SUPER-MASSIVE BINARY BLACK HOLE AND POLARIZATION IN THE BROAD LINES

Đorde Savic, Luka C. Popovic, Frederic Marin

Astronomical observatory of Belgrade
Observatoire astronomique de Strasbourg

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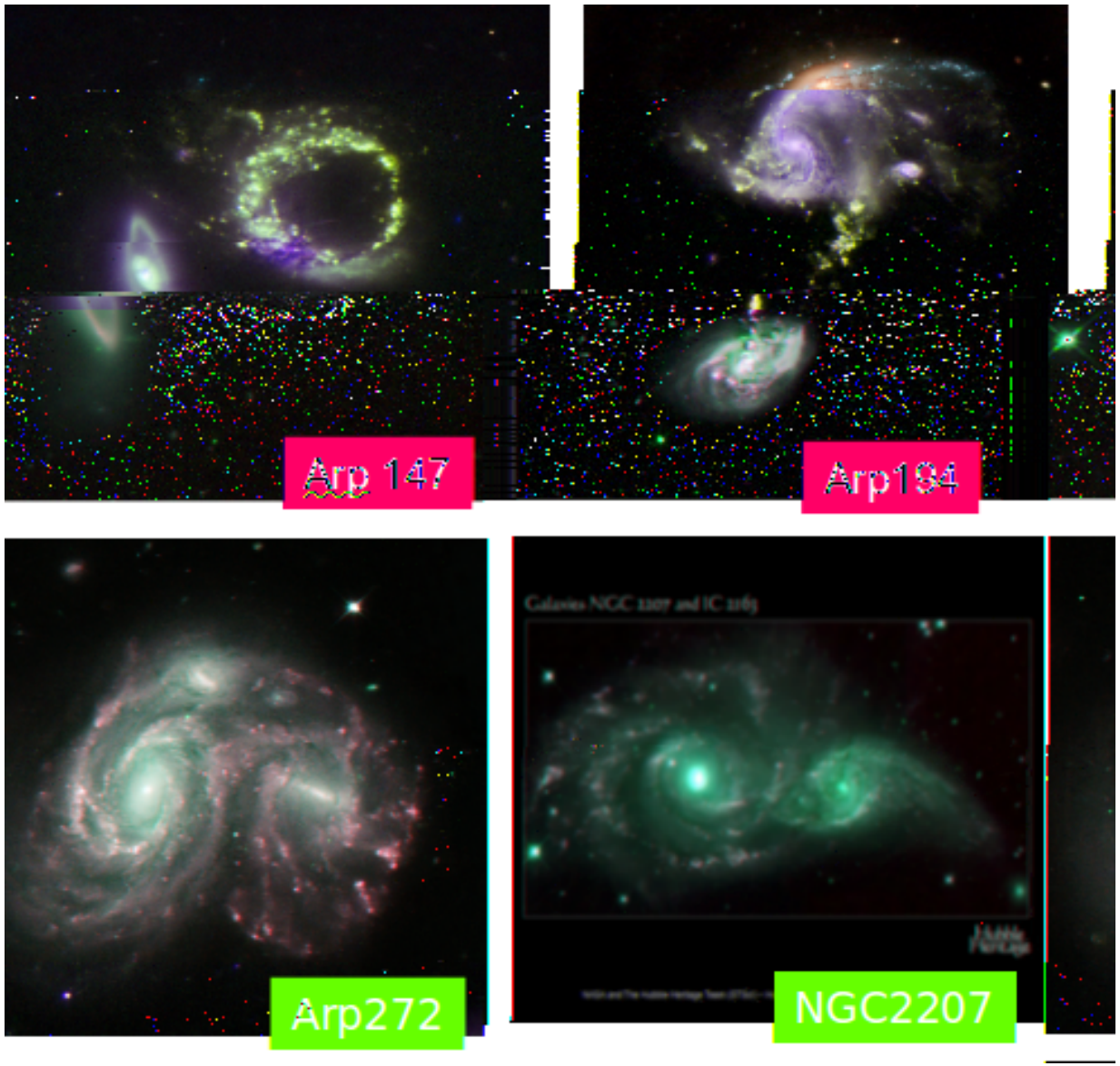
The search for SMBBHs

- Supermassive black holes (SMBH) at the center of massive galaxies
- Mass range 10^6–$10^9\ M_\odot$ (Kormendy & Richstone 1995)
- SMBHs play an important role in the co-evolution of the host galaxy (Kormendy & Ho 2013)
- Growth by accretion – slow process and cannot explain the most massive cases (Mayer et al. 2010)

Galaxy mergers

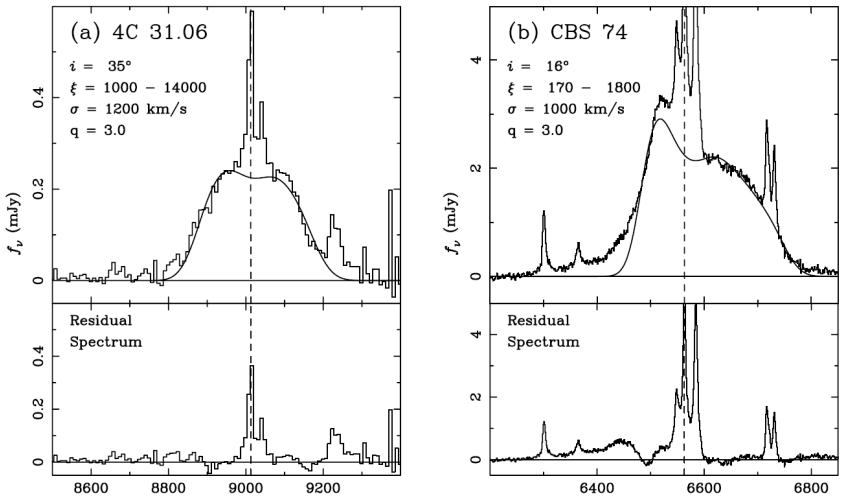


Galaxy mergers

- Evolution of SMBH via mergers with other SMBHs (Volonteri et al. 2003a,b)
- Dynamical friction as a main process for bringing two SMBHs together (Begelman et al. 1980)
- The nal parsec problem once the merging of the galaxies completes (Milosavljevic & Merritt)
- Growth by accretion { slow process and cannot explain the most massive cases (Mayer et al. 2010)
- Emission of gravitational waves

The search for SMBBHs

- It is hard to spatially resolve at pc-scale the central part of the nearest galaxies
- Double-peaked Balmer lines may be associated with binary systems (Eracleous & Halpern 2003)
- Signi cant number of AGNs show broad line pro les that could not be explained by "disk-like\ pro les
- Strong asymmetric broad line peaks
- The broad line pro les and their variability may indicate the SMBBH presence (Popovic 2012)



The search for SMBBHs

- Indications for SMBBH presence in the center of some active galaxies (see e.g. Bon et al. 2012; Li et al. 2016).
- Low probability of nding amongst quasars
- Only two candidates from SDSS catalog (Boroson and Lauer 2009)
- From simulations 5 10 per 10000 sources (Volonteri 2009)

Unified model

Antonucci (1993)

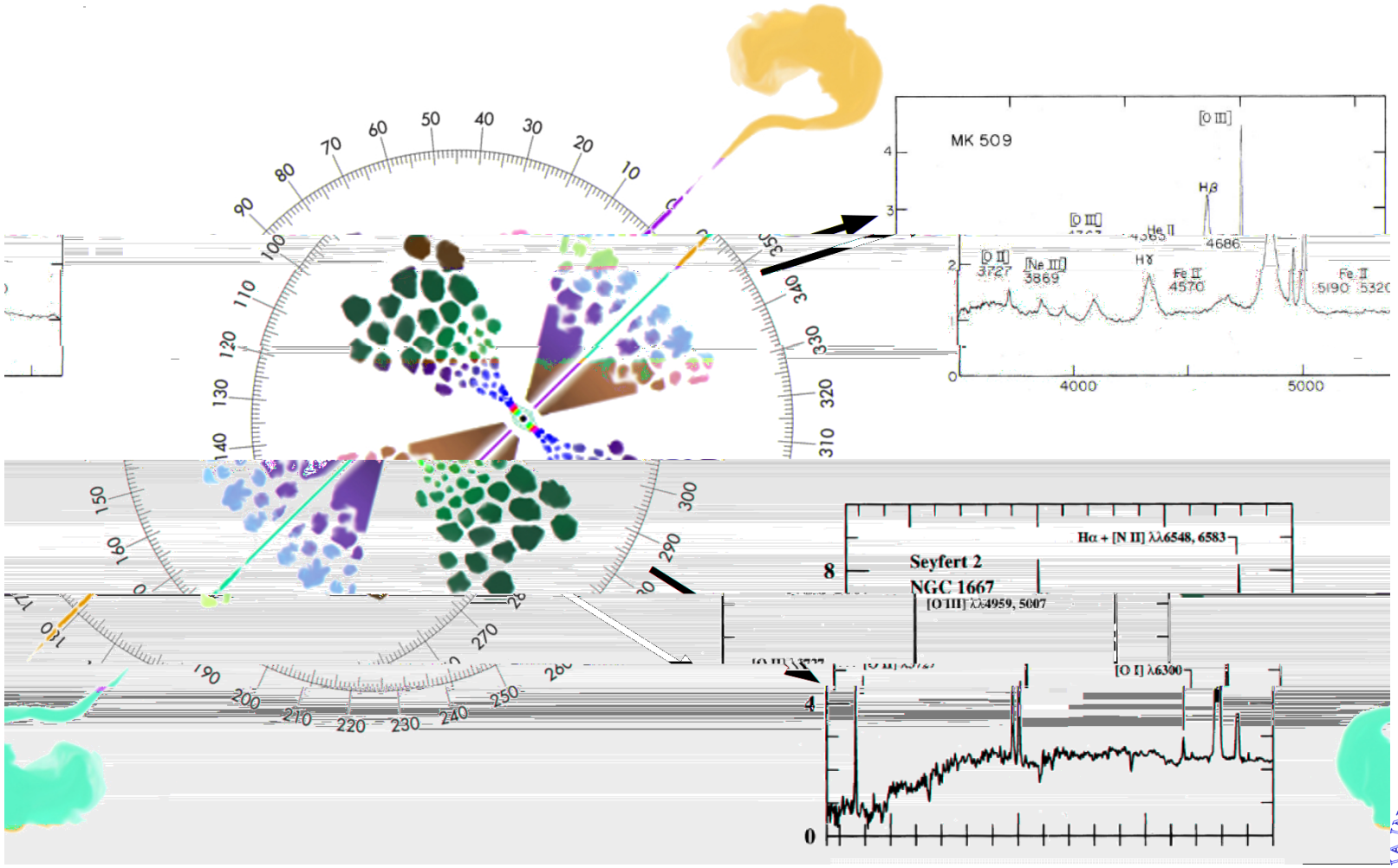
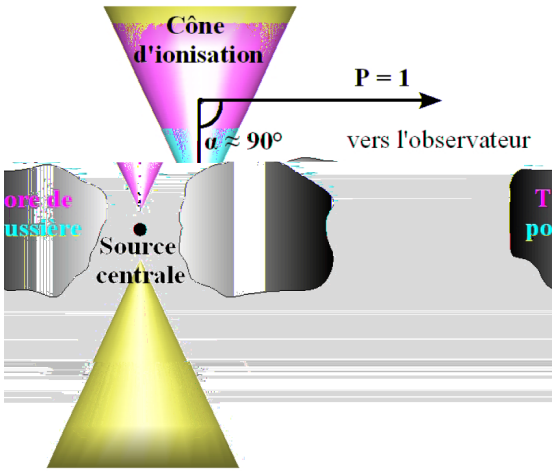
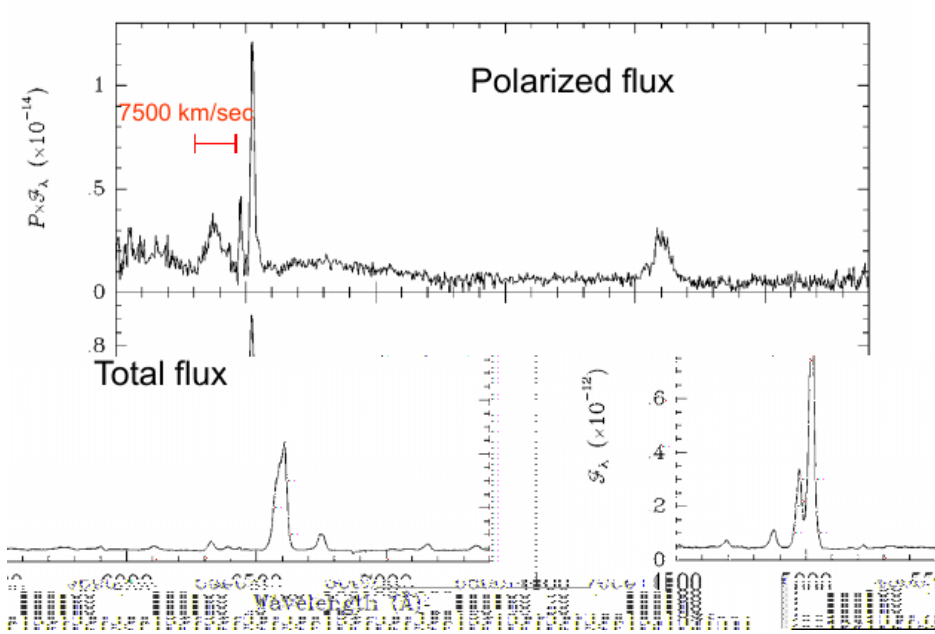


