LONG-TERM SPECTRAL OPTICAL MONITORNIG OF ACTIVE GALACTIC NUCLEI

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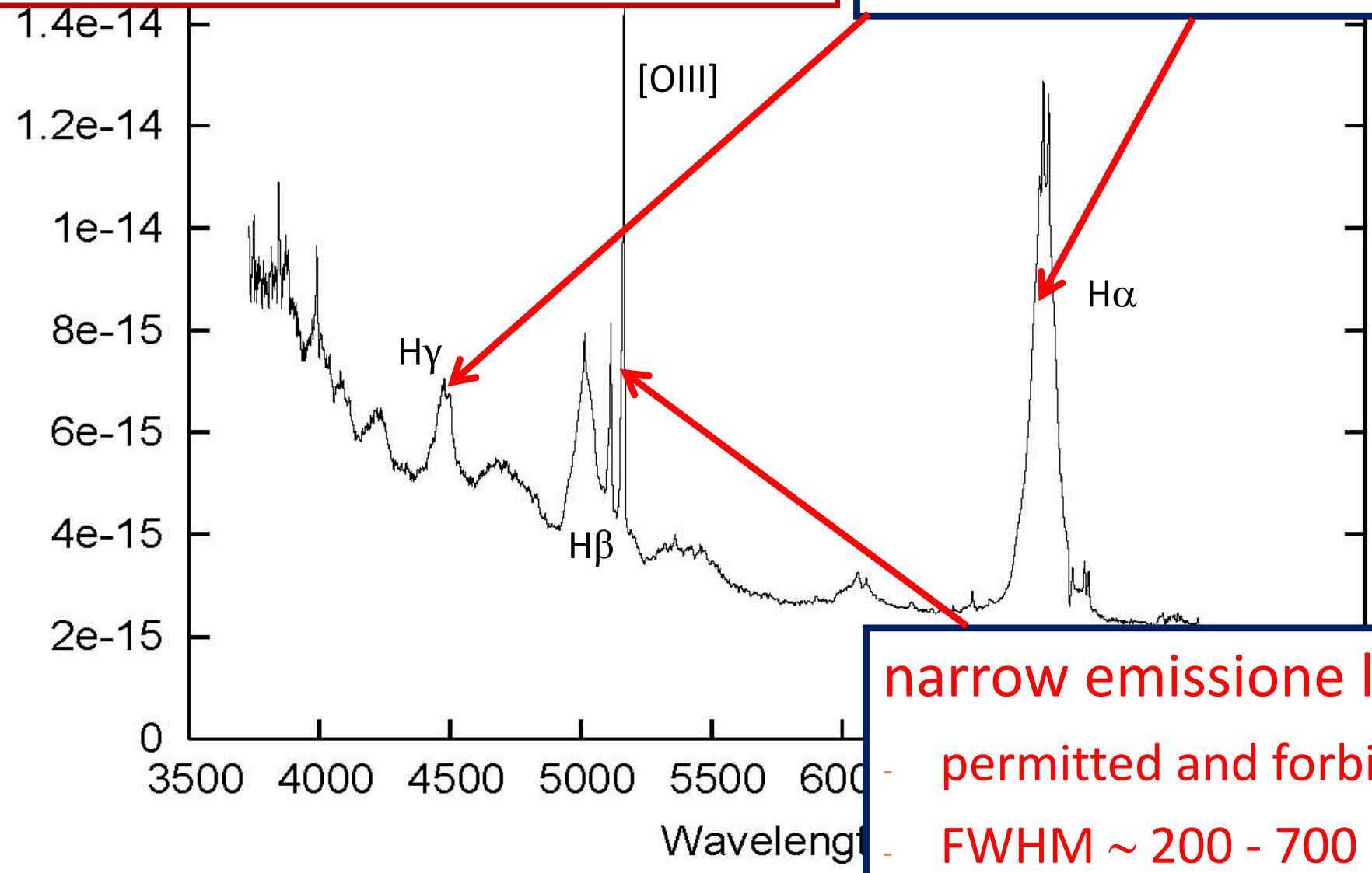
EMISSION LINES

