Exploratory X-ray Monitoring of High Redshift Radio-Quiet Quasars

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The X-ray Universe 2011, Berlin, June 28, 2011

Outline

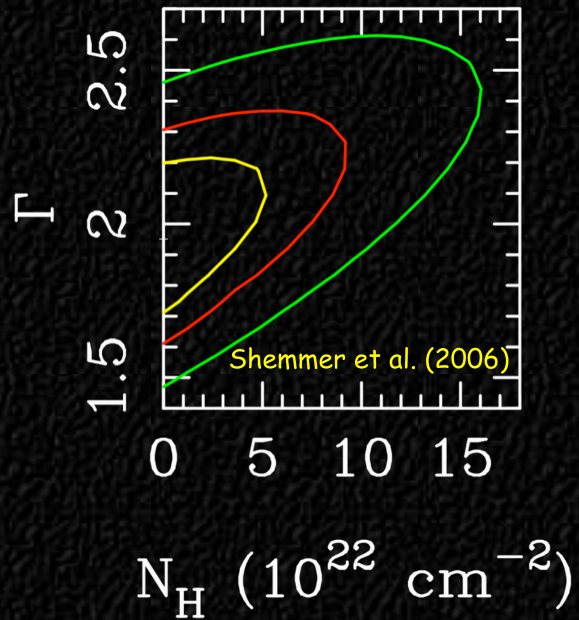
1. Were Quasars More X-ray Variable in the Early Universe?

2. *Chandra* Monitoring of Radio-Quiet Quasars at $z \simeq 4.2$

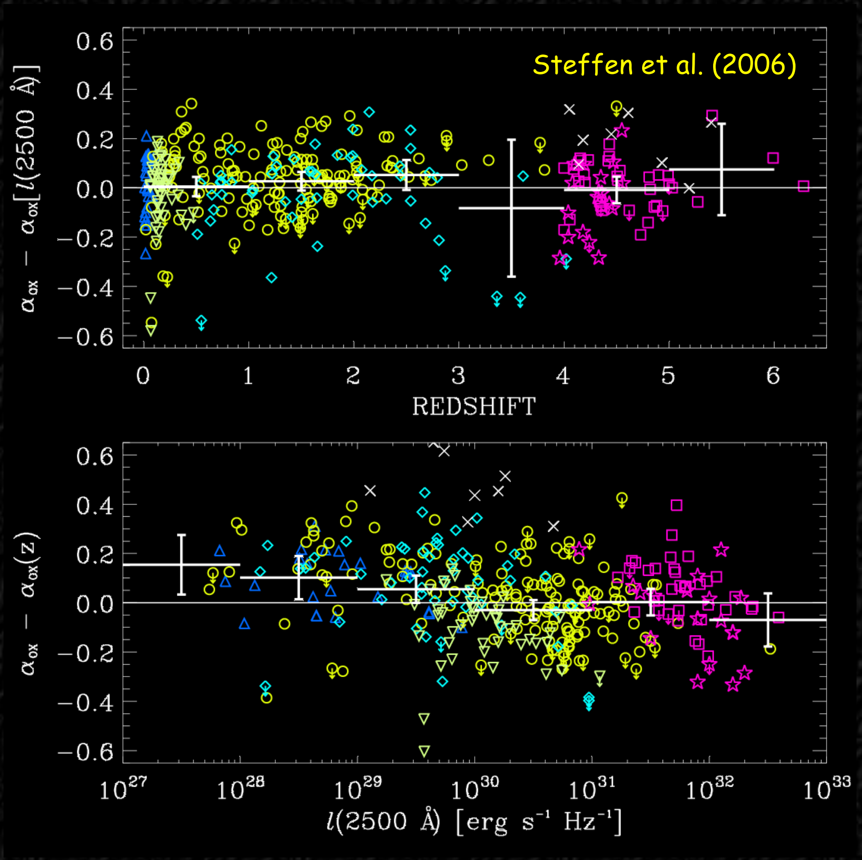
3. *Swift* Monitoring of Radio-Quiet Quasars at $z \simeq 2$

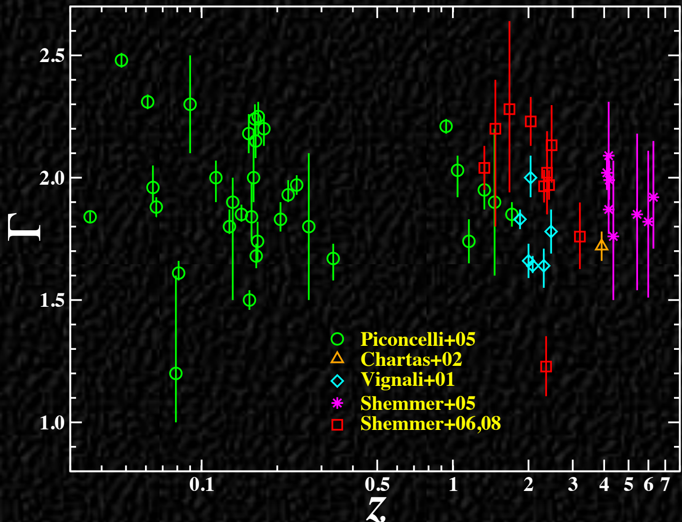
4. Ongoing and Future Work

1. Were Quasars More X-ray Variable in the Early Universe?



Motivation (a):

