Long term optical monitoring of Active Galactic Nuclei: past & future

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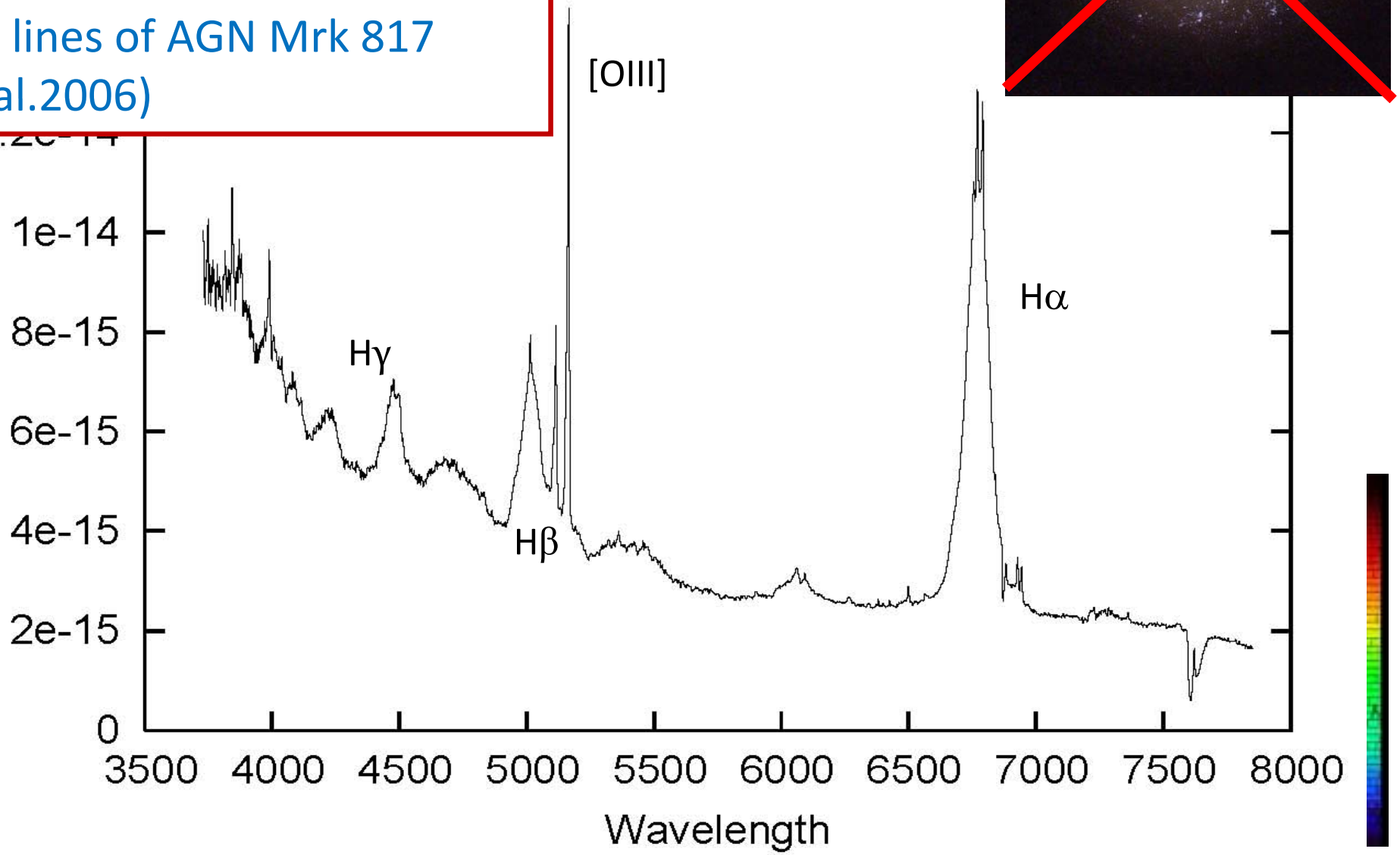
all about spectra

Balmer lines of AGN Mrk 817
(Ilic et al.2006)



Long-term spectral monitoring

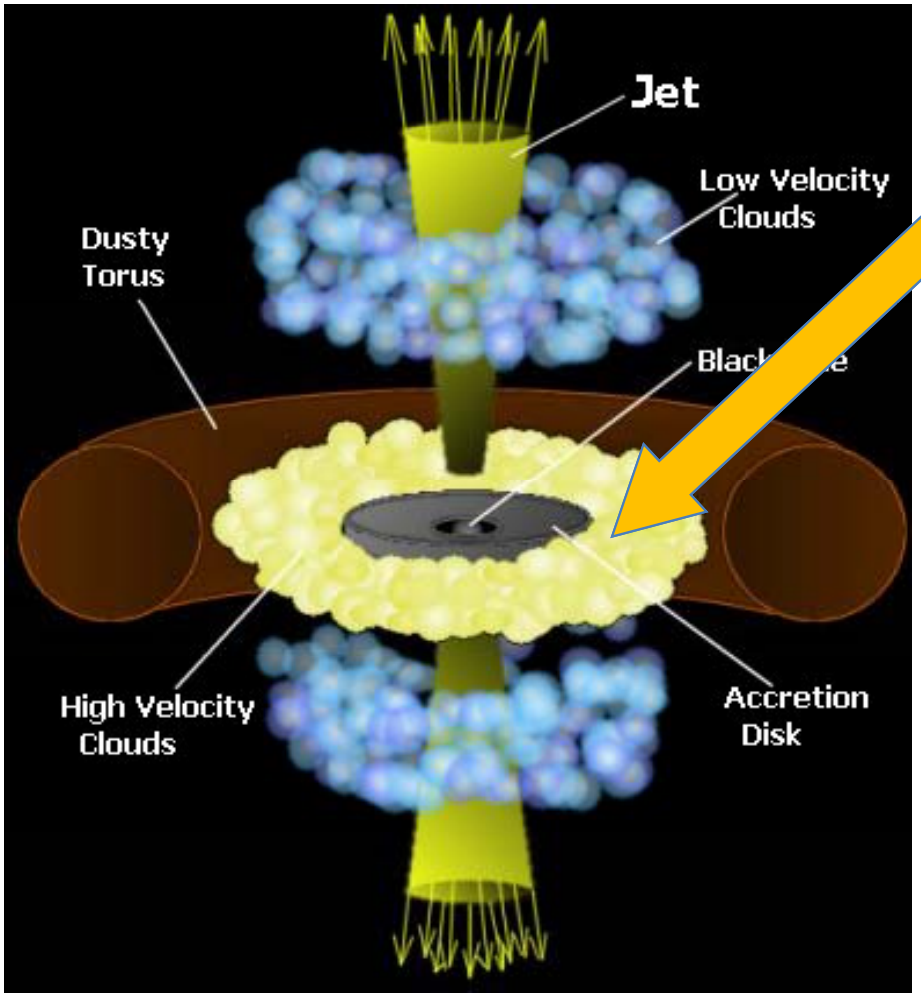
- PIs: Alla I. Shapovalova (Russia)
  Vahram H. Chavushyan (Mexico)
- constantly observing well known AGN:
  - NGC 5548 – 9 years (Shapovalova+ 2004, Ilić 2007, Popović+ 2008)
  - NGC 4151 – 11 years (Shapovalova+ 2008, 2009, 2010a, Bon et al. 2012)
  - 3C390.3 – 13 years (Shapovalova+ 2010b, Popović+ 2011, Jovanović+ 2010)
  - Ark 564 – 11 years (Shapovalova+ 2012, ApJS)
  - Arp 102B – 12 years (in prep.)
- Study of variability: continuum flux, line shapes, line fluxes …

