Some investigation of active galactic nuclei and gravitational lenses using SCORPIO instrument

Luka Č. Popović

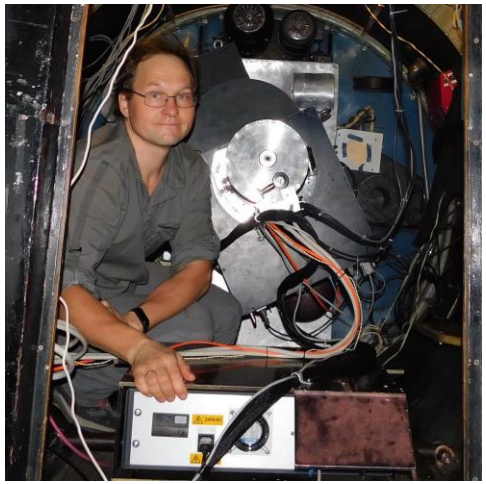
Astronomical Observatory, Belgrade, Serbia

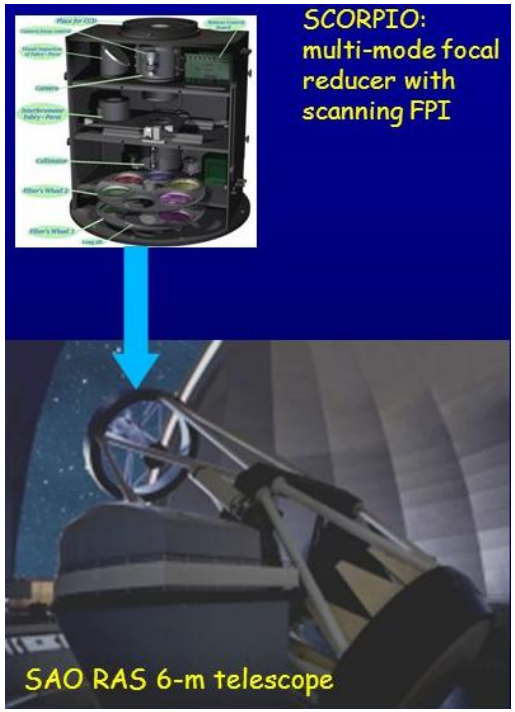
Department of Astronomy, Faculty of Mathematics, University of Belgrade, Serbia

MATΦ
University of Belgrade
Faculty of Mathematics

OMNIA IN NUMERO ET MENSURA
1887

Посматрања гравитационих макросочива – углавном на 6м телескопу САО





THE ASTROPHYSICAL JOURNAL LETTERS, 721:L139–L142, 2010 October 1 doi:10.1088/2041-8205/721/2/L139

RXJ 0921+4529: A BINARY QUASAR OR A GRAVITATIONAL LENS?

L. Č. POPOVIĆ[1,7], A. V. MOISEEV[2], E. MEDIAVILLA[3,4], P. JOVANOVIĆ[1,7], D. ILIĆ[5,7], J. KOVAČEVIĆ[1,7], AND J. A. MUÑOZ[6]
[1] Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia
[2] Special Astrophysical Observatory, Nizhnii Arkhyz, Karachaevo-Cherkesia 369167, Russia
[3] Instituto de Astrofísica de Canarias, Vía Láctea S/N, 38200 La Laguna, Tenerife, Spain
[4] Departamento de Astrofísica, Universidad de La Laguna, E-38205 La Laguna, Tenerife, Spain
[5] Department of Astronomy, Faculty of Mathematics, Studentski trg 16, Belgrade, Serbia
[6] Departamento de Astronomía y Astrofísica, Universidad de Valencia, 46100 Burjassot, Valencia, Spain
Received 2010 July 30; accepted 2010 August 23; published 2010 September 10

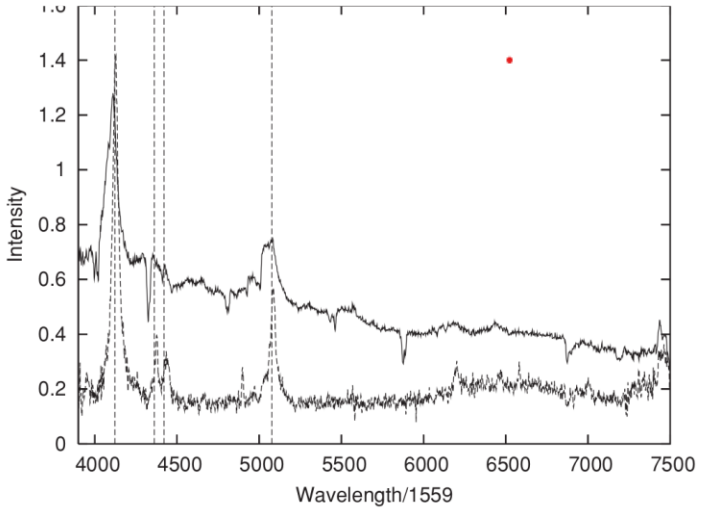


Figure 1. Observed spectra of components A (solid line) and B (dashed line)

Среда, 24.09.2025. у 13:00, Сала 301ф, Математички Институт САНУ, Кнеза Михаила 36 и Онлине

Гравитациона сочива и допринос српских научника у истраживању овог феномена
Лука Ч. Поповић
Астрономска опсерваторија, Београд

Mon. Not. R. Astron. Soc. 377, 480–490 (2007) doi:10.1111/j.1365-2966.2007.11635.x

The gas kinematics in the Mrk 533 nucleus and circumnuclear region: a gaseous outflow

A. A. Smirnova,[1⋆] N. Gavrilović,[2,3] A. V. Moiseev,[1] L. Č. Popović,[2] V. L. Afanasiev,[1] P. Jovanović[2] and M. Dačić[2]

THE ASTRONOMICAL JOURNAL, 137:3548–3557, 2009 March doi:10.1088/0004-6256/137/3/3548

THREE-DIMENSIONAL SPECTROSCOPIC STUDY OF THE LINE-EMITTING REGIONS OF Mrk 493

L. Č. POPOVIĆ[1,2], A. A. SMIRNOVA[3], J. KOVAČEVIĆ[1,2], A. V. MOISEEV[3], AND V. L. AFANASIEV[3]

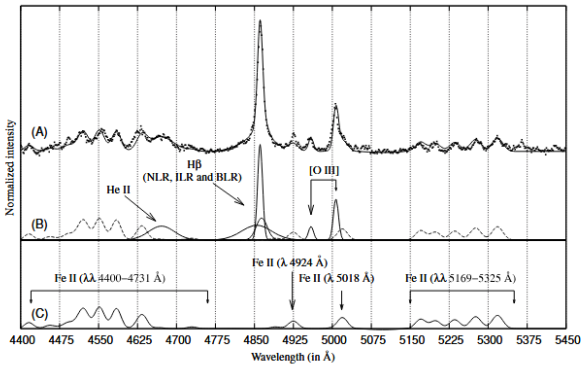


Figure 5. Decomposition of the observed Hβ spectral region (dots) using the χ^2 best-fit minimization (*c*). The Gaussian functions denoted with solid lines in panel (*b*) represent the components of He II, Hβ, and [O III]. The Fe II template obtained from the best fit (53 Gaussian functions) is presented in panel (*c*).

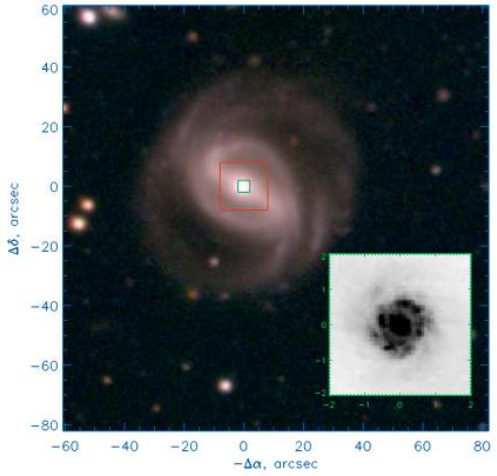
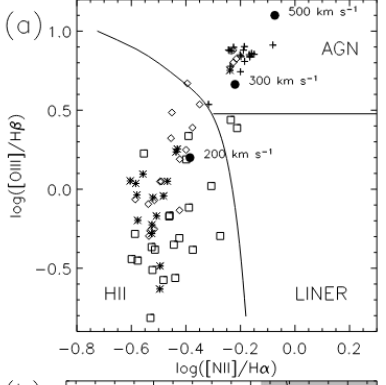


Figure 1. Composite BVR_C color image obtained with SCORPIO at 6 m telescope. The large red box shows the region observed with MPFS. The small green box marks the field shown in the bottom right corner. It is the *HST* WFPC2 image in the optical band with F606W filter.

(A color version of this figure is available in the online journal.)



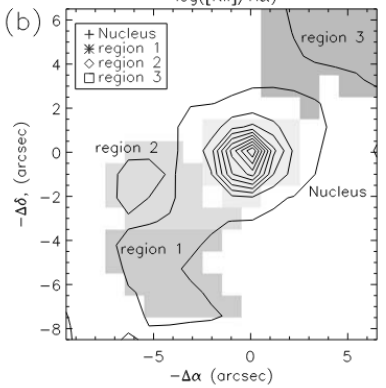


Figure 10. The flux ratio of [O III]/Hβ lines versus [N II]/Hα (a) and th map of Mrk 533 with regions for which this ratios are found (b). The He isophotes are overlapped on this map. The full circles in Fig. 4(a) represen the calculated ratio by Dopita & Sutherland (1995), where 'shock plus pre cursor' models were used. The calculated values are for the shock velocitie of 200, 300 and 500 km s^{-1} (the values are given near the full circles).

- Very productive collaboration between SAO and AOB
- More than 50 papers, more than 25 in leading astronomical journals

Tuesday, August 24, 2021

SPECIAL SESSION DEDICATED TO VICTOR L. AFANASIEV: AGN Polarization

Chair: L. Č. Popović

9:00 - 9:30	***Serguei Dodonov***	*Multi Object Methods for finding and study QSO's and Galaxies* - VIDEO
9:30 - 10:00	***Martin Roth***	*25 years of integral field spectroscopy - from the BTA to the VLT* - VIDEO
10:00 - 10:30	***Alexei Moiseev***	*Observations of large-scale ionizing cones in Seyfert galaxies* - VIDEO
10:30 - 10:50	*Roman Uklein*	*Universal reducer for small telescopes* - VIDEO
10:50 - 11:10	*Eugene Malygin*	*The photometric reverberation mapping of active galaxies in SAO RAS* - VIDEO
11:10 - 11:30	*Coffee break*	

SPECIAL SESSION DEDICATED TO VICTOR L. AFANASIEV: AGN Polarization

Chair: S. Dodonov

11:30 - 12:00	***Luka Č. Popović***	*Polarization in broad emission lines of active galactic nuclei* - VIDEO
12:00 - 12:30	***Elena Shablovinskaya***	*New capabilities of AGN polarimetry* - VIDEO
12:30 - 13:00	***Alexander Burenkov***	*Monitoring of Seyfert 1 galaxies at the Special Astrophysical Observatory of the Russian Academy of Science* - VIDEO
13:00 - 13:20	*Đorđe Savić*	*Broad emission line polarization of lensed quasars* - VIDEO
13:20 - 13:40	*Daria Kozlova*	*Ionized-gas clouds in the 2MASX J013130.00-062550.8 galaxy*
13:40 - 14:00	*Alina Ikhsanova*	*Gas and stars in the Teacup quasar* - VIDEO
14:00 - 15:30	*Lunch break*	

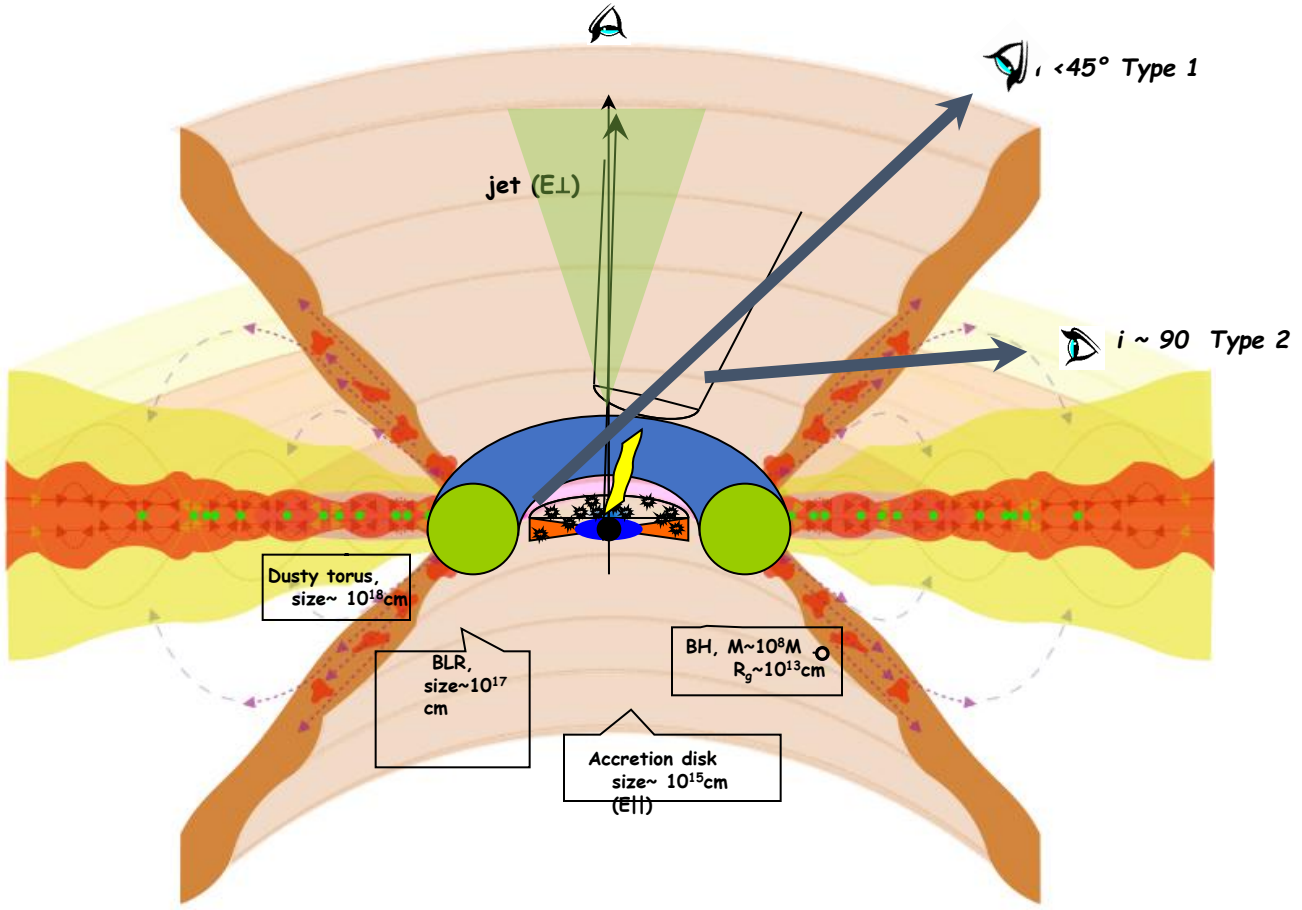
Optical emission of AGNs – different emission regions!

