A Hot Spot Model for Black Hole QPOs

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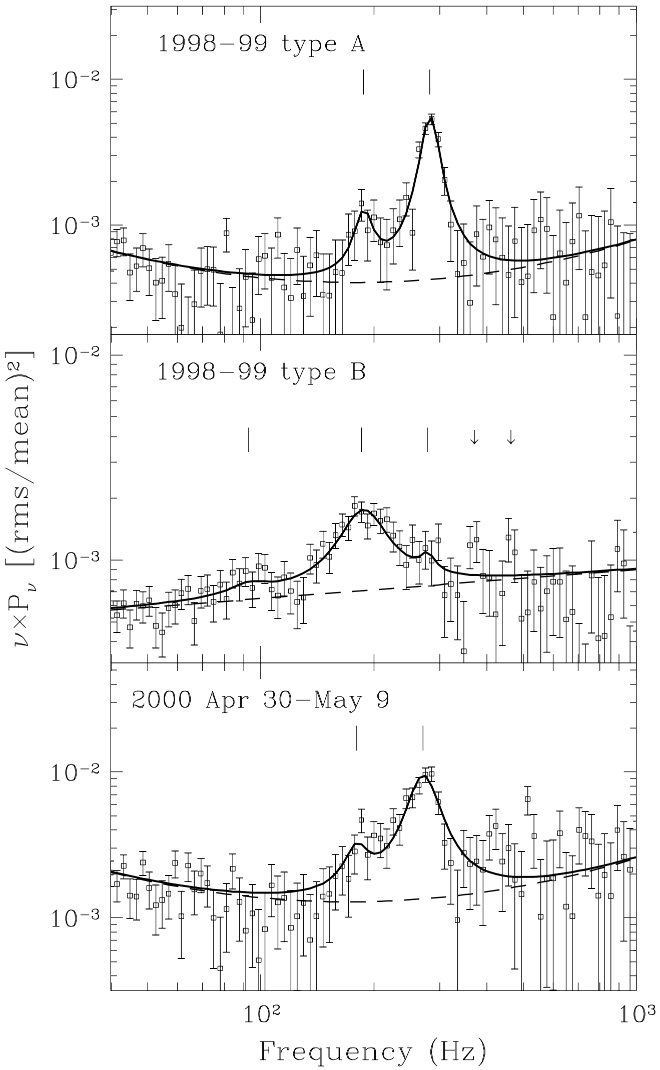
Outline

- Motivation
- Geodesic orbits of hot spots (“blobs”)
- Light curves, power spectra
- “Multi-blob model”
- Peak broadening in power spectra
- Conclusions

Recent RXTE observations show QPOs at commensurate frequencies with integer ratios

Remillard et al. (2002)

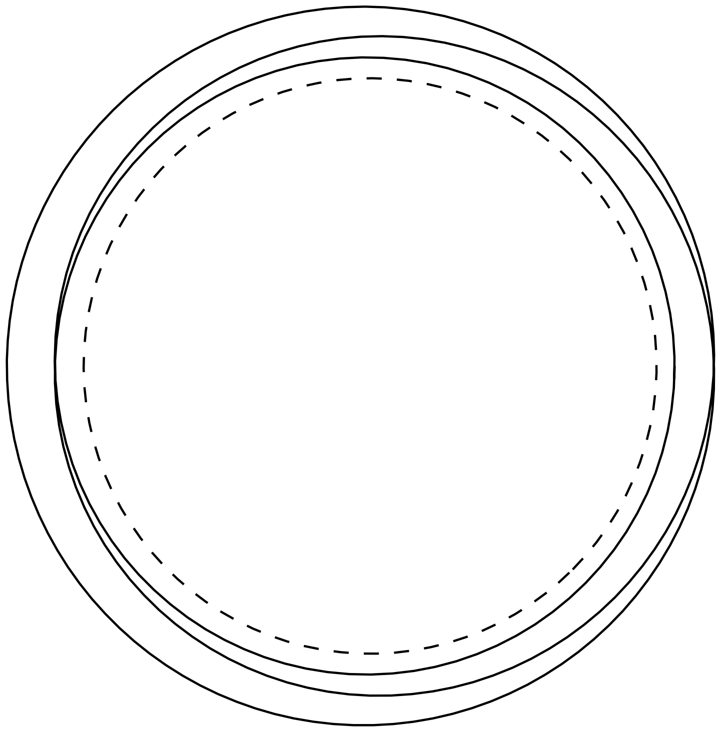


The geodesic hot spot model provides a robust framework for interpreting QPO data