Observations

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

Future Science 2012: Ilić et al.

Aims:



- investigation of the broad line region using spectral monitoring
  1. to constrain the BLR physics and geometry
  2. needed for accurate BH mass estimates
- some results from our spectral monitoring:
  NGC 4151
  Ark564
  3c390.3

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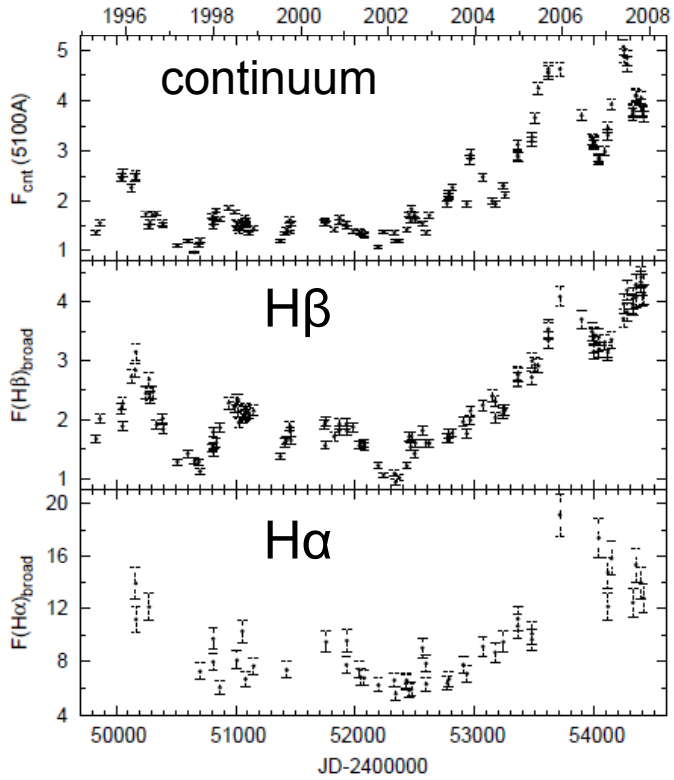
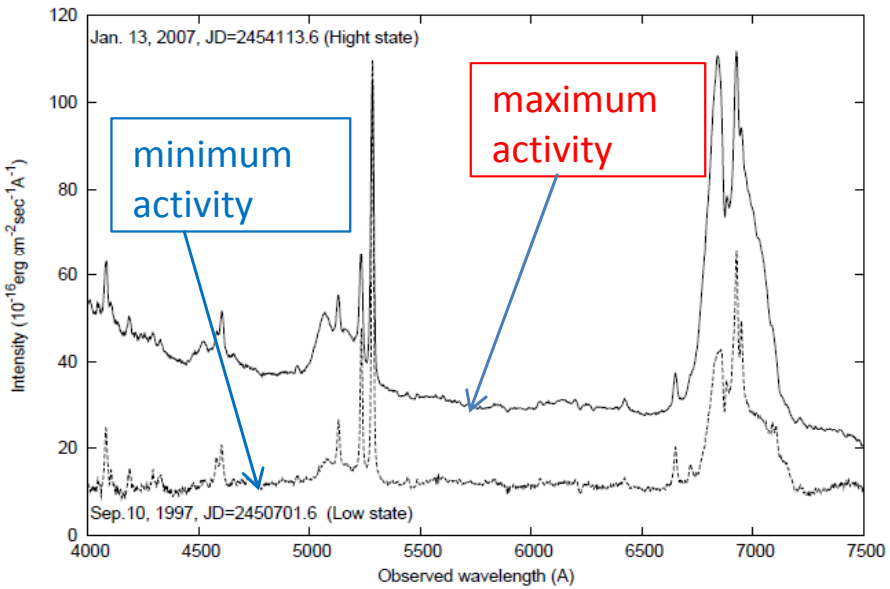
AGN: variable optical spectra



- Everything varies!
  1. line flux and continuum flux
  2. line profiles
     (e.g. bumps/asymmetries appears)
  3. so strong that AGN type change:
     type 1 -> type 2

3c390.3
(Shapovalova + 2010)



