IAU symposium 324: New Frontiers in Black Hole Astrophysics, Ljubljana, Sept. 12-16, 2016

The extremes of AGN variability

S. Komossa, *in collab. with*: D. Grupe, N. Schartel, L. Gallo, M. Parker, K. Leighly, W. Kollatschny, M. Zetzl, G. Kriss, D. Wilkins, J.L. Gomez, M. Santos-Lleo, I. Myserlis, E. Angelakis, T. Krichbaum, A. Fabian, et al.

- **Intro: variability in classical Seyferts: absorption & reflection**
- **Deep X-ray low-flux states in (NL)S1 galaxies (factor 10)**
- **AGN at the highest amplitudes: giant drops & outbursts (>factor 100)**

- **"Changing-look" AGN: multi-λ view of extreme Sy-type changes**
- **Blazars/SMBBHs: OJ 287 (periodicity)**
- **The highest amplitudes today (factor > 1000): TDE flares from *quiescent* galaxies**

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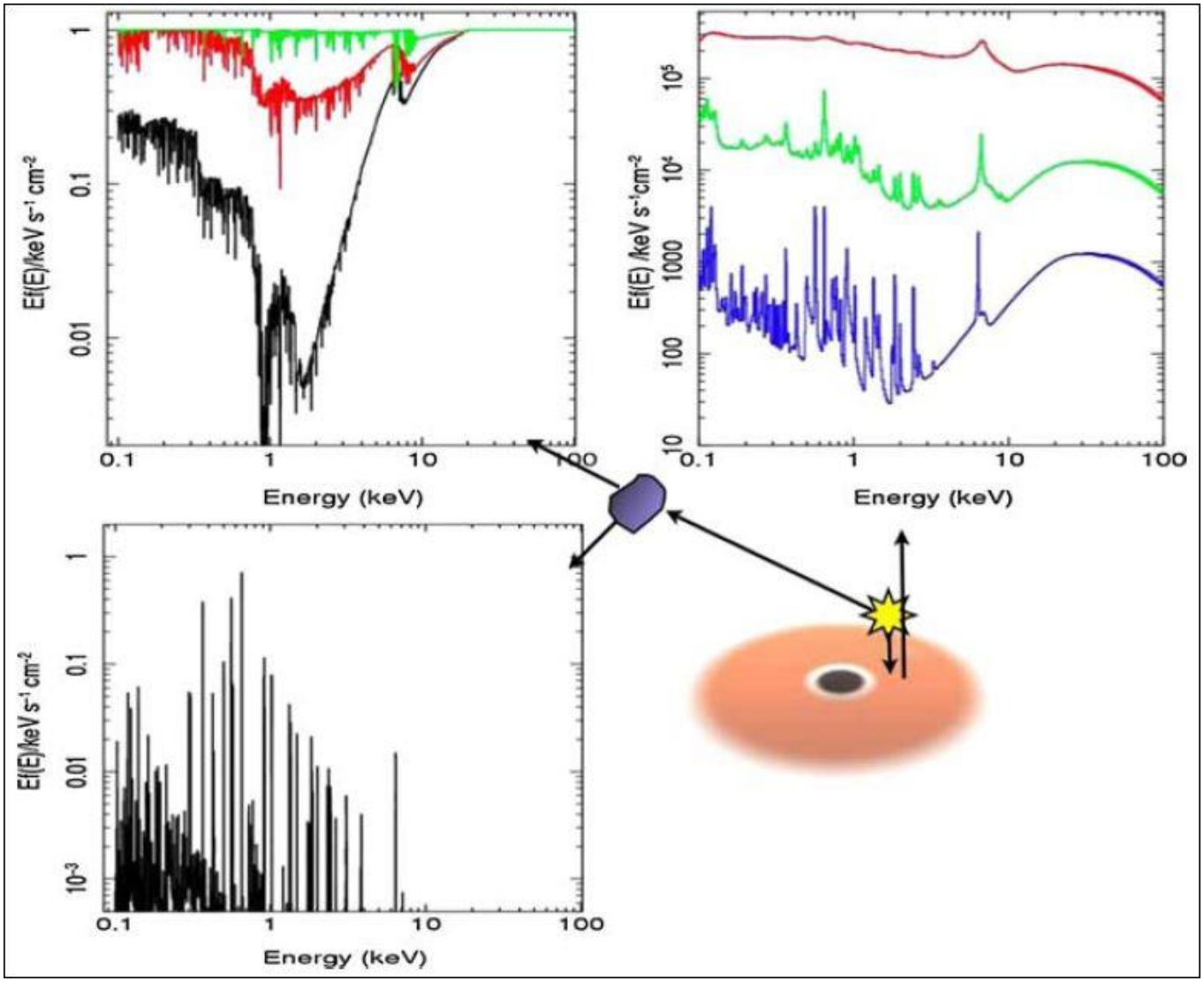
extreme flux and spectral states: -- can reveal the nature of the inner accretion disk, -- the physics of matter under strong gravity, -- offer a way of measuring BH spin, -- provide insight on the material expelled by the SMBH incl. strong outflows, feedback; -- route to discovery of rare new transients, TDEs, changing-look AGN, SMBBHs, ...

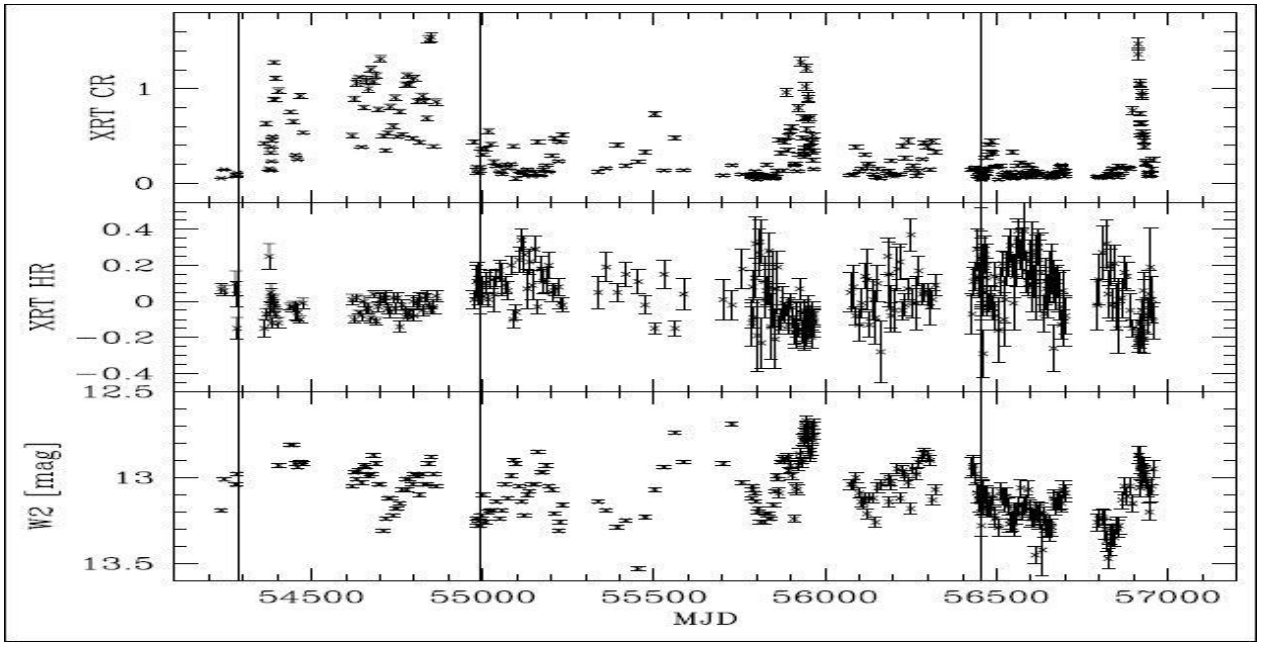
absorption & reflection in AGN



[recent reviews: Turner & Miller 09, Brenneman 13, Reynolds 14, Fabian 15]

