NuSTAR spectral analysis of the two bright Seyfert 1 galaxies: MCG 8-11-11 and NGC 6814

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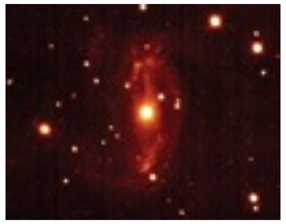
ROMA TRE UNIVERSITÀ DEGLI STUDI
SEVENTH FRAMEWORK PROGRAMME
STRONGGRAVITY
EU FP7-SPACE research project 312789
2013 - 2017

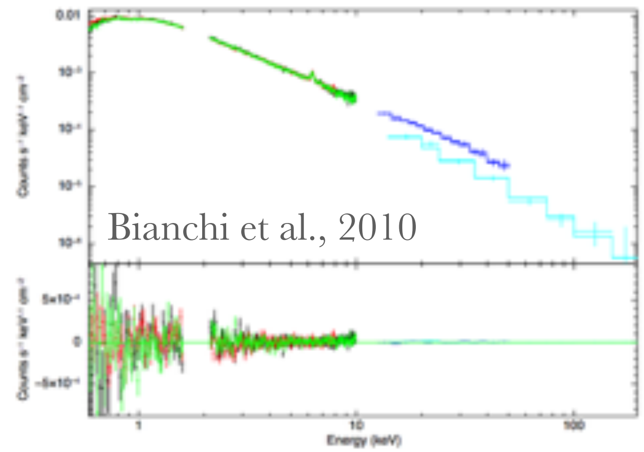
Overview



MCG +8-11-11

$z = 0.0204$ $\quad F_{2-10\mathrm{keV}} = 5.62 \times 10^{-11} \mathrm{erg cm^{-2} s^{-1}}$

$\log \frac{M_{BH}}{M_\odot} = 8.07 \pm 0.02$ $\quad F_{20-100\mathrm{keV}} = 8.46 \times 10^{-11} \mathrm{erg cm^{-2} s^{-1}}$



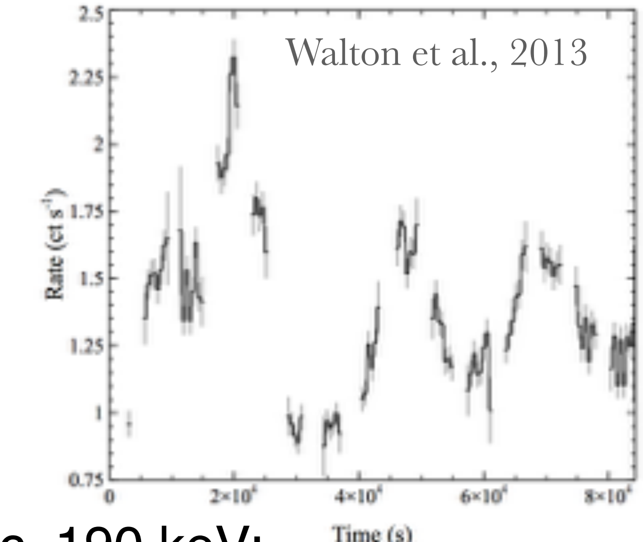
Suzaku+Swift BAT best-fit model in the whole 0.6-150 keV band, and contour plot (Bianchi et al., 2010)

- **Suzaku + Swift BAT** (Bianchi et al., 2010; Mantovani et al., 2016): relativistic FeKα line + narrow component with no associated reflection component + Fe XXVI line emission;
- **ASCA and OSSE** (Grandi 1998): absorbed power law, Γ=1.73 & E_c~250 keV + reflection component + cold iron line;
- **BeppoSAX** (Perola 2000): Γ=1.84 ± 0.05 & $E_c = 169^{+318}_{-78}$ keV;
- **XMM-Newton** (Matt et al., 2006): lack of a soft excess + a large reflection component + narrow iron line + Fe XXVI line emission.

NGC 6814

$z = 0.0052$ $\quad F_{2-10\mathrm{keV}} = 0.17 \times 10^{-11} \mathrm{erg cm^{-2} s^{-1}}$

$\log \frac{M_{BH}}{M_\odot} = 6.99^{+0.32}_{-0.25}$ $\quad F_{20-100\mathrm{keV}} = 5.66 \times 10^{-11} \mathrm{erg cm^{-2} s^{-1}}$



0.5-10 keV XIS light curve for the Sukazu observation (Walton et al., 2013)

- **INTEGRAL** (Malizia et al., 2014): quite flat spectrum Γ=1.68 & Ec~190 keV;
- **XMM-Newton** (Ricci et al., 2014): FeKα line with EW~84 eV;
- **Suzaku** (Walton et al., 2013): no soft excess, fairly hard photon index Γ=1.53, variability.

NuSTAR Observation

MCG +8-11-11

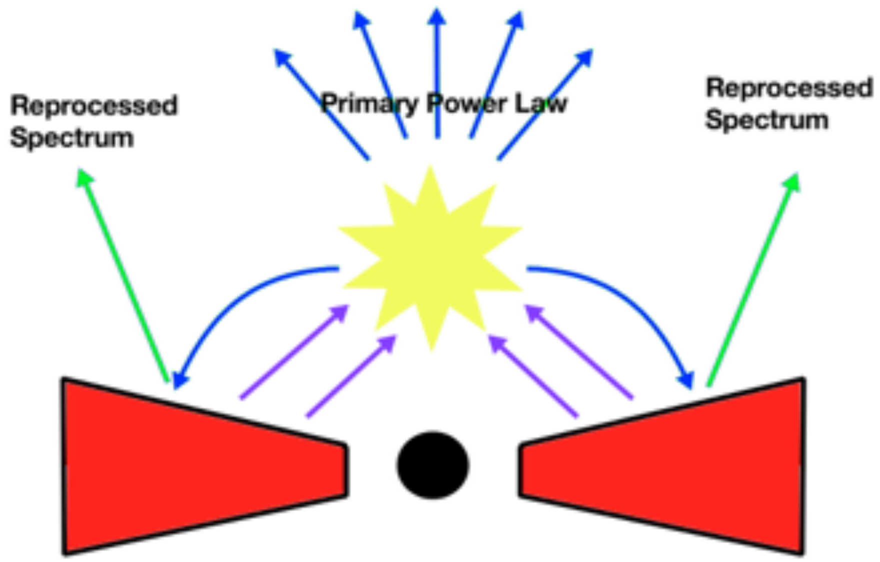
100 ks observation in the *NuSTAR* AO2 (on 2016, August 19)

NGC 6814

150 ks observation in the *NuSTAR* AO2 (on 2016, July, 04)

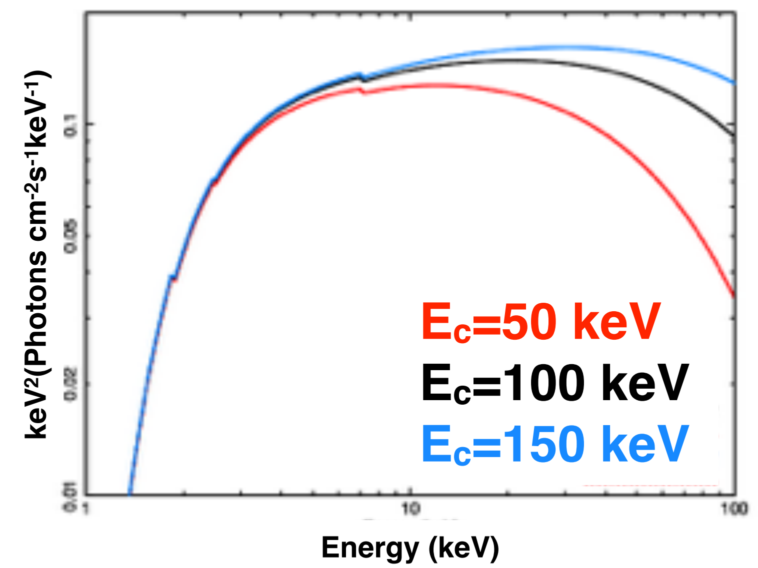
- Why? To investigate the Comptonization mechanisms acting in the innermost regions of AGN and which are believed to be responsible for the X-ray emission;
- *NuSTAR* (Nuclear Spectroscopic Telescopic Array) works in the band 3 - 79 keV;
- First focusing hard X-ray (10-79 keV) telescope in orbit;
- ~100 times more sensitive in the 10-79 keV band than any previous mission working in this band;

AGN in X-Rays



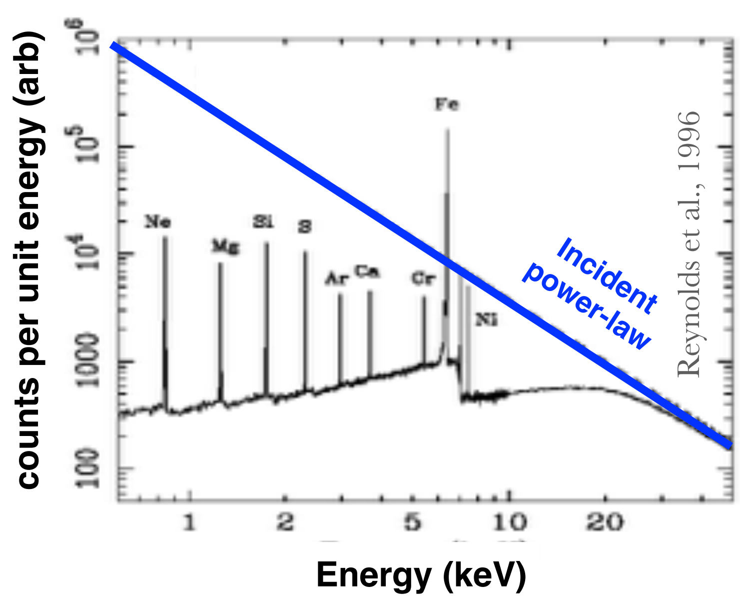
X-RAYS EMISSION:

In AGN the primary X-ray emission is due to Inverse Compton by electrons in a hot corona of the UV/soft X-ray disc photons.



