

IF THE MASS OF THE COLLAPSED CORE IS $> 3M_{\odot}$ THE DEGENERACY PRESSURE OF NEUTRONS CANNOT SUPPORT IT, AND IT COLLAPSES INTO A SINGLE POINT — A SINGULARITY IN SPACETIME. THE RESULTING OBJECT IS CALLED BLACK HOLE.

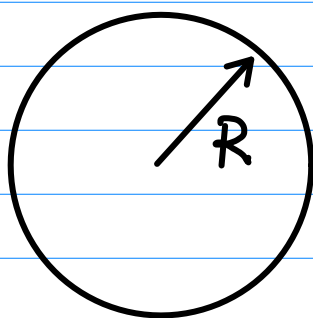
RECALL THE CONCEPT OF ESCAPE VELOCITY (v_{esc}) FROM A BODY OF MASS M AND RADIUS

R :

GRAVITATIONAL CONSTANT



$$v_{esc}^2 = \frac{G \cdot M}{R}$$



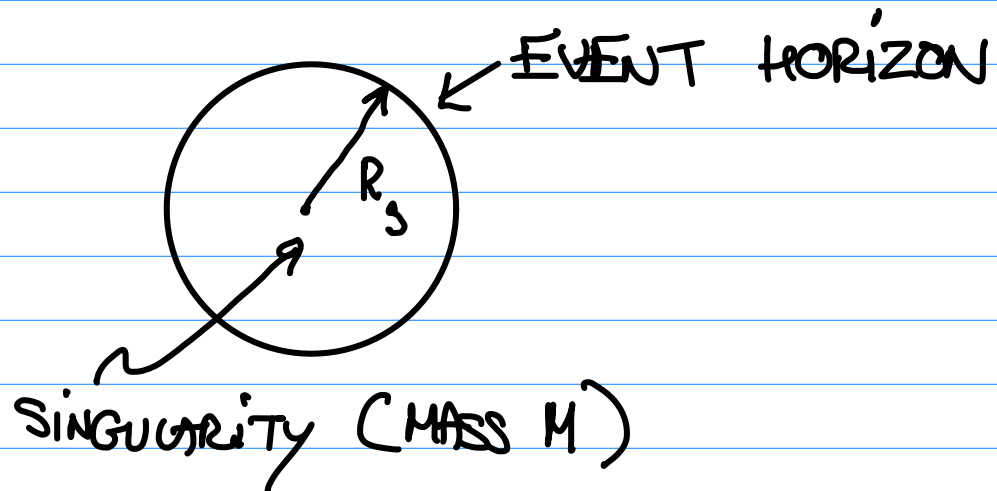
MASS M

(RESULT OBTAINED WITH NEWTONIAN GRAVITY)

FOR GIVEN MASS (M) AS THE RADIUS (R) IS REDUCED v_{esc} INCREASES, AND COULD

BECOME GREATER THAN THE SPEED OF LIGHT c ($= 300,000 \text{ km/s}$). THEN NOTHING, INCLUDING LIGHT, CAN ESCAPE THE GRAVITY OF THE BODY. HENCE THE NAME BLACK HOLE.

SCHWARZSCHILD RADIUS R_s : IT IS A DISTANCE FROM THE BODY WITHIN WHICH THE ESCAPE VELOCITY IS GREATER THAN THE SPEED OF LIGHT:

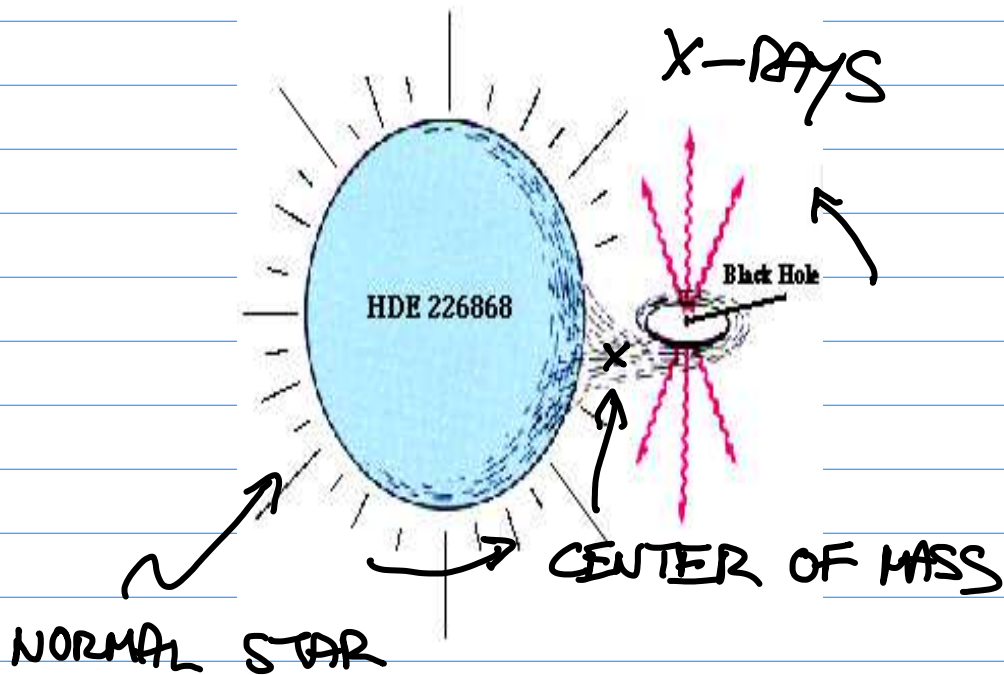


$$R_s = 3 M$$

↑ in km ↑ in M_\odot

THUS FOR $M = 10 M_\odot$ $R_s = 30 \text{ km}$.

WHAT IS THE OBSERVATIONAL EVIDENCE FOR BLACK HOLES?

