A QPO in the Optical Polarization of PKS 2155 – 304

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ICTS International Centre for Theoretical Sciences
Tata Institute of Fundamental Research

OVERVIEW

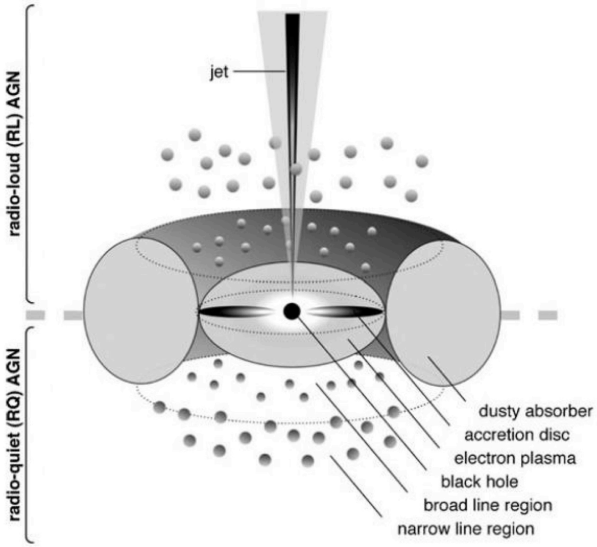
1. Discovery of first quasi-periodic oscillation (QPO) in the intra-day polarization degree of the active galaxy PKS 2155 – 304.
2. First simultaneous optical polarization and very high-energy γ–ray observations (photons with energies exceeding a few GeV) during a high-state.

PKS 2155–304

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

PROPERTIES

- Bright & highly variable (from minutes to years [1,2])
- Broad-band, non-thermal continuum
- Polarization observed at optical & radio



1. *HESS Collaboration 2007*
2. *Kastendieck et al. 2011*

POLARIZATION

- In optically thin regime, polarization direct indicator of magnetic field in emission region

OBSERVATIONS

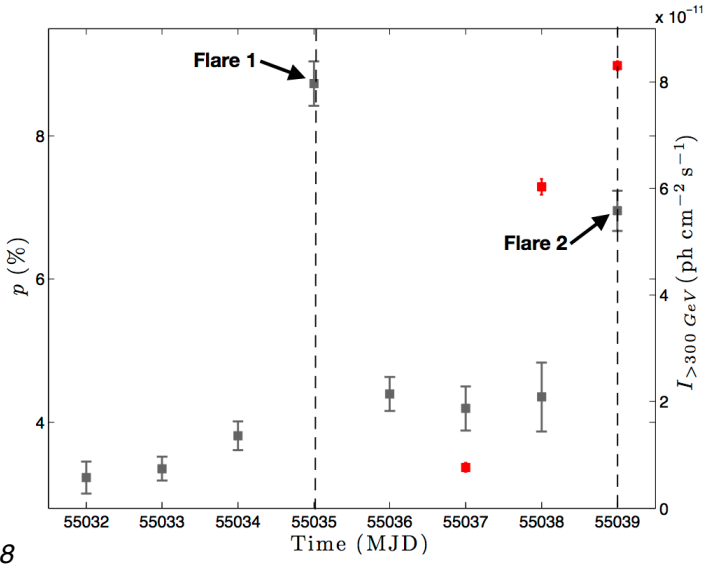
- Recorded with high-speed polarimeter HIPPO[3]
- Source monitored intermittently between 2009 and 2012
- Results from July 2009 observations

- Intra-day variability (IDV) from 25 to 27 July
- 5 min temporal resolution (factor of 3 better [4])

- Recorded with the HESS, overlaps polarization observations
- Monitored from 19 to 27 July 2009 [5],
- Yielding 3 simultaneous polarization & γ–ray observations