PRIMARY POWER-LAW:

- Power-law with photon index and cutoff energy directly related to the temperature and to the optical depth of the coronal plasma.
- Most popular Comptonization models imply: $E_c = 2\text{-}3 \times kT_e$

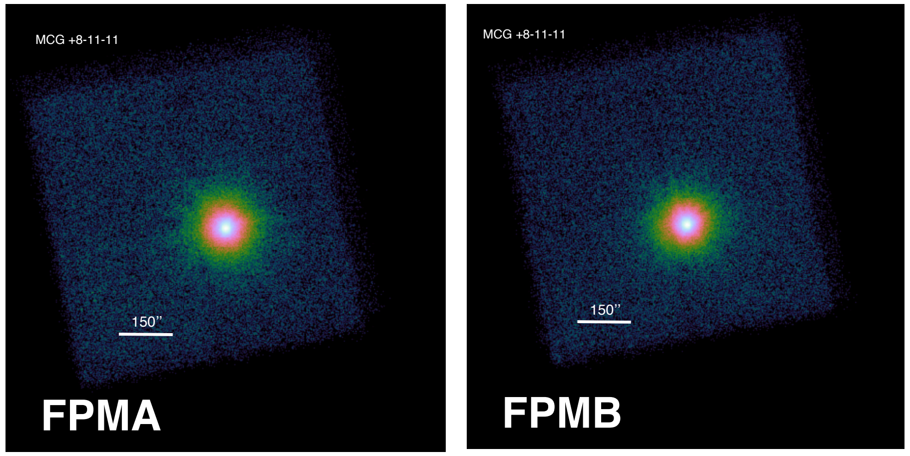


REPROCESSED EMISSION:

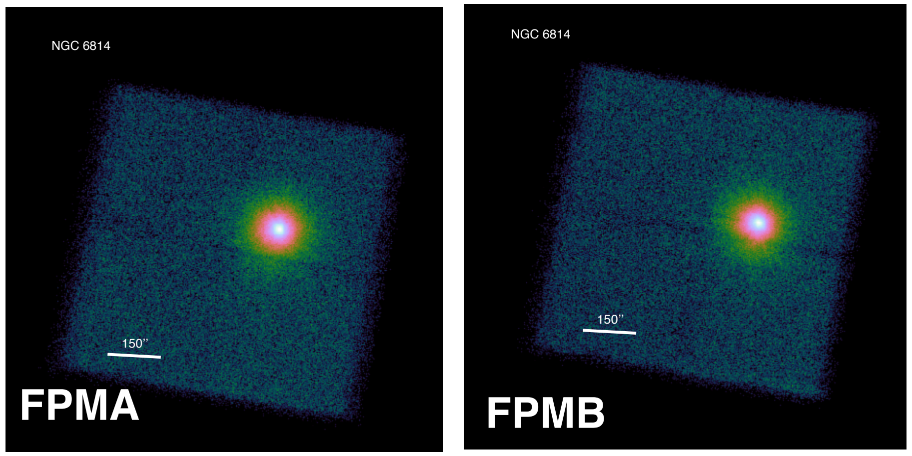
Typical X-ray features of the reflection by <u>cold circumnuclear material</u> include intense Fe Kα line @ 6.4 keV and the associated Compton reflection continuum peaking @ ~30 keV.

Analysis

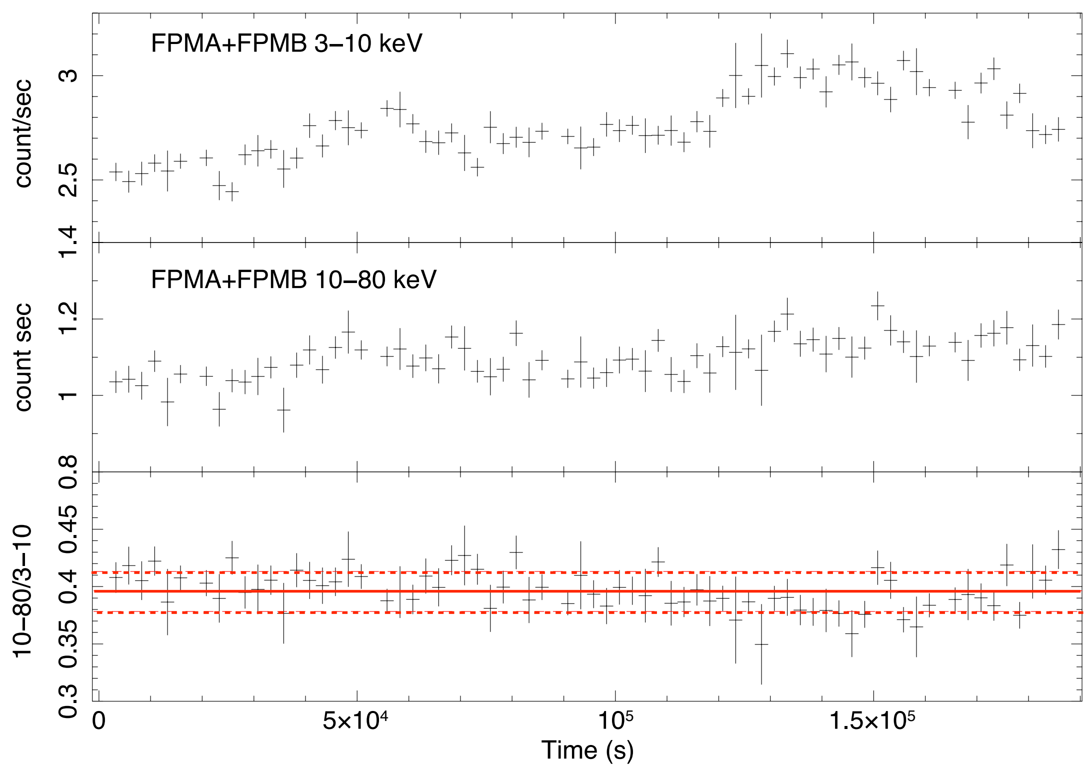
MCG +8-11-11

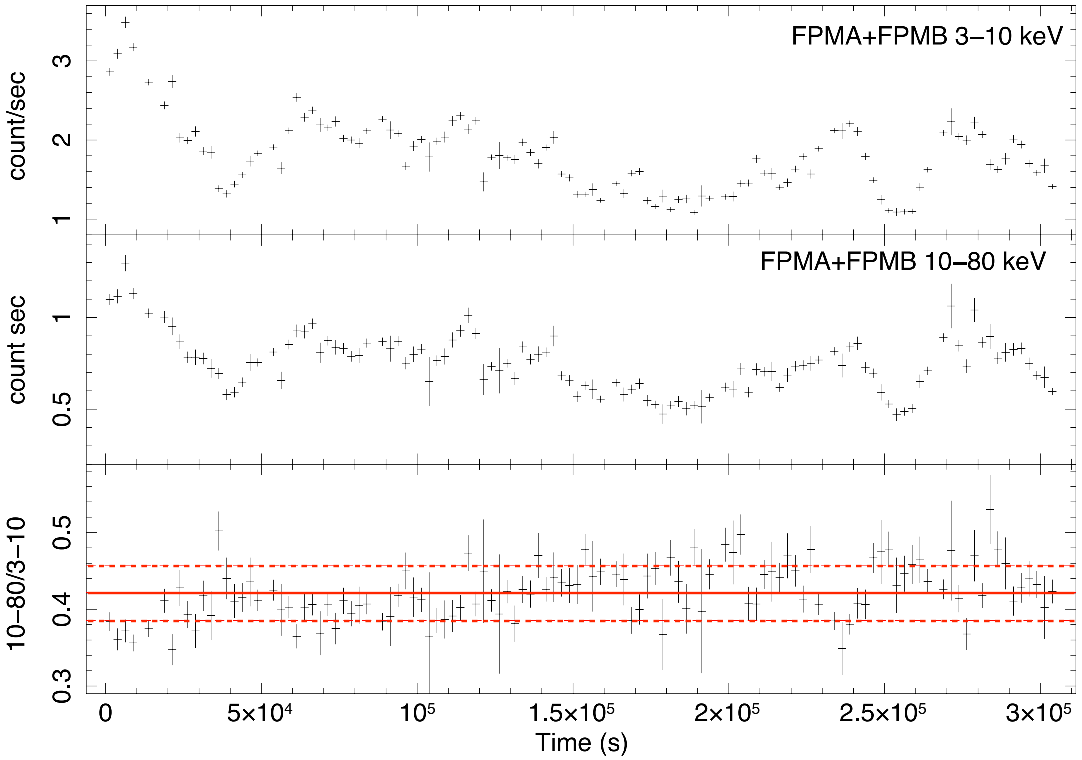


NGC 6814



Both sources show variability in their light curves but since no spectral variation is found in the ratio between the 10-80 and 3-10 keV count rates we used **time-averaged spectra** in our analysis.