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



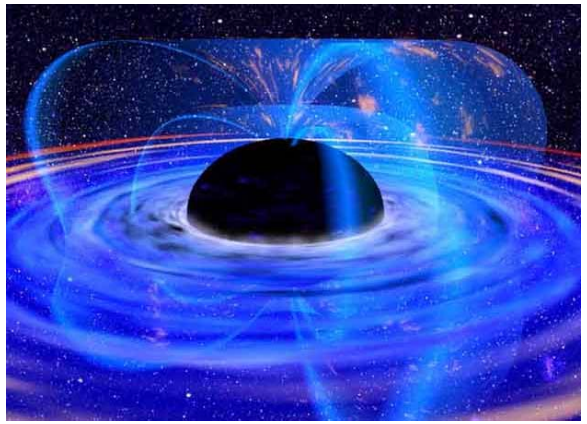
broad emission lines

- permitted transitions
- FWHM ~ 2000 - 10000 km/s

narrow emissione lines

- permitted and forbidden
- FWHM ~ 200 - 700 km/s

Black Hole mass M_{BH} estimates

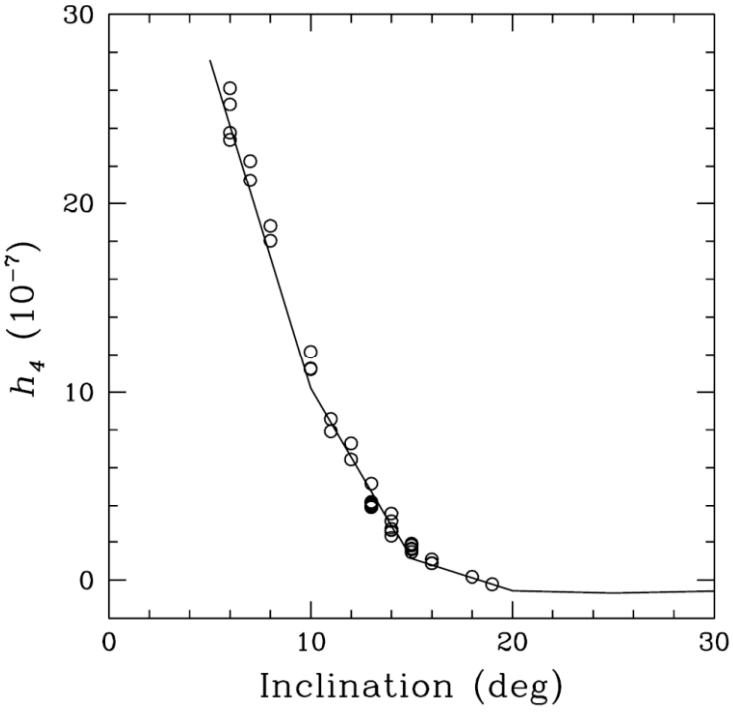


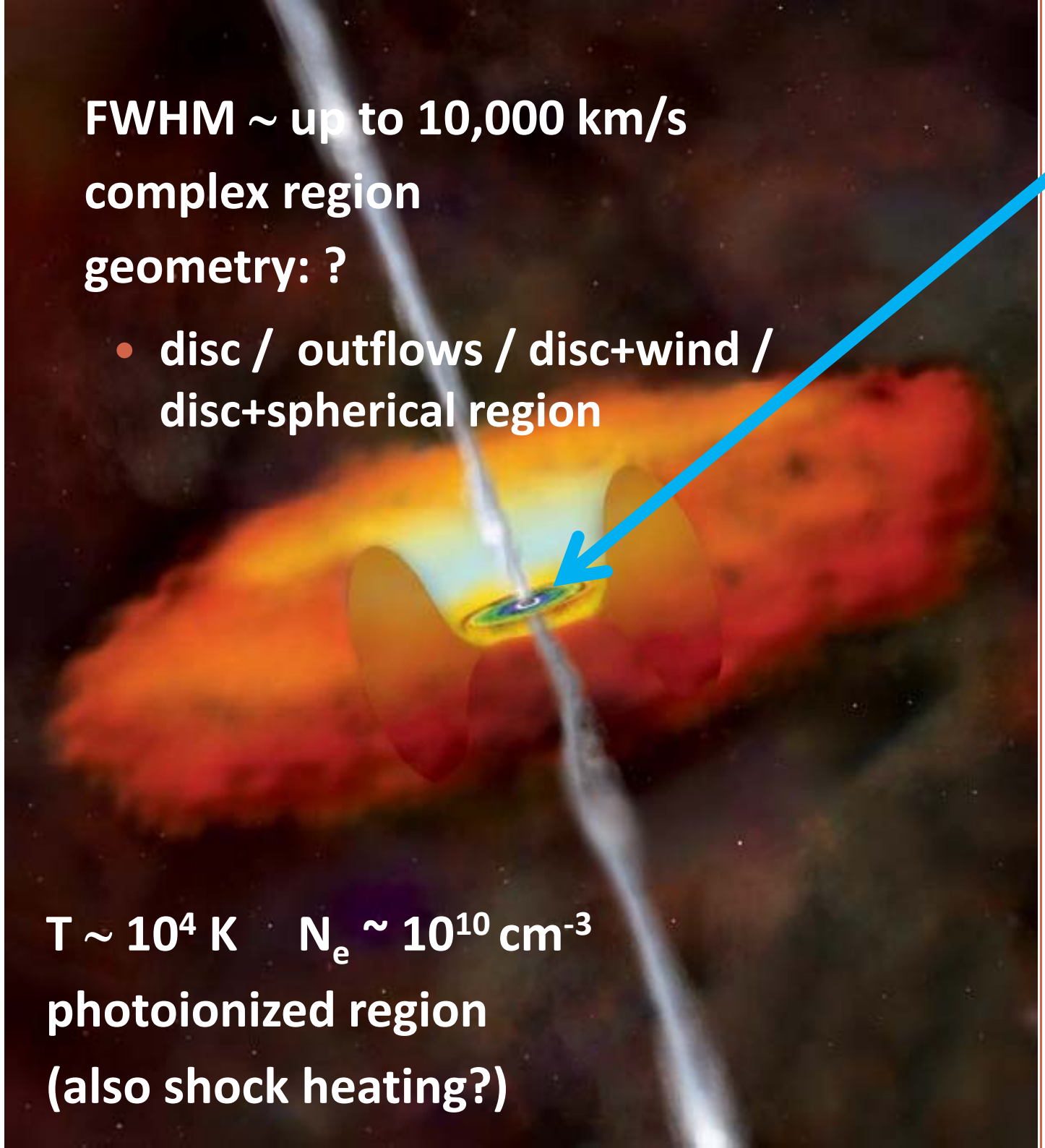
- virial theorem: $$M_{BH} = f \frac{R_{BLR} v^2}{G}$$

