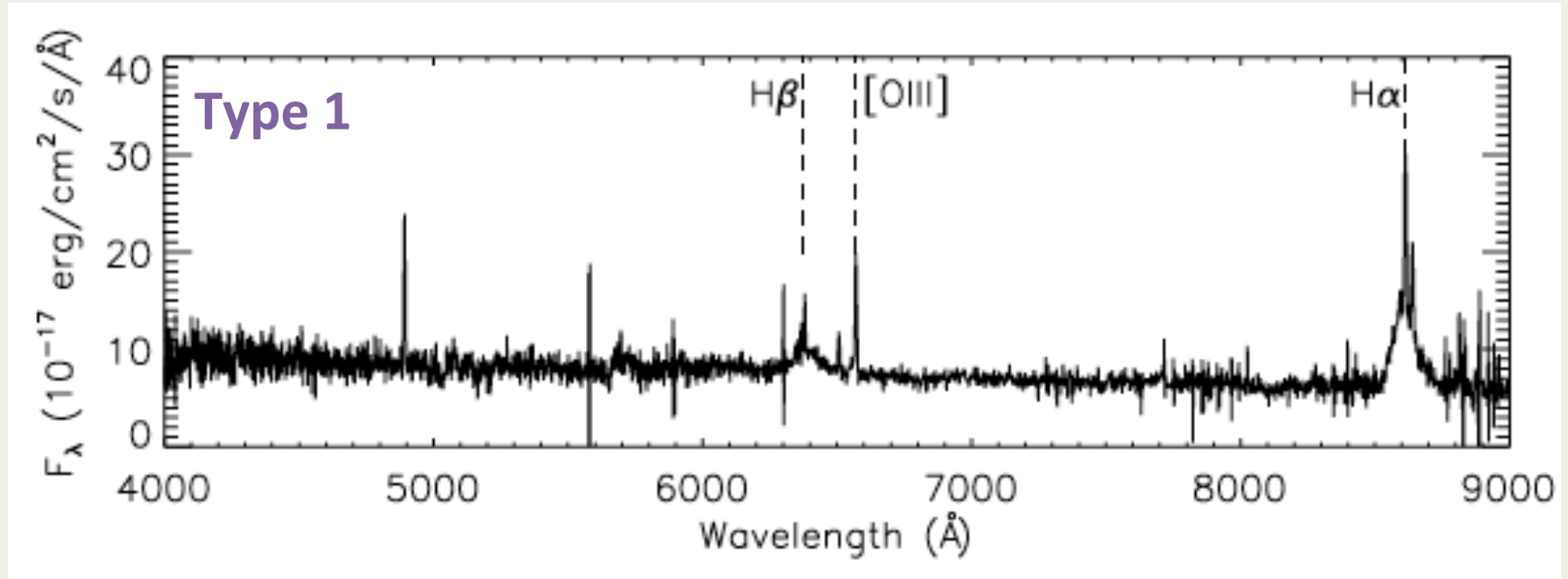


The Changing Looks of AGN

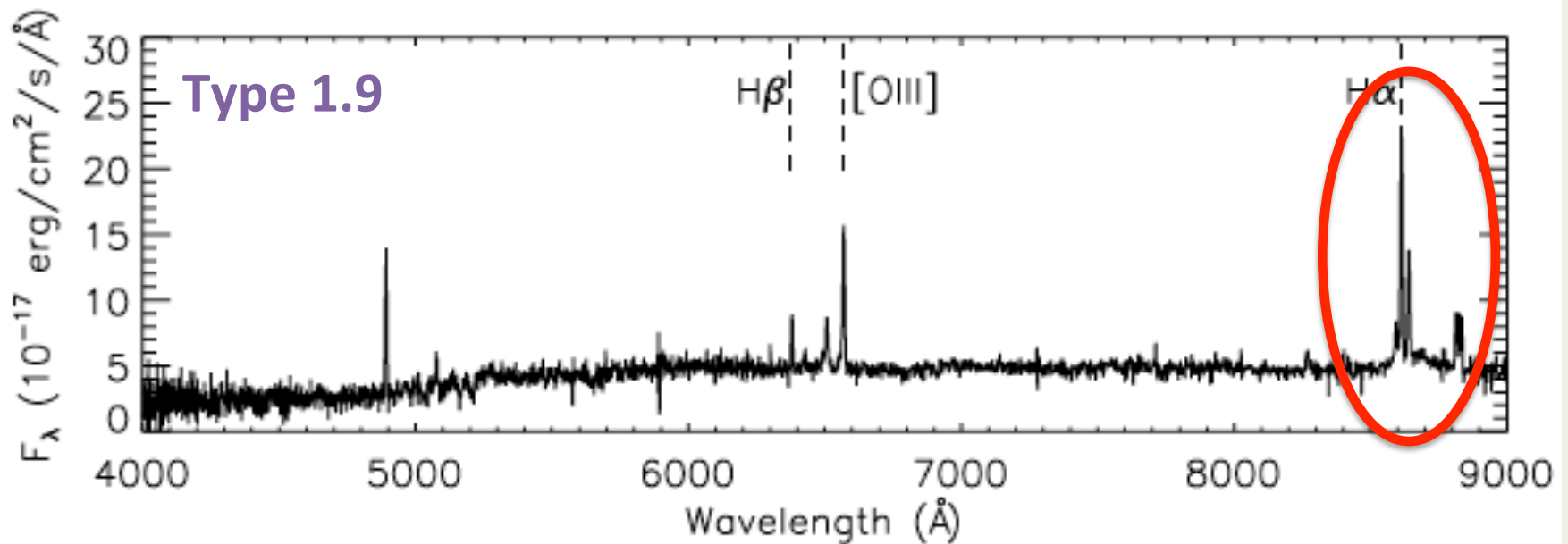
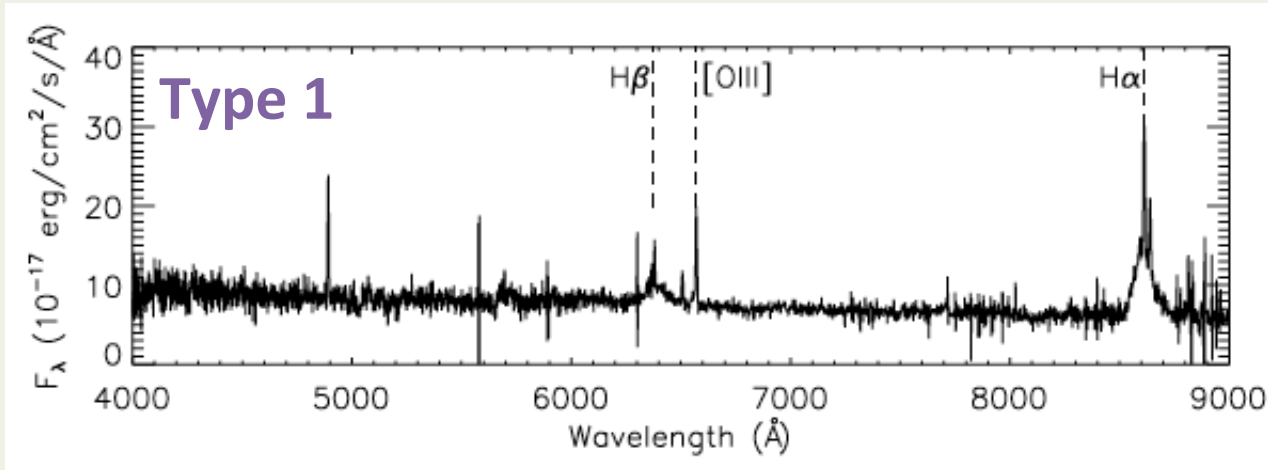
Stephanie LaMassa (NPP Fellow, GSFC)