Figure : Marin 2015

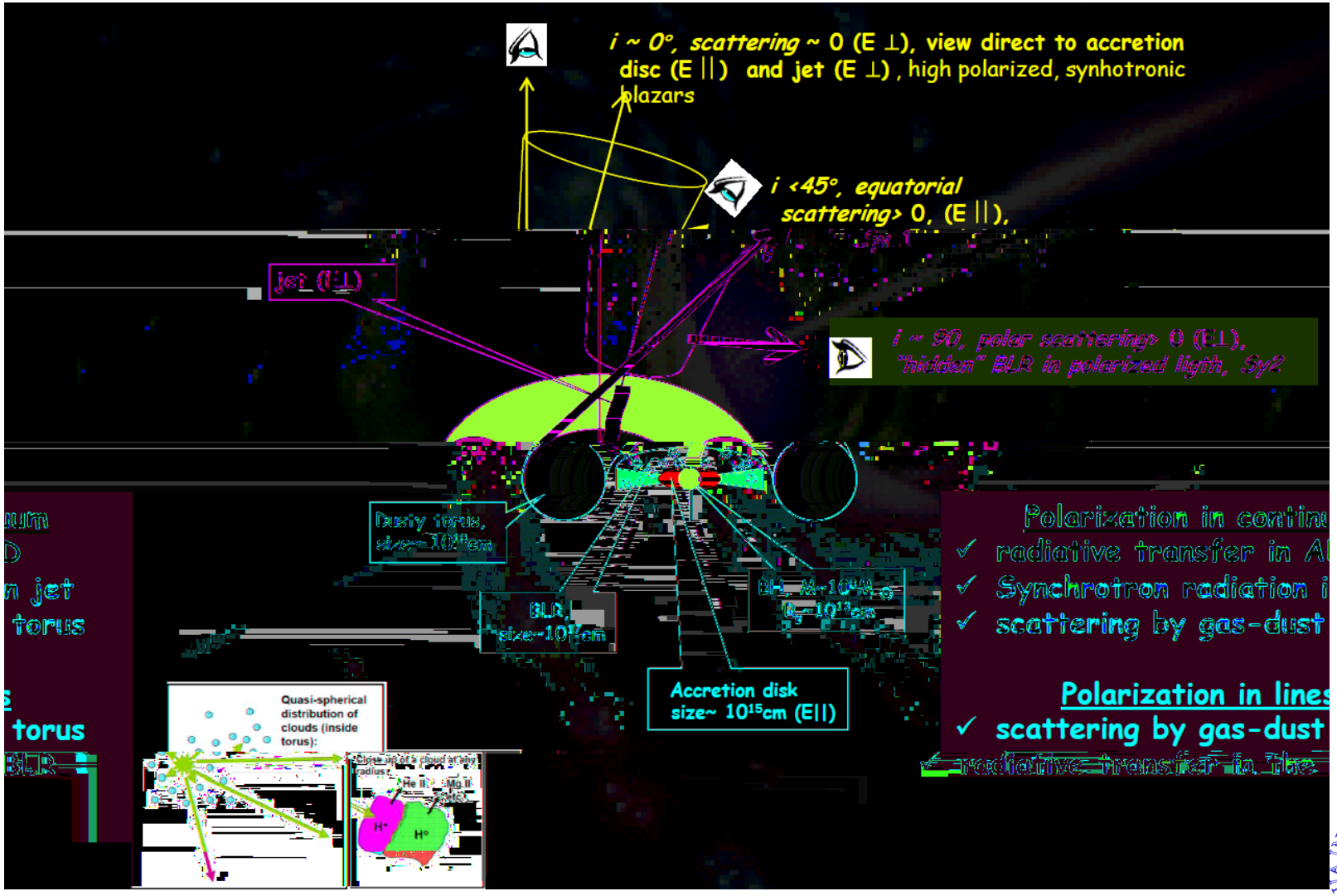
Polarization observations

- A major break-through for the uni ed model for NGC 1068 (Antonucci & Miller 1985).
- A periscope view of AGN in polarized ux





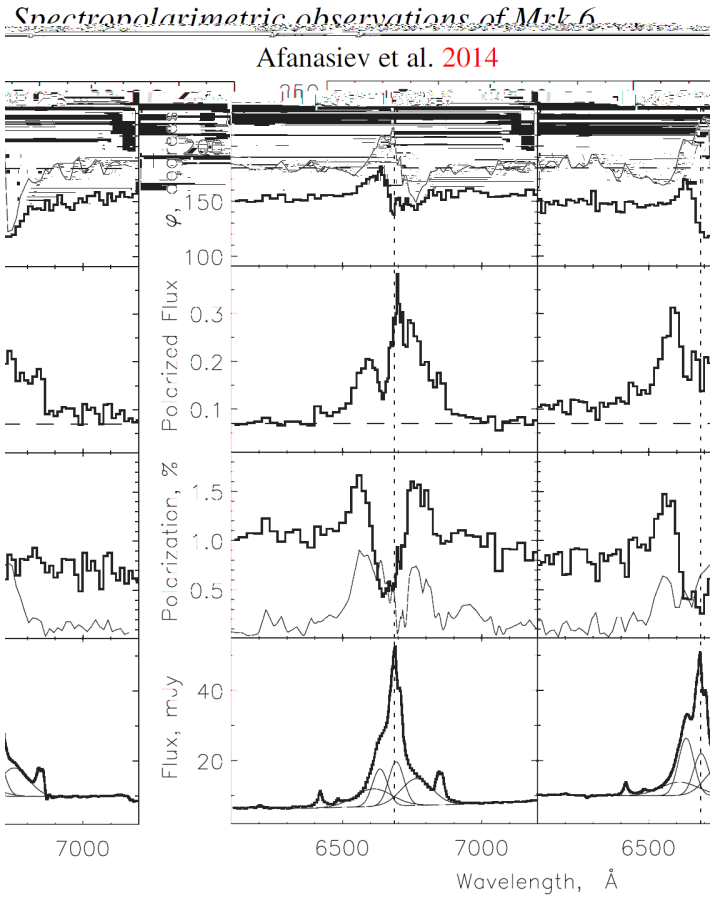
The origin of polarization



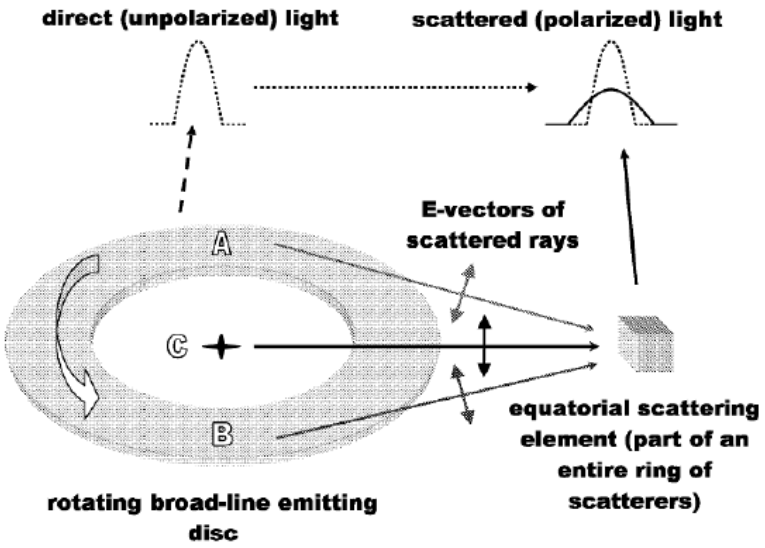
Polarization in Sy 1s

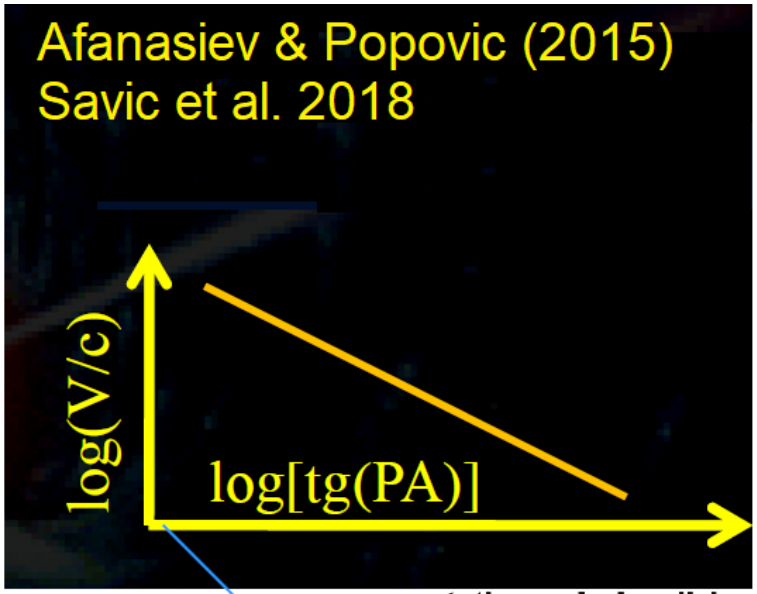
- Polarization position angle (PA) rotation as evidence for equatorial scattering in Sy 1s.
- Weak polarization, typically few percents.