Model Parameters	QPO Observables
BH Mass BH Spin	Peak Locations (frequency)
Disk Inclination Geodesic r_0, e Hot Spot Size Overbrightness	Peak Amplitudes
Hot Spot Lifetime	Peak Widths/Shape

Light curves are calculated by integrating emission from hot spots orbiting along geodesic orbits

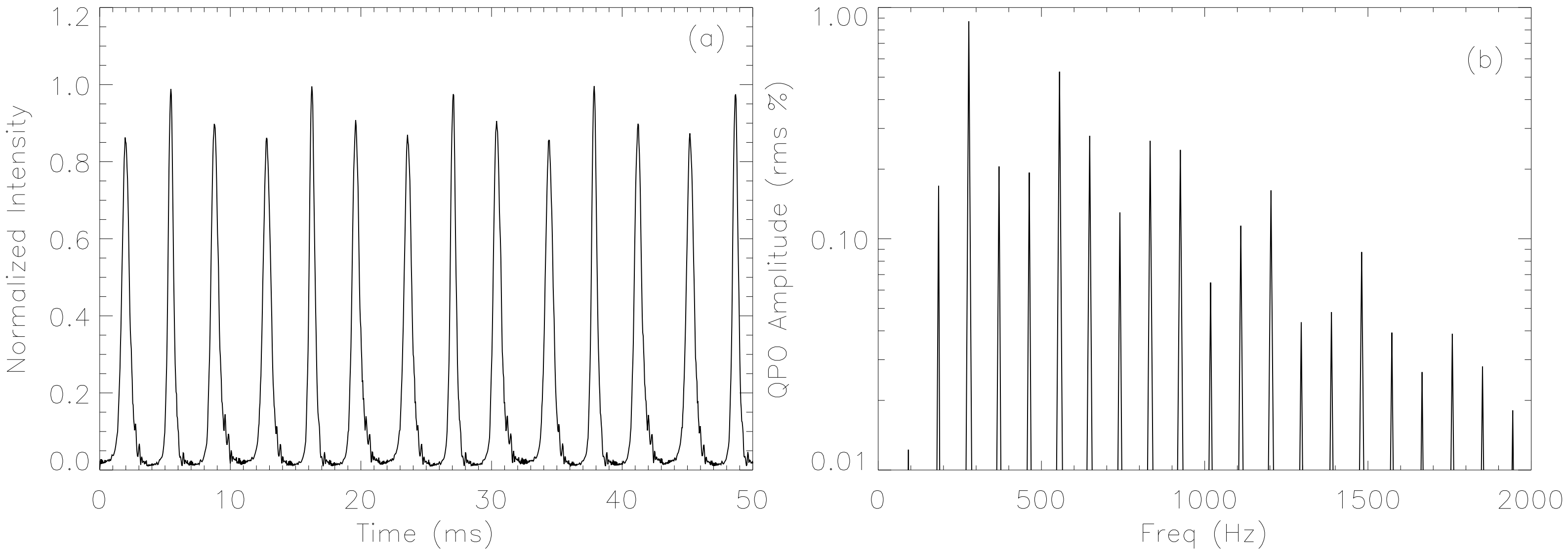
$$e \equiv \frac{r_{max} - r_{min}}{r_{max} + r_{min}} = 0.09 \quad R_{ISCO} = 4.23M \quad \nu_\phi = 3\nu_r$$



