When a Seyfert…

…has a Crash on a Model

(Nature Astronomy, in Preparation)

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Outline

- BELR and Accretion Power
- The astonishing case of Mkn 590
- Nicastro00 vs Elitzur+14
- Changing-Look AGNs and the Viscosity Crisis

Toy-Model for BELR (Nicastro, 2000)

[based on Witt, Czerny and Zwycki, 1997]

2. THE MODEL

The three main ingredients of our model are (*a*) the transition radius r_{tran}, derived by setting equal the radiation pressure at $r < r_{tran}$ and the gas pressure at $r > r_{tran}$, in a standard SS disk (SS73):

$$r_{tran} f^{-16/21} \simeq 15.2(\alpha m)^{2/21} \left(\frac{1}{\eta}\dot{m}\right)^{16/21}, \qquad (1)$$

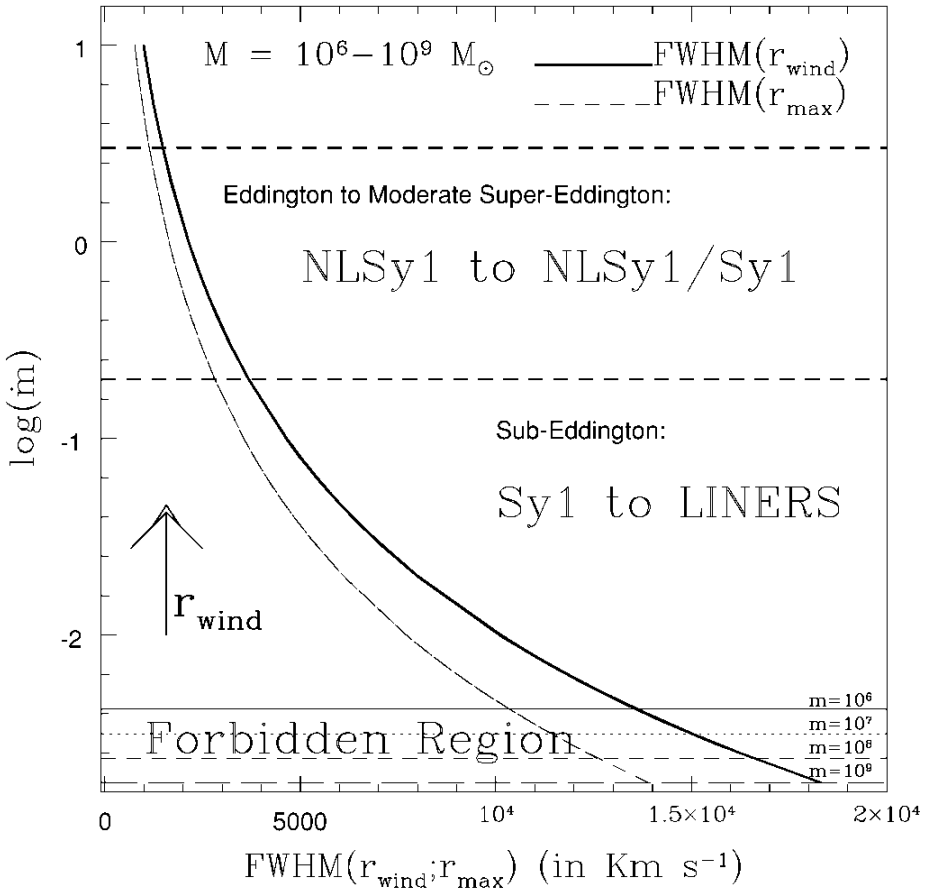
(*b*) the approximate analytical relationship giving the fraction of energy dissipated in the corona, in a dynamical disk/corona configuration (WCZ97):

$$(1-\beta) \simeq 0.034 \left(\alpha f \frac{1}{\eta}\dot{m}\right)^{-1/4} r^{3/8}, \qquad (2)$$

and (*c*) the maximum radius below which a stable co-accreting disk/corona configuration can exist, obtained by setting $\beta = 0$ (WCZ97):

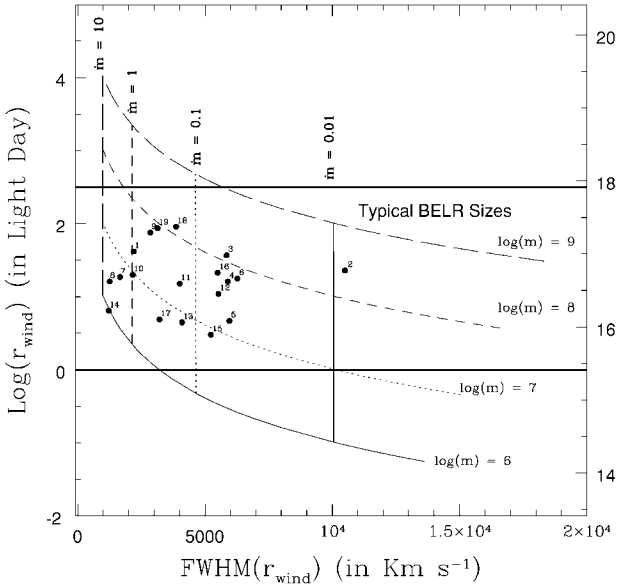
$$r_{max} f^{-2/3} \simeq 8000 \left(\alpha \frac{1}{\eta}\dot{m}\right)^{2/3}. \qquad (3)$$