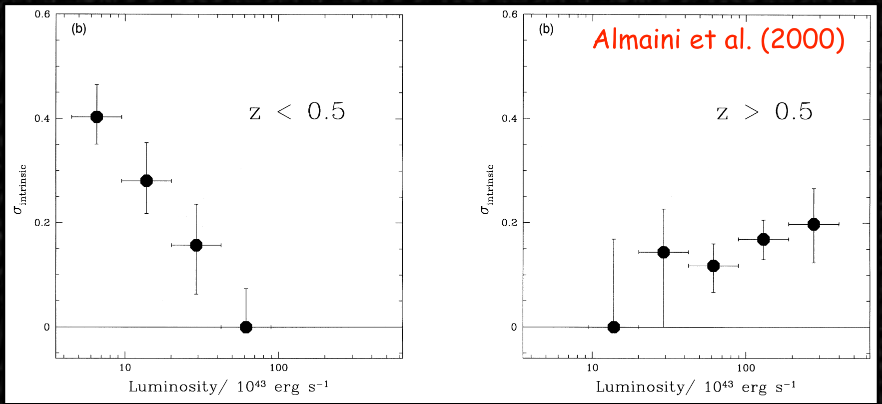


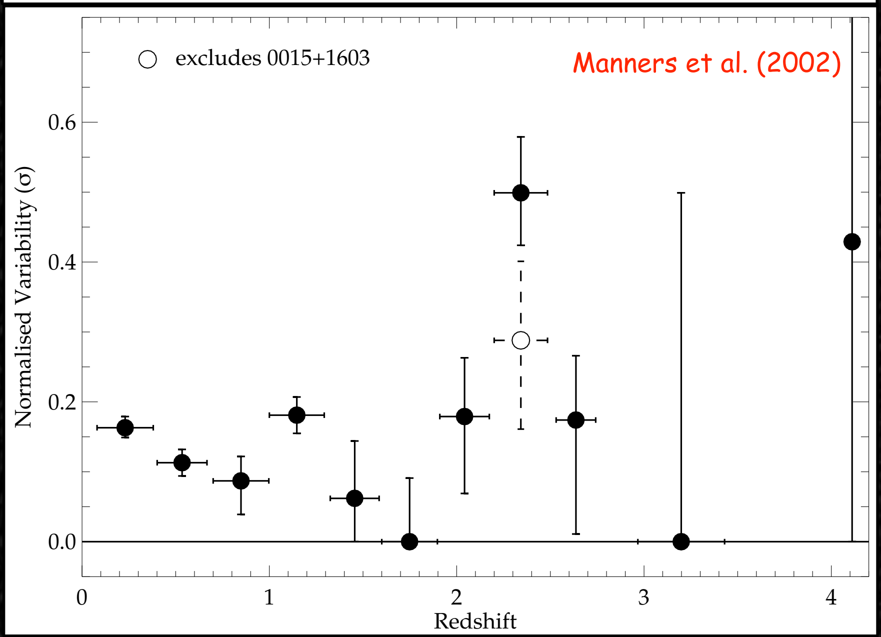


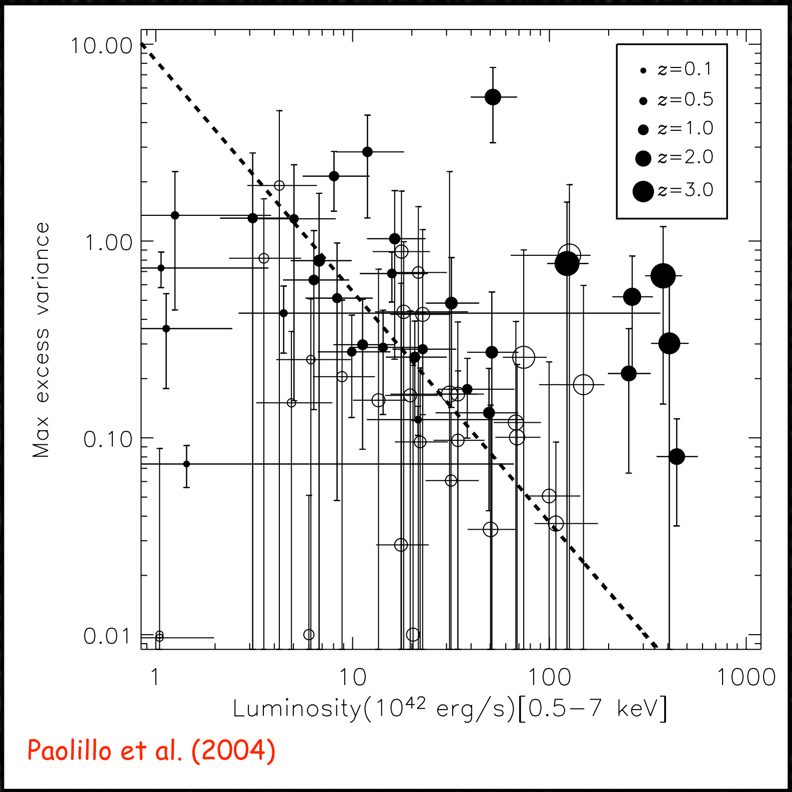
X-ray spectral properties of quasars have not changed significantly across cosmic time.