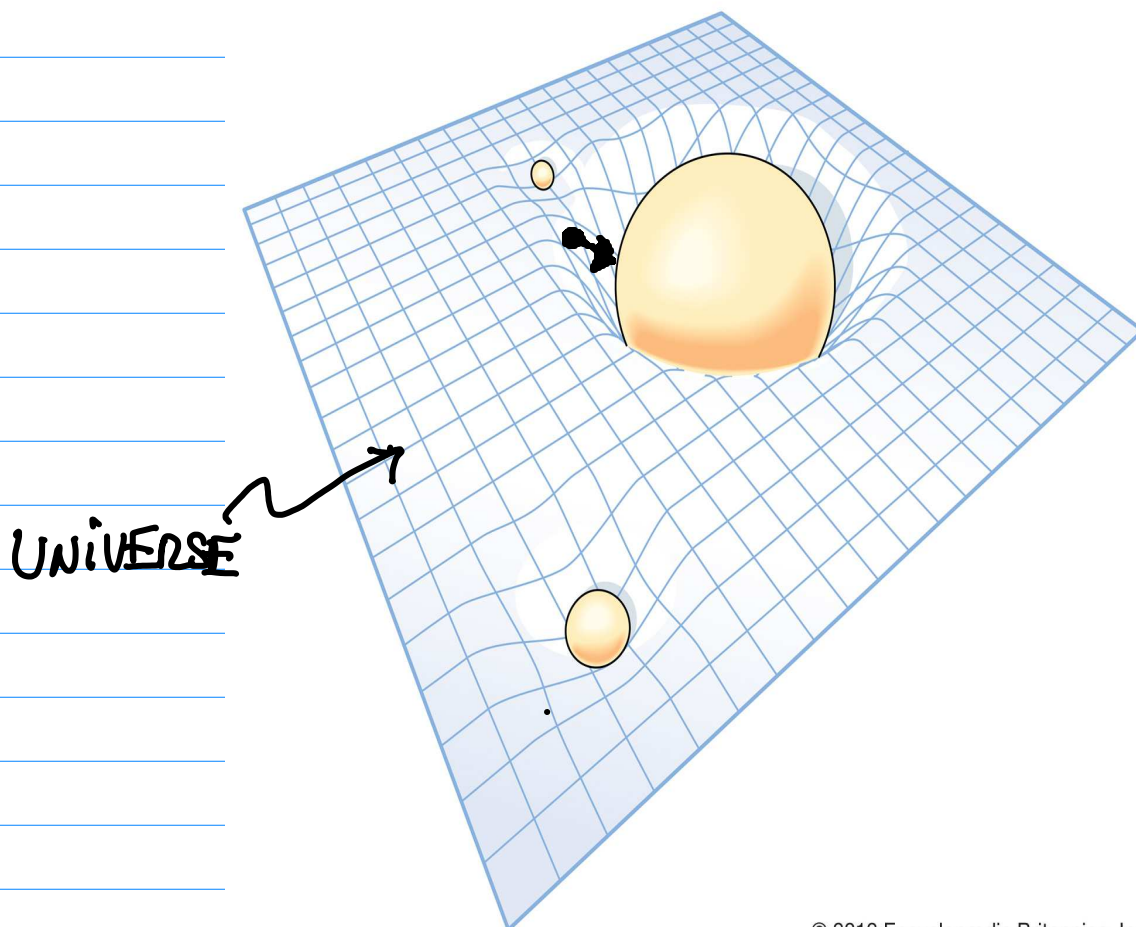


ONE LOOKS FOR A BINARY SYSTEM OF NORMAL STAR AND AN INVISIBLE COMPANION WITH A MASS OF AT LEAST $3M_{\odot}$ WHICH IS A STRONG SOURCE OF X-RAYS (PRODUCED BY ACCELERATION OF STELLAR WIND PARTICLES AS A RESULT OF A STRONG GRAVITATIONAL PULL BY THE BLACK HOLE).

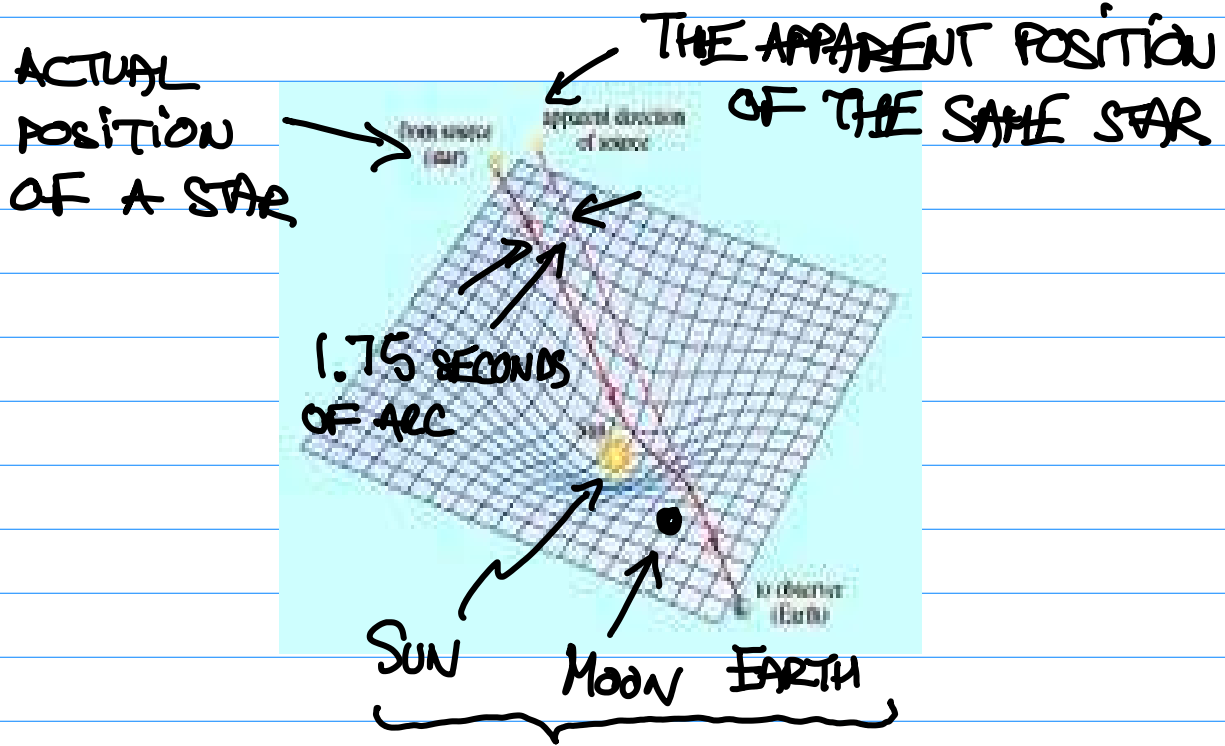
THE FIRST OBSERVATION WAS MADE BY TOM BOLTON IN 1971 USING 1.9m REFLECTOR TELESCOPE AT THE DAVID DUNLAP OBSERVATORY IN RICHMOND HILL.

