Optical polarization of AGN with significant VLBI-Gaia offsets

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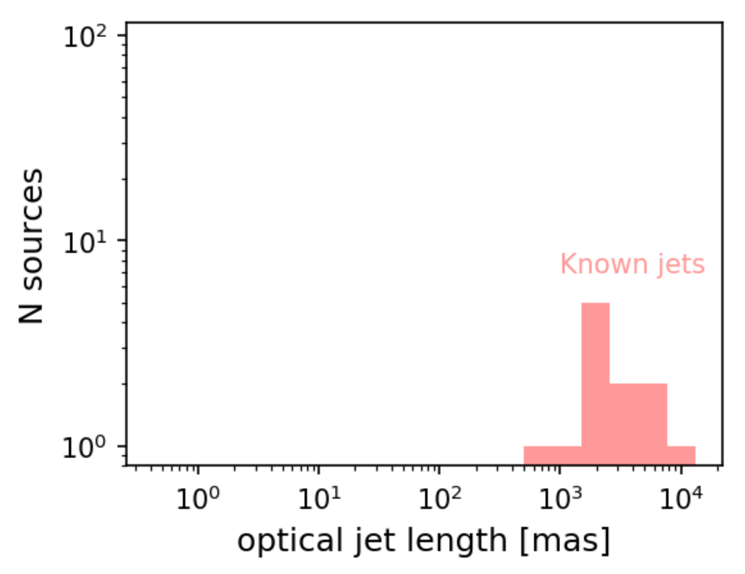
Optical jets of AGN

Name	z	Length (arcsec)	Length (kpc)
3C 15	0.073	4.2	5.3
3C 66B	0.022	8.0	3.2
3C 78	0.029	1.5	0.8
3C 120	0.033	15.0	24.8
PKS 0521-365	0.055	6.5	6.4
3C 200	0.458	0.8	3.6
3C 212	1.049	2.2	12.5
3C 245	1.029	1.6	9.1
3C 264	0.022	2.2	0.9
3C 273	0.160	23.0	56.2
M87	0.004	25.0	2.1
3C 346	0.161	3.6	9.0
3C 371	0.051	4.5	4.1
3C 380	0.692	1.4	8.5
PKS 2201+044	0.028	2.1	1.1

Whiting M. T. 2000, PhD Thesis, U. of Melbourne



Credit:
NASA, ESA, and the Hubble Heritage Team (STScI/AURA)
Acknowledgment: P. Cote (Herzberg Institute of Astrophysics) and E. Baltz (Stanford University)

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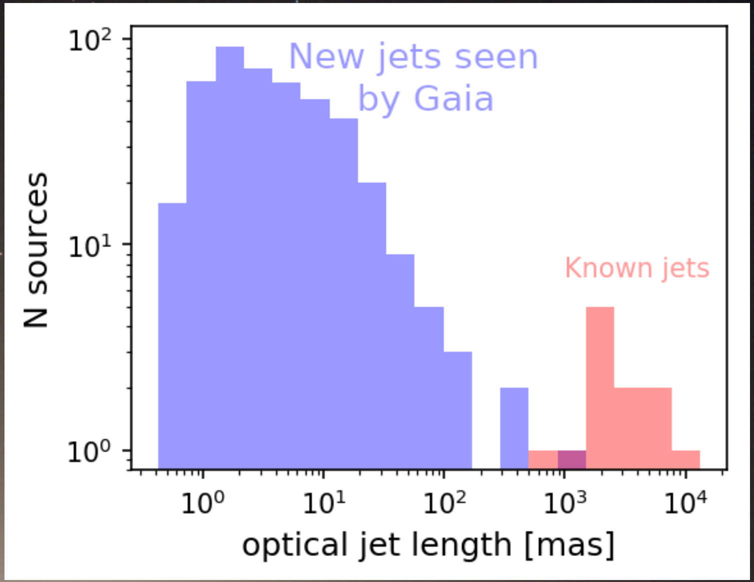
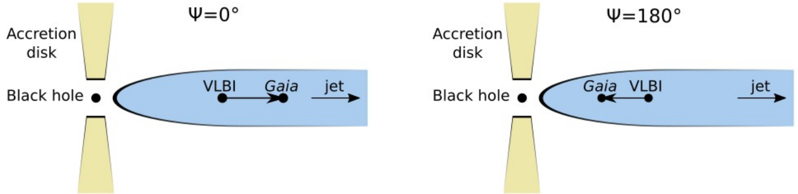
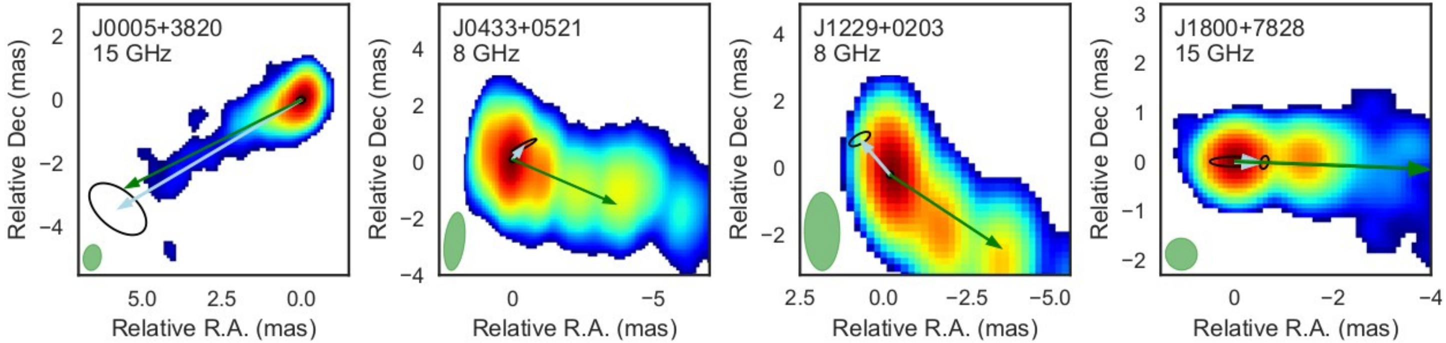