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Black Hole mass estimates

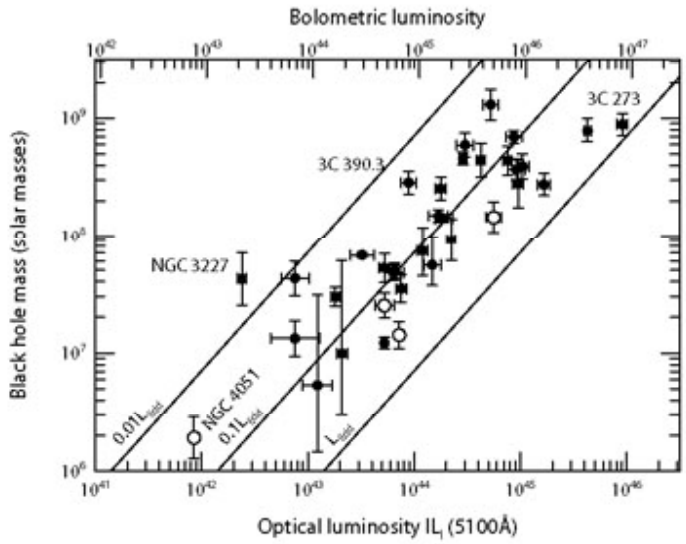
- virial theorem: $$M_{BH} = f\,\frac{R_{BLR}v^2}{G}$$

  calculated from line widths, e.g. FWHM

  (Wandel+ 1999; Kaspi+ 2000, 2005; Peterson+ 2004, Bentz+ 2009)

- reverberation mapping → the BLR radius from time-lag: R_{BLR}
  (e.g. for NGC 4151, 3c390. 3 in Shapovalova+2009, 2010)

- scaling relationships: $M_{BH} \sim L_{opt} \sim R_{BLR}$



- Problems e.g. BLR geometry :
  f depends on geometry and kinematics
  - e.g. most common AGN spectra
    show $i < 20°$ (La Mura et al. 2009, ApJ, 693, 1437)

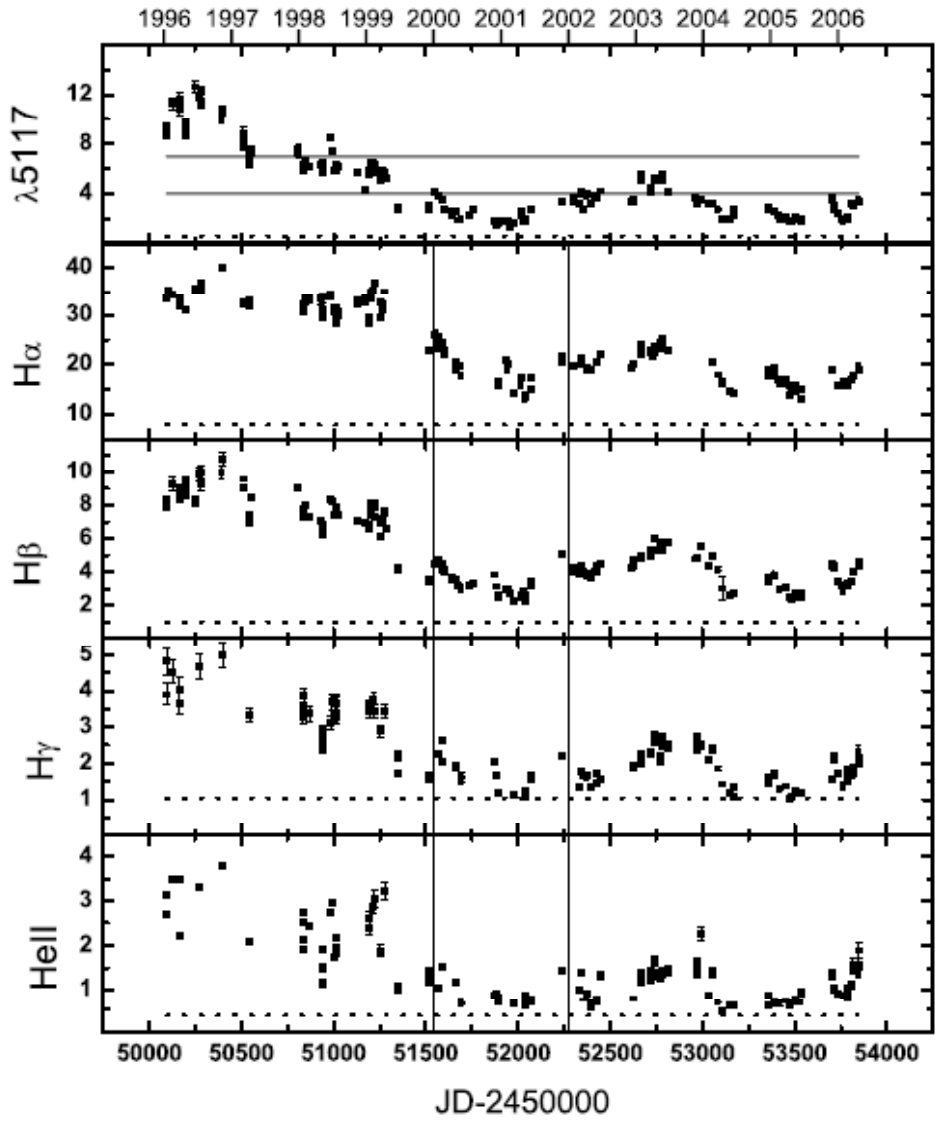
1.case: NGC 4151

- data from 11 years
- CCF analysis

⇒extremely compact BLR

⇒~ 0-2 light days!!

- 3 characteristic periods



Shapovalova, Popović et al. 2008, A&A, 486, 99, ...2010a, A&A, 509, 106

More on NGC 4151 in Edi Bon's talk!

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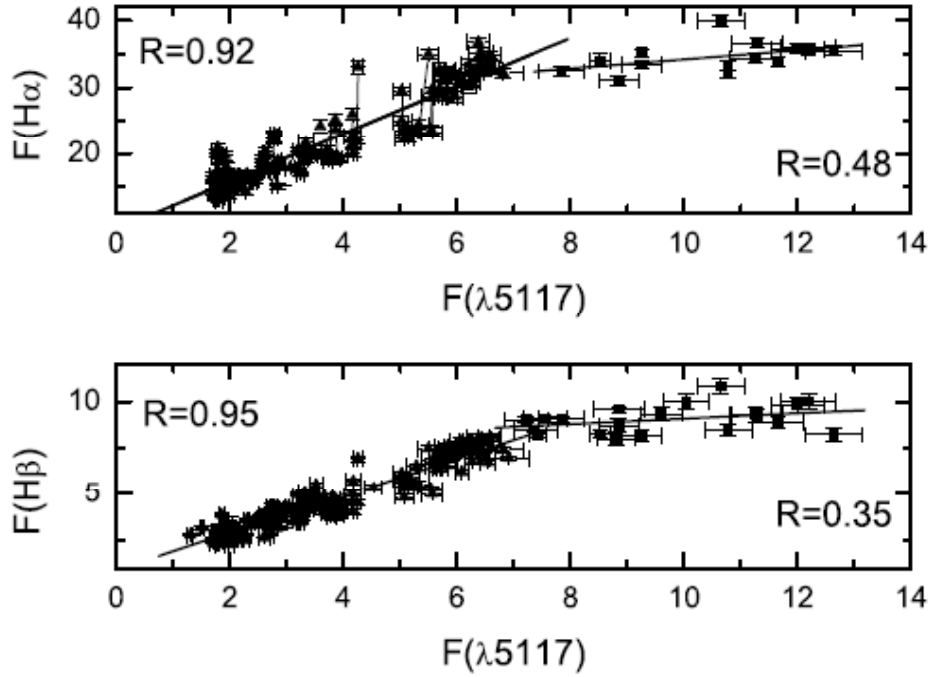
NGC 4151

