

Astronomy 353 (Spring 2008)



ASTROPHYSICS: From Black Holes to the First Stars (Lecture 20: Black Holes)

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BH Formation by Stellar Collapse:

à The view from afar!



• Black Hole = "Frozen Star"!

BH Formation by Stellar Collapse:

à Taking the plunge!



• Reach central singularity in split second!

The more general case: Rotating Black Holes



<u>Kerr metric</u>

$$dz^{2} = \left(I - \frac{2M}{r}\right)dt^{2} + \frac{4Ma}{r}dtd\phi - \frac{dr^{2}}{\frac{-2M}{r} + \frac{-2}{r^{2}}} - \left(I + \frac{a^{2}}{r^{2}} + \frac{2Ma^{2}}{r^{3}}\right)r^{2}d\phi^{2}$$

(here: G=c=1)

a=J/M -> angular momentum a≤ M (extreme Kerr BH)

• Ergosphere -> inside, no observer can remain at rest!

Rotating (Kerr) Black Holes: Frame Dragging



• purely a GR effect!

How can black holes ever be observed?

• After all, they are invisible by definition!



Black Hole Binaries are Visible in X-rays!



Cygnus X-1





X-ray



Cygnus X-1



analyze binary motion à

 $M_{BH} > 7 M_{O}$

Cygnus X-1: The Thorne-Hawking Wager



Whereas Stephen Hawking has such a large investment in General Relativity and Black Holes and desires an insurance. policy, and whereas Kyp Thomas like to Quie dangerously without an insurance policy , Therefore be it resolved that stephen Hawking Bets I year's subscription to Penthouse as again Kip Thorma's wages of a 4-year subscription to "Frivate Eye", that Cygnus XI does not contain a black hole of mass above the Chandrasekkar Rimit Conde

The Heart of Darkness: Center of the Milky Way



• In optical waveband: heavily obscured by dust!

The Galactic Center in Radio Wavelengths





• Radio Map (VLA) ~1,000 lightyears

The Galactic Center in the Infrared



• Near IR cameras with adaptive optics (AO)

The Galactic Center in the Infrared



Map out complete Galactic revolutions of stars!

The Galactic Center: A Supermassive Black Hole



• Estimated mass: ~ 3.6 million solar masses!

Summary:

More general case: rotating BH = Kerr BH
New phenomenon: Ergosphere!

- There is a maximum amount of BH spin!

• Observing real BHs:

- stellar BHs (few 10s of solar masses): X-ray binaries

supermassive BHs (million-billion solar masses):
Active Galactic Nuclei (AGN), Quasars, Center of MW