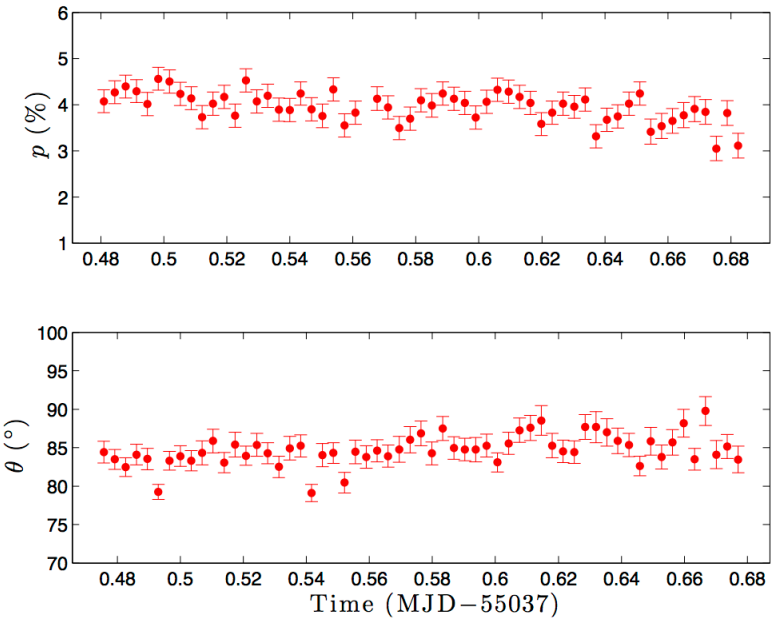
Table 1. The mean daily optical polarization of PKS 2155–304 in July 2009.

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



3. *Potter et al. 2008*
4. *Barres del Almeida et al. 2008*
5. *HESS Collaboration 2014*

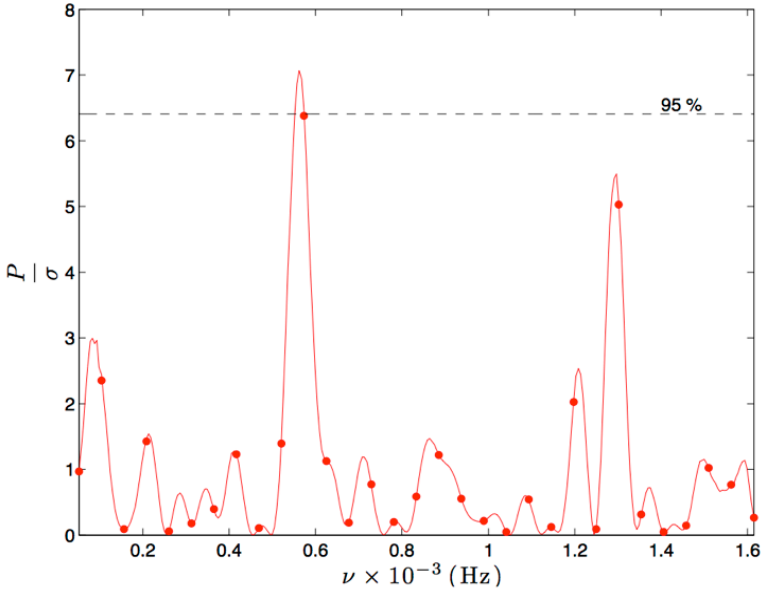
RESULTS



- Two dominant frequency components from Lomb-Scargle periodogram
- Corresponding to period $P = 30$ & 13 min.
- Only primary peak statistically significant
- Similar to 15 min optical QPO of blazar S50716+714 [6]