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

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

- Problem 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)



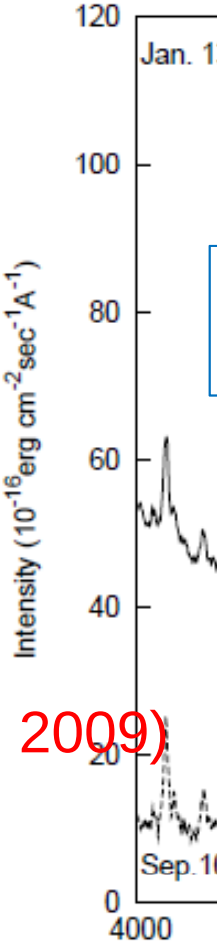


in order to estimate M_{BH} we need to know the geometry of the BLR

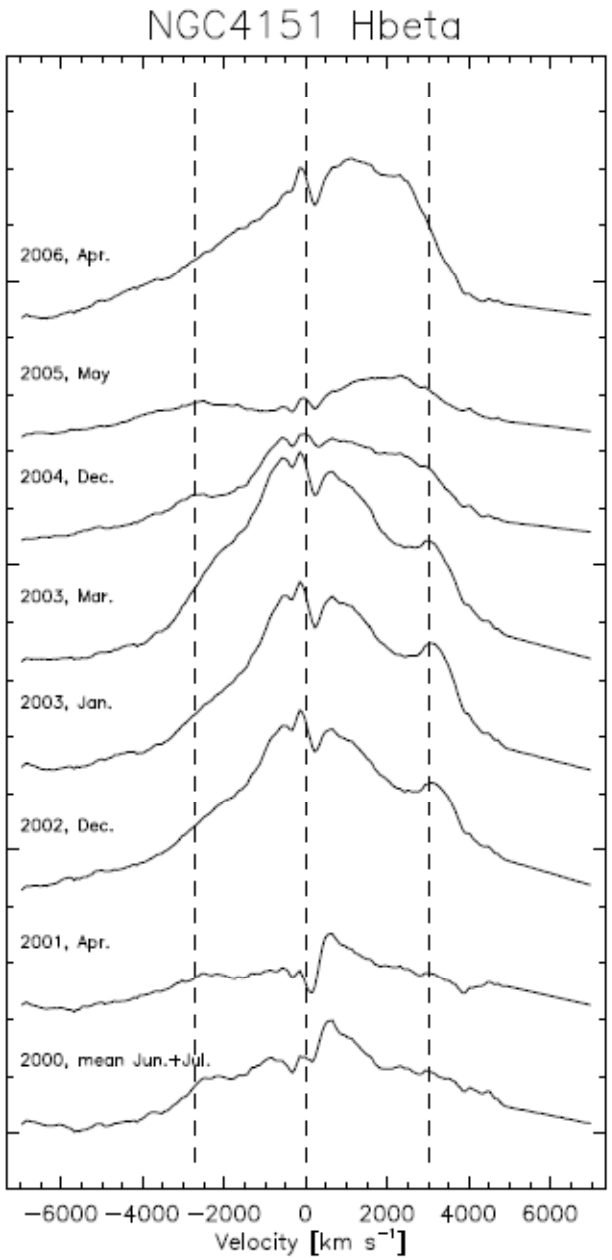
what do we know about BLR?