Model

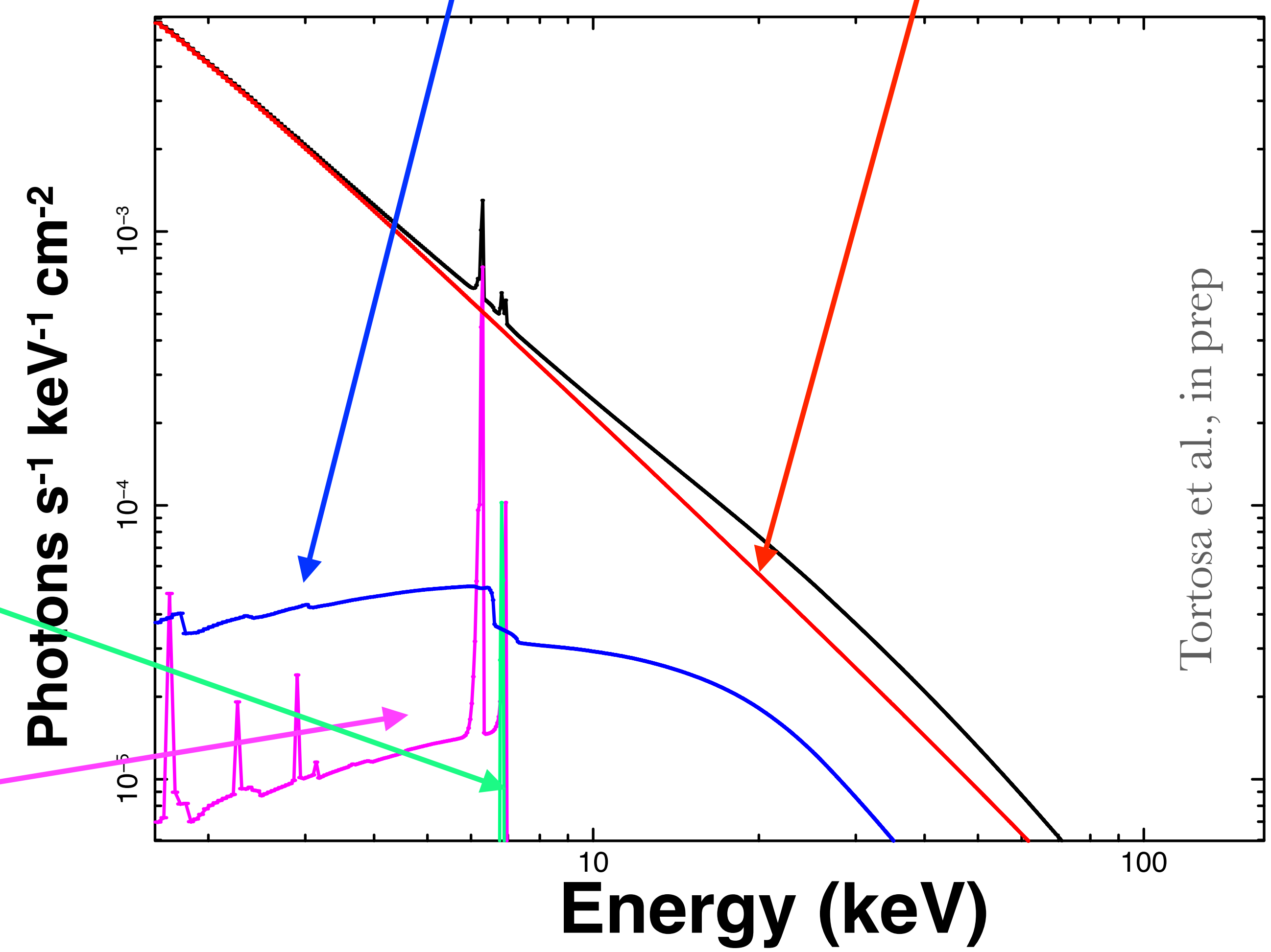
- Primary X-ray emission;
- Relativistic disk reflection;
- Cold, distant reflection;
- Narrow Fe XXVI line @ 6.966 keV (MCG +8-11-11);

Relxill
(García et al. 2014)

Power law with
exponential cutoff

Fe XXVI

Xillver
(García & Kallman 2010;
García et al. 2013)



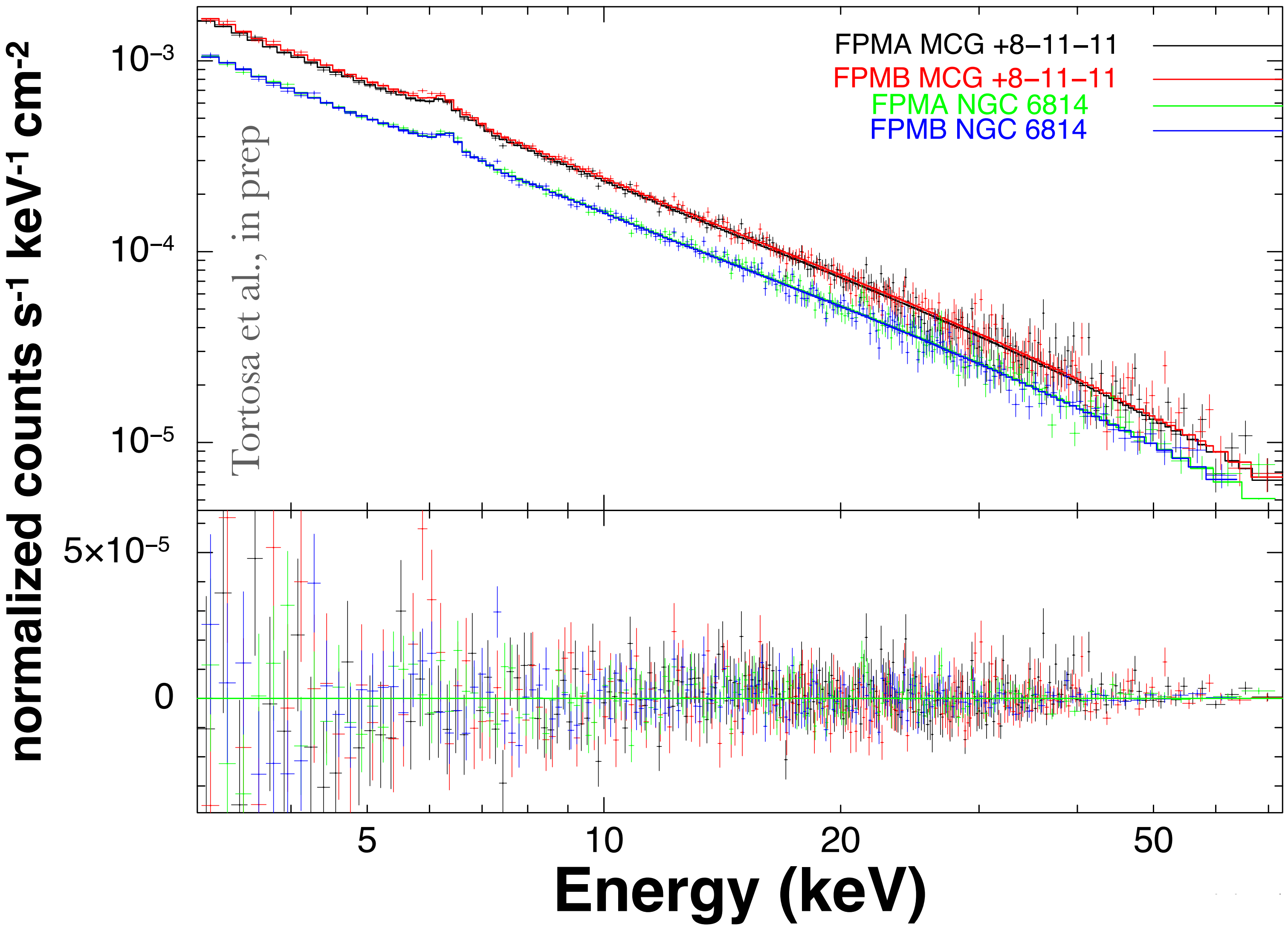
Spectral Parameters

MCG +8-11-11

$$\Gamma = 1.77 \pm 0.04$$
$$E_c = 180^{+110}_{-50}\,\mathrm{keV}$$
$$R^{rel} = 0.25^{+0.10}_{-0.14}$$