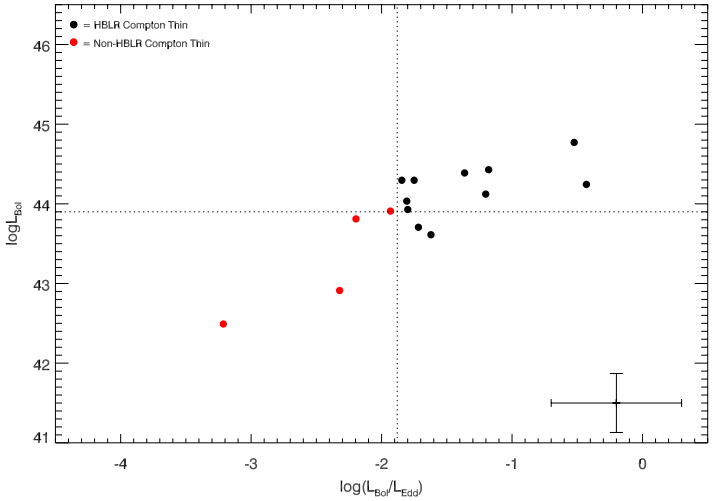
In the above equations we have used dimensionless quantities: $m = M/M_{\odot}$, $\dot{m} = \dot{M}/\dot{M}_{Edd}$, $r = R/R_0$, with $\dot{M}_{Edd} = 1.5 \times 10^{17} \eta^{-1} m$ g s^{-1}, and $R_0 = 6GM/c^2$, for a nonrotating black hole; here η is the maximum efficiency. Finally, f gives the boundary conditions at the marginally stable orbit: $f = f(r) = (1 - r^{-0.5})$.

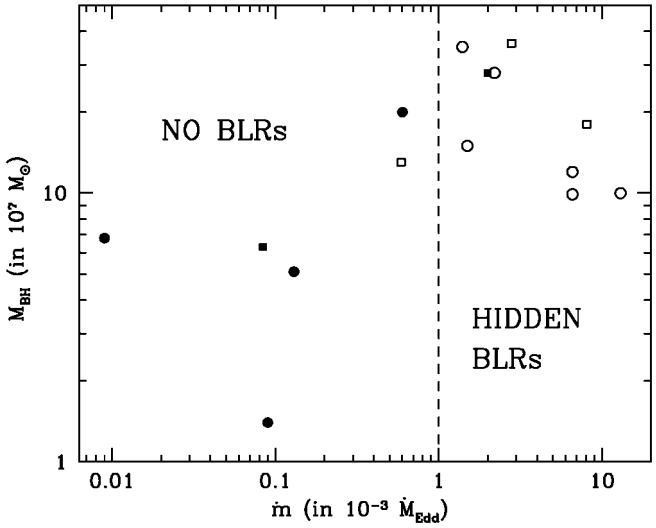


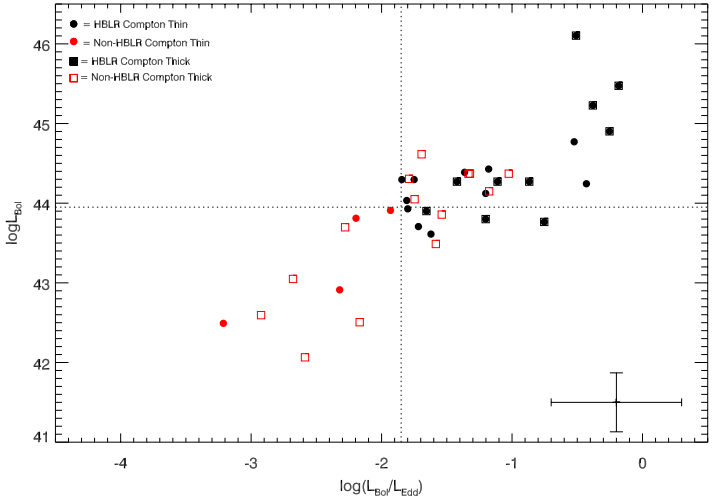
Testing the Model

(Nicastro, 2000; Nicastro, Martocchia & Matt, 2003; Marinucci+12)

