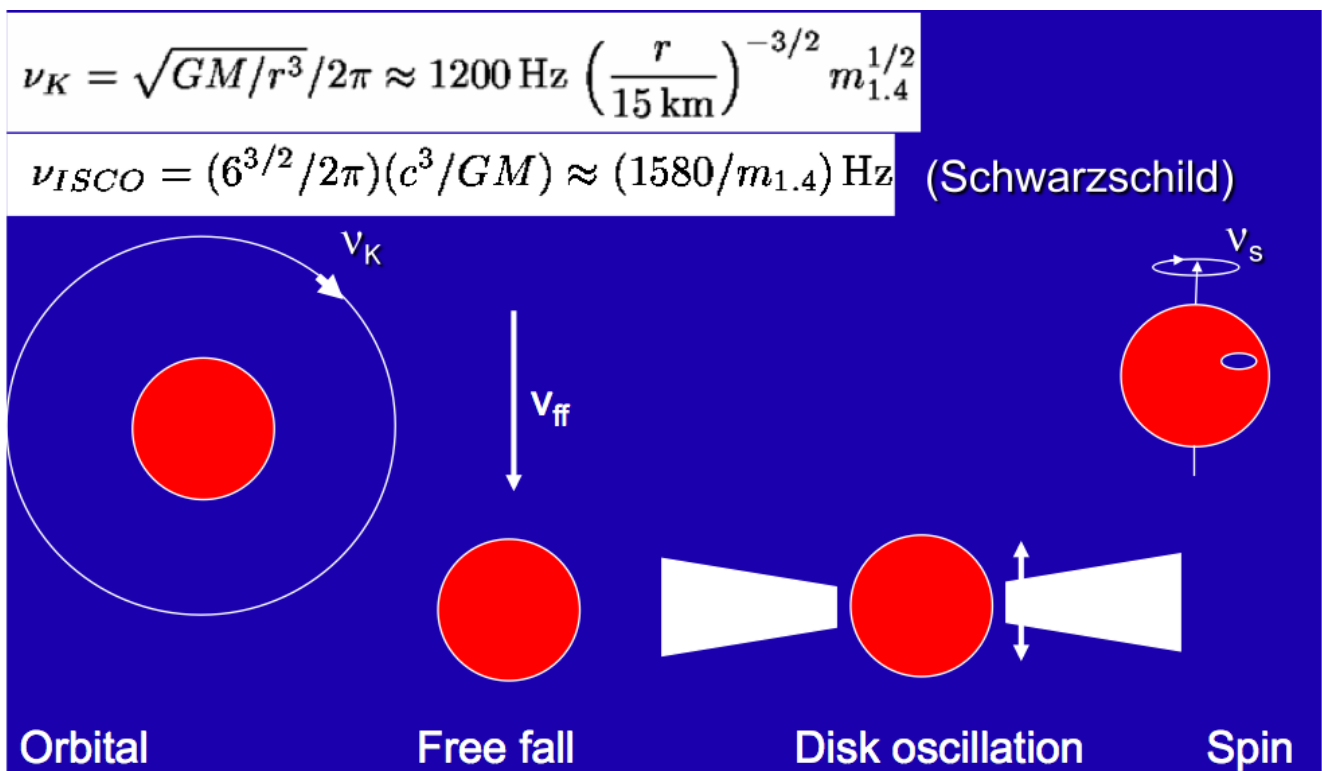


Chen, Tao

The principal motivation for studying Accreting Black Hole is that these objects provide a unique window on the physics of strong gravity and dense matter. One of the most basic expressions of the compactness of these compact objects is the short dynamical time scale characterizing the motion of matter under the influence of gravity near them.

Millisecond variability will naturally occur in the process of accretion of matter onto a stellar-mass compact object — an insight that dates back at least to Shvartsman (1971). For example, hot clumps orbiting in an accretion disk around black holes will cause quasi-periodic variability on timescales of about a millisecond (Sunyaev 1973). Accreting, low-magnetic-field neutron stars will reach millisecond spin periods, which can be detected when asymmetric emission patterns form on the star's surface during X-ray bursts. These early expectations were finally verified in a series of discoveries with NASA's Rossi X-Ray Timing Explorer (RXTE) within 2.5 years after its launch on 30 December 1995.



It is clear that as the characteristic velocities near the compact object are of order $(GM/R)^{1/2} \sim 0.5c$, the dynamical timescale — the timescale for the motion of matter through the emitting region is short:

τ
dyn
 \square
(
r
3
/
GM
)
1
/
2
~
0.1ms for
r
=
10km and
~
2ms for
r
=
100km, near a 1.4 M
 \square
neutron star, and
~
1ms at 100km from a 10M
 \square
black hole. Therefore, the significance of millisecond X-ray variability from X-ray binaries is clear: milliseconds is the natural timescale for the accretion process in the X-ray emitting regions, and hence strong X-ray variability on such timescales is almost certainly caused by the motion of matter in these regions.

Three different millisecond phenomena have now been observed in X-ray binaries. Historically, the first to be discovered were the twin kilohertz quasi-periodic oscillations (kHz QPOs), widely interpreted now as resulting from orbital motion in the inner accretion flow. Then came the burst oscillations, probably a result of the spin of a layer in the neutron star's atmosphere in near-corotation with the neutron star itself. Finally, RXTE detected the first true spin frequency of an accreting low-magnetic field neutron star, the long-anticipated accreting millisecond pulsar.

FOURIER TRANSFORM

A Fourier transform gives **decomposition of signal into sine waves**



At ω , best-fit sinusoid is: $a \cos(\omega t - \phi) = A \cos \omega t + B \sin \omega t$
 ($a = \sqrt{A^2 + B^2}$ and $\tan \phi = -B/A$)

Do this at many frequencies ω_j , then

$$x(t) = \frac{1}{N} \sum_j a_j \cos(\omega_j t - \phi_j) = \frac{1}{N} \sum_j (A_j \cos \omega_j t + B_j \sin \omega_j t)$$

Fourier: $A_j = \sum_k x_k \cos \omega_j t_k$; $B_j = \sum_k x_k \sin \omega_j t_k$; $x_k \equiv x(t_k)$

~~Multiple the signal by the cosine and sine functions and integrate over the time interval. This gives the Fourier coefficients.~~