1. Were Quasars More X-ray Variable in the Early Universe?

Motivation (b):







Quasars of matched luminosity appear to be ***more*** X-ray variable at higher redshift.

Motivation (c):

But distant quasars, being more luminous and hence physically larger than nearby quasars/AGN/Seyferts, are supposed to exhibit slower and suppressed variations?!?

Some possible interpretations include evolution of:

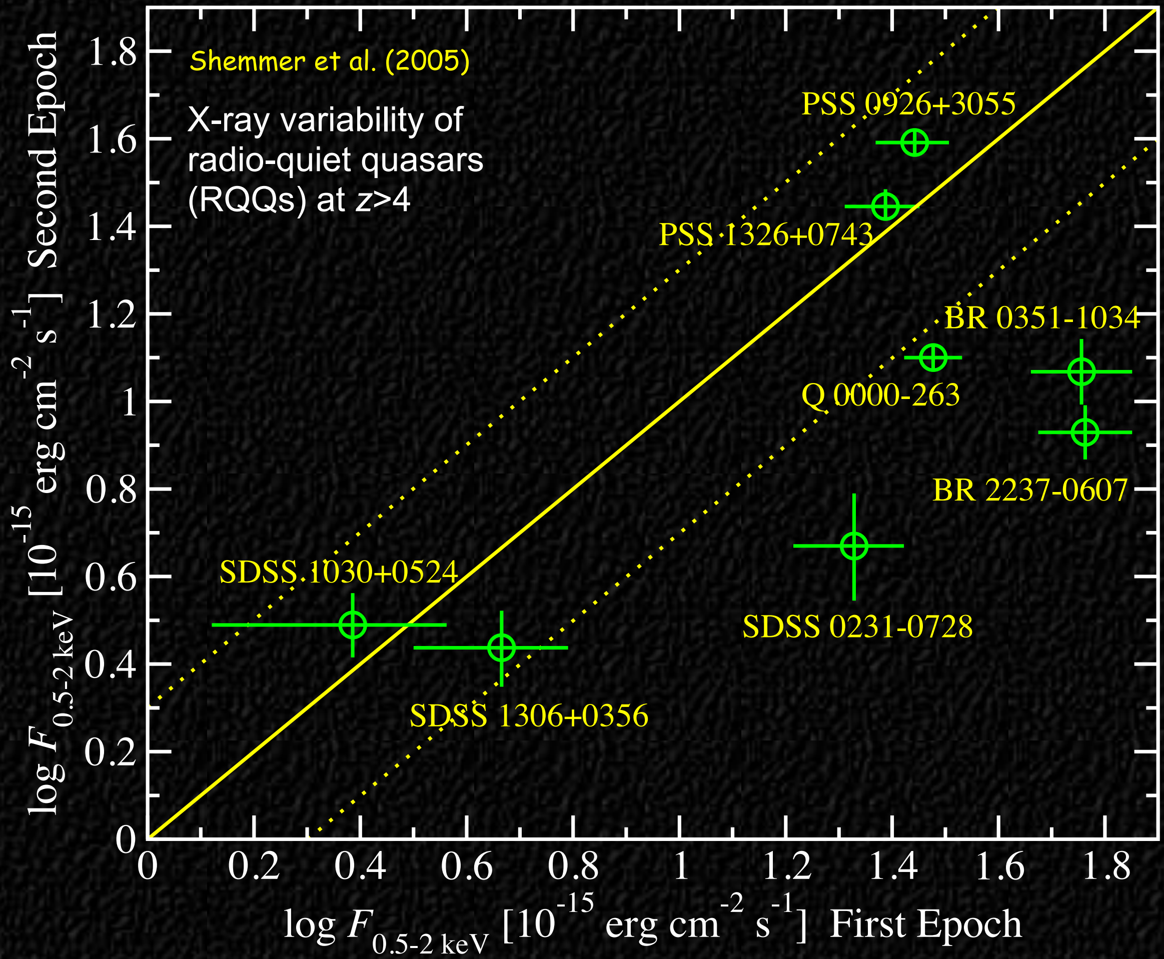
- ✳ The X-ray variability mechanism
- ✳ The X-ray emitting region size
- ✳ The accretion rate/mode/efficiency

Testing this requires X-ray variability information about the most distant quasars.