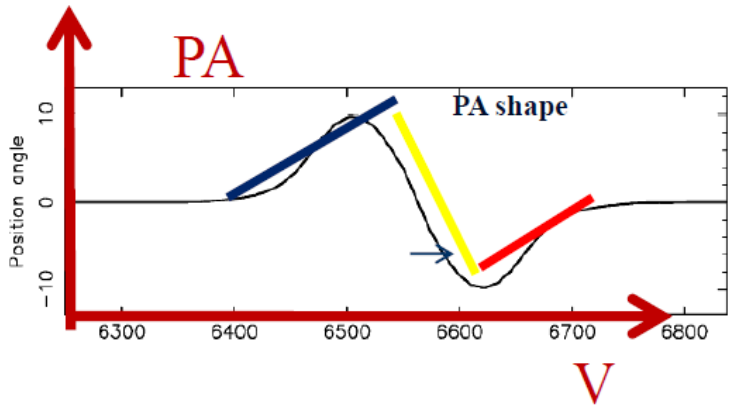
Smith et al. 2002

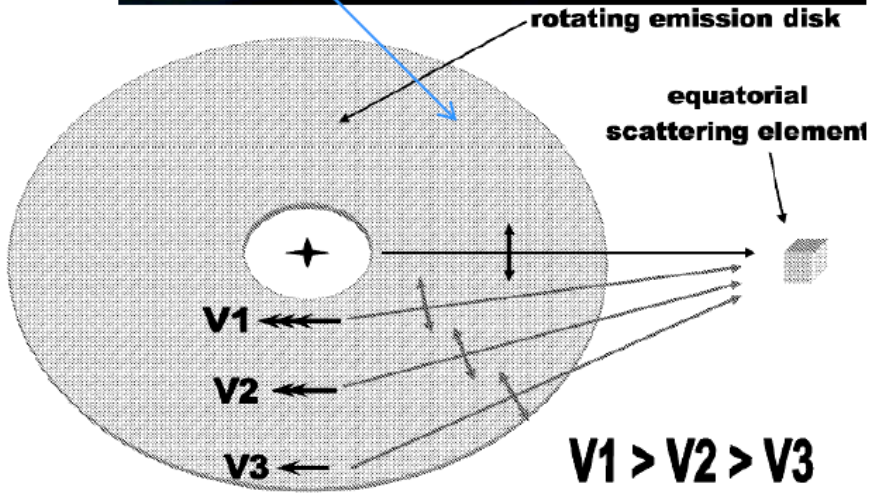


Polarization of broad lines in Sy 1s



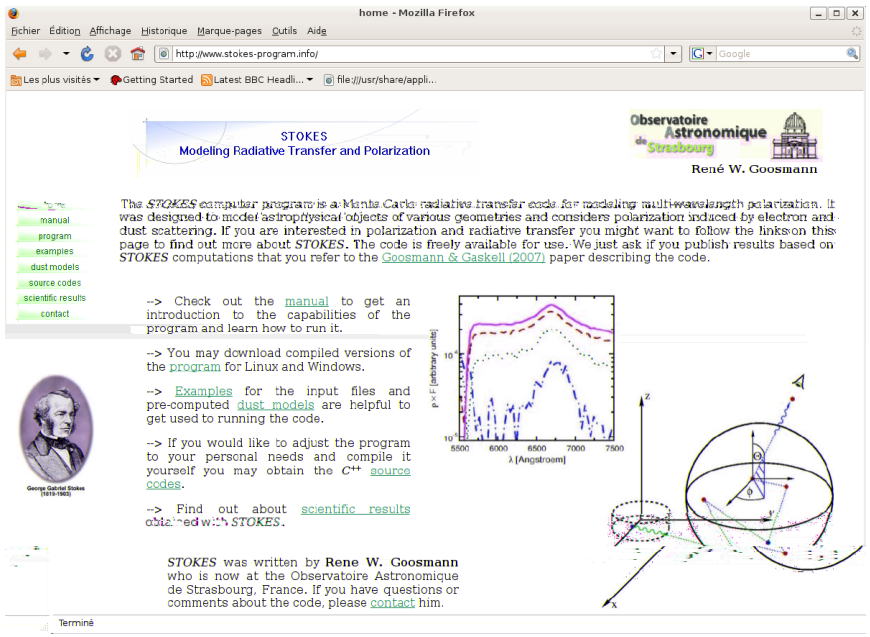






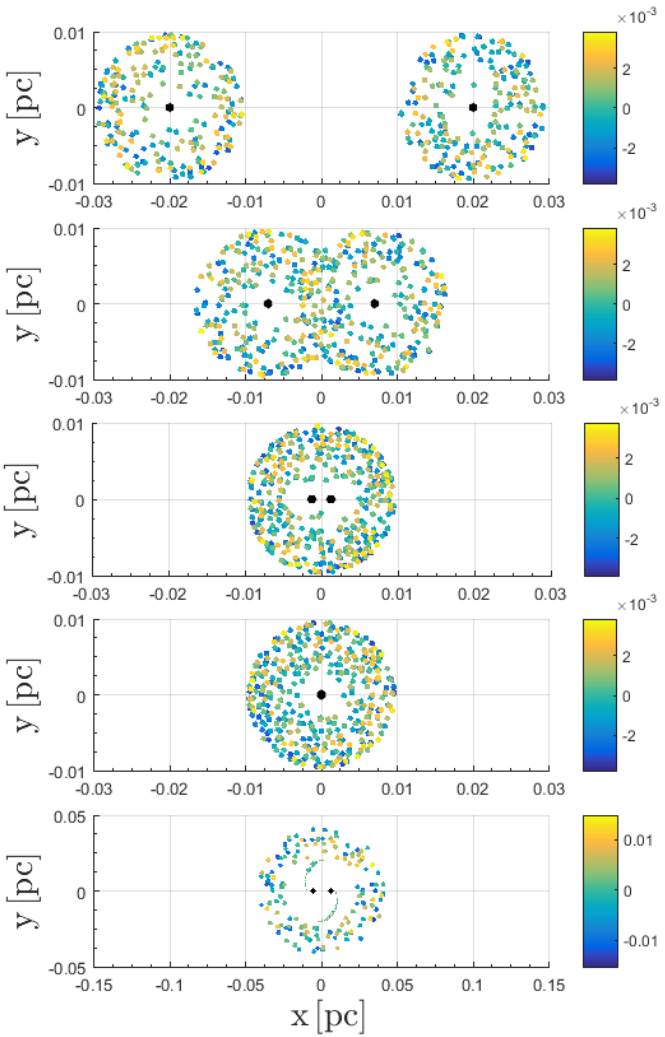
Modeling (scattering-induced) polarization with STOKES

- Full 3D MonteCarlo radiative transfer.
- Various geometries for the emission/scattering regions.
- Polarization due to (multi) electron scattering and dust (Mie) scattering.
- Resonant line scattering included.
- Goosmann & Gaskell (2007); Marin et al. (2012, 2015).



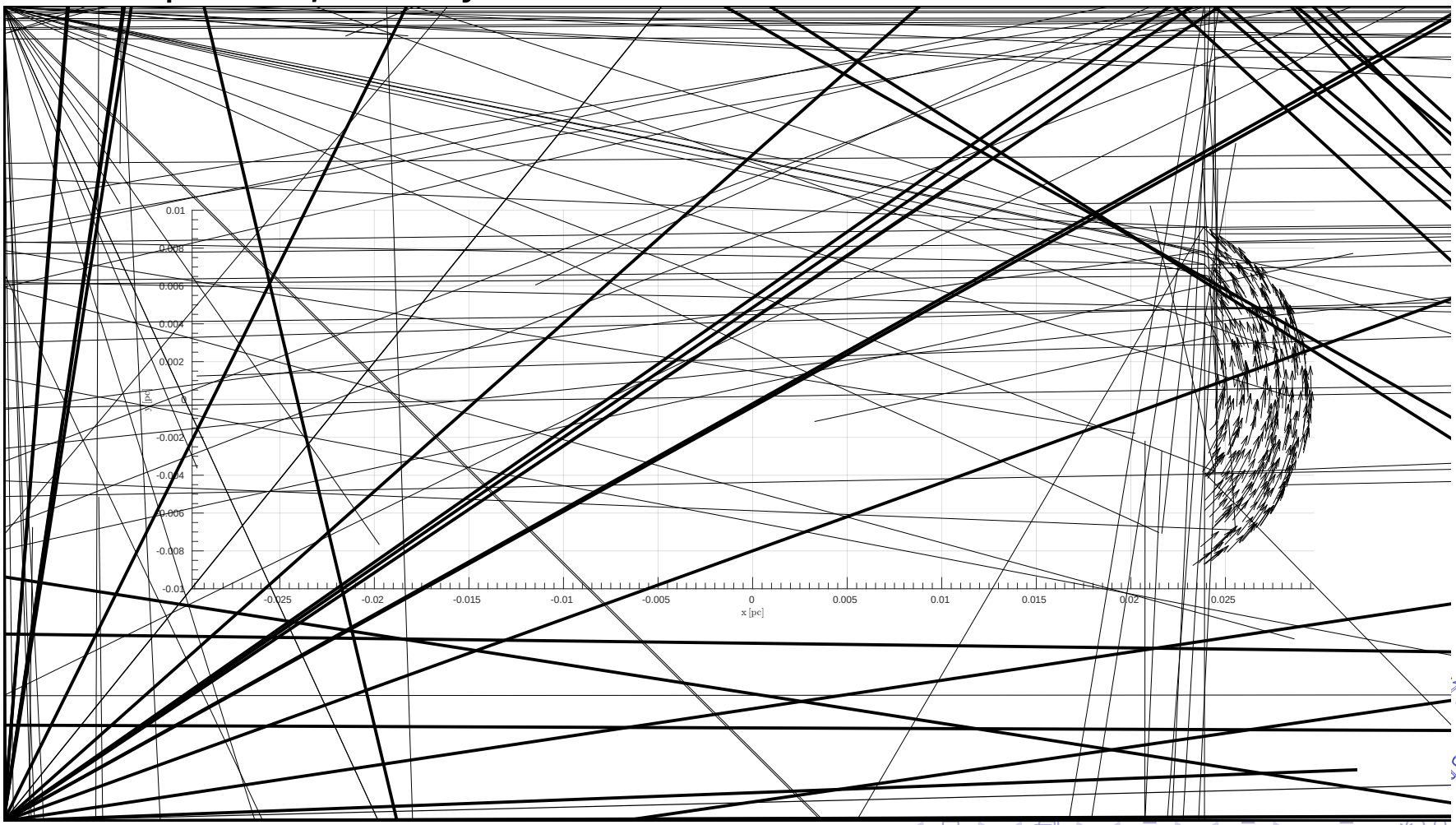
Polarization in Sy 1s

- Two SMBHs with mass 5 $10^7 M_\odot$
- Two point-like source of isotropic continuum radiation, $F_\nu \ / \ \nu^{-2}$.
- Clumpy BLR, lling factor $f = 0.25$
- Four di erent cases of BLR con guration.
- Half opening angle of the BLR is 20°



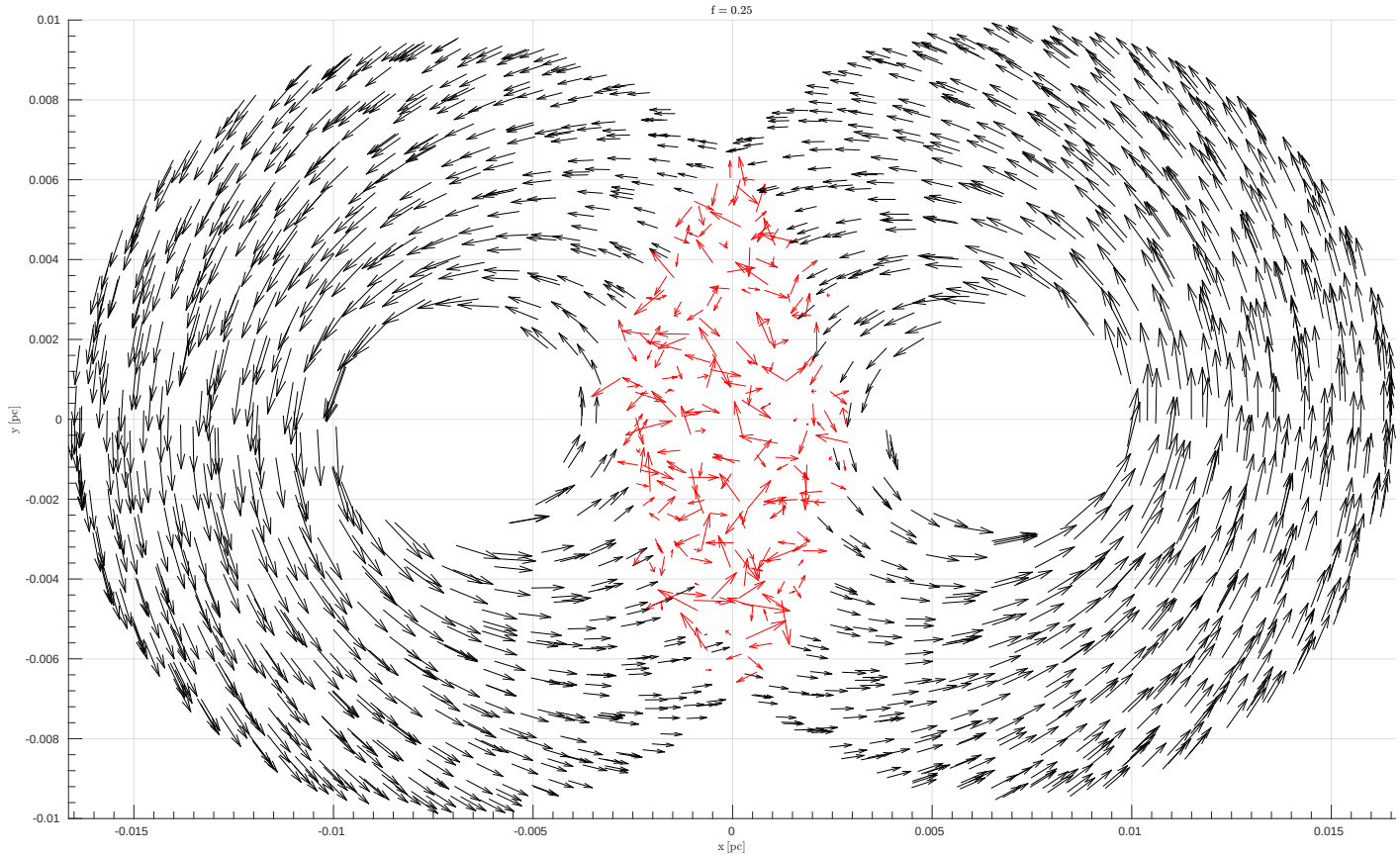
Distant BLR

- Orbital separation $a = 47.6\,\mathrm{ld}$
- Orbital period $p = 75\,\mathrm{years}$