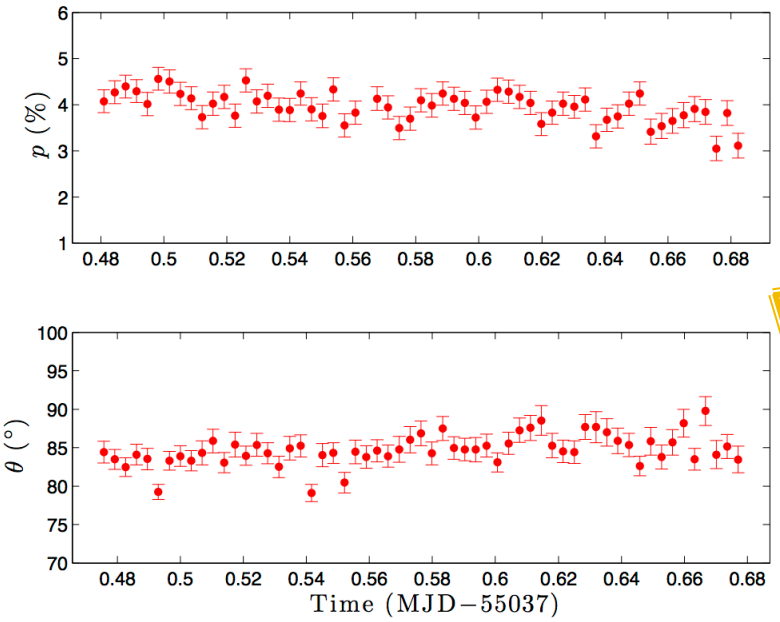
- Possible amplitude modulation at onset of Flare 2 on 25 July 2009
- Appears to cycle every 30 min
- ~4 h observation run
- No apparent modulation of the EVPA (θ)

