Multi-Time Scale X-ray Spectral Monitoring of Seyfert AGN with RXTE

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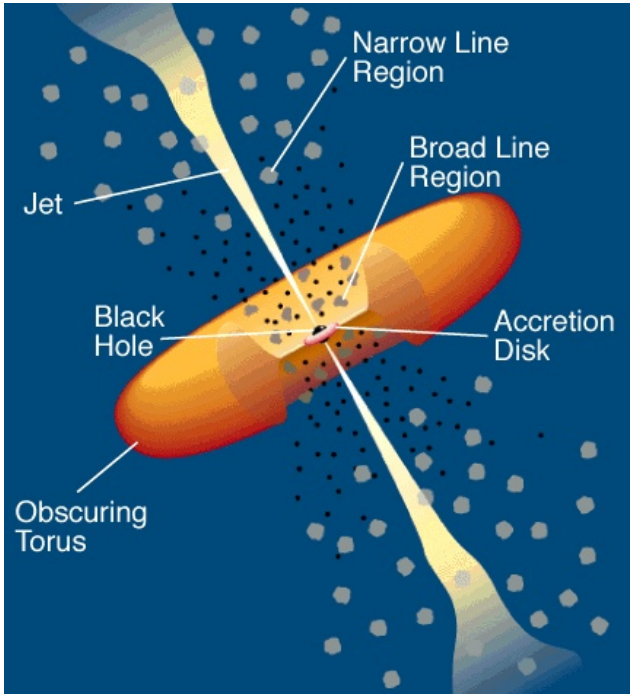
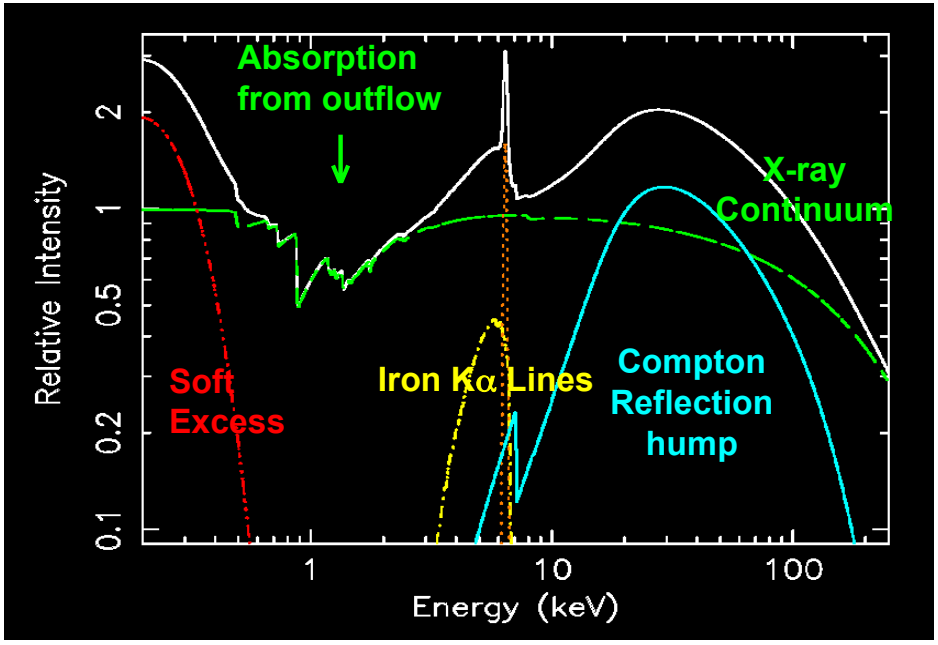
Black Holes 2012, Bamberg, June 21, 2012