THE NORMAL STAR WAS CYGNUS AND THE BLACK HOLE WAS NAMED CYGNUS X1. $M_{\text{STAR}} = 27 M_{\odot}$ AND $M_{\text{BLACK HOLE}} = 15 M_{\odot}$.

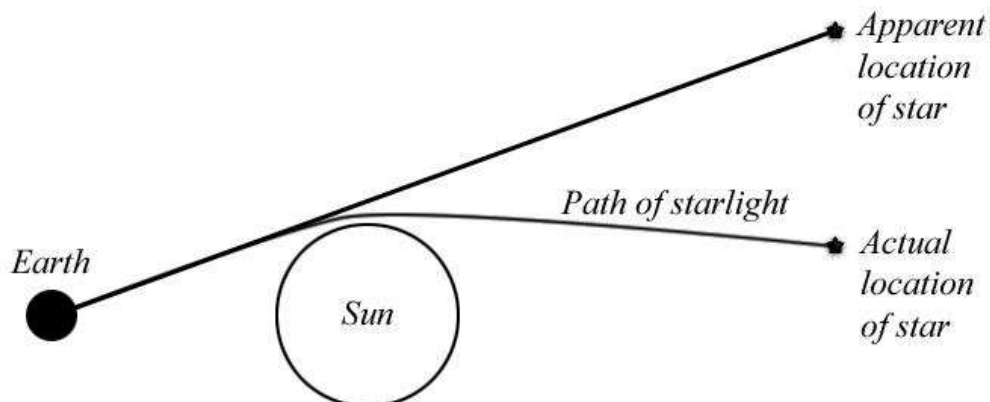
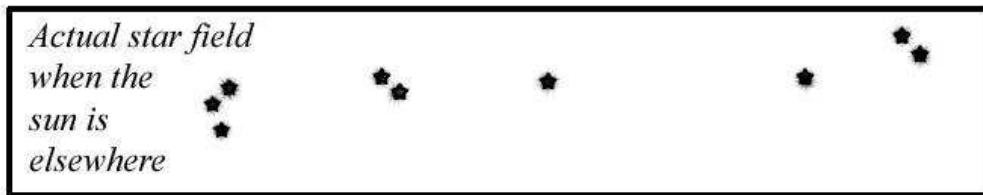
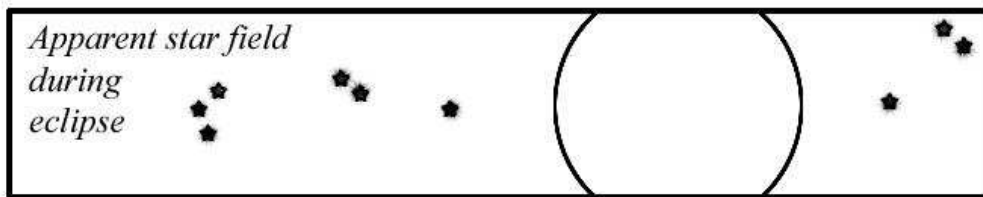
TO DESCRIBE THE VICINITY OF BLACK HOLES (NEUTRON STARS, WHITE DWARFS, AND STARS [E.G. SUN]) ONE NEEDS EINSTEIN'S GENERAL THEORY OF RELATIVITY (1915): MASS OR ENERGY BENDS SPACE AND OTHER OBJECTS MOVE IN THAT BENT SPACE ALONG THE PATHS OF SHORTEST DISTANCE (GEODESICS).



THE SUN ($M = 10^{30} \text{ kg} = 300,000$ TIMES THE MASS OF THE EARTH) BENDS THE STARLIGHT



DURING A TOTAL SOLAR ECLIPSE





EINSTEIN ARRIVES IN NEW YORK IN 1921

Daily Mirror

Goodbye, Britain—Hello New York



Fans on a roof at London Airport wave goodbye to the Beatles yesterday.

3d. Saturday, February 8, 1964 No. 18,704

YEAH! YEAH! U.S.A.!



That old Beatlemania hits New York... a screaming girl tries to get nearer the Beatles.



Paul, Ringo, George and John answer questions at the Press conference.

From **BABIE HARRING**
New York, N.Y.
FIVE thousand screaming, chanting teenagers—most of them playing truant from school—gave the Beatles a fantastic welcome here today.

5,000 scream 'welcome' to the Beatles

crowd swarmed...
Money
Part of the...
...and...
...and...
...and...

THE BEATLES ARRIVE IN NEW YORK IN 1964