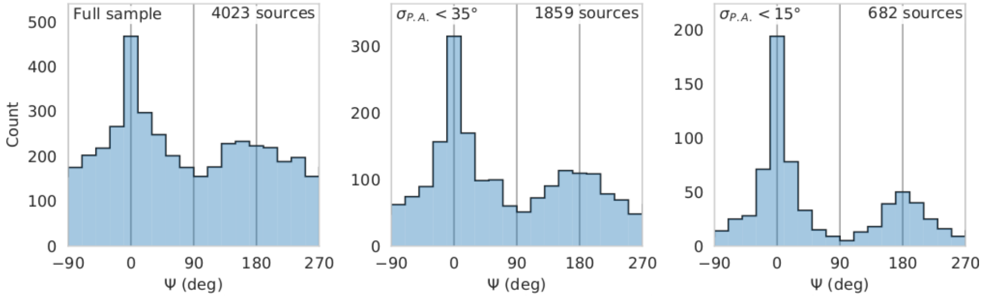
VLBI-Gaia positional offsets

Significant VG offsets
first reported based on DR1
by Mignard et al. (2016)





Kovalev et al. (2017)

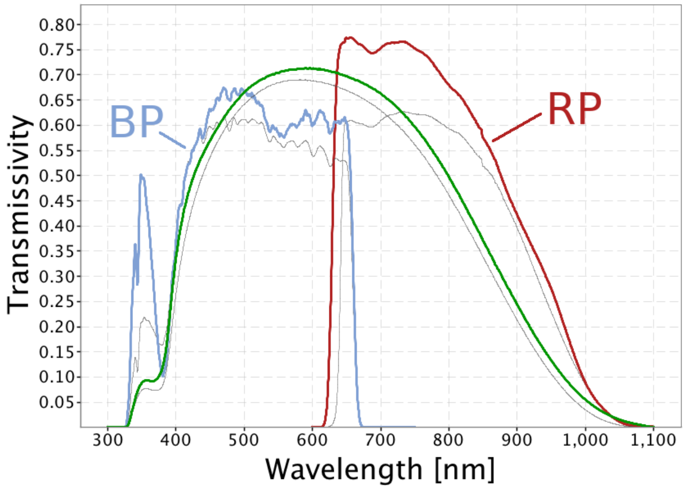


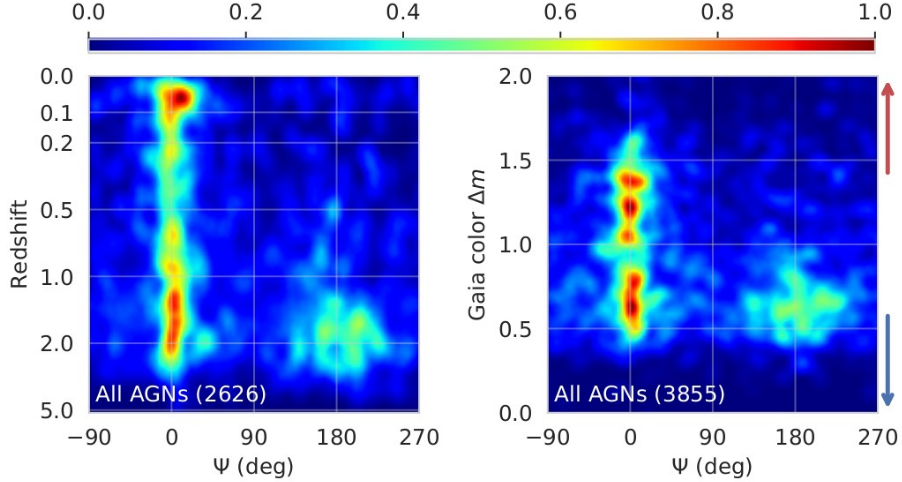
Plavin et al. (2019)

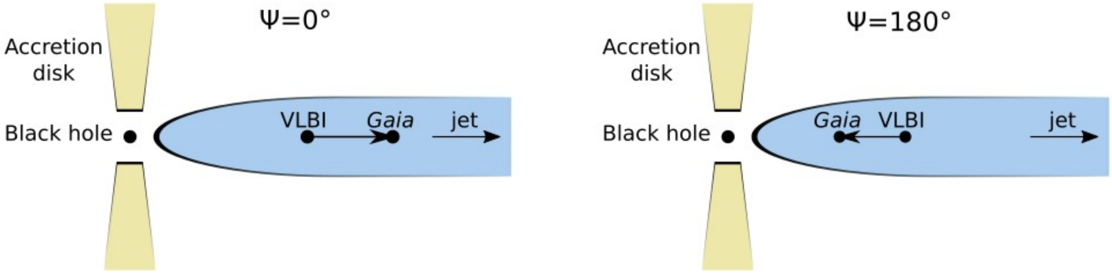
RFC vs Gaia DR2:
9081 matches
9% have significant offsets
4023 have clear jet PA

Petrov et al. (2019)