Collaborators: Sabrina Cales, Ed Moran, Adam Myers, Richard Gordon, Michael Eracleous, Tim Heckman, Luigi Gallo, Meg Urry, Jessie Runnoe, John Ruan

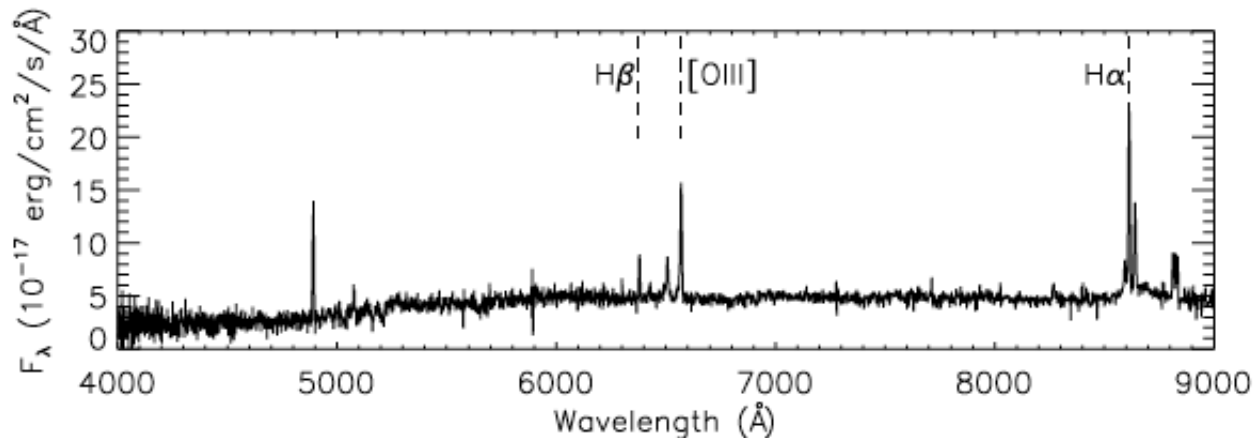
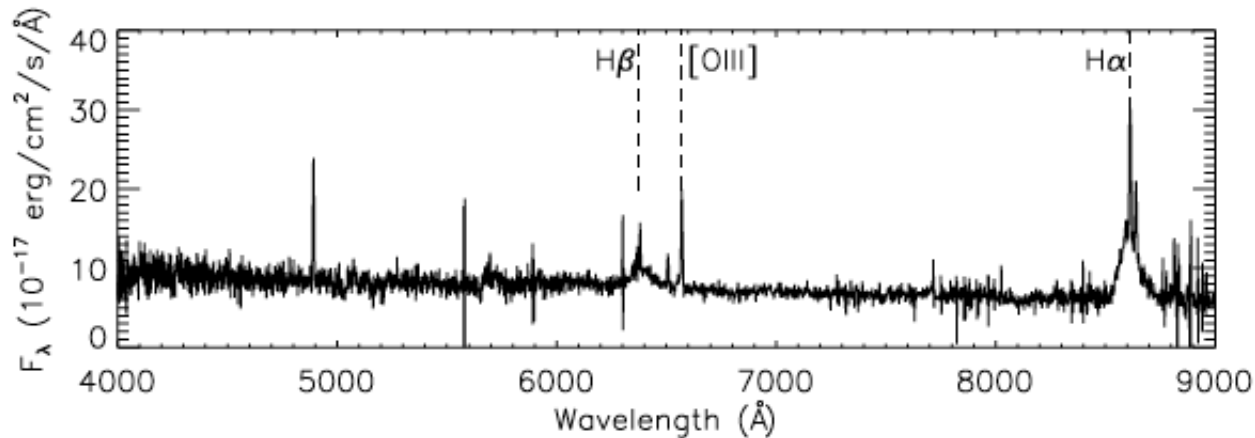
Defining AGN via Optical Spectra