deep X-ray low-flux states: the NLS1 Mrk 335

- nearby, highly variable NLS1 galaxy
- has traditionally been a bright X-ray source
- deep X-ray low-state (factor >10 drop) seen with Swift in 2007
- triggered follow-ups, and ongoing monitoring
- since then: - deep low-state in 2013: XMM, Suzaku & NuStar follow-ups
  - bright flare in 2014: another NuStar follow-up
  - rapid UV decline in 2015/16: HST & XMM-RGS follow-up



[Grupe,Komossa,Gallo+ 07, 08, 12; Longinotti+ 13, Gallo+ 13, Parker+ 14, Komossa+ 14, Gallo+ 15, Wilkins+ 15, Longinotti+ 16-- prep]

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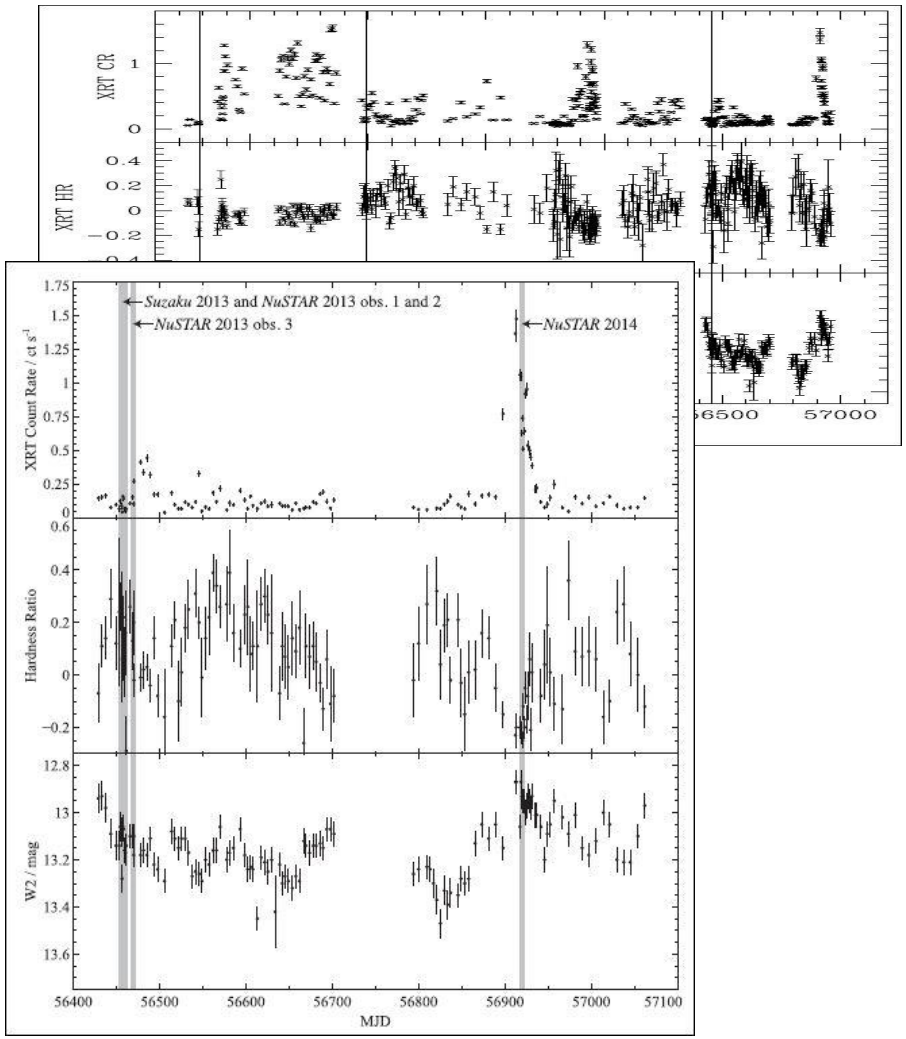
deep low-state (NuSTAR/Suzaku)



[Grupe,Komossa,Gallo+ 07, 08, 12; Longinotti+ 13, Gallo+ 13, **Parker+ 14**, Komossa+ 14, **Gallo+ 15**, Wilkins+ 15]

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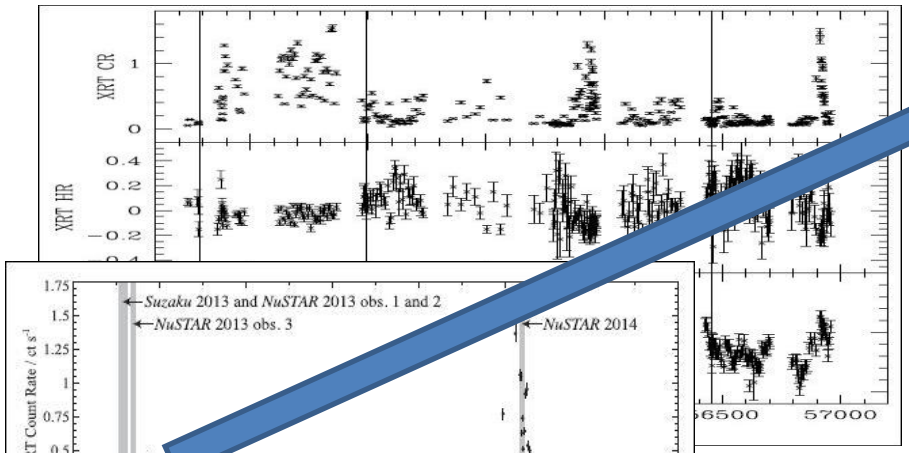
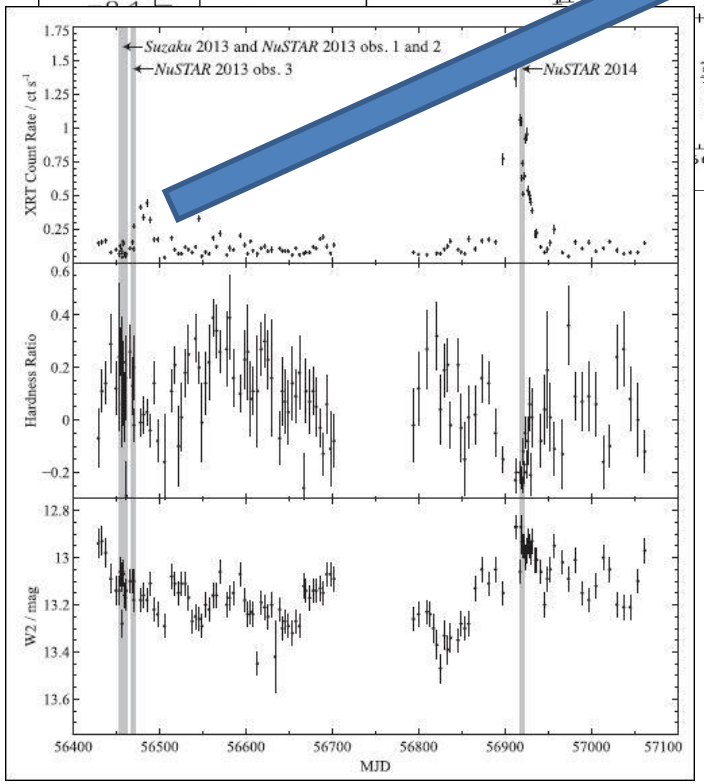
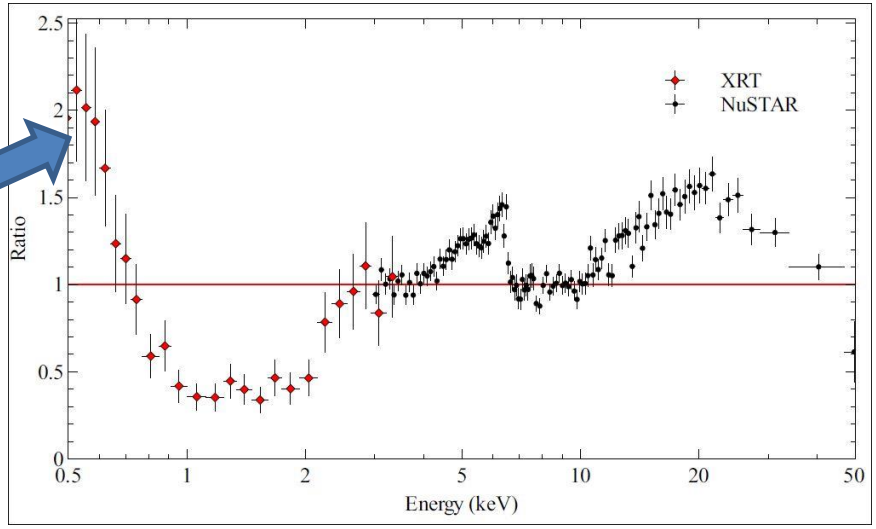