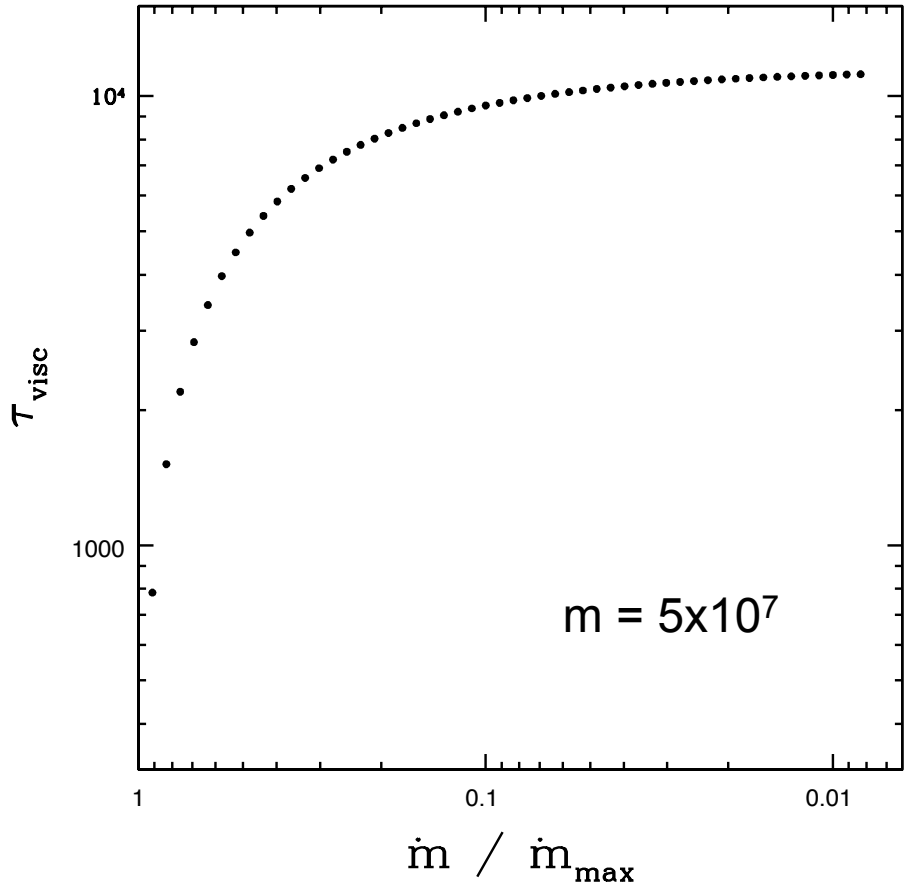








Impossible to test on individual AGNs?



$$\tau_{visc} = \int_{r(\dot{m}_{max})}^{r(\dot{m})} \frac{dr}{v_s} \approx \int_{r(\dot{m}_{max})}^{r(\dot{m})} \frac{\sqrt{m_p}\,dr}{\sqrt{kT_{SS}(r)}}$$

$$\dot{m}_{max} \approx 0.3$$

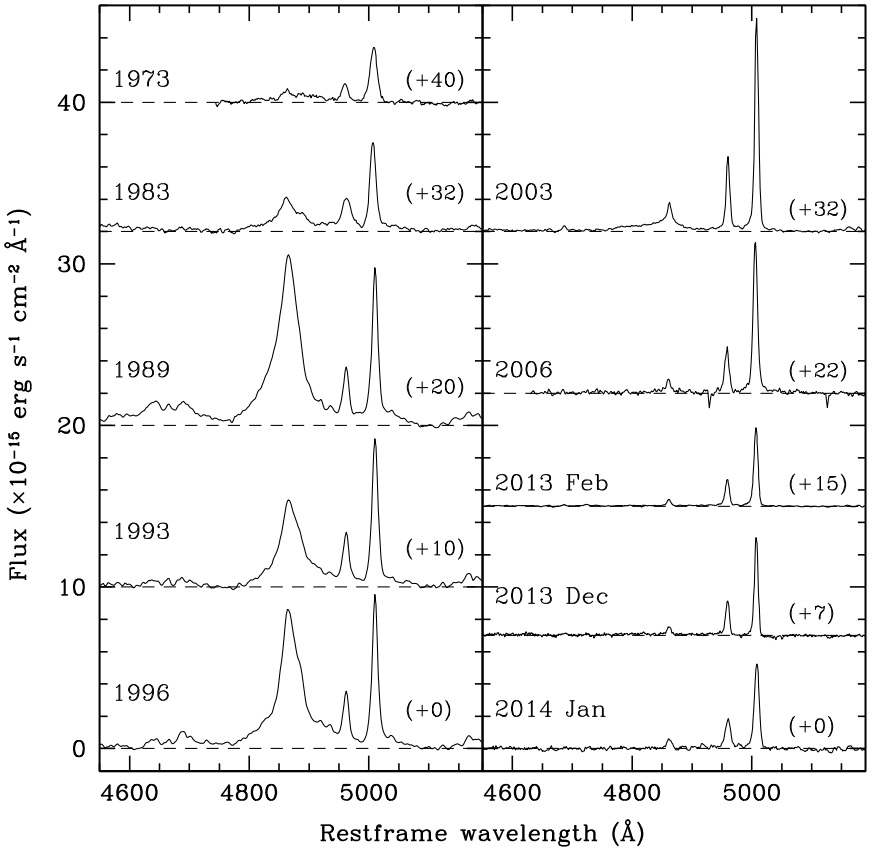
$$r(\dot{m}_{max}) \approx 5000\,R_g \quad \text{for } m = 5\times10^7$$