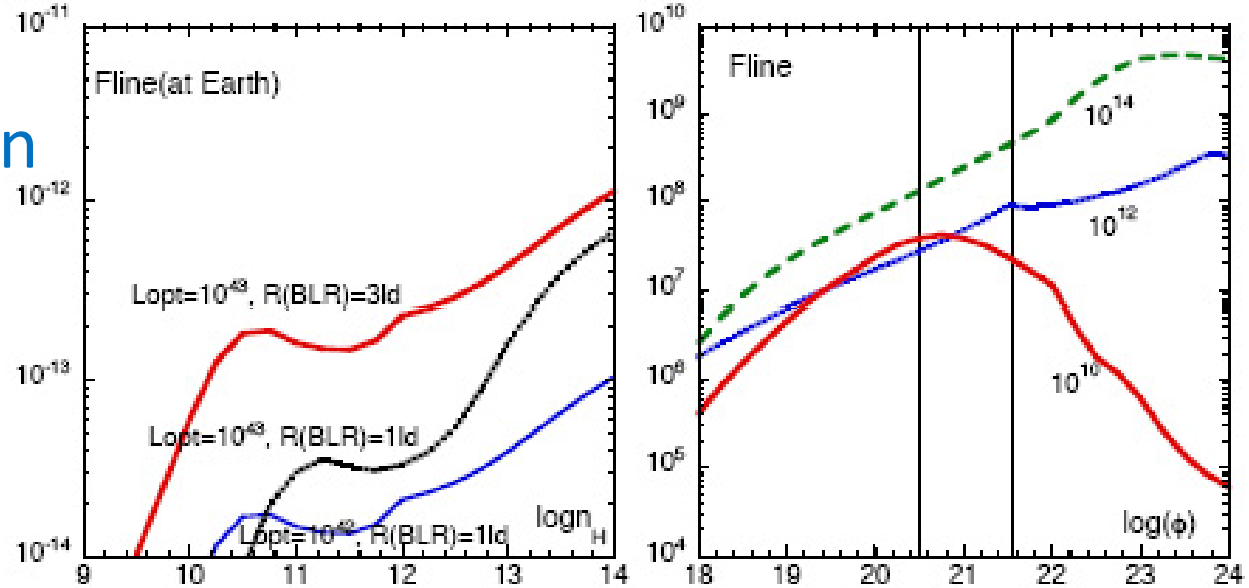
- line fluxes saturate for the high continuum

$F_{obs}(H\beta)=(2.3\text{-}9.8)\times10^{-12}$erg cm^{-2}s^{-1}



- calculate the line response to the continuum flux using photoionization model ⇒ **observed line flux much larger than computed ones**

- non-photoionized region contributes to the BEL (could be associated with radio jet)



Line fluxes vs. density (left) and ionizing flux (right)

Shapovalova, Popović, et al. 2008, A&A, 486, 99

Future Science 2012: Ilić et al.

2. case: 3c390.3

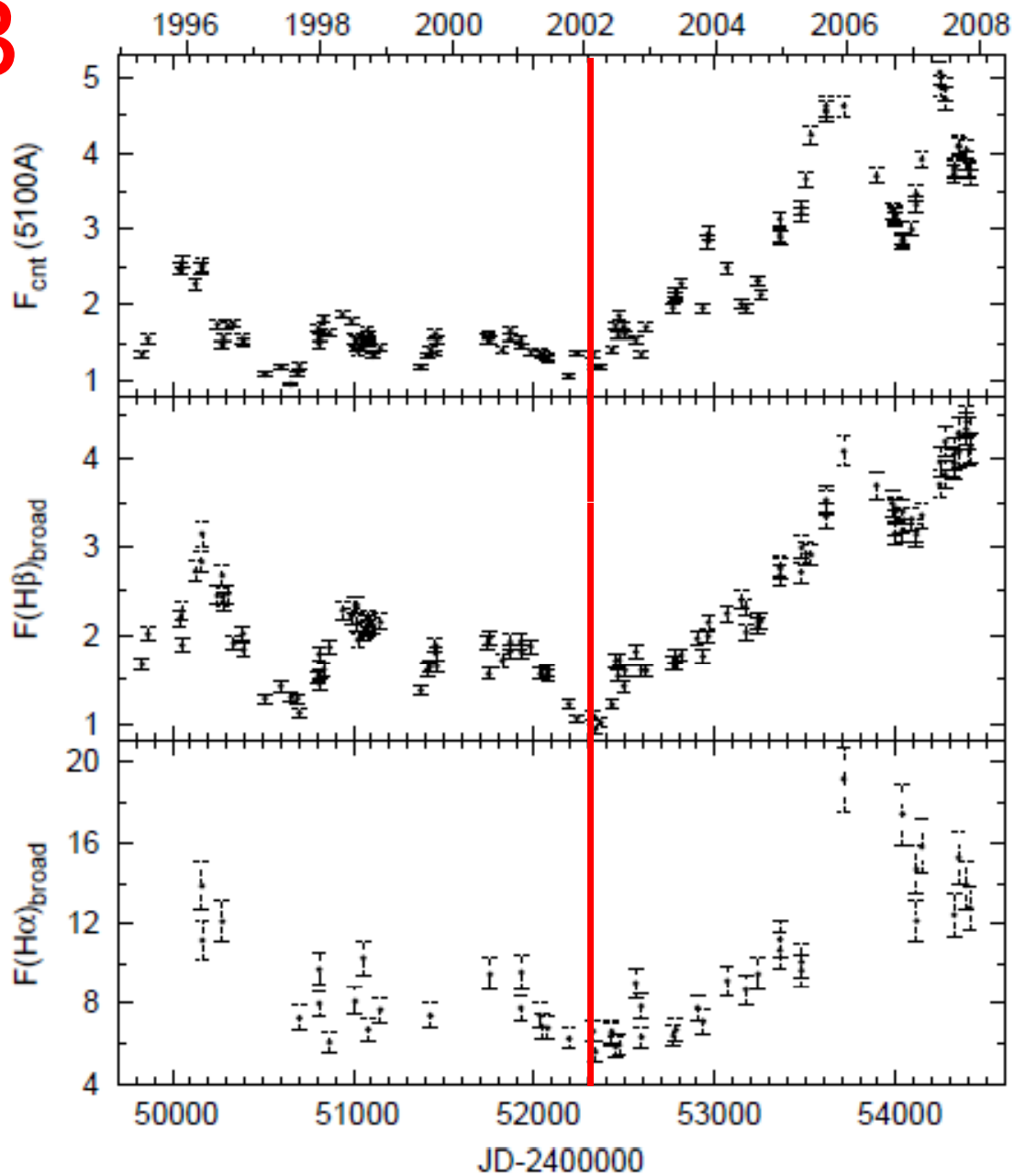
- 13-year data
- several max & min
- CCF analysis (ZDCF, ICCF)