deep low-state scenarios:

(1) reflection-dominated spectrum: low coronal height, above inner disk → strong light bending and blurring
best-fit models require: most of the reflection originates from within a few r_g & high spin
((+ additional warm absorption))

(2) partial covering absorption, unobscured at high-state, strongly absorbed at low-state (cf ~0.95, log N ~ 23.3)

[Grupe,Komossa,Gallo+ 07, 08, 12; Longinotti+ 13, Gallo+ 13, **Parker+ 14**, Komossa+ 14, **Gallo+ 15**, Wilkins+ 15]

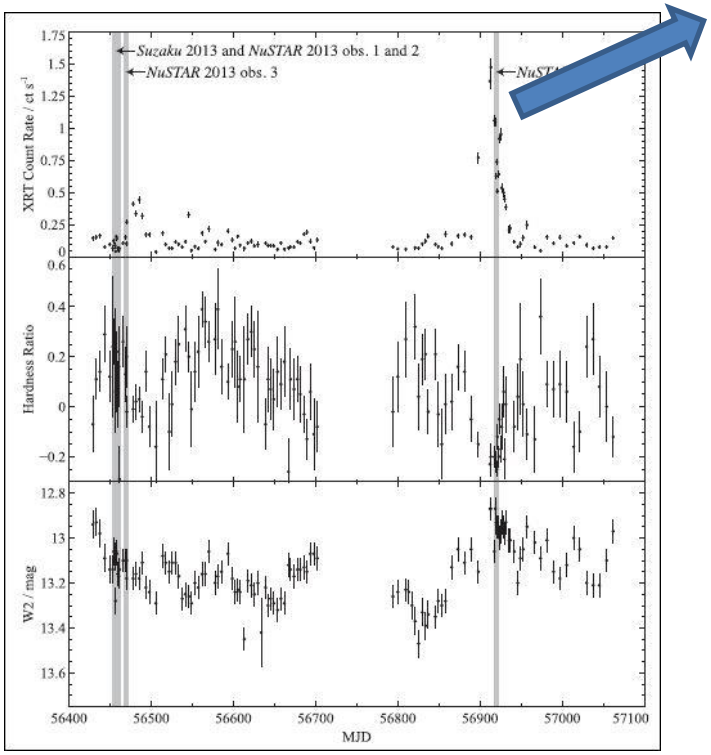
deep X-ray low-flux states: the NLS1 Mrk 335

flare state (NuSTAR):

in reflection scenario, still requires compact X-ray source few r_g above disk; however, reflection fraction is very small

→ ejection of vertically collimated X-ray corona (at mildly relativistic speed, so emi beamed away from disk) ?

→ related to the ejection of radio-jet component ?



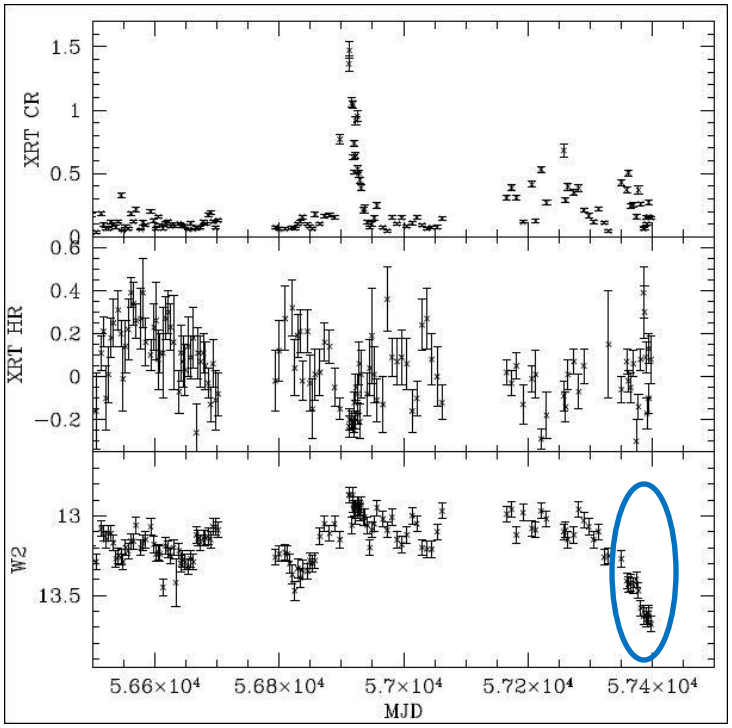
[Grupe,Komossa,Gallo+ 07, 08, 12; Longinotti+ 13, Gallo+ 13, Parker+ 14, Komossa+ 14, Gallo+ 15, **Wilkins+ 15**]

deep X-ray low-flux states: the NLS1 Mrk 335

independent evidence for (some) absorption:

(1) **XMM-RGS**: 3-component WA, N_H = 3 10^{21} – 6 10^{22} cm^{-2}, v ~ 5000 km/s

(2) **HST**: new CIV absorption, v ~ v_x



latest UV low-state: quasi-simultaneous XMM & HST-COS observations triggered. analysis ongoing → test abs. scenarios & measure WA properties

other deep low-flux states with triggered follow-ups: e.g., PG0844+349, Mrk 1048, 1H0707-495, ……..

