Energy dependence of power-spectral noise in X-ray binaries

H. Stiele & W. Yu
Shanghai Astronomical Observatory, Chinese Academy of Sciences

Black hole and neutron star X-ray binaries show variability on time-scales ranging from milliseconds to years. In the last two decades a detailed phenomenological picture of short-term variability in low-mass X-ray binaries has emerged mainly based on RXTE observations that cover energies above 3 keV. This picture comprises periodic or quasi-periodic variability, seen as spikes or humps in power density spectra, that are superposed on broad noise components. The overall shape of the noise components as well as the occurrence of quasi-periodic oscillations is known to vary with the state of the X-ray binary. We are accomplishing a comprehensive study of archival XMM-Newton observations in timing or burst mode of more than ten black hole and more than thirty neutron star low-mass X-ray binaries to investigate the variability properties of these sources at softer energies where the thermal disk component starts to emerge.

Here we present some results of the energy dependence of the noise component in power density spectra: a discussion of the energy dependence of the power spectral state that we found in the “plateau” state of GRS 1915+105; the dependence of the break-frequency of the band-limited noise component as well as the quasi-periodic oscillations on the studied energy band in several X-ray binaries like GX 339–4 or Swift J1753.5–0127. Our results indicate that both the appearance of the power law noise and the disappearance of the band-limited noise plus low frequency QPOs are indicators of the emergence of the disk component in the X-ray energy spectrum.

### Energy dependence of the band-limited noise component in the low hard state

- Studied eight XMM-Newton EPIC/pn observations of five BH candidates
- Determine characteristic frequency $\nu_{\text{max}} = \sqrt{\nu^2 + \Delta^2}$ in a soft (1–2 keV) and hard (4–8 keV) band, where $\nu$ is the centroid frequency and $\Delta$ is the half width at half maximum (Belloni et al. 2002, ApJ, 572, 392), for each component present in the power density spectra
- For most observations we find that at least for the component with the highest characteristic frequency $\nu_{\text{max}}$, 1–2 keV $< \nu_{\text{max}}, 4–8$ keV
- The flux ratio $F_{\text{bb}}/F_{\text{pl}}$ in the 1–2 keV band is below 10% for observations where the characteristic frequencies in both bands are consistent within errors, and > 10% for all other observations

### Schematic picture of the possible accretion geometry

Power spectral state depends on which spectral component we are looking at!

**Low hard state:**
- X-ray emission down to lowest observable energies is dominated by Comptonized emission
- Power spectra show band-limited noise independent form energy band

**Hard intermediate state:**
- Direct emission from the accretion disc has a significant contribution (~30%) to the emission in the soft energy band
- Power spectrum in the soft band shows power law noise
- While power spectrum in hard band still shows band-limited noise + QPOs (complete evolution picture was shown for MAXI J1659 in Yu & Zhang 2013, ApJ, 770, 135)