Type 1 or Type 2 AGNs? Very important:

- dust => rate of accretion

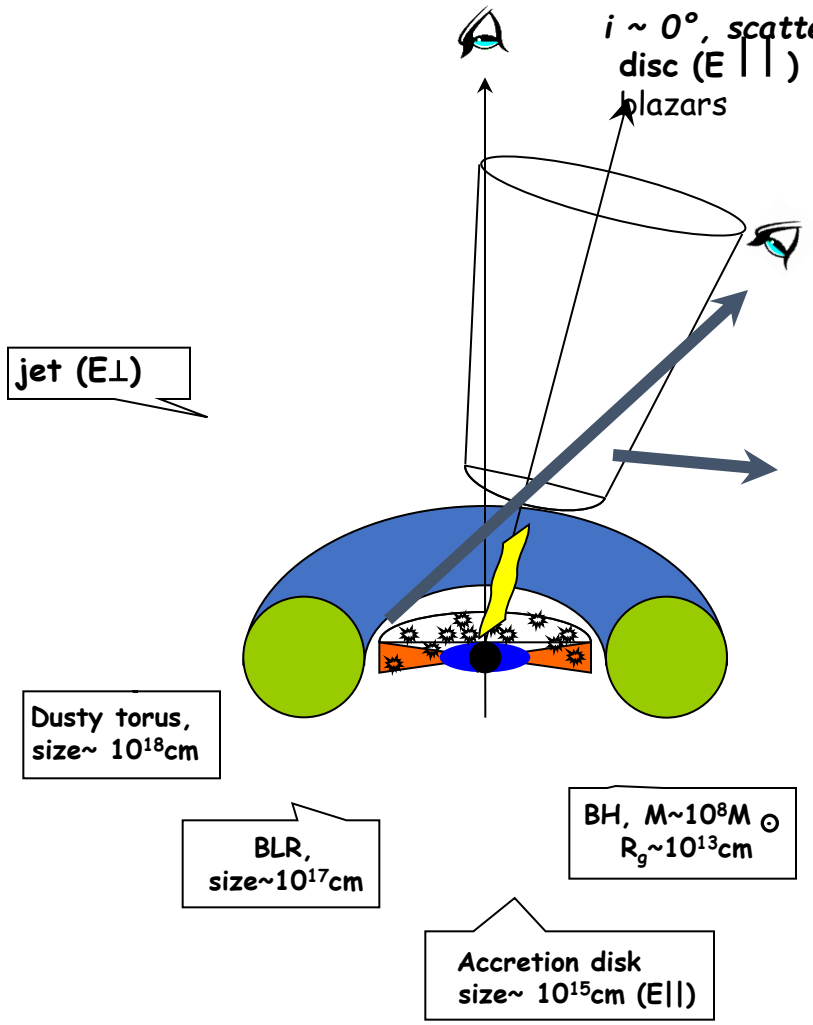
- dust distribution with respect to an observer

(Hoenig 2019) =>



Possible sources of AGN polarization

(Shablovinskaya & Afanasiev 2019, OpenAst, 28, 213)



Polarization in continuum

✓radiative transfer in AD

✓Synchrotron radiation in jet

✓scattering by gas-dust torus

Polarization in lines

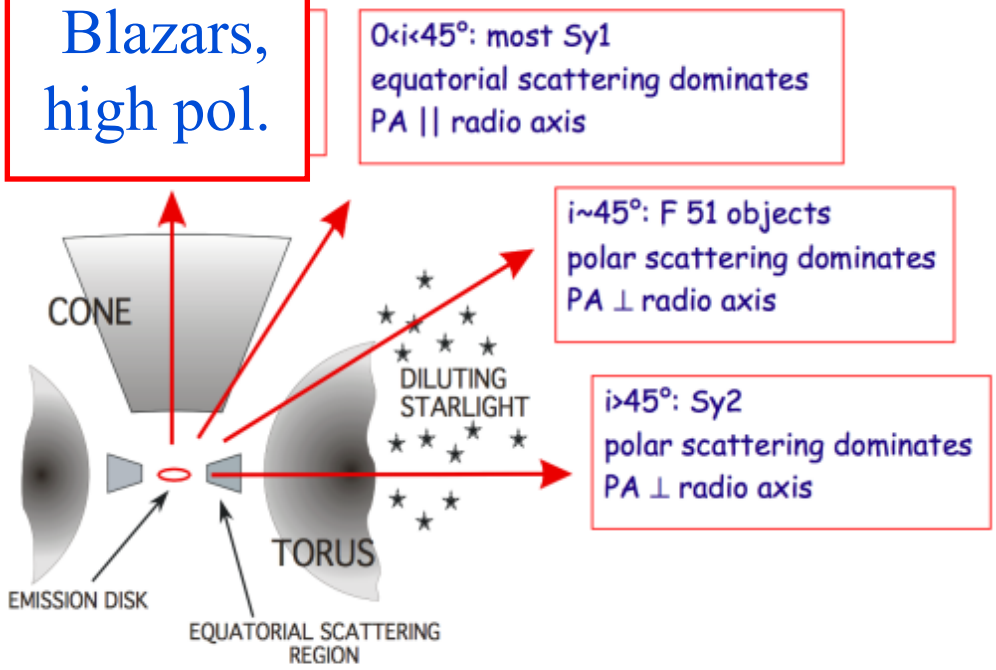
✓scattering by gas-dust torus

✓radiative transfer in the BLR

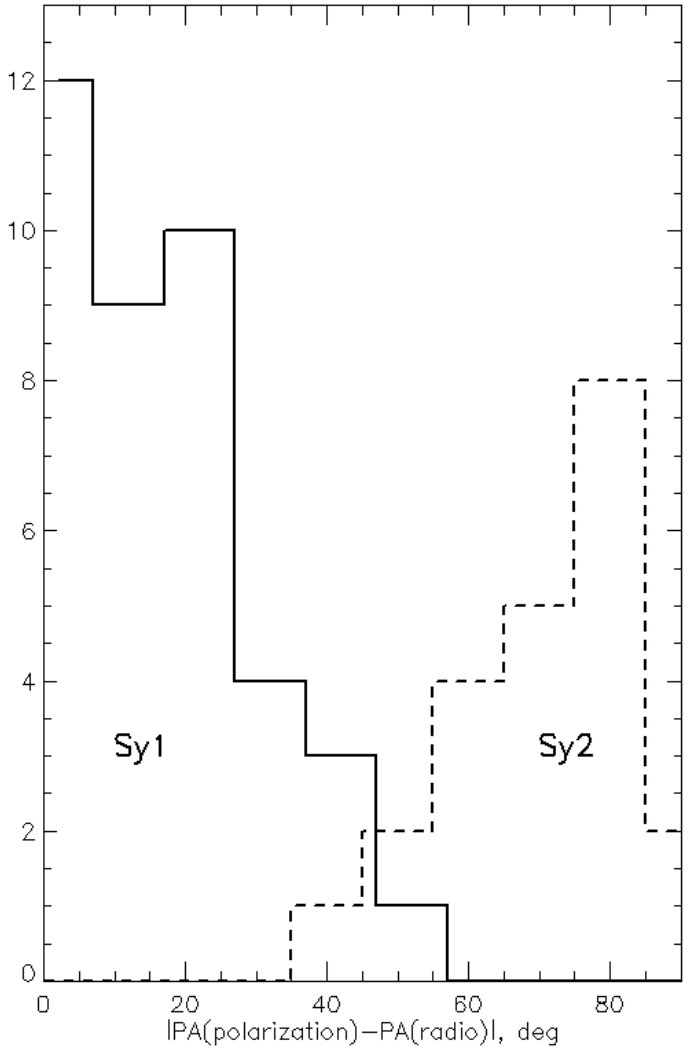
Scheme is made by V. L. Afanasiev

Polarization of AGNs - a simple (UNIFIED) model (e.g. NLS1, see Popovic, Afanasiev et al. 2018)

Blazars, high pol.



Relation between polarization class and orientation in the generic scattering geometry that broadly explains the optical polarization spectra of Seyfert galaxies Smith et al. (2004)



Orientation is important !

AGN polarization

MNRAS 440, 519–529 (2014)
Advance Access publication 2014 March 11
doi:10.1093/mnras/stu231

Variability in spectropolarimetric properties of Sy 1.5 galaxy Mrk 6

V. L. Afanasiev,[1]★ L. Č. Popović,[2,3,4] A. I. Shapovalova,[1] N. V. Borisov[1] and D. Ilić[3,4]

The Astrophysical Journal Letters, 800:L35 (4pp), 2015 February 20
doi:10.1088/2041-8205/800/2/L35

POLARIZATION IN LINES—A NEW METHOD FOR MEASURING BLACK HOLE MASSES IN ACTIVE GALAXIES

Victor L. Afanasiev[1] and Luka Č. Popović[2,3,4]

MNRAS 482, 4985–4999 (2019)
Advance Access publication 2018 November 10
doi:10.1093/mnras/sty2995

Spectropolarimetry of Seyfert 1 galaxies with equatorial scattering: black hole masses and broad-line region characteristics

V. L. Afanasiev,[1] L. Č. Popović[2,3]★ and A. I. Shapovalova[1]

The Astrophysical Journal Letters, 921:L21 (6pp), 2021 November 1
https://doi.org/10.3847/2041-8213/ac2d30

The First Supermassive Black Hole Mass Measurement in Active Galactic Nuclei Using the Polarization of Broad Emission Line Mg II

Đorđe V. Savić[1,2], Luka Č. Popović[2,3], and Elena Shablovinskaya[4]

Broad line region & SMBH mass, velocity & radius; radius & Luminosity – first case Mrk6

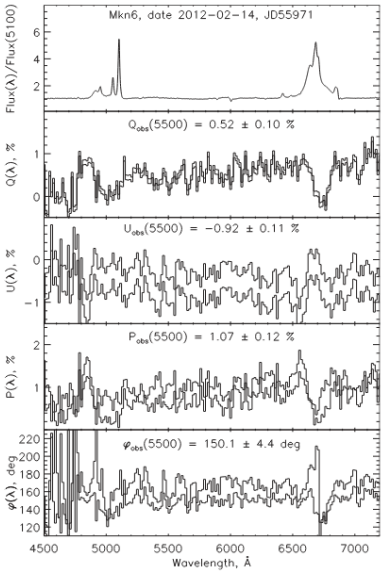
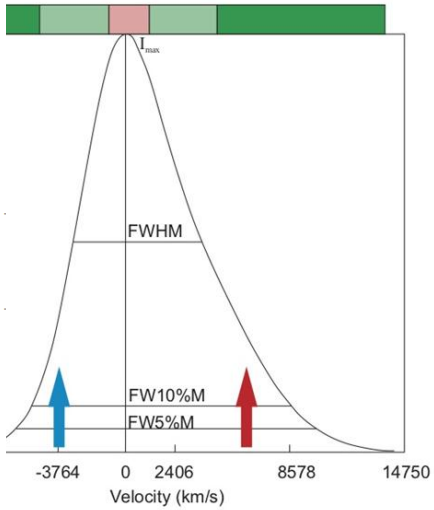
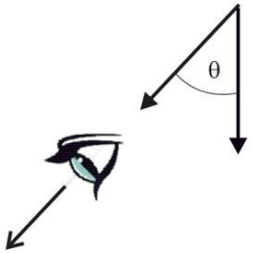
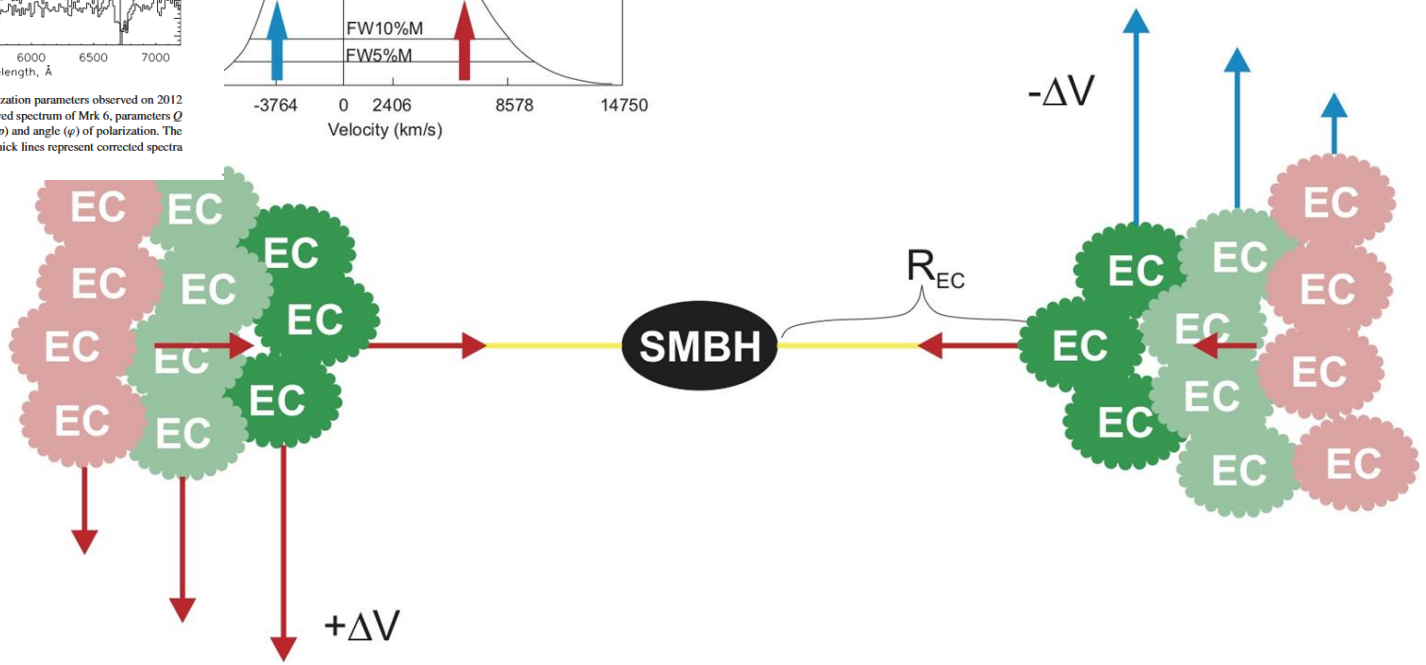


Figure 2. The spectrum and its polarization parameters observed on 2012 Feb 14. From top to bottom: the observed spectrum of Mrk 6, parameters Q and U and corresponding percentage (p) and angle (φ) of polarization. The thin lines represent observed and the thick lines represent corrected spectra for the ISM polarization.



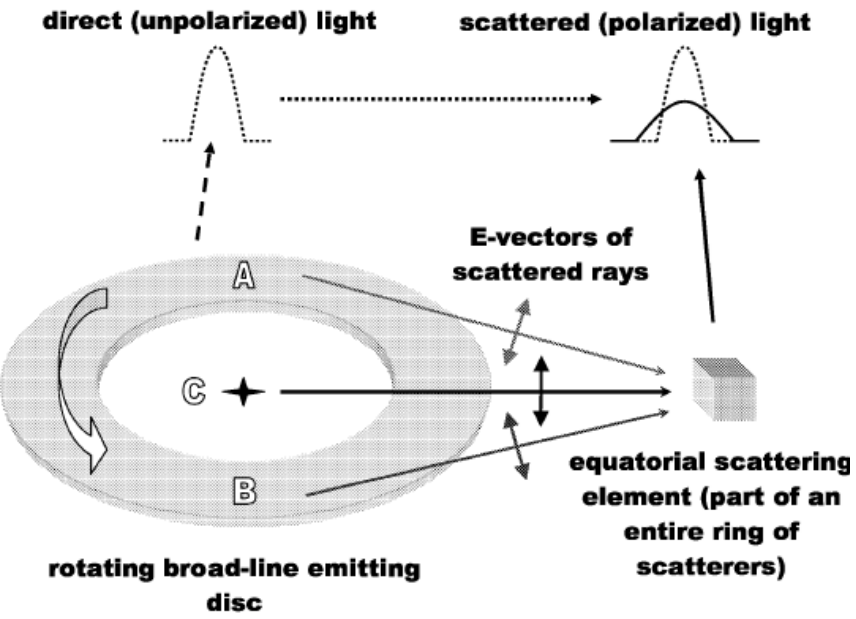


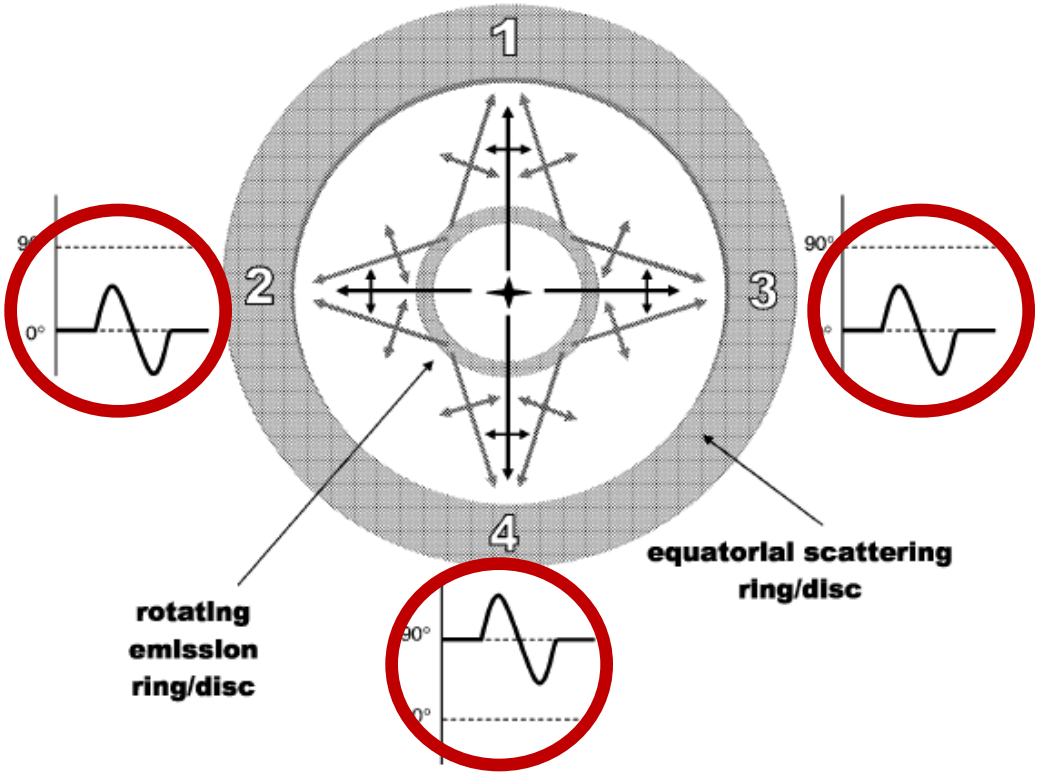


Type 1 AGN: Equatorial polarization in broad lines (Smith et al. 2004,2005) - BLR gas motion – specific PA shapes!

