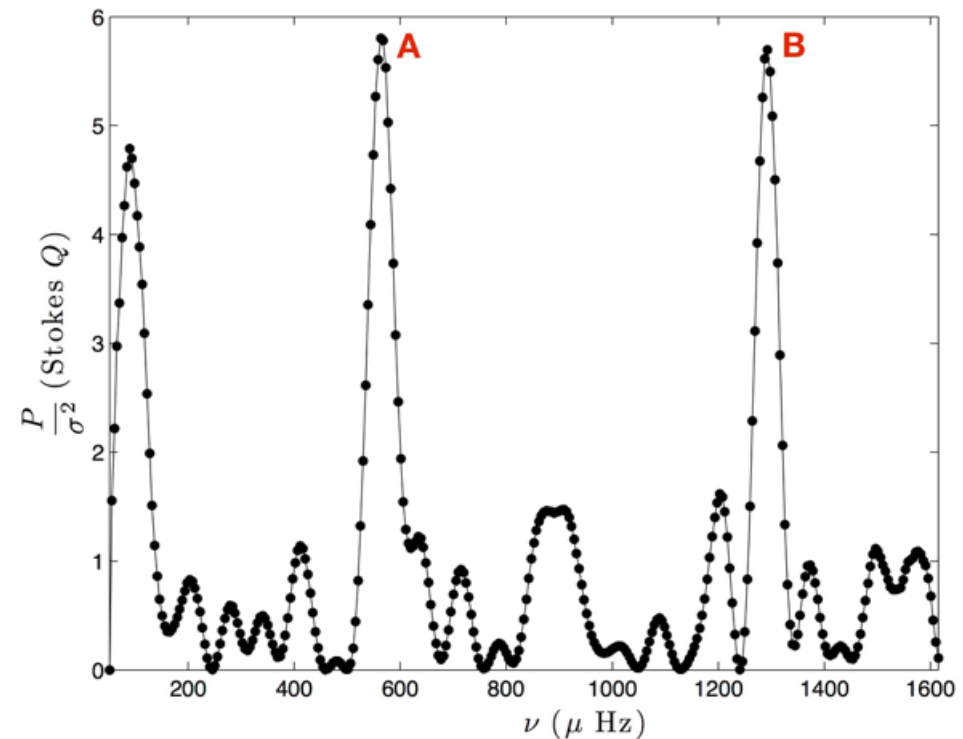
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Periodogram?



A QPO IN POLARIZED FLUX?

Periodogram

- Two components A & B
- $P = 30$ min & $P = 13$ min
- Similar to 15 min optical QPO of blazar S50716+714⁹



DISCUSSION

QPO ORIGIN?

IDV in blazars due to shocks in jet ¹⁰

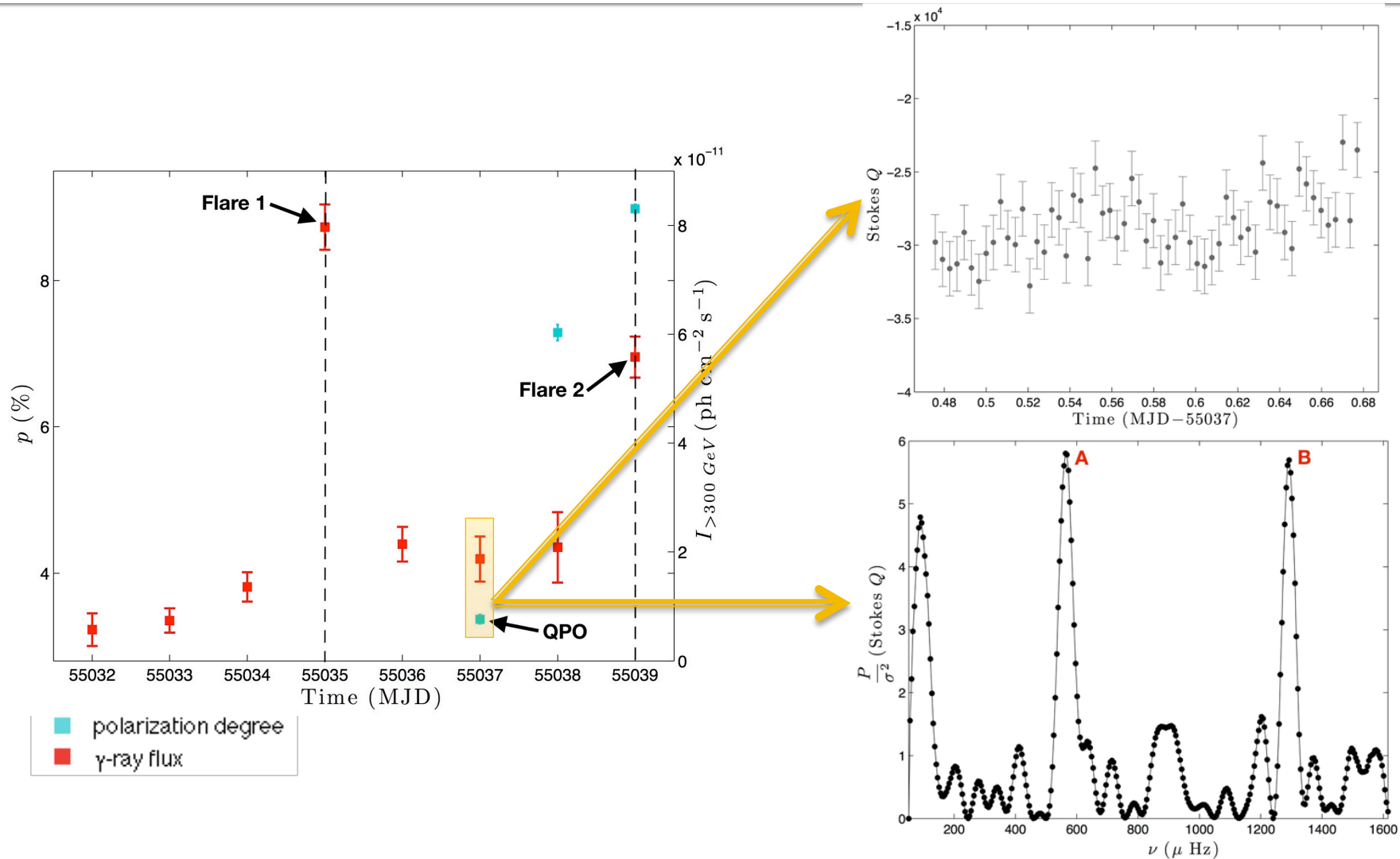
1. Quasi-helical structures in jet, e.g. magnetic field or electron density
2. Turbulence behind shock travelling in jet ¹¹
3. Orbital motions of rotating hotspots near central engine

How do we discriminate between these scenarios?

Polarization in blazars due to synchrotron emission in jet

Polarized QPO implies jet origin!

SUMMARY & CONCLUSIONS



SUMMARY & CONCLUSIONS

Polarization & γ -rays show:

- Polarized QPO is associated with rise in γ -ray activity
- Polarization and γ -ray flux show correlated behaviour (inter-day)
- Related to late phase of Flare 1 or early phase of Flare 2



Suggests QPO is part of longer-lived phenomenon in jet!

FUTURE WORK

Study of high time-resolution IDV of optical polarization & γ -rays