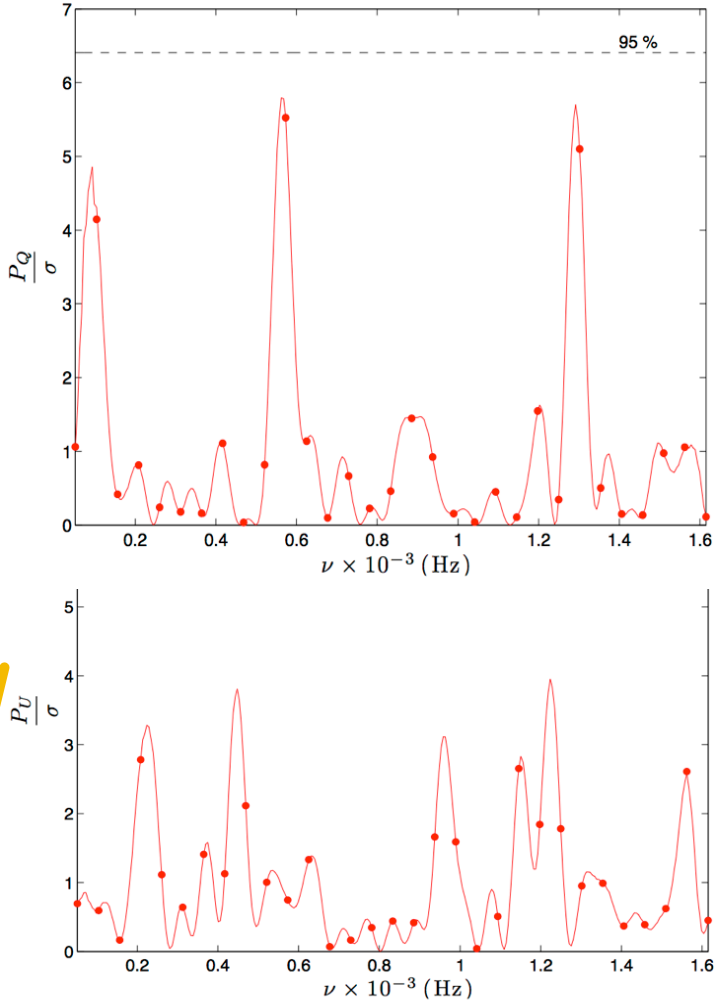
PERIODOGRAM



6. Rani et al. 2010

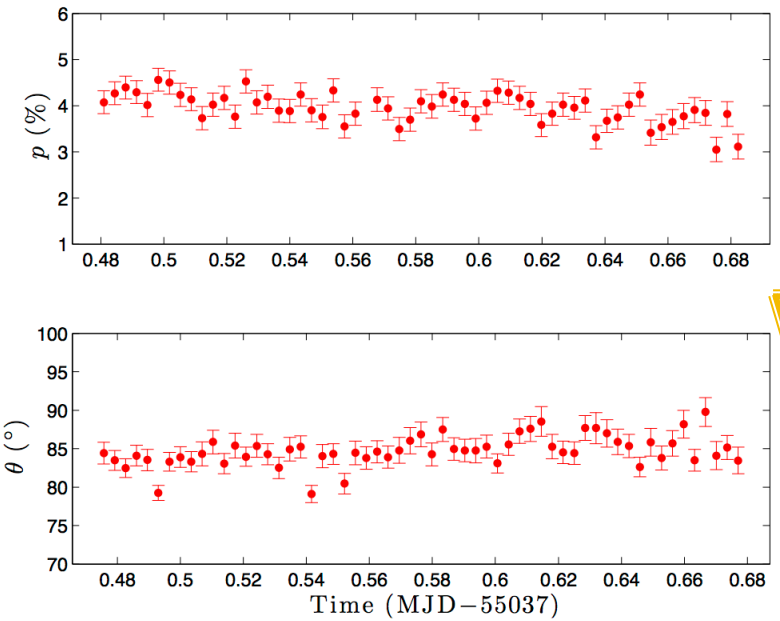
RESULTS

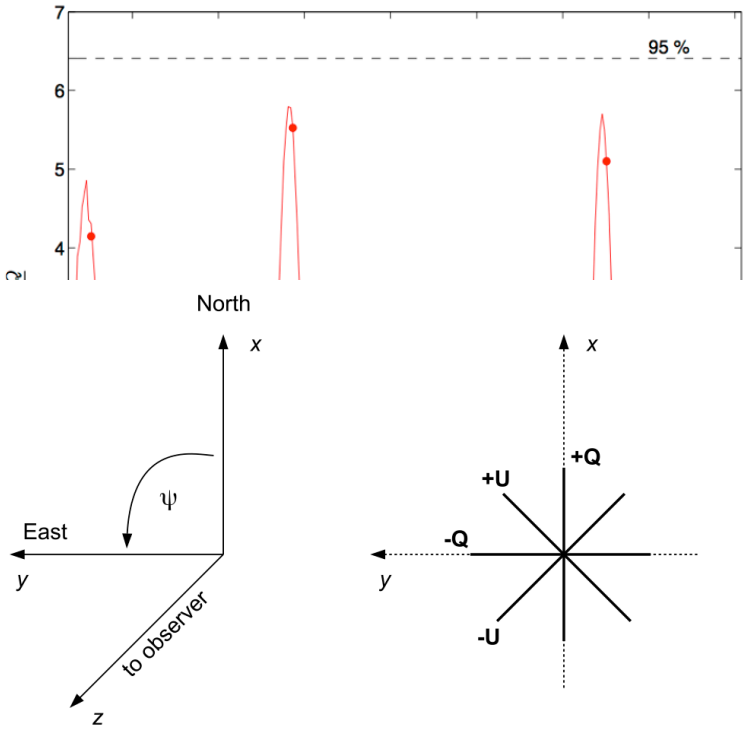


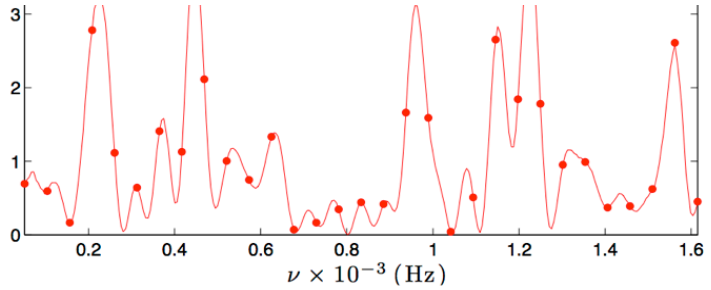


- Detect same two dominant frequency components (P = 30 min. & 13 min.)
- No significant peaks detected for U !