NGC 6814

$$\Gamma = 1.71 \pm 0.04$$
$$E_c = 155^{+70}_{-35}\,\mathrm{keV}$$
$$R^{rel} = 0.28^{+0.11}_{-0.13}$$



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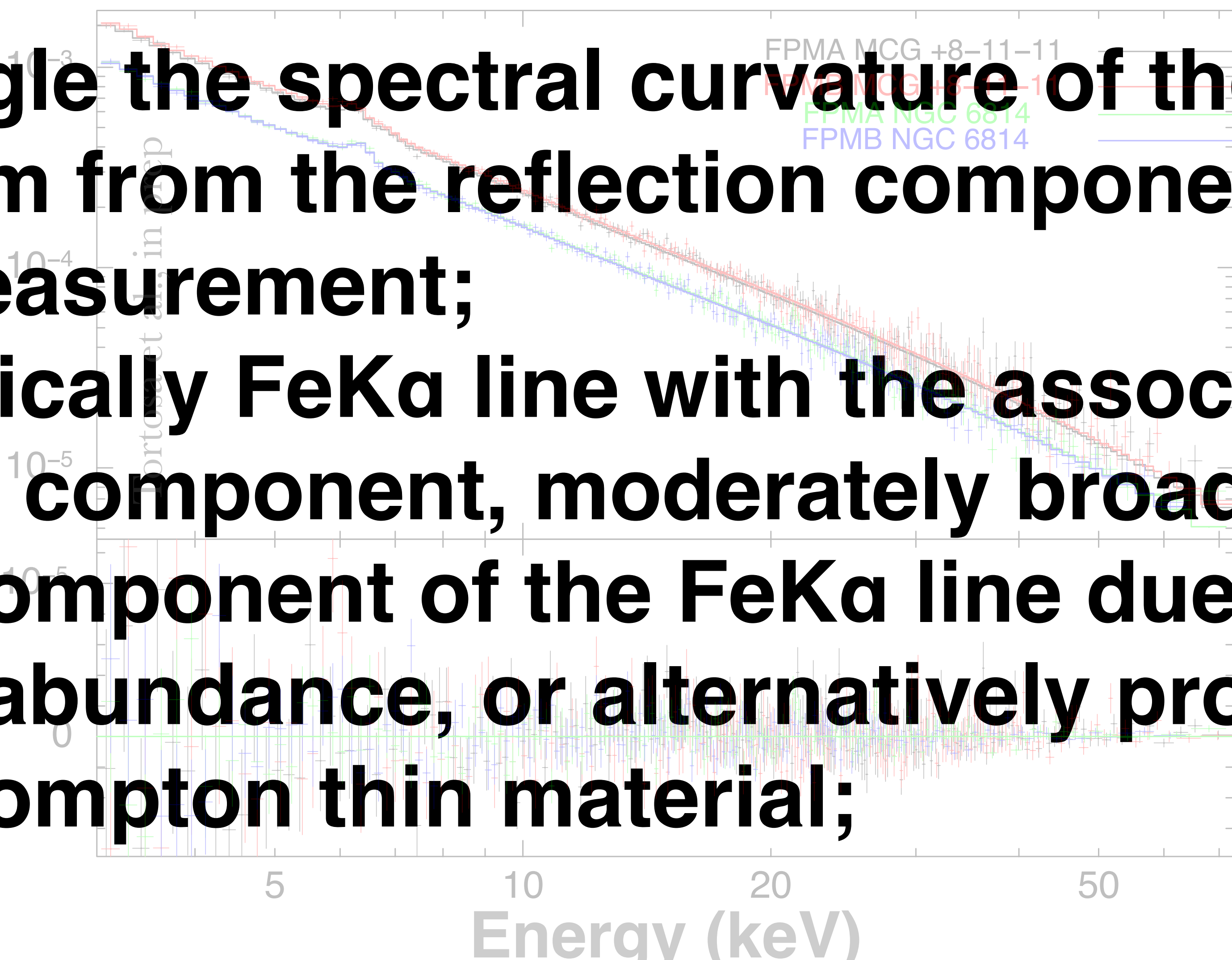
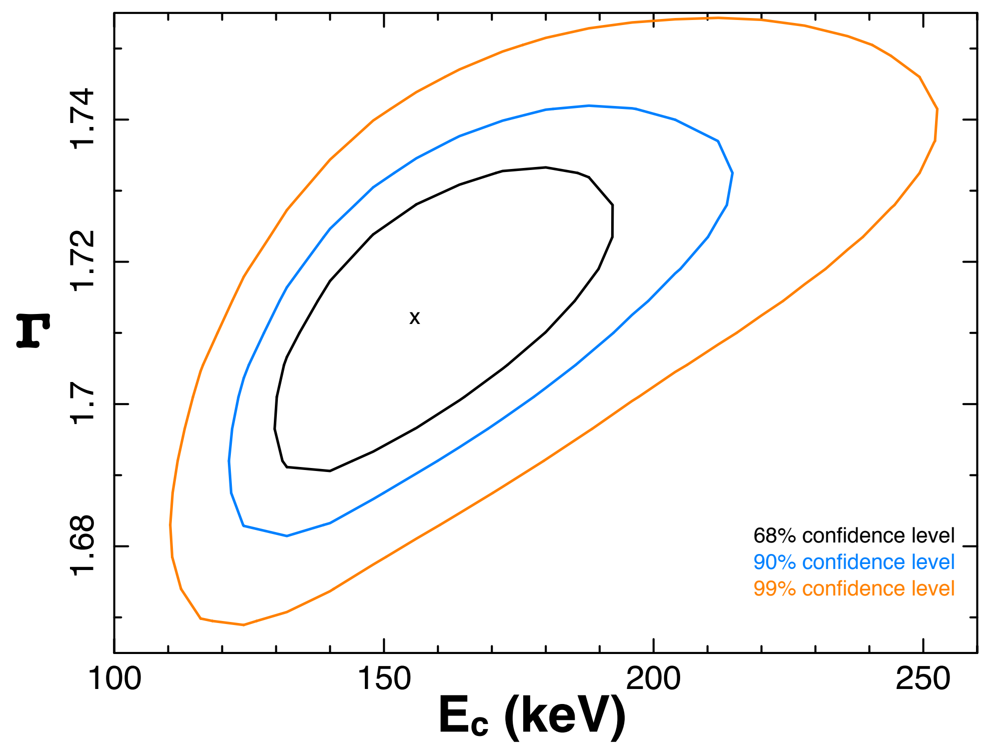
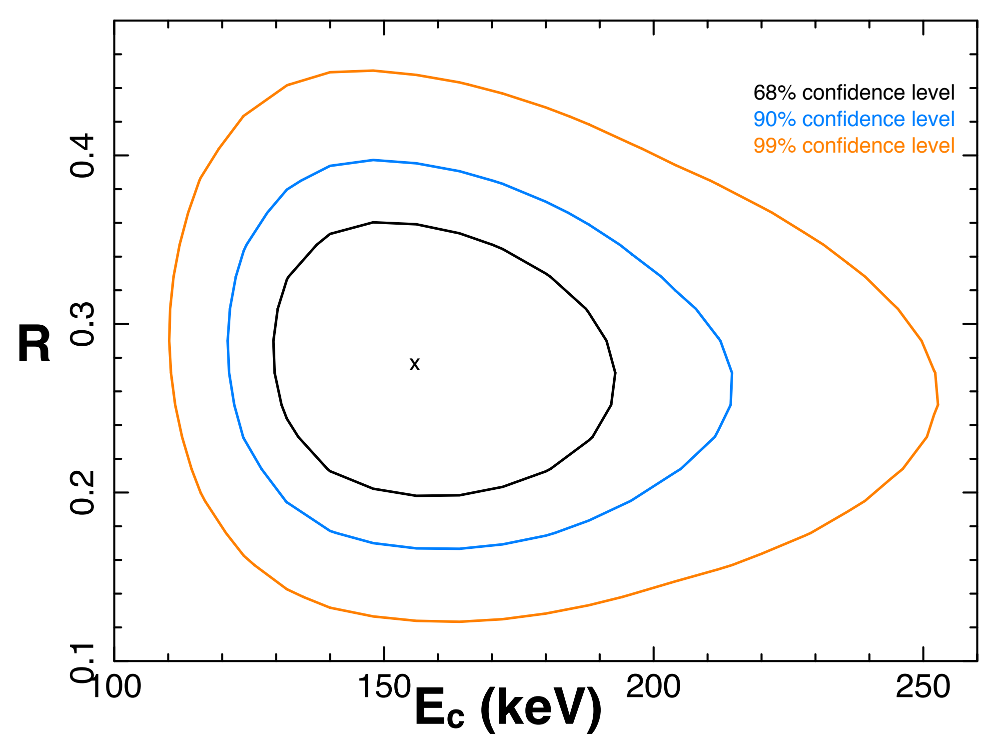