Color indices vs VLBI-Gaia offsets



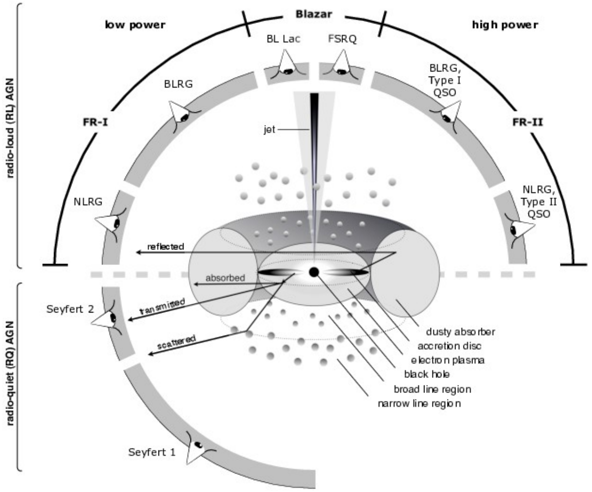




Plavin et al. (2019)

Optical polarization vs VLBI-Gaia offsets?

Cental engine — (Scattering, reflection, ...) — low polarization
Jet — (Synchrotron) — high polarization



Beckmann & Shrader (2012)

Archival optical polarimetry data:

Monitoring:
RoboPol Angelakis et al (2016)
Kanata Itoh et al. (2016)

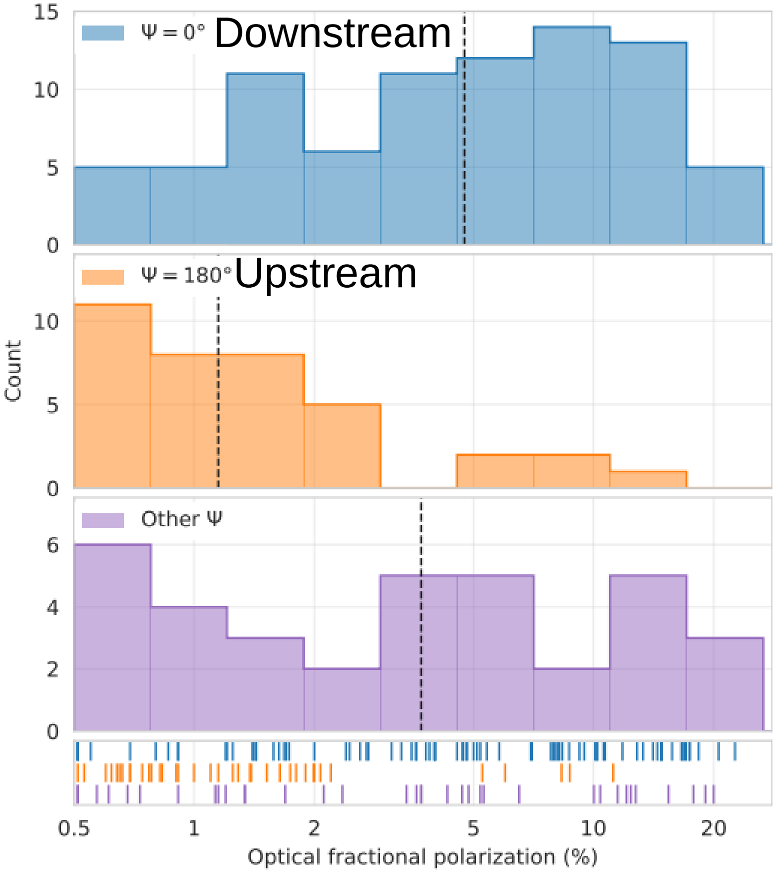
Single epoch surveys:
Hutsemékers et al. (2005)
Hutsemékers et al. (2018)

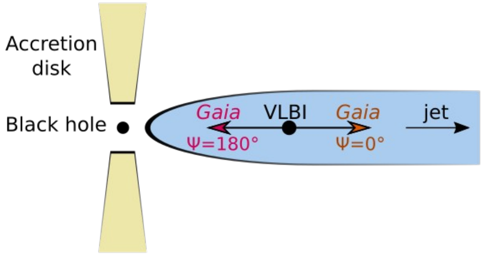
V, R - band polarimetry for 535 AGN

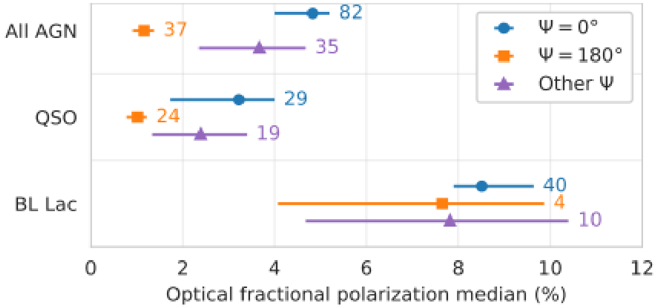
+ 2957 PA_{jet} determined in Kovalev et al. (2017)