Defining AGN via Optical Spectra



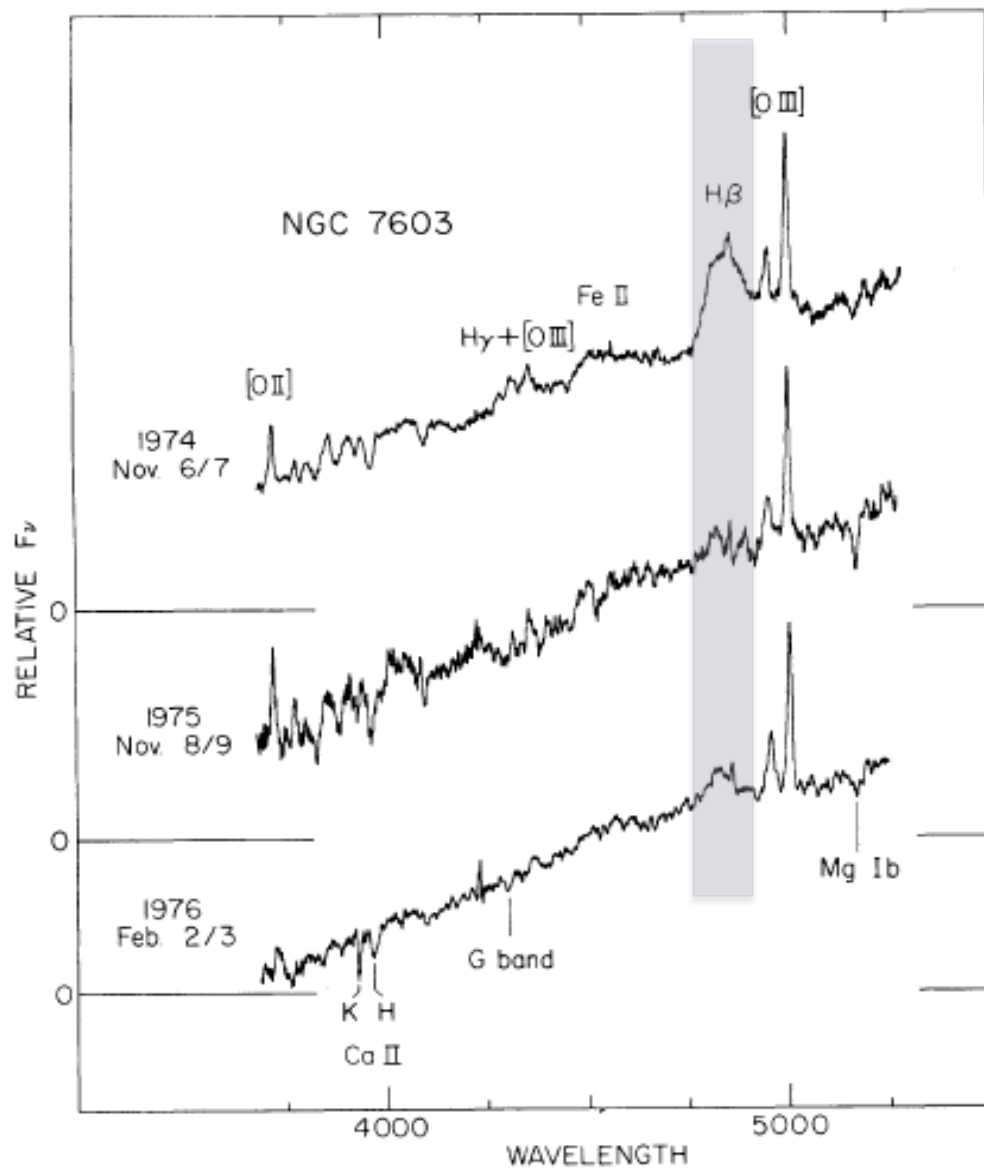
SDSS J015957.64+003310.5



Changing-Look AGN History

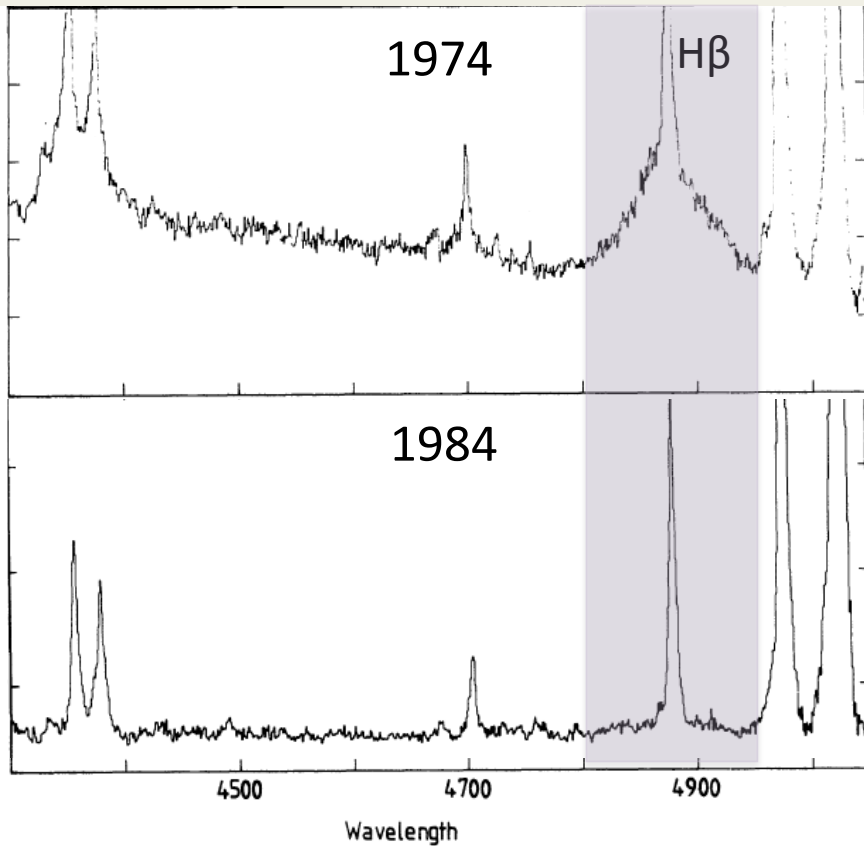
NGC 7603

Tohline & Osterbrock '76

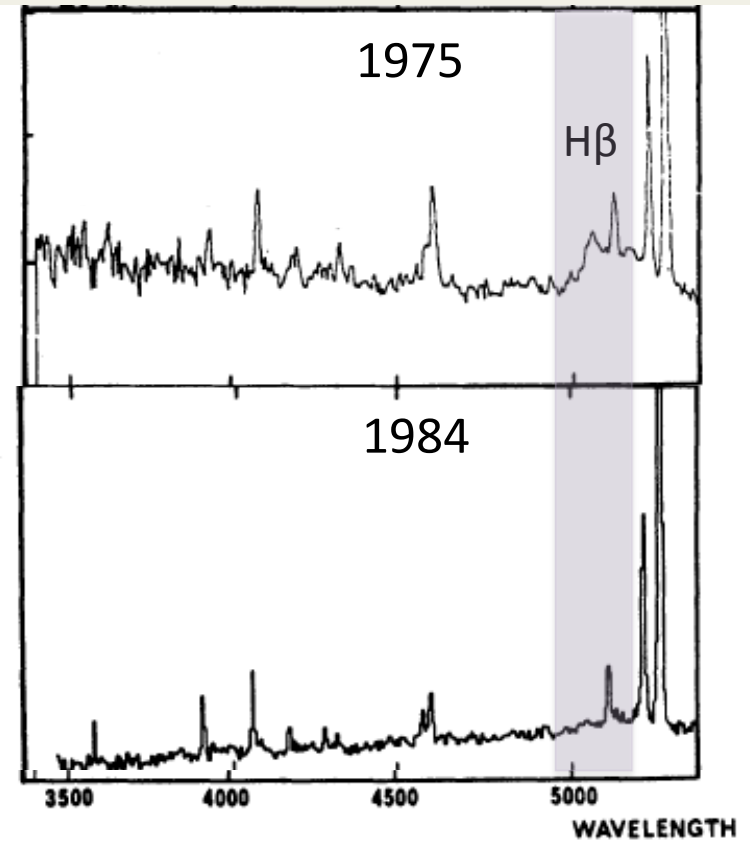


Disappearance of Broad Lines

NGC 4151