⇒ Hα ~ 120 light days

⇒ Hβ ~ 95 light days

⇒ stratified BLR

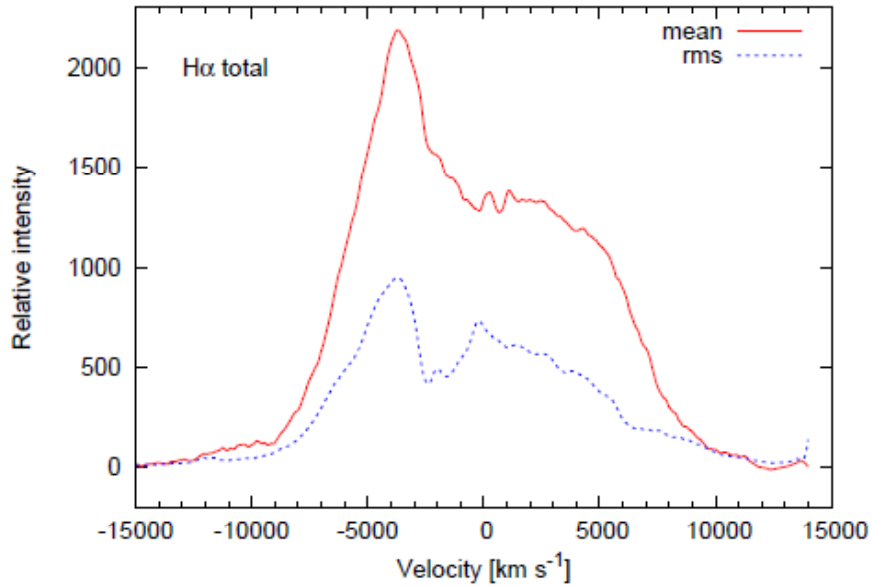
- minimum in 2002 ⇒ 2 characteristic periods



Shapovalova, Popović, Ilić, et al. 2010b, A&A, 517, 42

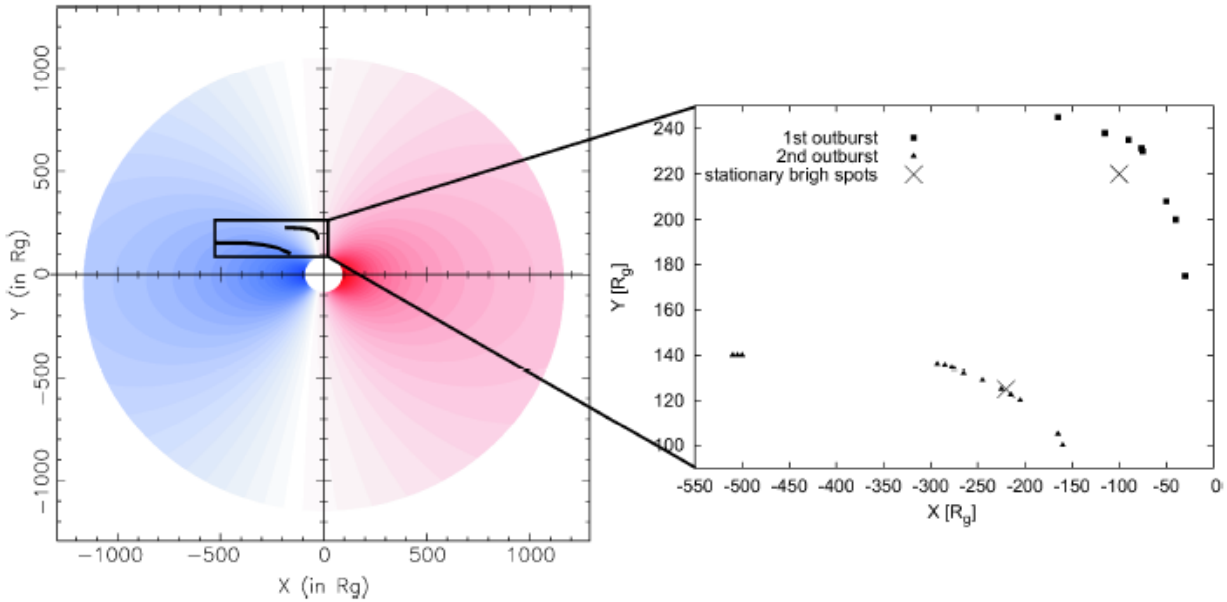
3c390.3 – line profiles

- line profiles vary dramatically: disk-like profile with strong blue peak always present, BUT sometimes also the central peak appears ⇒ additional emission region