What are the amplitudes and timescales of X-ray variations of the most distant quasars?

2. Chandra Monitoring of Radio-Quiet Quasars at z≃4.2

Systematic X-ray variations of the most distant quasars have not been carried out yet.



Why X-rays?

X-ray variations are typically faster and stronger relative to those in the optical.

↓

X-ray monitoring is more efficient for studying continuum variations in the most distant quasars.

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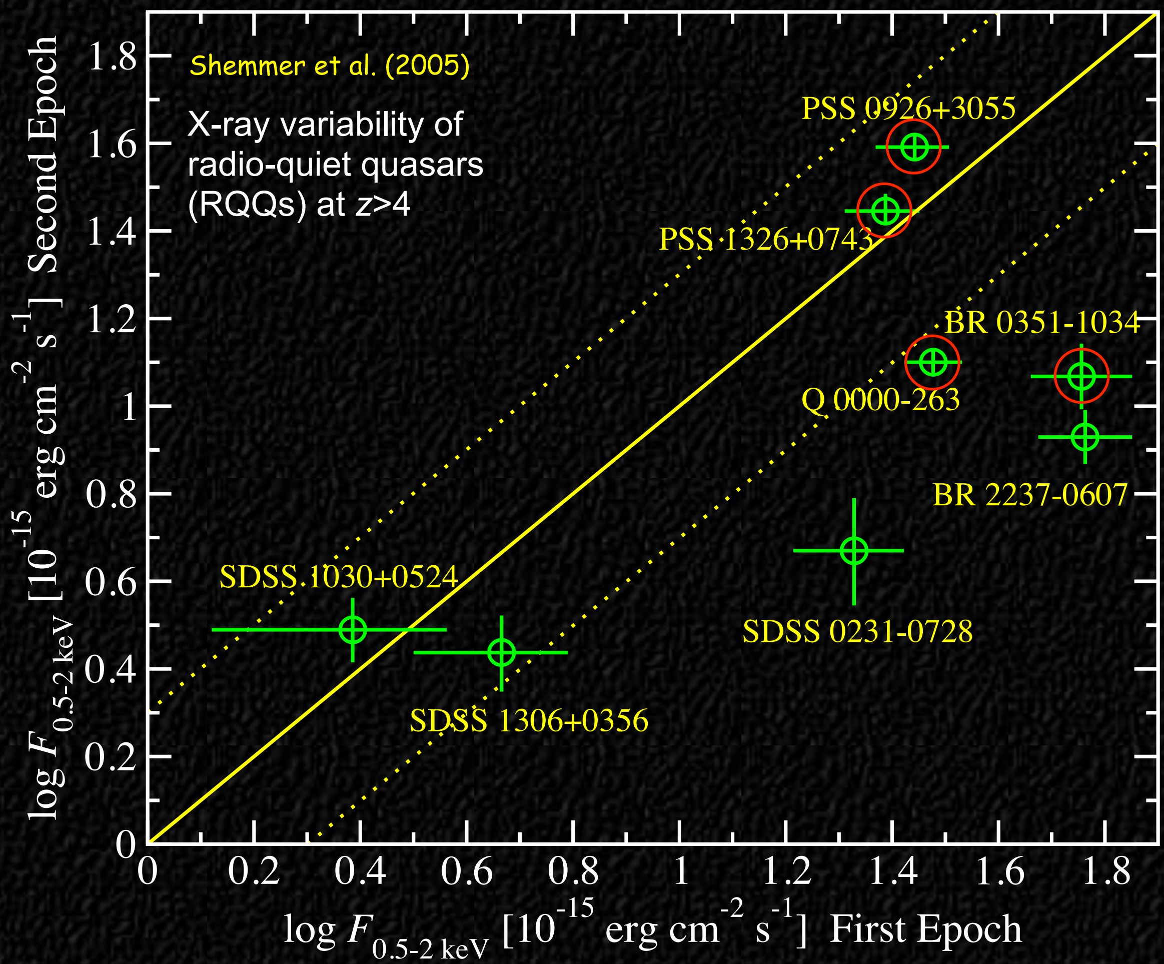

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2. Chandra Monitoring of Radio-Quiet Quasars at $z \simeq 4.2$