* Disentangle the spectral curvature of the primary continuum from the reflection component;
* Cutoff measurement;
* Relativistically FeKα line with the associated reflection component, moderately broad;
* Narrow component of the FeKα line due to a large iron overabundance, or alternatively produced in distant Compton thin material;

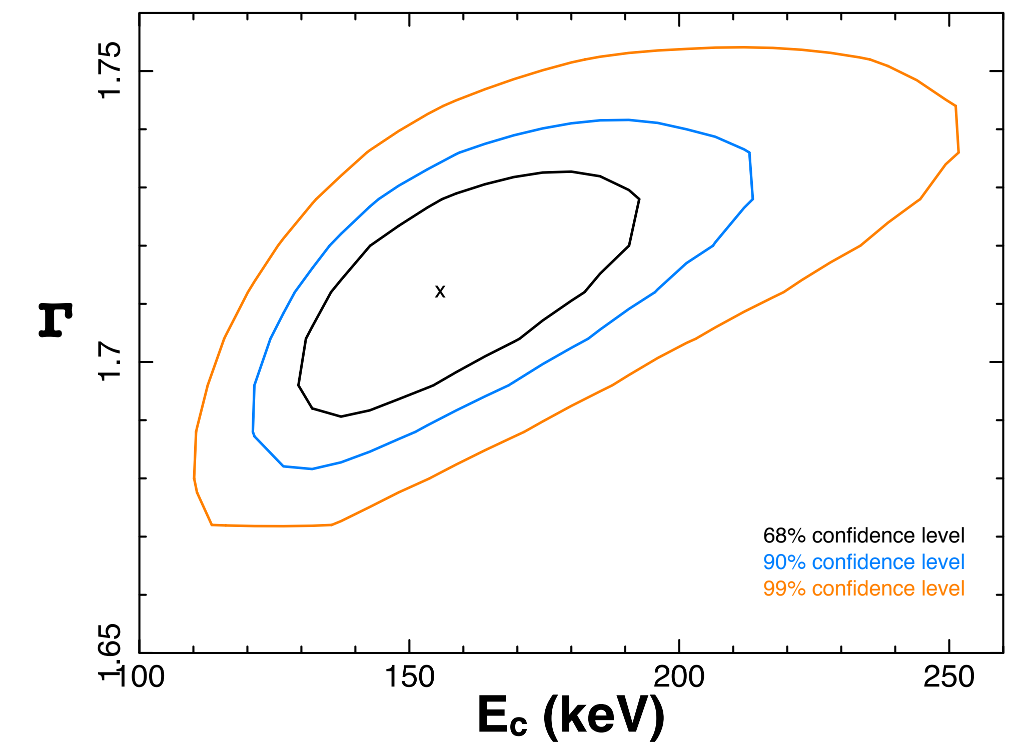
Spectral Parameters

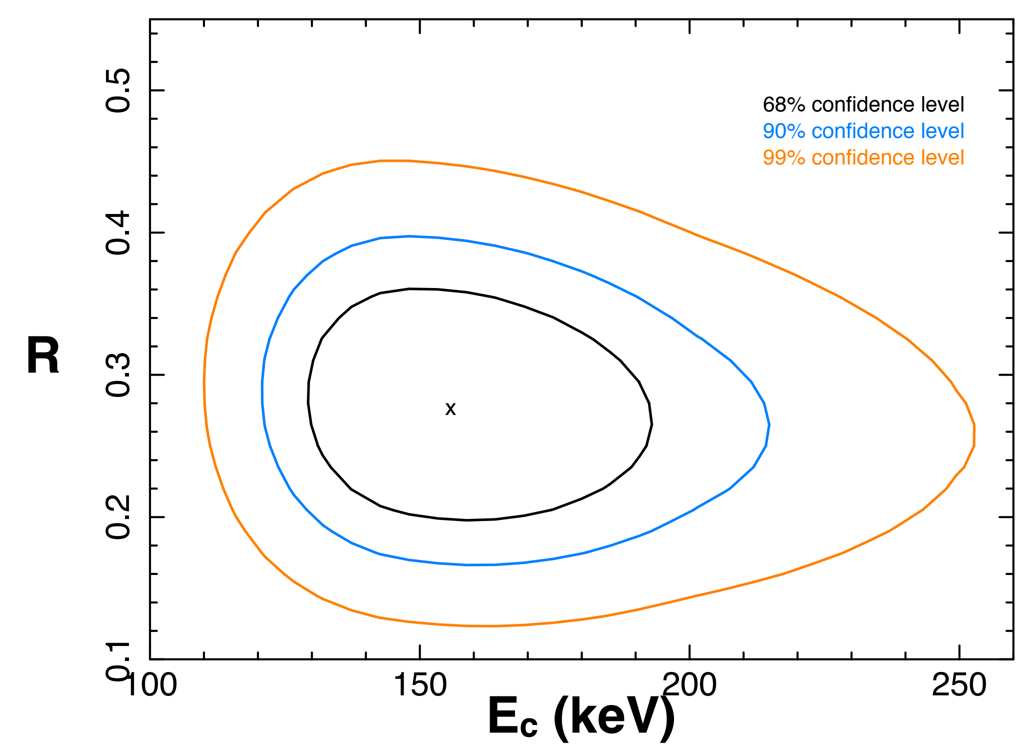
MCG +8-11-11





NGC 6814





Coronal Parameters

CompTT (Titarchuk et al., 1994) convolved with the **REFLECT** model in XSPEC (reflection from neutral material according to the method of Magdziarz & Zdziarski, 1995)

The coronal temperature is expected to be related to the cutoff energy by E_c=2-3 x kT_e (Petrucci 2000, 2001)

MCG +8-11-11 | NGC 6814

SLAB:

MCG +8-11-11:

$$\mathrm{kT} = 150^{+140}_{-60}\mathrm{keV}$$

$$\tau = 0.19^{+0.08}_{-0.12}$$

NGC 6814:

$$\mathrm{kT_e} = 140^{+100}_{-60}\mathrm{keV}$$

$$\tau = 0.25^{+0.22}_{-0.14}$$

SPHERE:

MCG +8-11-11:

$$\mathrm{kT} = 150^{+140}_{-60}\mathrm{keV}$$

$$\tau = 0.7^{+0.7}_{-0.3}$$

NGC 6814:

$$\mathrm{kT_e} = 110^{+90}_{-60}\mathrm{keV}$$

$$\tau = 1.1^{+0.3}_{-0.8}$$

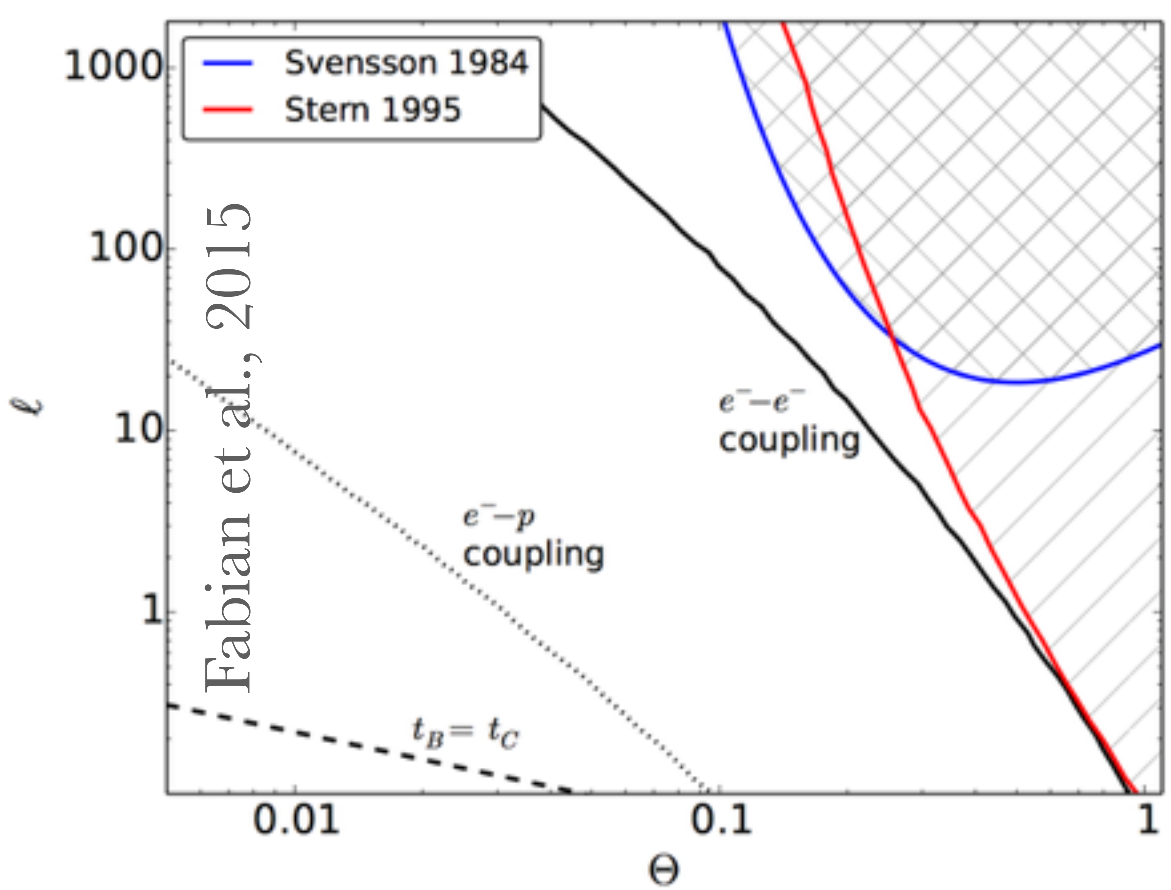
Θ-ℓ plane

Θ electron temperature normalized to the electron rest energy

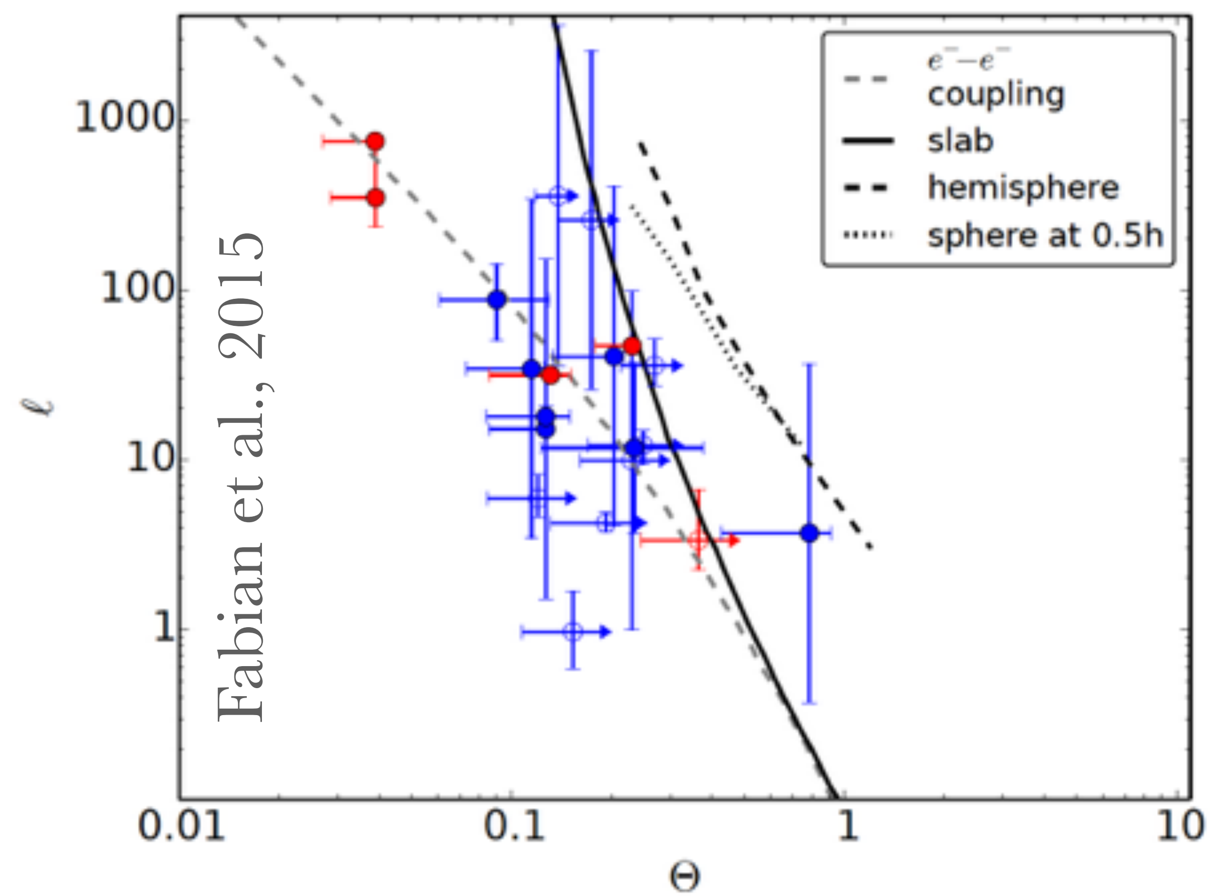
$$\Theta_e = \frac{kT_e}{m_e c^2}$$

ℓ the dimensionless compactness parameter

$$\ell = \frac{L}{R}\frac{\sigma_T}{m_e c^3}$$



Summary of the theoretical understanding of the **Θ**-ℓ plane.



Θ-ℓ distribution for *NuSTAR* observed AGN (blue points) and BHB (red points)

Θ-ℓ plane

Θ electron temperature normalized to the electron rest energy

$$\Theta_e = \frac{kT_e}{m_e c^2}$$

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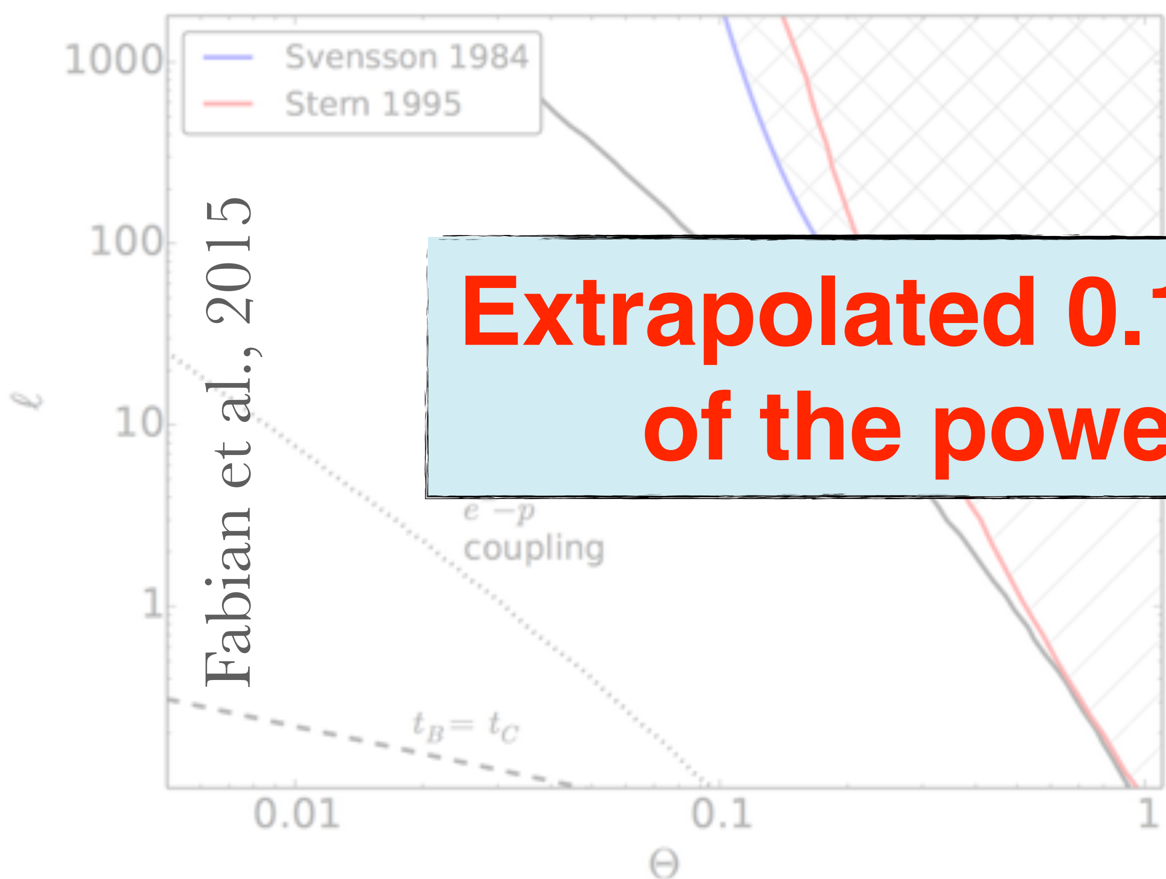
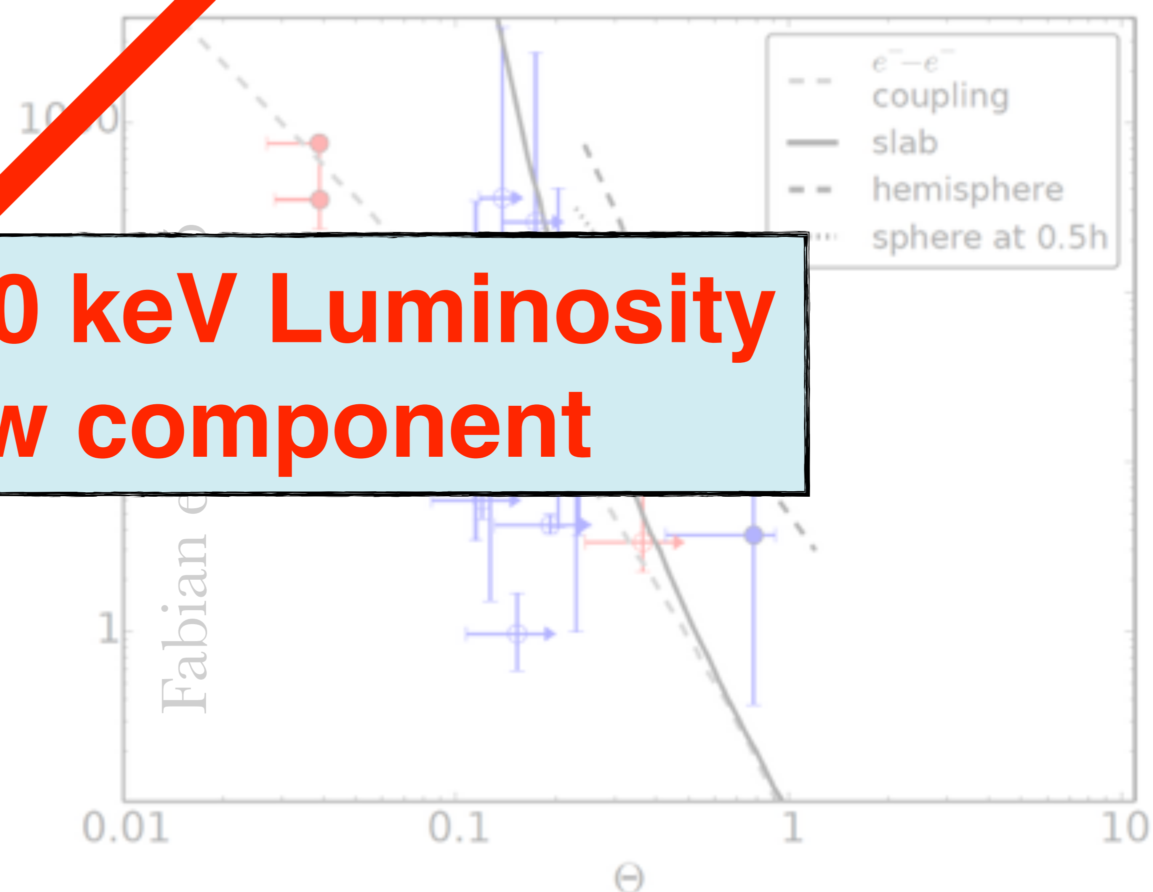