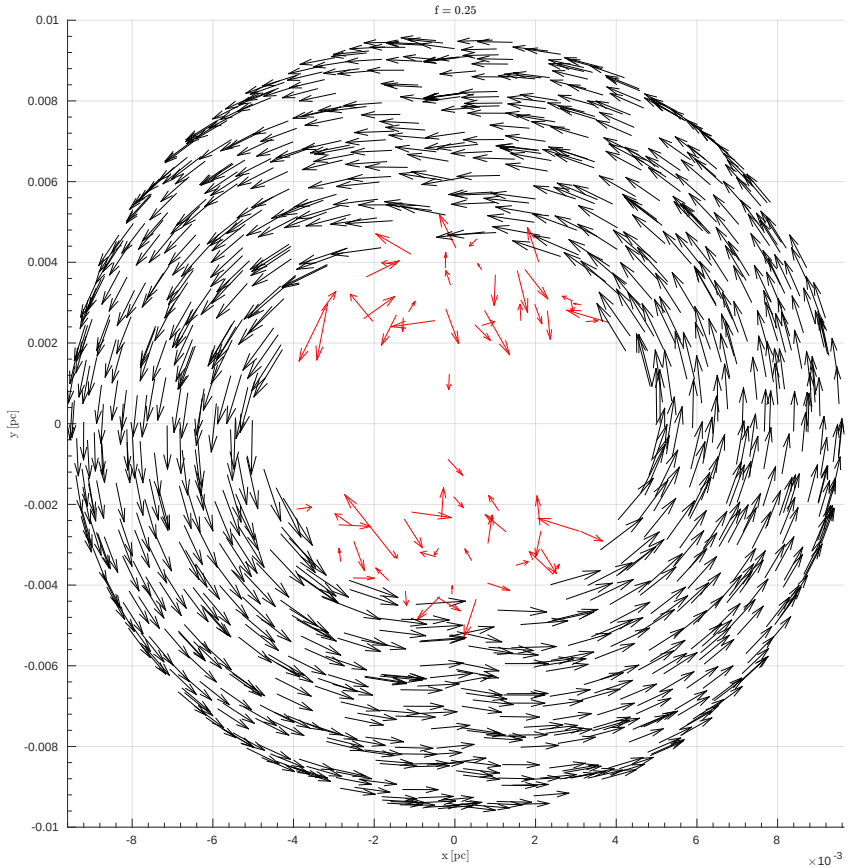
Contact BLR

- Orbital separation $a = 16.7\,\mathrm{ld}$
- Orbital period $p = 15.5\,\mathrm{years}$



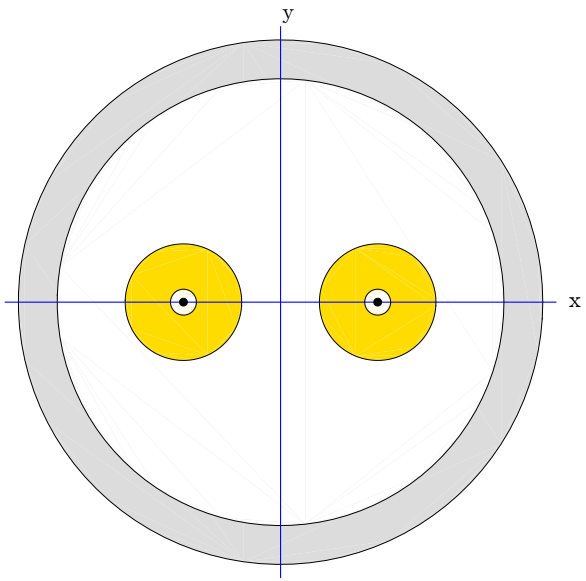
Mixed BLR

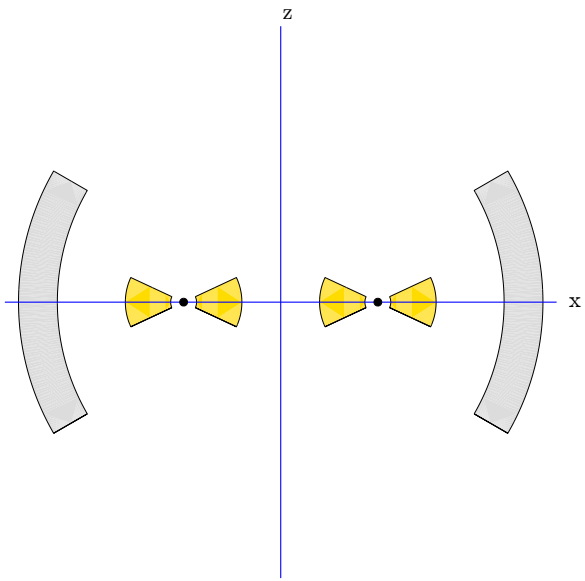
- Orbital separation $a = 2.97\,\mathrm{ld}$
- Orbital period $p = 1.17\,\mathrm{years}$



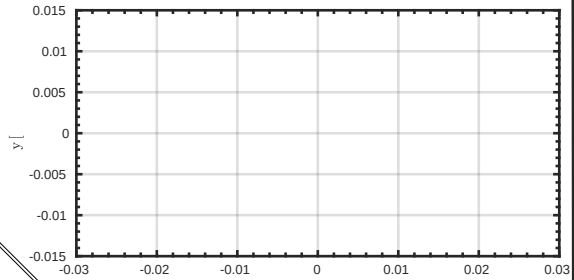
Scattering region

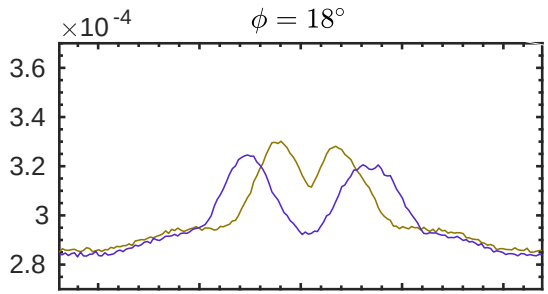
- From 0.1 { 0.5 pc
- Half opening angle 30°
- Radial optical depth is 3
- Thomson scattering





Results: Distant BLRs





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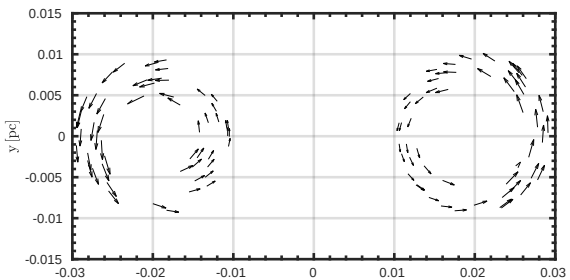

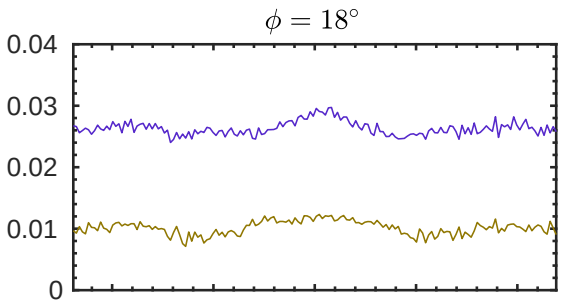

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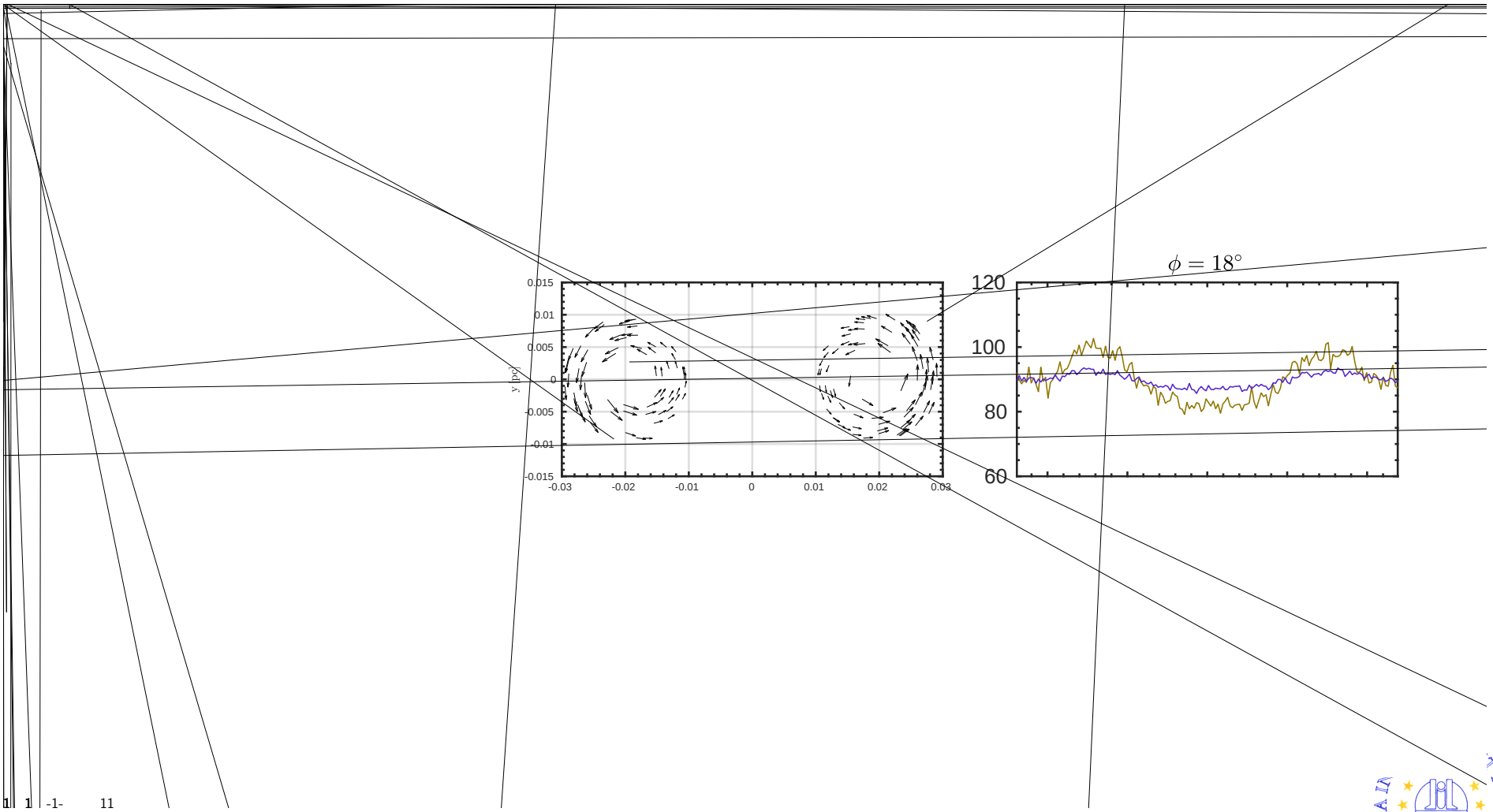
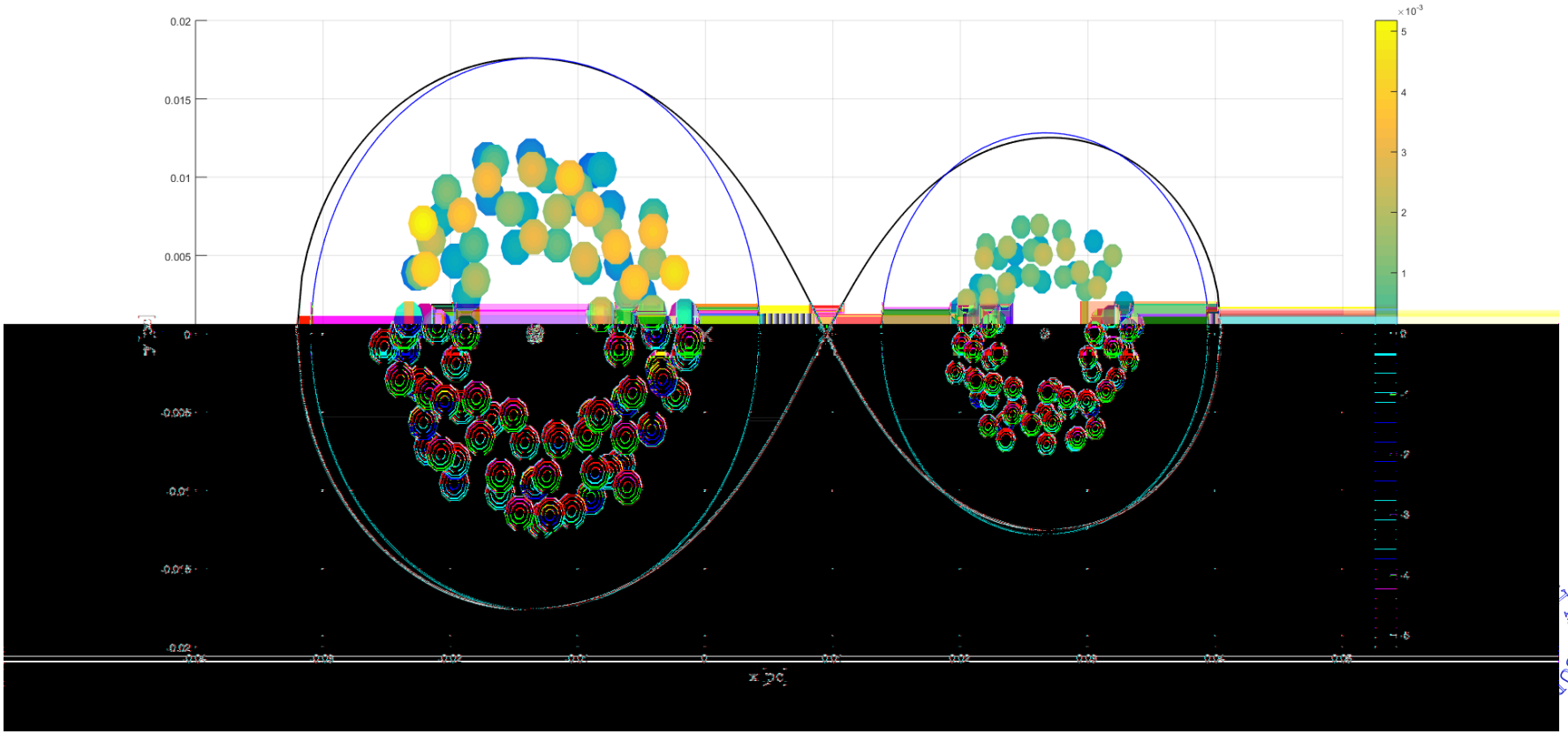