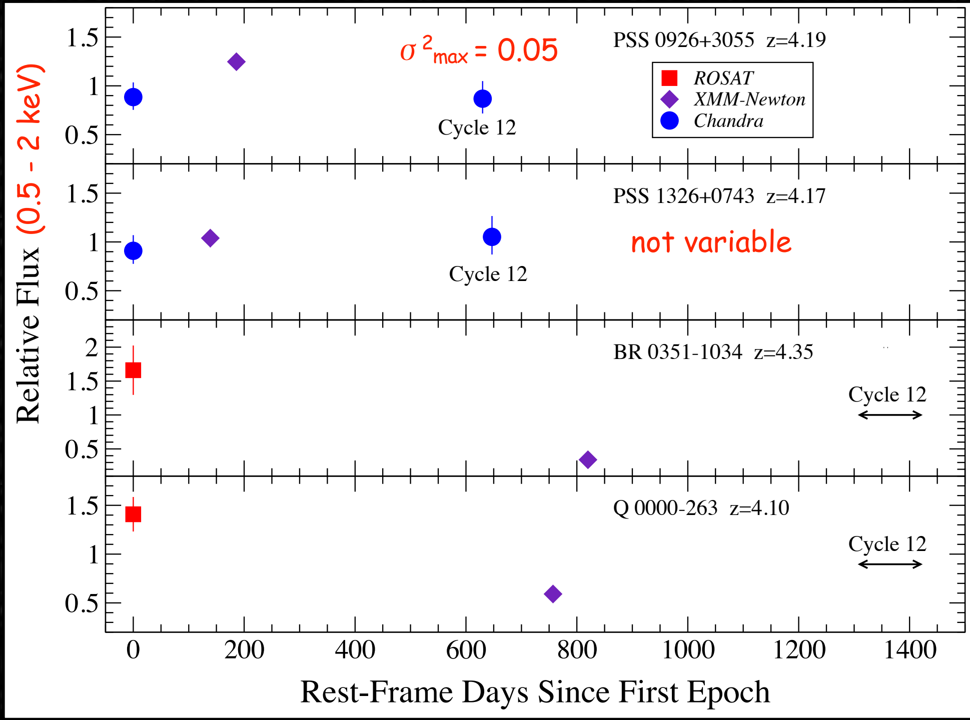
Target selection

- ✳ RQQs at z > 4.
- ✳ Have at least two distinct epochs (i.e., continuous exposures).
- ✳ Bright enough for economical *Chandra* observations.

Sample Properties

Quasar	z	M_B	Galactic N_H (10^{20} cm^{-2})	log $L_{2-10\ \mathrm{keV}}$ (erg s^{-1})	α_{ox}
PSS 0926+3055	4.19	−30.1	1.89	45.8	−1.76
PSS 1326+0743	4.17	−29.6	2.01	45.7	−1.76
Q 0000−263	4.10	−29.3	4.08	45.7	−1.70
BR 0351−1034	4.35	−28.2	1.67	45.4	−1.69

Light Curves



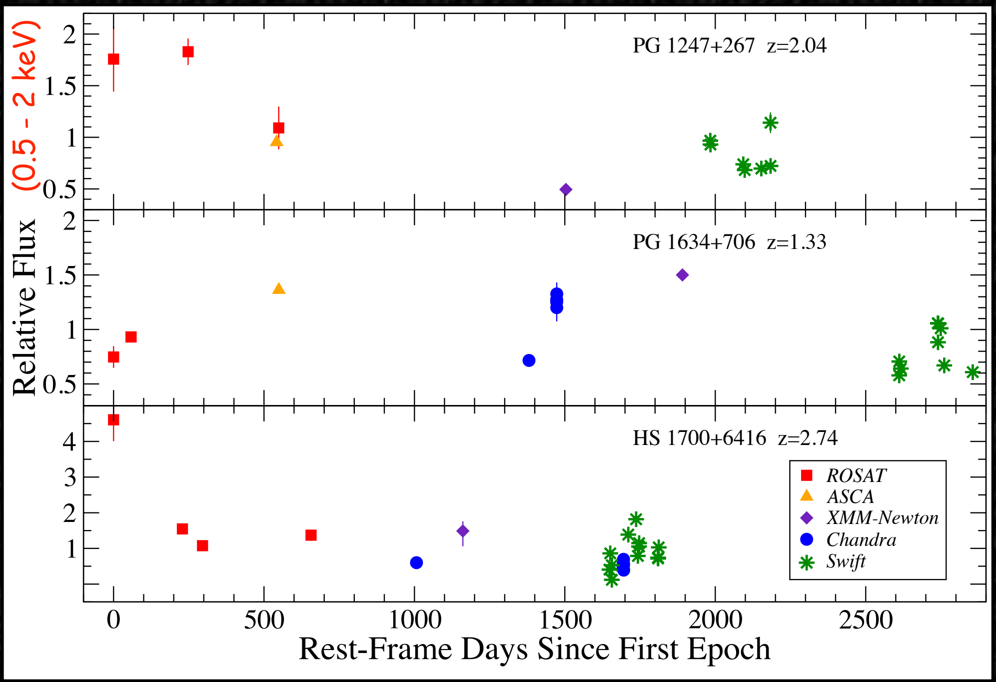
Maximum excess variance: $\sigma_{\max} = \max_{i \in 1,\ldots,N_{\rm obs}} \sqrt{\left[\frac{(n_i - \bar{n})^2 - \sigma_i^2}{\bar{n}^2}\right]}$

Need to break the strong L-z dependence inherent in quasar samples.