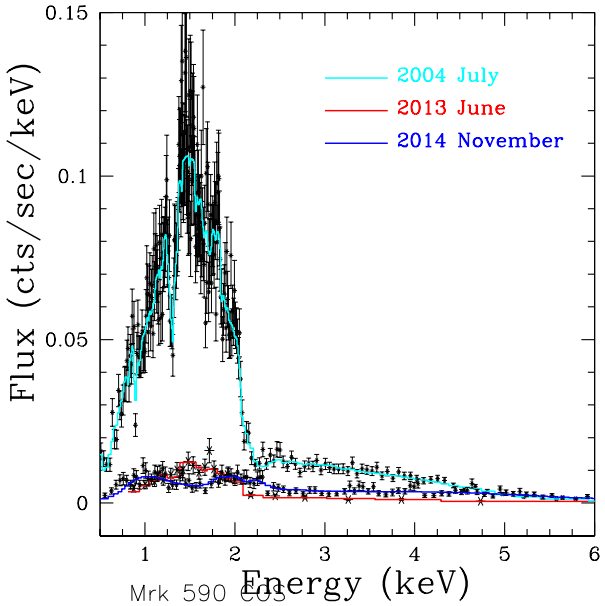
The Changing-Look Seyfert Mkn 590

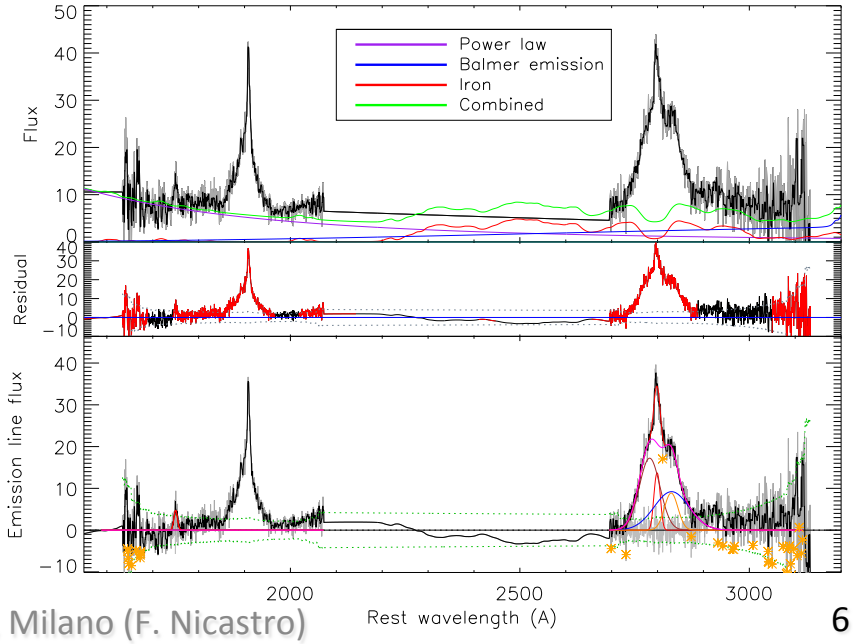
m = 5x10^7

(Mathur+18)

No BELs in 2013 (Denney+14)







…has a Crash on a Model!

Neglecting the boundary condition factor $f(r)$:

$$r_{wind} = r_{\max} \approx 8000\left(\alpha\frac{1}{\eta}\dot{m}\right)^{2/3}$$

$$\beta(r) = \sqrt{\frac{GM}{R}} = \frac{c}{\sqrt{6}}\sqrt{\frac{6GM}{c^2R}} = c(6r)^{-1/2}$$

In a cylindrical geometry:

$$FWHM(r) = 2(<v^2>)^{1/2} = \sqrt{2}\beta c = c(3r)^{-1/2} \quad \Rightarrow$$

$$\Rightarrow \quad FWHM(r_{wind}) = c\left[3\times 8000\left(\alpha\frac{1}{\eta}\dot{m}\right)^{2/3}\right]^{-1/2} \approx$$

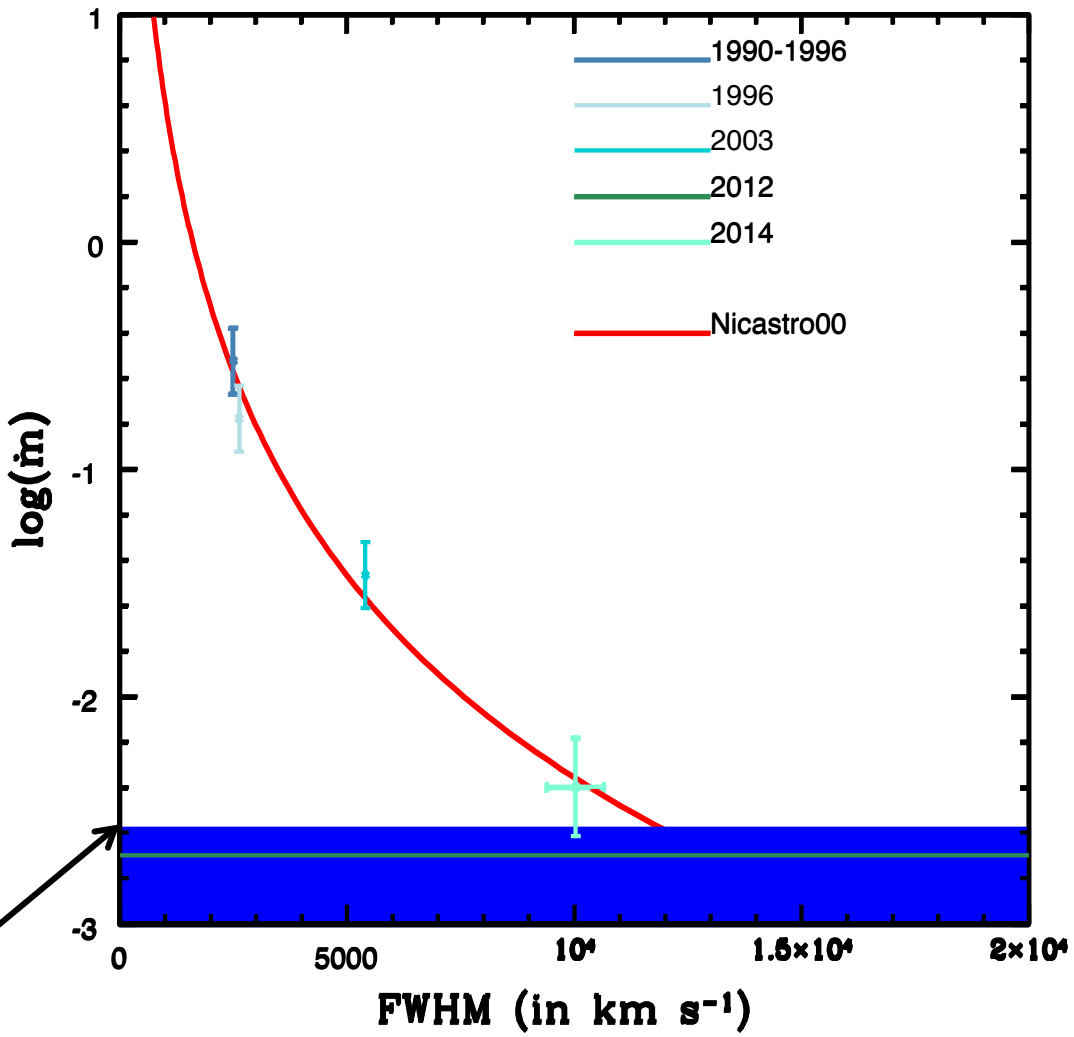
$$\approx 1936\left(\alpha\frac{1}{\eta}\right)^{-1/3}\dot{m}^{-1/3} \quad \Rightarrow$$