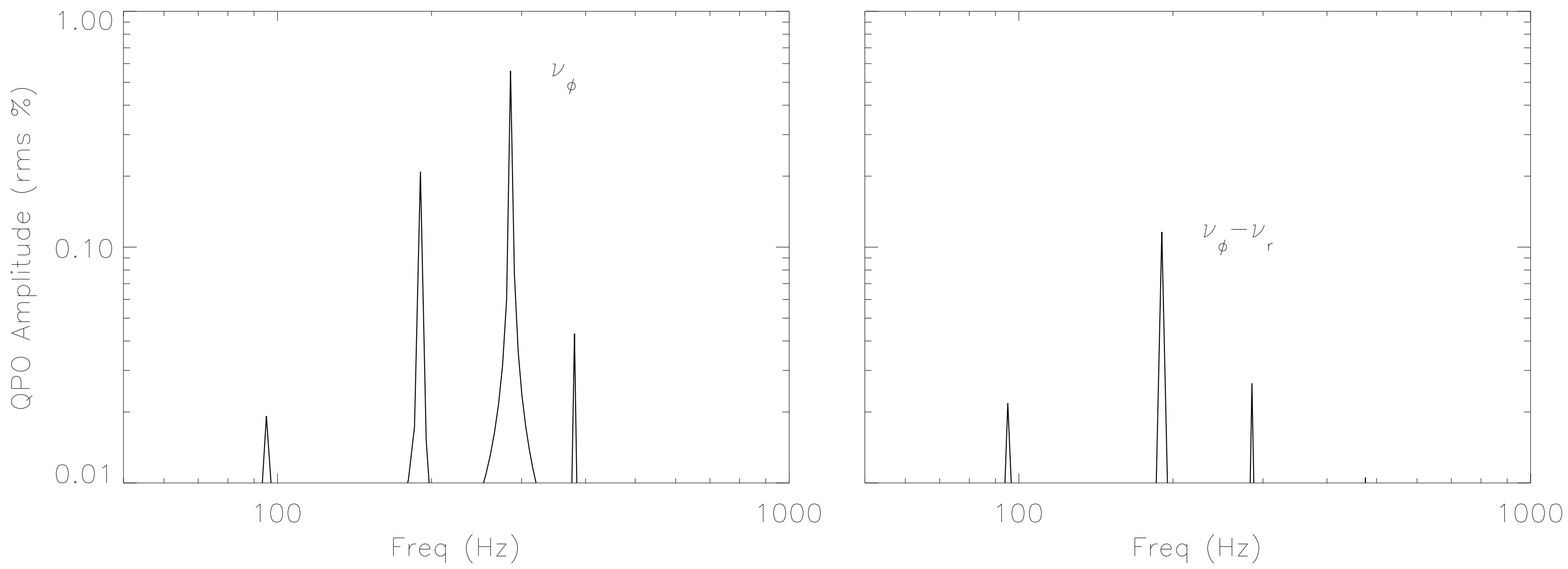
The power spectrum of the X-ray light curve shows the characteristic coordinate frequencies of the hot spot orbit

$$a/M = 0.5 \qquad M = 10.3 M_\odot$$

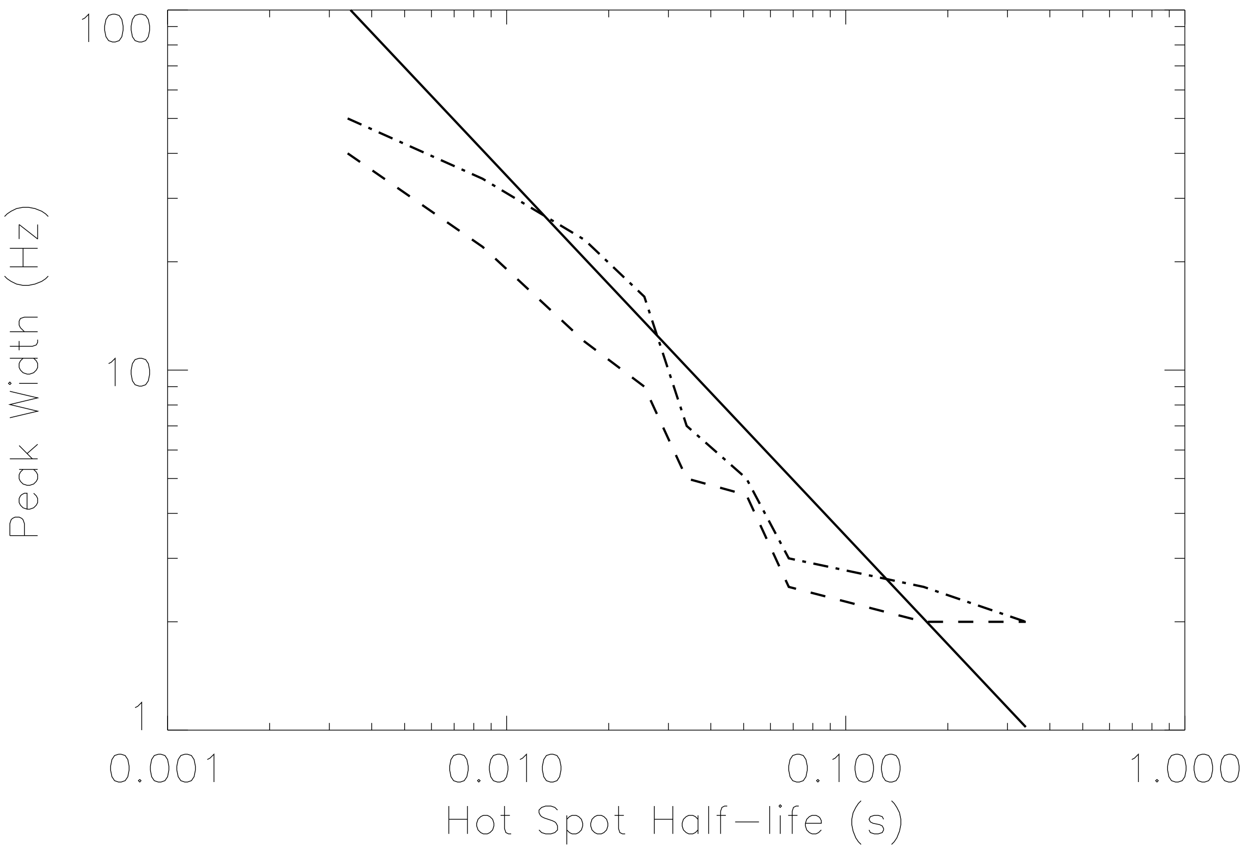
$$\nu_\phi = 276\mathrm{Hz} \qquad \nu_r = 92\mathrm{Hz}$$