287 AGN with polarimetry, significant offset and jet direction

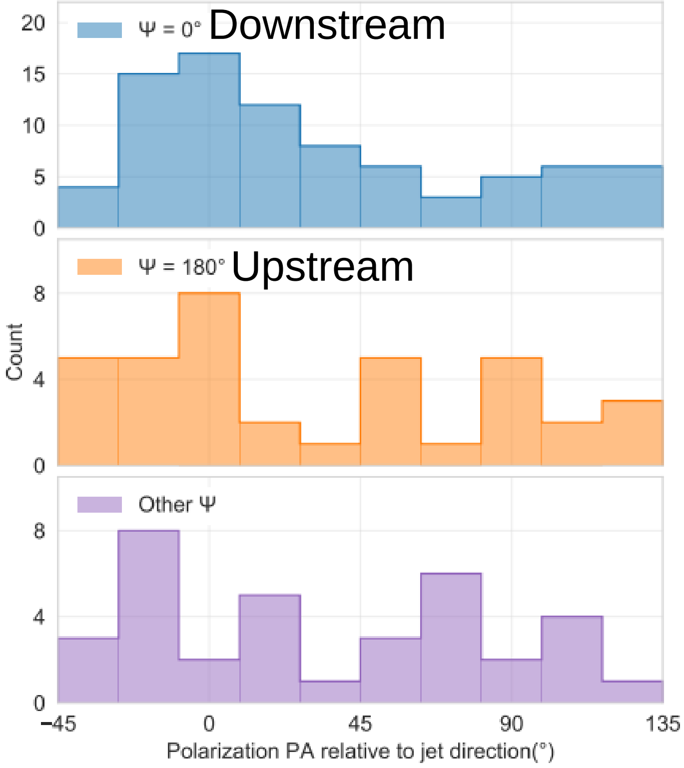
Optical polarization vs VLBI-Gaia offsets

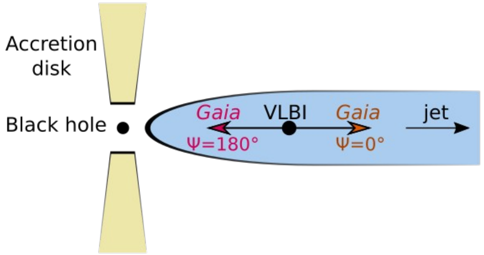


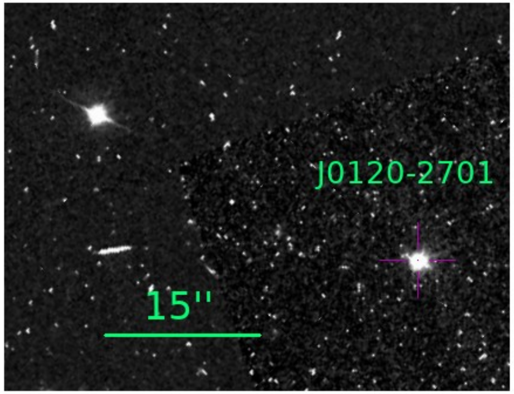


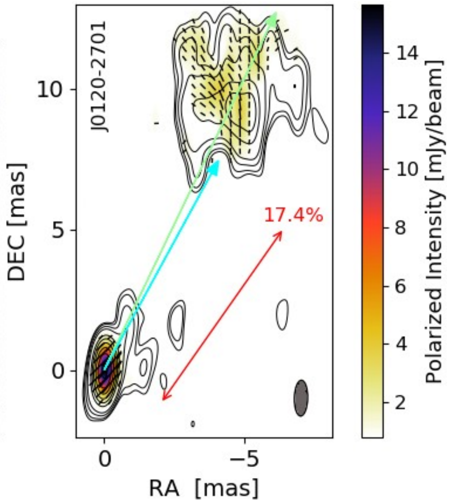


Optical polarization vs VLBI-Gaia offsets









HST O'Dowd & Urry, 2005 MOJAVE

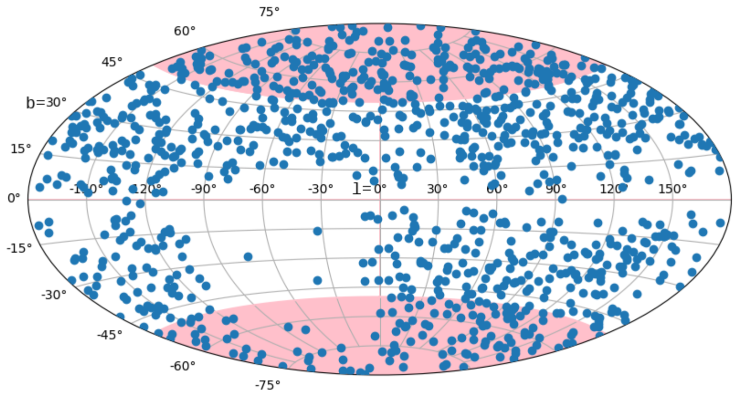
What is next?

