BROAD EMISSION LINES VARIABILITY: A WINDOW INTO THE HEART OF AGN

Dragana Ilić and..

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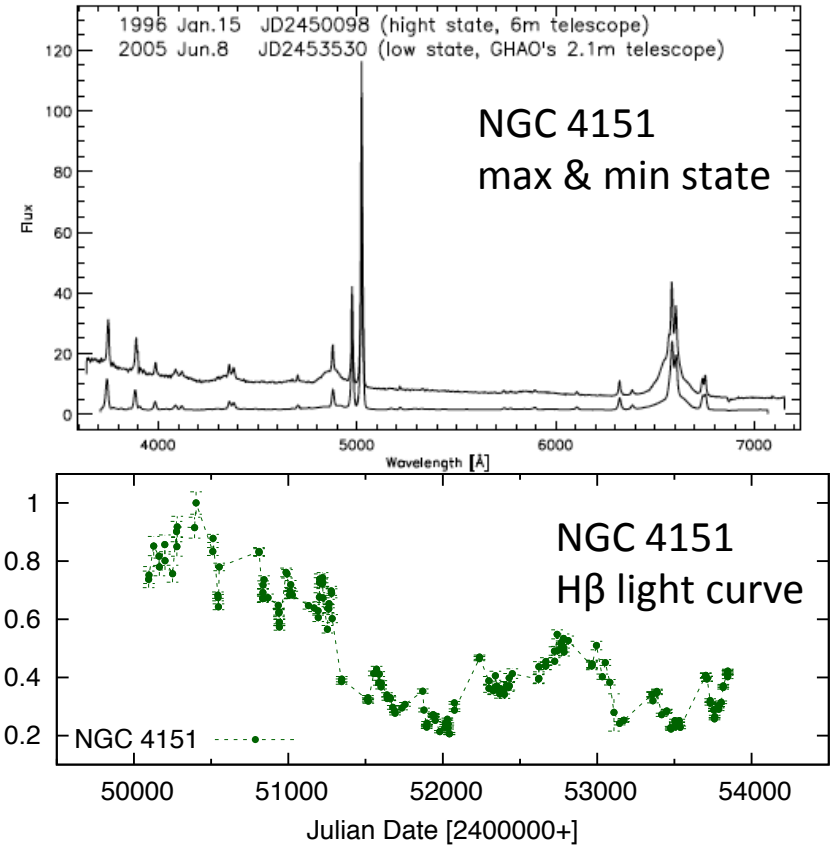
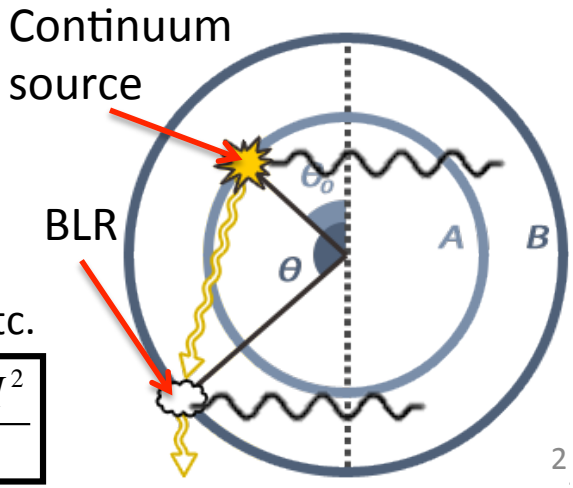
AGN variability:
- innermost central region

- center cannot be resolved with current optical telescopes
  ➔ spectroscopy is an important tool
- moreover, AGN are variable objects in optical ➔ everything varies:
  - line flux and continuum variations, line profile
  - we can estimate: BLR geometry and physics, etc. --> M_{BH}



Shapovalova+ 2008



see e.g. Peterson+2004, etc.

$$M_{BH} = f \frac{R_{BLR} FWHM^2}{G}$$

Long-term monitoring of AGN

- **PIs: Alla Shapovalova (Russia) Vahram Chavushyan (Mexico)**
- constantly observing well known AGN with broad emission lines:
  - NGC 5548 – 9+ years (Shapovalova+ 2004, Ilić 2007, Popović+2008, Bon+ 2016 accepted)
  - NGC 4151 – 11+ years (Shapovalova+ 2008, 2009, 2010a, Ilić+2010, Bon+ 2012, , Rakić+ 2016 submitted)
  - 3C390.3 – 13 years (Shapovalova+ 2001, Shapovalova+ 2010b, Popović+ 2011, Jovanović+ 2010, Kovačević+ 2014)
  - Ark 564 – 11 years (Shapovalova+ 2011, Shapovalova+ 2012)
  - Arp 102B – 12 years (Shapovalova+2013, Popović+ 2014, Kovačević+ 2014, Ilić+2015)
  - E1821+643 – 25 years (Shapovalova+2016, Ilic+2016 in prep.)