Distant BLR

- Orbital separation $a = 47.6\,\mathrm{ld}$
- Orbital period $p = 75\,\mathrm{years}$
- Mass ratio $q = 0.5$



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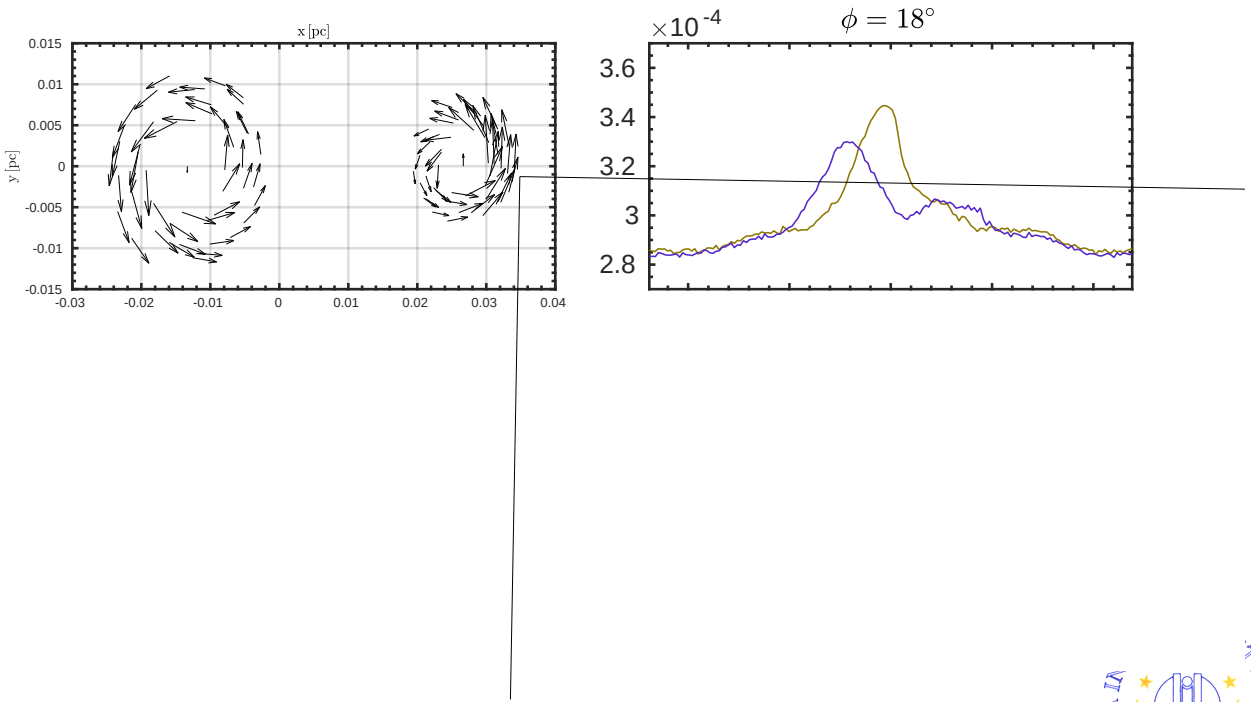

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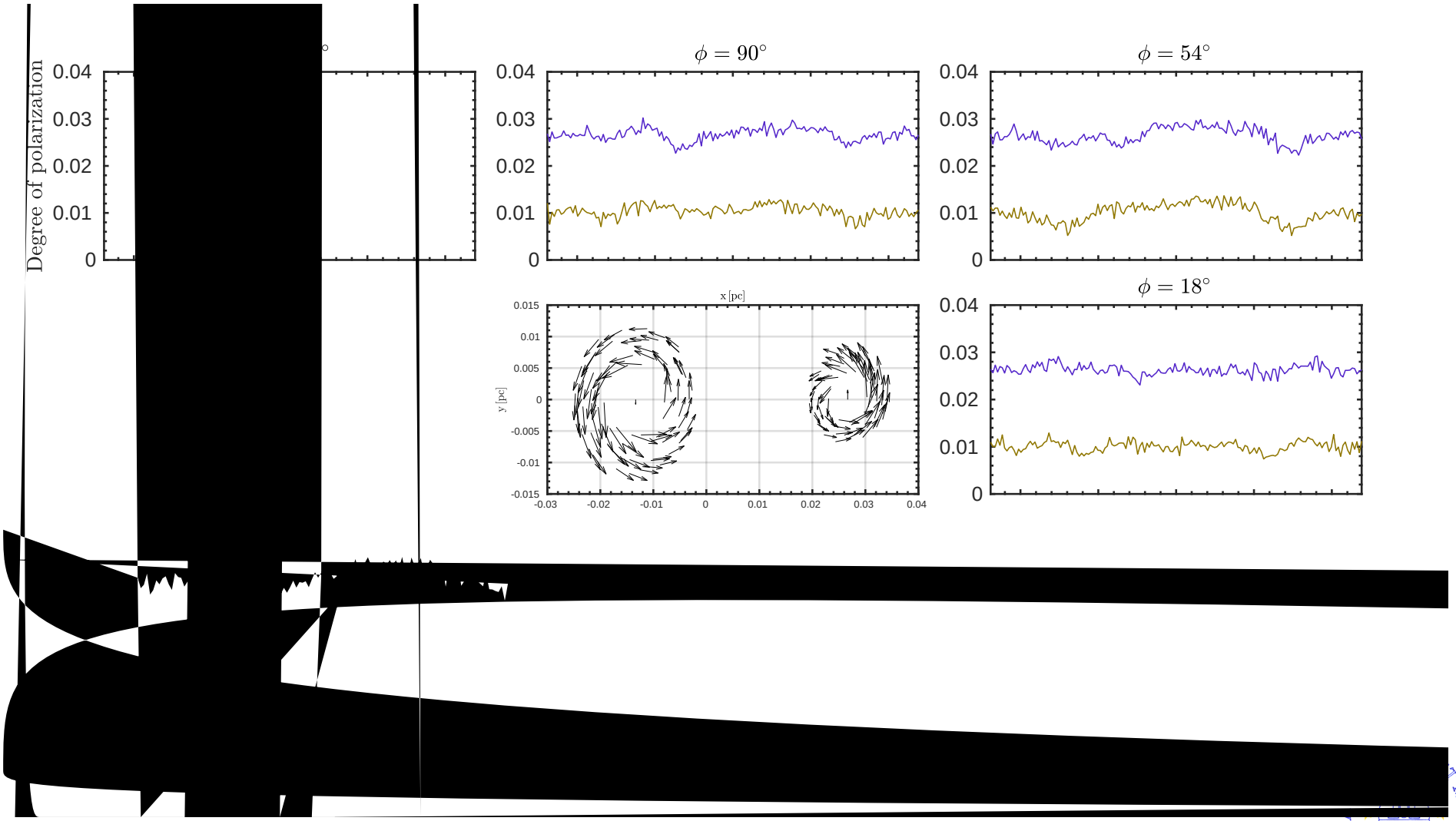

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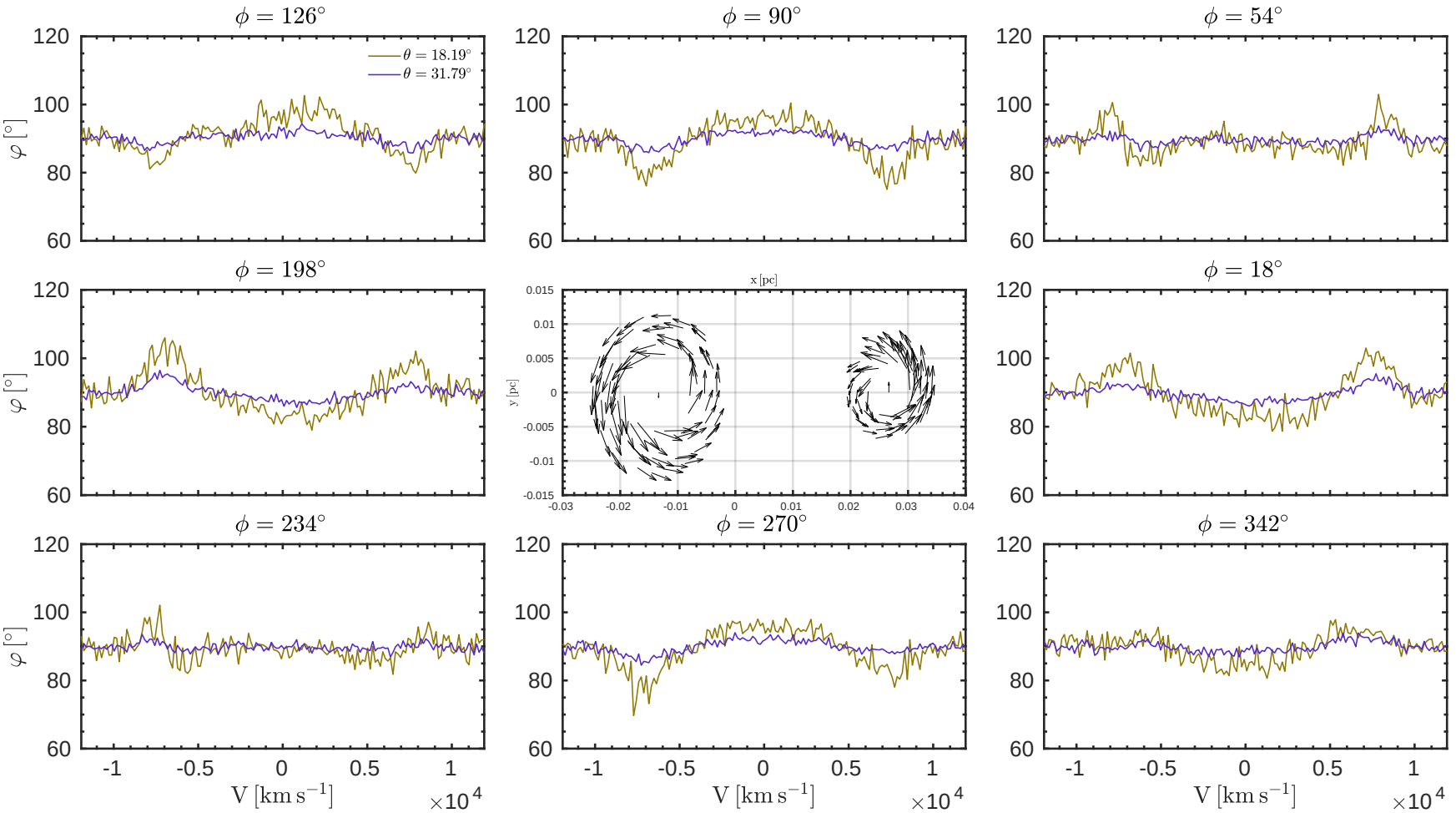