these do *not* come with significant optical broad line variability

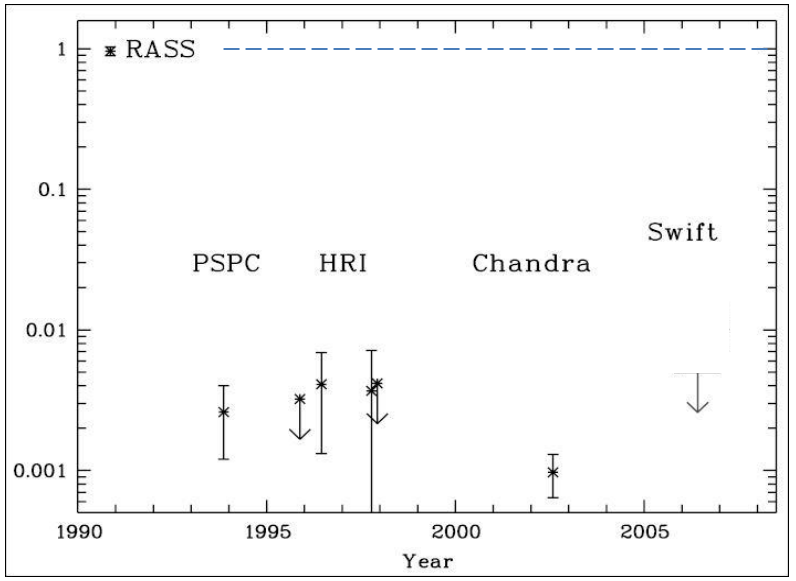
highest-amplitude AGN variability & transience: huge flares & dips

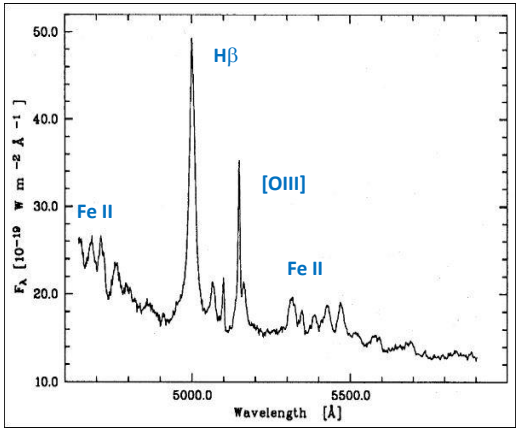
galaxy	X-ray amplitude	notes
1E1615	100	
WPVS007	400	drop
IC3599	100	flare, emi-line response
PHL1092	260	temp. drop
GSN069	240	flare
XMMJ061927-6553	140	flare
Mrk 590	100 (UV)	accretion event ? Sy-type change

[e.g., Piro+ 90, Grupe + 95a,b, 12, 15, Miniutti+ 09, 12, 14, Komossa+ 14, Saxton+ 14, Denney+ 14]

the AGN that 'disappeared': WPVS007

- unique, giant-amplitude drop in its X-ray emission (factor ~400), never seen in any other AGN.
- its optical spectrum is that of a NLS1 (z=0.028); little/no changes from 1993-2012





[Grupe+ 95, Grupe + 07, 08, 13, Leighly+09, 15]

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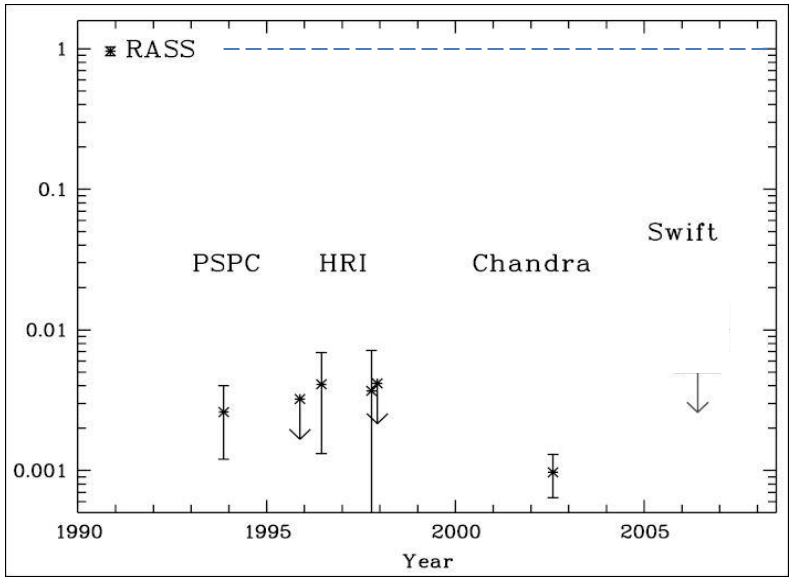
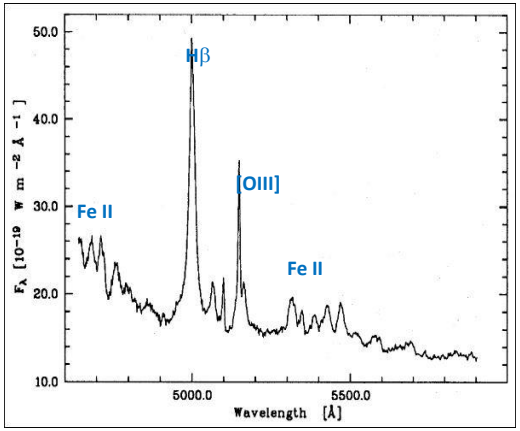
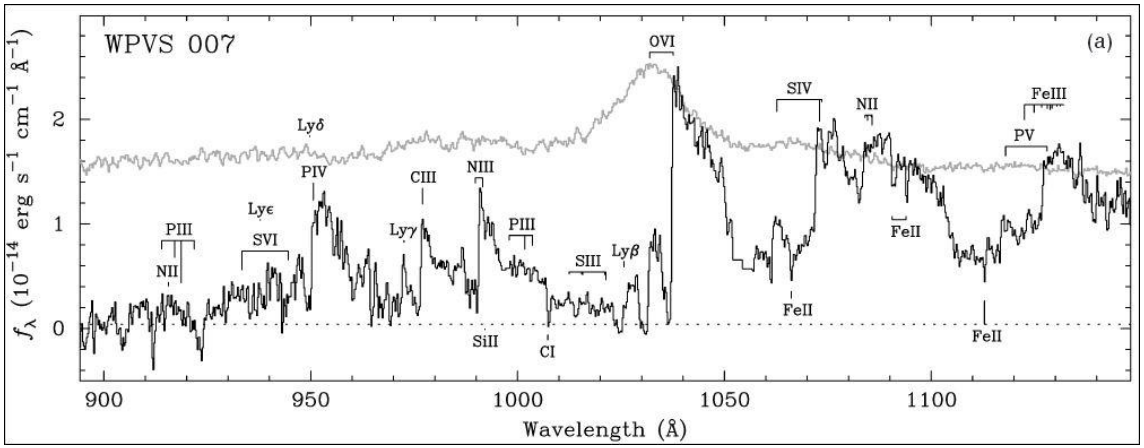
- its optical spectrum is that of a NLS1 (z=0.028); little/no changes from 1993-2012
- ***FUSE*** UV (vs earlier *HST*) then revealed launch of BAL flow, v_{max} ~ 6000 km/s and FWHM = 3400 km/s