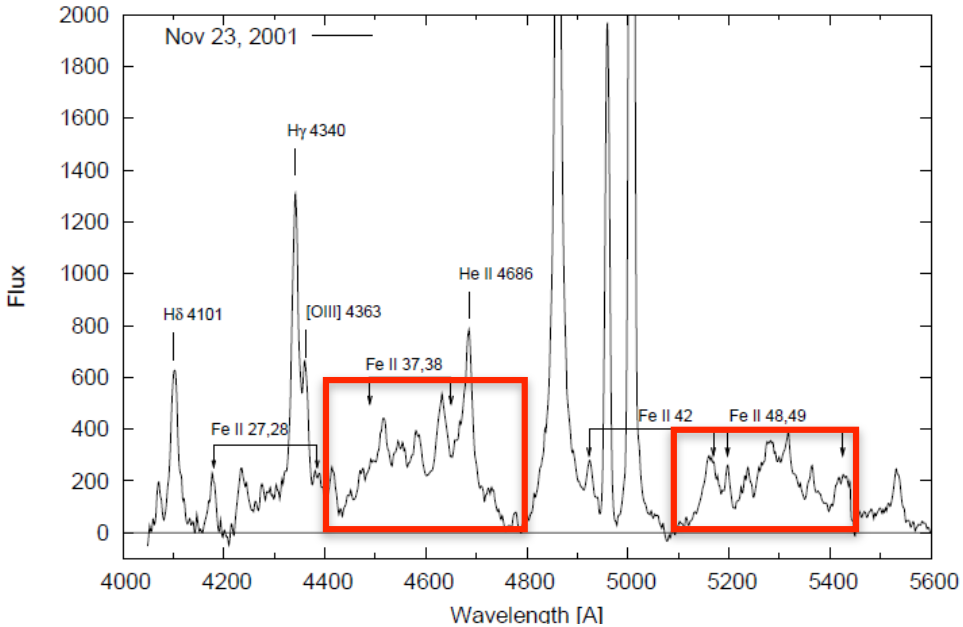
Observations

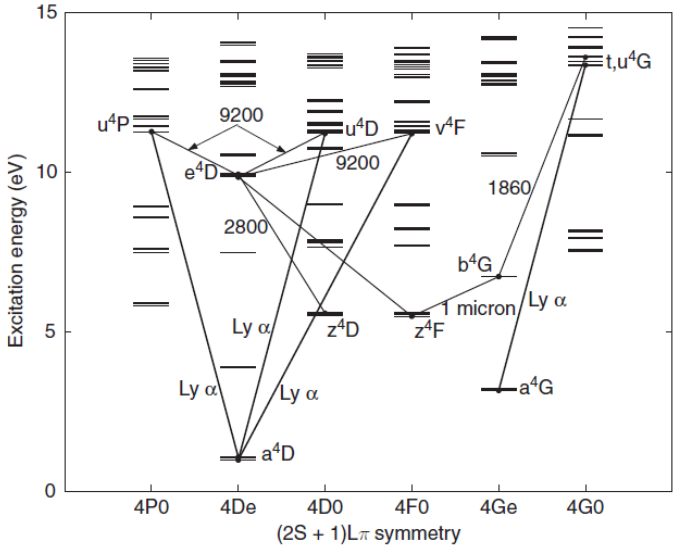
- 6m + 1m telescopes - SAO RAS (Russia)
- 2.1m telescope - Guillermo Haro Observatory, Cananea, Sonora, Mexico
- 2.1m telescope - Observatorio Astronómico Nacional, San Pedro Martir, Baja California, Mexico
- 3.5m + 2.2m telescopes – Calar Alto Observatory, Spain

1. case: NLSy1 Ark 564

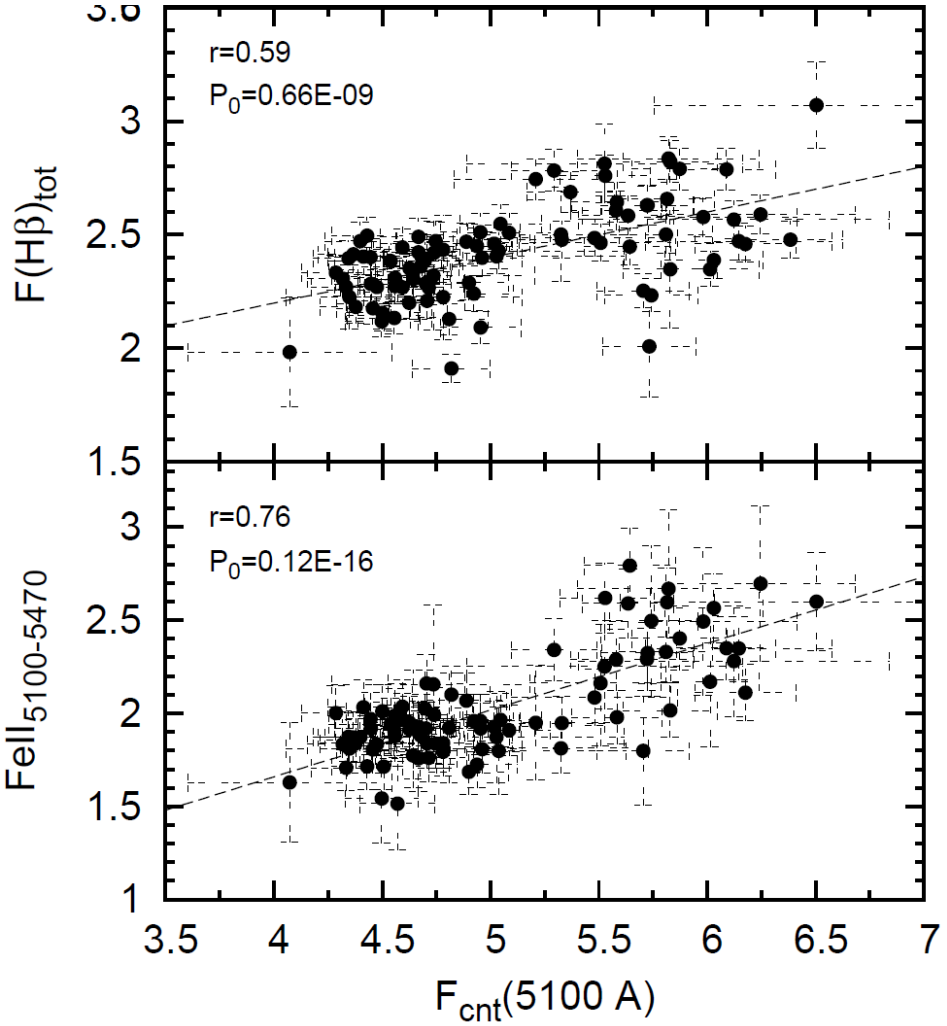
- nearby narrow-line Sy 1 galaxy: narrow permitted lines, z=0.025 (e.g. Shemmer et al. 2001)
- strong Fe II emission: many line transitions, blended (multiplets)
  - where is the origin of Fe II and how lines are produced?

Fe II is coming from the intermediate line region (see e.g. Kovačević+2010)

