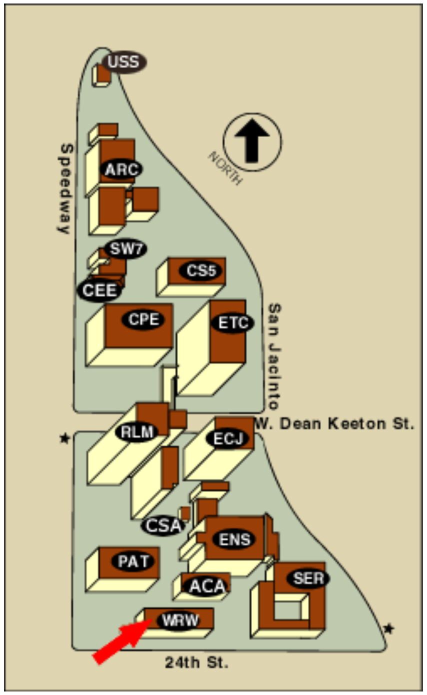
Monday, November 11, 2013

Exam 4 Friday. Review sheet posted.

Review session Thursday, 5 – 6 PM, WRW 102

Reading: Chapter 9: all except 9.6.3, 9.6.4

Chapter 10, Sections 10.1-10.6, 10.9




Astronomy in the news?

GOCE crash?

# Goal:

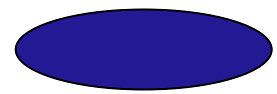
To understand the full space-time associated with rotating black holes.

# Rotating Kerr Black Hole

Mass and spin, but no electrical charge

Assume all mass is in the singularity, no mass anywhere else (assumption necessary to solve equations)

Find ***singularity is a ring*** (not a point)