$$\Rightarrow \quad \log\dot{m} = -3\log(FWHM) + 9.860 + \log(\eta/\alpha)$$

For $\alpha = 0.1$ and $\eta = 0.06$

$$\Rightarrow \quad \log\dot{m} = -3\log(FWHM) + 9.638$$

$$\dot{m}_{\min} \approx 0.3\eta(\alpha m)^{-1/8} \approx 2.6\times 10^{-3}$$



Comparison with Elitzur+14

R_d = Dust Sublimation Radius

$R_{BEL} = \xi R_d \quad \Rightarrow \quad \xi = (R_{BEL} / R_d) < 1$

$R_d(pc) \approx 0.4 L_{45}^{1/2} \quad \Rightarrow \quad R_d(cm) \approx 1.2 \times 10^{18} L_{45}^{1/2} \approx 3.8 \times 10^{-5} L_{bol}^{1/2}$

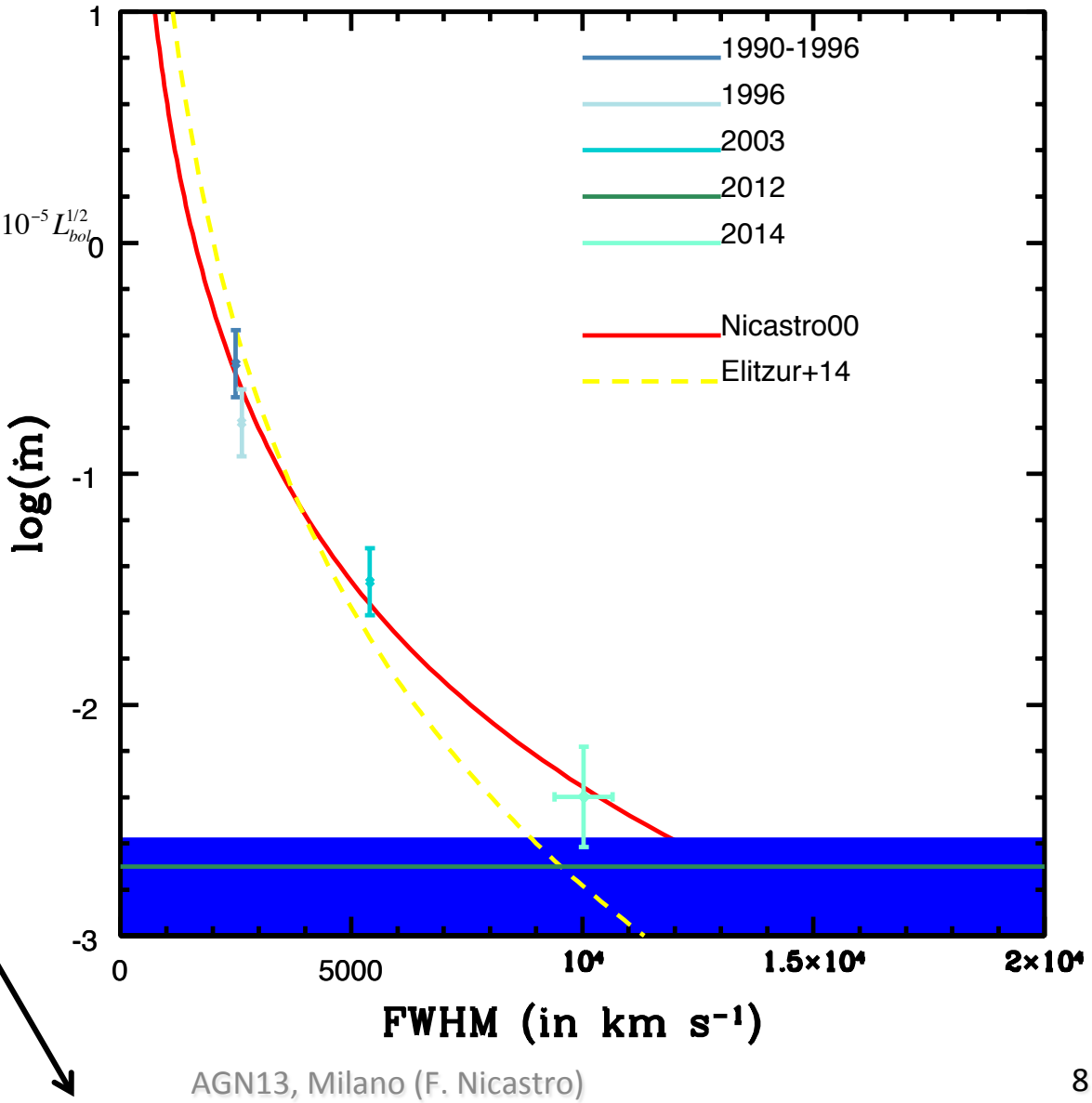
$L_{Edd} \approx 1.2 \times 10^{38} m \quad \Rightarrow$