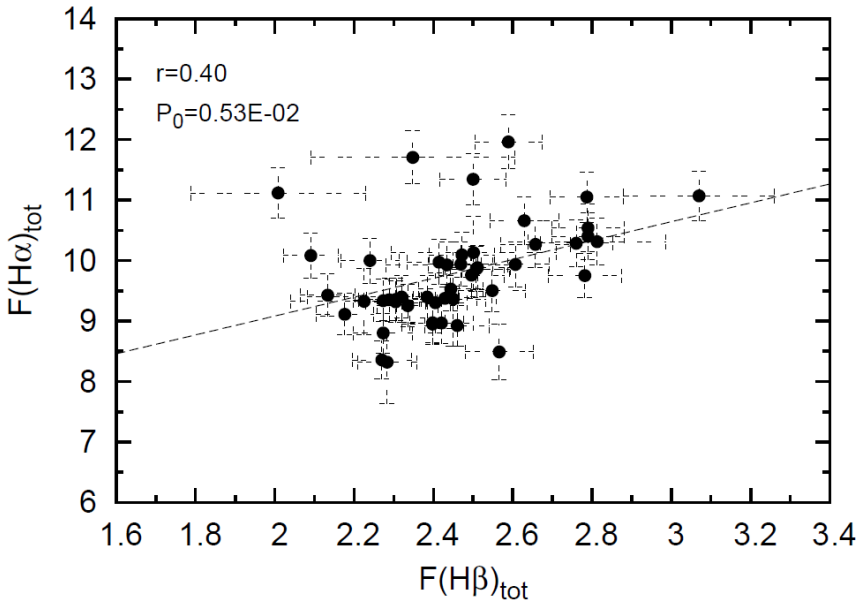




Correlations: continuum vs. lines



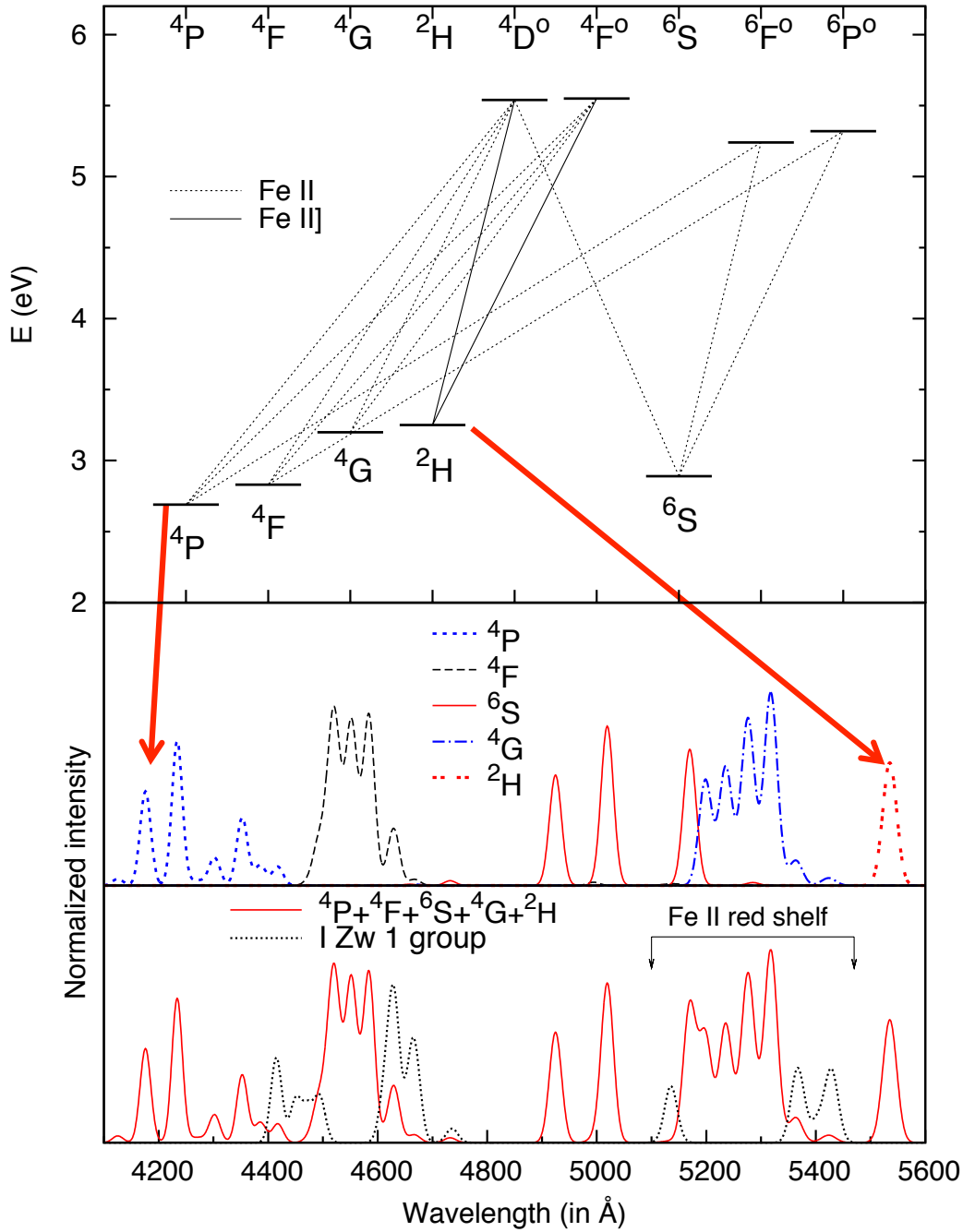
- Hβ and Fe II follow change of the continuum flux
- Hα and Hβ fluxes: low level of correlation!