- describe the line profiles with disk perturbations

Jovanović, Popović, Stalevski, Shapovalova 2010, ApJ, 718, 168



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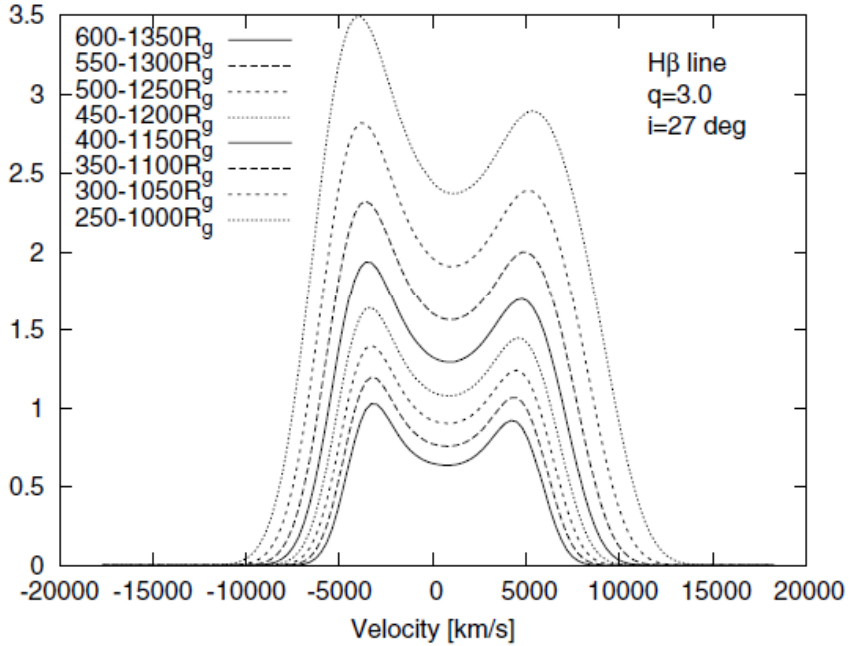
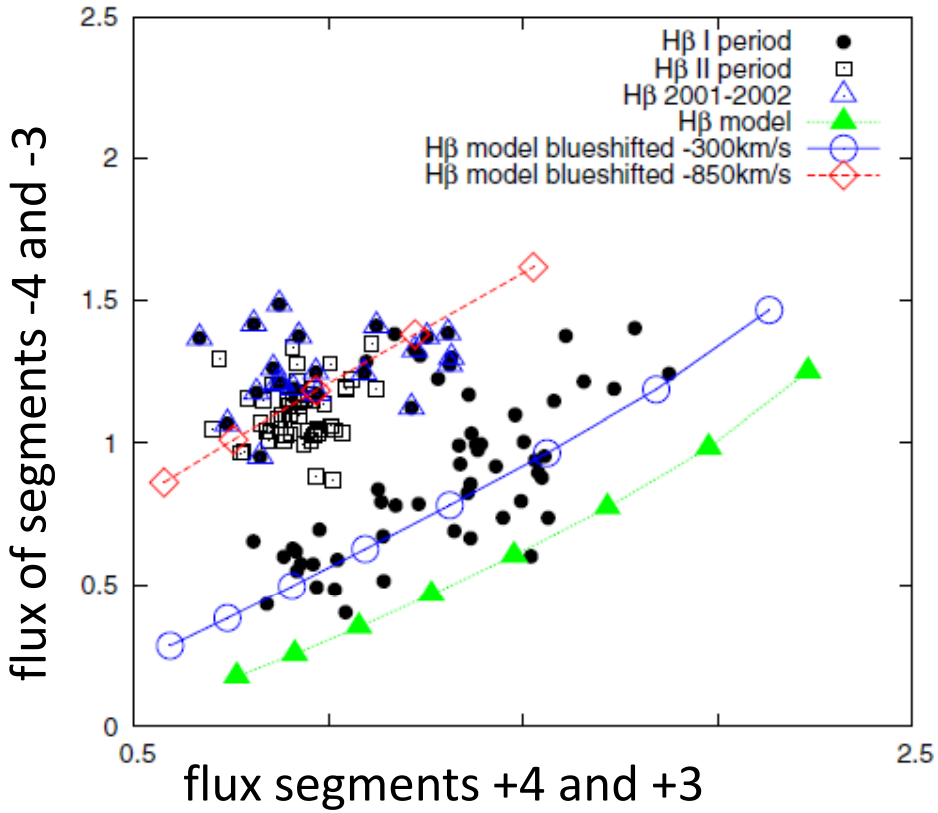
3c390.3 – models

- part of the disk that is emitting lines is shifted along the radius





- models vs. observations
- Period I: the change can be explained with the change of the disk position with respect to the BH
- Period II (when burst starts): disc position is fixed