Extrapolated 0.1-200 keV Luminosity of the power-law component

Summary of the theoretical understanding of the plane.

Θ-ℓ

points) and BHB (red points)

Θ-ℓ plane

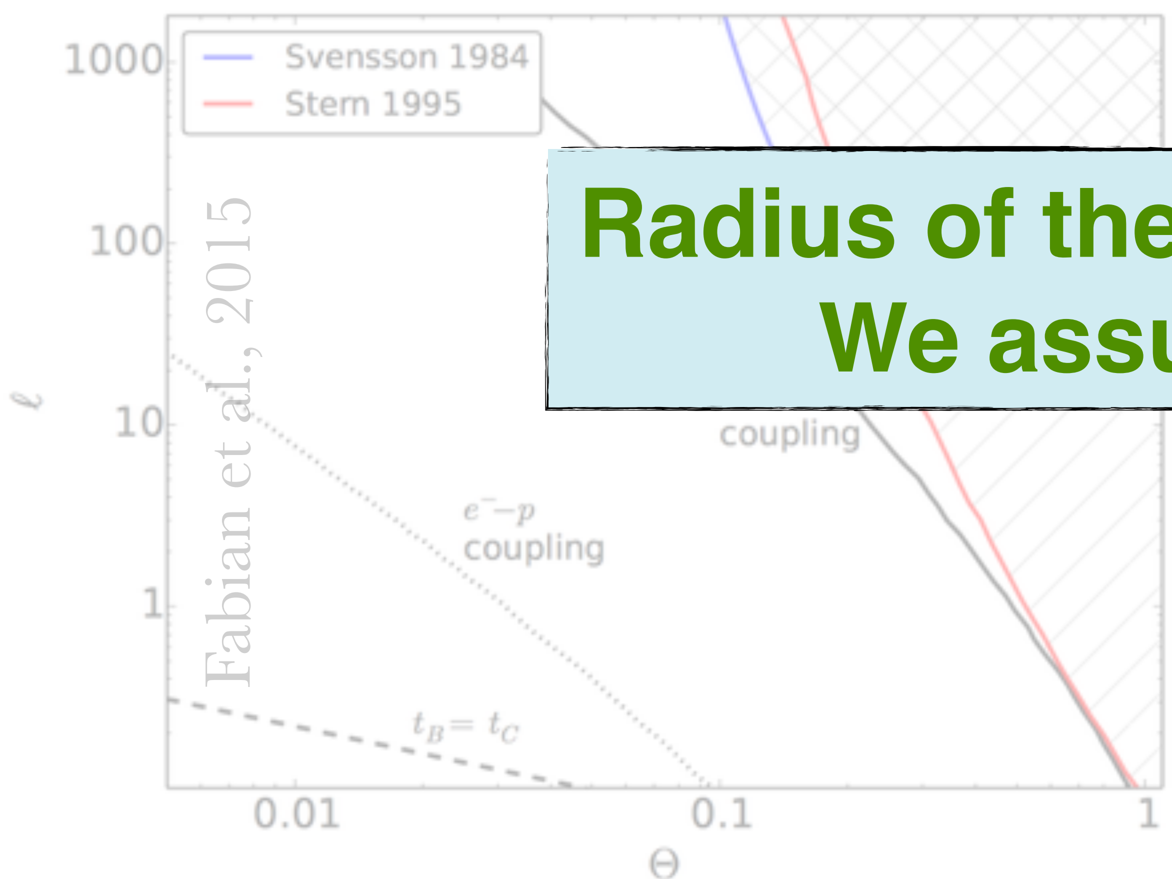
Θ electron temperature normalized to the electron rest energy

$$\Theta_e = \frac{kT_e}{m_e c^2}$$

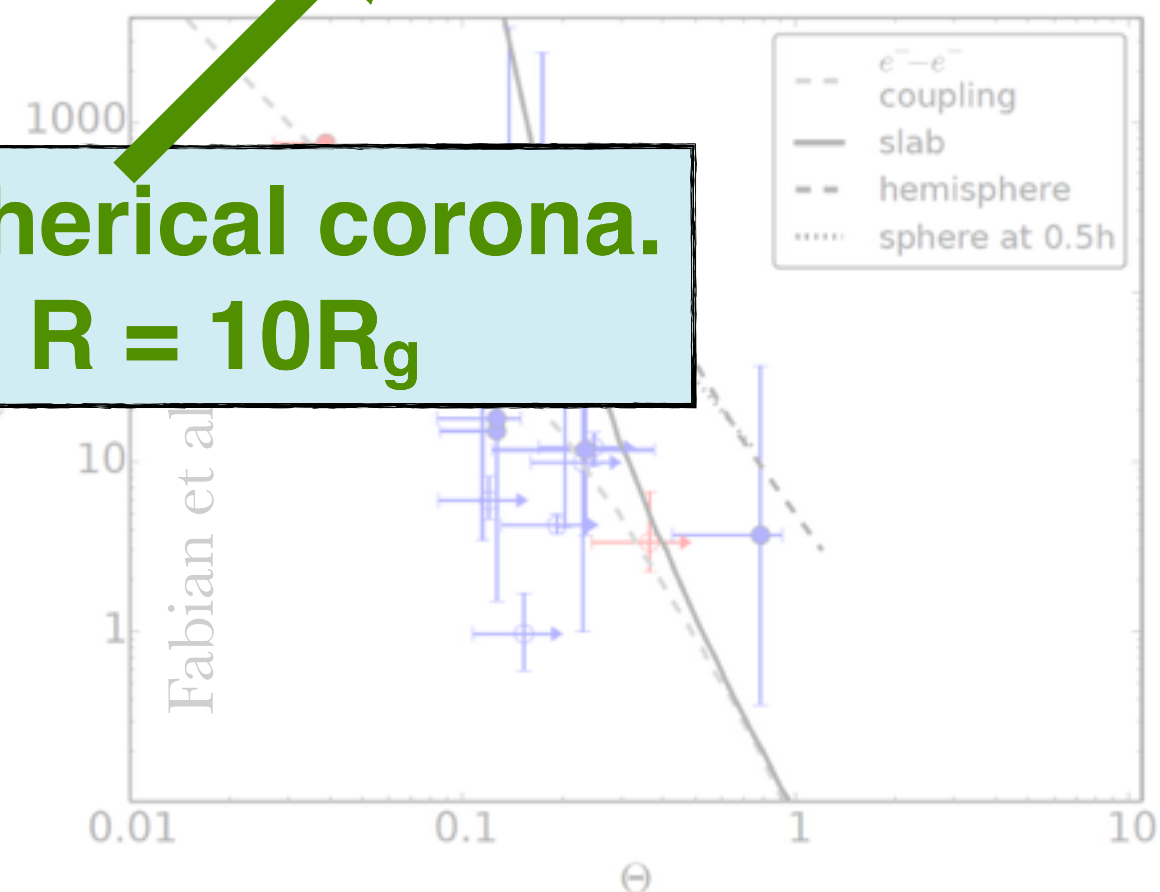
ℓ the dimensionless compactness parameter

$$\ell = \frac{L}{R} \frac{\sigma_T}{m_e c^3}$$

Radius of the spherical corona.
We assume $R = 10R_g$



Summary of the theoretical understanding of the plane.