Single epoch survey

FORS2/VLT 8.2m — 46 sources
CAFOS/CAHA 2.2m — 25 sources

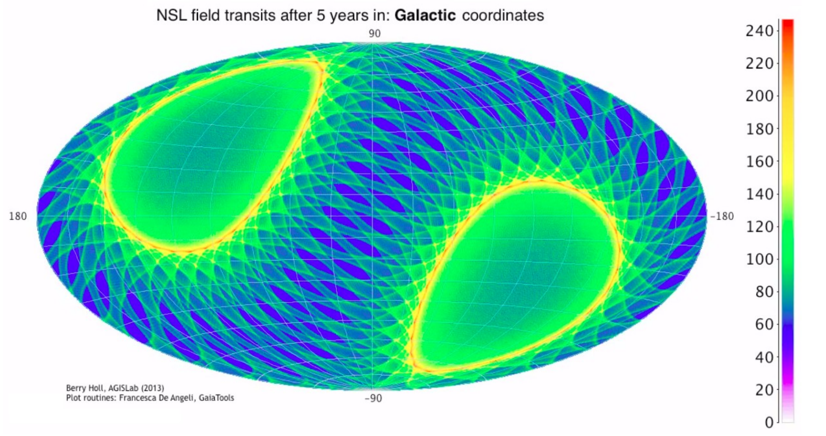
+ RoboPol filler program ~ 40 sources

PASIPHAE coverage

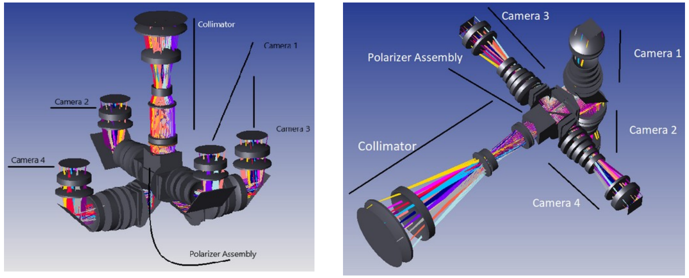


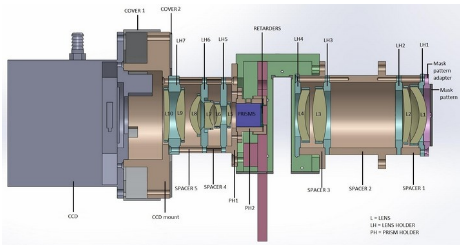
~350 sources
http://pasiphae.science

Monitoring is needed



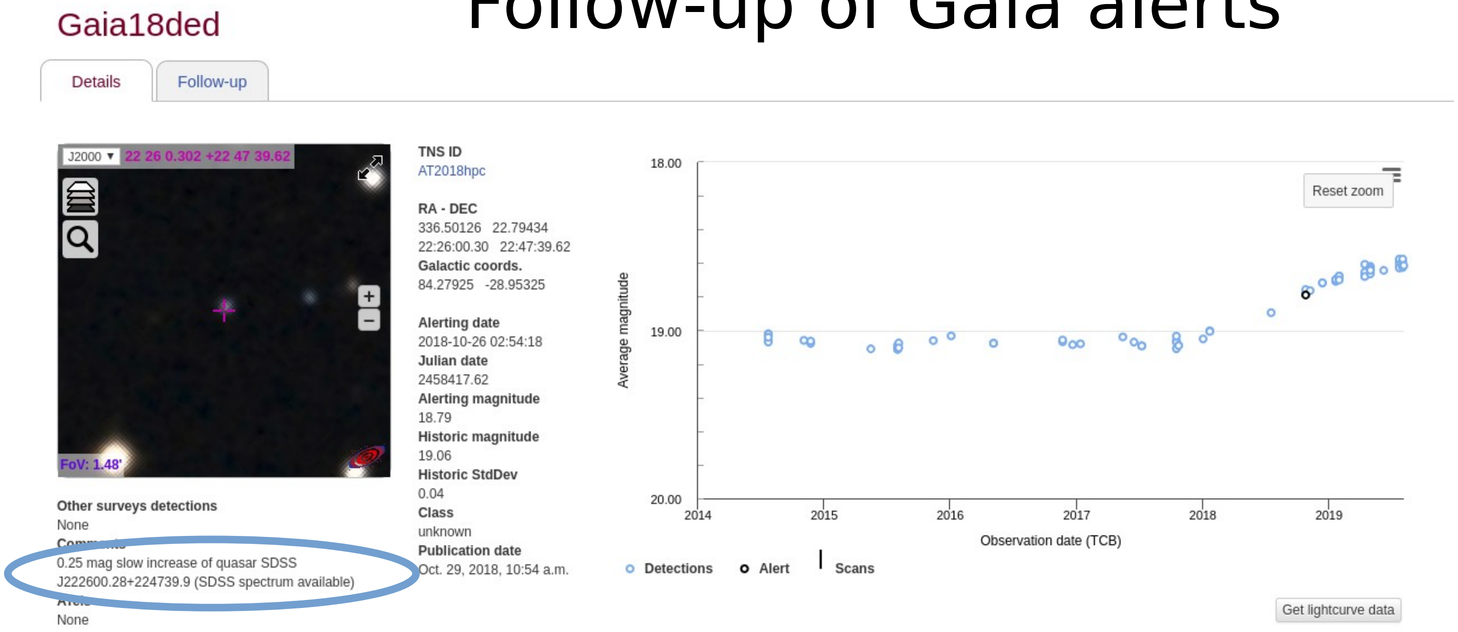
~70 Gaia measurements in 5 years
i.e. 1 measurement every 26 days