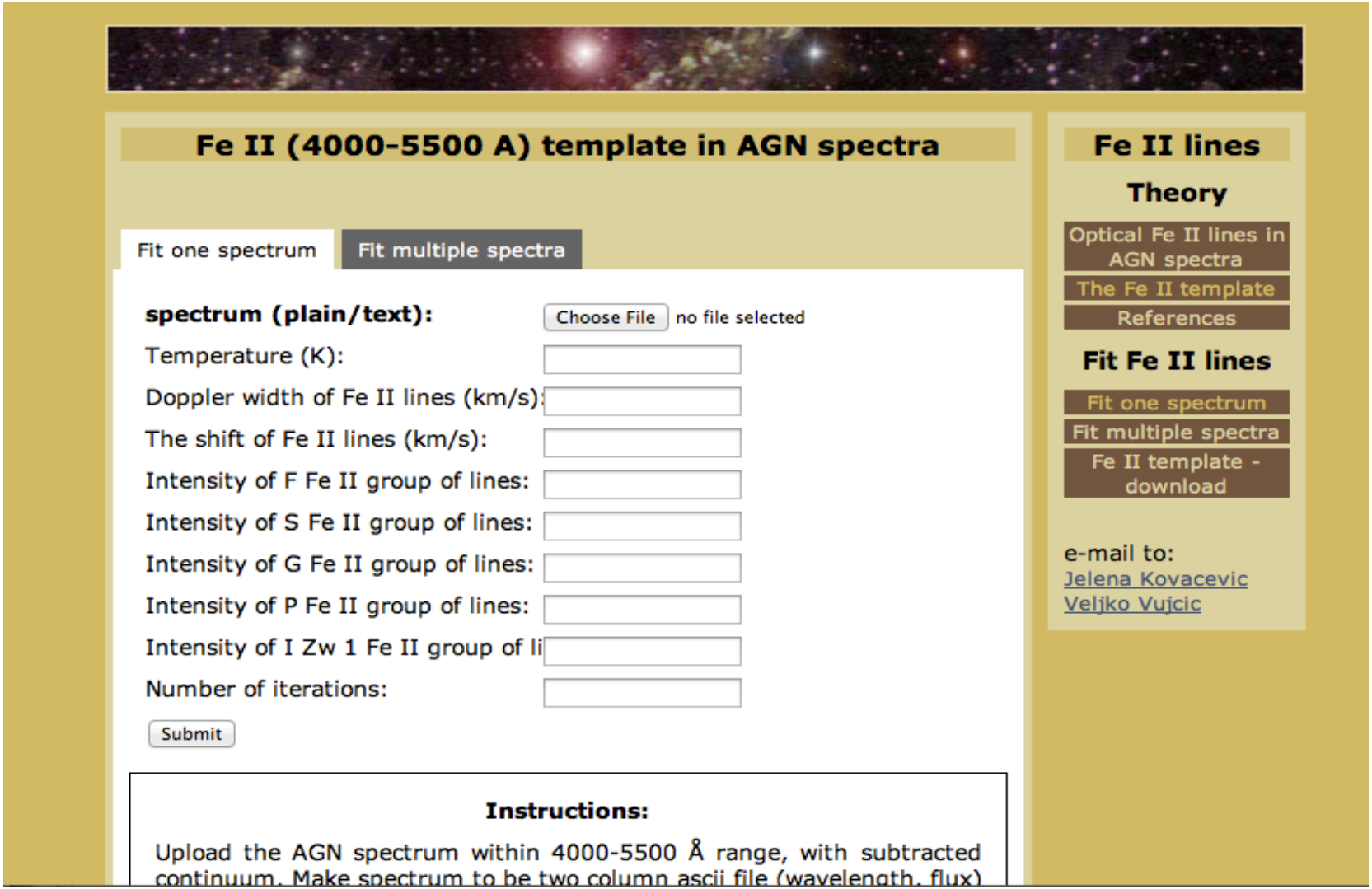
Shapovalova+ 2012

Fe II fittings

- Extended template for Fe II fitting (Kovačević+ 2010, Shapovalova+2012)
- **The new optical Fe II template**, which enables better fit of the iron lines than any other empirical or theoretical template