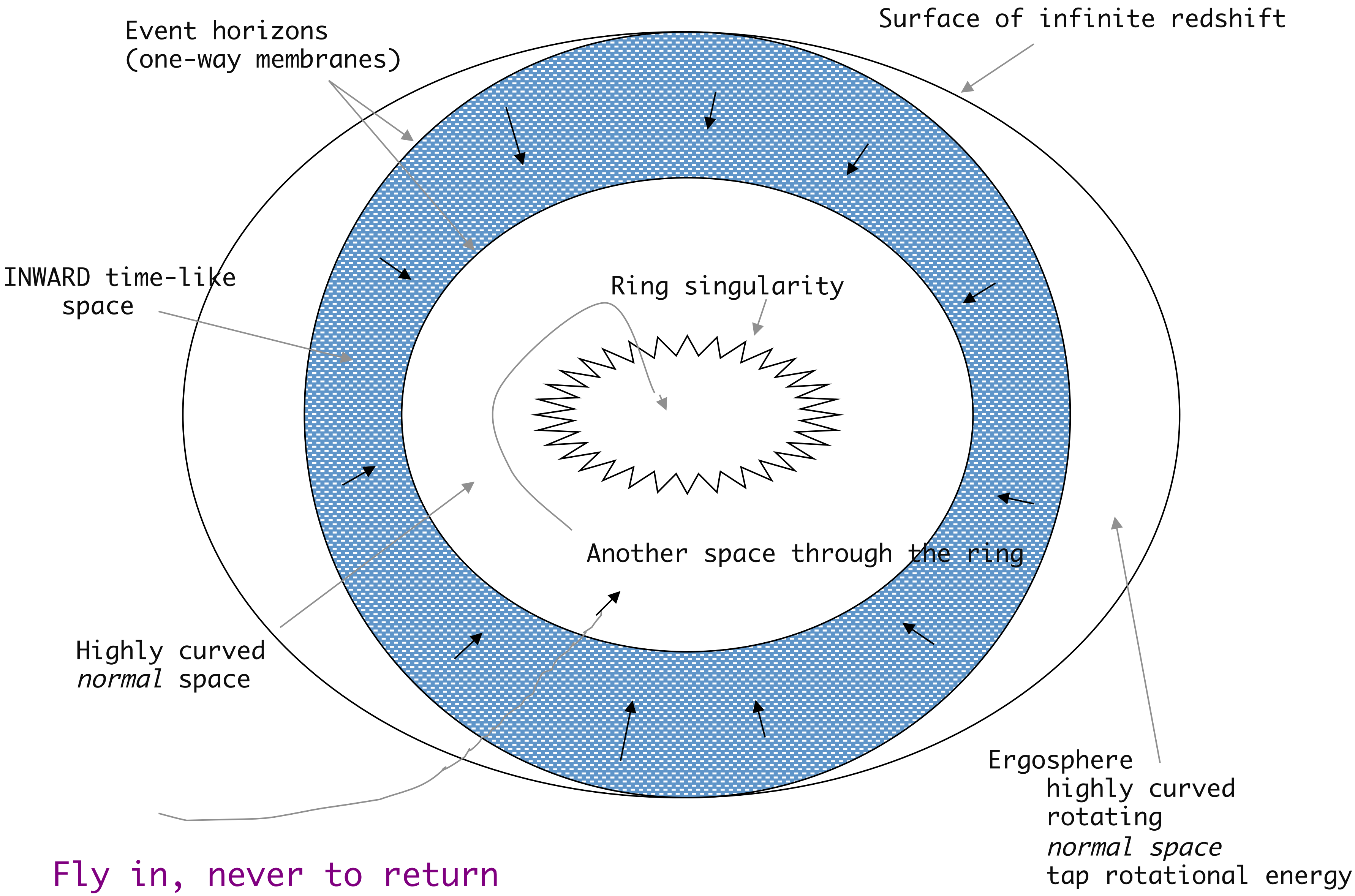


0 thickness, ∞ density, still uncertainty problem

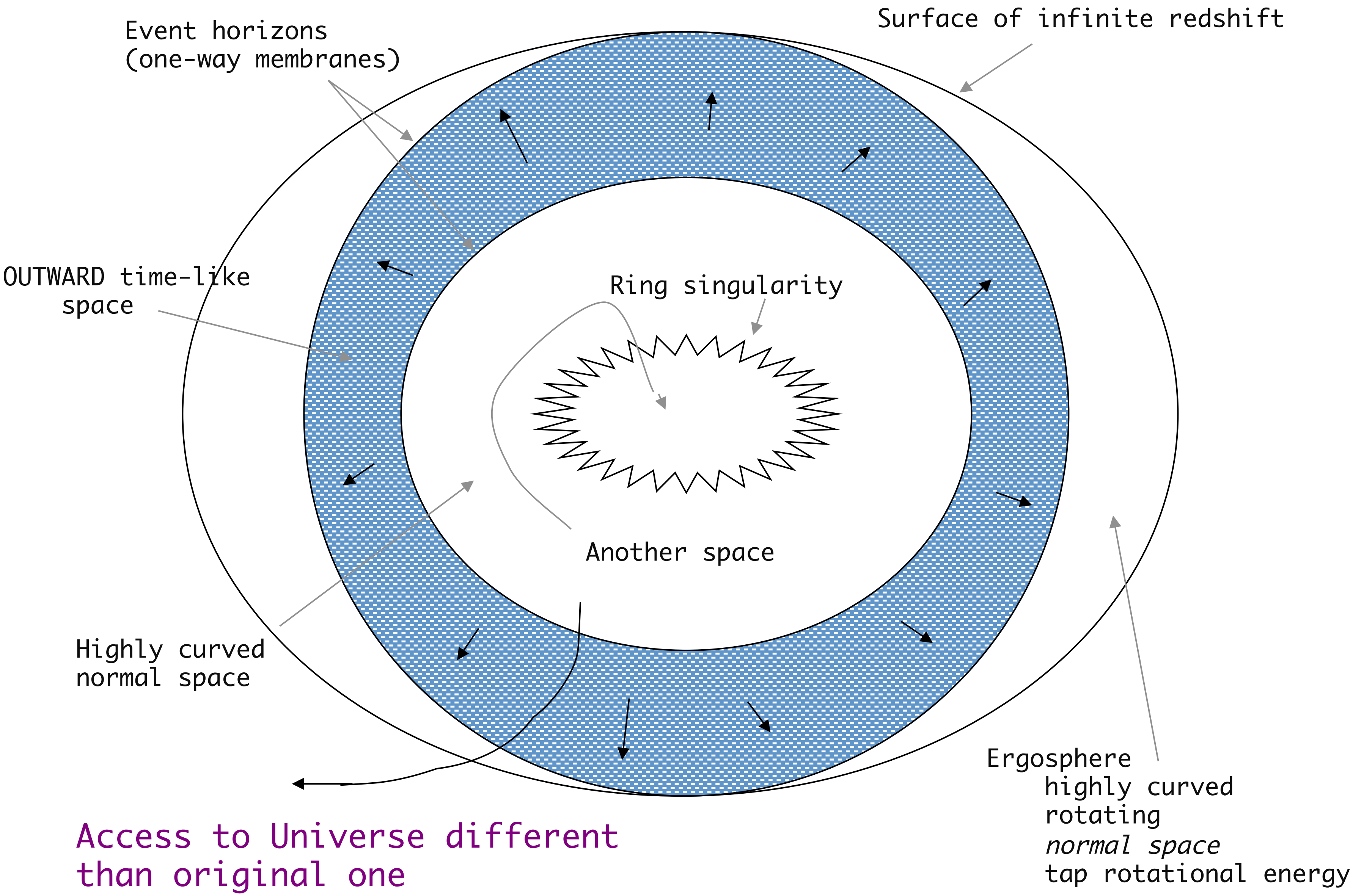
Infinite Universes!