  unusual for such a low-mass AGN; most BAL sources are massive quasars



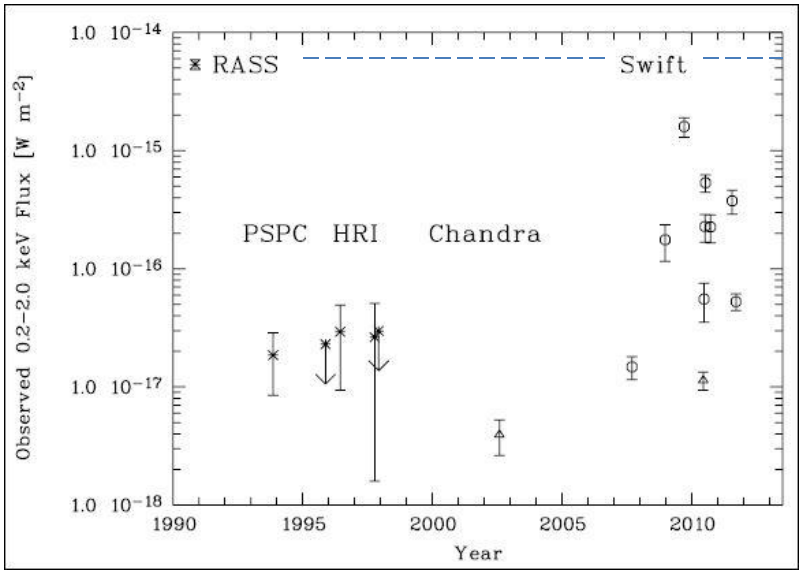




[Grupe+ 95, Grupe + 07, 08, 13, Leighly+09, 15]

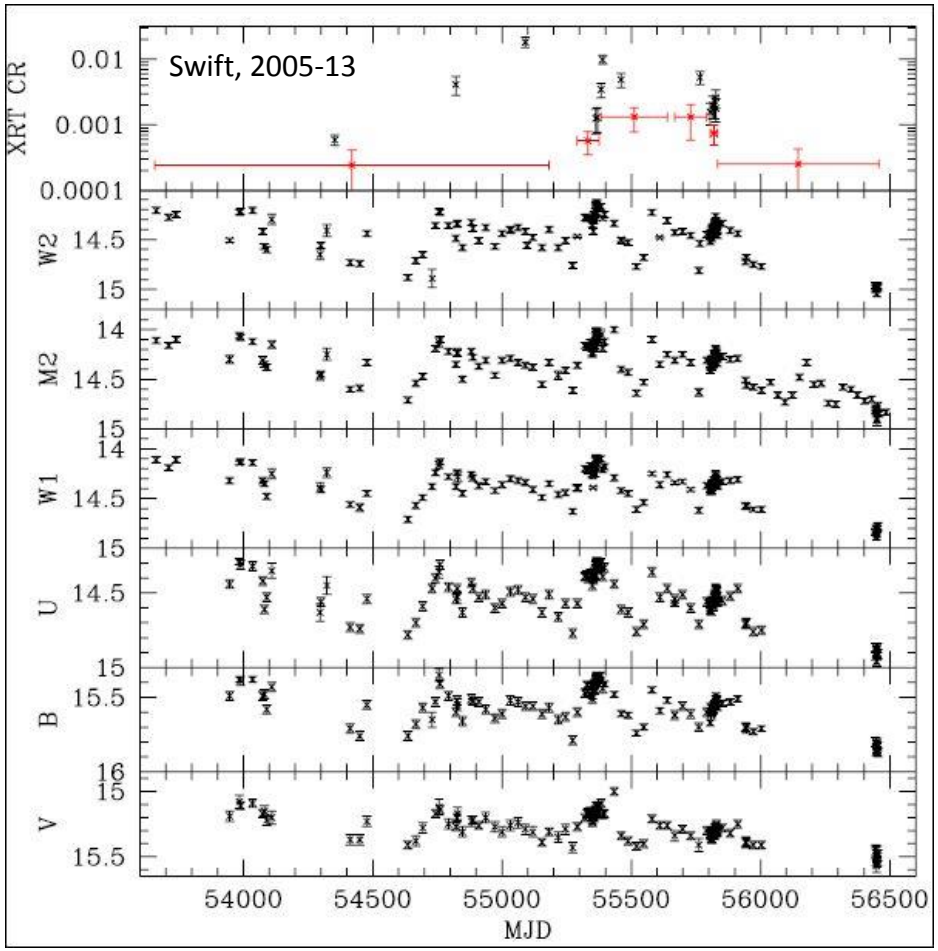
WPVS007

has remained X-ray faint ever since the 90s, except occasional rapid flaring:



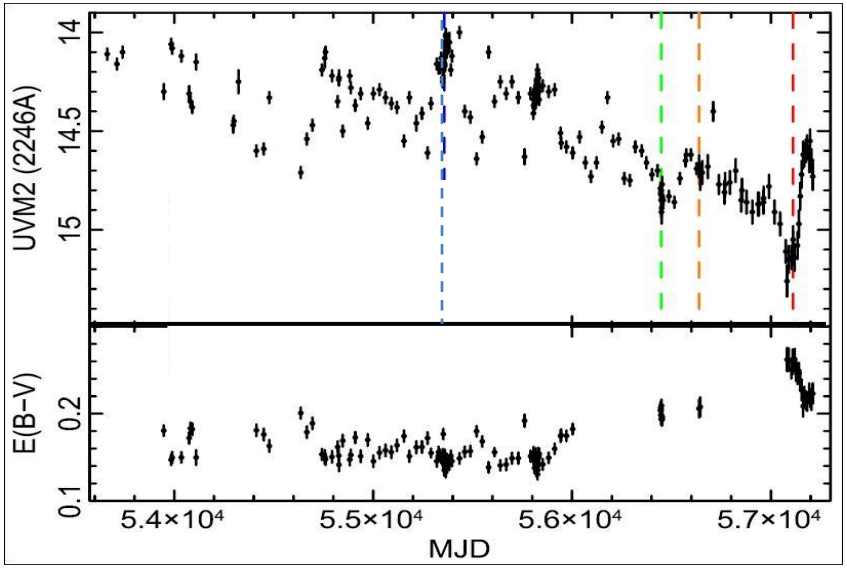
highly variable UV

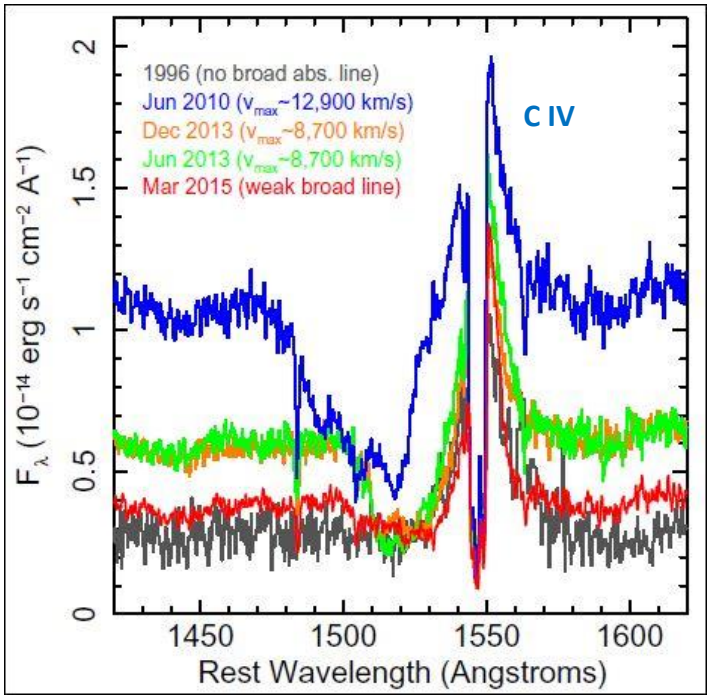
recent strong change in UV, into very low state: triggered HST observation