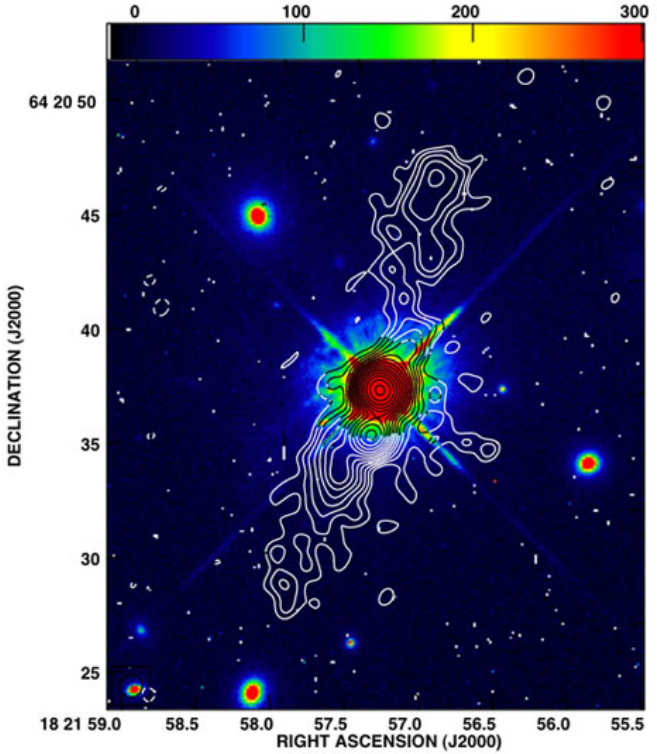


Fe II lines fitting - online tool: may help

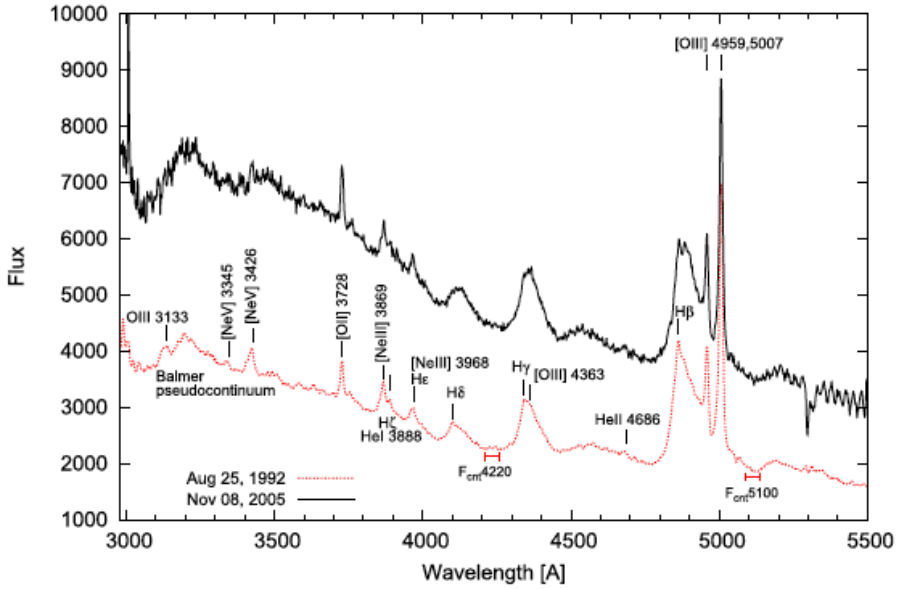


Serbian VO: http://servo.aob.rs/FeII_AGN/

2. case: Quasar E1821+643

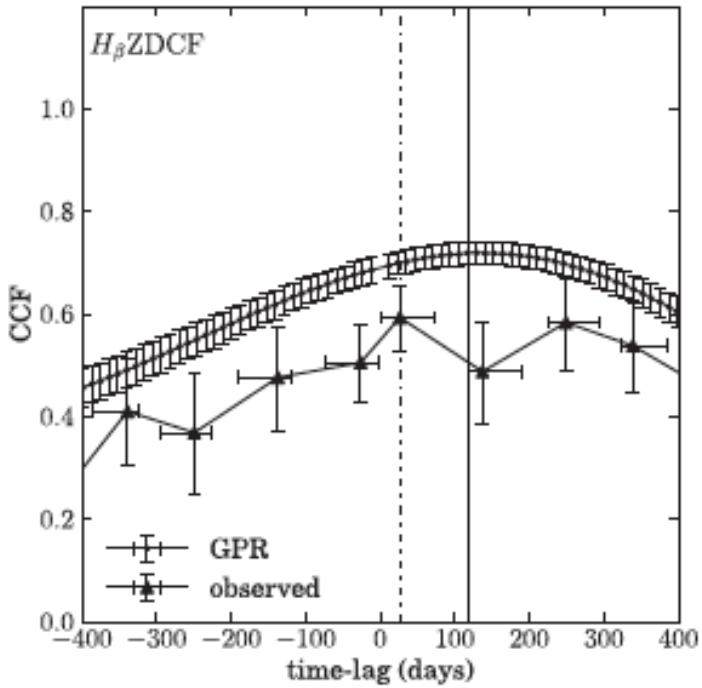


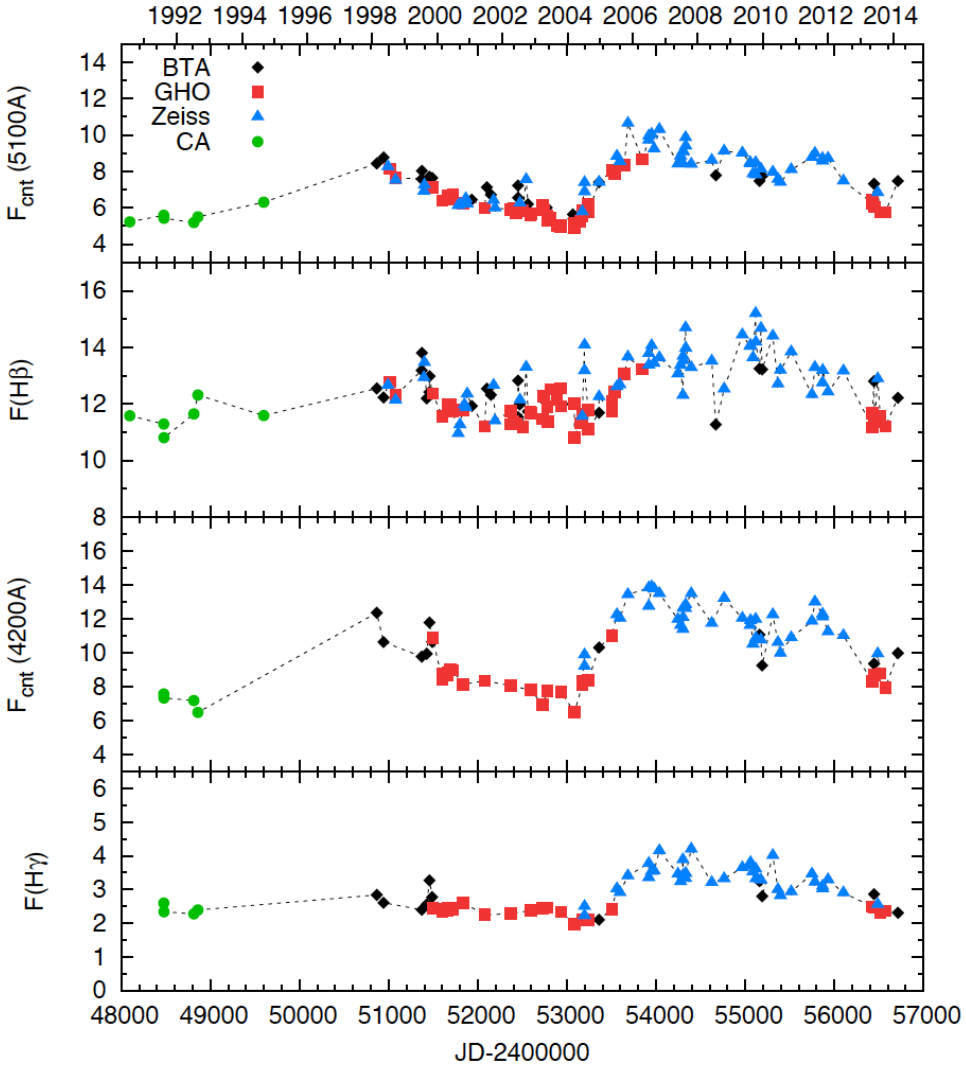
- the most luminous, radio-quiet quasars in local universe (z = 0.297, M_V = −27.1)
- models of strong optical/UV "blue bump" gives SMBH mass of $3 \times 10^9 M_{sun}$ (Kolman+ 1993)
- a candidate for SMBHs binary (recoil?) since it has very interesting broad line profiles:
  - highly red asymmetric profiles
  - redshifted (≈1000 km/s)
- we did: **first long-term spectral optical monitoring**



QSO E1821+643

- light curves in 1990 - 2014
- CCFs give lags of ~120ld
- giving $M_{BH}=2.6\times10^{9}$Msun

