Decade-long linear polarization variability properties of parsec-scale AGN jets

Daria Zobnina[1,2]

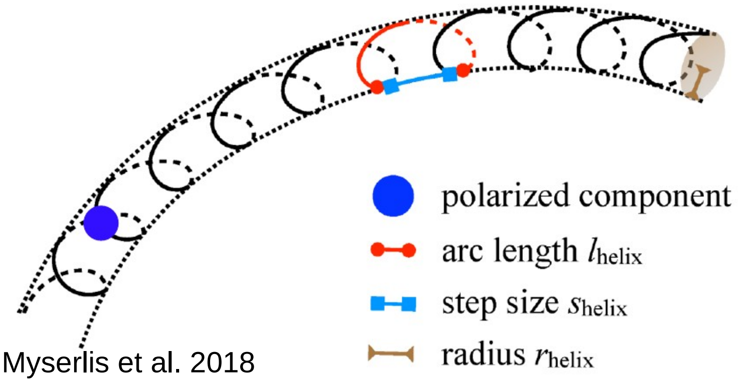
Alexander Pushkarev[3,1], Ilya Pashchenko[1,2], Yuri Y. Kovalev[1,2,4], Hugh Aller[5], Margo Aller[5], Daniel Homan[6], Matthew Lister[7], Tuomas Savolainen[8,9,4]

[1] Astro Space Center of Lebedev Physical Institute, Russia;
[2] Moscow Institute of Physics and Technology, Russia;
[3] Crimean Astrophysical Observatory, Russia;
[4] Max-Planck-Institut für Radioastronomie, Germany;
[5] University of Michigan, USA;
[6] Denison University, USA;
[7] Purdue University, USA;
[8] Aalto University Department of Electronics and Nanoengineering, Finland;
[9] Aalto University Metsähovi Radio Observatory, Finland