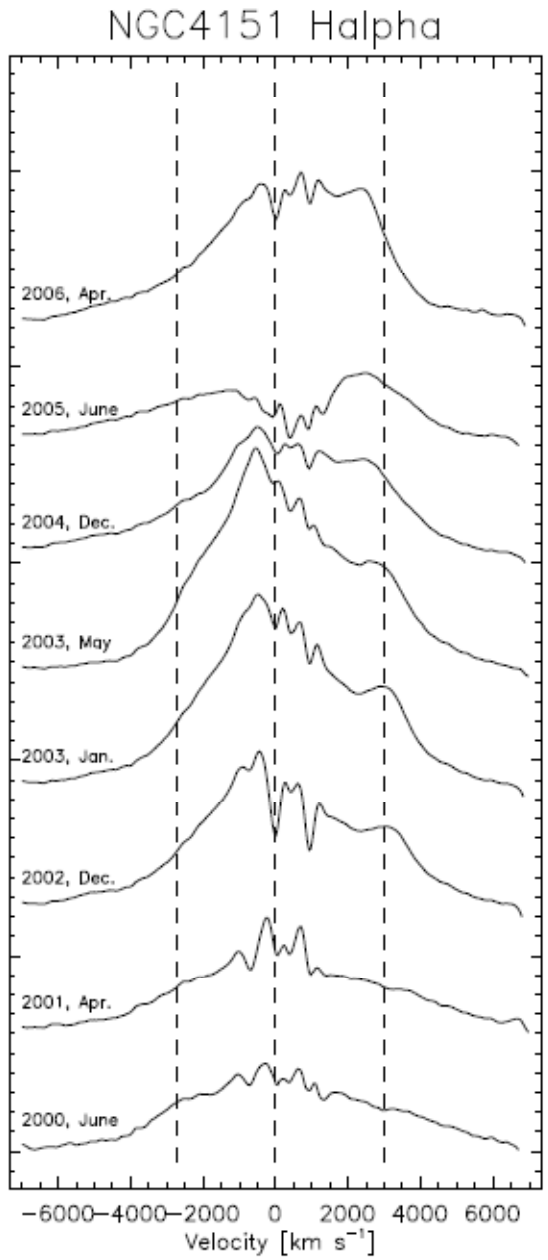
AGN – HIGHLY VARIABLE OBJECTS

- variation in the c
- change of the gal
- line profile variability



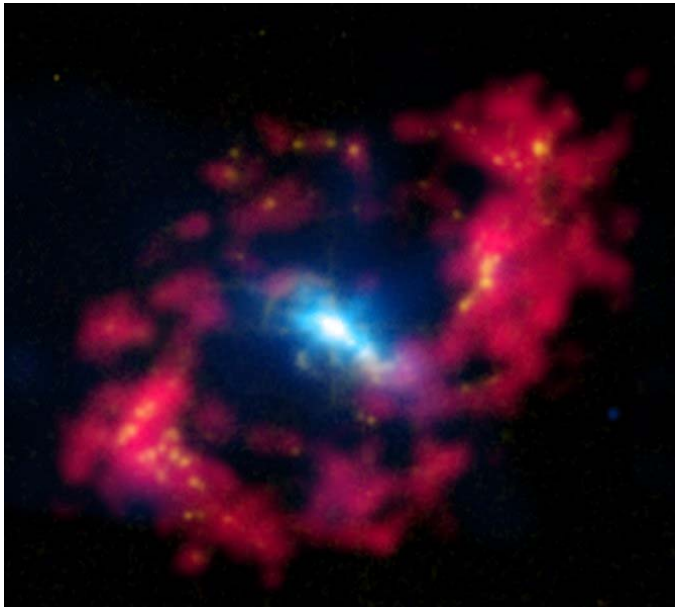
(Shapovalova et al. 2009)





3c390.3 (Shapovalova et al

LONG-TERM MONITORING



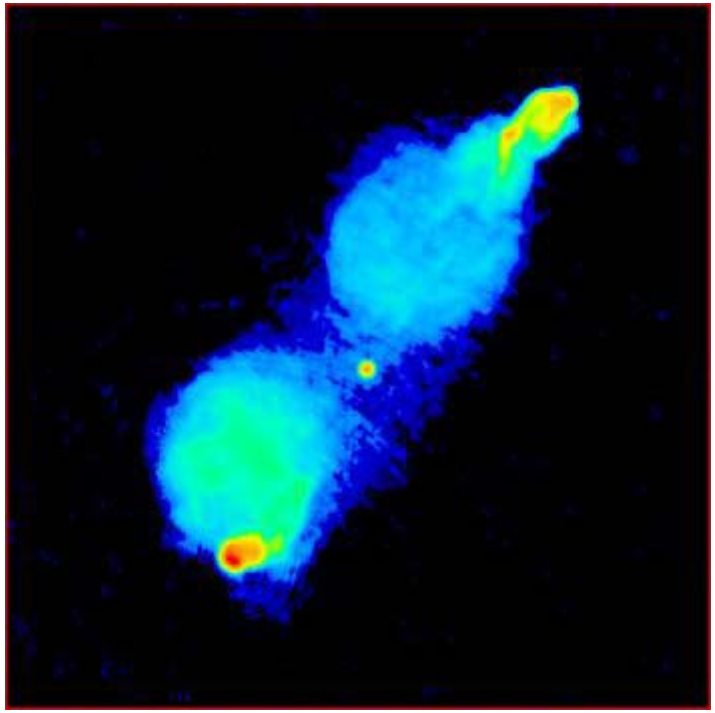
- PIs: Alla I Shapovalova (Russia)
  Vahram H. Chavushyan (Mexico)
- constantly observing well known AGN:
  - NGC 5548 – 9 years (Ilić 2007, Popović et al. 2008)
  - NGC 4151 – 11 years (Shapovalova et al. 2008, 2009, 2010a)
  - 3C390.3 – 13 years (Shapovalova et al. 2010b, Popović et al. 2011, Jovanović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