Broad line P.A.

Broad line shapes

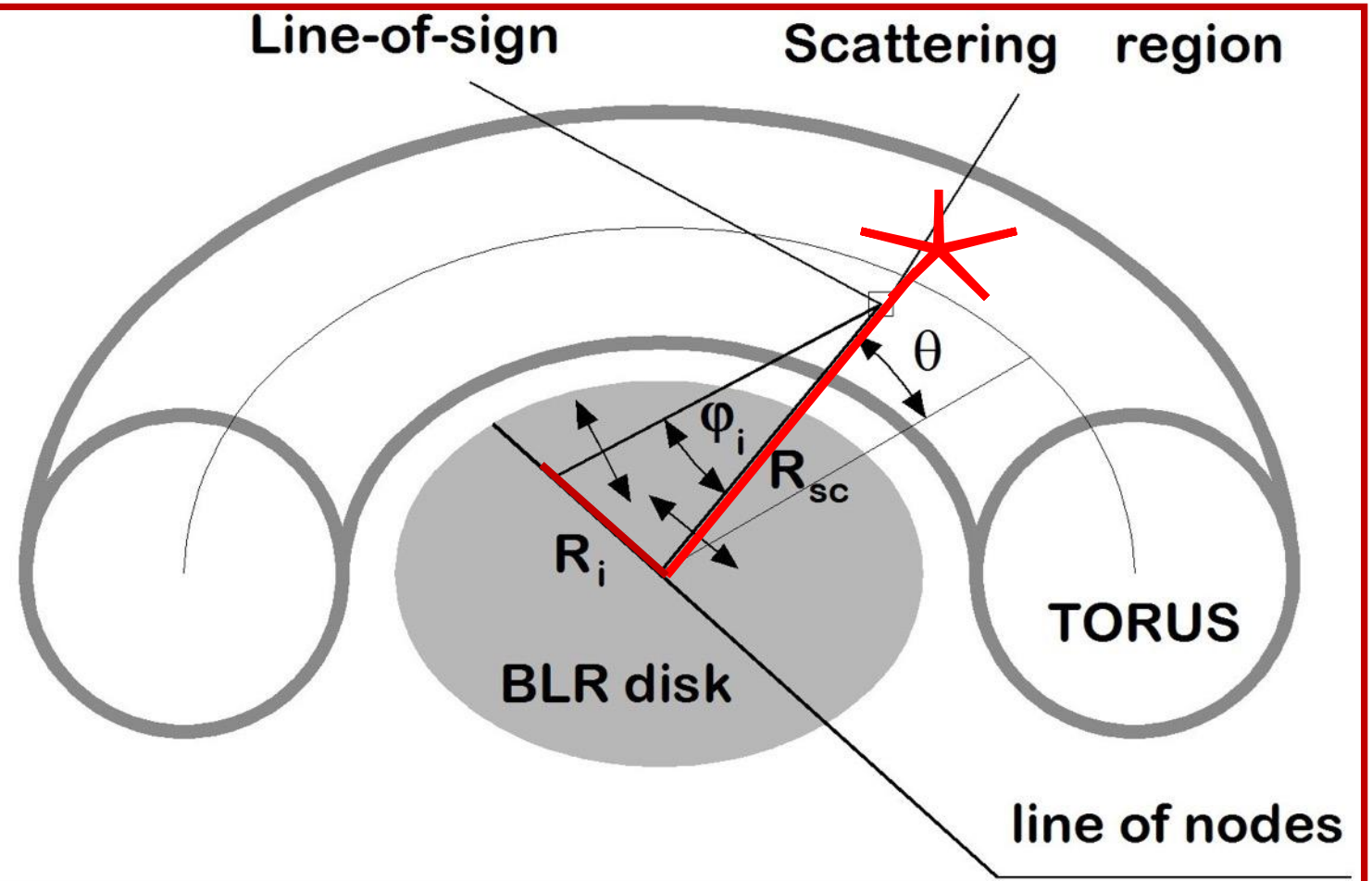




$$v_i = \sqrt{\frac{GM_{BH}}{R_i}}$$

$$R_i / Rsc = \tan(\varphi)$$

$$Rsc = const.$$



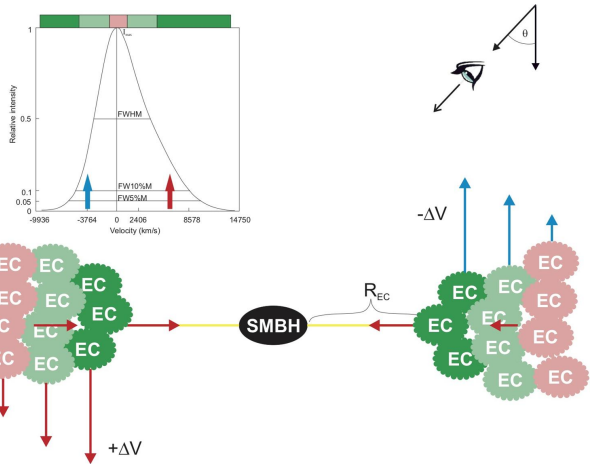
Polarization in the broad Hα
Equatorial scattering - idea

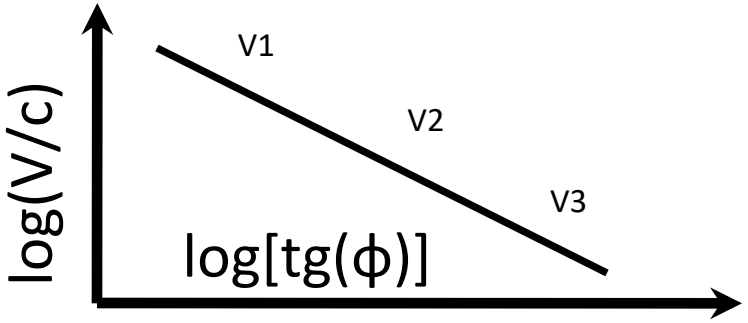
$$v_i = \sqrt{\frac{GM_{BH}}{R_{SC}\tan(\varphi_i)}},$$

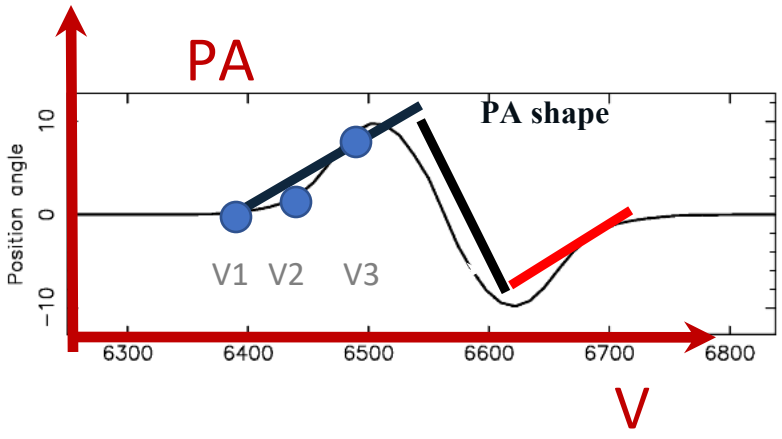
$$\log(v_i) = a - b\log(\tan(\varphi_i)),$$

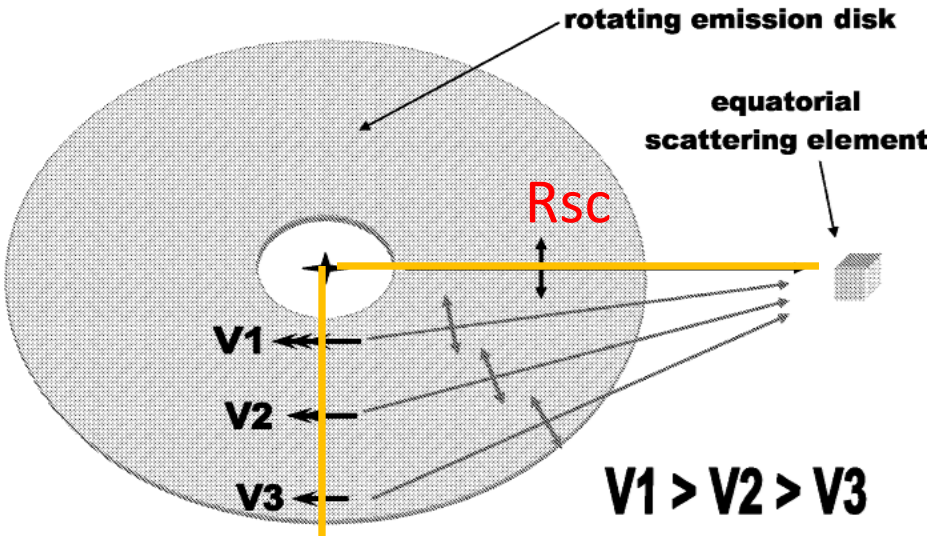
$$b = 0.5$$

$$a = f\left(\frac{M_{BH}}{R_{SC}}\right)$$



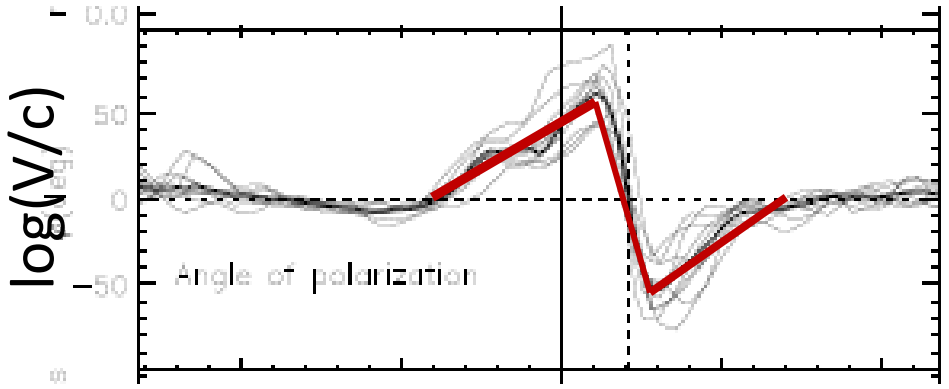


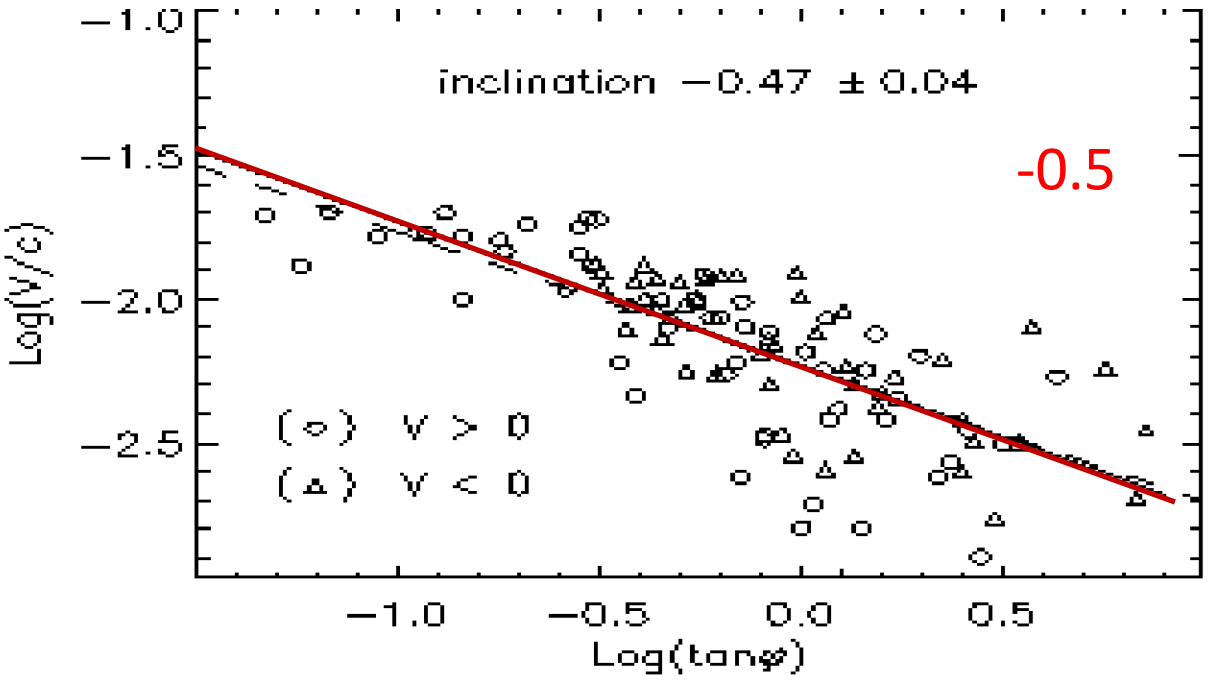




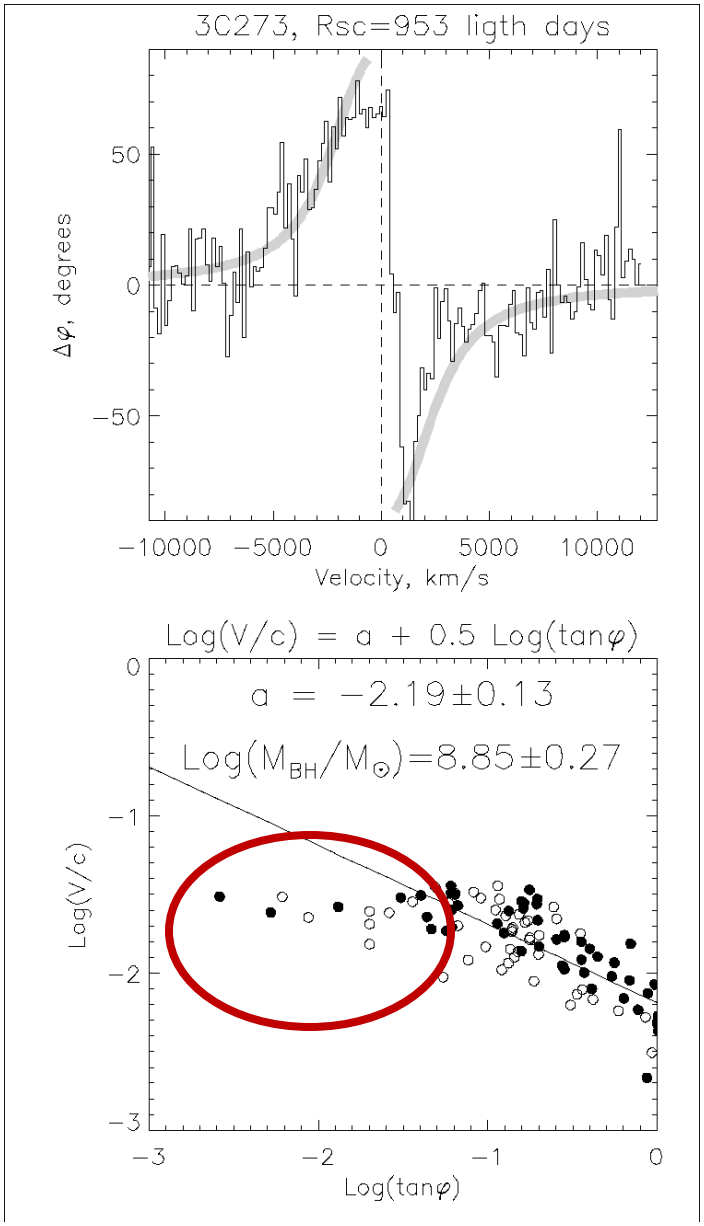
V vs. tan(ϕ) – direct evidence of Keplerian motion in the BLR of Mrk 6, Afanasiev et al. 2014