funded by RFBR grant No 20-32-90108

15th EVN Symposium & Users Meeting July 11-15, 2022

Linear polarization variability of AGNs



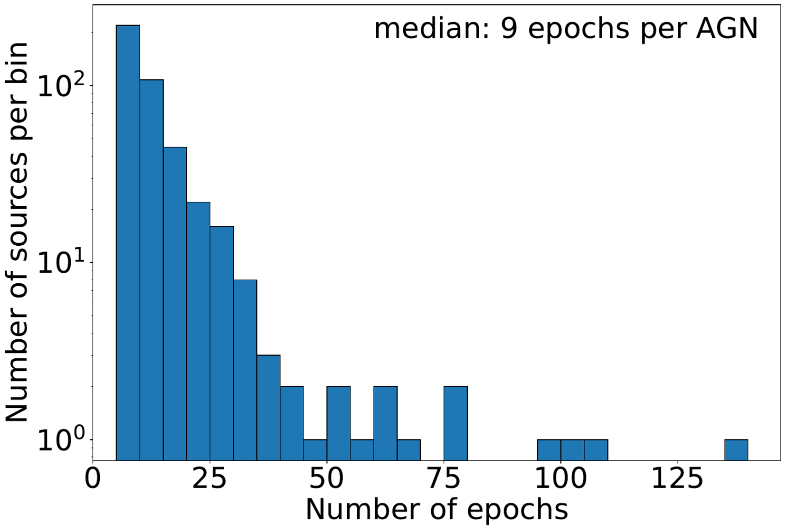
Myserlis et al. 2018

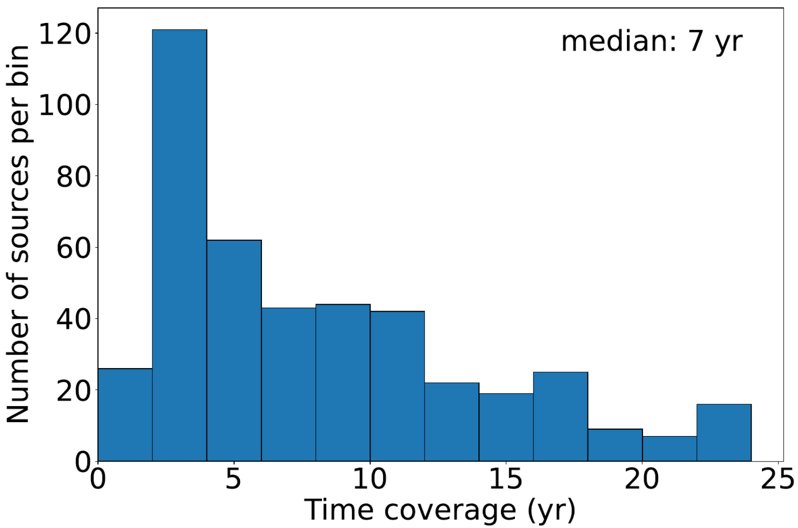
- Variability mechanisms:
  - Component moving in helical magnetic field (Marscher et al. 2008) or along jet bend (Gomez et al. 1994, Myserlis et al. 2018)
  - Doppler boosting + jet precession
  - ...

- **Main goal of our study** is to investigate pol. variability distribution in AGNs at 15 GHz to quantify the scale and understand the reason for variations

Sample & Observations

- MOJAVE VLBA program (Lister et al. 2018) and archival VLBA observations at 15 GHz
- Selection requirements:
  - Full Stokes observations
  - At least 5 epochs between 1996 and 2019
- Full sample 436 AGNs: quasars (60%), BL Lacs (31%), radio galaxies (4%) or LSP (83%), ISP (10%), HSP (6%)

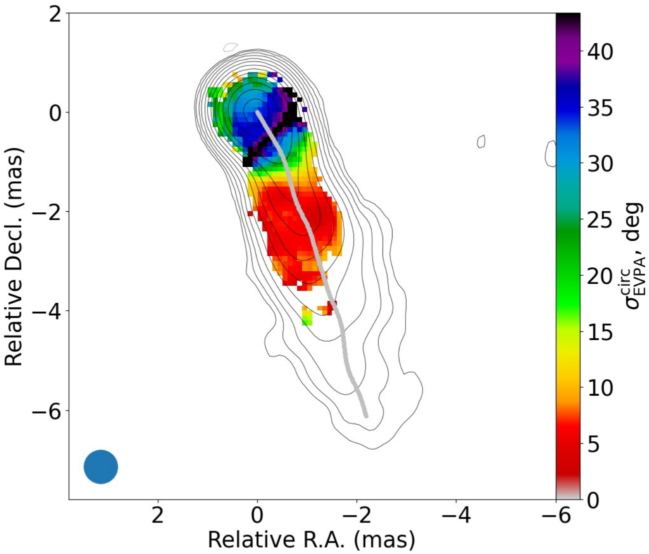




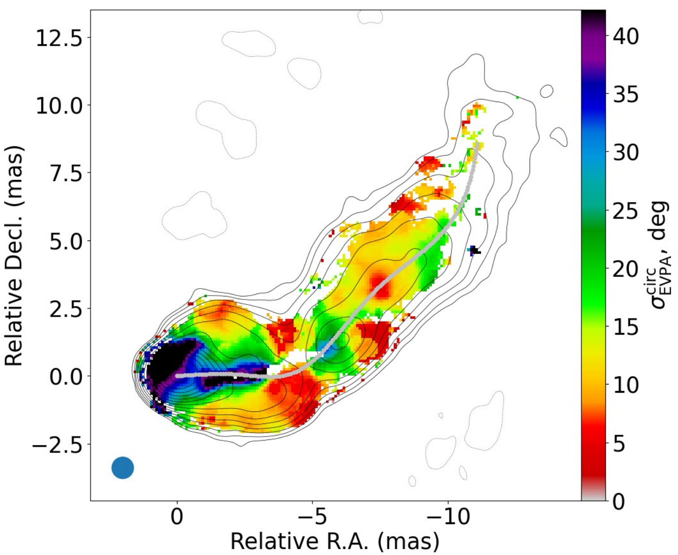
EVPA variability maps

- EVPA variability σ_{EVPA} = standard deviation ($EVPA_i$), $EVPA_i$ – single-epoch EVPA