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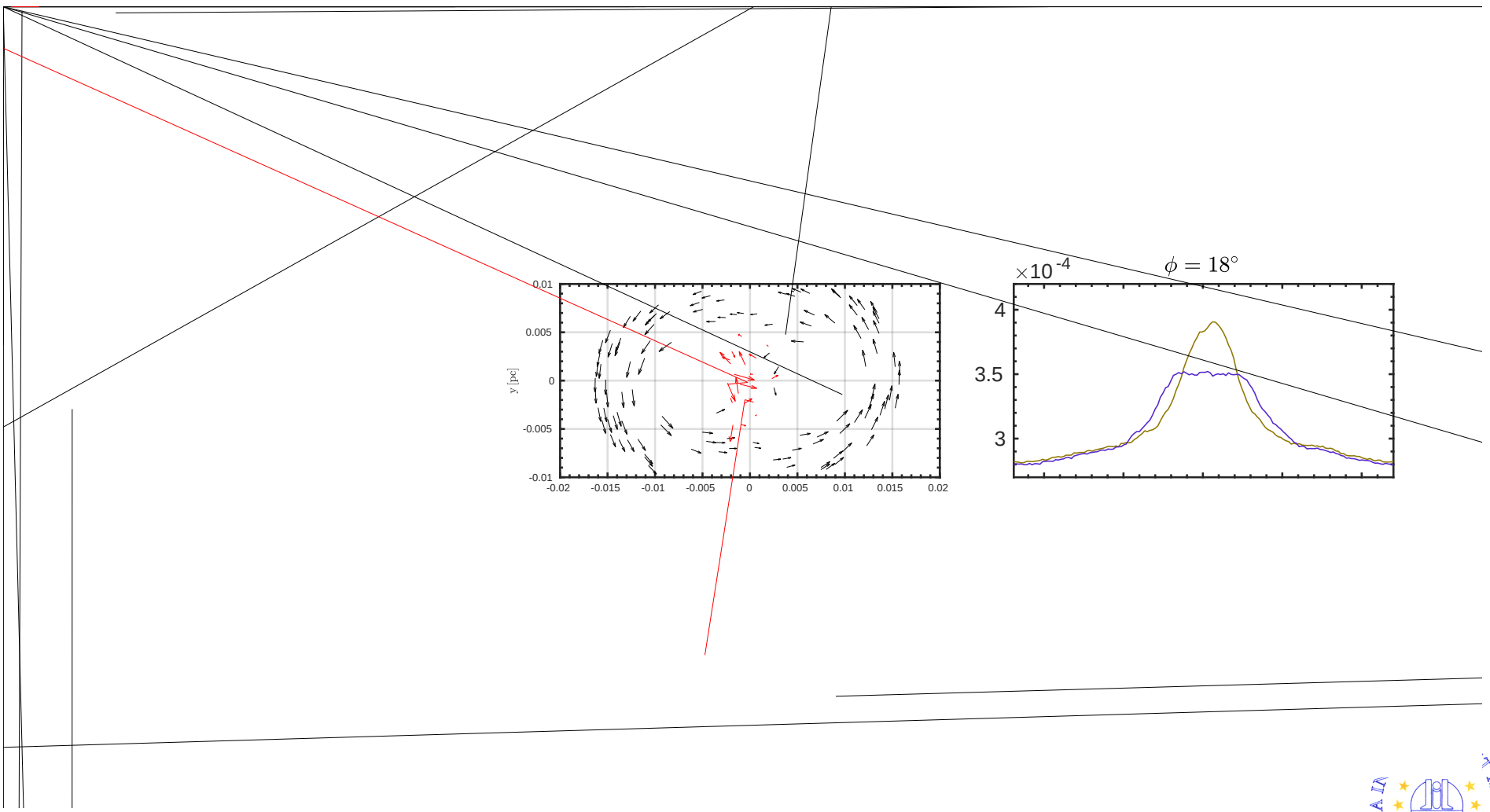

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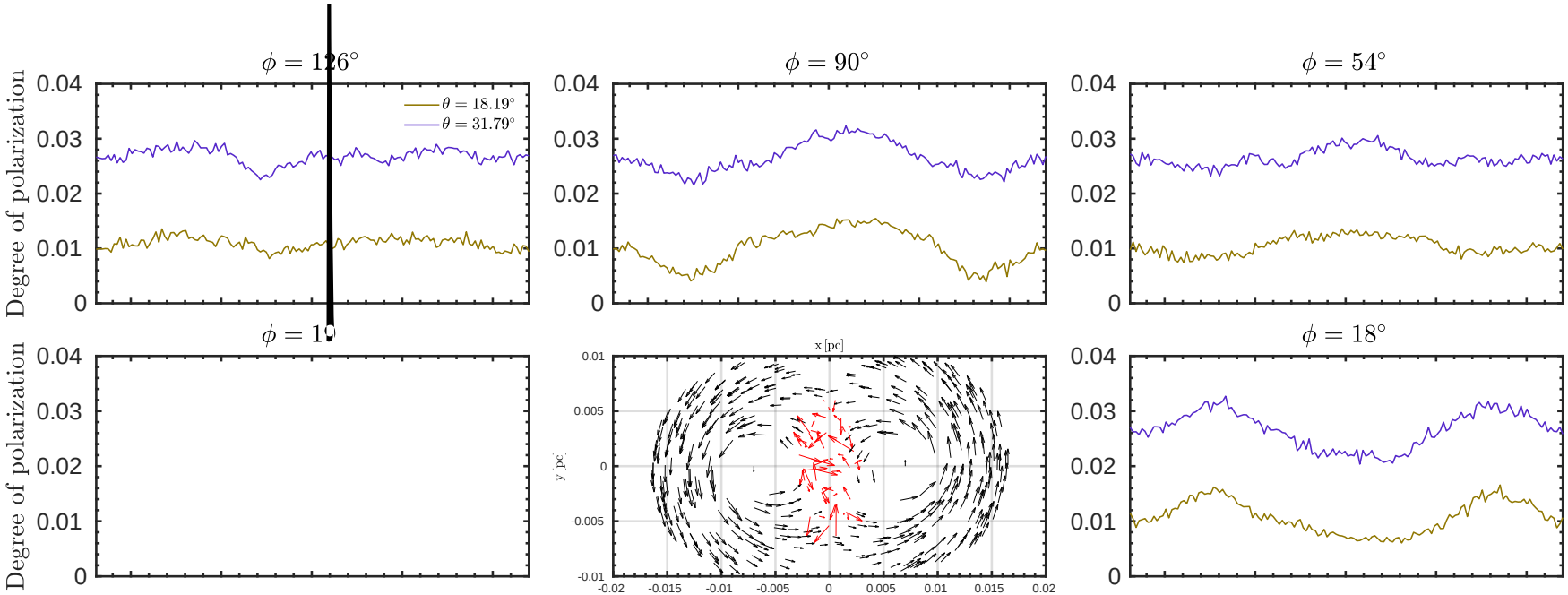

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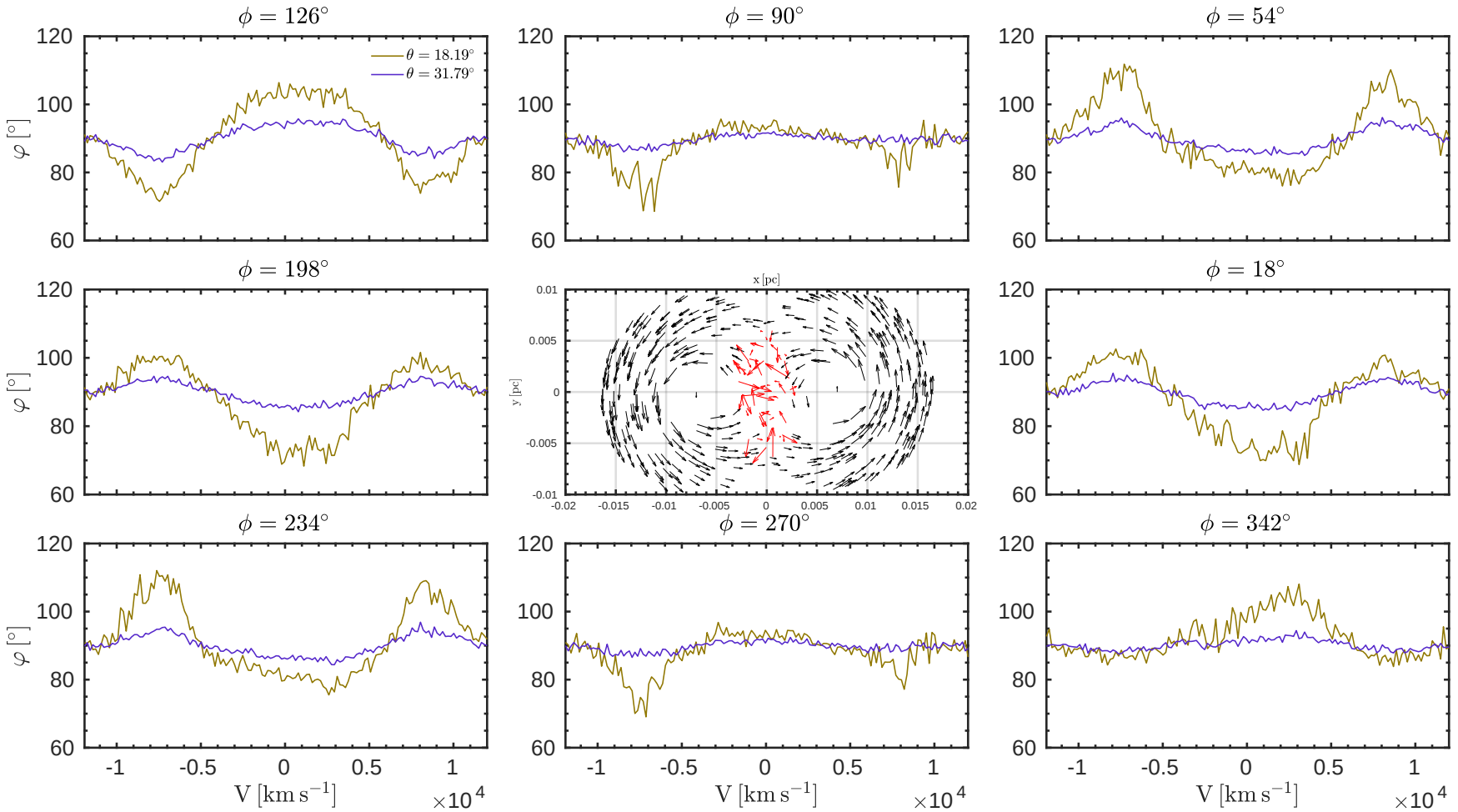