OBSERVATIONS

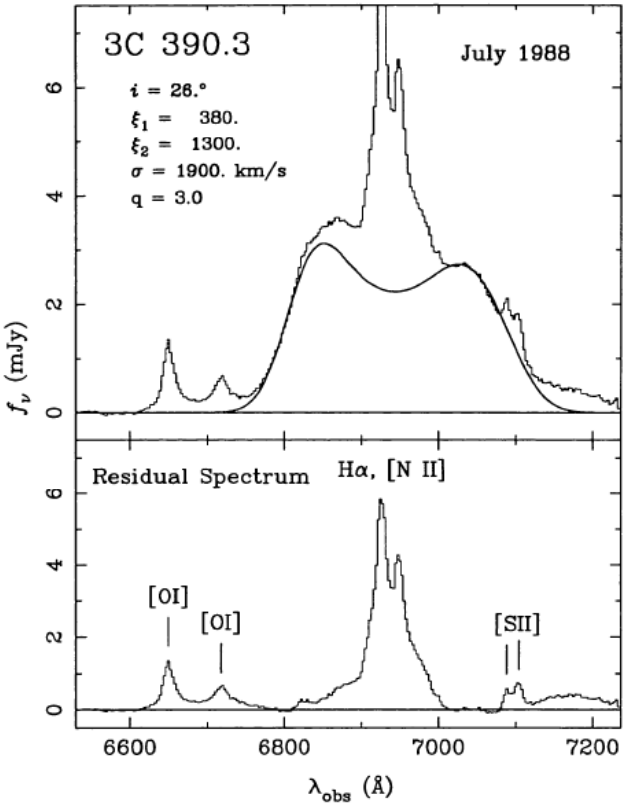
- 6m + 1m telescopes - SAO RAS (Russia)
- 2.1 m telescope - Guillermo Haro Observatory, Cananea, Sonora, Mexico
- 2.1 m telescope - Observatorio Astronómico Nacional, San Pedro Martir, Baja California, Mexico

3C390.3

- double radio-loud galaxy with strong radio core (Leahy & Perley 1991)



- double-peaked broad line (Eracleous & Halpern 1994)
- proof of the line disc-emission
- variable line profiles ⇒ different complex BLR models: binary BLR, disc precession, disc perturbation, etc.



3c390.3

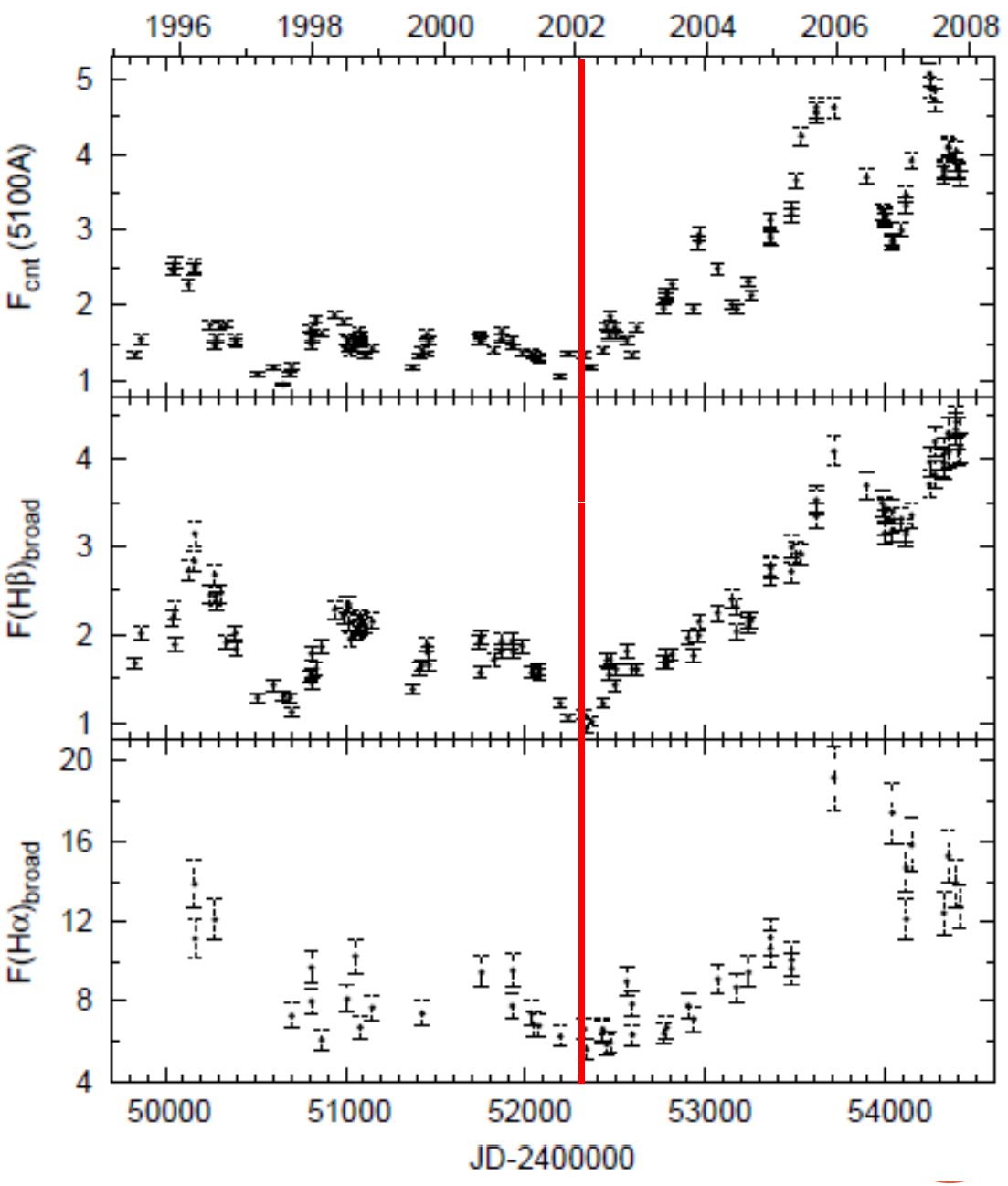
- 13-year data
- several max & min
- CCF analysis (ZDCF, ICCF)