(implicitly spread through hyperspace)

# Cross-sectional view of rotating Kerr black hole



# In future




Access to Universe different than original one

Are Different Universes Real?

In Real Universe:

Light falls into the black hole

Photons are Doppler blue shifted, accelerated to higher energy, compacted into a thin shell: ***Bluesheet***
=>the energy/mass of the blue sheet warps the space
changes the mathematical, hence the physical solution

So, probably not in this case, but stay tuned…

One Minute Exam

In the mathematical solution for a rotating black hole:

→ The surface of infinite redshift is identical to the event horizon.

← You can escape the black hole back to the universe from which you entered.

↑ There are exactly two universes.

↓ The space entered through the ring singularity is different than the space surrounding the singularity.

# Chapter 10 - Finding Black Holes for Real

Reading: Chapter 10, Sections 10.1-10.6, 10.9

We know that massive stars evolve to form iron cores that absorb energy and collapse. A compact object must be left behind.

Some explode and leave rotating, magnetic pulsars

Some explode and leave highly magnetic magnetars

Some explode but leave black holes or completely collapse to leave black holes

**We don't know which massive stars do which!** Tendency to think that more massive stars are more prone to making black holes, but the rotation of the star, the presence of a binary companion, and other factors may influence the outcome.

We do know that black holes exist, so some stars make them.

# Goal:

To understand how we search for real black holes and why binary systems with mass transfer and accretion disks are so important.

Black hole candidates in the directions of Sagittarius, Ursa Majoris, Perseus, Scorpius, Ophiuchus, Vulpecula, Monoceros, Lupus, Cygnus (2) (Find and observe the constellations for sky watch)

Cygnus X-1

AO620-00 = Nova Mon 1975 = V616 Monocerotis - one of the first and best studied with a small mass companion, black hole about 5 solar masses.

V404 Cygni - somewhat evolved companion, but one of the best cases for a black hole with "dark" mass of about 12 solar masses.

Two candidates in the Large Magellanic Cloud:
LMC X-1, LMC X-3

Total number of such systems known, about 45.

# Black Holes for Real

There may be 1 - 100 million black holes in the Galaxy made by collapsing stars over the history of the Galaxy.

That means that the nearest black hole may be only a few tens of light years away. How do we find them?

Black holes made from stars are really black! (Negligible Hawking radiation).

Those alone in space are not impossible to find, but very tough.

Event horizon of 10 solar mass black hole has a radius of 30 km ~ 20 miles, somewhat bigger than size of Austin, easily fit between Georgetown and San Marcos

Very black

None yet identified.