Results: Mixed BLRs

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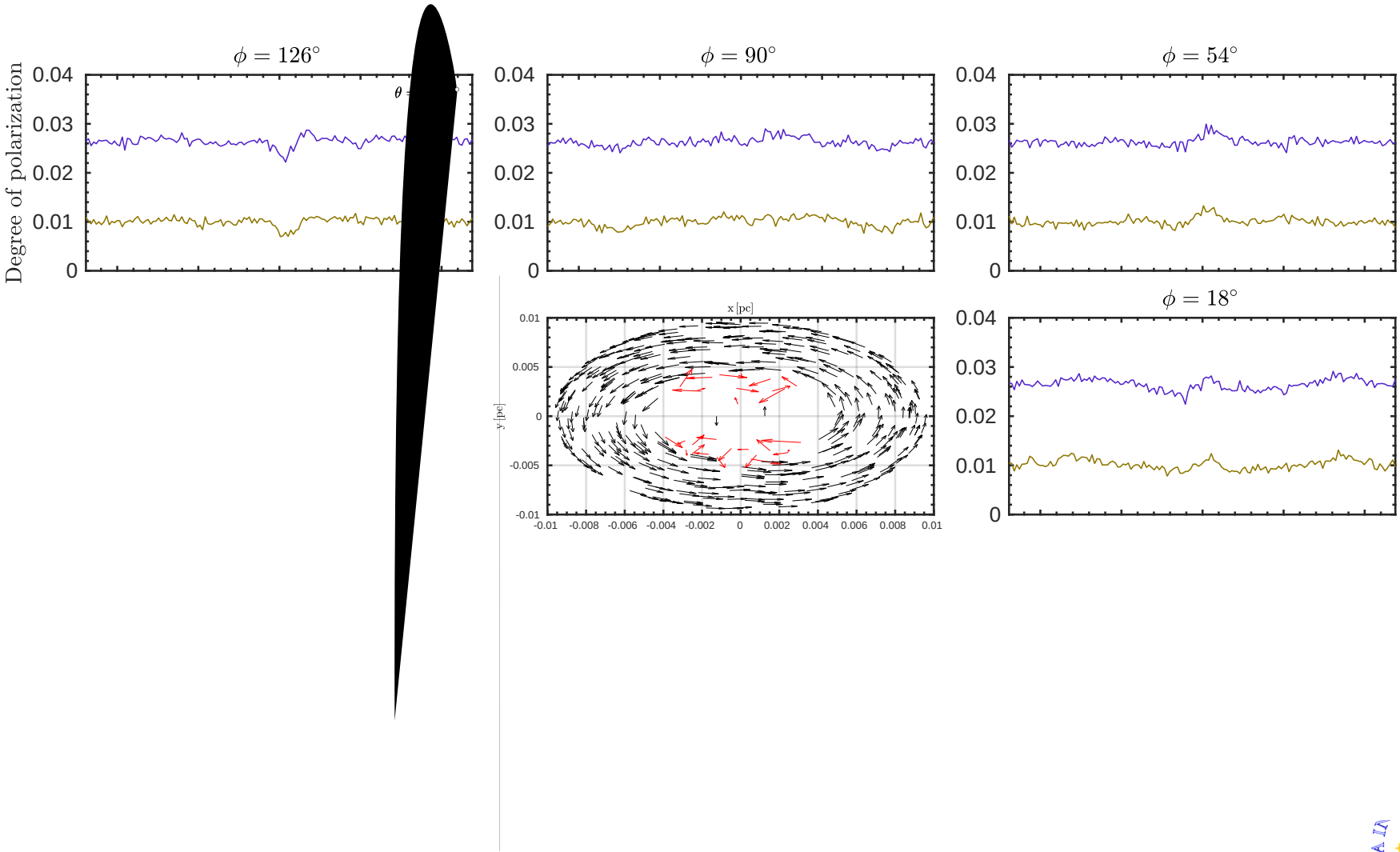

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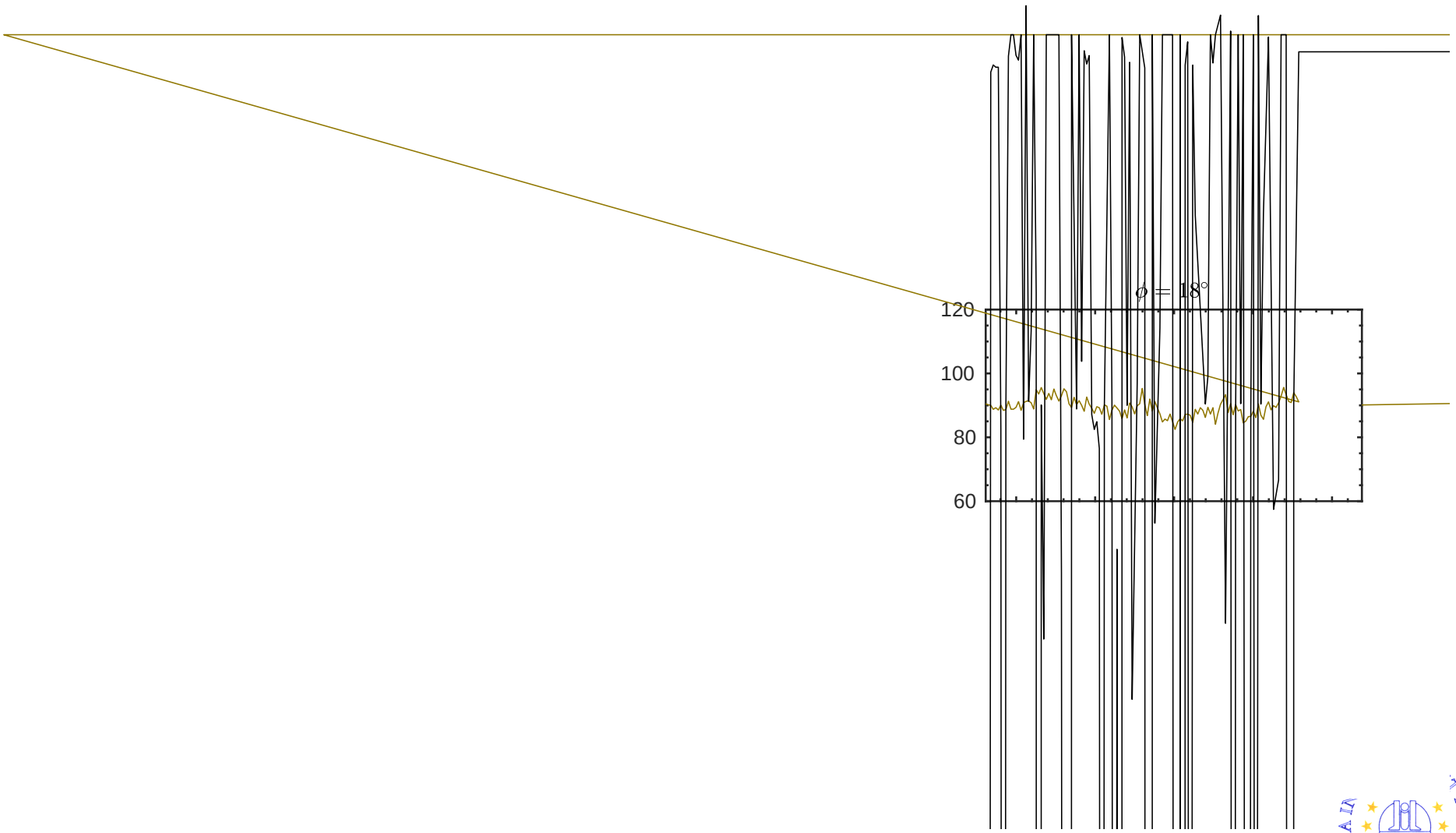
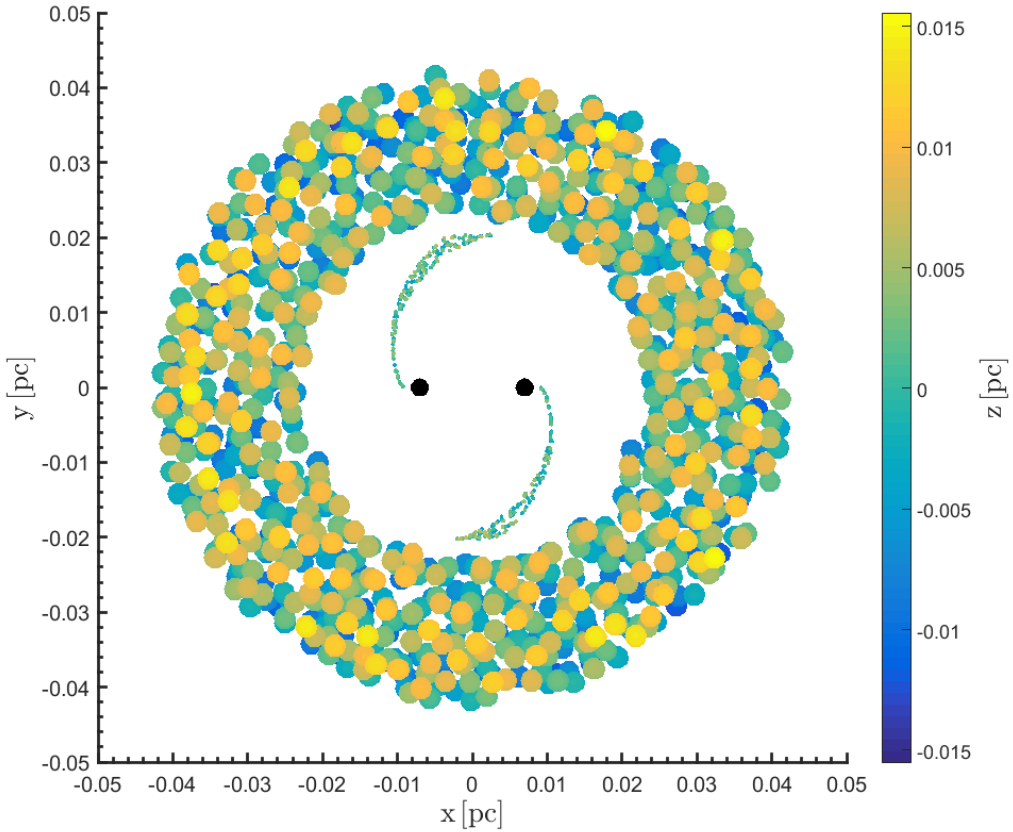
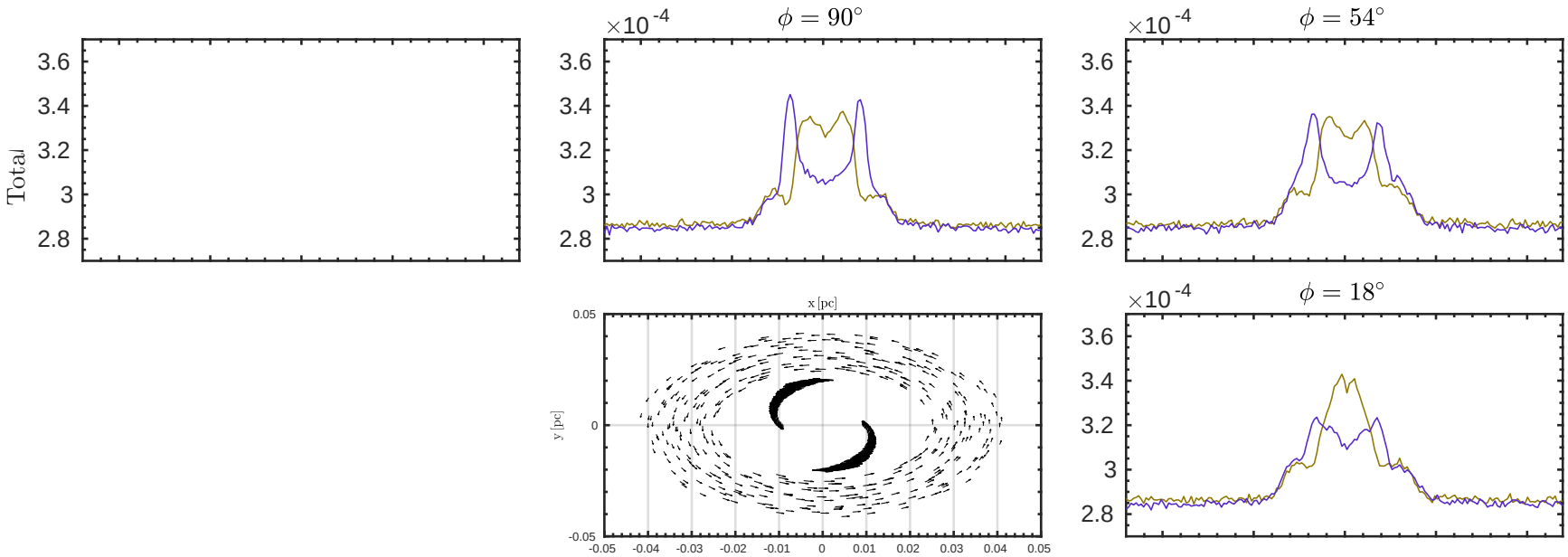


Spiral BLR

- Orbital separation $a = 16.7\,\mathrm{ld}$
- Orbital period $p = 15.5\,\mathrm{years}$
- Model similar as the one by Smailagic & Bon (2015)