[Grupe + 95, 07, 08, 13, Komossa+ 14, Leighly+09, 15]

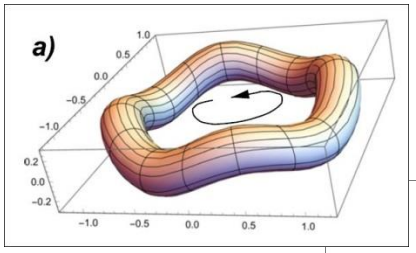
WPVS007



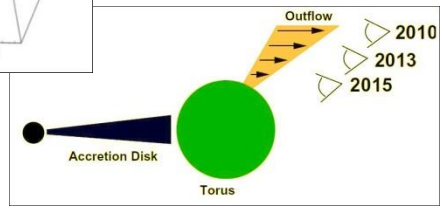


- overall UV decline &2015 occultation event
- photometry (Swift) consistent with change in reddening
- deep, highly variable CIV absorption (HST) anti-correlated with reddening

→ l.o.s. grazes edge of clumpy, dusty torus
- clumps produce occultation event(s)
- else: view through wind launched from edge of torus, r ~ 0.1-1pc



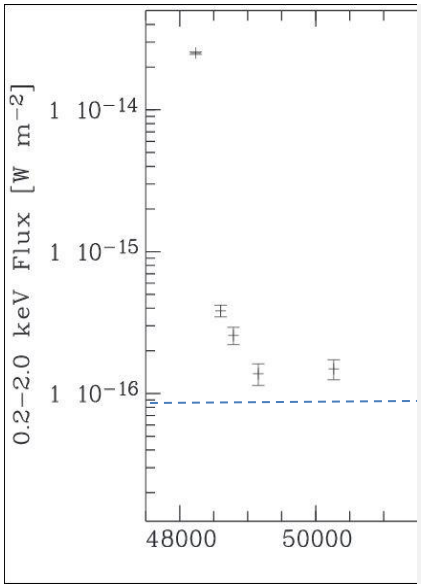
simplified illustration of a possible geometry

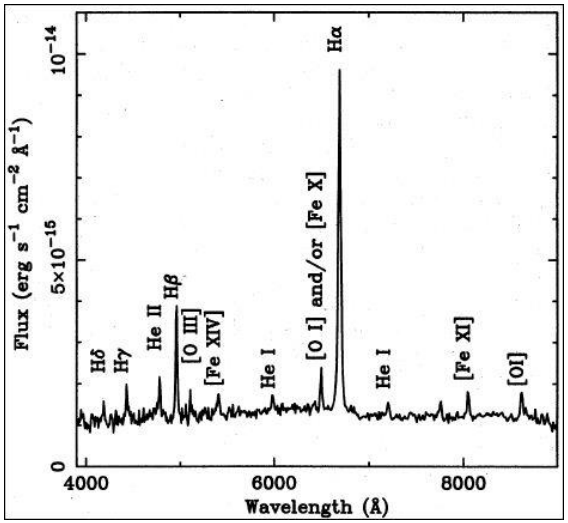


why this unique behavior of WPVS007 ?
shorter timescales in this low-mass AGN,
M_{BH} ~ 4 10^6 M_{sun}

[Grupe + 07, 08, 13, Leighly+09, 15, Cooper+16-prep]

The X-ray transient Sy1.9 galaxy IC 3599



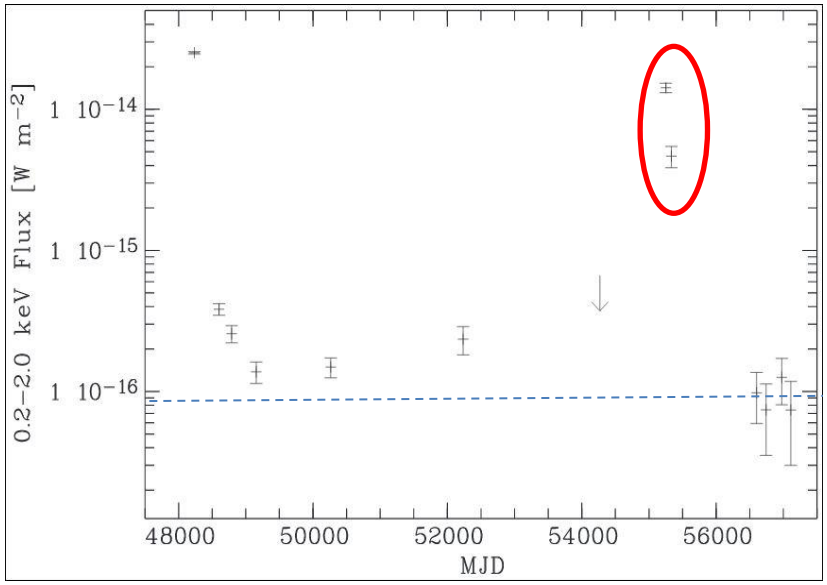


- luminous X-ray outburst (RASS)
- ‚classical' opt AGN before & after, z=0.02 (based on: narrow lines, radio, MIR spec)
- accompanied by variable broad H & forbidden (Fe) lines

photoion. modelling: variable lines consistent with CLR – origin

[Brandt+ 95, Grupe+ 95, Komossa & Bade 99]

IC 3599 did it again



- second flare discovered by Swift, ~ 20yr after first one
- with similar amplitude (~ factor 100)
- preceeded by opt high-state ~ 1yr earlier (Catalina survey)
- now back to X-ray low-state (our latest Swift data point is from July 2016)

[Komossa+14, Grupe, Komossa, Saxton 15]

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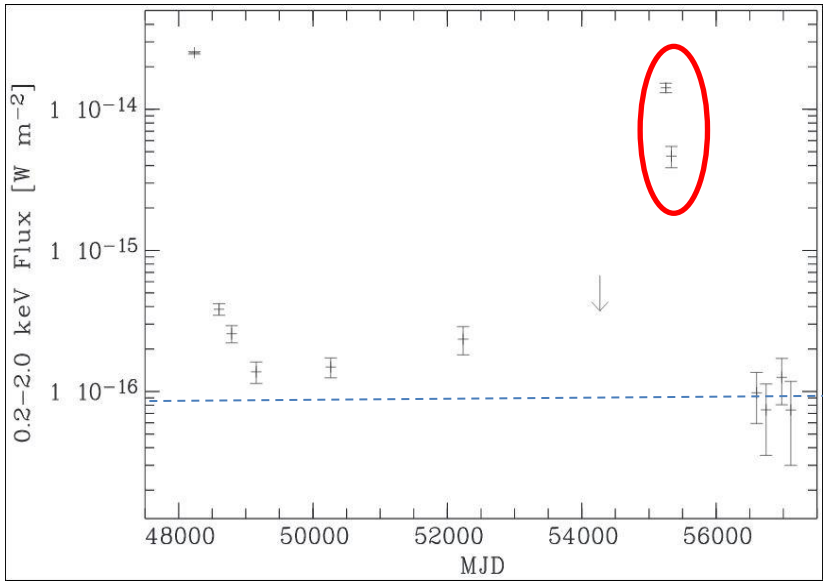