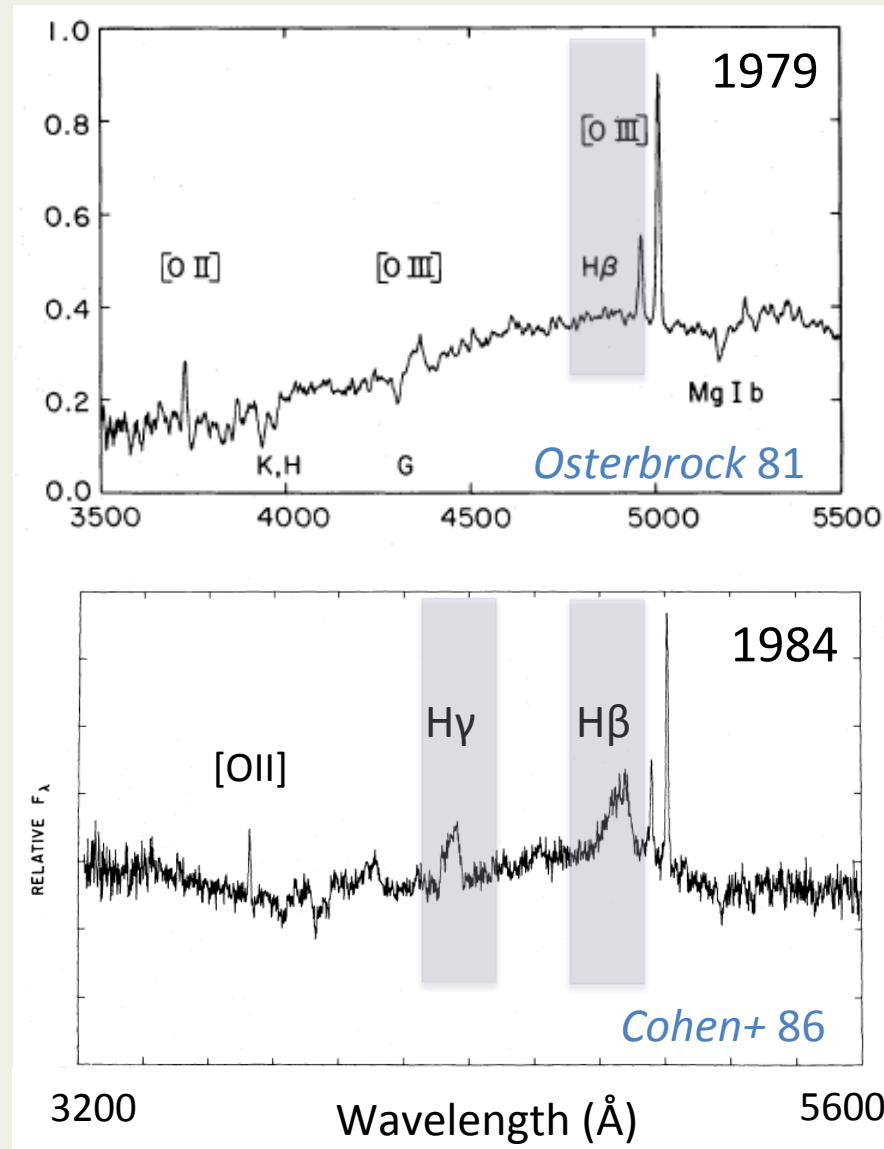
3C390.3



Penston & Perez 84; see also Goodrich 95

Appearance of Broad Lines

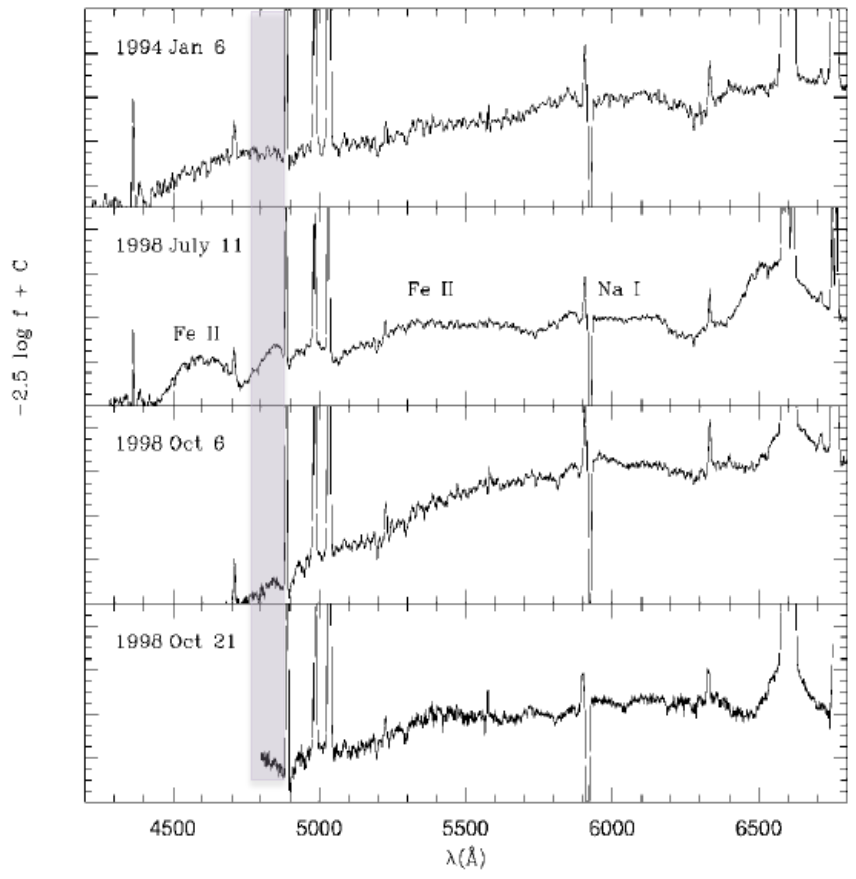
Mrk 1081



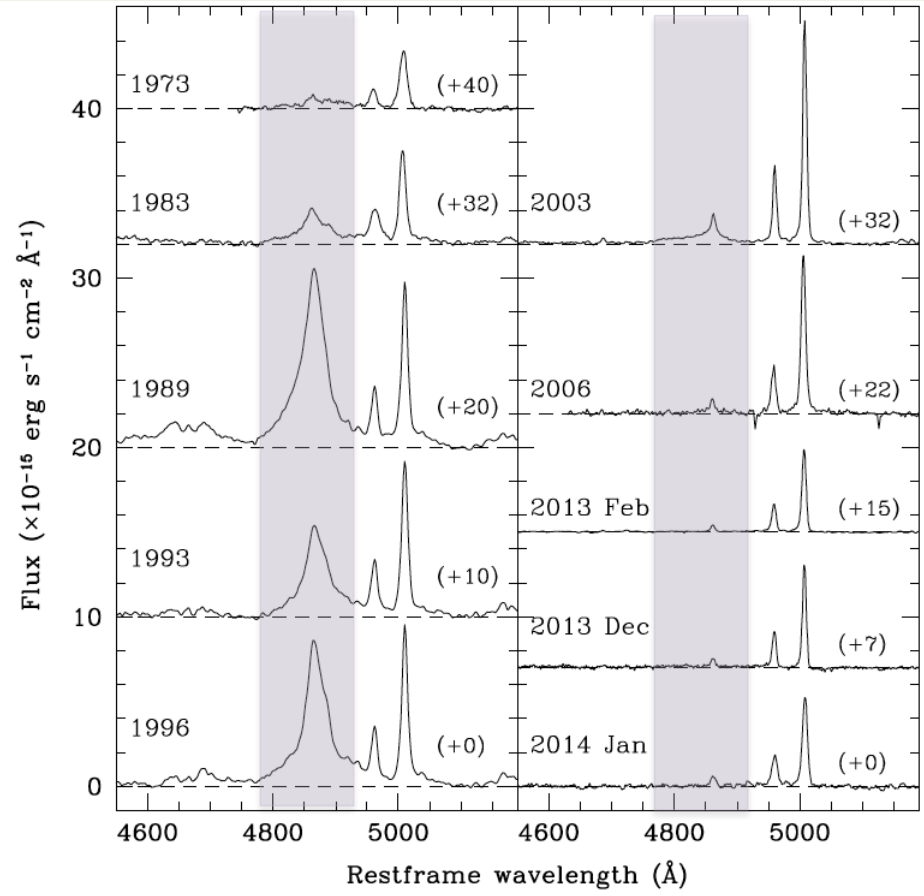
See also [Tran+ 92](#), [Storchi-Bergmann+ 93](#), [Goodrich+ 95](#), [Eracleous & Halpern 01](#), [Shappe+ 14](#)