$\Rightarrow \quad r_d \approx 4.6 \times 10^{8} m^{-1/2} \dot{m}^{1/2}$

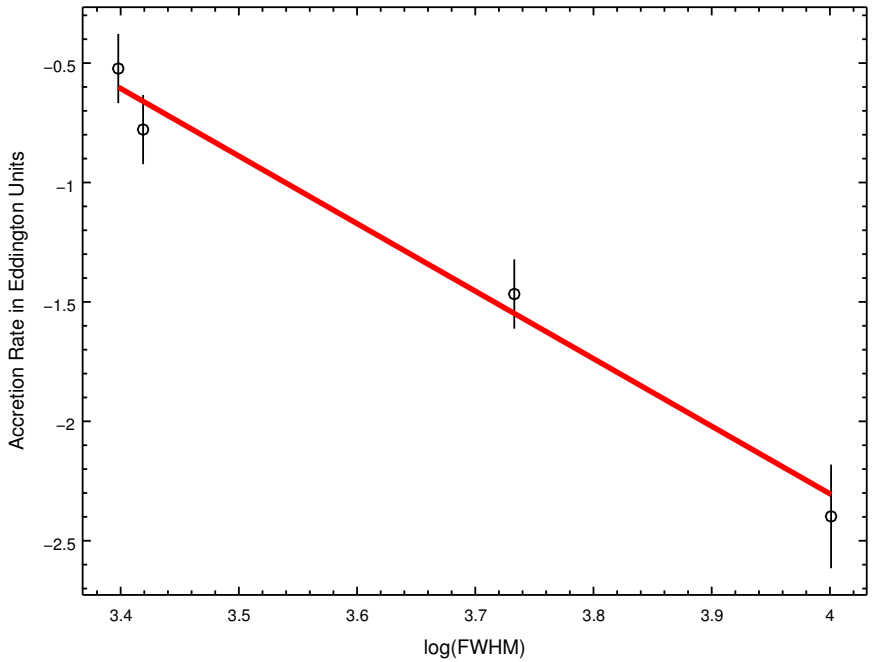
$\Rightarrow \quad FWHM(r_{BEL}) \approx 8 \xi^{-1/2} m^{1/4} \dot{m}^{-1/4}$ or:

$$\log(\dot{m}) \approx -4 \log(FWHM) + 3.602 - 2 \log \xi$$

$$\dot{m}_{\min} \approx 9.2 \times 10^{-4} m^{-1/3} \approx 2.5 \times 10^{-6}$$



Best Fitting Parameters



$$\log \dot{m} = -\Gamma \log(FWHM) + A$$

Best-Fit (1σ Errors)