⇒ Hα ~ 120 light days

⇒ Hβ ~ 95 light days

⇒ stratified BLR

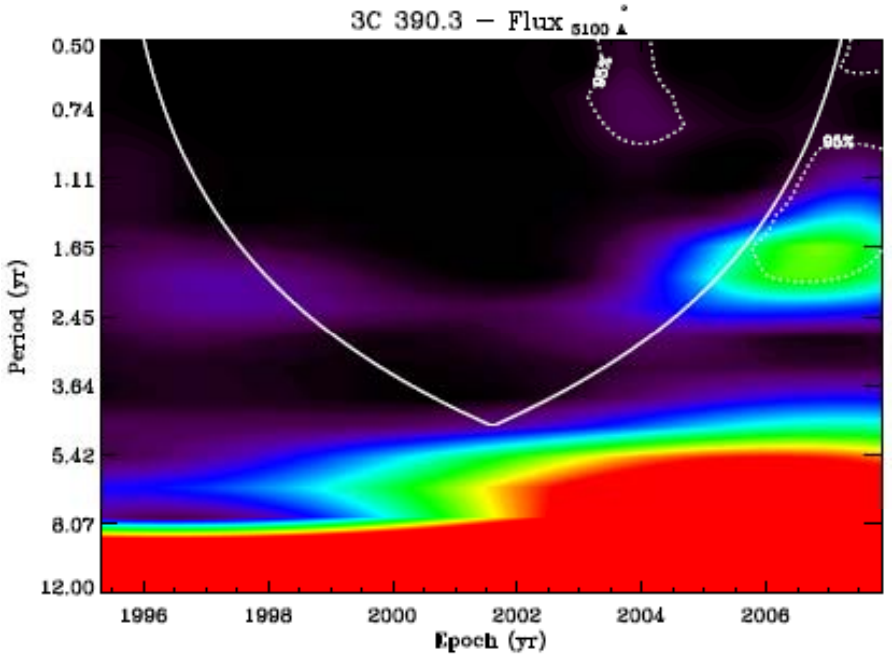
- minimum in 2002 ⇒ 2 characteristic periods

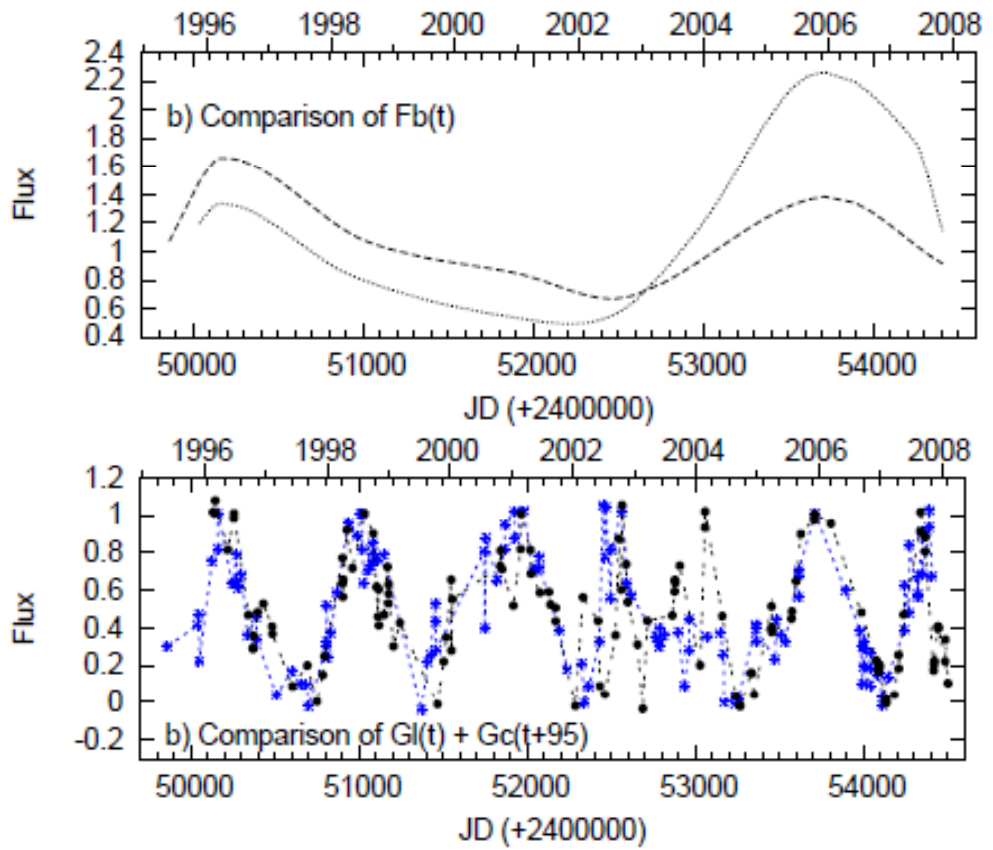


Shapovalova, Popović, Ilić, Chavushyan et al. 2010b, A&A, 517, 42

3c390.3 - QPOs

- quasi-periodic oscillations (QPOs)
  - Morlet wavelet transformation
  - analysis of the minima and maxima of Hβ and continuum
- QPOs with periods:
  ~ 10 years (Veilleux & Zheng 1991)
  ~ 2-4 years
- shock waves near the SMBH spreading in the outer part of the disc OR contribution of either ejection or jets to QPOs