There & Back Again

NGC 7582 *Aretxaga+ 99*



Mrk 590 *Denney+ 14*



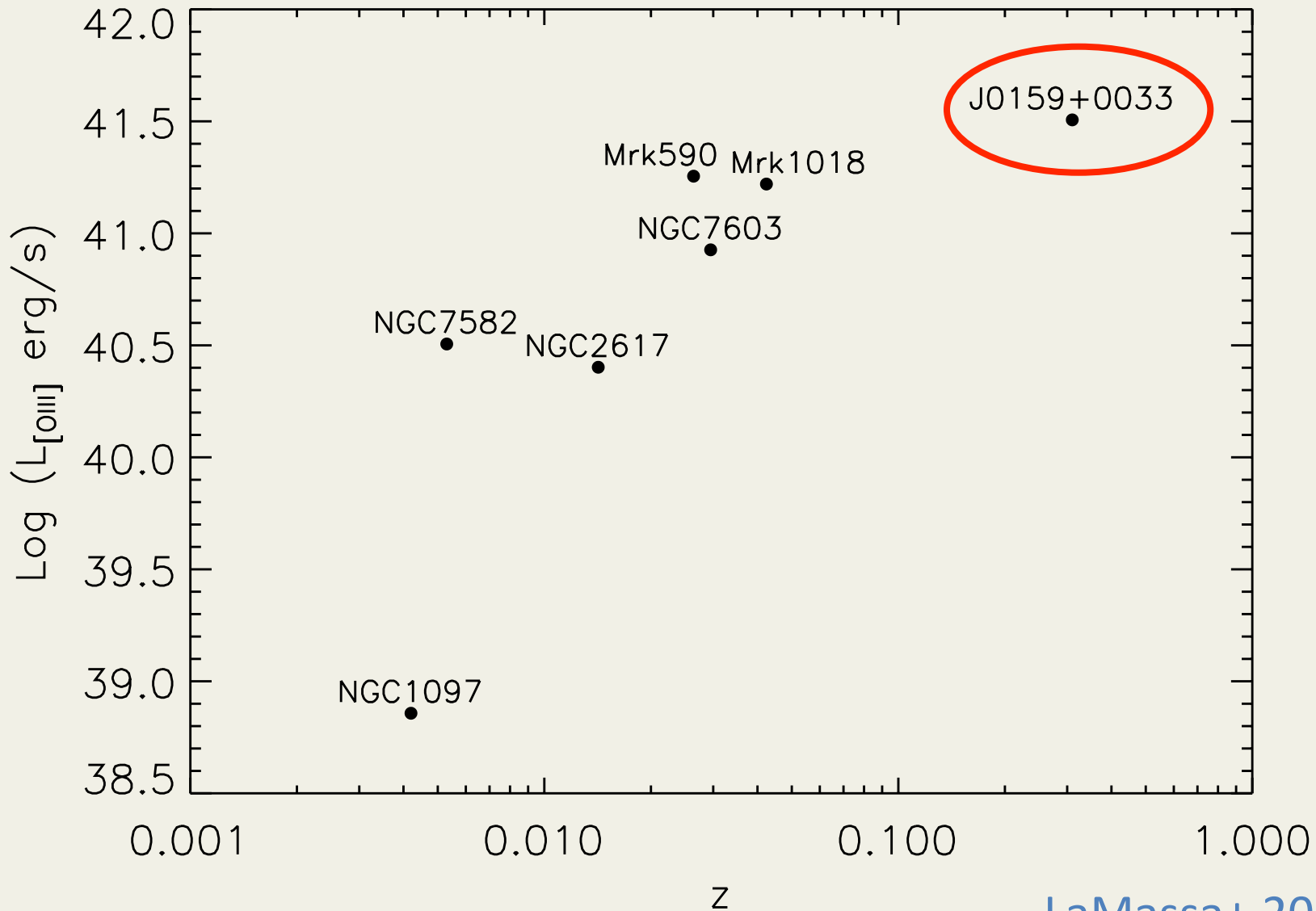
Changing-Look AGN Causes

- Variable absorption Mrk 1018, Mrk 993, NGC 7603, NGC 1097, NGC 7582 (?)
- Ionizing continuum change Mrk 590, NGC 2617, Mrk 883, NGC 3065, J0159+0033
- SN NGC 7582 (?)
- TDE NGC 3065 (?), NGC 7582 (?), J0159+0033 (?)

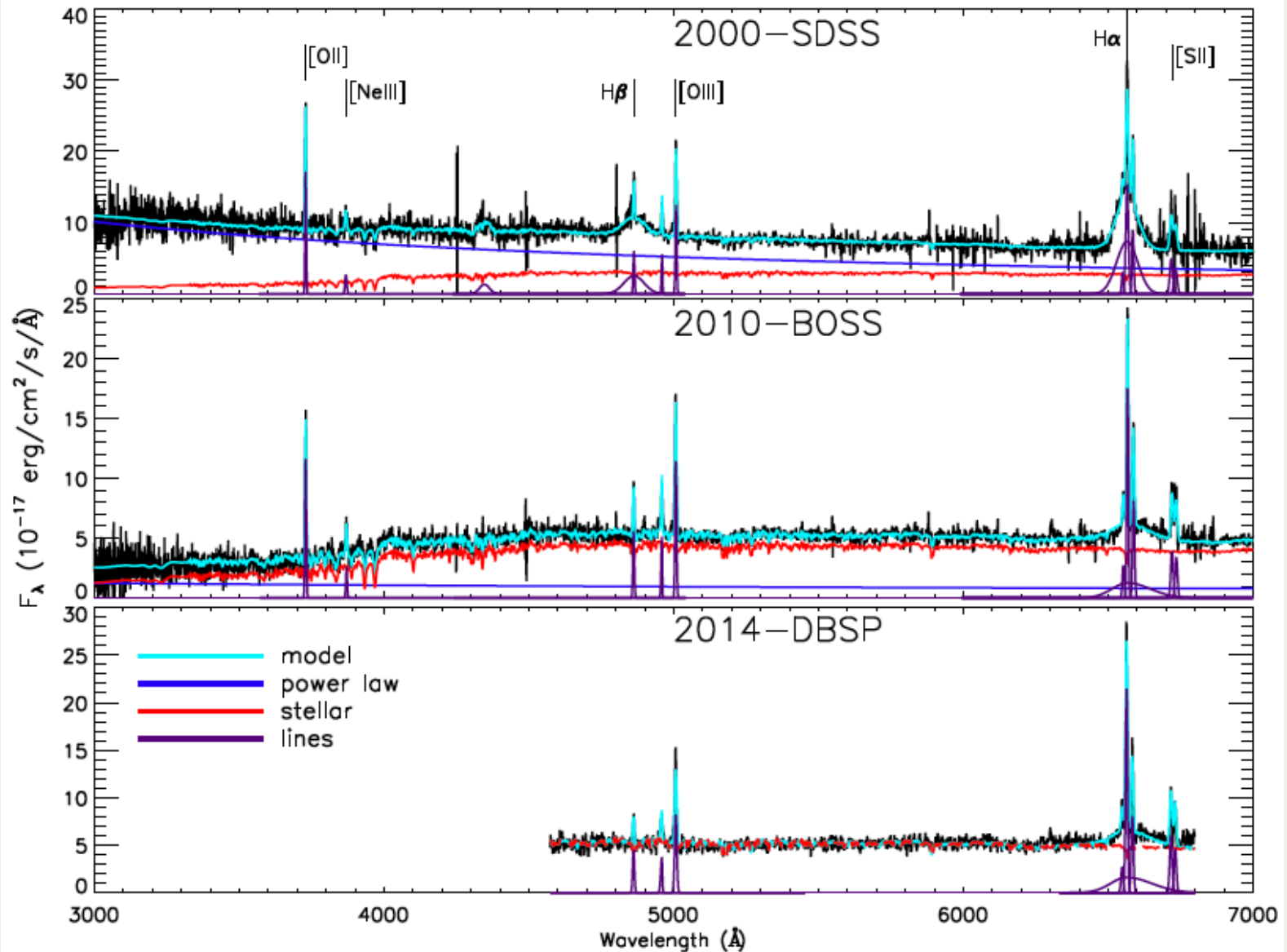
Case Study: J0159+0033

- Discovered in $\sim 31 \text{ deg}^2$ Stripe 82 X-ray survey ([LaMassa+ 2013b,c,2015a](#); see also [Merloni+ 2015](#))
- $z = 0.31$
- “Quasar” in 2000