https://robopol.org

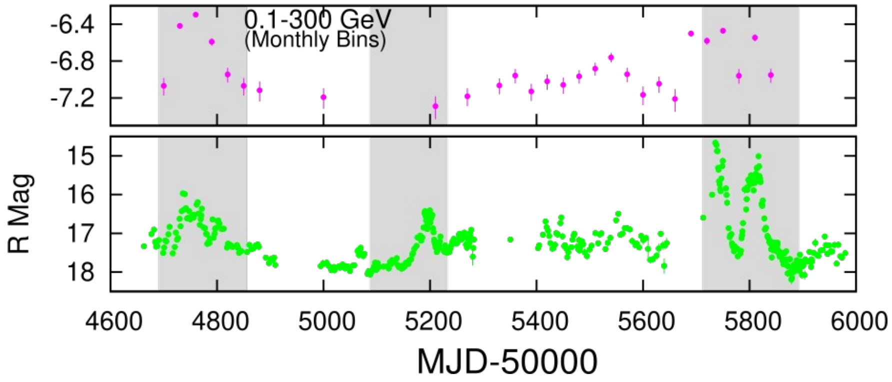
What is next?
Follow-up of Gaia alerts



QSO/BLLac/AGN class alert every 16 days

http://gsaweb.ast.cam.ac.uk/alerts/alertsindex

What can we learn using VLBI-Gaia offsets? Nature of optical orphan flares

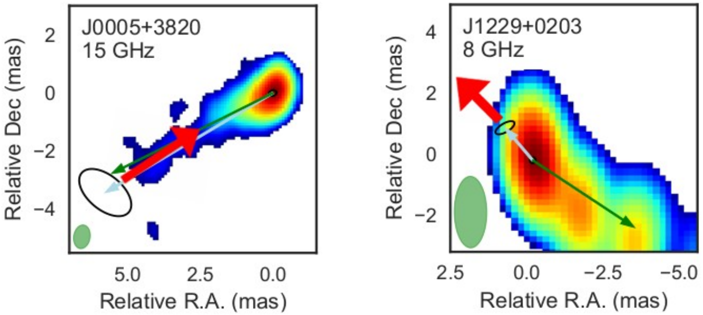


PKS 0208-512

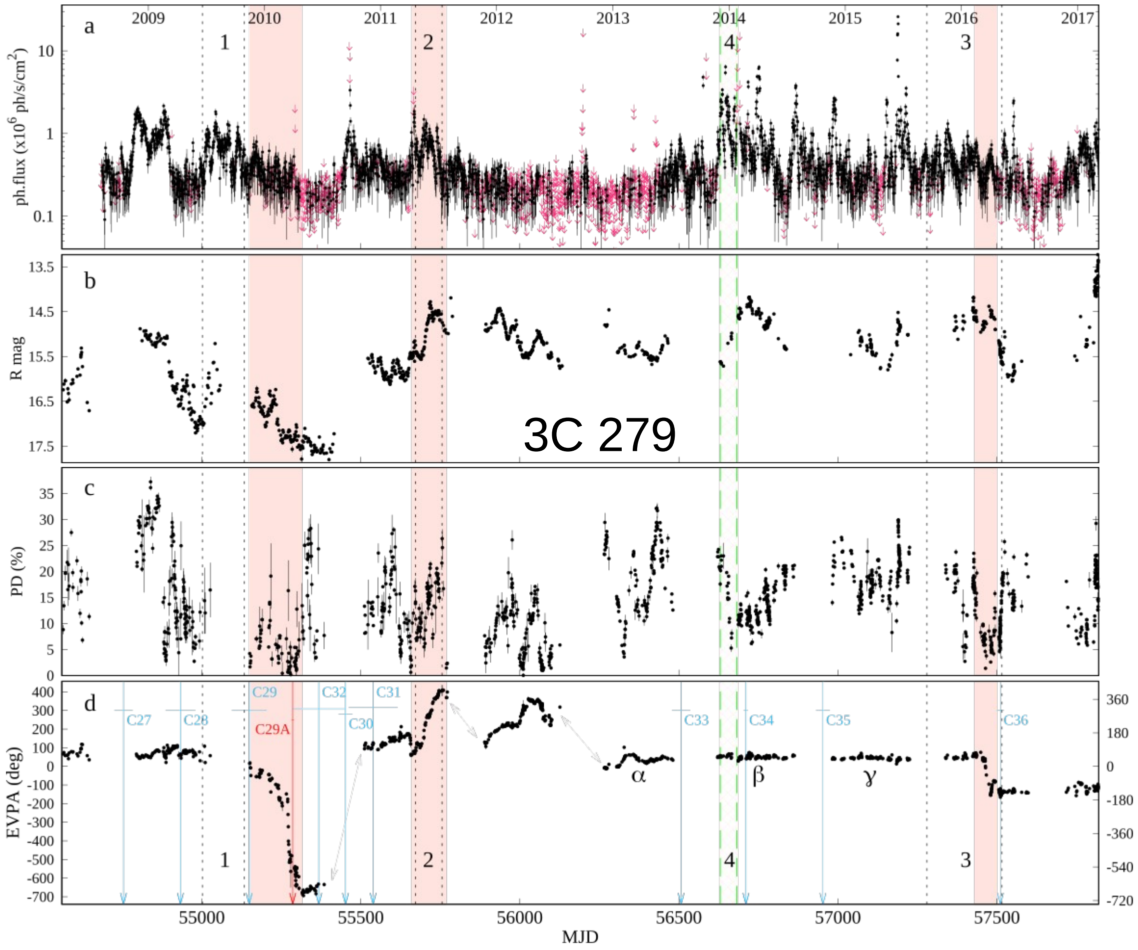
Chatterjee et al. (2013)

Flare in the jet due to change in the magnetic field without changes of the number of emitting particles or δ factor Chatterjee et al. (2013)

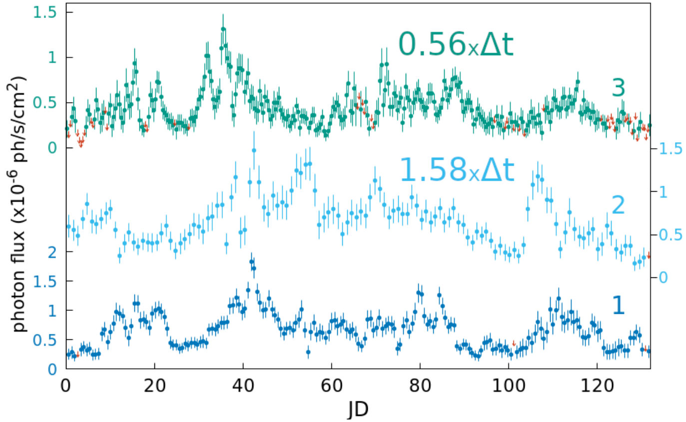
Flare in the accretion disk Ackermann et al. (2014)