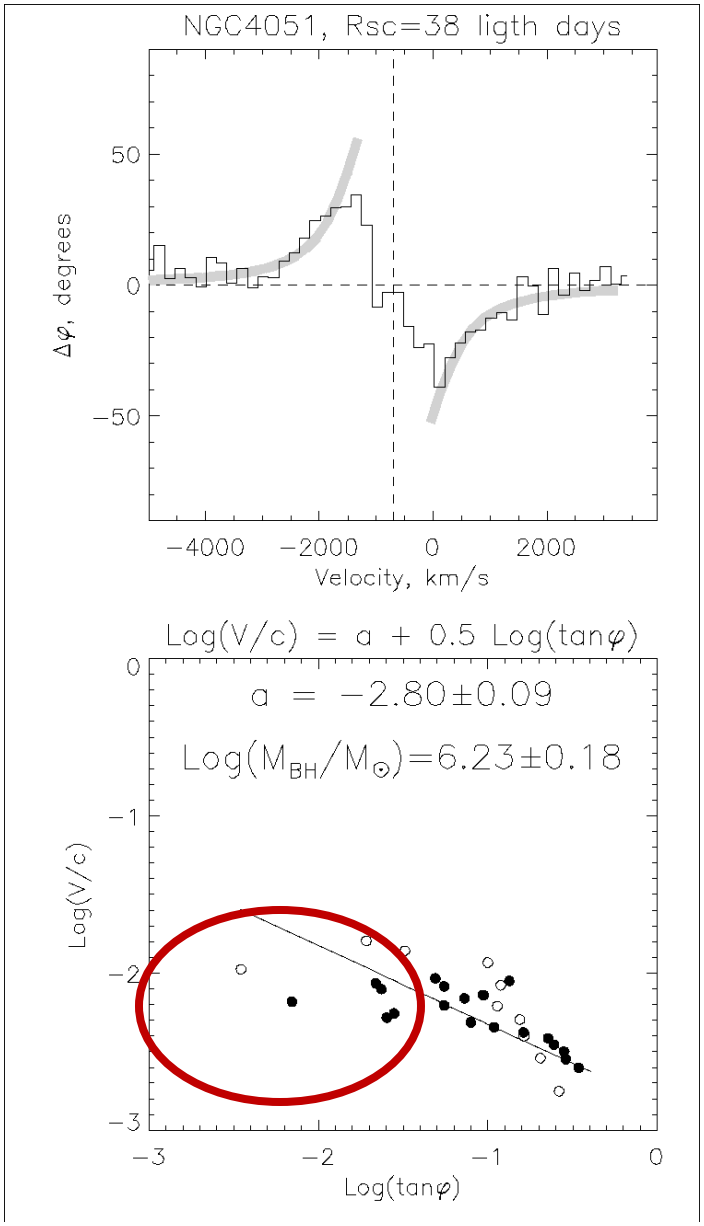
$$\log\left(\frac{V_i}{c}\right) = a - b \cdot log(\tan(\varphi_i)),$$

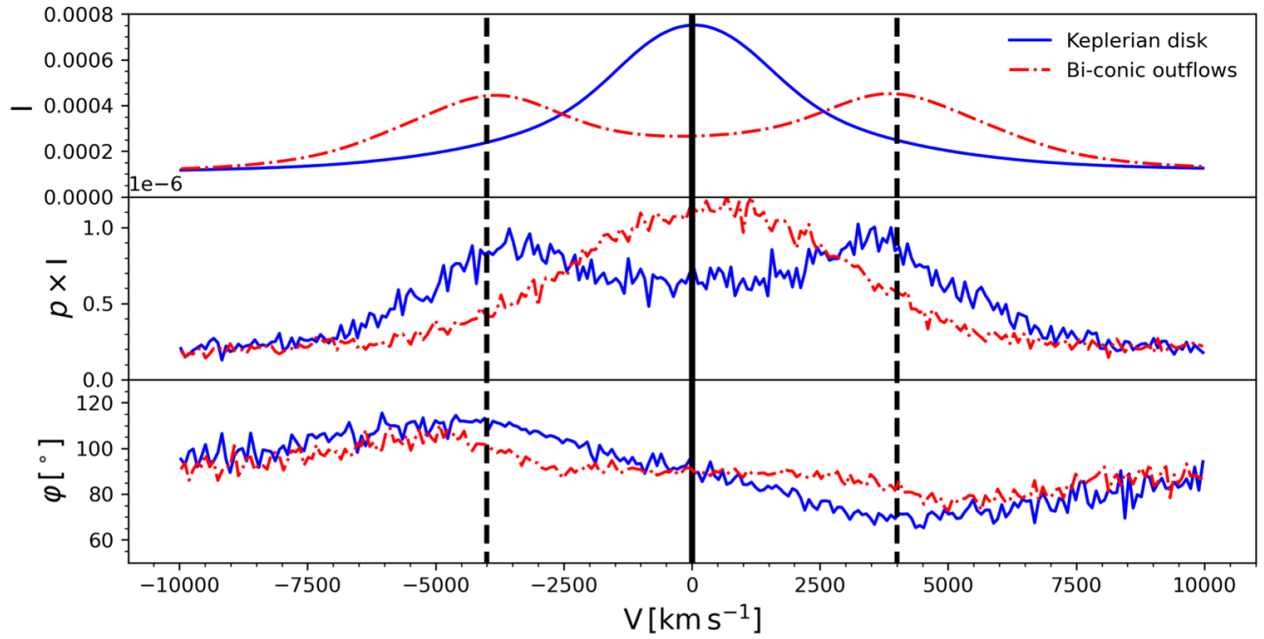




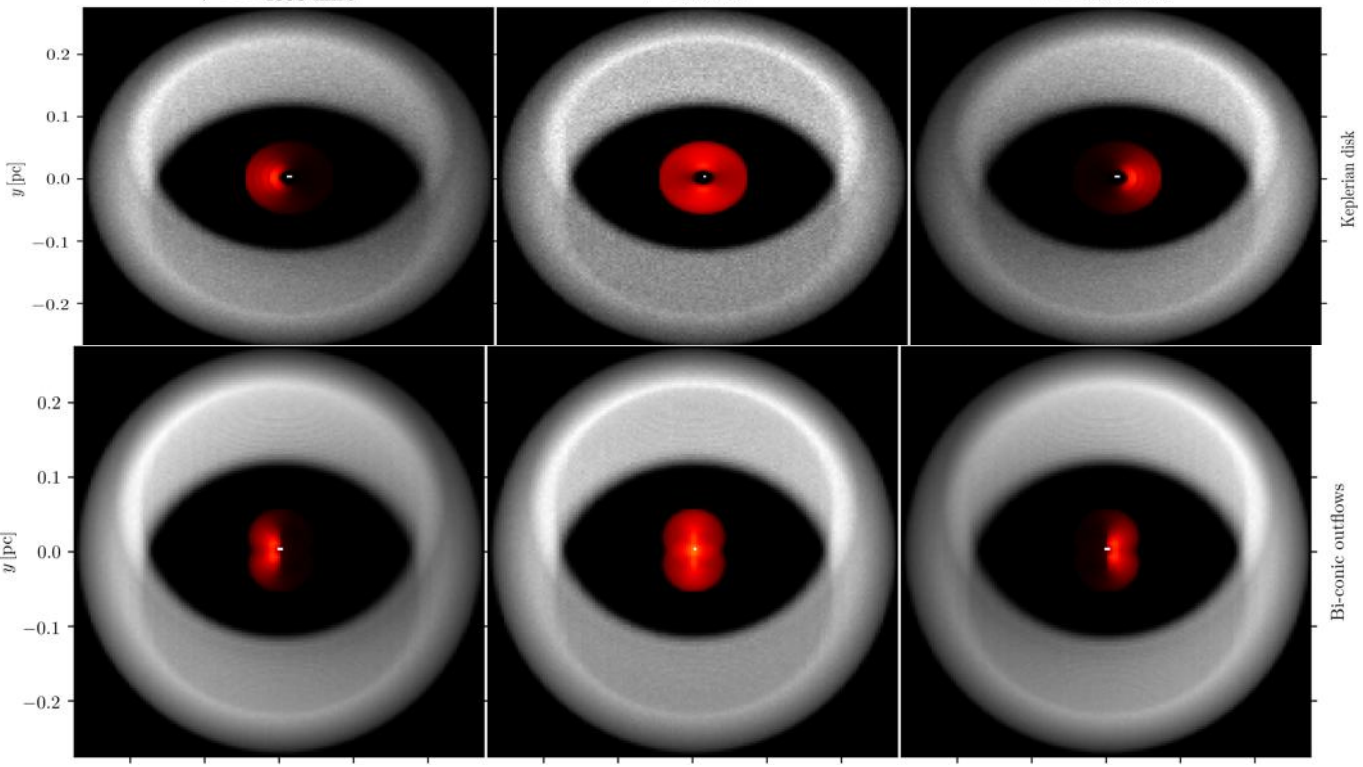
Observed P.A, Afanasiev & Popovic 2015







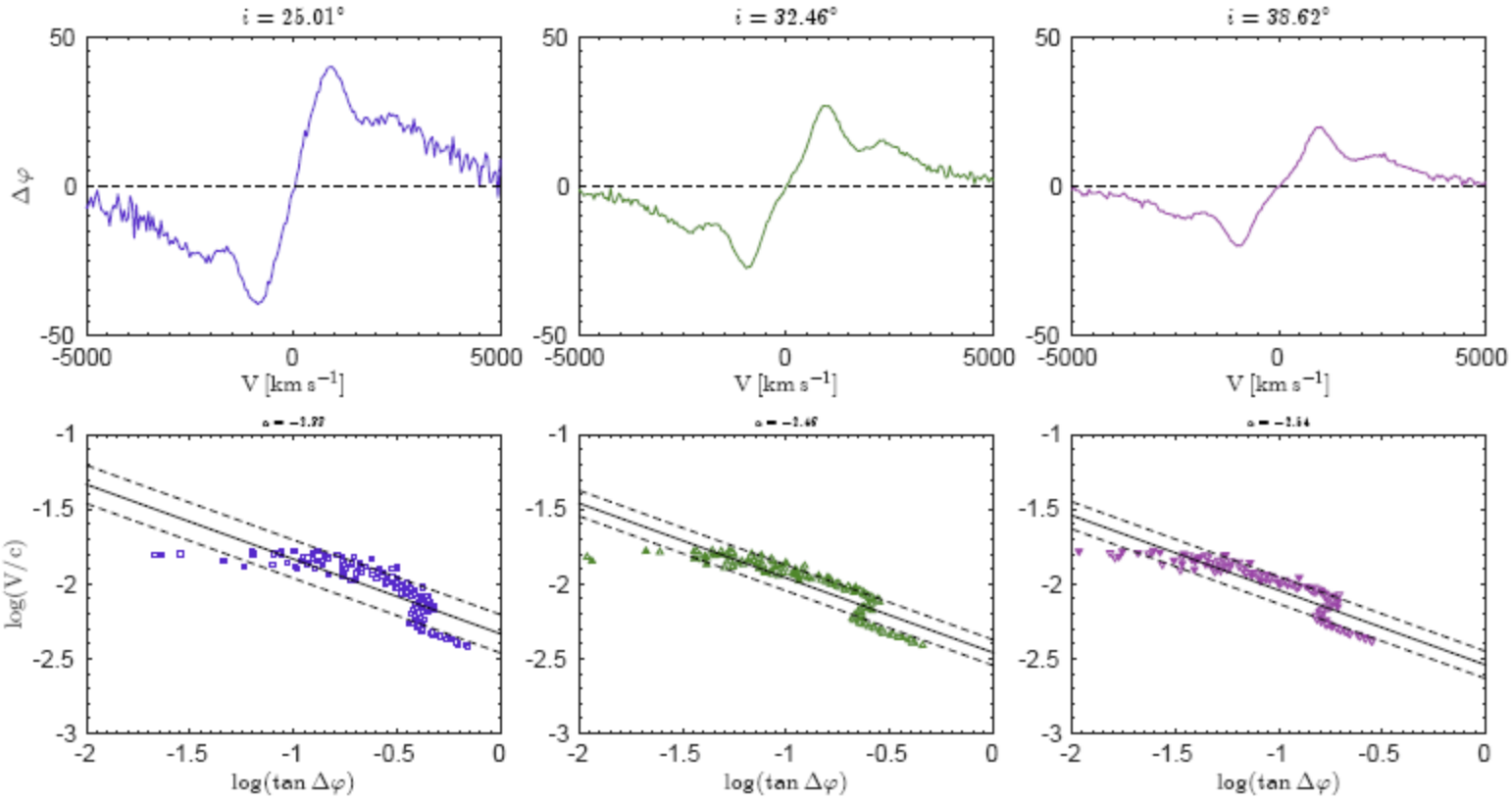
Theory - Equatorial scattering for different BLR geometries, Savic et al. 2018