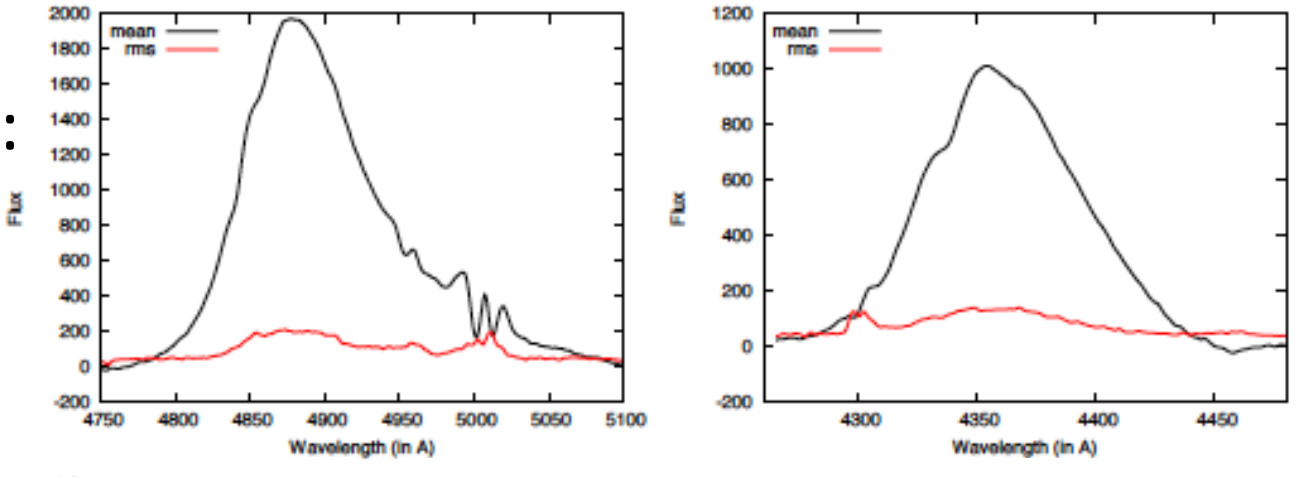




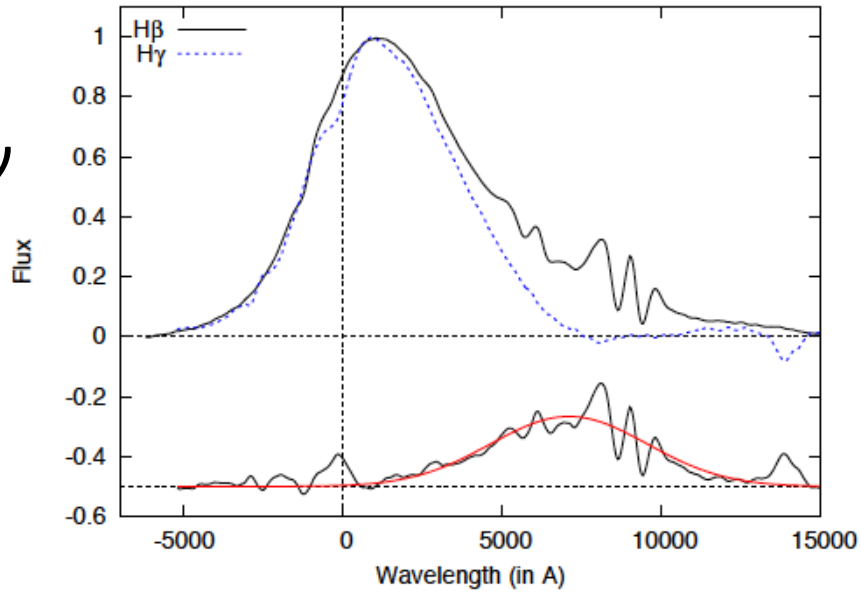
- Shapovalova +, 2016, ApJS

Mean & rms profiles of Hβ and Hγ

Mean/RMS profiles:
no change in
25 years!



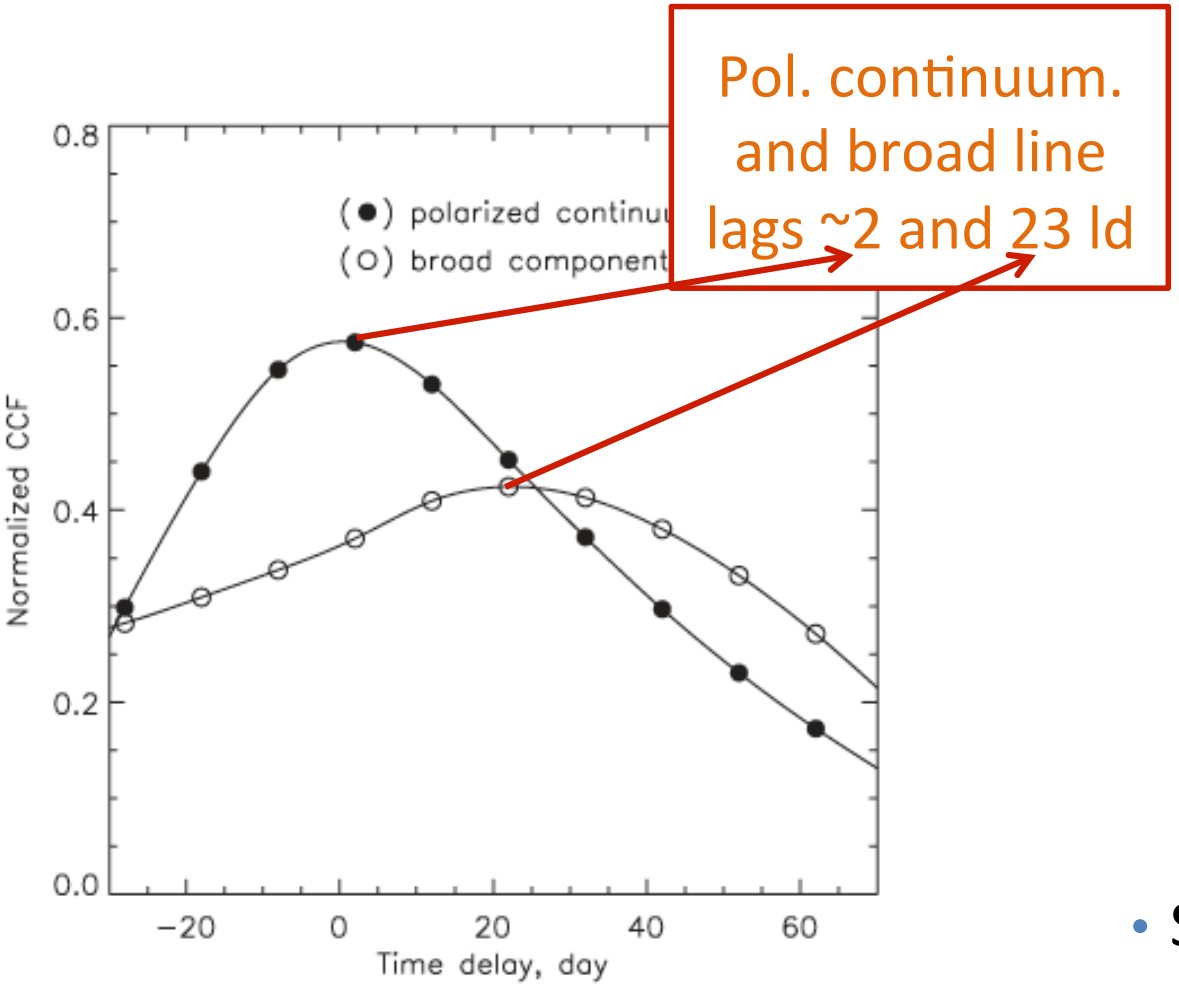
- the mean Hβ has a more extensive red wing than mean Hγ
- an additional emission in the far wing of the Hβ line
- the difference has:
  - shift~ 7100 km/s
  - FWHM ~5800 km/s