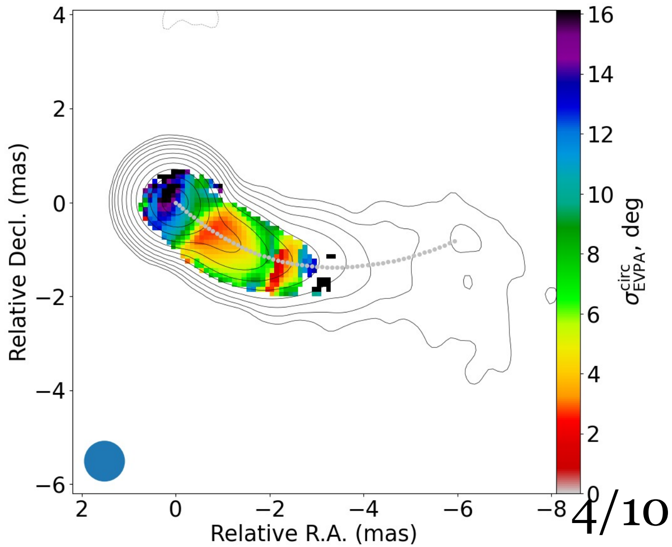
1150+497: 14 epochs
EVPA variability map



2251+158: 59 epochs
EVPA variability map



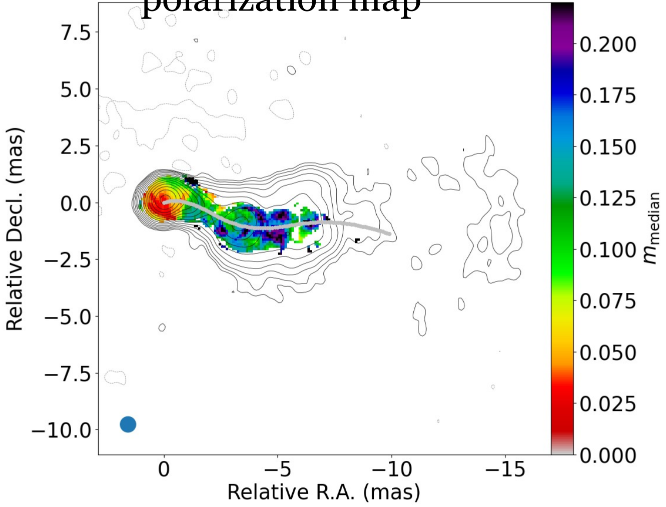
2254+074: 9 epochs
EVPA variability map



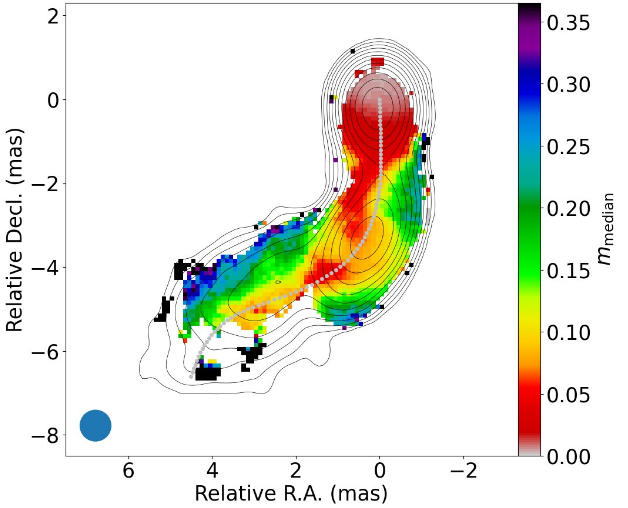
Median fractional polarization m_{median} maps

- Median fractional polarization m_{median} = median (m_i), m_i – single-epoch m
- Median fractional polarization used as a measure of typical over epochs values
- Corrected for Rician bias (Wardle & Kronberg 1974) and CLEAN bias (see talk of A. Pushkarev)