Karl Remeis Sternwarte

Quickie Intro: Accreting Circumnuclear Gas

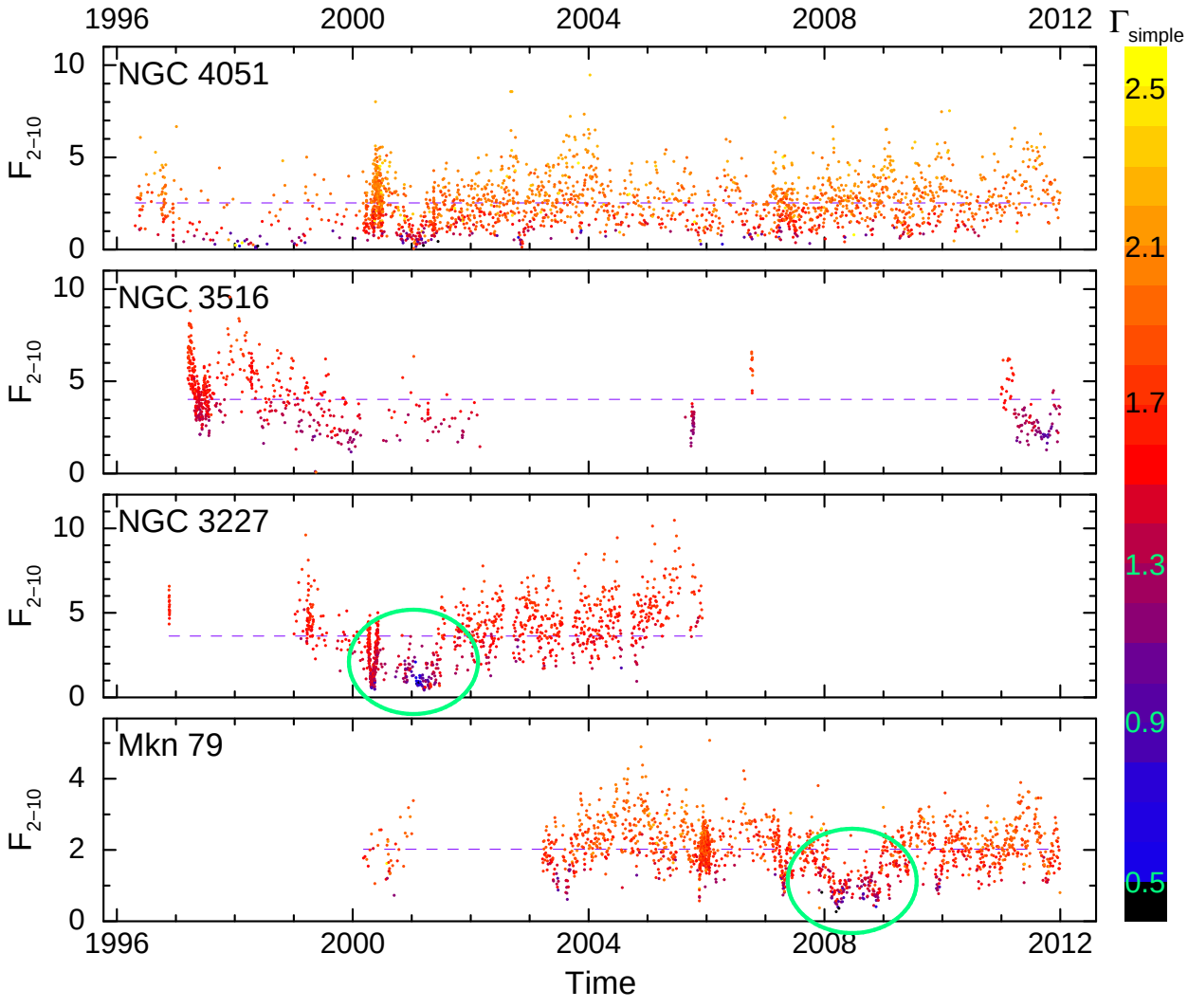




(Urry & Padovani 1995)

- **Traced by Fe Kα profile, line-of-sight neutral absorption & Compton reflection**

RXTE's Legacy: The AGN *Spectral* Variability Database

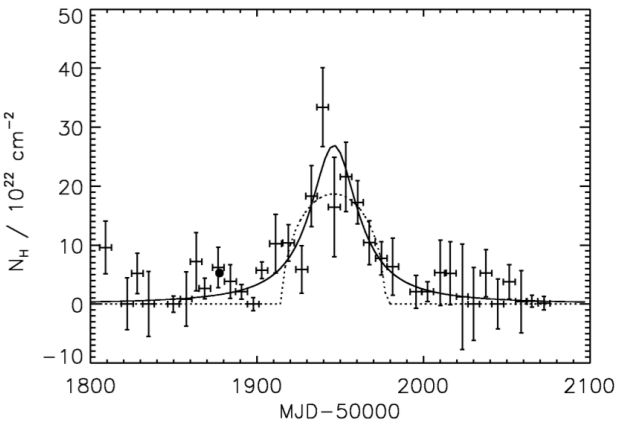


- **Spectral Monitoring** $\rightarrow$ $\Gamma(t)$, $I_{\rm FeK\alpha}(t)$, $N_{\rm H}(t)$

Time scales of months–years are interesting for AGN!

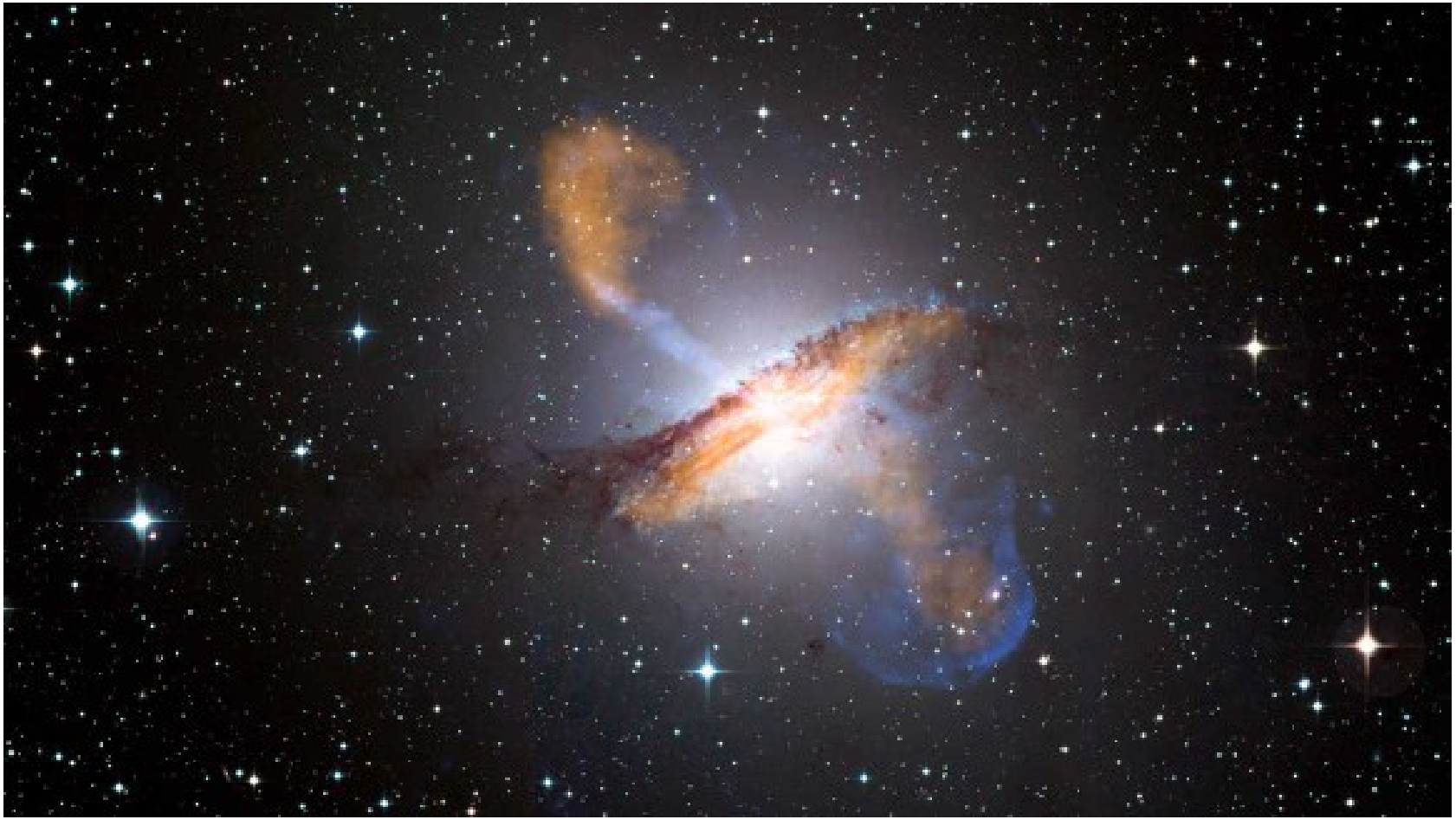
Variability in Line of Sight Absorbers

• Variations in X-ray absorbing columns in *both* Sy 1s & 2s, on time scales of hours–years (Risaliti+ 2002, Puccetti+ 2007, Turner+ 2008)