RESULTS







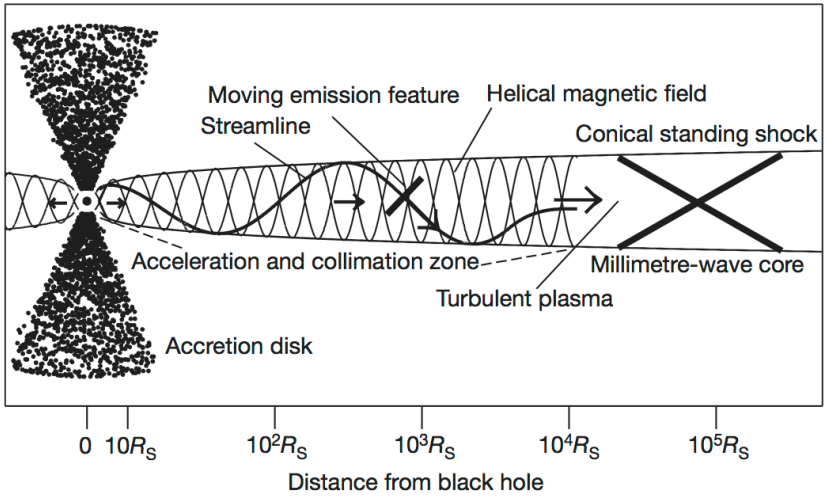
- Detect same two dominant frequency components (P = 30 min. & 13 min.)
- No significant peaks detected for U !
- Mean daily EVPA of ~90° implies most polarized flux carried in Q on sky-plane
- Excludes instrumental origin

DISCUSSION

ORIGIN OF POLARIZED QPO?

Simplest way:

1. Emission feature propagating in quasi-helical structures in the magnetic field or electron density of the jet
   - Moving emission feature traces spiral path (on timescale of a few months[9])
   - Timescale of QPO constrains emission region size $r < 10^{15}$ cm
   - EVPA undergoes periodic change
   - Halfway through one cycle, polarization degree drops to minimum



Optical polarization measurements show:
- Intra-day variability timescale
- EVPA does not demonstrate cyclic modulation (projection effects?)

9. *Marscher et al. 2008*

DISCUSSION

ORIGIN OF POLARIZED QPO?

2. Turbulence behind shock moving in a helical magnetic field[10]
   - Then, turnover time of dominant turbulent cell determines period of QPO
   - Natural explanation for fast & short-lived QPOs and,
   - Presence of QPO consisting of multiple components

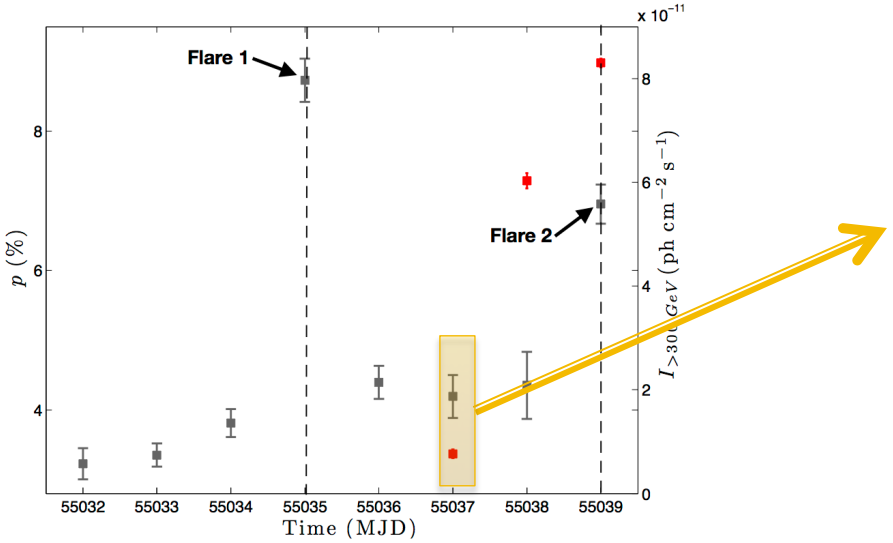
3. Orbital motions of rotating hotspots near central engine[11]:
   - Seems unlikely since blazar emission dominated by jet but,
   - Possible through jet-disk connection (How?)