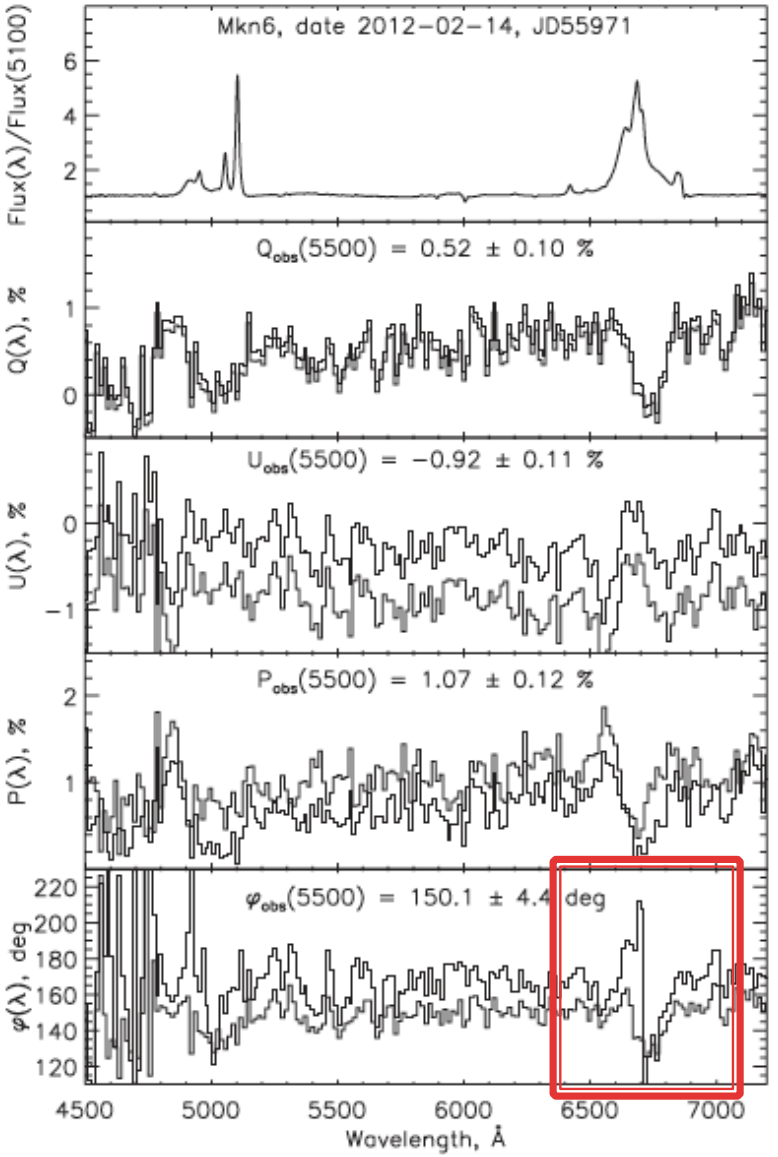


- Ilić+, 2016 in prep.

Spectro-polarimetric monitoring: Mrk 6 (2010-2013)

- **12 epochs observed –** 6m SAO telescope
- **NOTE**: ISM polarization can strongly affect P.A. across the line profile