Results: Spiral BLRs



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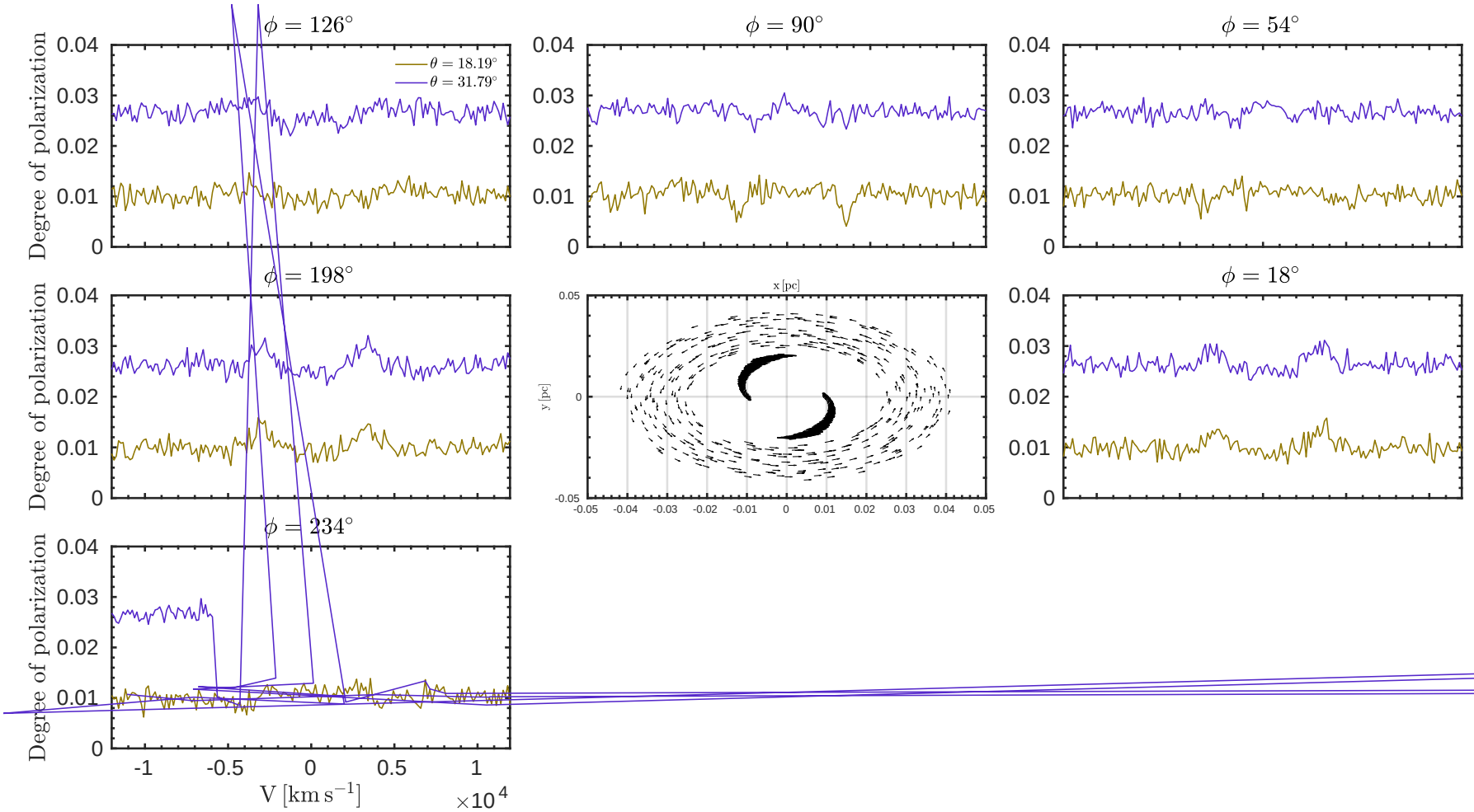

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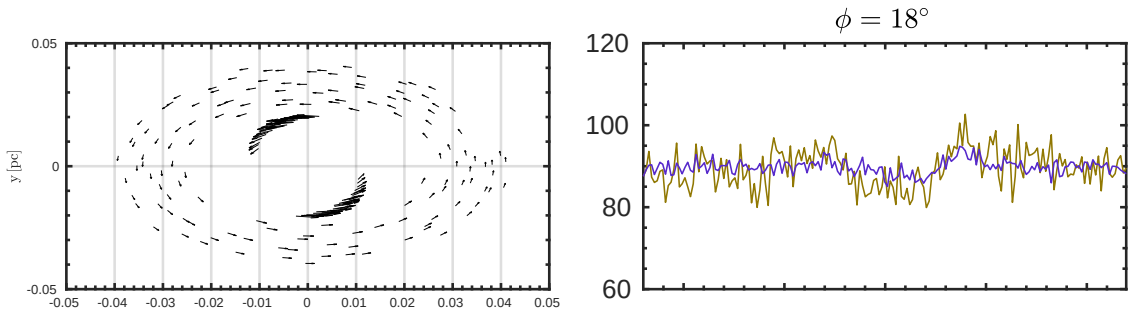
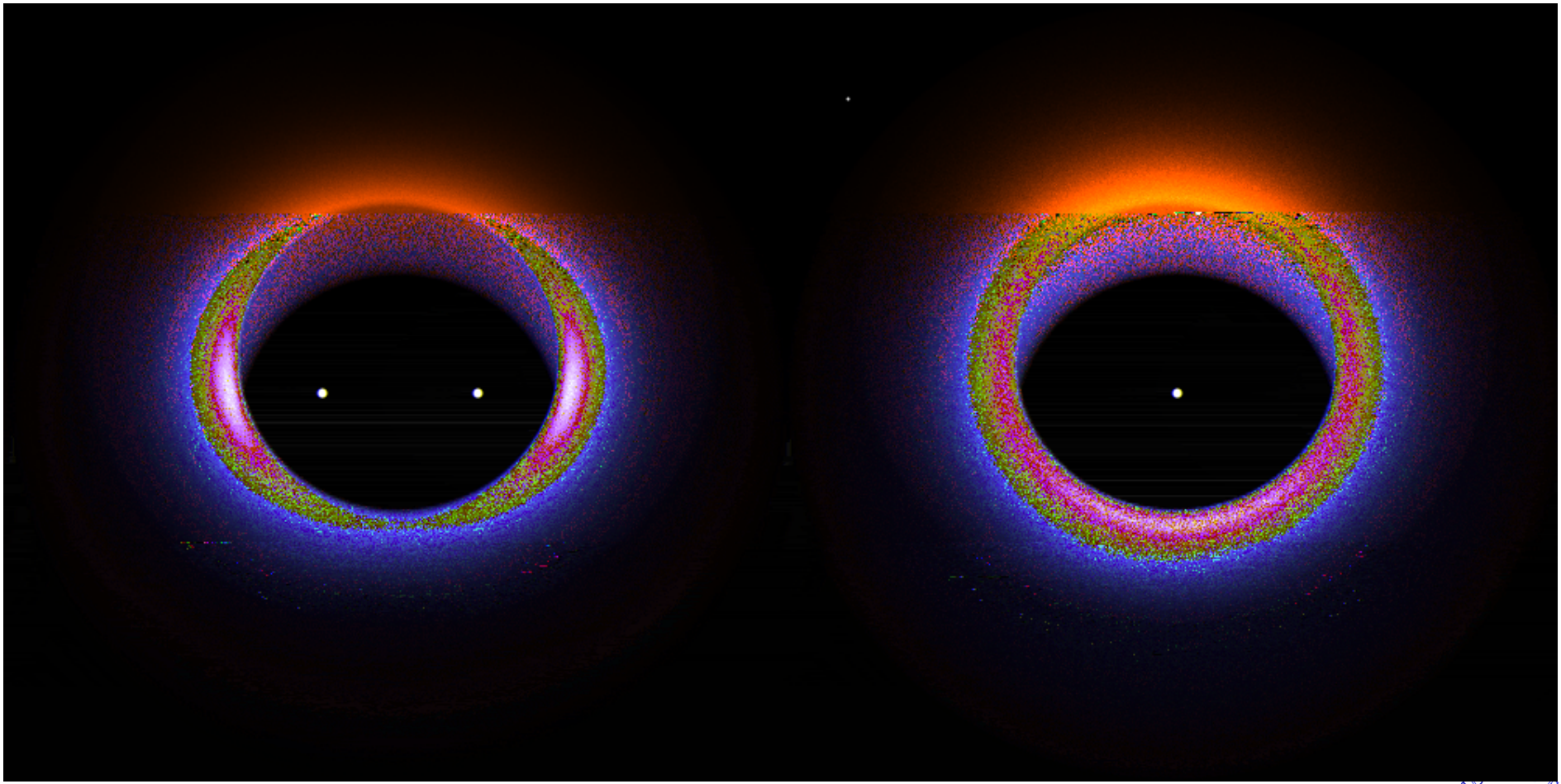
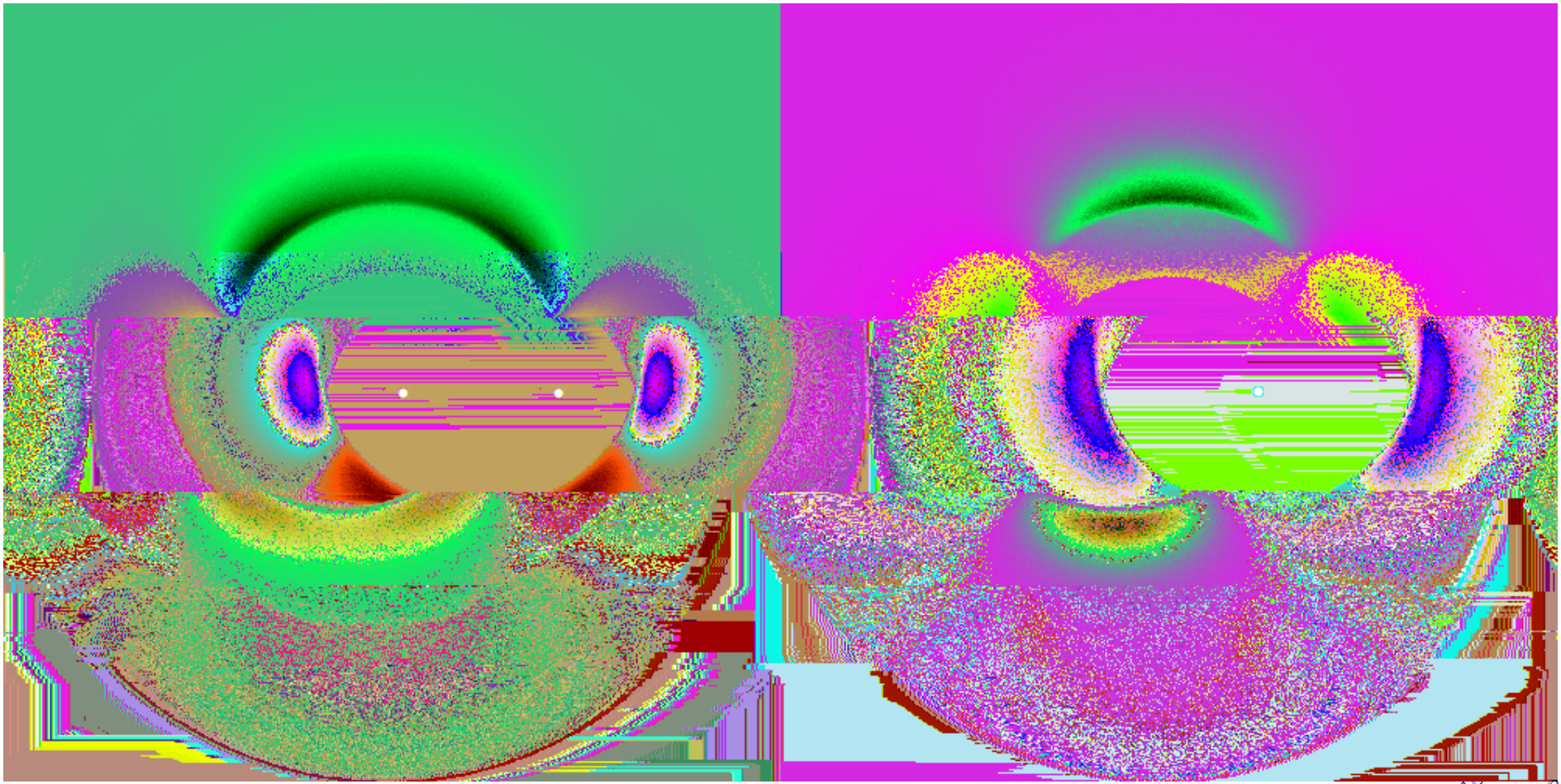


Polarization maps: I



Polarization maps: Q



Polarization maps: U

Conclusions

- Spectropolarimetry is powerful tool for the SMBBHs search
- Position angle pro les show variable W- or M-like pro les
- Unpolarized lines show periodic variations
- Spatially resolved polarization maps are highly sensitive to the presence of SMBBHs