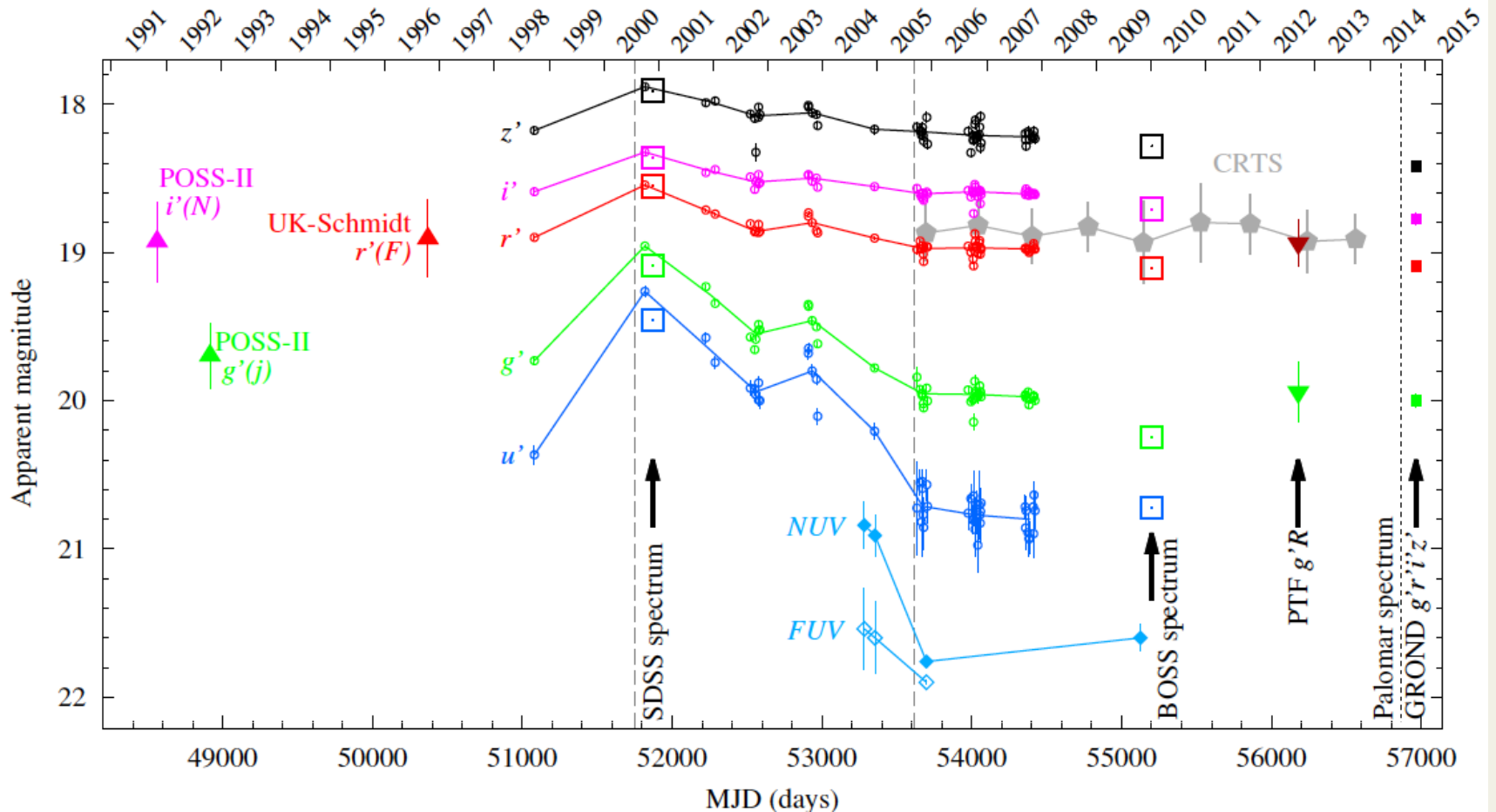
J0159+0033 in Context



1st “Changing-Look” Quasar

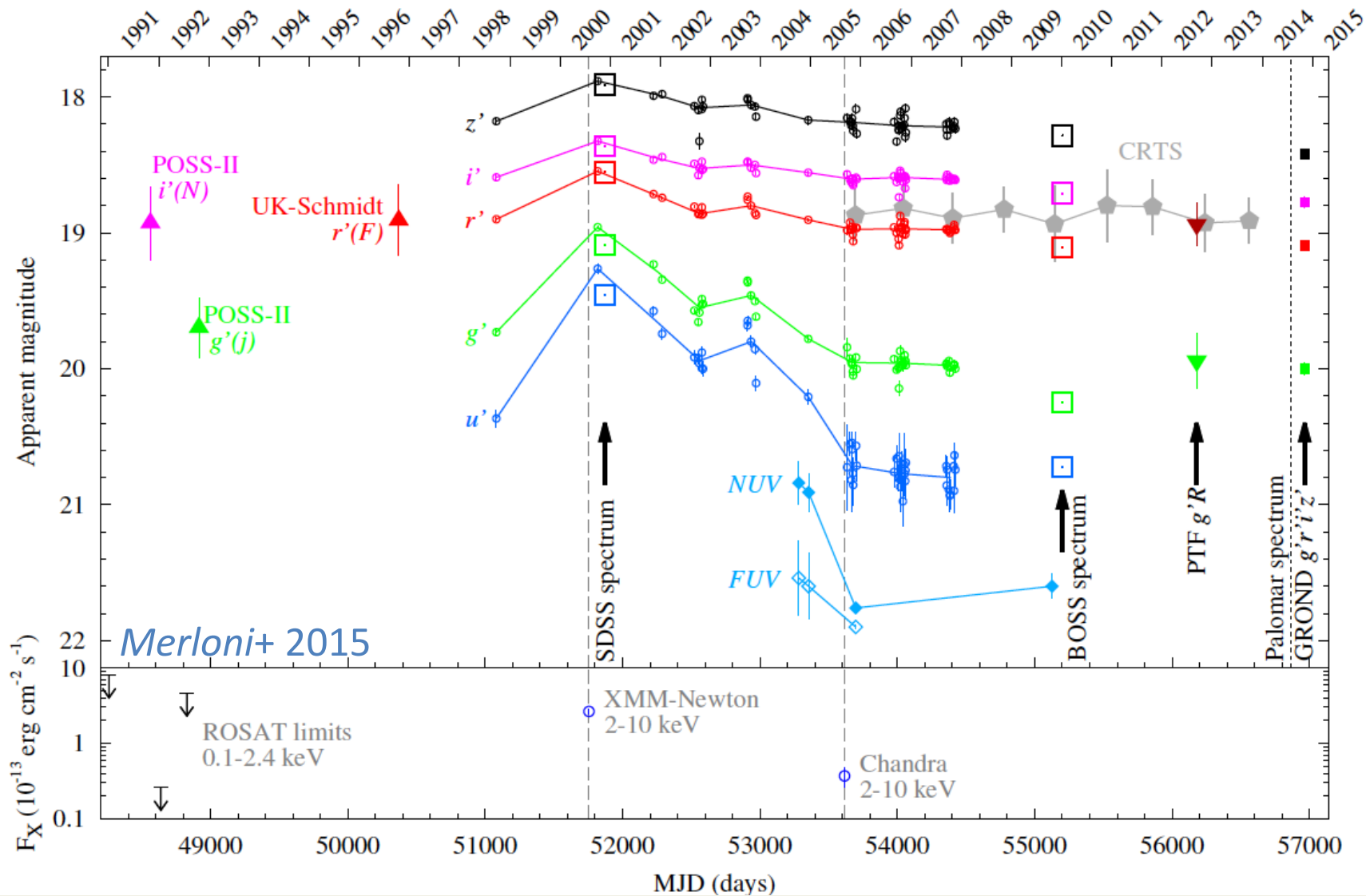


Brightness Variations

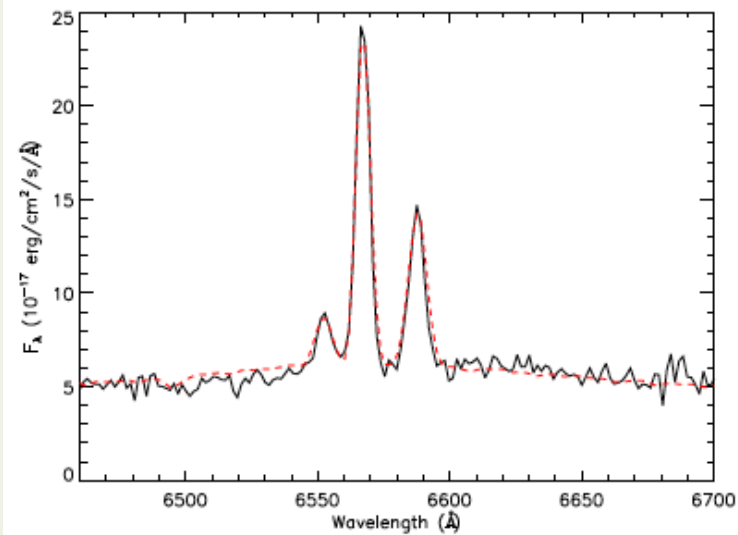
