

QPO is evident in every one of the 30 RXTE observations conducted over a 6-month interval in 1996–1997 (Muno et al. 2001). This degree of stability suggests that LFQPOs are tied to the flow of matter in the accretion disk. However, the frequencies of these QPOs are much lower than the **Keplerian** frequencies for the inner disk. For example, a 3 Hz orbital frequency around a Schwarzschild BH of $10 M_{\odot}$ corresponds to a radius near $100 R_g$, while the expected range of radii for X-ray emission in the accretion disk is $\lesssim 10 R_g$.

LFQPOs are seen in the SPL state, the hard:SPL intermediate state, and in some hard states, particularly when the X-ray luminosity is high (McClintock & Remillard 2006; Rossi et al. 2004). The rms amplitude generally peaks at photon energies $\gtrsim 10$ keV (e.g., Vignarca et al. 2003; Rodriguez et al. 2002), and detections have been made at energies above 60 keV (Tomsick & Kaaret 2001). This behavior clearly ties LFQPOs to the nonthermal component of the X-ray spectrum. However, in principle, the oscillation could still originate in the accretion disk if the PL mechanism is inverse Compton scattering of disk photons and the coherence of the original oscillation is not destroyed by the scattering geometry. Alternatively, the mechanism that creates the energetic electrons required for Comptonization could be an oscillatory type of instability. In this case, the disk temperature or the thermal energy flux might control the QPO properties.

These concepts regarding QPO origins motivate correlation studies that compare QPO frequencies and amplitudes with various spectral parameters. In Figure 10 we show an example of such a correlation between LFQPO frequency and disk flux for two sources. The X-ray states are symbol coded, using the conventions adopted in §5. The QPO frequencies in the hard and intermediate states are highly correlated with disk flux, but this is not true for the QPOs at higher frequency in the SPL state. Presently, there is no explanation for this result. Possibly, the QPO mechanisms could differ between the hard and SPL states, or there could be a common mechanism that exhibits some type of dynamical **saturation** as the source moves into the SPL state.

Another avenue for QPO investigations is the study of phase lags and coherence functions that compare two different energy bands, e.g., 2–6 versus 13–30 keV. Such analyses have been conducted for the QPOs in XTE J1550-564. Unexpectedly, the phase lag measurements showed groups distinguished by positive, negative, and $\sim$ zero lags defining, respectively, LFQPO types A, B, and C (Wijnands et al. 1999; Cui et al. 2000b; Remillard et al. 2002b; Casella et al. 2004). These details are surely complicated, but the ramifications are very significant. The A and B types are associated with the SPL state and the presence of high-frequency QPOs. On the other hand, C-type LFQPOs mostly occur in the intermediate and hard states, and they are responsible for the frequency versus disk flux correlation shown in Figure 10. There are also similarities between these BH LFQPO subtypes and the three QPOs of **Z-type neutron-star systems** (Casella, Belloni, & Stella 2005).

Given the relatively high amplitudes of all LFQPOs above 6 keV, it is clear that the C-type oscillations are well connected to both the thermal and PL components in the X-ray spectrum. In this sense, QPOs can provide insights regarding the origin of the PL spectrum. Furthermore, we now have a comprehensive archive of accurate LFQPO measurements for a wide range of disk conditions. These data are available for testing any detailed models that are proposed to explain the nonthermal states in BHs.