Disc – like

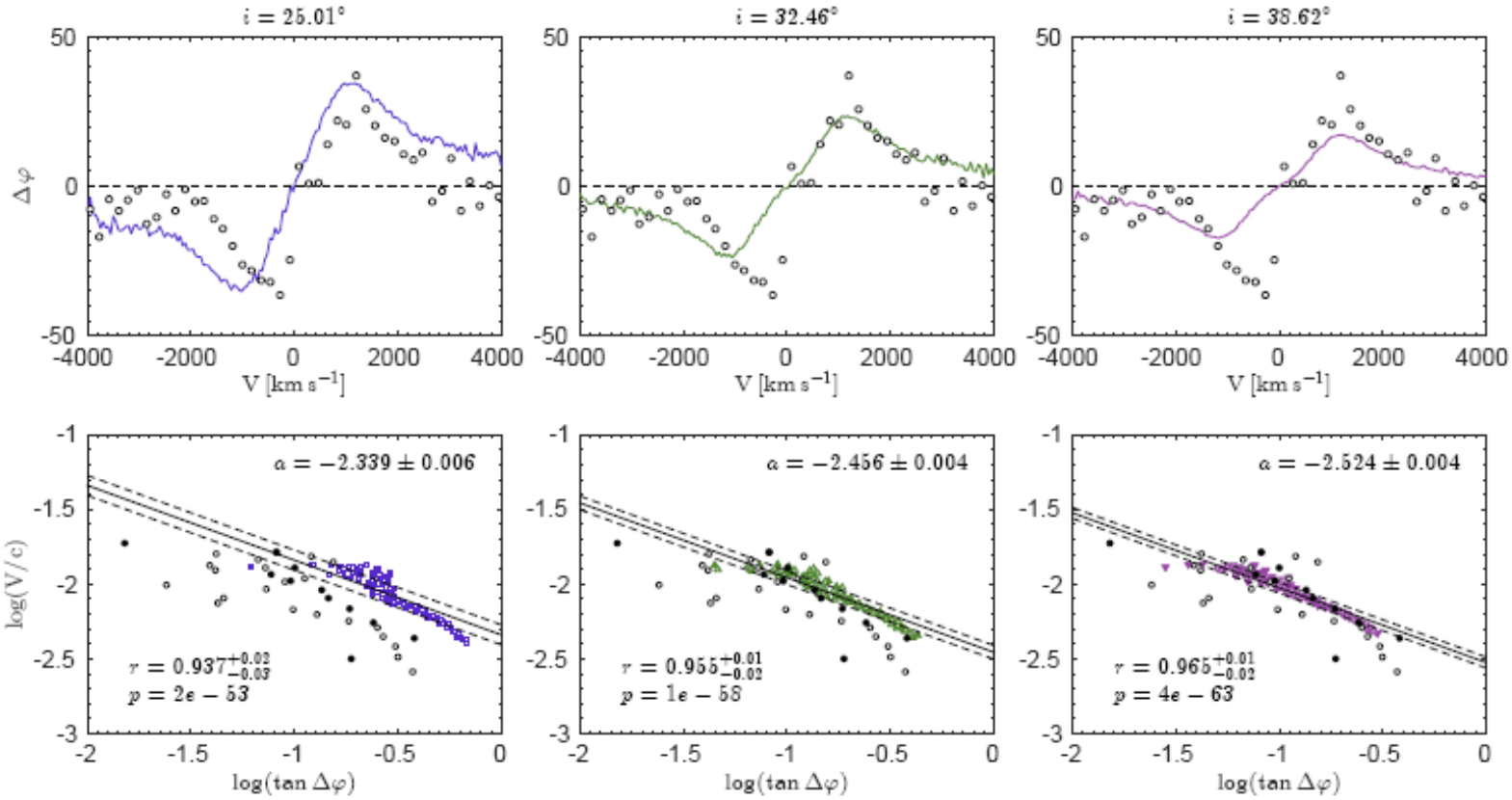
Otuflow

Theory vs. Observations
Savić et al. 2018



Keplerian motion + outflow -2000 km/s

Theory vs. Observations
Savić et al. 2018



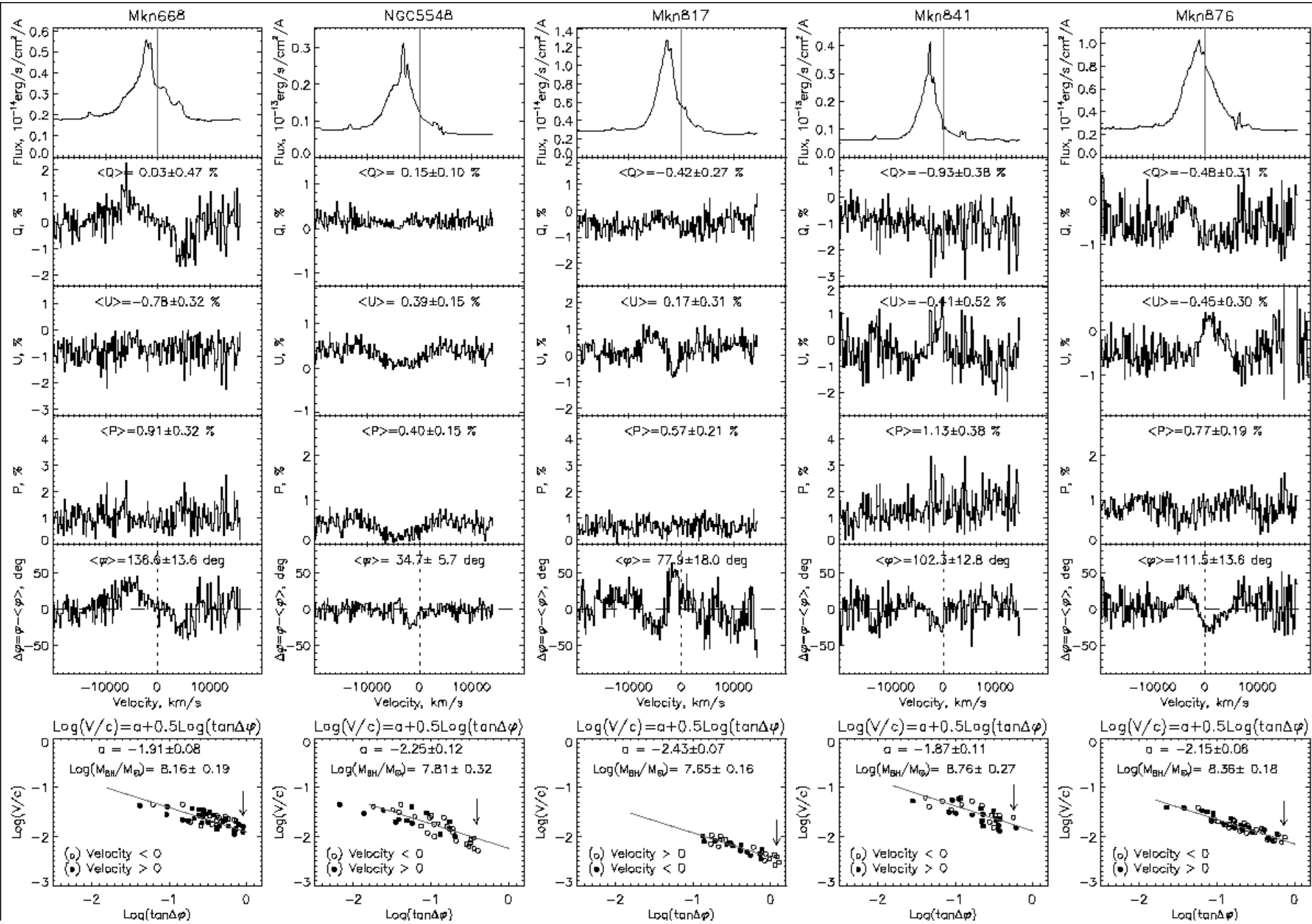
Fitted observations for NGC 4051

Black hole masses for 30 Type 1 AGNs

Afanasiev, Popović, Shapovalova 2019, MNRAS, 482, 4985

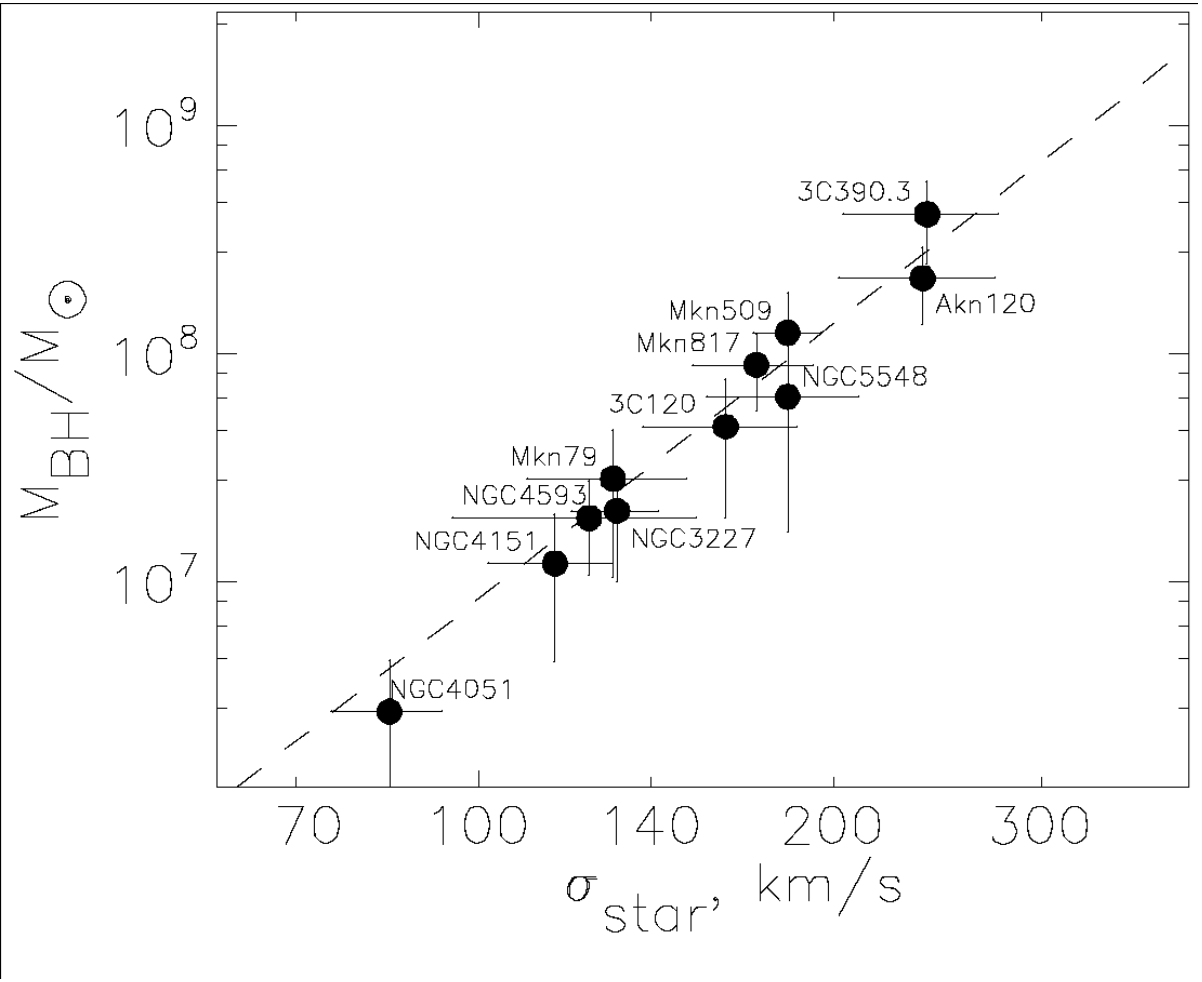
Observations with 6m telescope SAO RAS

- 6-m telescope + SCORPIO, spectral coverage 4000-8000 AA
- Different type analyzer – Savart plate, Single and Double Wollaston prisms
- Spectral resolution 5-40AA,
- Polarization measurement accuracy ~ 0.1-0.3%


Mkn668
NGC5548
Mkn817
Mkn841
Mkn876
Flux, 10^-14erg/s/cm^2/A
Flux, 10^-13erg/s/cm^2/A
<Q>= 0.03±0.47 %
<Q>= 0.15±0.10 %
<Q>=-0.42±0.27 %
<Q>=-0.93±0.38 %
<Q>=-0.48±0.31 %
Q, %
<U>=-0.78±0.32 %
<U>= 0.39±0.15 %
<U>= 0.17±0.31 %
<U>=-0.41±0.52 %
<U>=-0.45±0.30 %
U, %
<P>=0.91±0.32 %
<P>=0.40±0.15 %
<P>=0.57±0.21 %
<P>=1.13±0.38 %
<P>=0.77±0.19 %
P, %
<φ>=136.6±13.6 deg
<φ>= 34.7± 5.7 deg
<φ>= 77.9±18.0 deg
<φ>=102.3±12.8 deg
<φ>=111.5±13.6 deg
Δφ=φ−<φ>, deg
Velocity, km/s
Log(V/c)=a+0.5Log(tanΔφ)
a = −1.91±0.08
Log(MBH/M⊙)= 8.16± 0.19
a = −2.25±0.12
Log(MBH/M⊙)= 7.81± 0.32
a = −2.43±0.07
Log(MBH/M⊙)= 7.65± 0.16
a = −1.87±0.11
Log(MBH/M⊙)= 8.76± 0.27
a = −2.15±0.08
Log(MBH/M⊙)= 8.36± 0.18
Log(V/c)
Log(tanΔφ)
(o) Velocity < 0
(•) Velocity > 0
(o) Velocity > 0
(•) Velocity < 0

Black hole masses for 30 Type 1 AGNs

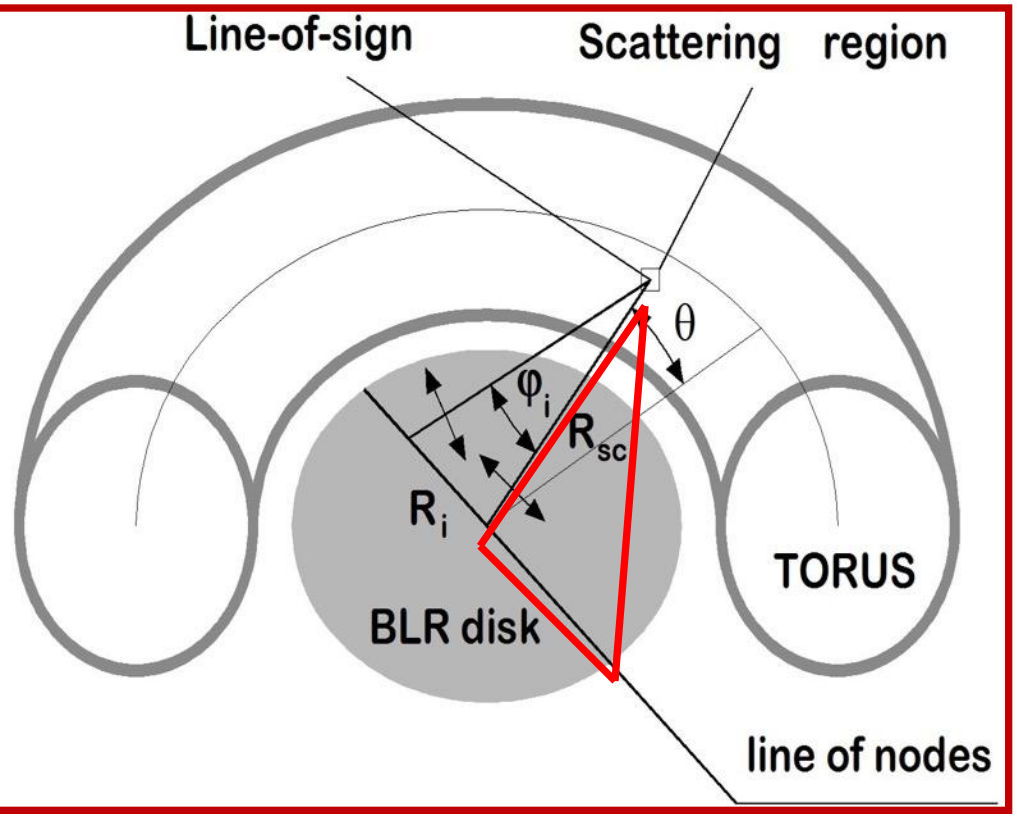
Afanasiev et al. 2019

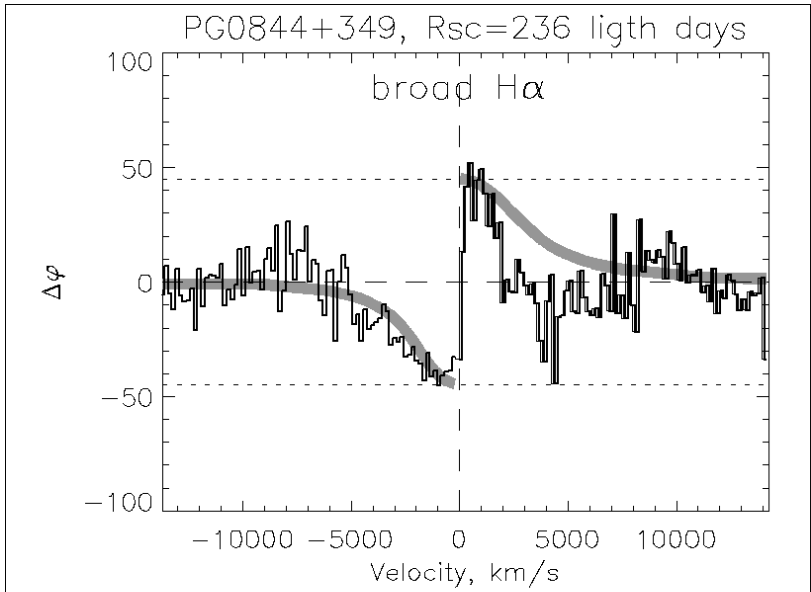


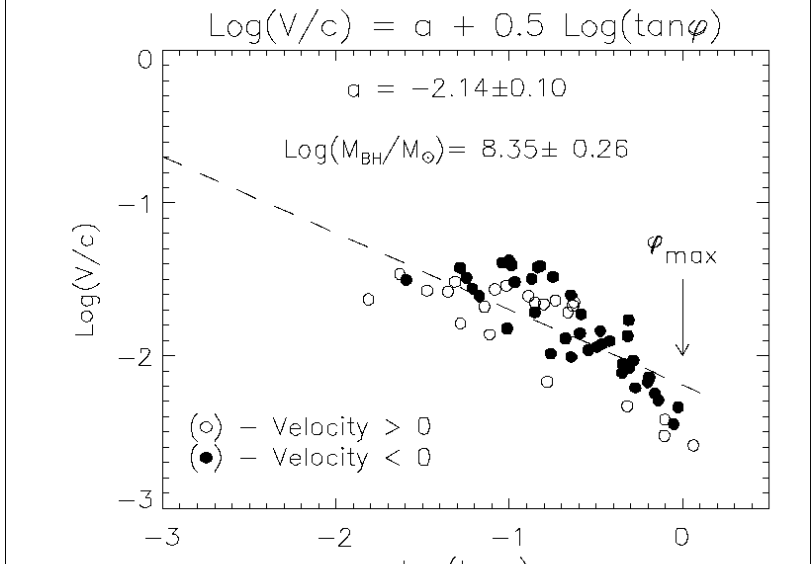
Our measurements of BH masses as a function of host galaxy bulge stellar velocity dispersion *(taken from Onken et* al. 2004). The dashed line shows the dependence of M-σ taken from Tremaine et al (2002).