$\Gamma = 2.82 \pm 0.36$

$A = 9.0 \pm 1.3$

$\chi^2(\mathrm{dof}) = 1.4(2)$

$\Delta\Gamma(3.25\sigma;\ 2\ \mathrm{Int.Pars}) = 1.18$

➔ Inconsistent with Elizur+14 at 3.25σ

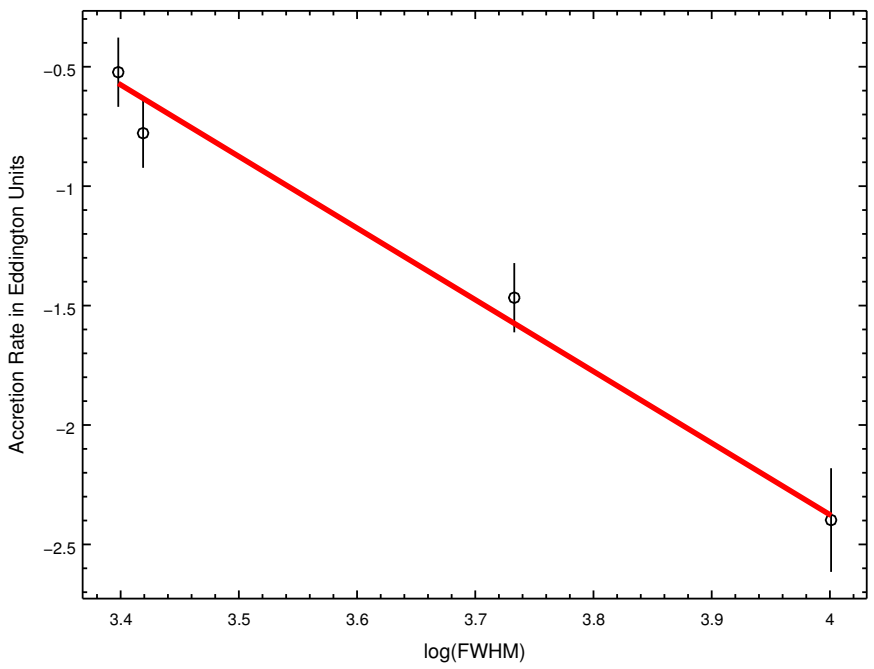
$$\log \dot{m} = -3\log(FWHM) + 9.860 + \log(\eta/\alpha) \quad \text{(Nicastro+00)}$$

$$\log(\dot{m}) \approx -4\log(FWHM) + 11.311 - 2\log\xi \quad (Elitzur+14)$$

$$\Rightarrow (\eta/\alpha) = 0.138^{+2.616}_{-0.131} \quad \text{(cf. with 0.6 for } \alpha\text{=0.1 and } \eta\text{=0.06)}$$

$$\Rightarrow \xi = r_{in}/r_d = 0.07^{+0.24}_{-0.05} \quad \text{(typically the H}\beta \text{ is at } \sim 0.5 r_d\text{)}$$

Γ Frozen to Nicastro00



$$\log \dot{m} = -3\log(FWHM) + A$$

Best-Fit (1σ Errors)

Γ = 3.0 (Frozen)

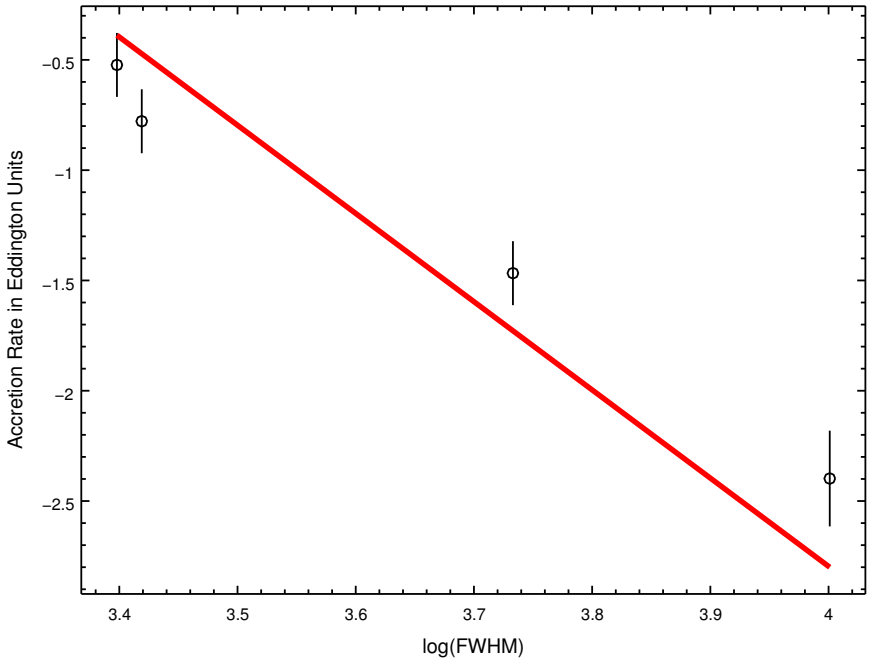
A = 9.62 ± 0.08

χ^2(dof) = 1.7(3)

$$\log \dot{m} = -3\log(FWHM) + 9.860 + \log(\eta/\alpha) \quad \text{(Nicastro+00)}$$

$$\Rightarrow (\eta/\alpha) = 0.57 \pm 0.05 \quad \text{(cf. with 0.6 for } \alpha\text{=0.1 and } \eta\text{=0.06)}$$

Γ Frozen to Elitzur+14



$$\log \dot{m} = -\Gamma \log(FWHM) + A$$

Best-Fit (1σ Errors)

Γ = 4.0 (Frozen)