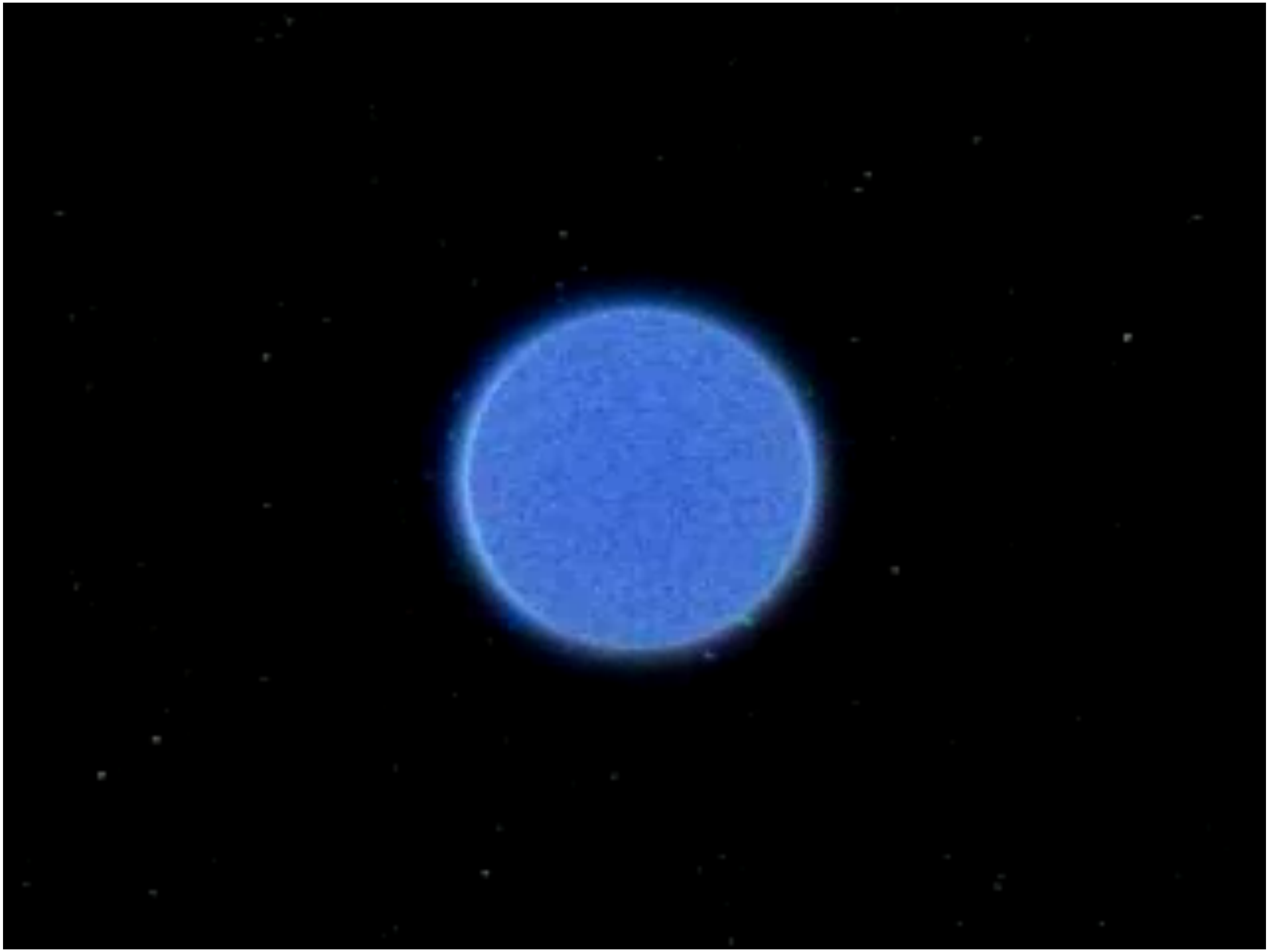
# Black Holes for Real

Look for binary systems, where mass accretion occurs.