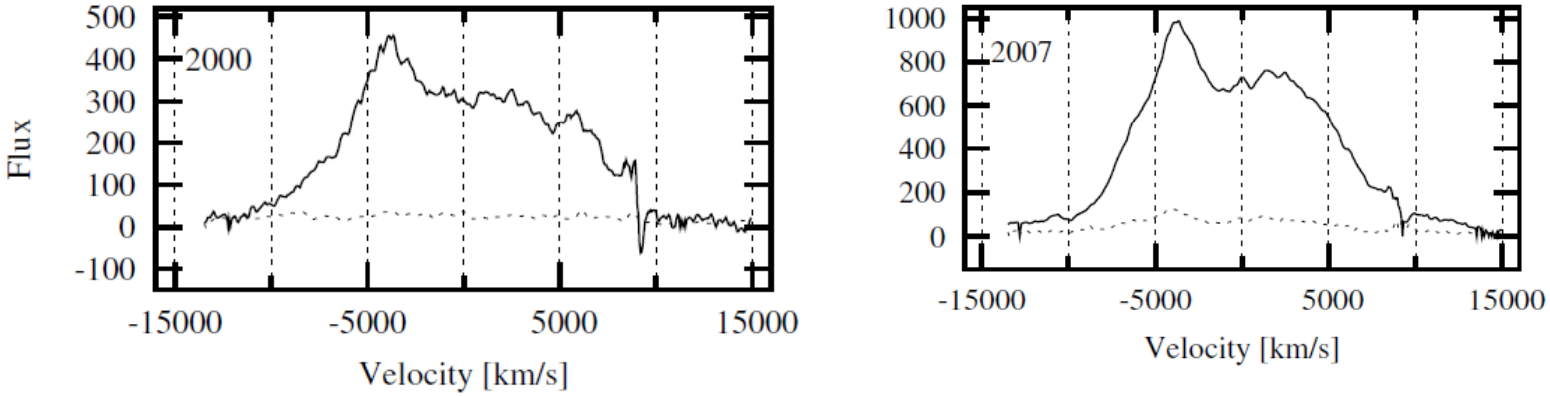




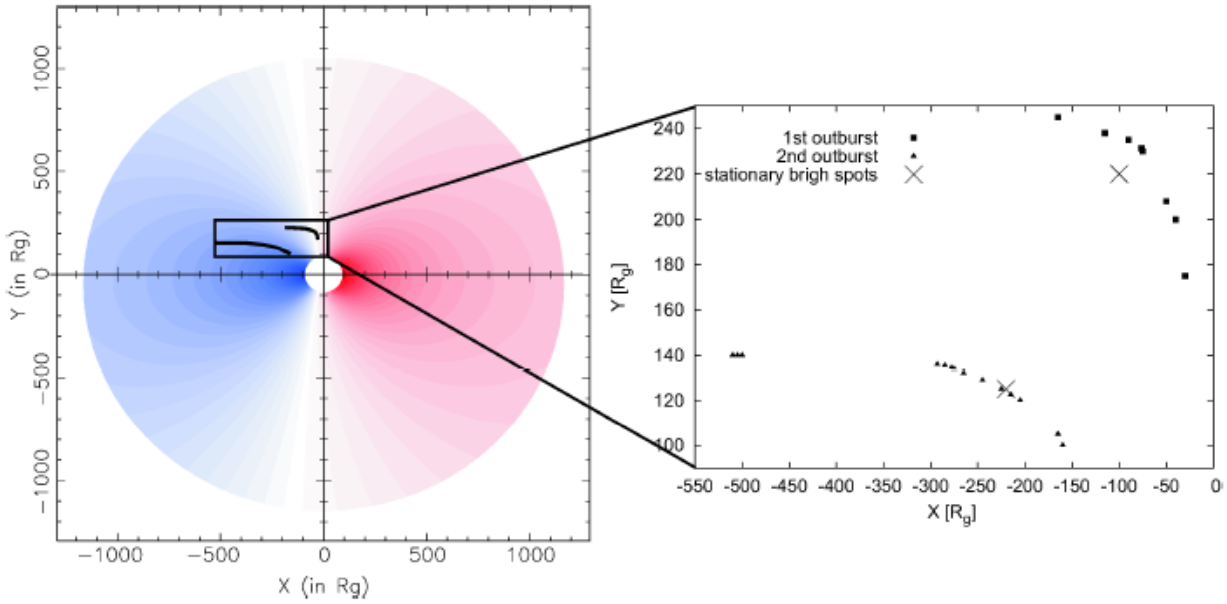
Shapovalova , Popović, Ilić, Chavushyan et al. 2010b, A&A, 517, 42