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- **repeat TDE ?**
  - boosted rate (Chen+ 09, Komossa & Merritt 08, Li+ 15), but no merger, & early recoil too unlikely
  - repeat tidal stripping: (Campana +15)
  - binary star disruption: (Mandel &Levin 2015), then don't expect a 3rd peak
- SMBBH ?: a la OJ287 (Valtonen+ 14), or stream feeding from disk with inner gap (Tanaka+ 13)
- **highly variable AGN:** perhaps a disc (LE) instability, as `seen' in Gal BH binary GRS1915 (many uncertainties, but most likely scenario, since a long-lasting AGN)

[Komossa+14, Grupe, Komossa, Saxton 15]

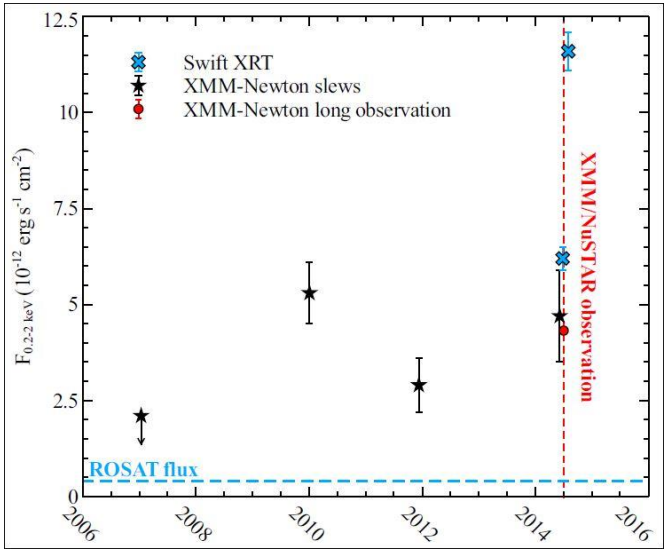
changing-look AGN: now you see it, now you don't

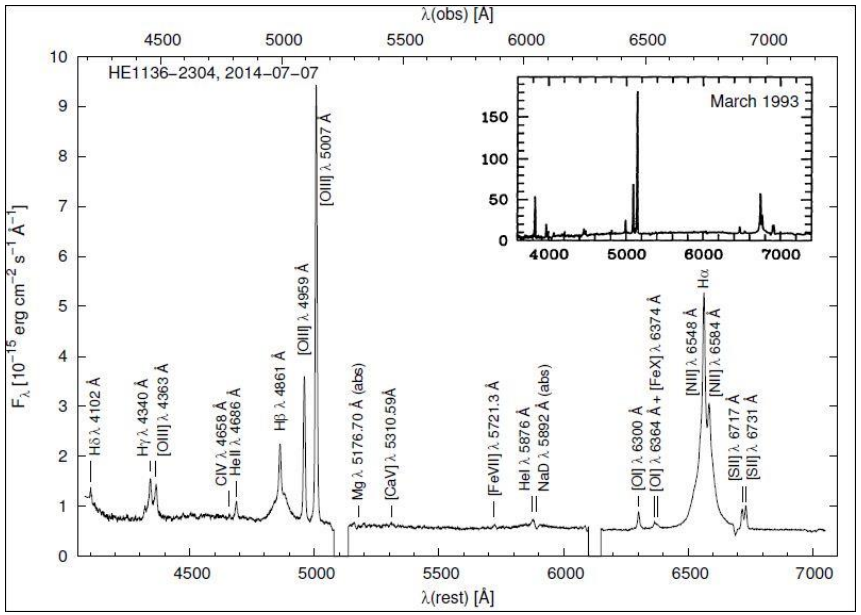
HE1136-2304

- discovered in high-state in XMM-slew → XMM, NuSTAR, Swift & SALT quasi-sim. within 3d
- change of Sy1.9 into Sy1 (Δt =11yr)
- high amplitude of X-ray increase (x 30) accompanied by strong broad-line increase (x >4)

-- unlikely changes in large-scale extinction/torus

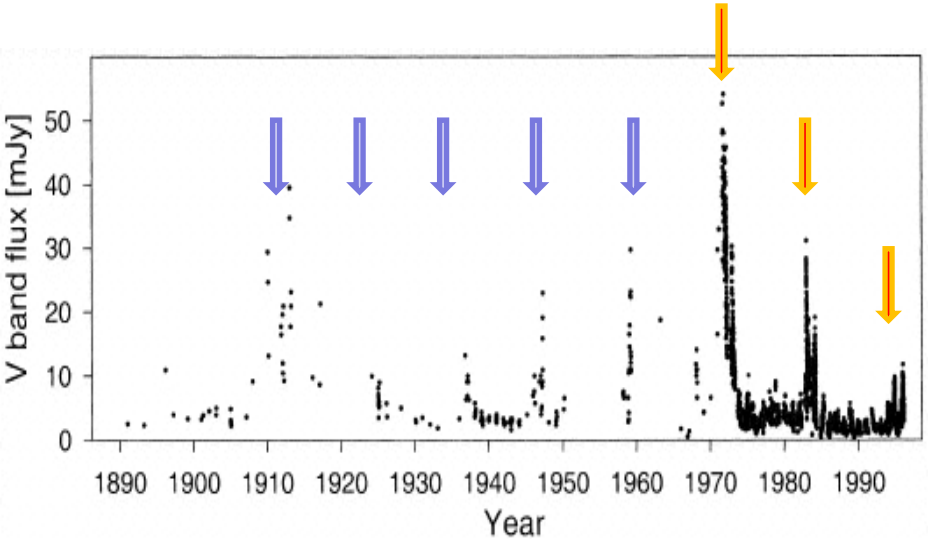
→ change in accretion rate ?
- either BLR sees more photons
- or cloud-formation conditions change (Nicastro+00, Elitzur+14)





[Parker, Komossa, Kollatschny et al. 16]

semi-periodic variability: SMBBH candidate OJ287



- BBH model: burst interval ~ orbital period, ~ 12 yrs
- double-peak structure: 2ndary in precessing orbit impacts warped, thick disk *twice*

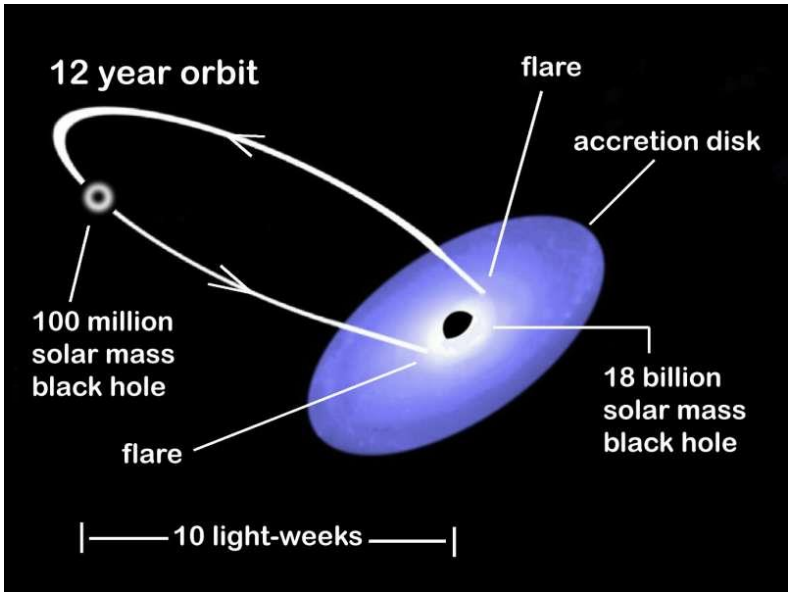
- orbital parameters of Valtonen et al.:

  $M_1 = 1.8\ 10^{10}\ M_{sun}$

  $M_2 = 1.4\ 10^{8}\ M_{sun}$

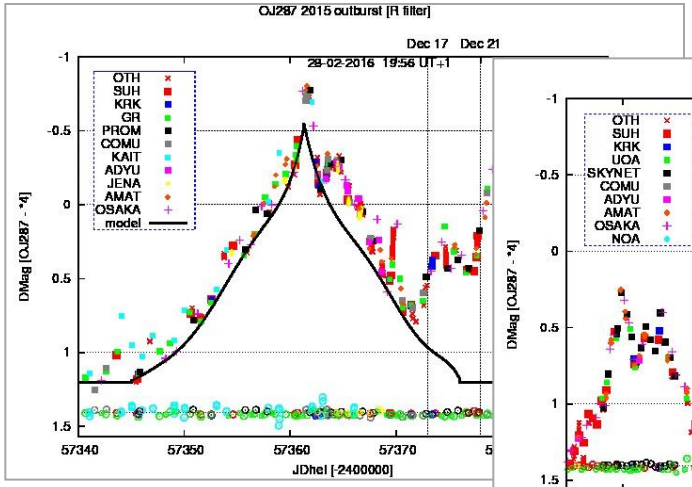
  e = 0.7, a = 9300 AU

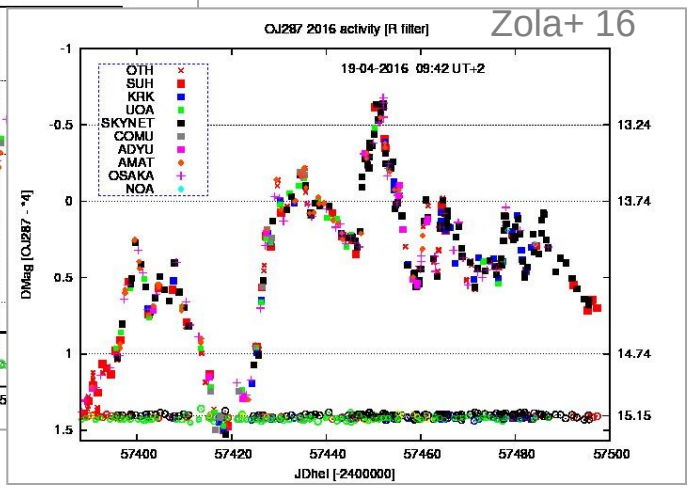
- tentative evidence for orbital shrinkage due to emission of GWs (DT_{GW} = 0.01 yr/period)



[e.g. Silanpää et al. 88, 96, Lehto & Valtonen 96, Katz 97, Sundelius+ 97, Villata+ 98, Pietilä+ 98, Liu & Wu 02, Valtonen+ 97,06, 07,10, 12.....]

candidate SMBBH OJ 287: already after (or, towards) the next maximum ?

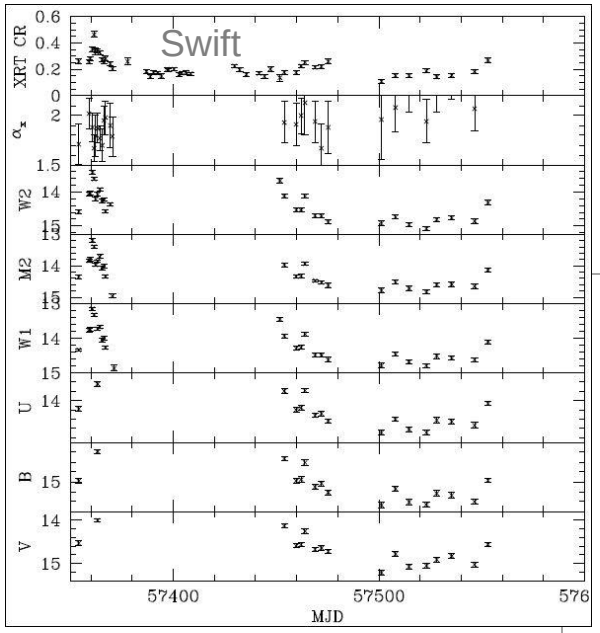


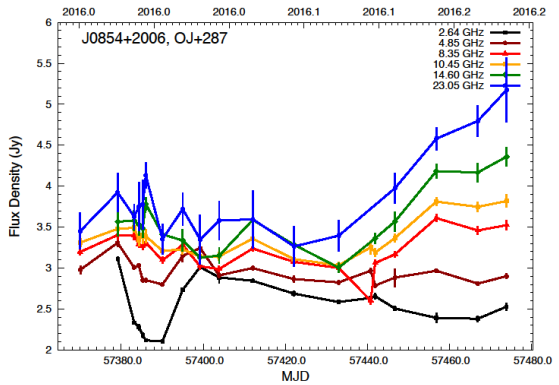


Zola+ 16

[e.g., ATEL #8372, #8374, #8378, #8382, #8411, 2015, #8667, 2016]

- strong optical flare Dec.5, 2015
- already the next „decadal“ maximum ? → then strong orbital (forward) precession required
- meanwhile, even brighter optical peak was seen; broad ongoing flare
- → multi-λ monitoring continues





Effelsberg, radio

[Valtonen+ 15, 16, Komossa+ 15, Zola+ 16]

summary

- ongoing monitoring programs (Swift) to search for AGN in extreme flux & spectral states

- (rapid) follow-ups at multiple wavebands (e.g., XMM, Suzaku, NuSTAR; HST, optical ground-based telescopes, Effelsberg, ….)

extremes of (X-ray) variability provide us with important insights on accretion physics; nature of the inner disk, relativistic effects; properties & location of absorbers and outflows; discovery of rare/new transients

- **factor ~10 - 20 var:** deep X-ray low (+high) states, absorption vs. reflection scenarios; no strong optical broad-line changes (best-observed case: Mrk 335)
- **factor ~30 - >100 var**: highest-amplitude outbursts and drops in AGN; some require extreme effects

  -- WPVS007: unique in dramatic X-ray & BAL variability in nearby, low-mass NLS1 galaxy

  -- IC3599: unique 2nd, high--amplitude outburst (factor 100), from disk instability ?

  -- HE1136: new changing-look AGN, with Sy-type change; driven by change in acc rate ?
- **quasi-periodic bursts:** multi-wavelength follow-ups of SMBBH candidate OJ 287: before or after next 'decadal' maximum?; ongoing radio monitoring to distinguish sev. SMBBH scenrs

future: - growing importance of *triggered* observations, to catch the extreme states

- higher sensitivity *& resolution* in X-rays, to break degeneracy of absorption/reflection
- multi-wavelength approach (incl. HST)
- dedicated searches for new outbursting AGN & TDEs in transient surveys & rapd f-ups