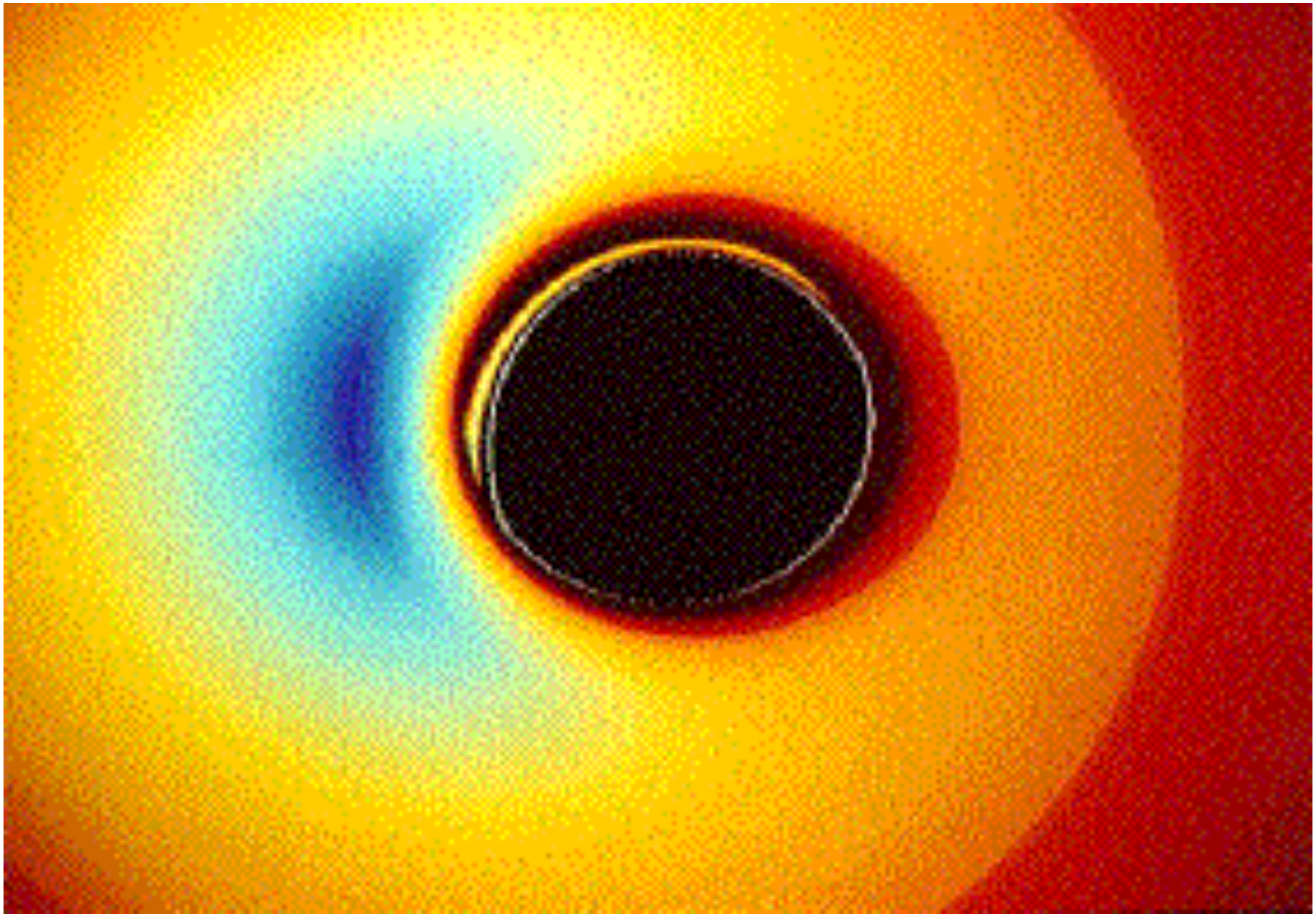
Will not see the black hole, do not yet have the technology to “see” a black spot.

Can detect the ***halo of X-rays*** from orbiting matter, the accretion disk, near the event horizon that will reveal the presence and nature of the black hole.

***Look in accreting binary systems!***



Goal is to get close-up study of strongly warped space



Perez and Wagoner, Stanford: computer simulation of radiation from inner black hole accretion disk

Black holes are so weird and so important that the standards of evidence have to be high!

***Current evidence is still primarily circumstantial, but very strong:***

***Stellar mass black holes*** (several to ~ 10 solar masses), in binary systems in our Galaxy or nearby galaxies

***Intermediate mass black holes*** (~ 1000 - 10,000 solar masses)??, in binary systems or stellar clusters in our Galaxy or nearby galaxies

***Supermassive black holes*** (million to a billion solar masses) in the middle of our Galaxy and in the middle of many, many others.

***Circumstantial arguments for presence of black hole in a binary system:***

Only neutron stars and black holes have the high gravity necessary for intense X-rays.

Use Kepler's laws to measure the total mass of the system, astronomy to determine the mass of the mass-losing star, subtract to get mass of "unseen" companion emitting X-rays.

Maximum mass of neutron star is ~ 2 solar masses

***Intense X-ray source with mass exceeding 2 solar masses is, by a process of elimination, a candidate black hole.***

There are about 20 binary star black hole candidates in our Galaxy and in the Large Magellanic Cloud (near enough to detect the X-rays) that have masses measured to be greater than 3 solar masses, and hence too massive to be a neutron star.

There are another 25 binary star black hole candidates with simlar X-ray properties, but no measured mass.

## *Cygnus X-1*

First X-ray source discovered in the direction of the constellation Cygnus.