Dimensions of the BLR

$$R_{max} = R_{sc} \tan(\varphi_{max})$$







Dimensions of the BLR
Afanasiev et el. 2019

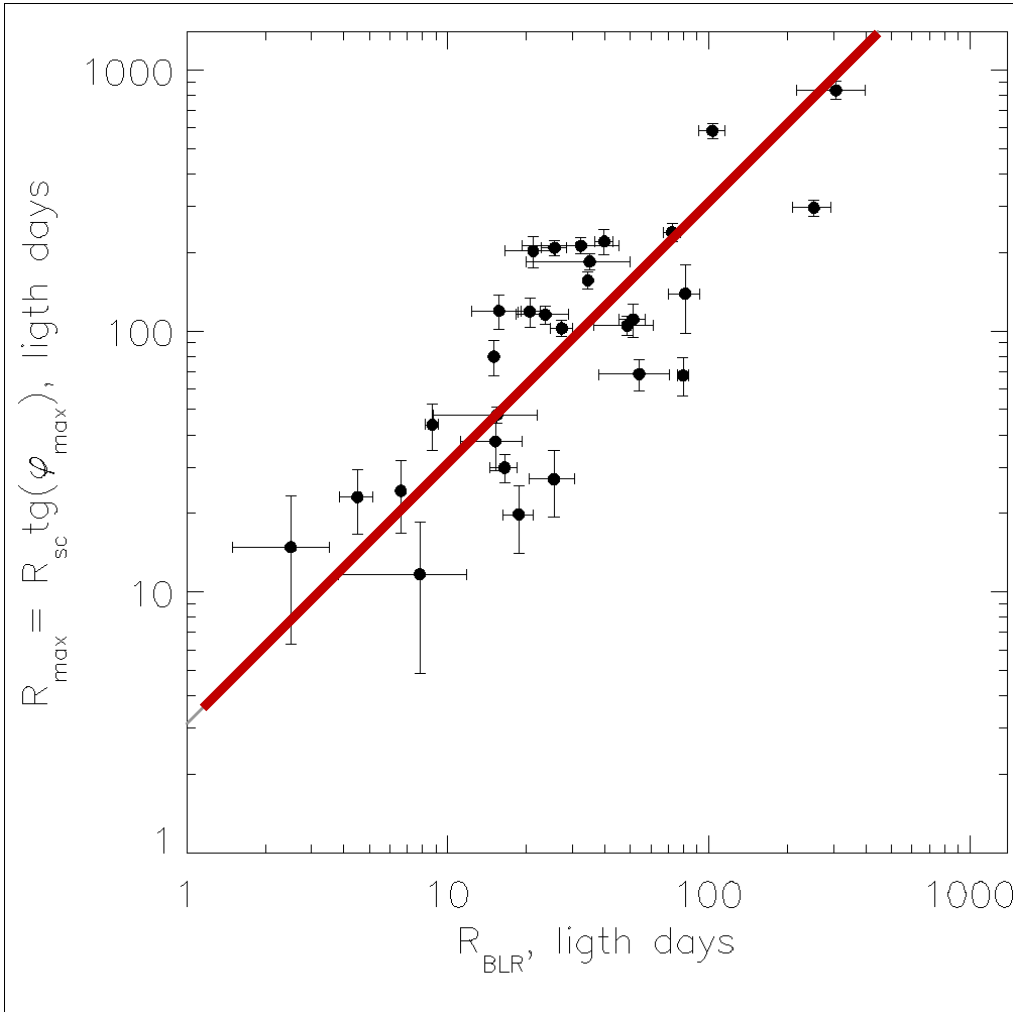
The maximal (*Rmax)* *vs photometric BLR (*R_{BLR}*)* *r*adius. The solid line represents the best fit

$R_{BLR} = (0.31 \pm 0.17) Rmax$

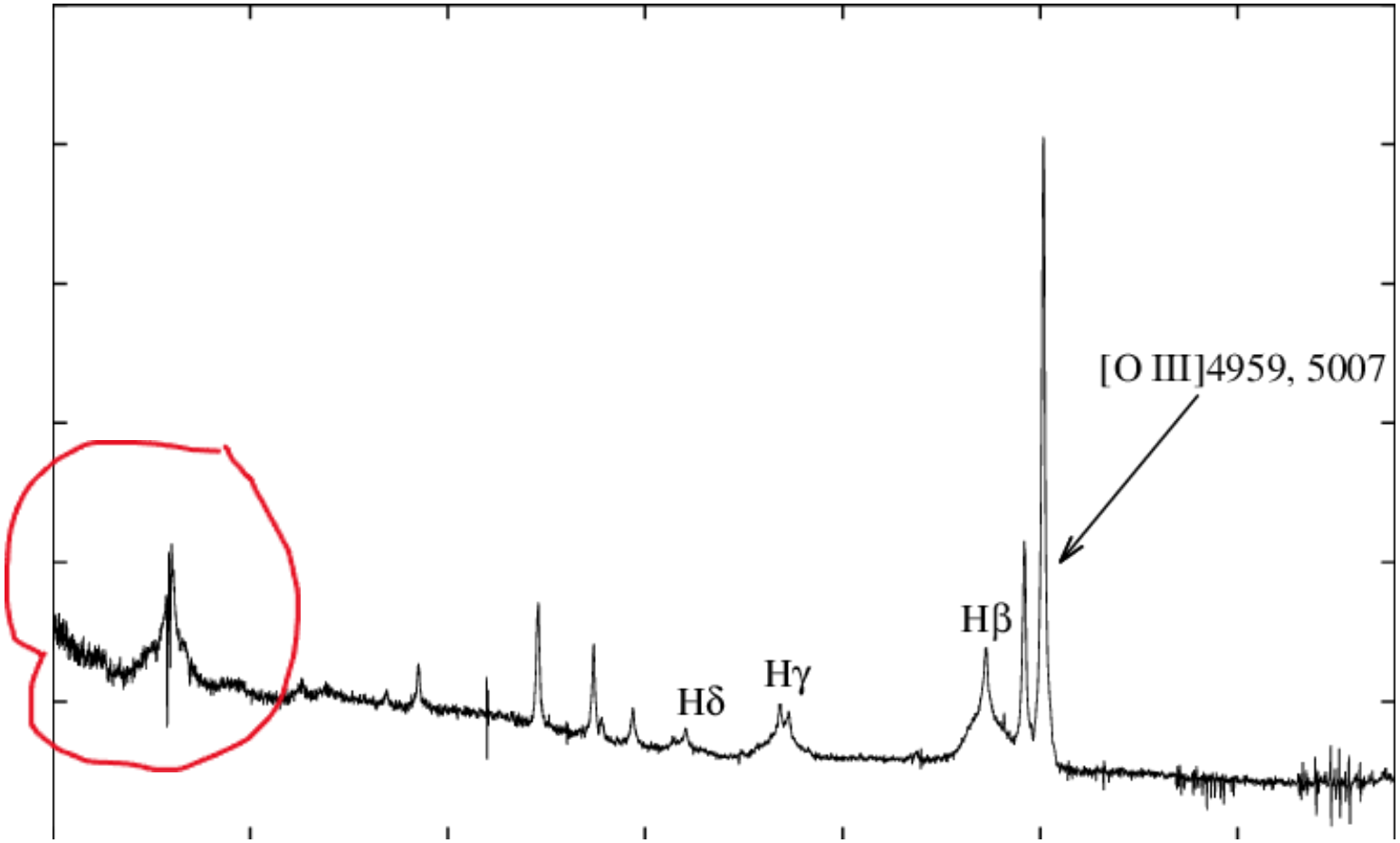
Relation between Rsc and R_{BLR}

$Rsc = (1.72 \pm 0.48)\ R_{BLR}$

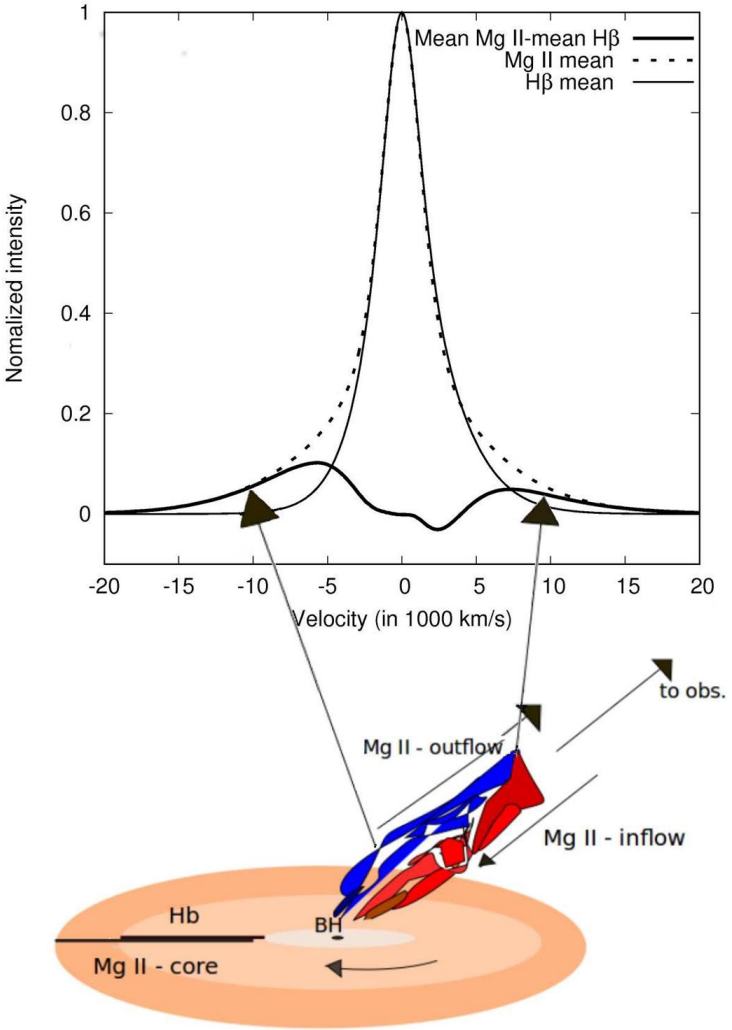
.

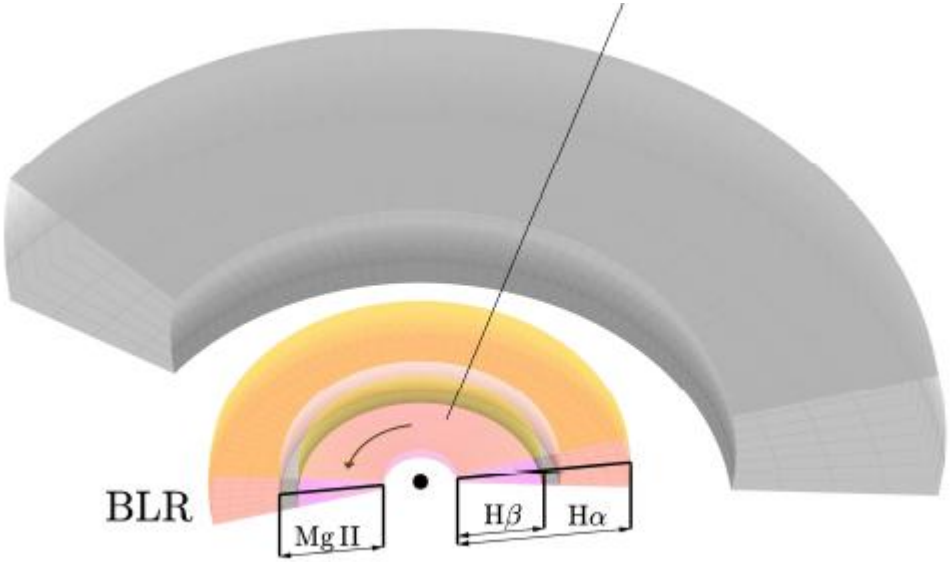


What is with other lines, e.g. Mg II?



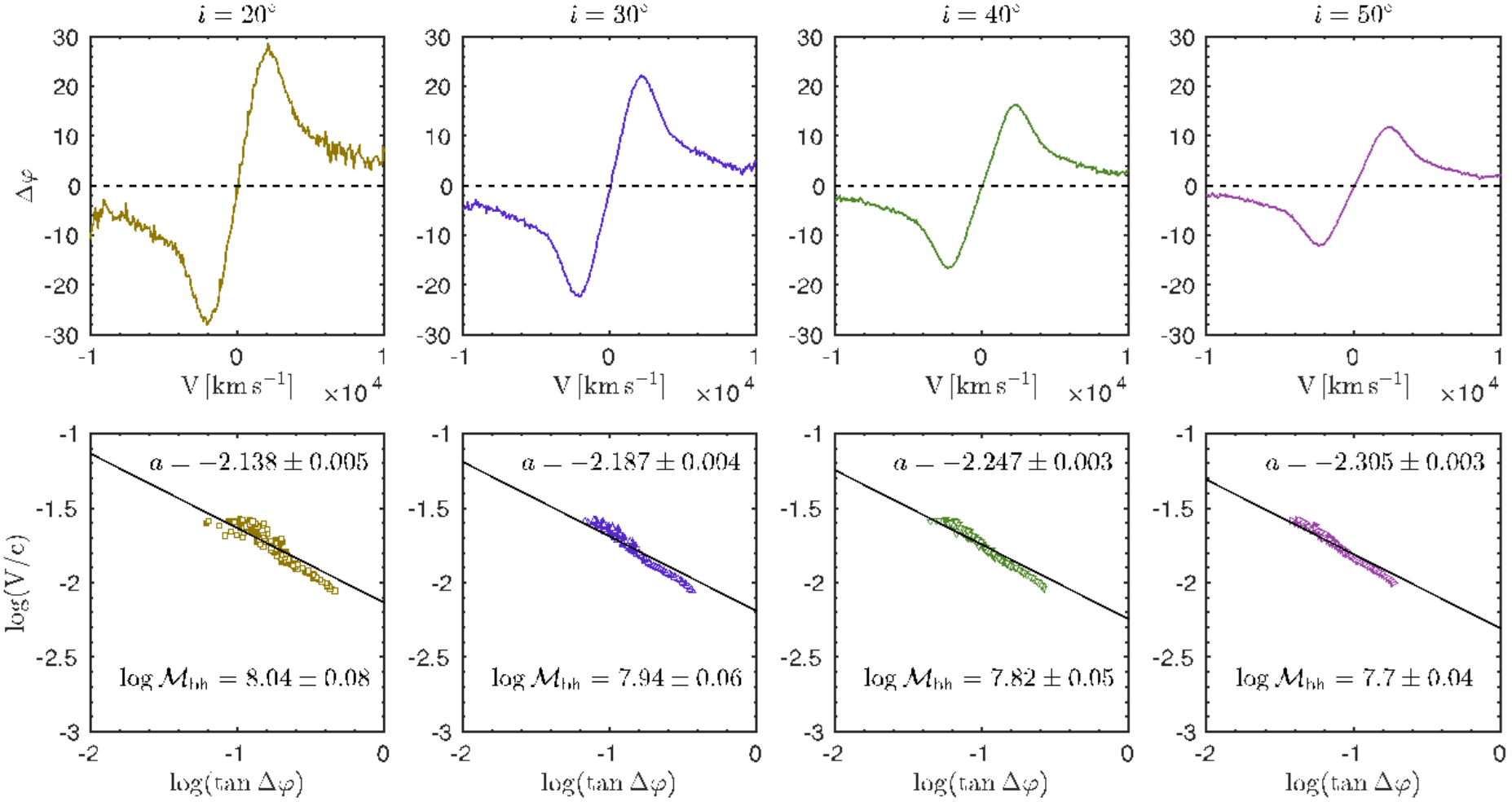
What is with other lines, as e.g. Mg II BLR – seems to be complex (Popovic et al. 2020, MNRAS, 484, 3180)



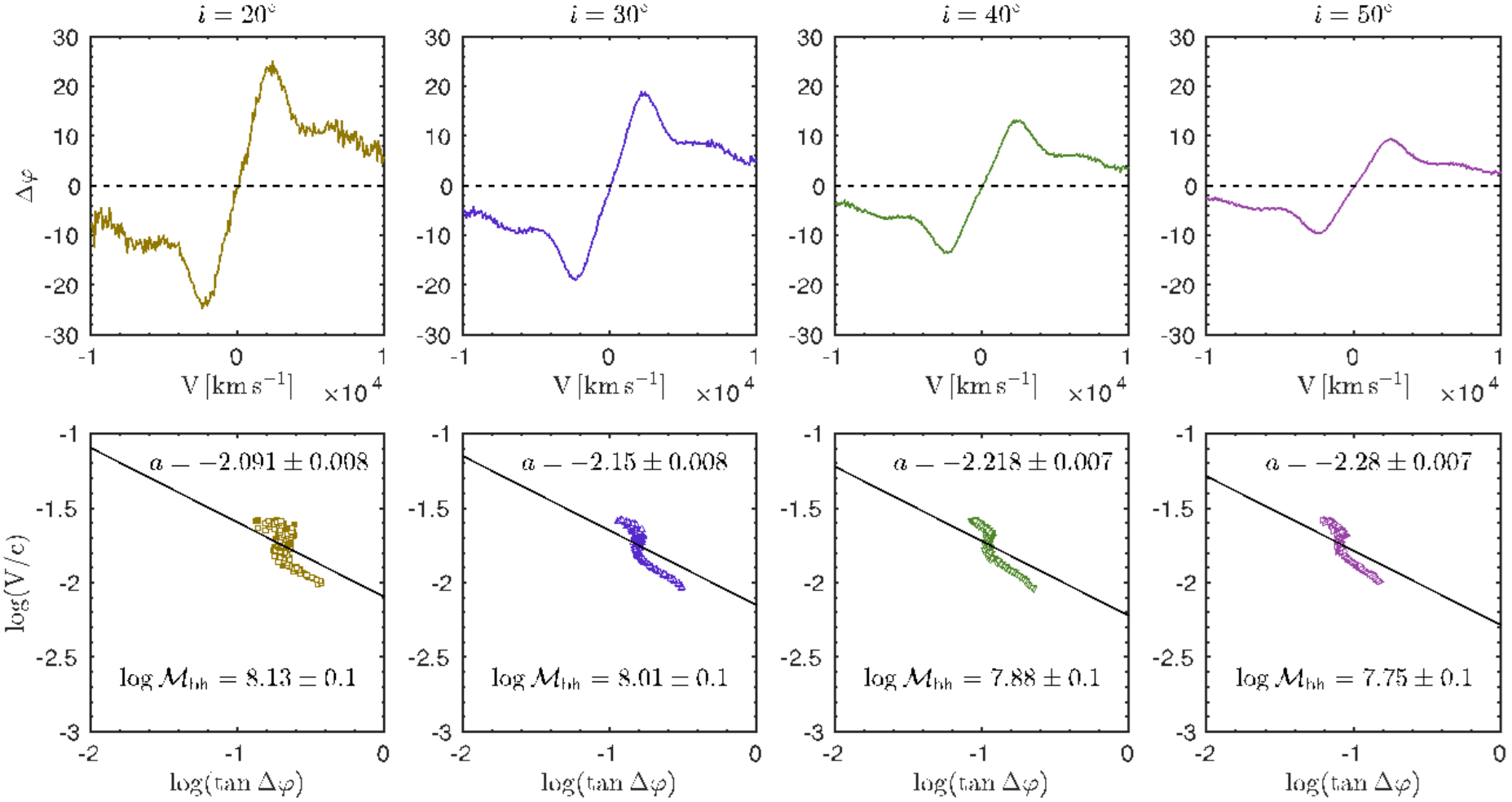


Savic et al. 2020, MNRAS, 497, 3947 – model, BLR with outflows/inflows

Hα


$i = 20°$
$i = 30°$
$i = 40°$
$i = 50°$
$\Delta\varphi$
V [km s^{-1}] ×10^4
log(V/c)
log(tan $\Delta\varphi$)
$a = -2.138 \pm 0.005$
$a = -2.187 \pm 0.004$
$a = -2.247 \pm 0.003$
$a = -2.305 \pm 0.003$
log $\mathcal{M}_{bh} = 8.04 = 0.08$
log $\mathcal{M}_{bh} = 7.94 = 0.06$
log $\mathcal{M}_{bh} = 7.82 \pm 0.05$
log $\mathcal{M}_{bh} = 7.7 \pm 0.04$