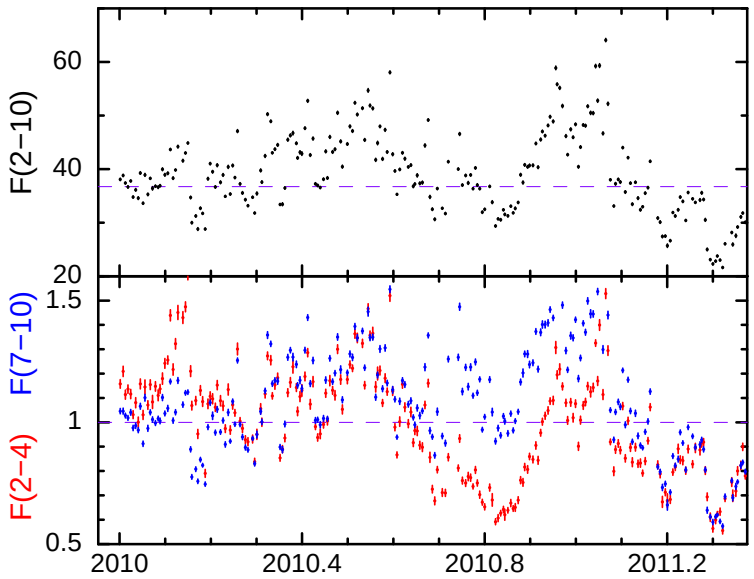
Lamer+ '03: NGC 3227:
3-month eclipse, 2000–1
$\Delta N_{\rm H} = 3 \times 10^{23}$ cm^{-2}
$R \sim 10 - 100$ lt.-days
BLR cloud likely

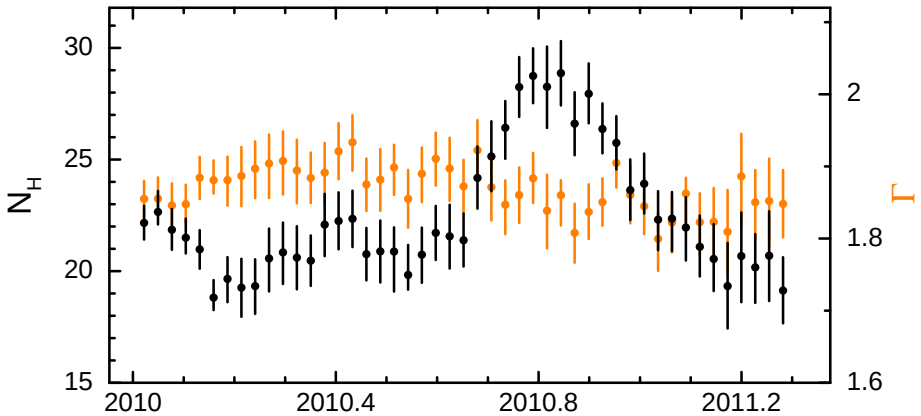
RXTE Monitoring of Cen A Reveals a Clumpy Absorber



credit: NASA/CfA/R.Kraft/MPIfR/ESO

Variability in Line of Sight Absorbers





Rivers, Markowitz & Rothschild, 2011, ApJ, 742, L29

RXTE monitoring of Cen A, Jan. 2010–Jan. 2012

6-month long eclipse, 2010–1

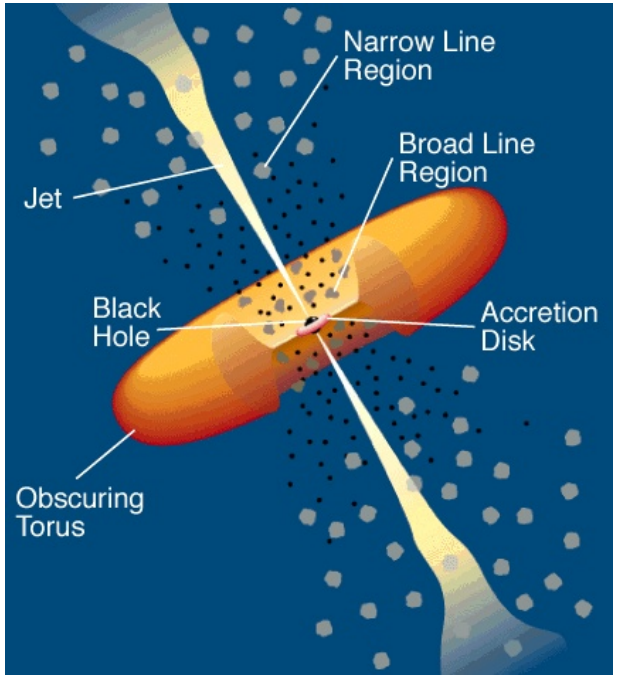
$\Delta N_{\rm H} = 8 \times 10^{22}$ cm^{-2}

$n_{\rm H} \sim 3 \times 10^{7}$ cm^{-3}; $D \sim 3 \times 10^{15}$ cm

$R \sim 0.1 - 0.3$ pc (Torus cloud likely)

$N_{\rm H}$ monitoring with RXTE: complementary to short-term results

Clumpy torus models



(Urry & Padovani 1995)