Θ-ℓ

points) and BHB (red points)

Θ-ℓ plane

MCG +8-11-11

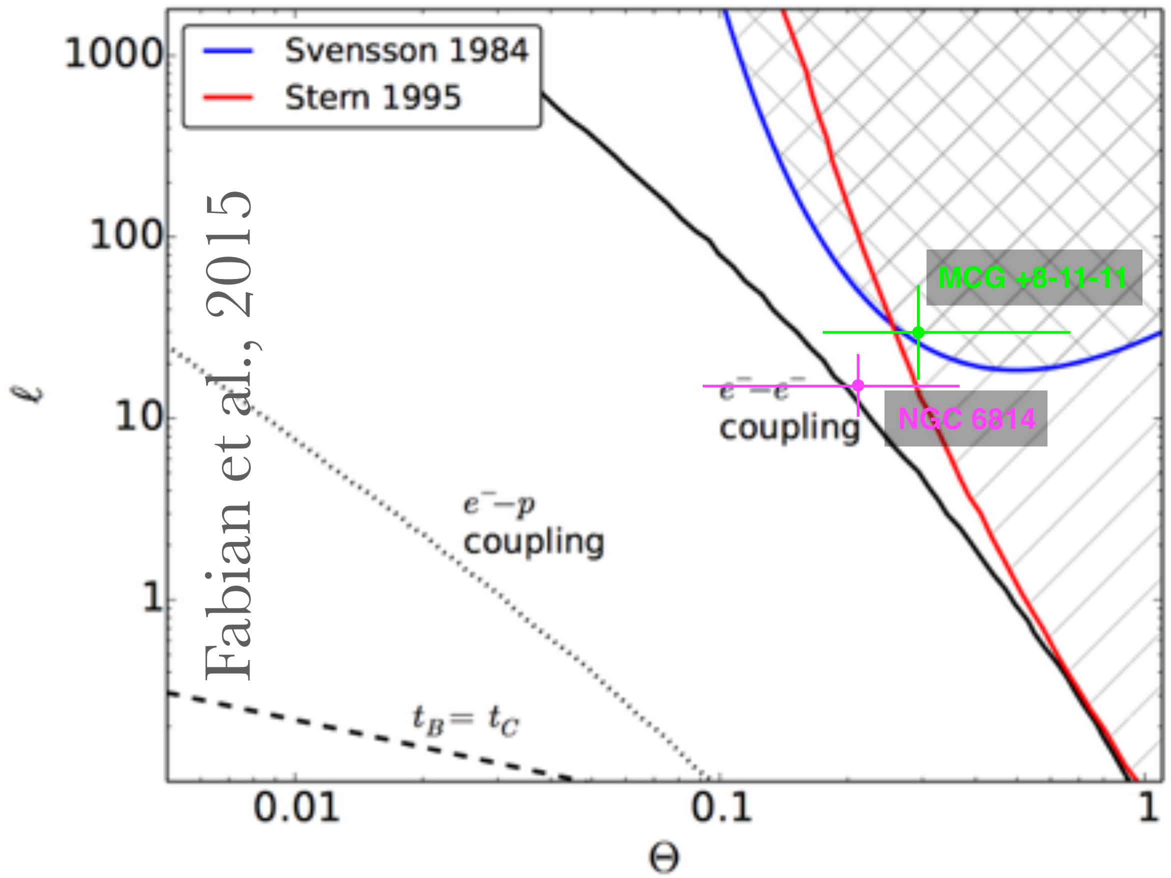
$$\Theta_e = 0.28^{+0.28}_{-0.11}$$

$$\ell = 27 \pm 12 (\mathrm{R}_{10})^{-1}$$

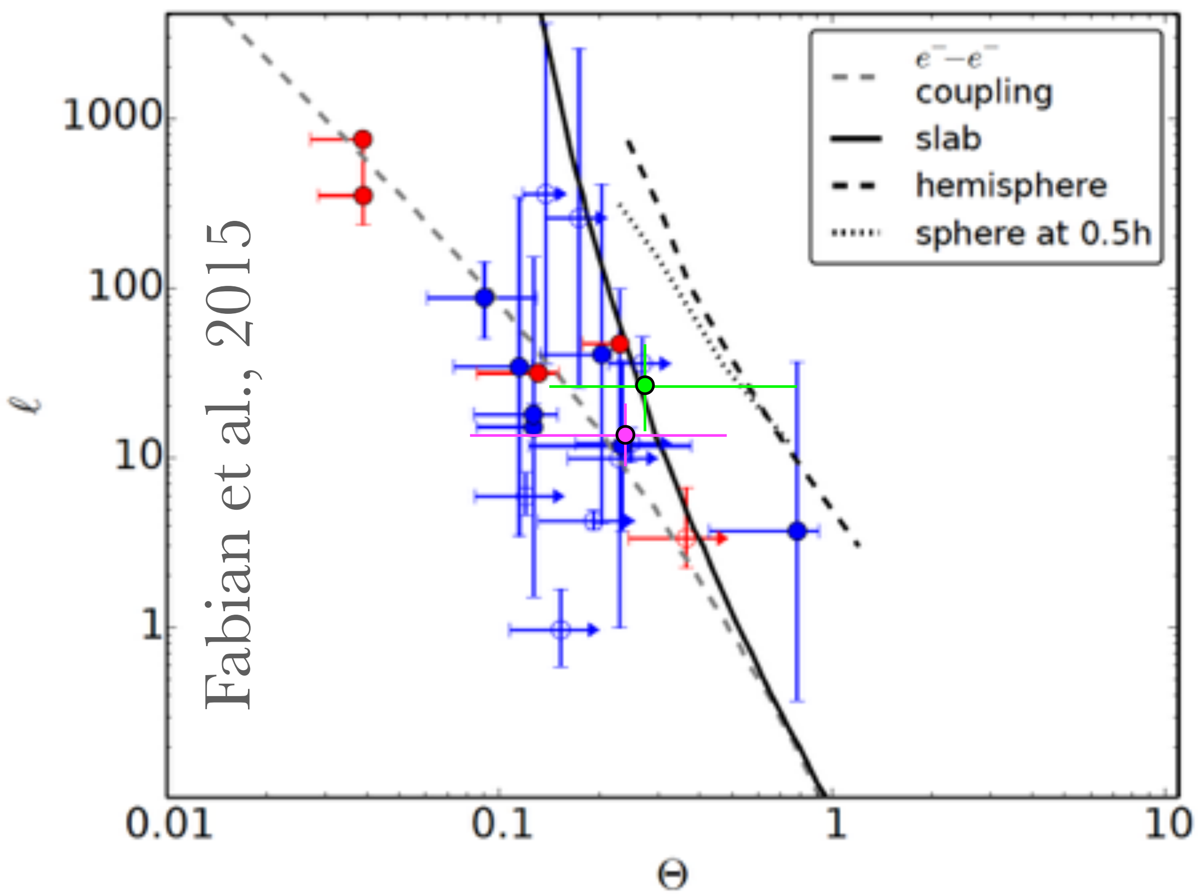
NGC 6814

$$\Theta_e = 0.22^{+0.15}_{-0.12}$$

$$\ell = 14.5 \pm 4.5 (\mathrm{R}_{10})^{-1}$$



Summary of the theoretical understanding of the **Θ**-ℓ plane.



Θ-ℓ distribution for *NuSTAR* observed AGN (blue points) and BHB (red points)

Conclusion

- Cutoff measurements and discrimination between primary power-law and reprocessed spectrum;
- Relativistic broadened FeKα line with disk reflection component;
- Narrow FeKα line due to a large iron overabundance, or alternatively produced in distant Compton thin material;
- Estimated Eddington ratio **η=0.01** for MCG +8-11-11 and **η=0.09** for NGC 6814;
- Both sources are located against the pair runaway line like most of the sources among those analyzed by Fabian et al.


THANK YOU!