As the hot spot is sheared into an arc, QPO power in the higher harmonics is significantly reduced

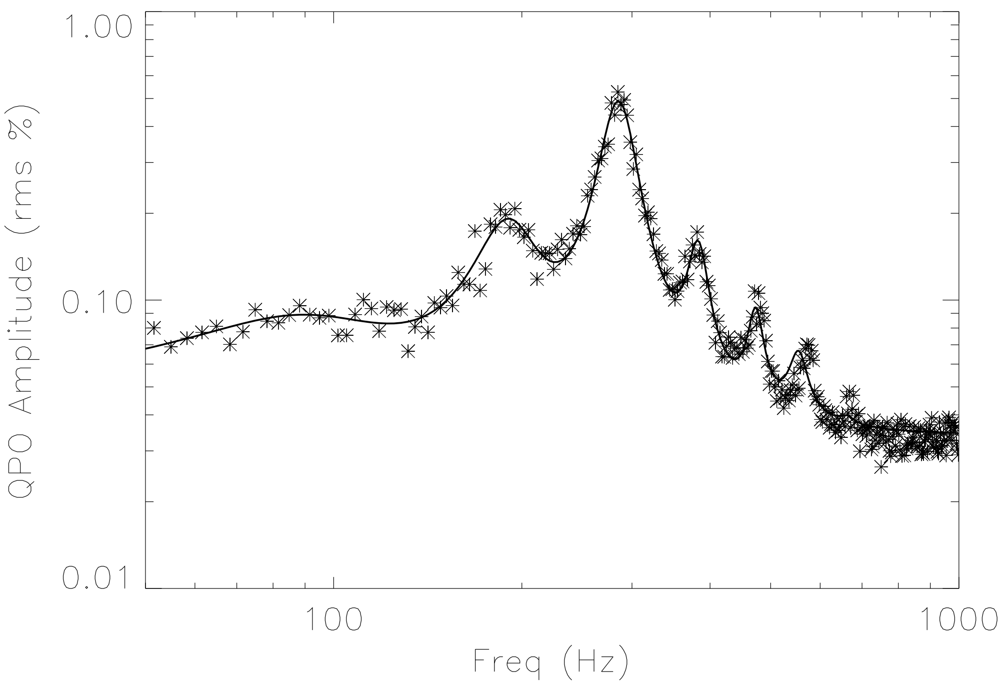


Multiple hot spots with random phases broaden the power spectrum peaks into QPO Lorentzians



The QPO power spectrum may give a complete description of the BH and accretion disk

Mass	$10M_\odot$
Spin a/M	0.5
Disk Inclination	70°
R_{ISCO}	$4.23M$
Geodesic r_0	$4.89M$
Eccentricity e	0.11
Overbrightness	100%
Arclength	180°
Hot Spot Lifetime	15 ms (4 orbits)
Peak FWHM	45 Hz



Conclusions and future work

- By calculating light curves from hot spots orbiting on geodesics, we gain insight into the features of high frequency QPO power spectrum
- The breadth of the QPO peak can be used as a direct measurement of the lifetime of a typical disk perturbation
- The hot spot model is a powerful building block for more detailed models of dynamic accretion disks