Mg II


$i = 20°$
$i = 30°$
$i = 40°$
$i = 50°$
$\Delta\varphi$
V [km s^{-1}] ×10^4
log(V/c)
log(tan $\Delta\varphi$)
$a = -2.091 \pm 0.008$
$a = -2.15 \pm 0.008$
$a = -2.218 \pm 0.007$
$a = -2.28 \pm 0.007$
$\log \mathcal{M}_{\rm bh} = 8.13 = 0.1$
$\log \mathcal{M}_{\rm bh} = 8.01 = 0.1$
$\log \mathcal{M}_{\rm bh} = 7.88 \pm 0.1$
$\log \mathcal{M}_{\rm bh} = 7.75 \pm 0.1$

Quasar SBS 1419+538, spectroploarometric observations of Mg II (Savic, Popovic, Shablovinskaya 2021 ApJL, 921, L21)

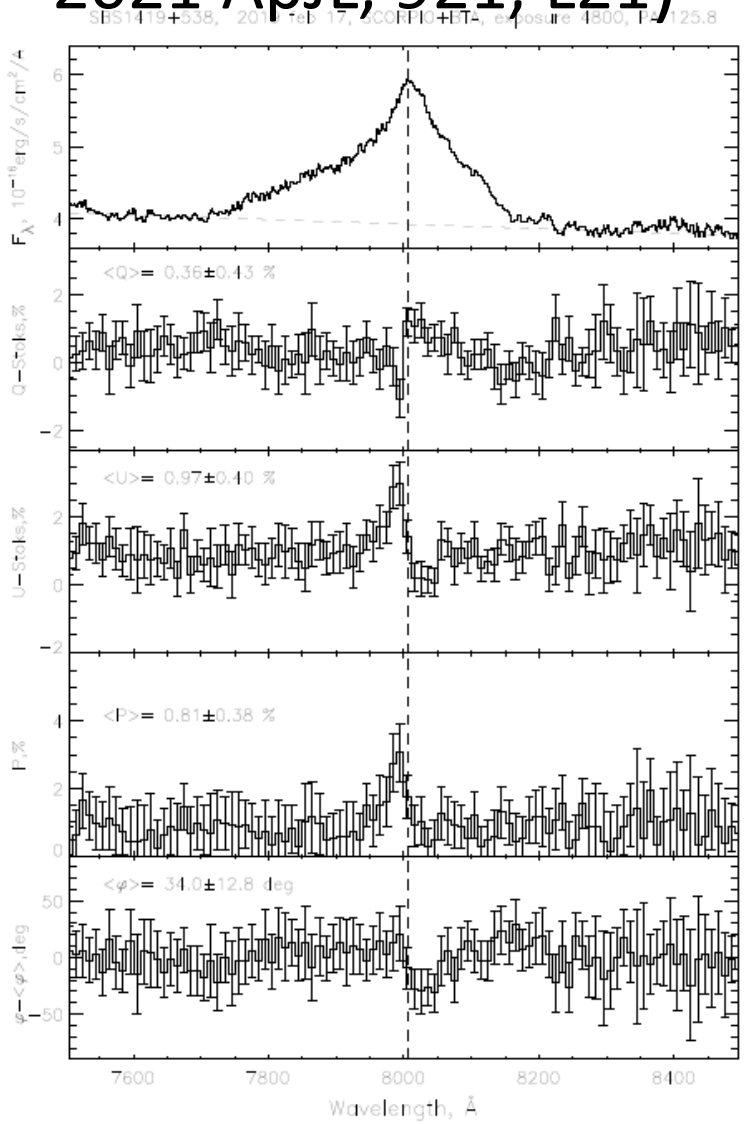
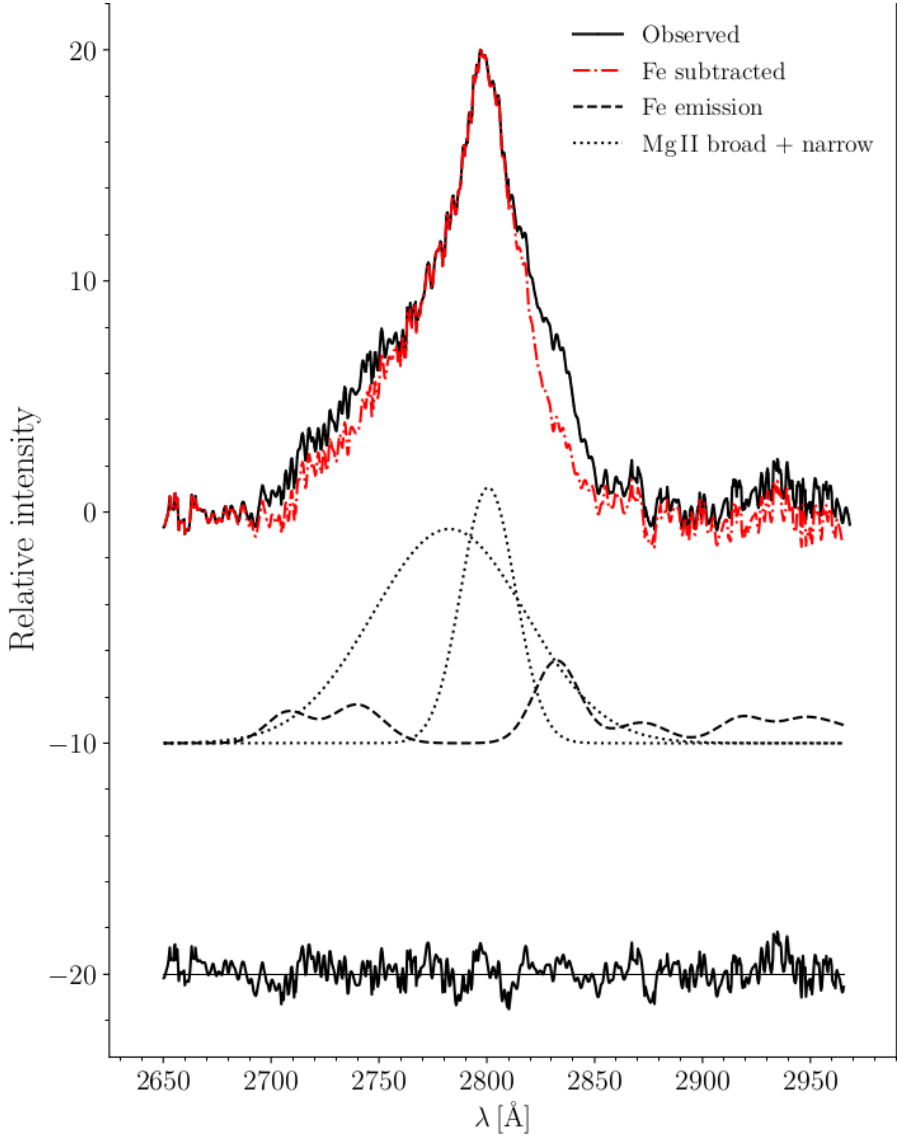
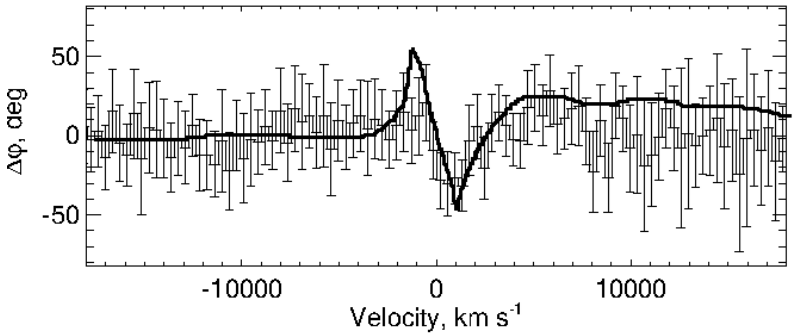


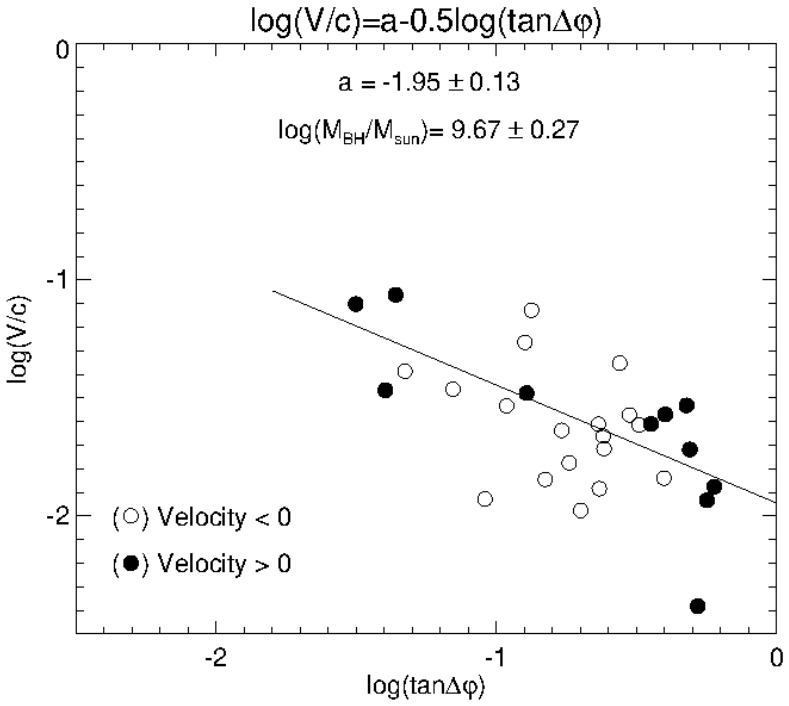
Fig. 5: The Mg II spectral region (1st panel), the Q and U Stokes

SBS1419+538 was observed with the 6-m telescope BTA of SAO RAS with the focal reducer SCORPIO-2 (Afanasiev & Moiseev 2011)

Quasar SBS 1419+538, spectroploarometric observations of Mg II (Savic, Popovic, Shablovinskaya 2021)







- Теорија и посматрања: Спектрополаризација и гравитациона сочива

A&A 634, A27 (2020)
https://doi.org/10.1051/0004-6361/201936088

Astronomy & Astrophysics

Spectroscopy and polarimetry of the gravitationally lensed quasar SDSS J1004+4112 with the 6m SAO RAS telescope★

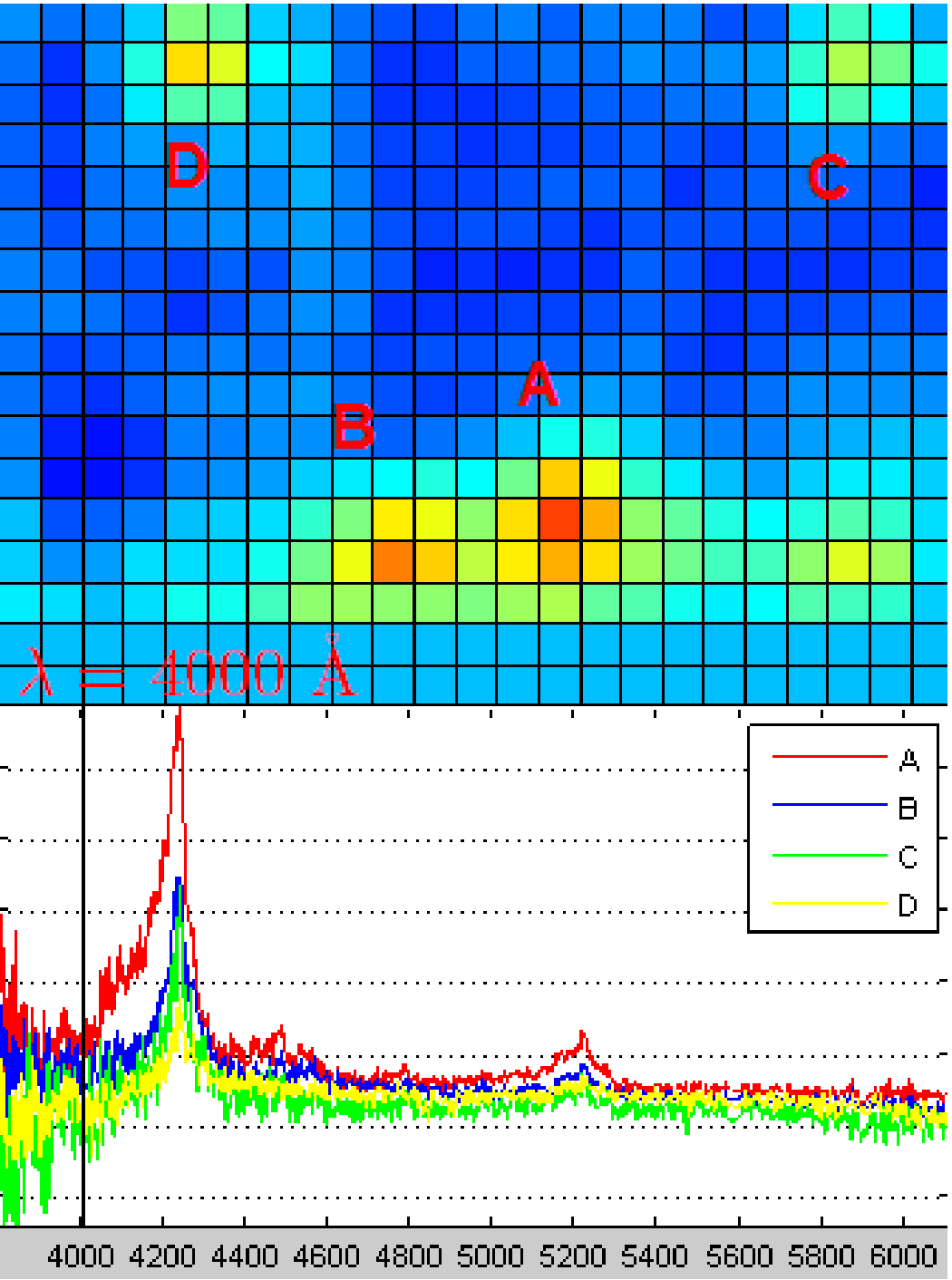
L. Č. Popović[1], V. L. Afanasiev[2], A. Moiseev[2,3], A. Smirnova[2], S. Simić[4], Dj. Savić[1,5], E. G. Mediavilla[6,7], and C. Fian[6]