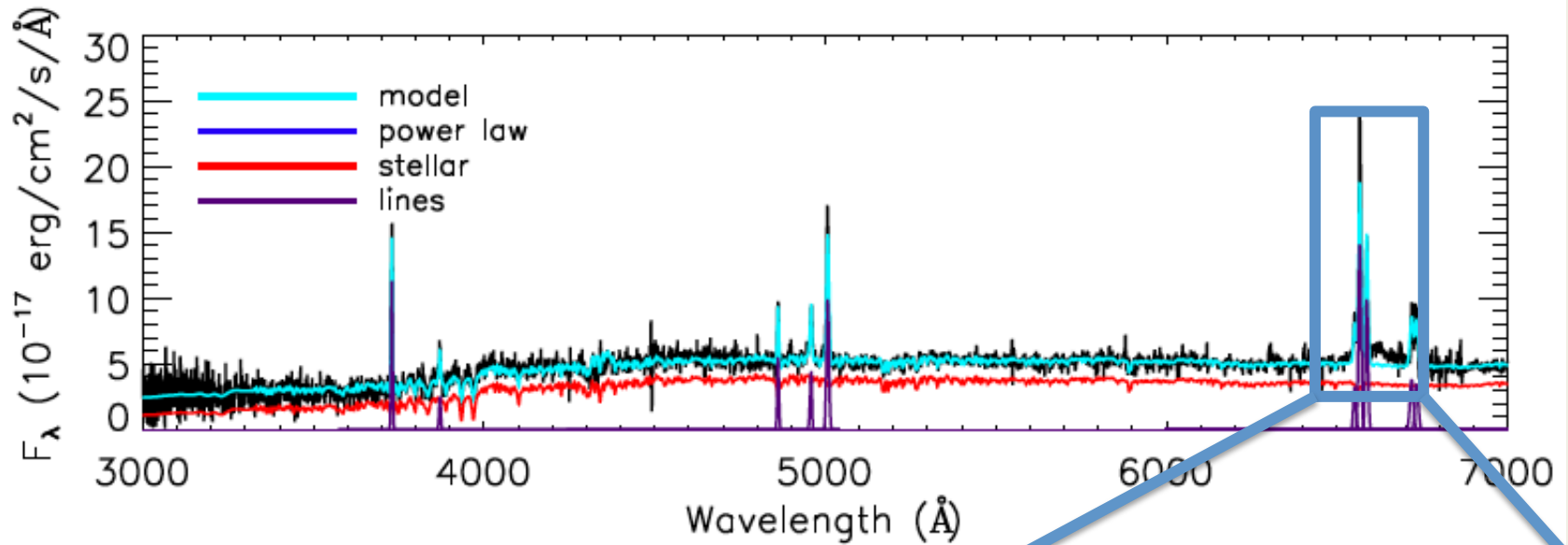


Merloni+ 2015

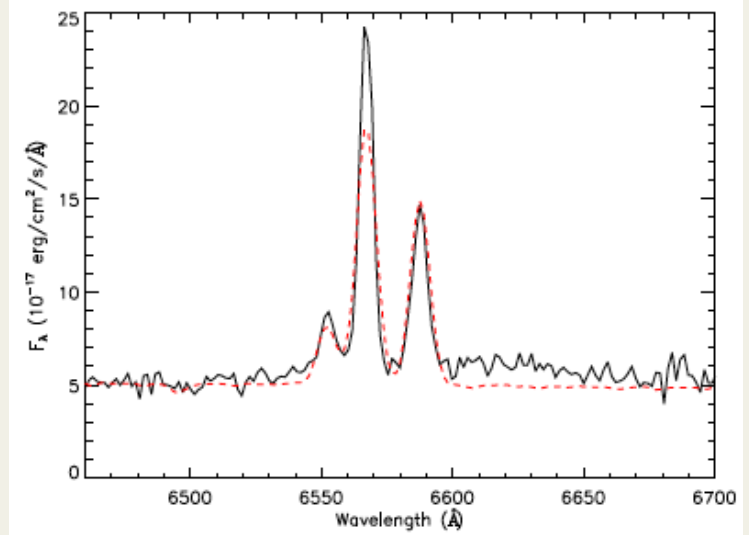
Brightness Variations



Variable Absorption?



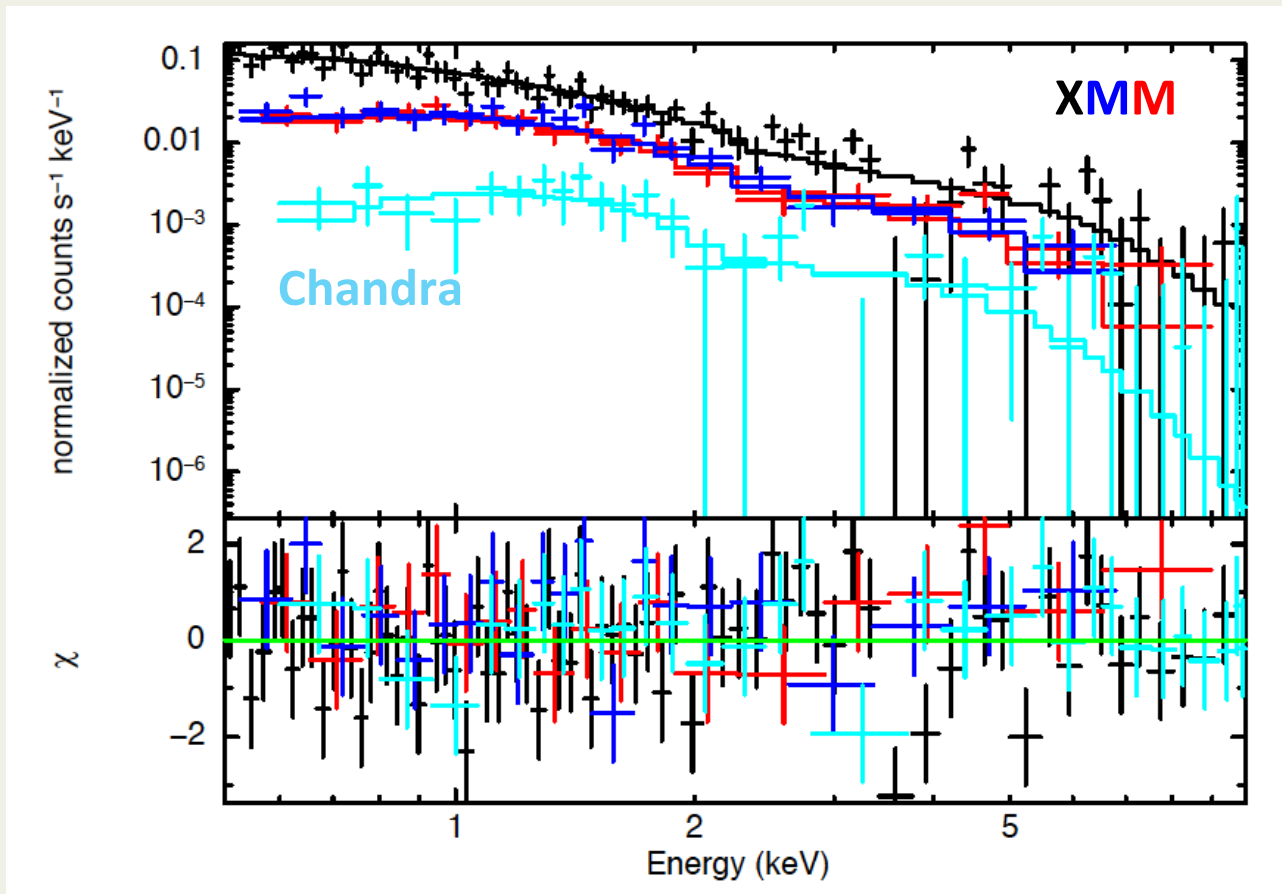
vs.



