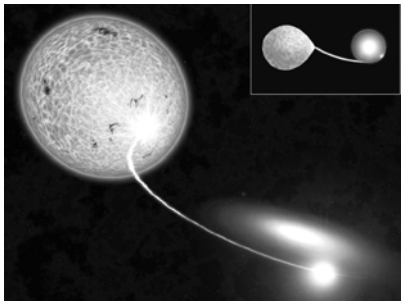
ASTR 1120: Stars & Galaxies



Prof. Juri Toomre TA: Ben Brown
Lecture 25 Wed 9 Mar 05
zeus.colorado.edu/astr1120-toomre

Today's Joys

- What happens in presence of *very strong gravity → light is red-shifted, passage of time slows down (all courtesy of Einstein)*
- *Black holes,* their general properties, and their "care and feeding"
- How to *detect BH*, even supermassive ones
- Mystery of fantastic explosions far away: *Gamma Ray Bursts (GRBs)*

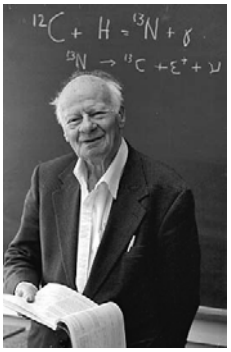
- *Second Mid-Term Exam* this Friday 11 Mar; *Review Session* by Ben tonight, here 7pm-9pm
- New *Homework Set 7* given out today; *HW 6* + answers returned today; *crib sheet winners*

Reading Needed

- Re-read *18.4 Black Holes*
- Overview read *S3 Spacetime and Gravity*, and more carefully *S3.4 New View of Gravity*
- For next Monday, overview read *Chap 19 Our Galaxy*

Hans Bethe

Nobel Prize 1967: nuclear reactions in stars



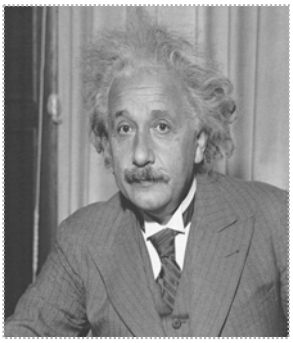
Clicker – Black Holes

- *What do we mean by the event horizon of a black hole?* *C.*

- *A.* The distance from black hole at which stable orbits are possible
- *B.* The very center of the black hole
- *C.* The sphere inward from which neither light nor anything else can escape
- *D.* The place where x-rays are emitted

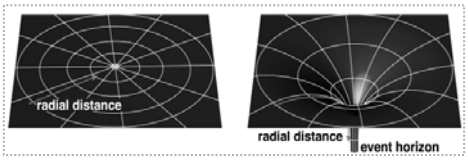
Black Holes – *sort of courtesy of Albert*

- *Einstein's (1911) General Theory of Relativity: gravity is really the warping of spacetime around an object with much mass*
- *Light travels in "straight lines" – and its bending comes from spacetime being curved by gravity*



Black Holes

- *Escape velocity* $v_{esc}^2 = 2 \times G \times \text{mass} / R$ *(sec 5.5)*
- *Mitchell & Laplace in 1700's (post Newton) speculated about objects so compact that v_{esc} exceeds speed of light*
- *Einstein showed space and time are not distinct (if speed of light c is constant) → SPACETIME singularity in spacetime → black hole*

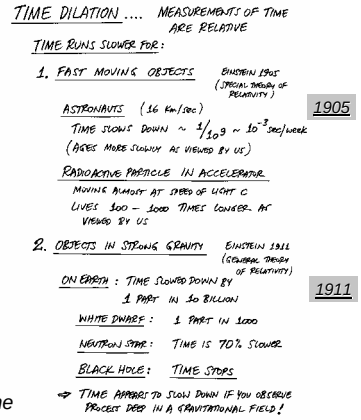


Time slowed down …. by moving fast or strong gravity

Einstein's Special / General Theories of RELATIVITY

Our sense of time is relative ..

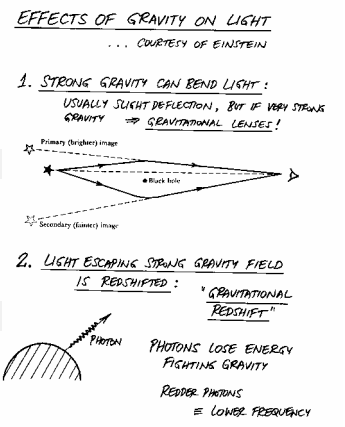
if nothing can move faster than speed of light, space and time are linked → spacetime