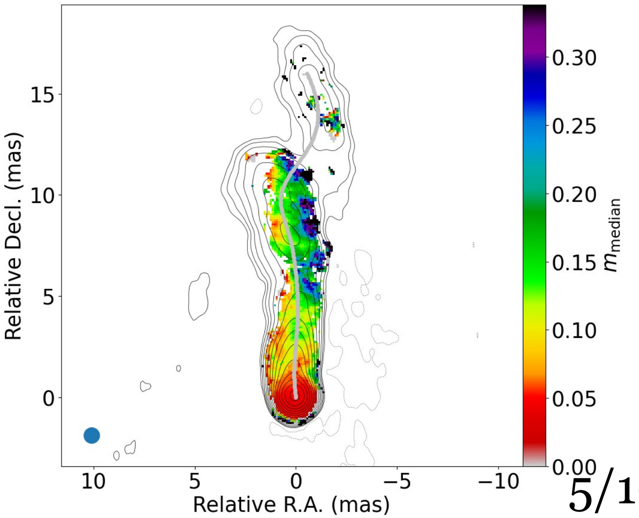
0420+417: 15 epochs median fractional polarization map



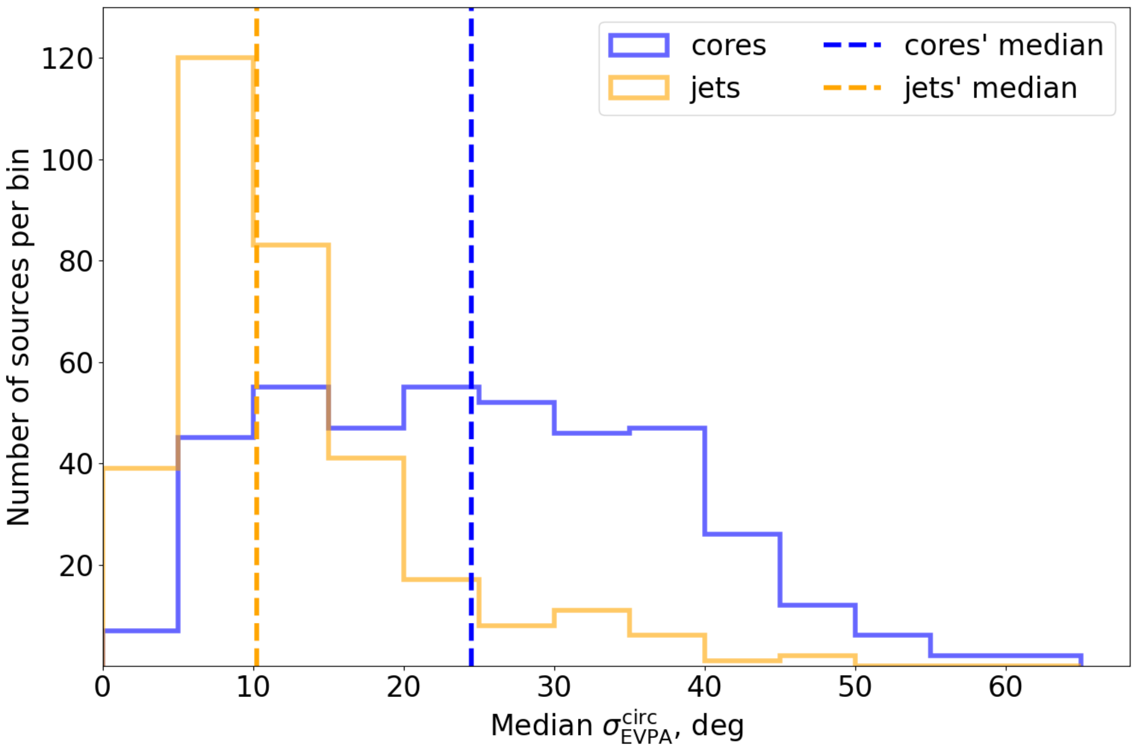
0738+313: 29 epochs median fractional polarization map