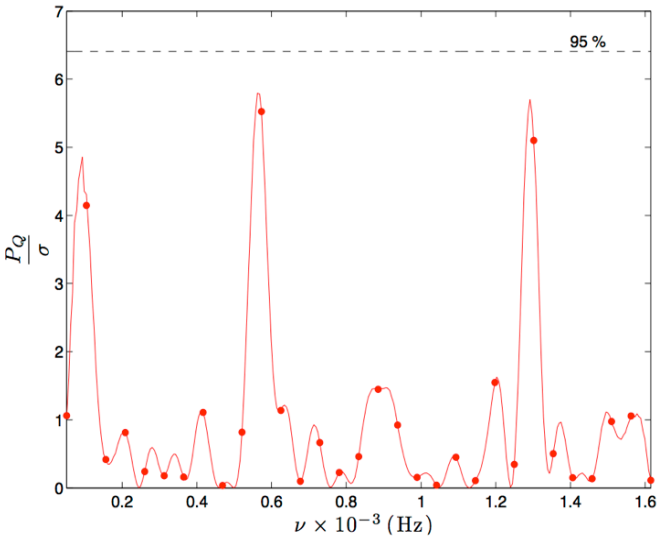
ORIGIN IN BLAZAR QPOs OPEN QUESTION, HOWEVER,

- Polarized QPOs constrains location of QPO to jet
- Is the QPO associated with rise in γ–ray activity?
- If so, this suggests QPO is part of longer-lived phenomenon in jet!

10. *Marscher et al. 1992*
11. *Zhang & Bao 1991*

SUMMARY & CONCLUSION





CONCLUDING REMARKS

- AGN QPOs rarely observed[7]
- PKS 2155 – 304 is one of few[8]
- First time QPO observed in polarized emission of <u>any</u> AGN!

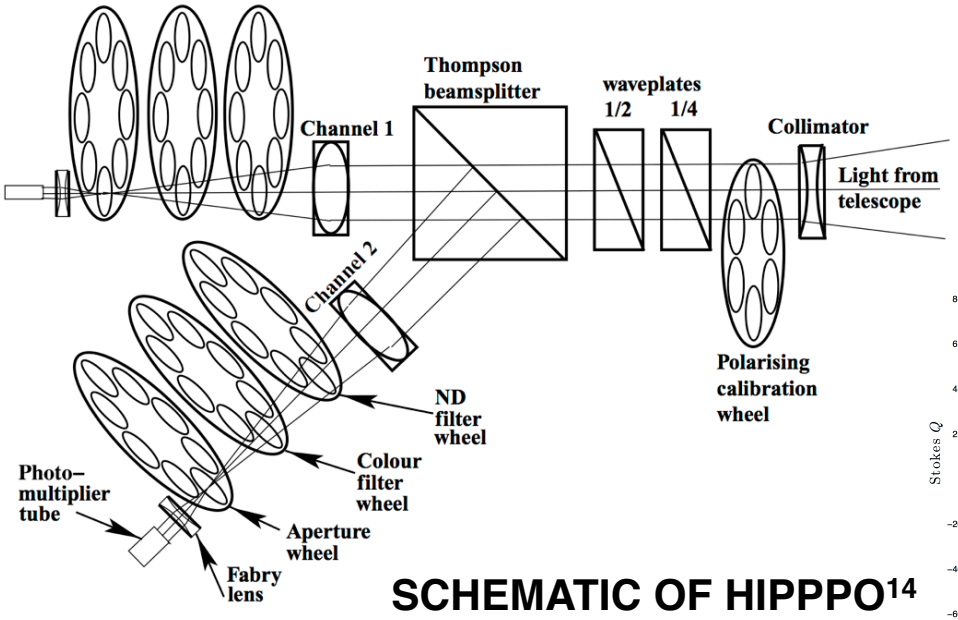
7. *Gierlieński et al. 2008*
8. *Lachowicz et al. 2009*