Effects of strong gravity on light

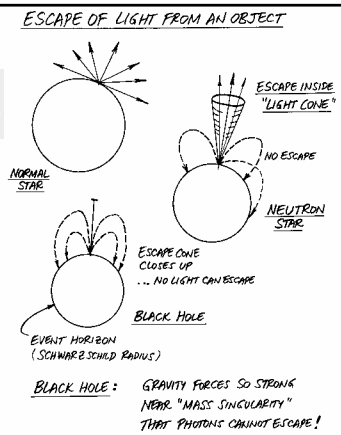
can act like lens

can redshift light



Light and "escape cones"

cone narrows as gravity forces get more intense

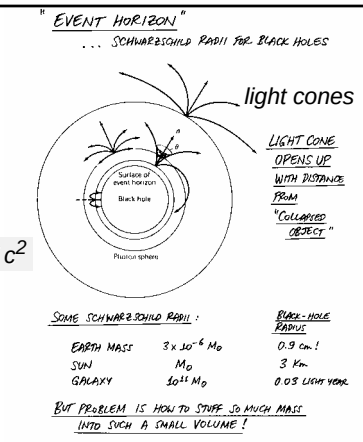


"Event horizon"

Schwarzschild radius: where escape velocity is speed of light

$R_S = 2G \text{ mass} / c^2$

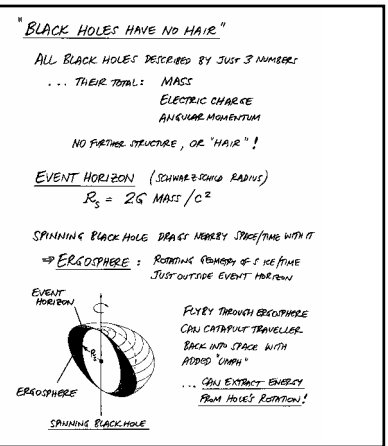
most simply:
(R_S in km,
$R_S = 3\,M$
M in M_{sun})



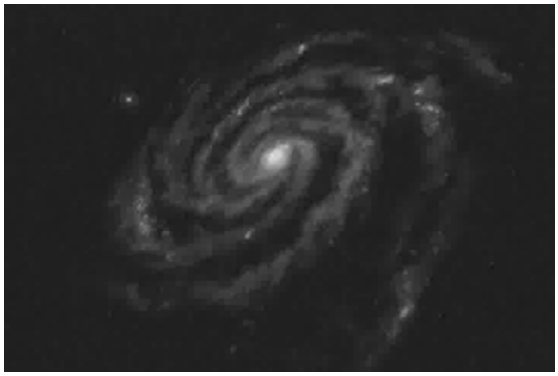
"Black holes have no hair"

Only three numbers describe BH!

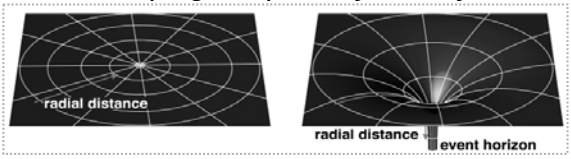
Ergosphere: spinning BH drags nearby spacetime along



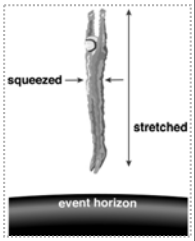
Fly-In to Black Hole



Warping of Space by Gravity

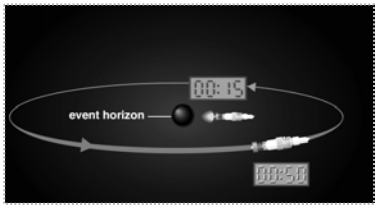


- *Gravity imposes <u>curvature on space</u>*
  - light's path through space will be "bent by gravity"
  - within the event horizon, it cannot climb out of the hole
- *As matter approaches <u>event horizon</u>…*
  - tidal forces are tremendous
  - object would be "spaghettified"



Warping of Time by Gravity

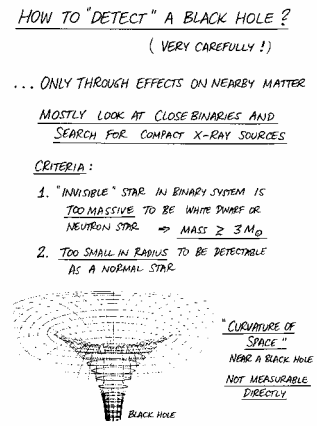
- *If we launched a probe to a black hole, time slows down as it approaches the <u>event horizon</u>*
  - it may take 50 min of time on <u>mother ship</u> for 15 min to elapse on <u>probe</u>
  - from *mother ship's view*, the probe takes forever to reach event horizon
  - light from probe is <u>redshifted more and more</u>, eventually disappears as light from it is redshifted beyond radio



From probe's view:

- it heads straight into the black hole
- light from the mother ship is <u>blueshifted</u>

How to "detect" a black hole



Crib sheet with <u>Highest Information Density</u>

Shannon Coffey

Crib sheet with <u>Most Aesthetic Appeal</u>

Allison Nuanes