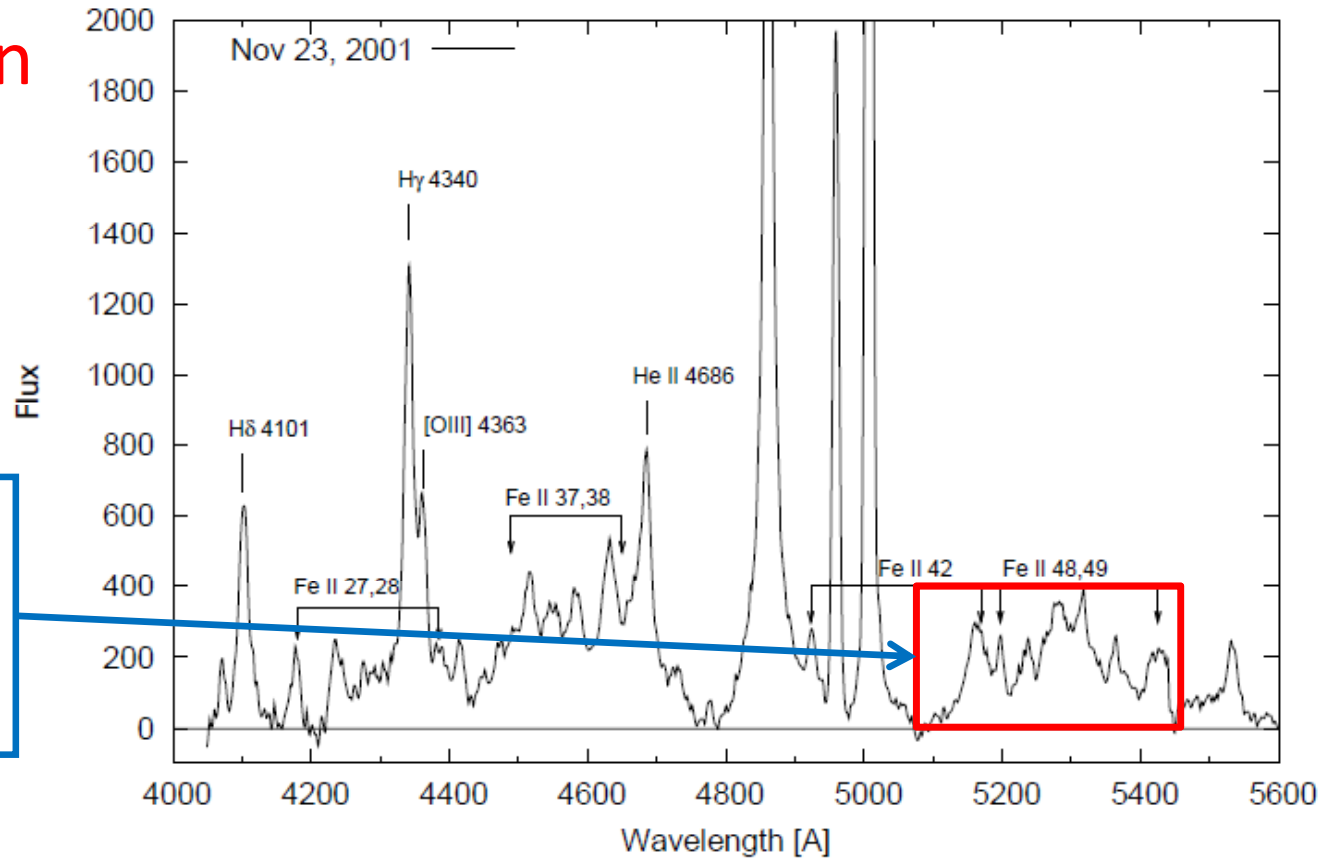
Popović, Shapovalova, Ilić, et al. 2011, A&A, 528,130

3. case: Ark 564

- nearby narrow-line Sy 1 galaxy: narrow permitted lines
- strong Fe II emission: many line transitions, blended

- where is the origin and how are they produced?

For Fe II 5100-5470:
- no fitting
- 48,49 multiplets



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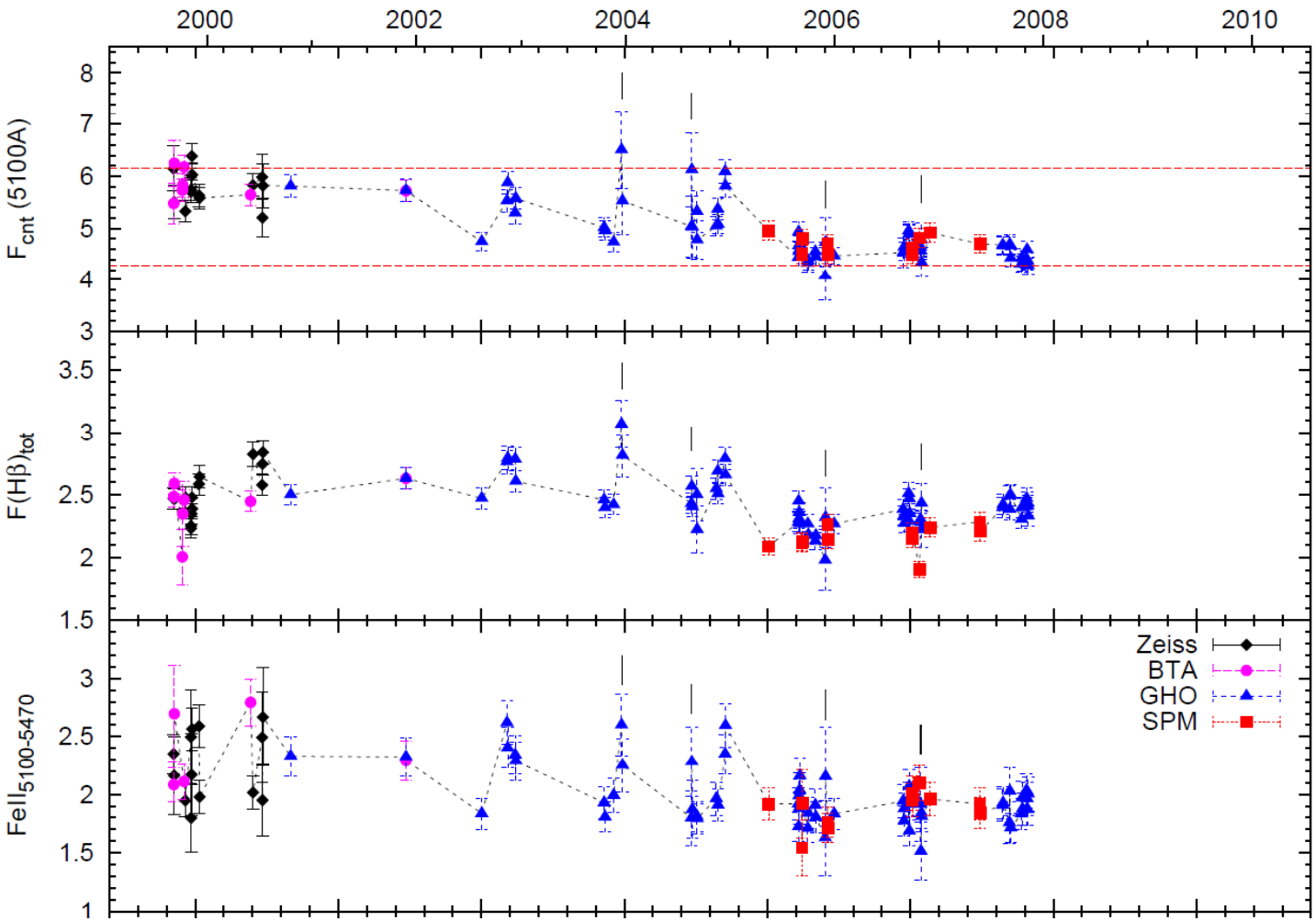
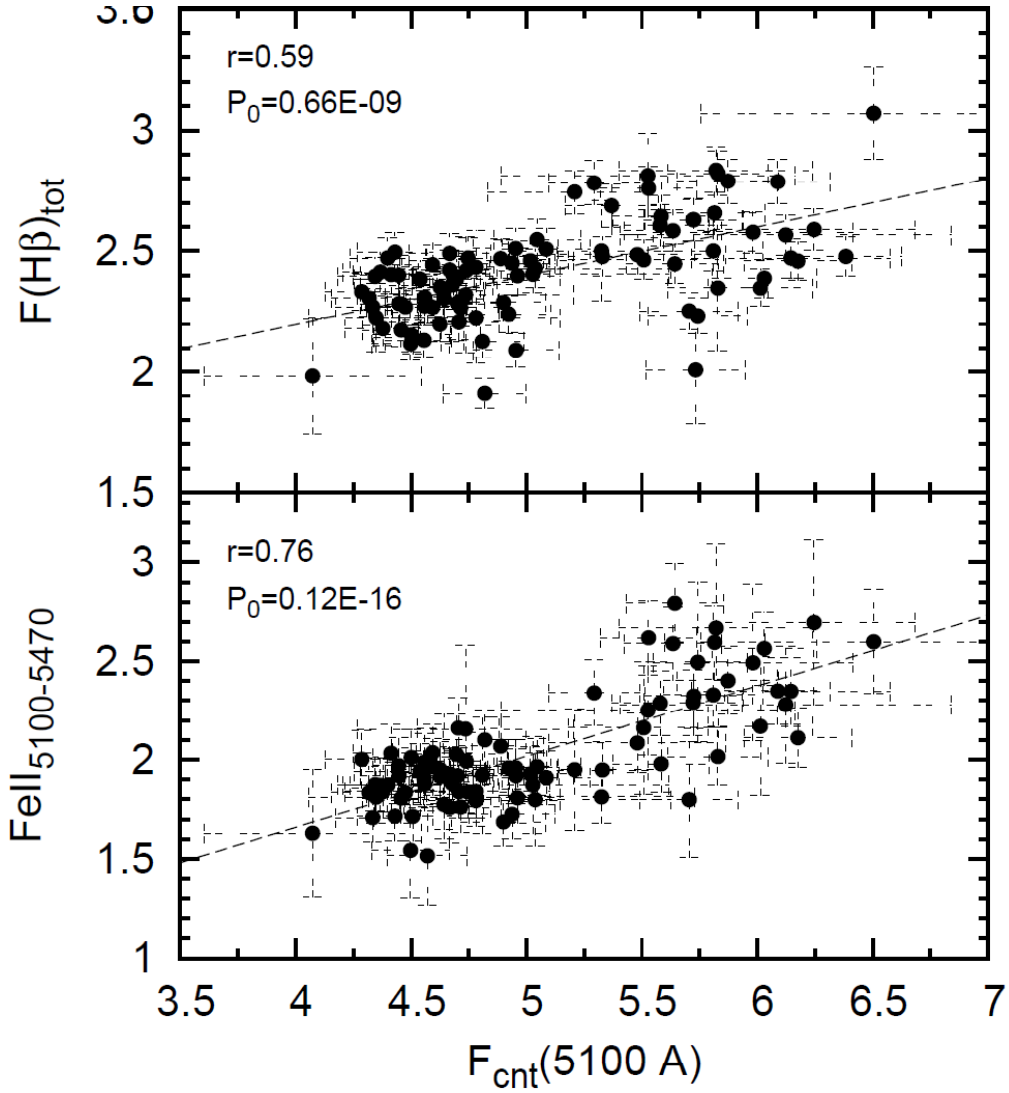
Light curves: continuum, Hb, Fe II