3. Swift Monitoring of Radio-Quiet Quasars at z≃2

Sample Properties and Light Curves

Quasar	z	M_B	Galactic $N_{\rm H}$ (10^{20} cm^{-2})	log $L_{2-10\ \rm keV}$ (erg s^{-1})	$\alpha_{\rm ox}$
PG 1247+267	2.04	−29.5	0.90	45.9	−1.75
PG 1634+706	1.33	−30.1	4.48	46.1	−1.68
HS 1700+6416	2.74	−29.9	2.66	46.2	−1.91



Target selection

- ✳ RQQs at z~2.
- ✳ Luminosities comparable to the *Chandra* sample.
- ✳ Have the most epochs (5-14).
- ✳ Bright enough for economical *Swift* observations.

Fractional variability amplitude

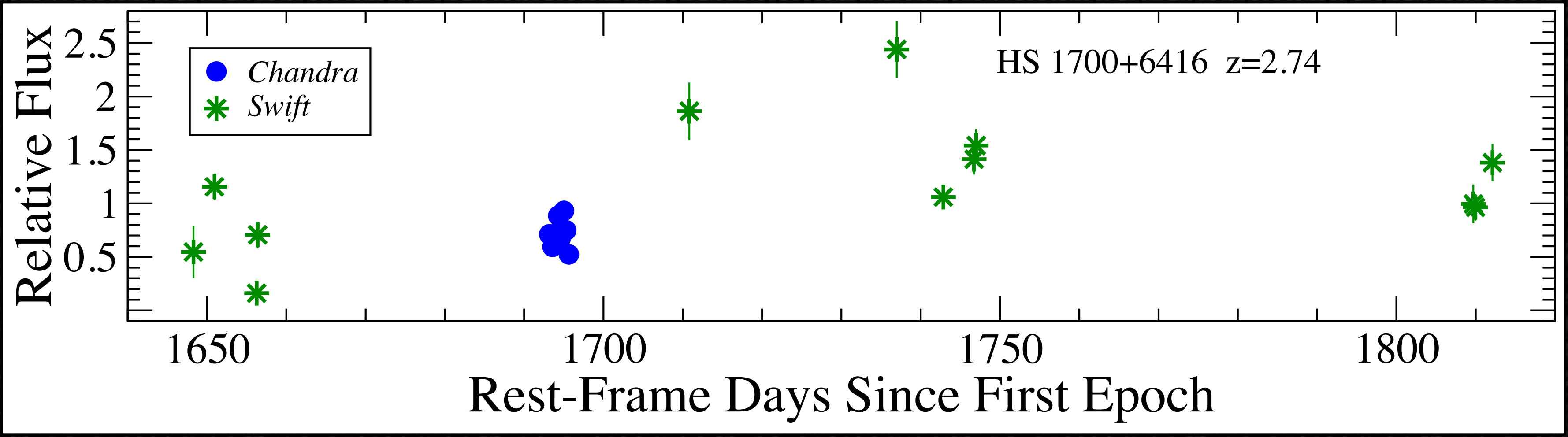
$$F_{\rm var} = \frac{1}{\langle X \rangle}\sqrt{S^2 - \langle \sigma_{\rm err}^2 \rangle}$$

Quasar	$F_{\rm var}$
PG 1634+706	0.29 ± 0.05
PG 1247+267	0.40 ± 0.09
HS 1700+6416	0.85 ± 0.12

Variability amplitudes similar to low-L AGN.

3. Swift Monitoring of Radio-Quiet Quasars at z≈2

Extreme X-ray variability of HS 1700+6416



X-ray fluctuations of $\gtrsim 4\times10^{12}\ L_\odot$ on timescales of $\lesssim$1 day(!)

↓

Implying $\Delta L/\Delta t \gtrsim 2\times10^{41}$ erg s^{-2}

↓

Taking a radiative efficiency (η) limit $\eta \gtrsim 4.8\times10^{-43}\Delta L/\Delta t$ (e.g., Fabian 79), this gives $\eta \gtrsim 0.1$.