1222+216: 48 epochs median fractional polarization map

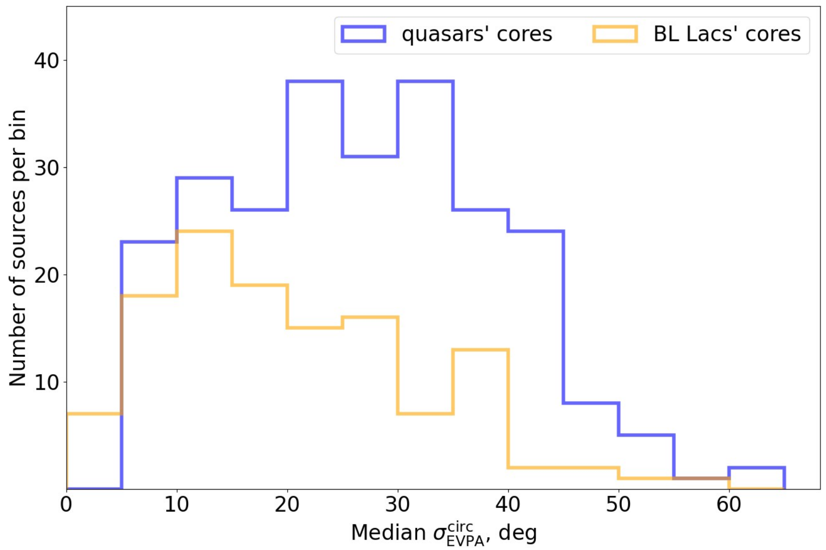


Core and jet EVPA variability

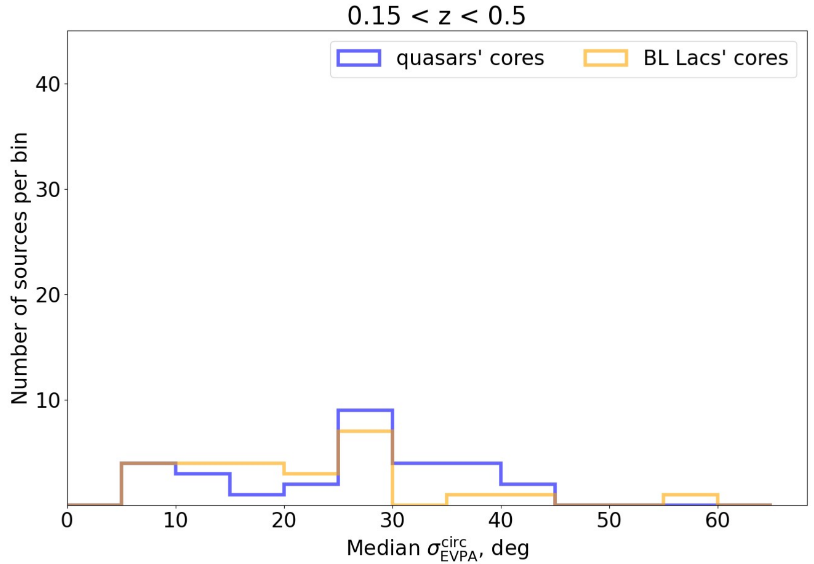


- Core EVPA variability is **significantly higher** than that of jet for the whole sample, optical and SED classes separately
- Reasons for **less stable** EVPA in the core:
  - **High variations of opacity** because of plasma flow or component blending
  - **Strong instability of magnetic field direction** because of component blending