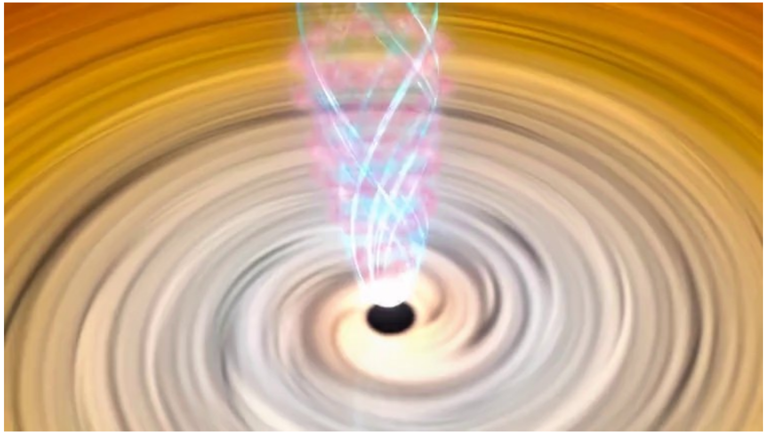


Motion of emission features in the jet



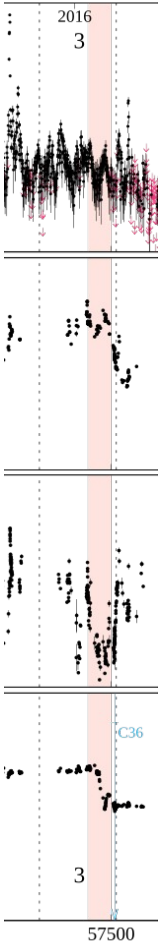
Blinov et al., MNRAS 505, 4616 (2021)

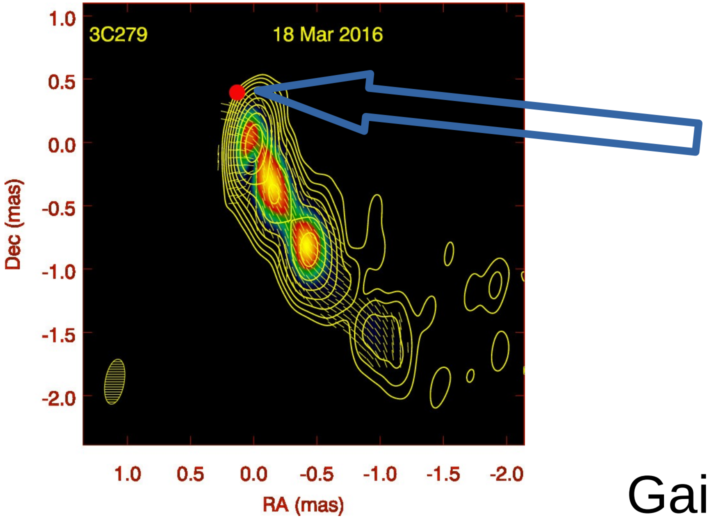




https://www.youtube.com/watch?v=L90Rqf4cxA8

VLBI-Gaia offsets changes related to motion of emission features in the jet

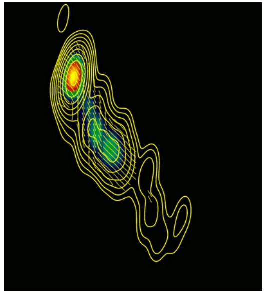


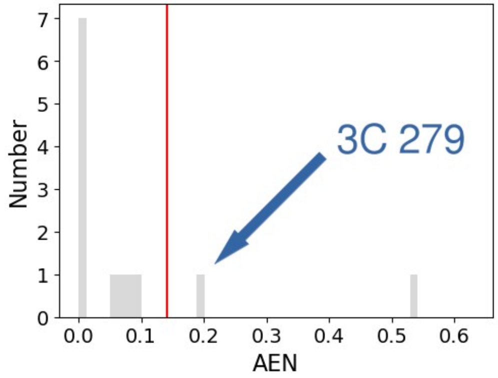


Credit:
http://www.bu.edu/blazars/VLBA_GLAST/3c279.html

C36 knot:
$\mu = 0.807 \pm 0.018$ mas yr^{-1}

Pattern duration:
236 days = 0.65 yr





Accuracy <0.1 mas
(Mignard & Klioner, 2009)
Currently ~0.2mas
Lindegren et al., (2021)

