Imaging Black Hole QPO Models

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Outline

• Motivation
• Ray Tracing in Kerr Metric
• Example Models
  o Geodesic Hot Spot
  o Precessing Ring
  o Oscillating Torus
• The Future...
RXTE observations of black holes in the steep power law state show a variety of QPOs

McClintock & Remillard (2005)

Many of the high frequency QPOs appear at commensurate frequencies with integer ratios

XTE J1550–564
GRO J1655–40
Miller et al. (2001)
Remillard et al. (2002)
GRS 1915+105
Remillard et al. (2003)
H1743–322
Homan et al. (2005)
Ray Tracing

We ray-trace photons backwards in time from a distant observer through a fixed grid.
The relativistic radiative transfer equation is solved along the photon path length.

\[ \frac{dI_\nu}{ds} = \left( \frac{\nu}{\nu'} \right)^2 j_\nu' - \left( \frac{\nu'}{\nu} \right) \alpha_\nu I_\nu \]

Rybicki & Lightman (1979)

Geodesic Hot Spot Model
Light curves are calculated by integrating emission from hot spots orbiting along geodesic orbits.

\[ M = 10M_\odot \quad a/M = 0.5 \quad r/M = 4.887 \]
\[ \nu_\phi = 285 \text{ Hz} \quad \nu_r = 95 \text{ Hz} \]

The X-ray light curves are characterized by the relative power in each of the beats and harmonic overtones.

Schnittman & Bertschinger (2004)
The geodesic ring model has been used to explain recent observations of GRS 1915+105

Miller & Homan (2005)
Oscillating Torus Model

Zanotti, Rezzolla, & Font (2003)

The Future

Light curves and spectral lines from global MHD simulations

De Villiers, de Villiers, Krolik, & Hawley (2003)
De Villiers, Hawley, & Krolik (2004)
Hirose, Krolik, de Villiers, & Hawley (2005)
De Villiers, Hawley, Krolik, & Hirose (2005)
Additional Features

- Electron Scattering
- More Detailed Emission Models
- Higher Resolution, Parallel Implementation
- More QPO Models!!