Further evidence against obscuration

LaMassa+ 2015a

- No absorption signatures in X-ray spectrum



Further evidence against obscuration

LaMassa+ 2015a

- No absorption signatures in X-ray spectrum
- Similar drop in optical & X-ray fluxes

$$(\lambda L_{5100,\text{bright}}/\lambda L_{5100,\text{dim}}) = 5.5$$

$$(F_{2-10\text{keV},\text{bright}}/F_{2-10\text{keV},\text{dim}}) = 7.2$$

Further evidence against obscuration

LaMassa+ 2015a

- No absorption signatures in X-ray spectrum
- Similar drop in optical & X-ray fluxes
- Similar BH masses in bright & dim states

$$M_{\text{BH}} = 9.7 \times 10^6 \left[\frac{\text{FWHM}(\text{H}\alpha)}{1000 \text{ km s}^{-1}} \right]^{2.06} \left[\frac{\lambda L_{5100}}{10^{44} \text{ erg s}^{-1}} \right]^{0.519} M_{\odot}$$

$$M_{\text{BH,bright}} = 1.7 \pm 0.1 \times 10^8 M_{\odot}$$

$$M_{\text{BH,dim}} = 1.6 \pm 0.4 \times 10^8 M_{\odot}$$

Further evidence against obscuration

LaMassa+ 2015a

- No absorption signatures in X-ray spectrum
- Similar drop in optical & X-ray fluxes
- Similar BH masses in bright & dim states
- H α profile change cf. λL_{5100} change

$$\text{FWHM} \sim R_{\text{BLR}}^{-1/2}; R_{\text{BLR}} \sim L^{1/2} \text{ (e.g. Bentz+ 06)}$$

$$\rightarrow \text{FWHM} \sim L^{-1/4}$$

Further evidence against obscuration

LaMassa+ 2015a

- No absorption signatures in X-ray spectrum
- Similar drop in optical & X-ray fluxes
- Similar BH masses in bright & dim states
- H α profile change cf. λL_{5100} change

$$\rightarrow \text{FWHM} \sim L^{-1/4}$$

$$\left(\text{FWHM}_{\text{H}\alpha, \text{bright}} / \text{FWHM}_{\text{H}\alpha, \text{dim}} \right) = 0.67$$

$$\left(\lambda L_{5100, \text{bright}} / \lambda L_{5100, \text{dim}} \right)^{-1/4} = 0.65$$

Further evidence against obscuration

LaMassa+ 2015a

- No absorption signatures in X-ray spectrum
- Similar drop in optical & X-ray fluxes
- Similar BH masses in bright & dim states
- H α profile change cf. λL_{5100} change
- t_{cross} for cloud to eclipse BLR

$$t_{\text{cross}} = 0.07 \left[\frac{r_{\text{orb}}}{1\text{lt} - \text{day}} \right]^{3/2} M_8^{-1/2} \arcsin \left[\frac{r_{\text{src}}}{r_{\text{orb}}} \right] \text{ yr.}$$

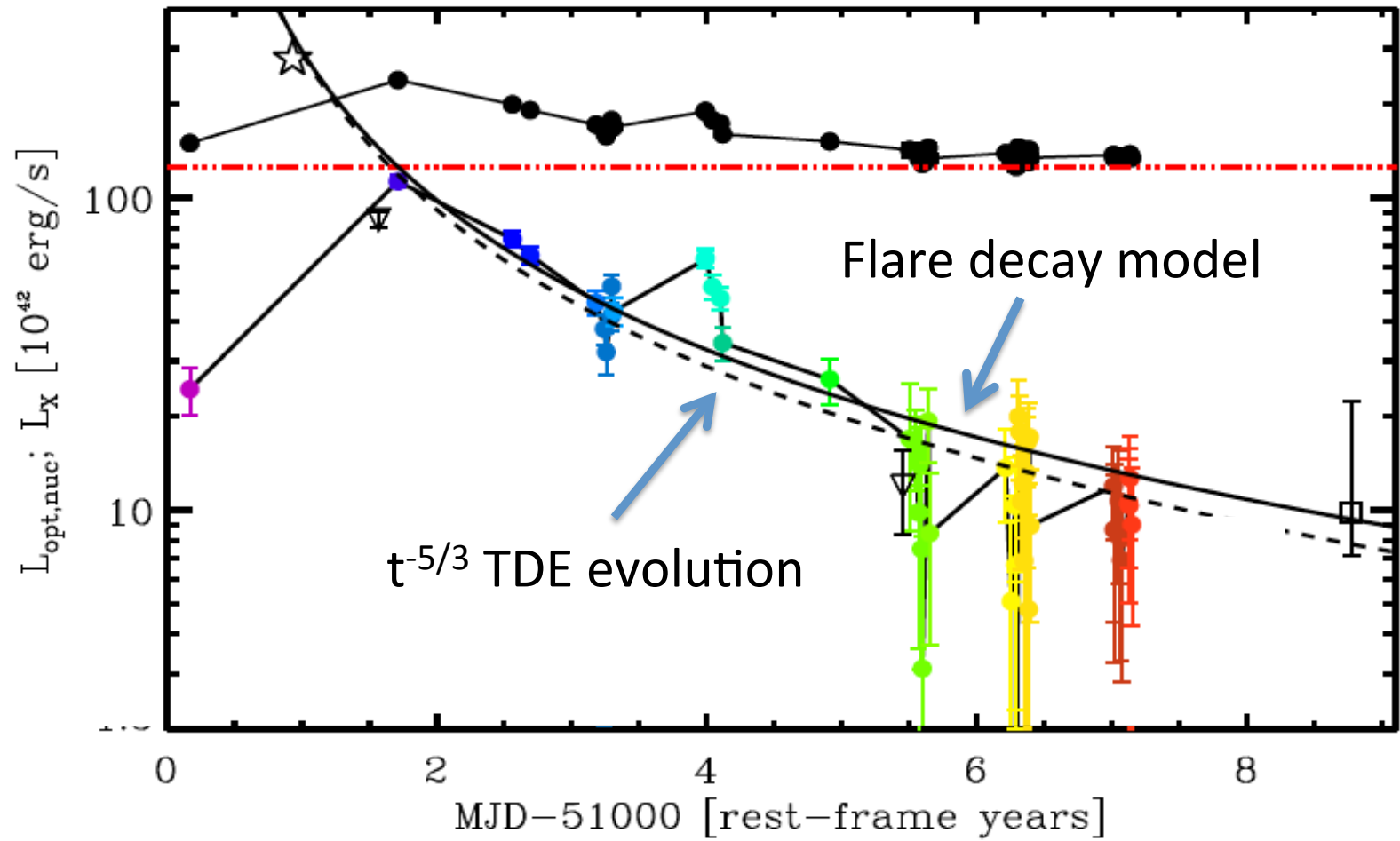
$$t_{\text{cross}} > 10\text{-}20 \text{ yrs}$$

$$t_{\text{change}} \sim 3 \text{ yrs}$$

Driver: Change in Ionizing Continuum

- Viscous time scale? *may need additional angular momentum loss (e.g., waves in inner disk, hydromagnetic winds)*
- Thermal time scale of inner disk or corona?
- Evolutionary sequence ([Elitzur + 2014](#)): Type 1 → Type 1.2/1.5 → Type 1.8/1.9 → Type 2 ([see Stern+ 2012](#))
- TDE? [Merloni+ 2015](#)

Driver: TDE?



Changing-Look AGN:

- Opportunity to study AGN lifetime/
intermittency
- Rare, but more being discovered
 - ➔ [Jessie Runnoe's talk](#)