Gaia EDR3

pm = 0.25 ± 0.06 mas yr^{-1}
$PA_{pm} = 40 \pm 14^{o}$

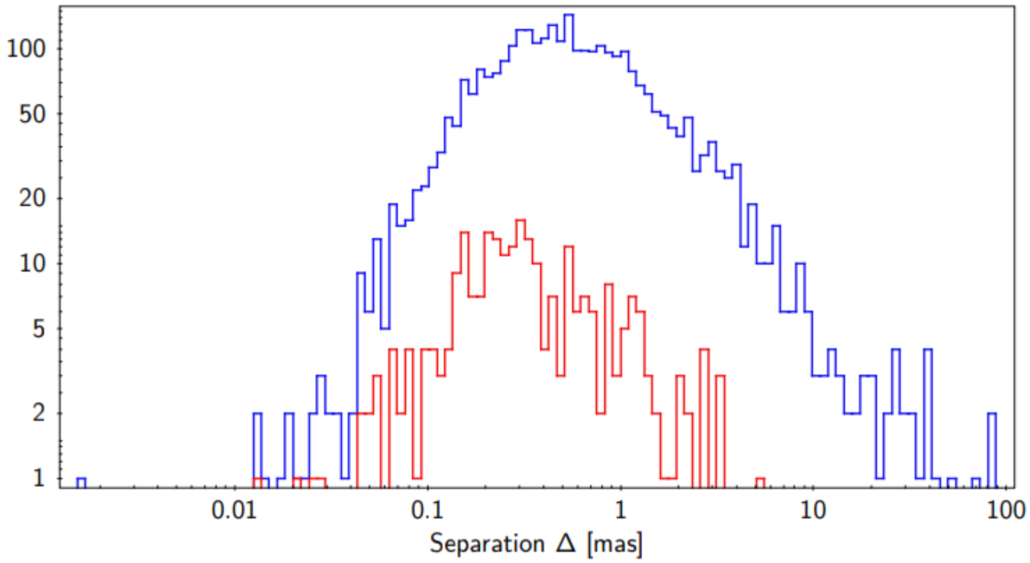
astrometric_excess_noise=0.2 mas

Impact on reference frames

Tied via 3142 AGN

Optical
Gaia-CRF3

Radio
ICRF3



Gaia-CRF3 and ICRF3 S/X for the full set of 3142 common sources (blue; the median is 0.516 mas) and the 259 defining sources (red; the median is 0.292 mas)

A plain match between the two catalogues leaves sources with true differences in position, much larger than the expected random scatter. These differences will not decrease with future versions of the radio and optical frames. Although this does not impact on the quality of either realisation, it could limit the attainable accuracy of their mutual alignment. To circumvent this problem, specific procedures may be required, such as the selection of a common set of reference sources for the alignment. More generally, **the importance of physical deviations between the reference frames at different wavelength bands needs to be better understood**.

Gaia Collaboration 2022 arXiv:2204.12574

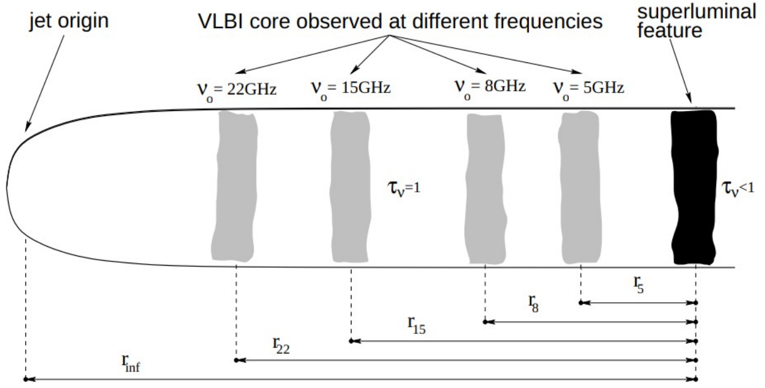
Conclusions

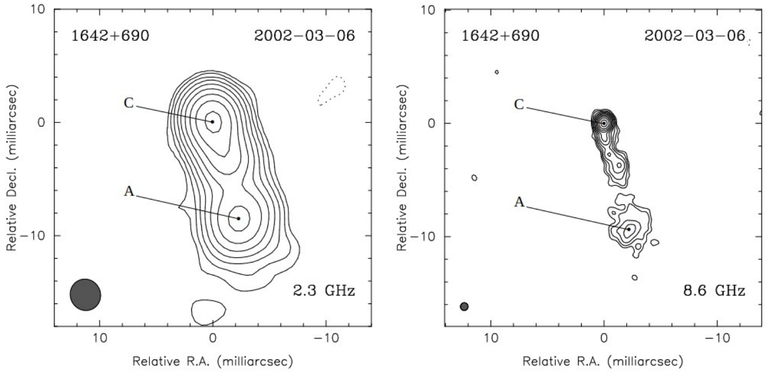
AGN with VLBI-Gaia offsets upstream the jet have significantly lower optical polarization compared to AGN with downsteam offsets

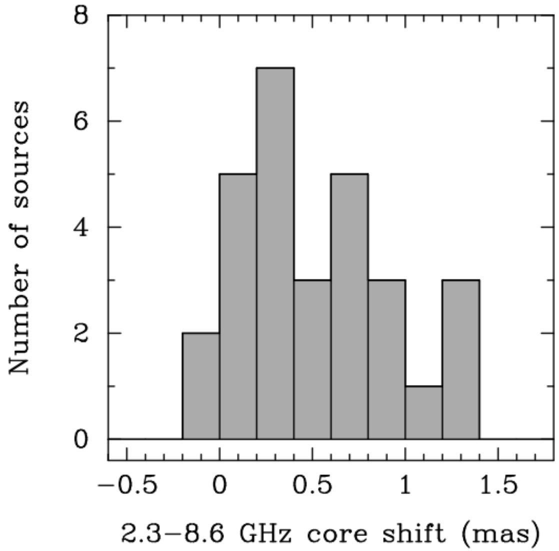
This confirms the physical origin of these positional offsets, which opens an entirely new window for probing AGN physics.

More details (+list of 1059 AGN with significant VLBI-Gaia offsets)
Y. Y. Kovalev, D. I. Zobnina, A. V. Plavin & D. Blinov
Optical polarization properties of AGNs with significant VLBI-Gaia offsets
MNRAS, 493, L54 (2020)

Core-shift effect







$$r_{\rm core} \propto \nu^{-1/k_{\rm r}}$$

An average shift between the radio (4 cm) and optical (6000 Å) bands is estimated to be approximately 0.1 mas,

Kovalev et al. A&A 483, 759 (2008)