A = 13.20±0.08

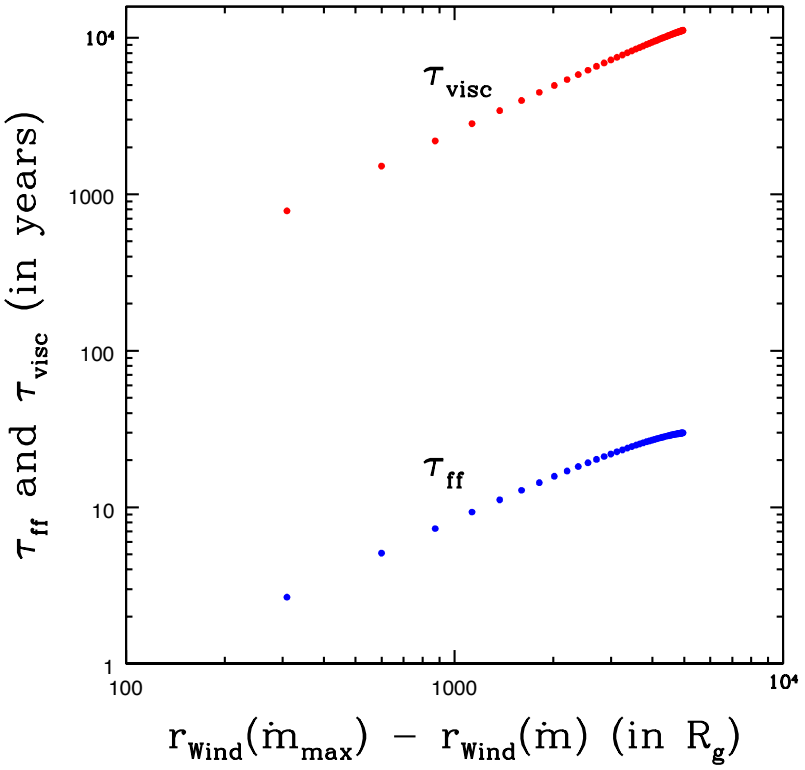
χ^2(dof) = 12.0(3)

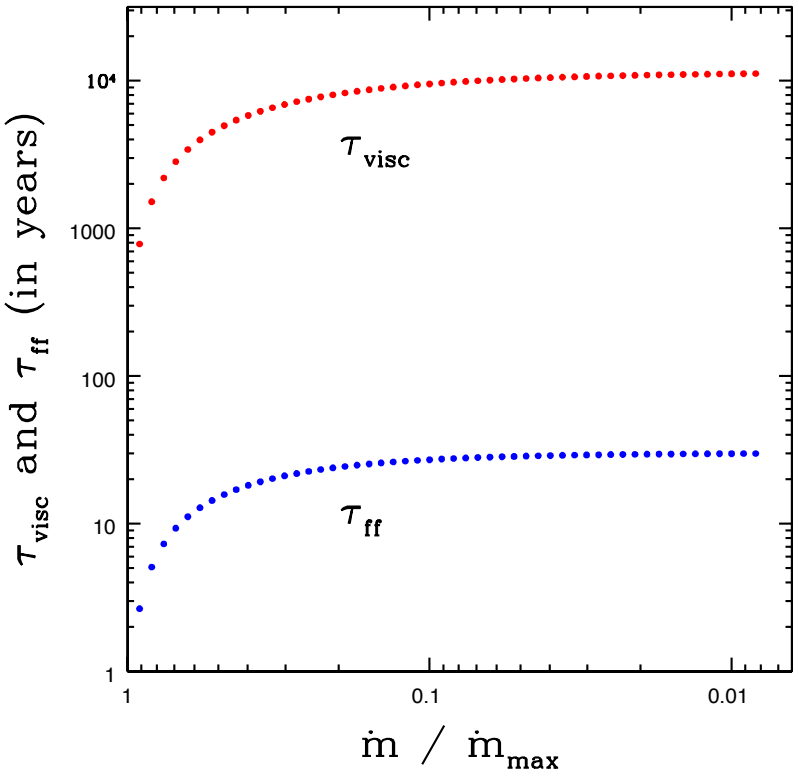
$$\log(\dot{m}) \approx -4\log(FWHM) + 11.311 - 2\log\xi \quad (Elitzur + 14)$$

$$\Rightarrow \xi = r_{in} / r_d = 0.114 \pm 0.009 \quad (\text{Probably too small})$$

The Viscosity Crisis of CL AGNs

...Free-Fall/Orbital-Time seems to work!





$$\tau_{visc} = \int_{r(\dot{m}_{max})}^{r(\dot{m})} \frac{dr}{v_s} \approx \int_{r(\dot{m}_{max})}^{r(\dot{m})} \frac{\sqrt{m_p}\, dr}{\sqrt{kT_{SS}(r)}}$$

$$\tau_{ff} = \int_{r(\dot{m}_{max})}^{r(\dot{m})} \frac{dr}{v_{ff}} \approx \frac{\sqrt{6^3} GM_{\oplus} m}{c^3} \int_{r(\dot{m}_{max})}^{r(\dot{m})} \sqrt{r}\, dr = \frac{2\sqrt{6^3} GM_{\oplus} m}{3c^3} [r(\dot{m}_{max})^{3/2} - r(\dot{m})^{3/2}]$$

Conclusions

- Mkn 590 drops its accretion rate by a factor of ~100 over a period of ~24-30 years
- During this period BELs get broader and eventually disappear
- This offers, for the first time, the opportunity to compare models for the BELR very existence and location, in a single source.
- Data are extremely well fit by a model that relates widths of BELs with accretion rate (N00)
- The same data rule out models were the location of BELRs is based on photo-ionization (i.e. R~L1/2, e.g. Elitzur+14), at a significance of 3.25σ
- Moreover, the Elitzur+09/+14 empirical relation on the minimum accretion rate below which BELRs disappear is seriously falsified by the data of Mkn 590 (perhaps LLAGNs and Seyferts are two completely different beasts)
- The data of Mkn 590 (and those of any other CL AGNs) pose a serious problem to the α-disk prescription (problem known as “viscosity crisis”)
- The phenomenon seems to happen over the free-fall (or orbital) timescale