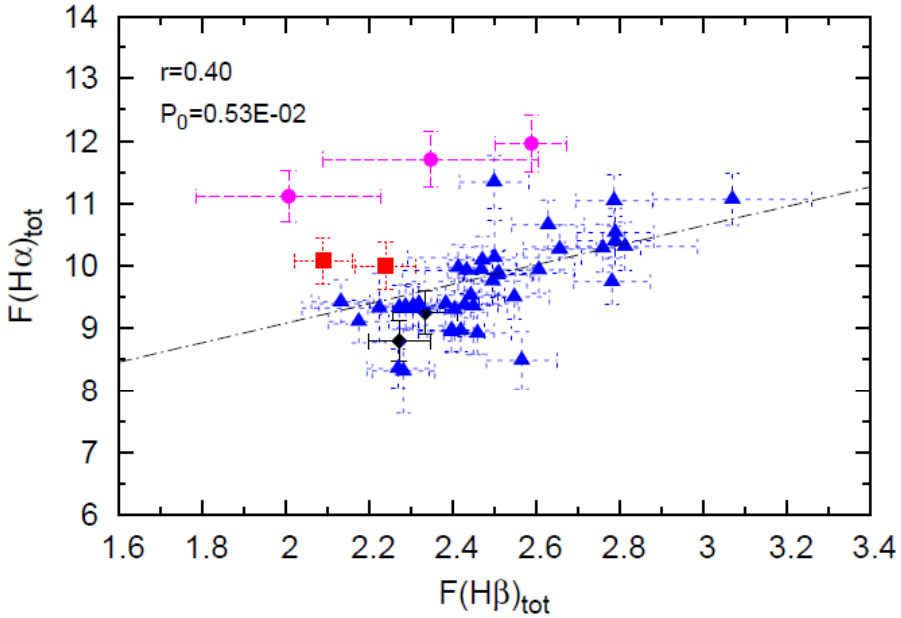
- 5 flare-like events lasting 1-3 days
- 10-20% variability

Shapovalova+ ApJS, 2012

Correlations: continuum vs. lines



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



Future Science 2012: Ilić et al.

Shapovalova+ 2012

Last slide: some conclusions

- the AGN broad line region is complex!

  $\longrightarrow$ different components: disk, outflows...
  $\longrightarrow$ contribution of other physical processes (apart from photoionization) to line formation
  $\Longrightarrow$ *reverberation method should be used with caution for M_{BH} estimates*

- more spectral observations needed

- can we still do significant science with meter-class telescopes?

YES!

Thank you!

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