EVPA variability of quasars’ and BL Lacs’ cores



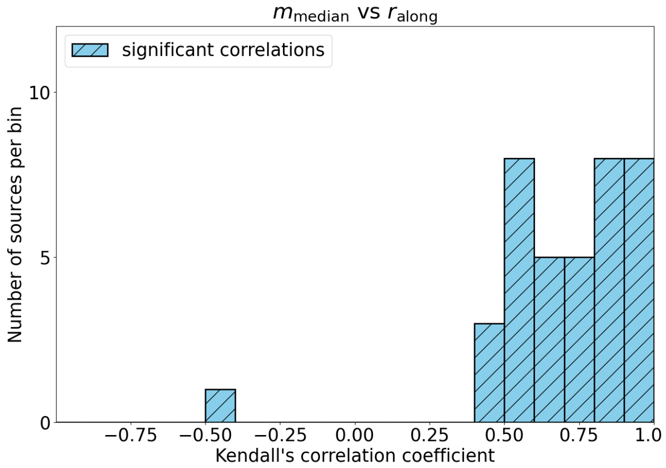
Significant difference



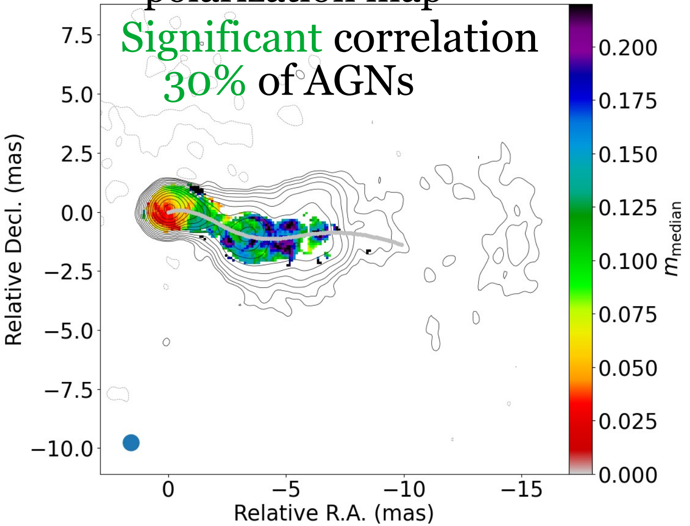
Insignificant difference

- Hodge et al. (2018): EVPA of BL Lacs' cores is more stable than that of quasars
- This result seems to be driven by distance difference: quasars are at **higher redshift** => **larger region** falls into beam => **larger median EVPA variability**

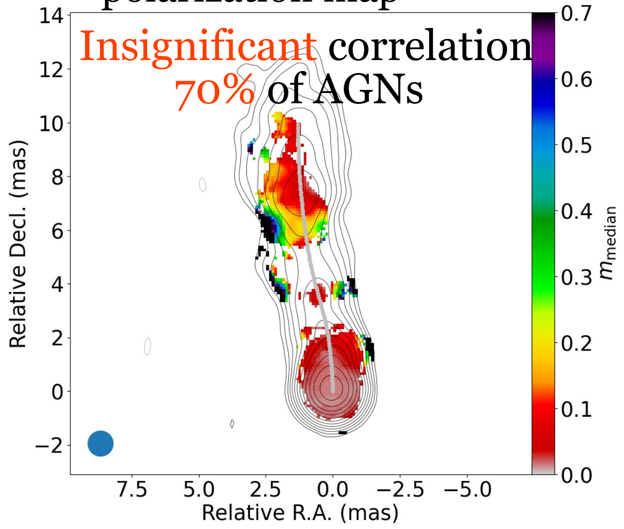
m_{median} in the jet vs distance from the core r_{along}