3. Swift Monitoring of Radio-Quiet Quasars at z≈2

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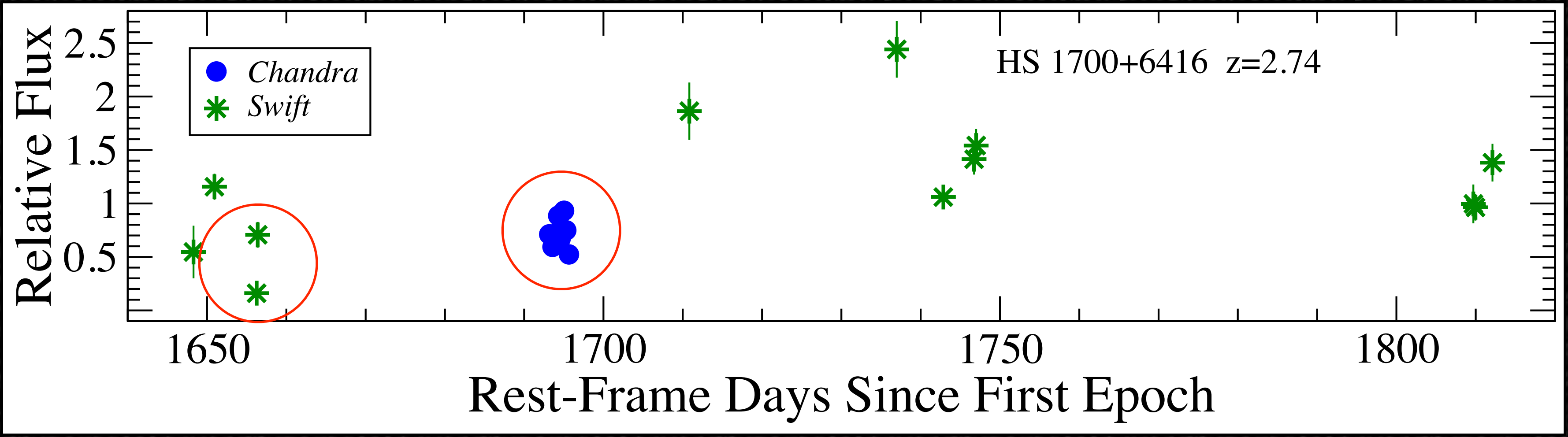

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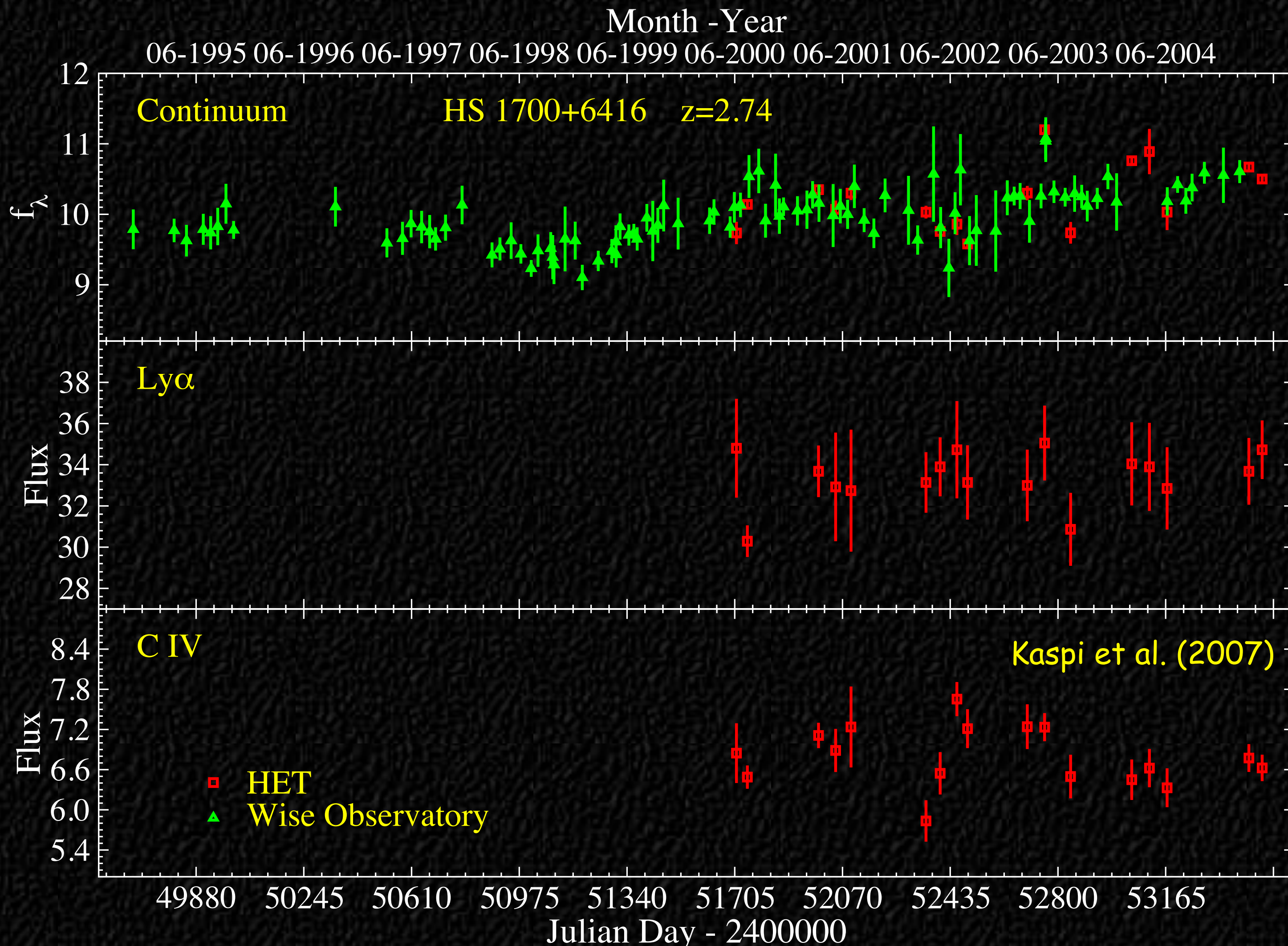
3. Swift Monitoring of Radio-Quiet Quasars at z≃2

Extreme X-ray variability of HS 1700+6416 ?