BACK-UP SLIDES

INTRINSIC VARIABILITY[12]

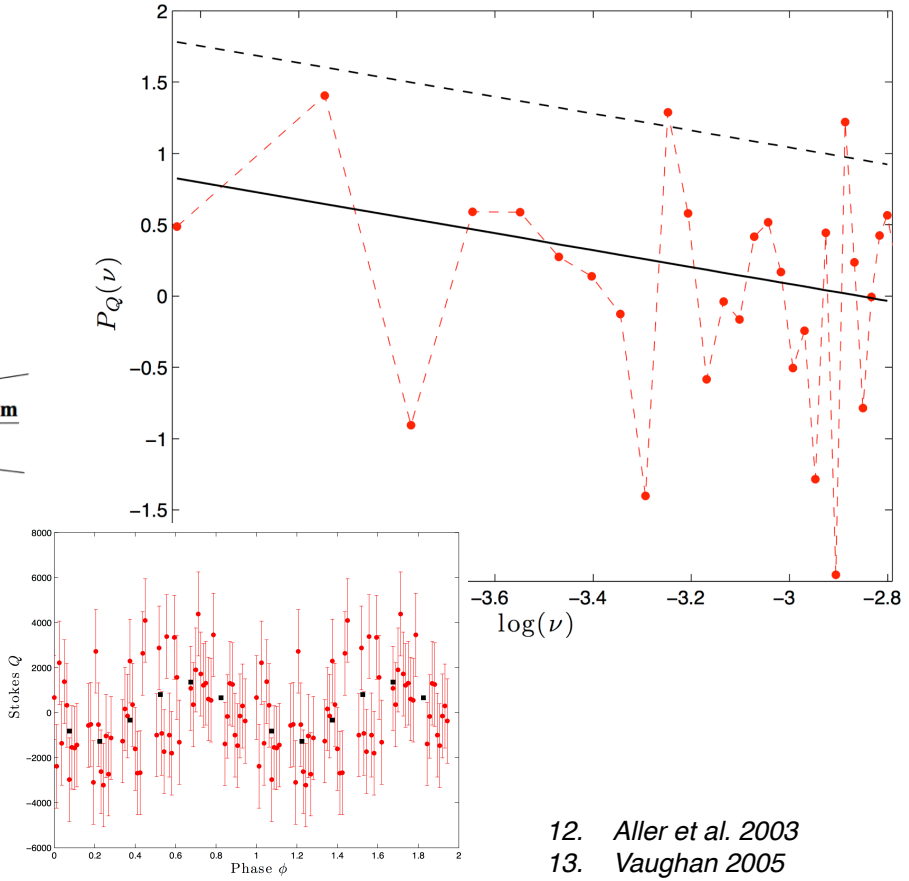
Table 2. The fractional variability amplitude $F_{\rm var}$ of the intra-day polarization.

MJD	$F_{\rm var}(\%)$
55037	5.1 ± 0.9
55038	2.2 ± 0.6
55039	3.5 ± 0.5



SCHEMATIC OF HIPPPO[14]

POWER SPECTRAL DENSITY[13]



12. *Aller et al. 2003*
13. *Vaughan 2005*
14. *Potter et al. 2008*