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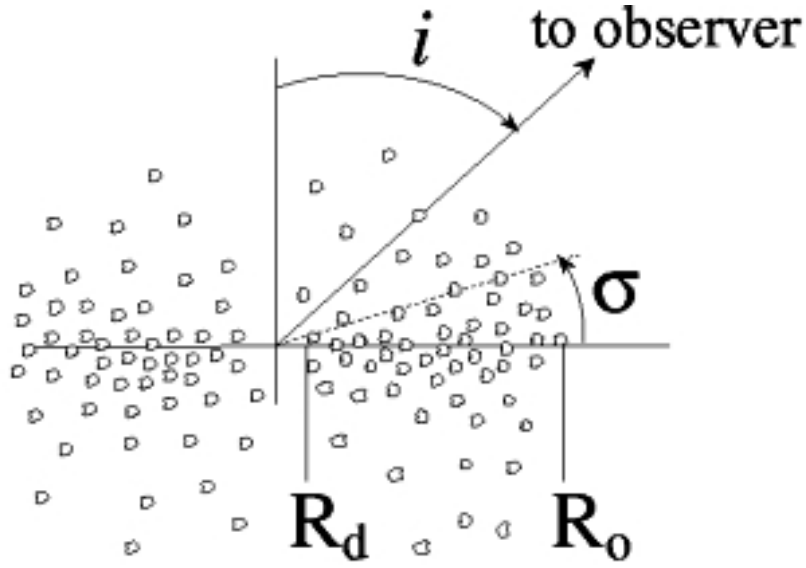
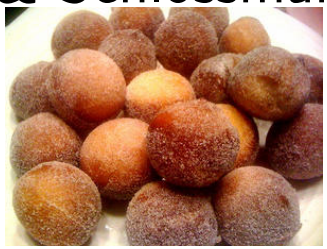
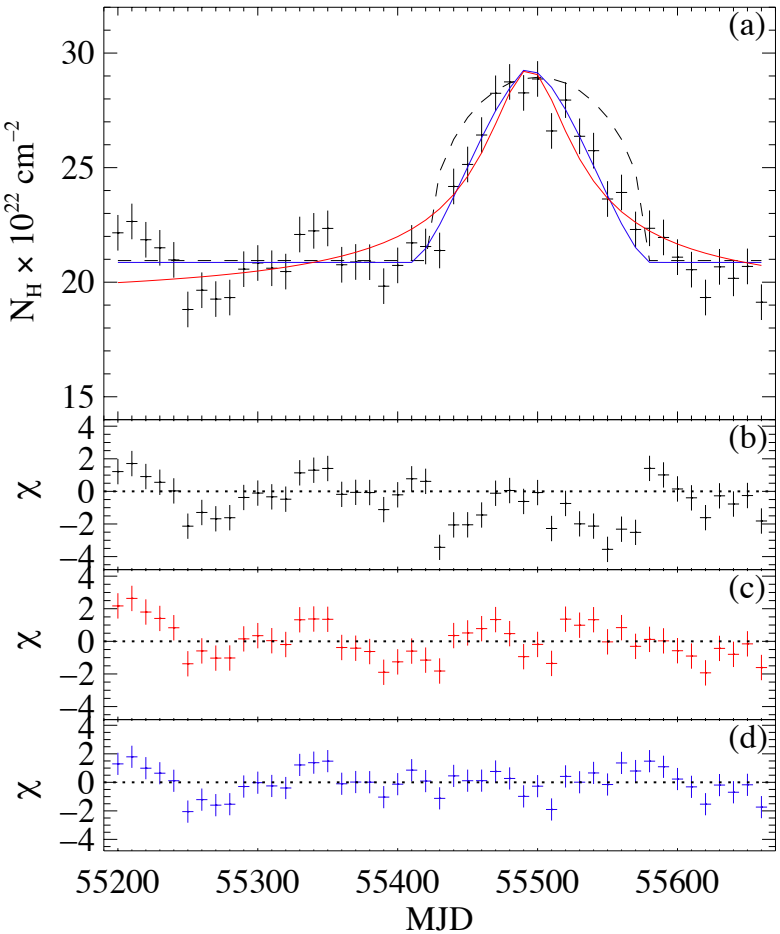


e.g., Nenvoka et al. 2002, 2008; Elitzur & Schlossmann 2006



Clump in Cen A



(Uniform sphere (worst fit) vs. β-profile vs. $n(r) \propto r^{-1}$ (best fit))

$N_{\rm H}/\Delta N_{\rm H} \sim 5$ clumps along l.o.s.

Nenkova et al. models: small number ($\lesssim$ 10–15) of clumps

See also Rothschild et al. (2011 & 2006) for a similar size obscuration event in 2003–2004.

RXTE Spectral Surveys: Long-term average X-ray spectral properties

Summed spectra from all archival data.

- References for long-term-averaged spectral parameters e.g., $\langle F_{20-100} \rangle \rightarrow$ reduce ambiguity due to source variability

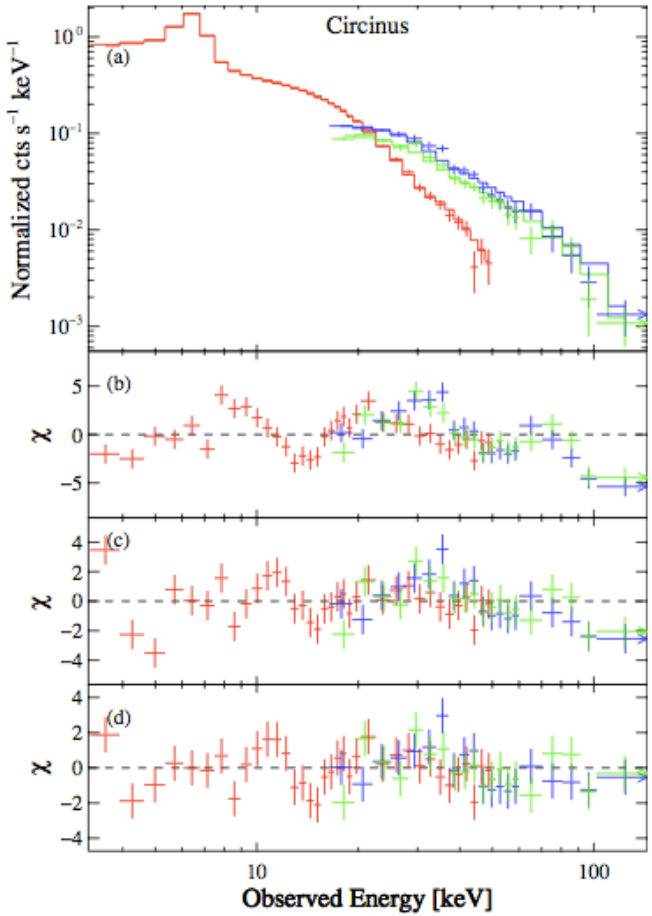
- **Rivers, Markowitz & Rothschild (2011a, ApJS, 193, 3):**