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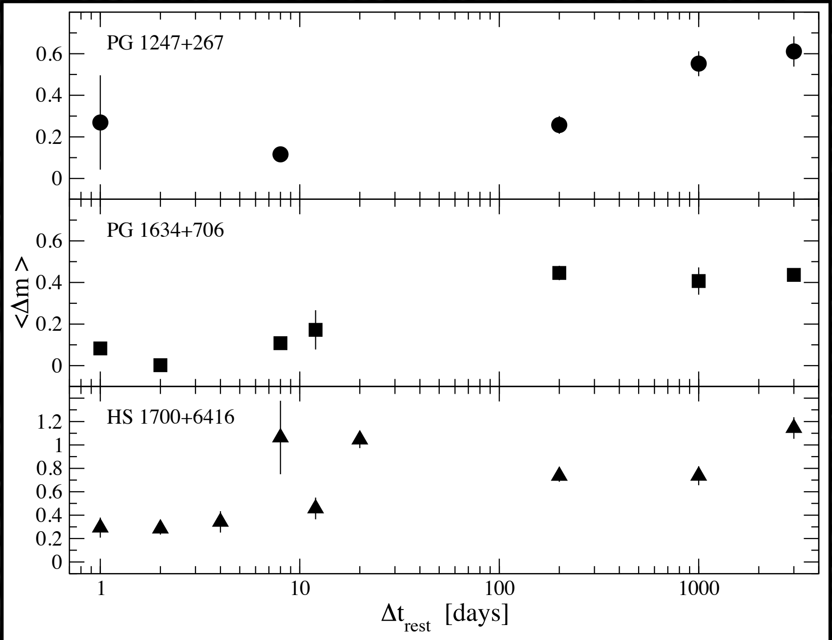
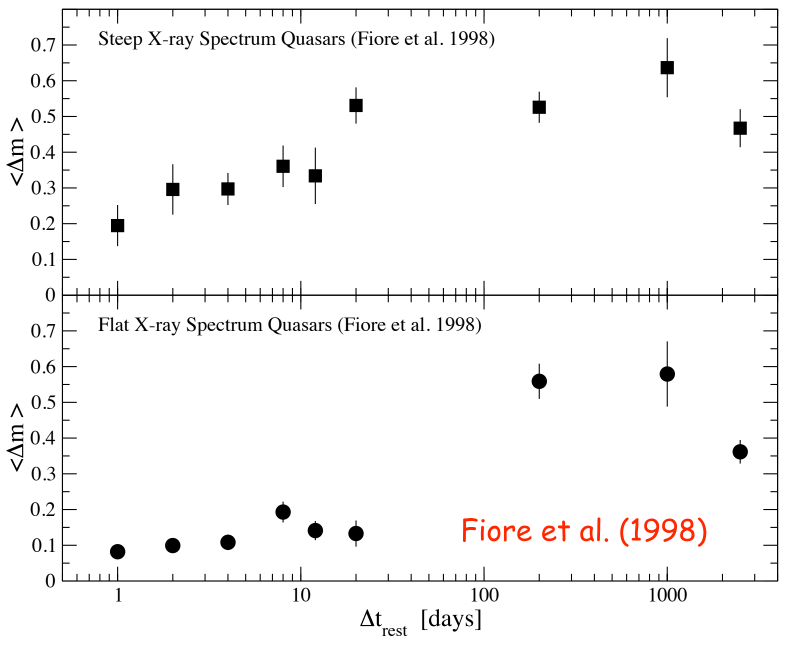
3. Swift Monitoring of Radio-Quiet Quasars at z≃2

Variability Structure Function

$$SF(\tau) \equiv \sqrt{\left\langle [m(t+\tau) - m(t)]^2 \right\rangle}$$





Denser sampling is required to assess variability timescales.

4. Ongoing and Future Work

- ✳Continue the *Chandra* monitoring and add one epoch per Cycle for the $z \simeq 4.2$ sources.
- ✳Continue the *Swift* monitoring to obtain better temporal sampling for the $z \simeq 2$ sources.
- ✳Compute variability structure functions and F_{var} values for the *Chandra* sources.
- ✳Search for correlated X-ray-optical variations (α_{ox}): 1) *Swift* XRT vs. UVOT, 2) *Chandra* vs. ground-based photometry and spectroscopy.
- ✳Search for X-ray spectral variations in the brightest *Swift* sources.
- ✳Obtain a ***qualitative*** assessment of the timescales and magnitudes of the X-ray variability allowing development of a strategy for more ambitious and long-term monitoring programs of distant quasars.