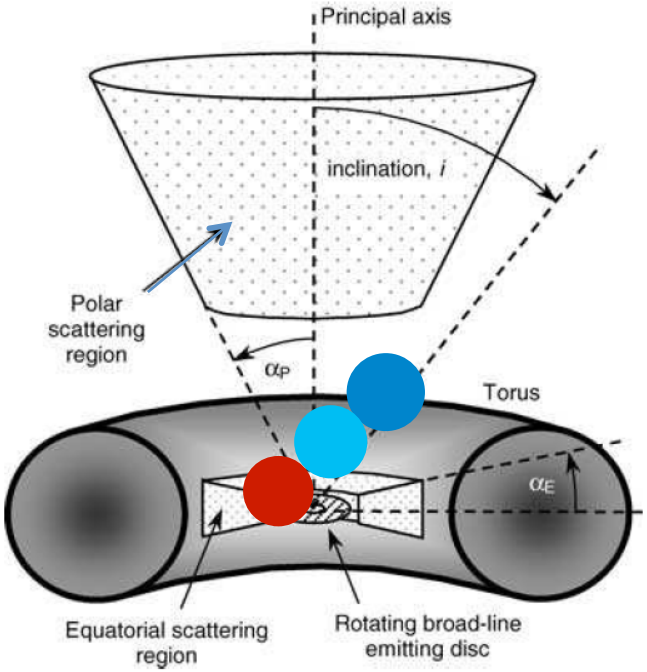




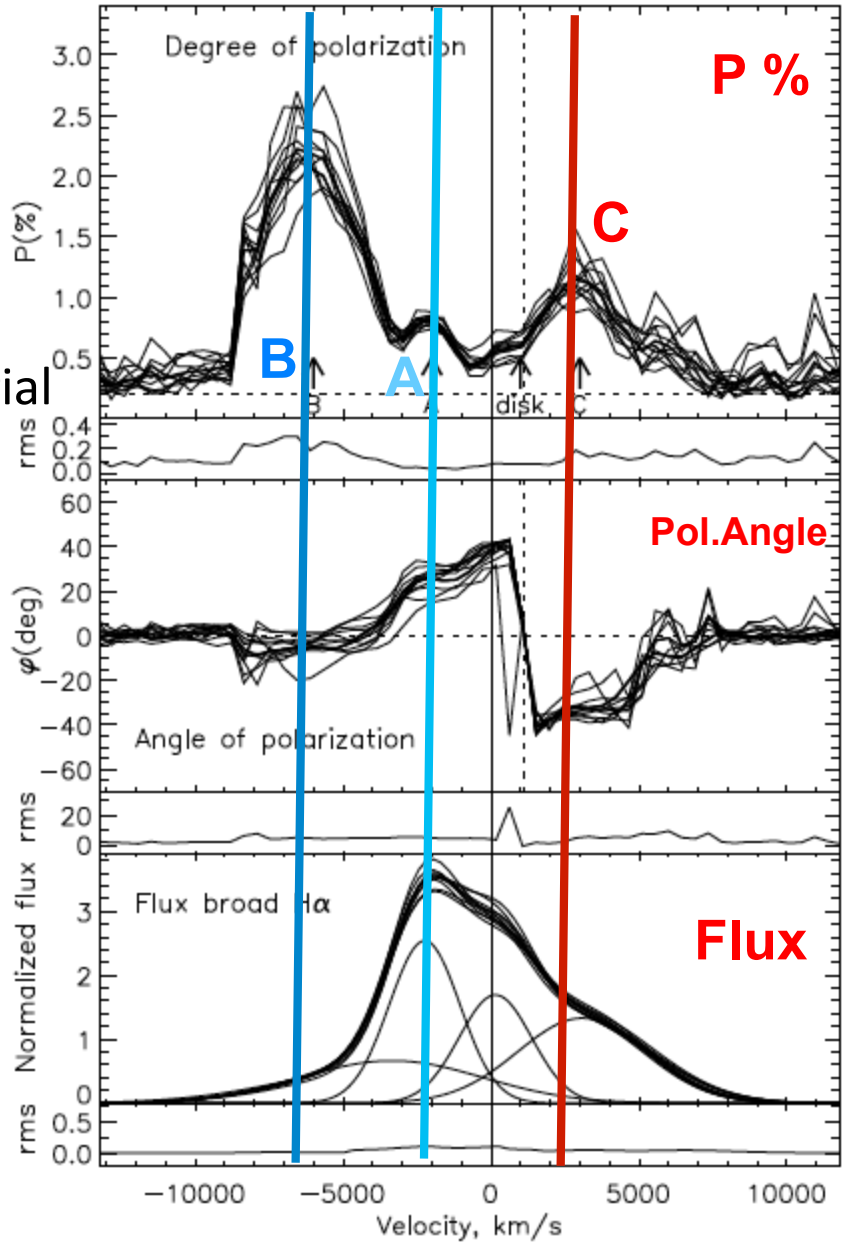
- See: Afanasiev+ 2014

Mrk 6: Polarization in broad lines

- continuum polarization subtracted
- different sources of polarization: **different geometries/kinematics**



- **Torus** – equatorial polarization
- **Two additional polarizations components** probably polar polarization



A: outflow, v=2000km/s, P~0.6%

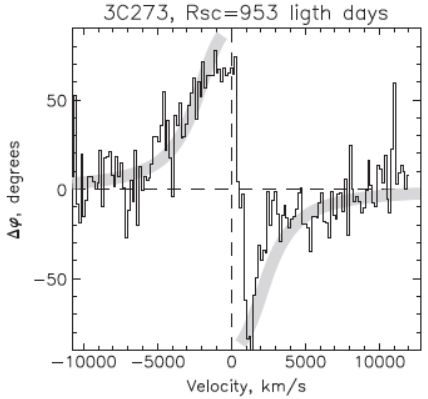
B: outflow (jet?) v=6000km/s, P>2%

(Afanasiev+2014)

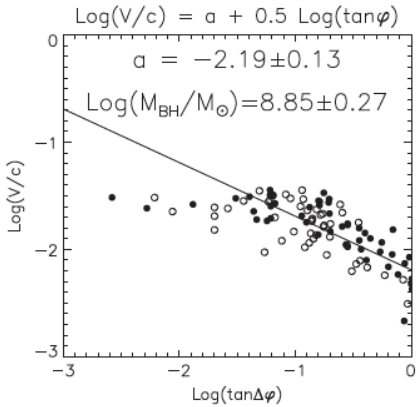
SMBH mass by spectropolarimetry of broad Hα

$$M_{BH-kep} = 10^{2a}\frac{c^2 R_{sc}}{G\cdot\cos^2(\theta)} = 1.78\cdot 10^{2a+10}\frac{R_{sc}}{cos^2(\theta)}M_\odot$$

observed shape of polarization angle across broad line

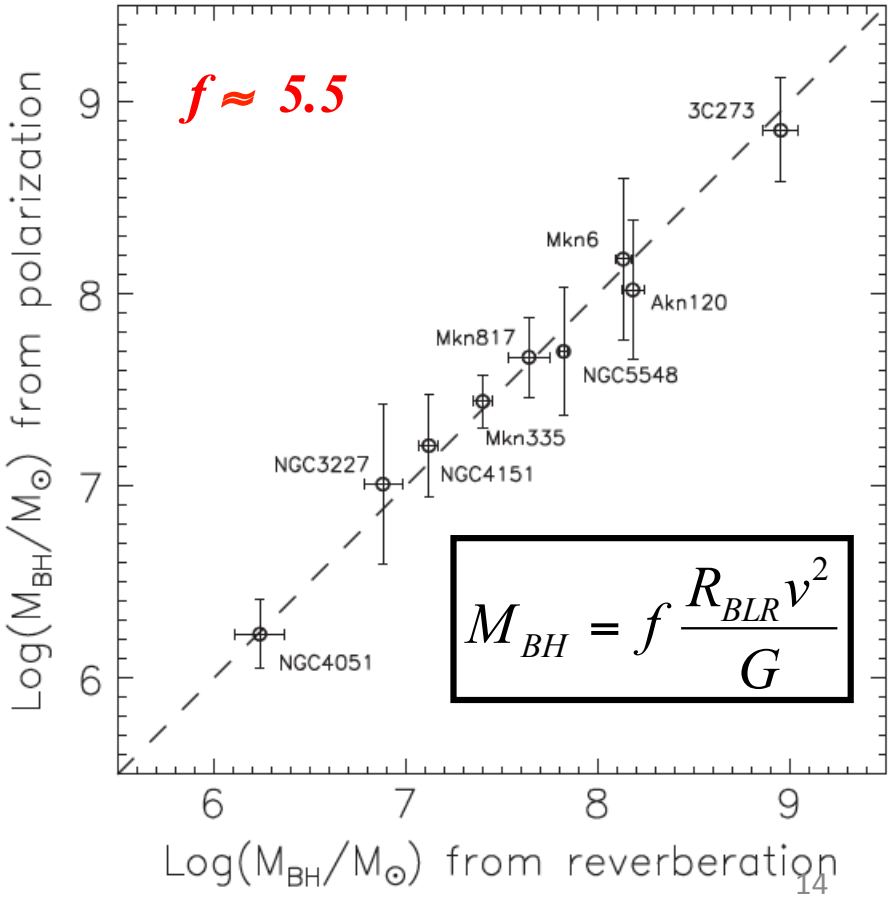


Velocity across line vs. tanφ



see
Poster B.11 of
Djordje Savic

Comparison: masses by polarization vs. reverbration



$$M_{BH} = f\frac{R_{BLR}v^2}{G}$$

Afanasiev & Popovic, ApJL, 2015, v.800, L35

Conclusions

- optical spectral variability is very useful for investigations of the innermost regions of AGN
- spectroscopy (+monitoring) is time-consuming, but the obtained results can be fundamental for other research
- high-quality polarization monitoring is the future
  - gives new information about the geometry, but also M_{BH}

Ad for the conference on spectral lines:
11th SCSLSA: August 2017, Serbia
http://www.scslsa.matf.bg.ac.rs

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