23 Brightest AGN at 100 keV (the $\sim 20 - 200$ keV sky is only recently becoming explored)

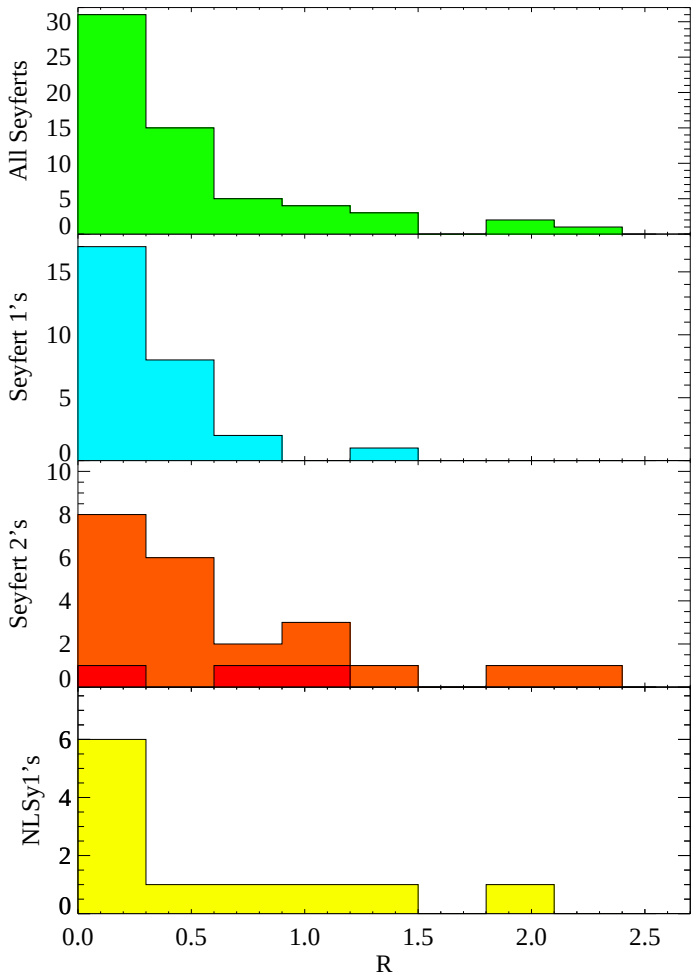
PCA + HEXTE, covering $3 - 100$ keV

- **Rivers, Markowitz & Rothschild, in prep.**: Expanded Survey: 97 AGN, $3- \gtrsim 30$ keV

Sample spectrum/fits:



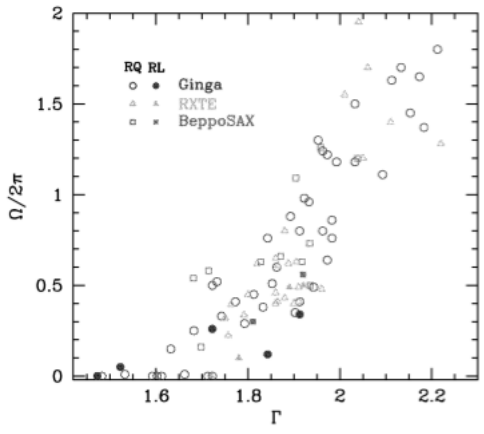
RXTE Spectral Surveys: Long-term average X-ray spectral properties



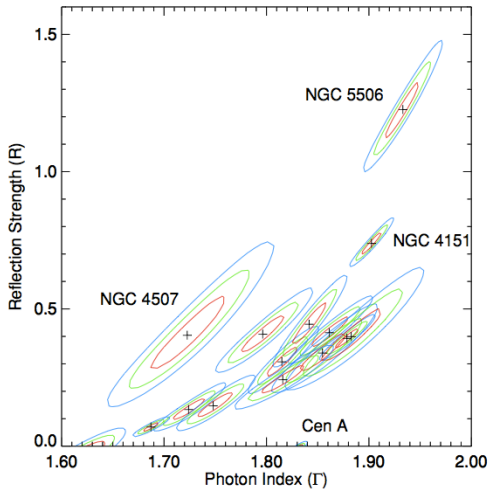
- Compton Reflection confirmed in $\sim 85\%$ of the brightest Seyferts.
- $R(\mathrm{Sy2}) \sim 2 \times R(\mathrm{Sy1})$
- Fe Kα Line Flux: $\sim 30\%$ from C-thick gas.
- Future RXTE Archival Work: Fe Line Flux & Compton Hump Variability; Testing Clumpy-Absorber Models

$R - \Gamma - \dot{m}$ Correlation in GBHs & AGN

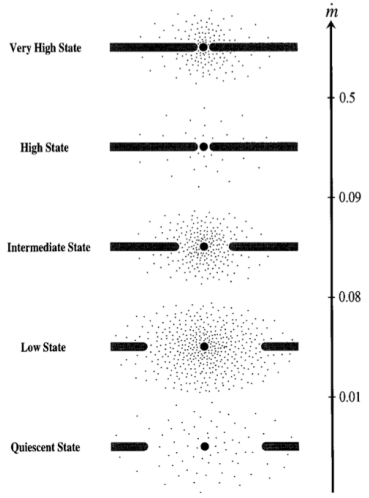
Global correlations and correlation within individual GBHs;
Global correlations across AGN:



Zdziarksi et al. (2003)



Rivers et al. (2011a)