3C390.3 – LINE PROFILES

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



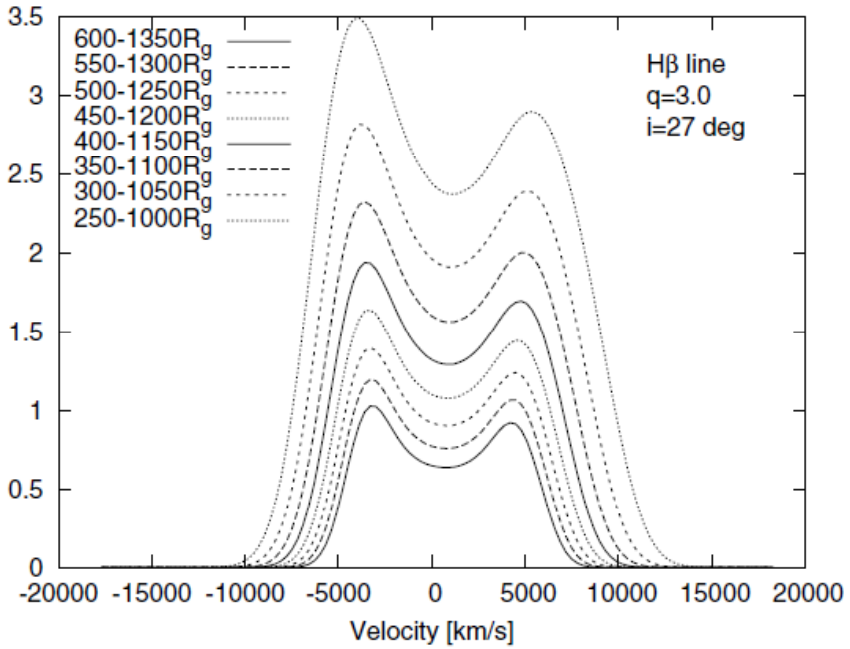
- disc perturbation to describe the line profiles

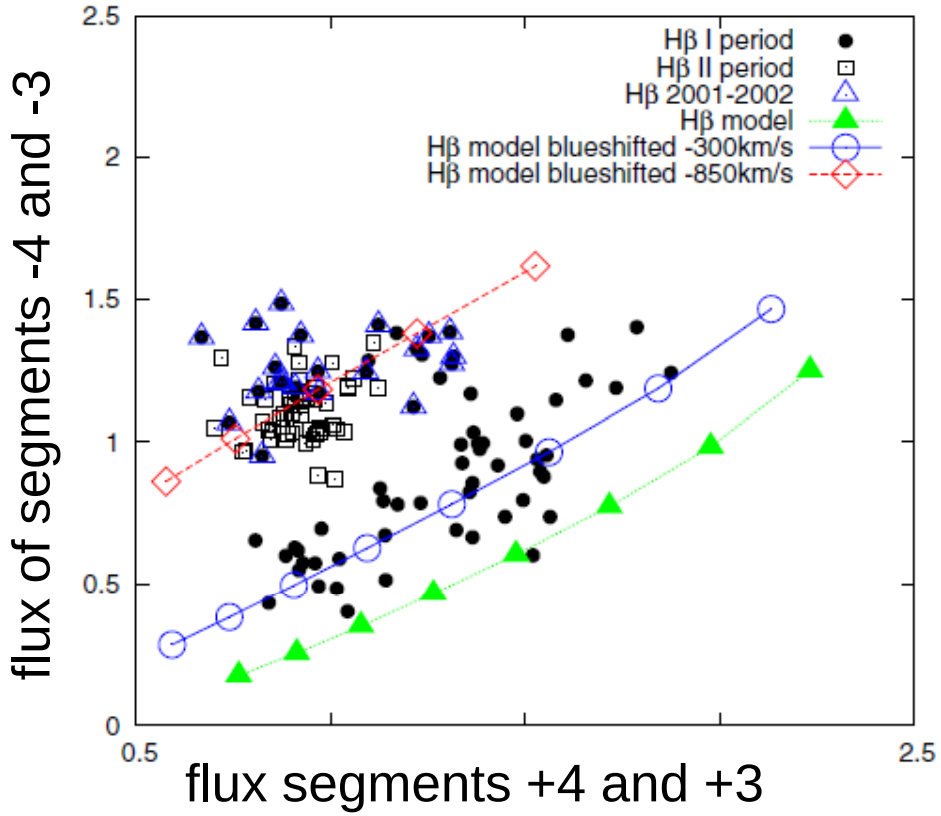


Jovanović, Popović, Stalevski, Shapovalova 2010, ApJ, 718, 168

3C390.3 – MODELS

- part of the disc 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, Chavushyan et al. 2011, A&A, 528,130

CONCLUSIONS

- the broad line region is a complex region (careful with M_{BH} estimates using reverberation mapping): disc, outflows, winds, combination...
- possibility of QSOs as with stellar black-holes
- possibility to have disc perturbations: e.g. shock waves, fragmented spiral waves

Thank you!

3C390.3: TWO COMPONENT BLR

- disc-like BLR1
- BLR2? =outflows, part of the jet, disc wind