A&A 647, A98 (2021)
https://doi.org/10.1051/0004-6361/202039914

Astronomy & Astrophysics

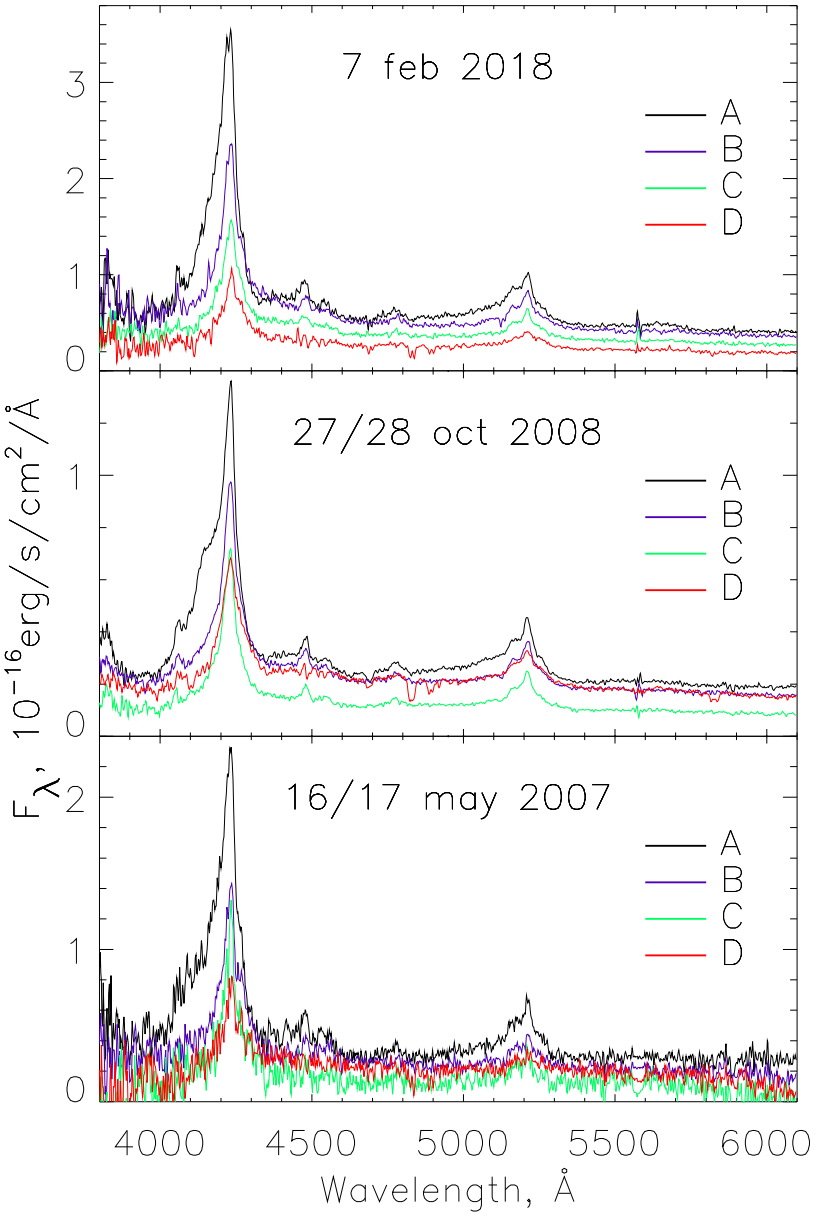
Spectroscopy and polarimetry of the gravitationally lensed quasar Q0957+561

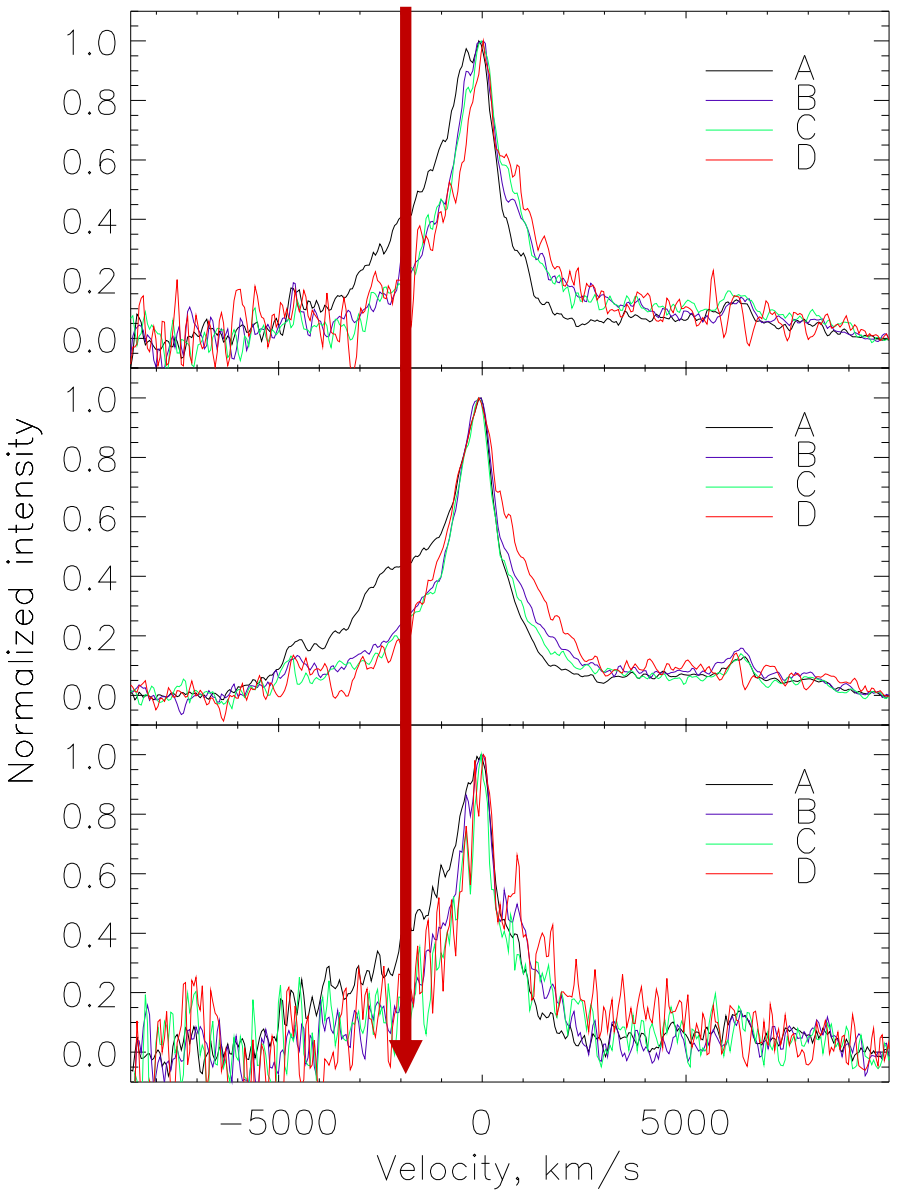
L. Č. Popović[1,2], V. L. Afanasiev[3,†], E. S. Shablovinskaya[3], V. I. Ardilanov[3], and Dj. Savić[1]



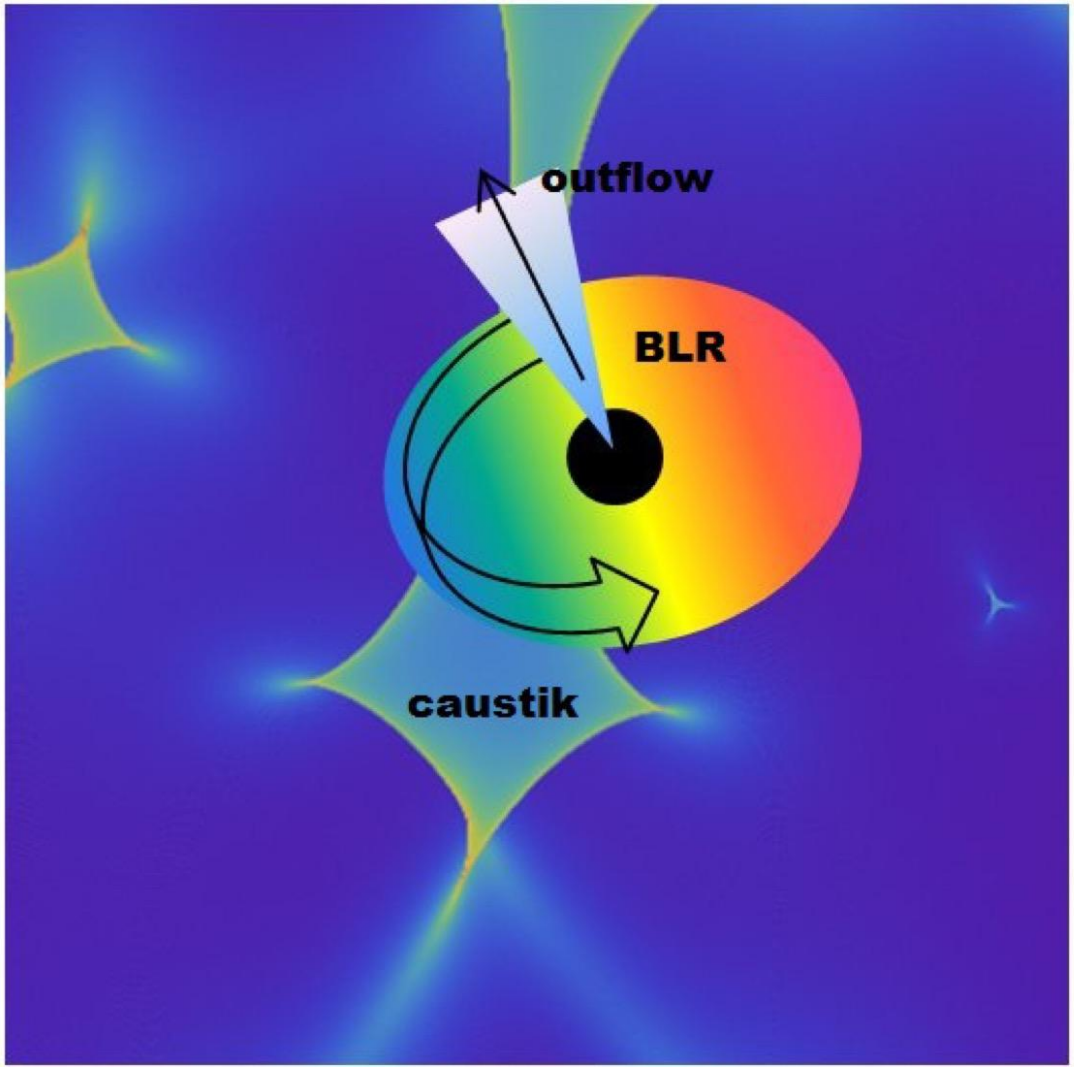
- Посматрања са 6м телескопом сочива SDSS J1004+4112, спектроскопски
- MPFS 2007
- SCORPIO 2008
- SCORPIO-2 2018
- Поларизациона посматрања у 2014. и 2017. години

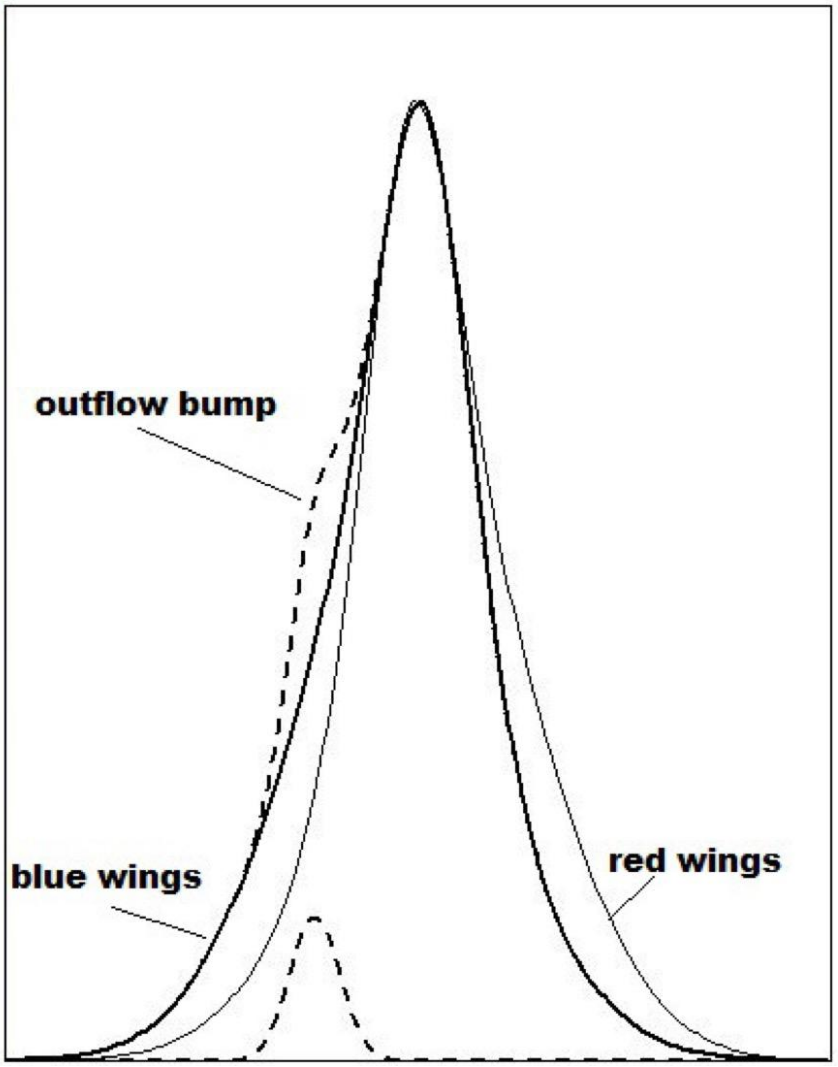
• A – компонента, промена у плавом крилу!



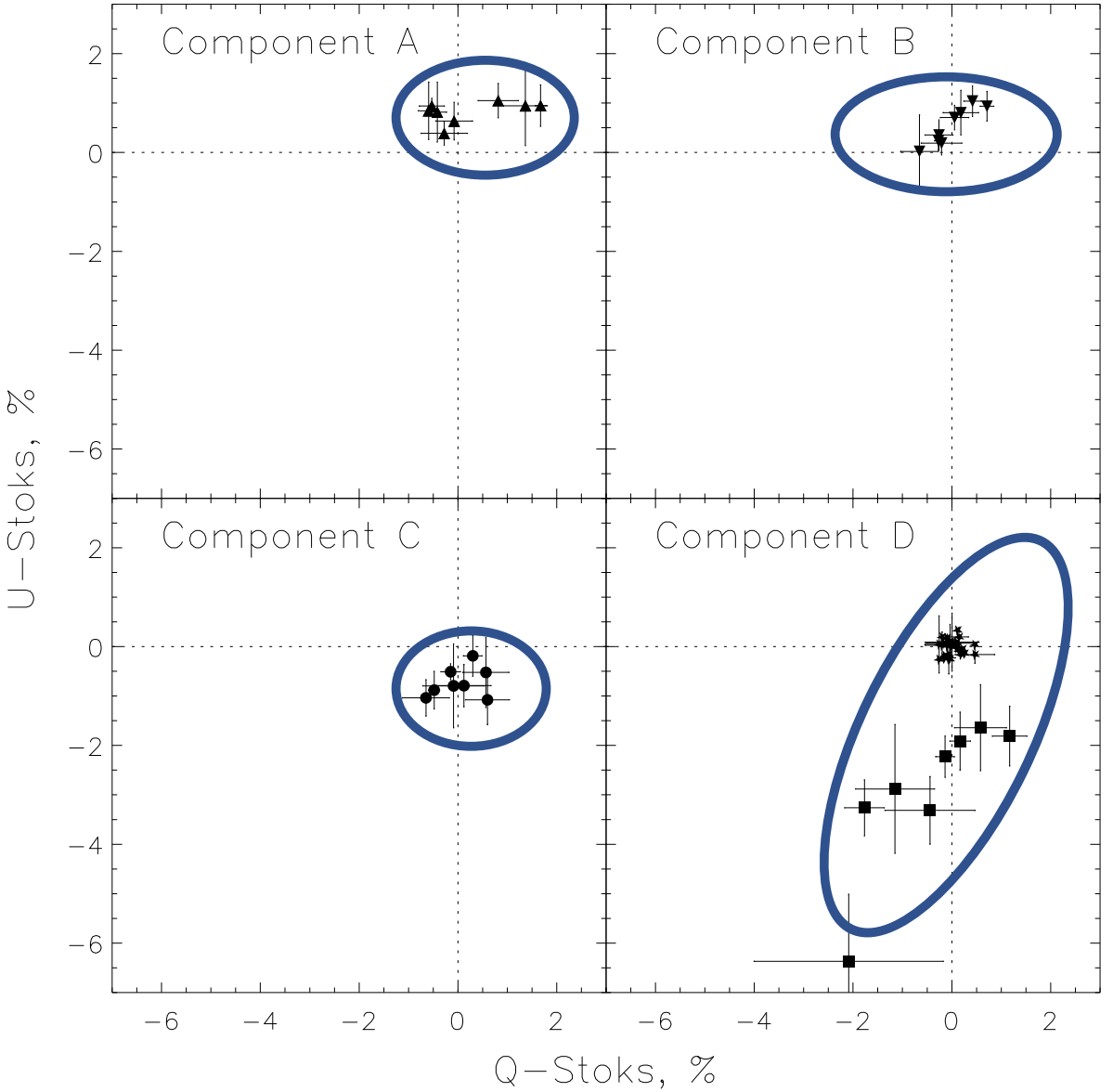


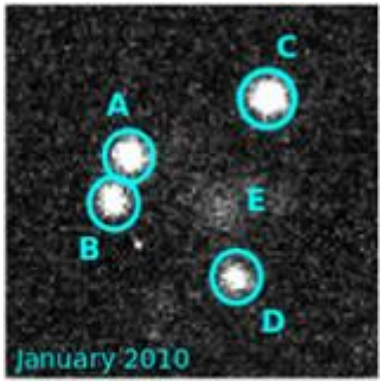
- Могуће објашњење је утицај сочива на део широколонијског регион
- BLR је вероватно доста велики да би могло микросочиво да утиче на укупан интензите линије, међутим C IV показује појачање плавог крила што указује на емисију млазова избачене материје!





- Поларизација – разлика између компоненти, компонента D као да мења поларизационе параметре






Спасибо за
внимание!