0420+417: 15 epochs median fractional polarization map

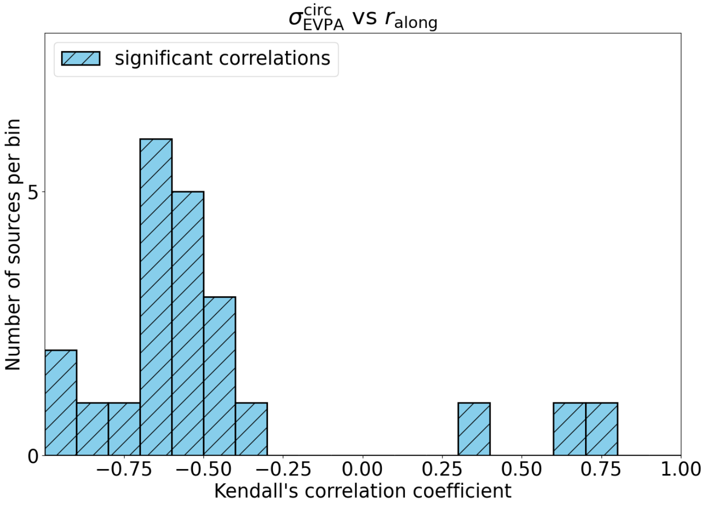


0451-282: 6 epochs median fractional polarization map

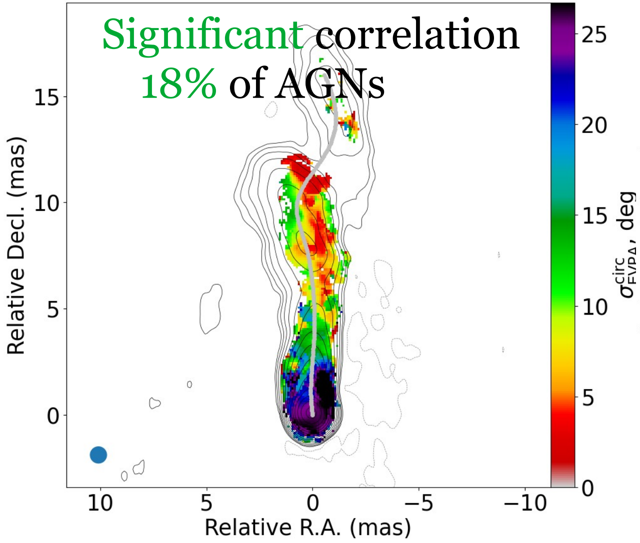


- For 30% AGNs correlation of median over epochs m with the distance from the core is significant
- Majority of AGNs shows non-monotonic behaviour of m_{median} with r_{along} because of bright components, jet bend, etc.
- Low m_{median} near the core due to strong Faraday depolarization
- m_{median} rise due to magnetic field order increase or the change of helical field pitch angle (e.g., Porth et al. 2011)

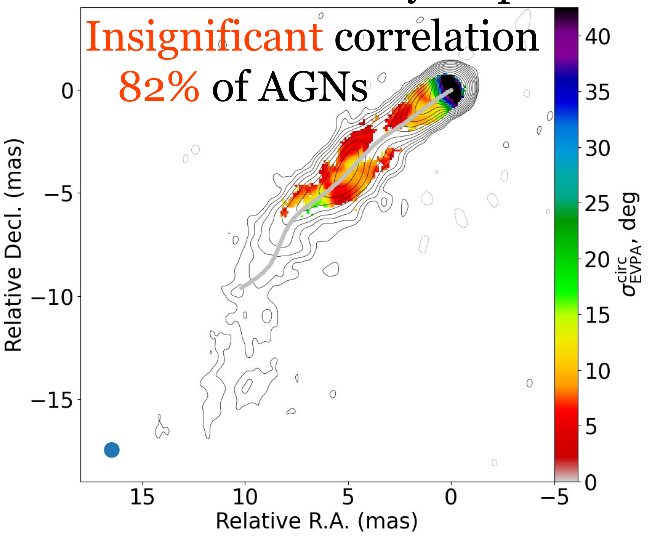
EVPA variability in the jet vs distance from the core r_{along}



1222+216: 48 epochs
EVPA variability map



0333+321: 21 epochs
EVPA variability map



- 18% of AGNs have significant correlations of EVPA variability with the distance from the core
- Majority of AGNs shows non-monotonic behaviour of EVPA variability with r_{along} because of bright components, jet bend, etc.
- Low m_{median} and high EVPA variability near the core <= less ordered magnetic field with less stable direction
- m_{median} increase and EVPA variability drop along jet <= the growth of order and stability of magnetic field along the jet
- Low m_{median} and high EVPA variability near the core <= component blending

Conclusions

- **Core** EVPA variability is **significantly higher** than that of the jet for the whole sample, optical and SED classes separately due to high opacity and magnetic field variations in the core.
- EVPA variability of quasars' and BL Lacs' cores **does not differ**.
- The **majority** of AGNs exhibit **non-monotonic behaviour** of EVPA variability and m_{median} along the jet due to bright components, jet bend, etc.
- **Significant** correlations show that **EVPA variability drops** and $\mathbf{m_{median}}$ **rises** downstream the jet. Reasons:
  - Faraday depolarization
  - component blending
  - changes of magnetic field characteristics.

  Observations with higher angular resolution can help to reveal the dominant cause of these trends.