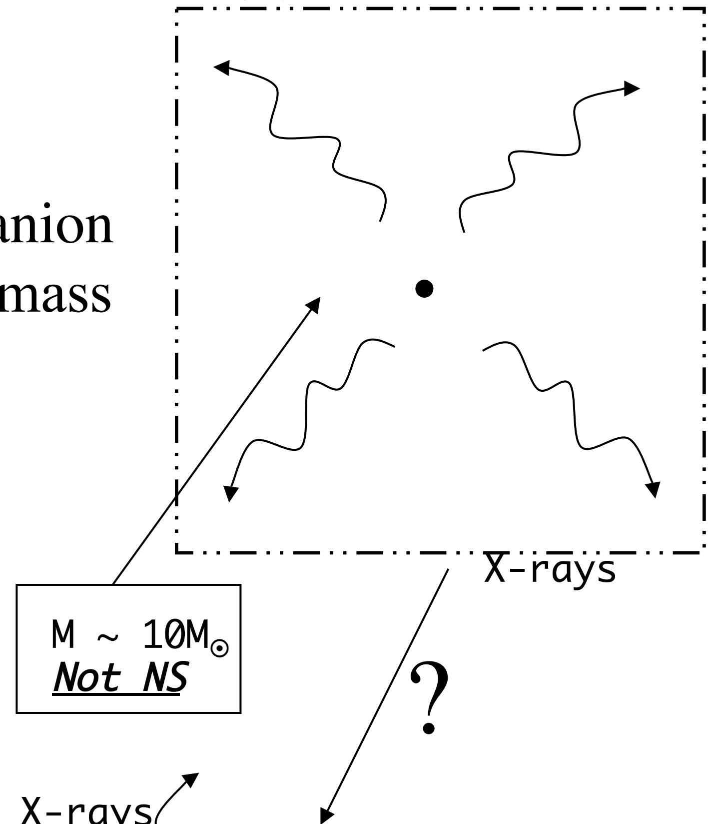
Discovered in 1970's by Uhuru Satellite (Swahili for Freedom).

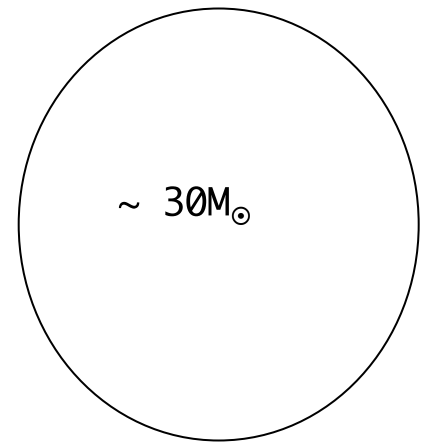
First and still most famous stellar-mass binary black hole candidate.

Can't see this system with the naked eye, but can find constellation Cygnus - look for it for sky watch!

# Cygnus X-1

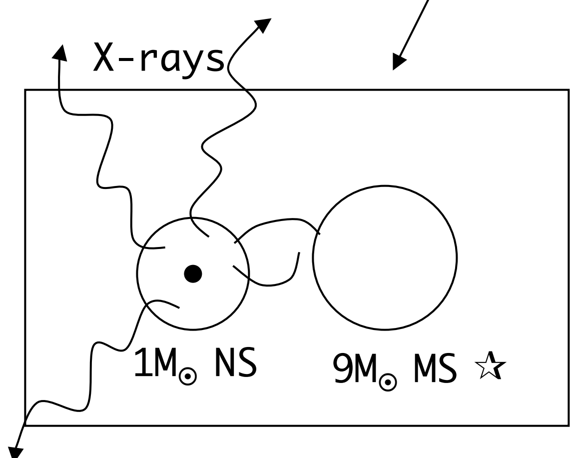
Optically dark
X-ray emitting companion
$\geq 10M_\odot$ >> NS max mass
$\Rightarrow$ BH




Blue supergiant, mass losing star

Could nature be tricking us? All we really know is that there is a $10M_\odot$ "thing" emitting X-rays




Total mass $10M_\odot$

One possibility:
$9M_\odot$ normal star
"lost in glare" of $30M_\odot$
like flashlight next to searchlight. Took hard work, but by now virtually ruled out.

Expect only two or three systems like Cygnus X-1 in our Galaxy.

Bright, massive, short-lived companion

Maybe only one, and we found it!

Surprisingly, most binary black hole candidates have small mass main sequence companions, typically ~ 1/2 solar mass.

Observe ~45 such systems and guess there may be ~1000 in the Galaxy