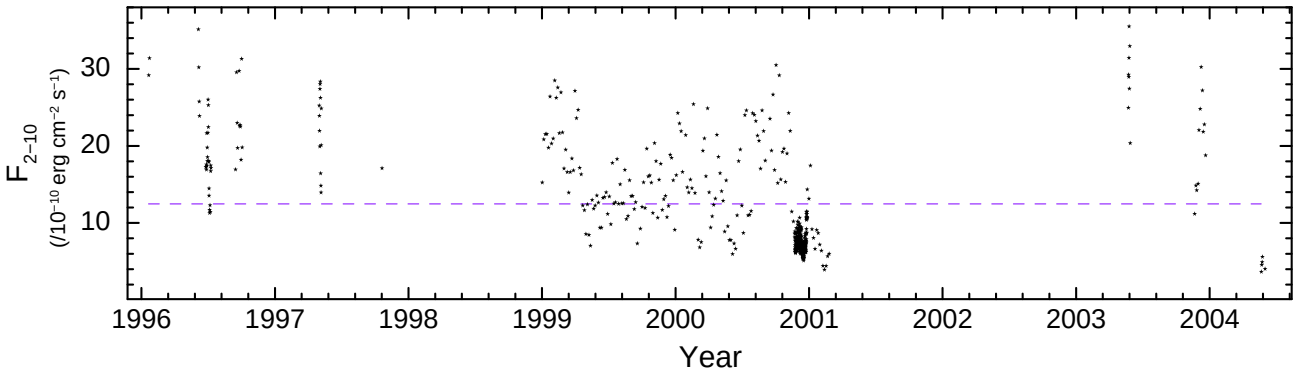


Thin disk migrates inward as $L_{\rm Bol}/L_{\rm Edd}$ increases? (e.g., Esin et al. 1997)

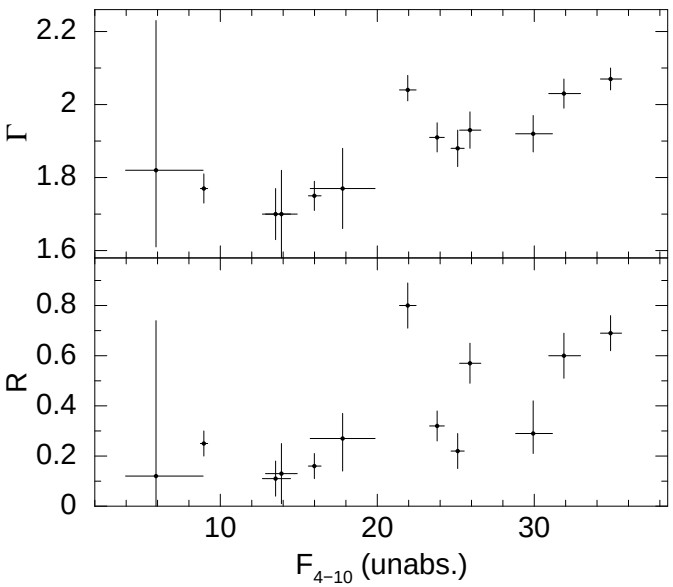
- For individual AGN: poor S/N above 10 keV can yield spurious correlations (Vaughan & Edelson 2001) and Nandra et al. (2000).

RXTE Spectral Monitoring of NGC 4151, 1996–2004

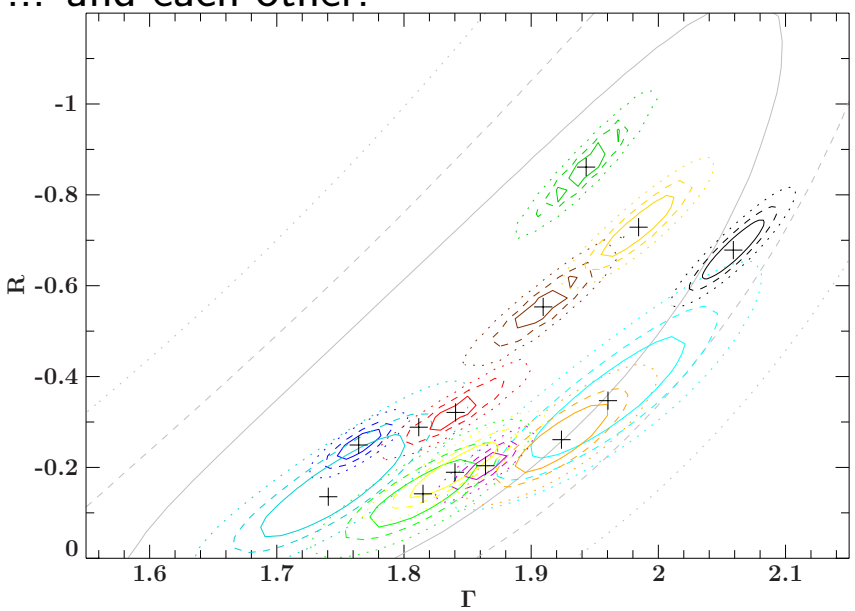
Markowitz et al., in prep:



R & Γ correlate with F_X:



... and each other:



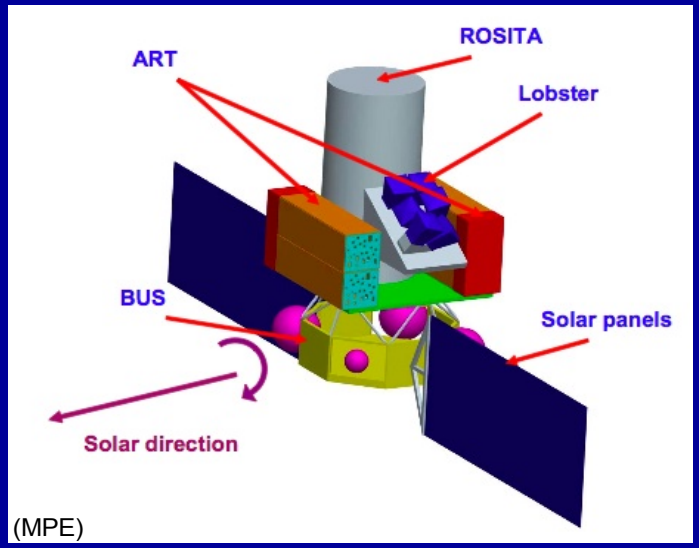
Future: eROSITA

extended ROentgen Survey with an Imaging Telescope Array

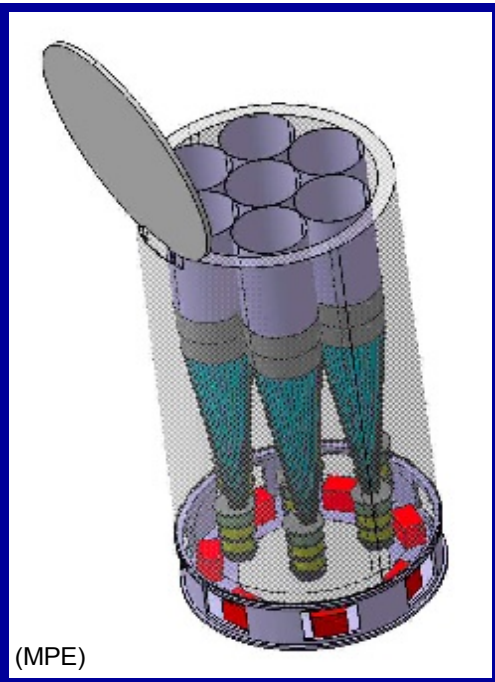
Primary Instrument aboard Spectrum X-Γ (ESA): Launch: late 2013(?) from Baikonur

First X-ray survey of entire sky since RASS (but 30x more sensitive!

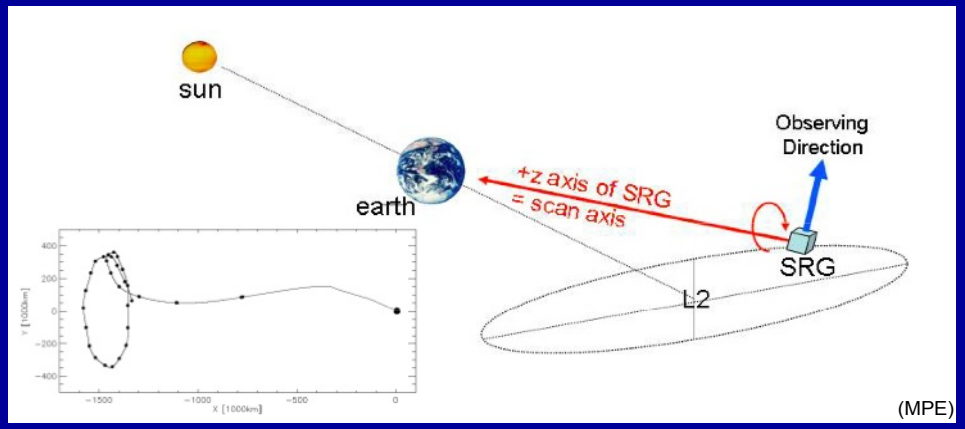
Monitor entire sky over 0.2-10 keV with CCD resolution (detectors based on XMM EPIC pn)



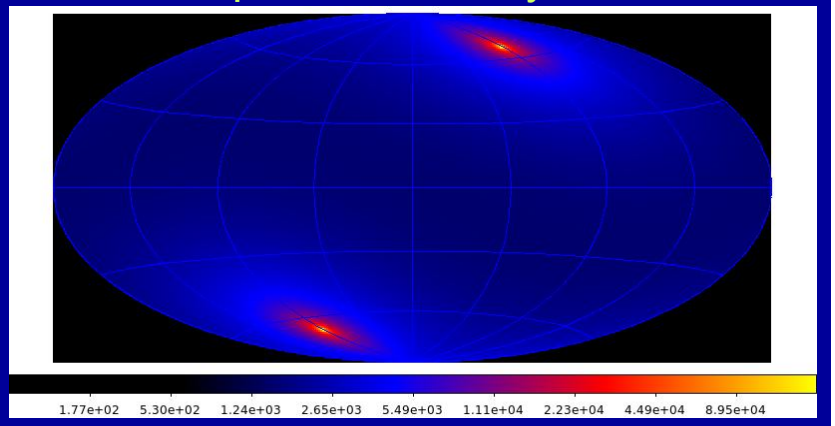
(MPE)


(MPE)

Future: eROSITA



Exposure after 4 years:

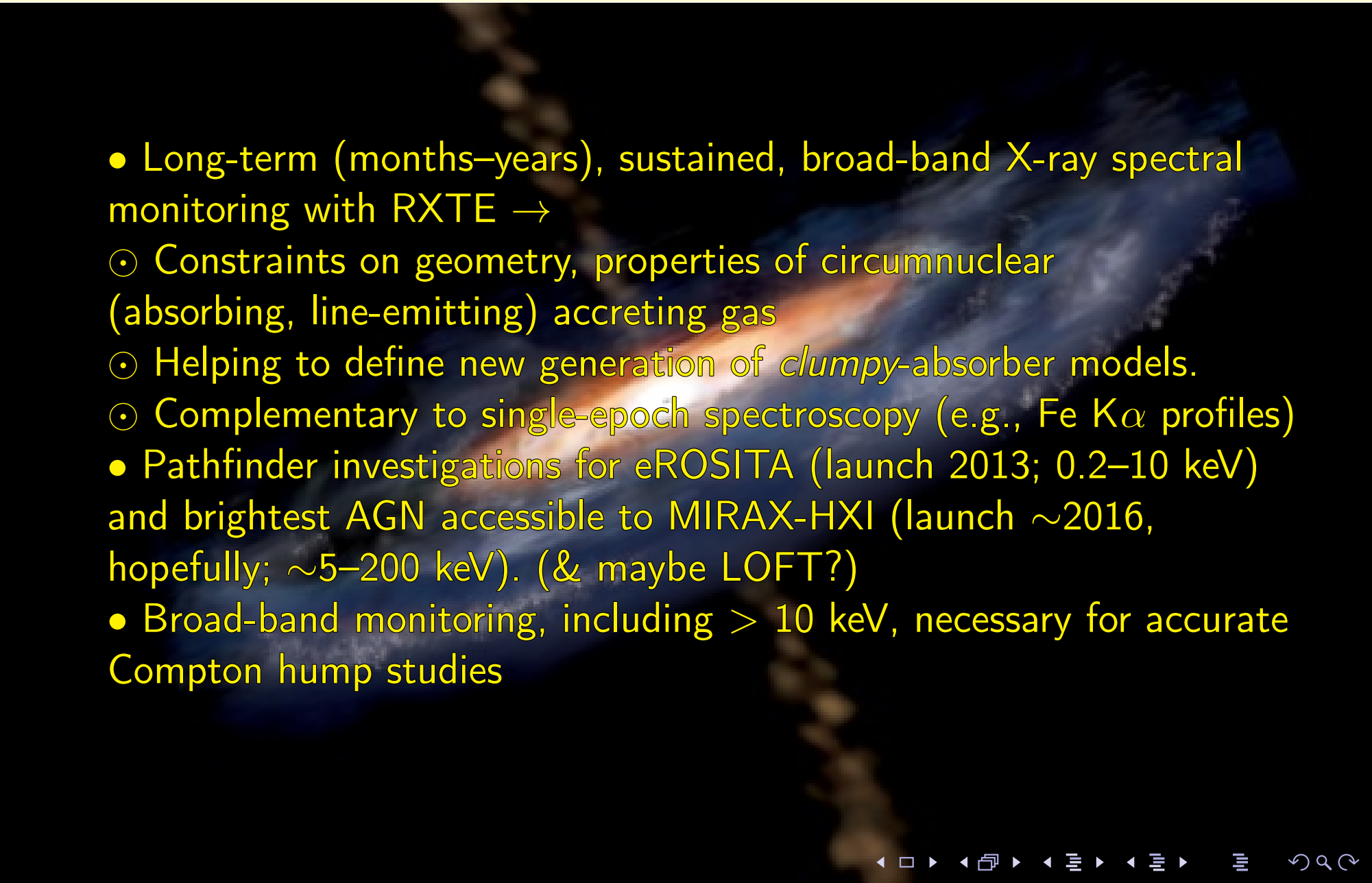


(from C.Schmid)

Largest survey of Fe Kα profiles and line-of-sight absorbers to date

Long-term monitoring: variability in absorbers and Fe Kα components, as a function of luminosity & object type

Summary



- Long-term (months–years), sustained, broad-band X-ray spectral monitoring with RXTE $\rightarrow$
  - $\odot$ Constraints on geometry, properties of circumnuclear (absorbing, line-emitting) accreting gas
  - $\odot$ Helping to define new generation of *clumpy*-absorber models.
  - $\odot$ Complementary to single-epoch spectroscopy (e.g., Fe Kα profiles)
- Pathfinder investigations for eROSITA (launch 2013; 0.2–10 keV) and brightest AGN accessible to MIRAX-HXI (launch $\sim$2016, hopefully; $\sim$5–200 keV). (& maybe LOFT?)
- Broad-band monitoring, including > 10 keV, necessary for accurate Compton hump studies

References & Back-up Slides

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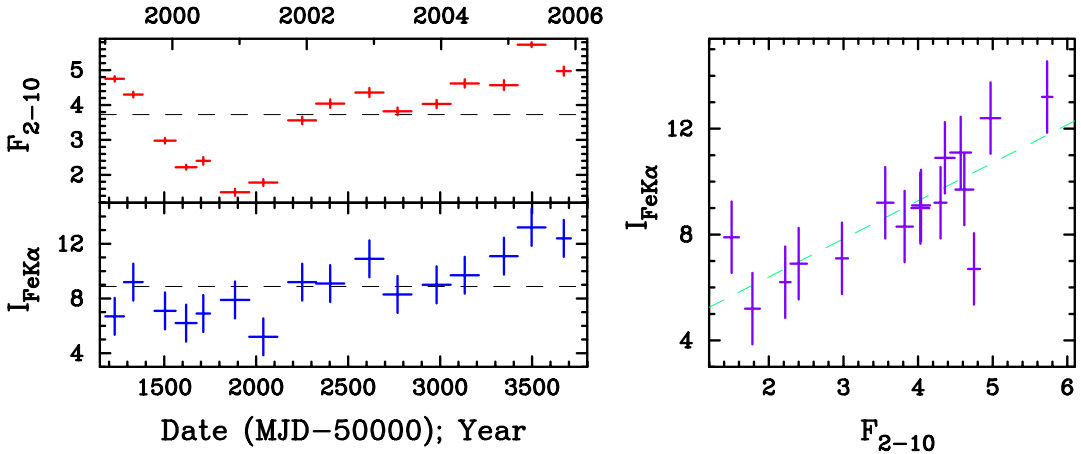
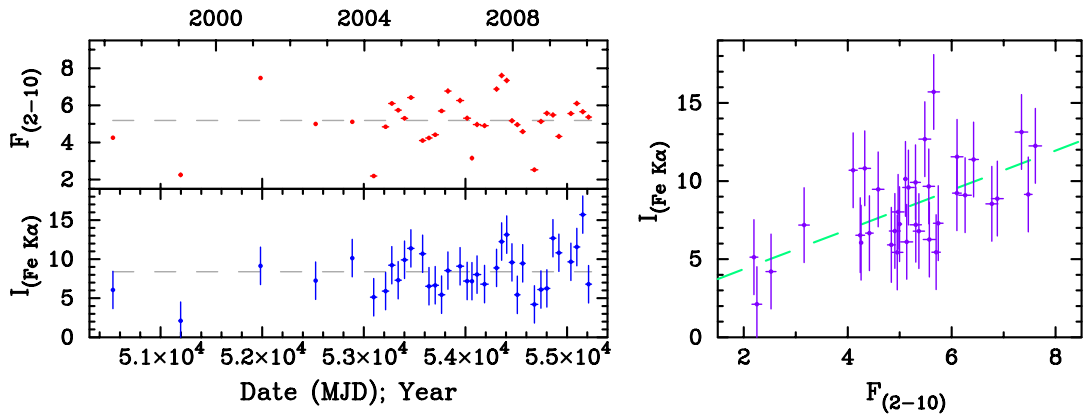
Reverberation Mapping with the Fe Kα Line

NGC 3227 (Markowitz et al. 2009)



3C 111 (Chatterjee et al. 2011)



50%/80% of line flux responds to continuum variations; variable portion of line originates in gas $< 700/< 60$ light-days from central engine

(Related: see also: Markowitz, Edelson & Vaughan 2003; Vaughan & Edelson 2001; Nandra et al. 2000)