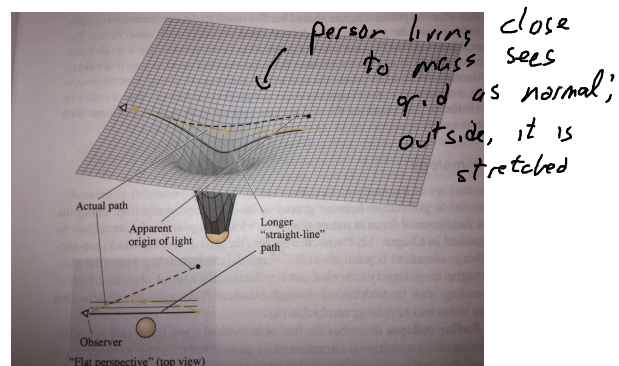


Einstein predicted that
 Mercury's perihelion (closest pt to Sun)
 will precess by 43 arc-seconds/century.

 If gravity warps time, warps space too.

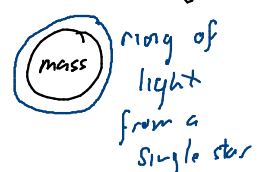
rubber-
 sheet
 analogy



light bends around large masses
 gravitational lensing

- we can look for black holes this way

"Einstein rings"



Four-Vectors

In S' moving at velocity v w.r.t. S

$\begin{pmatrix} x \\ y \\ z \\ t \end{pmatrix}$ marks an event

$$\begin{pmatrix} x' \\ y' \\ z' \\ t' \end{pmatrix} = \underbrace{\begin{pmatrix} \gamma_v & 0 & 0 & -\gamma_v v \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\gamma_v v & 0 & 0 & \gamma_v \end{pmatrix}}_{\text{Boost transformation } \beta} \begin{pmatrix} x \\ y \\ z \\ t \end{pmatrix}$$

magnitude of a 4-vector is spacetime interval

$$\left| \begin{pmatrix} x \\ y \\ z \\ t \end{pmatrix} \right|^2 = t^2 - x^2 - y^2 - z^2$$

$$\begin{pmatrix} ix \\ iy \\ iz \\ t \end{pmatrix} \text{ will let vector behave normally}$$

Momentum-Energy 4 vector $\begin{pmatrix} p_x \\ p_y \\ p_z \\ E \end{pmatrix}$

in
 $c=1$

$$\begin{pmatrix} p'_x \\ p'_y \\ p'_z \\ E' \end{pmatrix} = \beta \begin{pmatrix} p_x \\ p_y \\ p_z \\ E \end{pmatrix}$$

"magnitude" is $E^2 - p^2$

invariant under boosts
 same in all frames

What is it?

in frame $p=0$,

object is stationary,
 E^2 is m^2

Chapter 3 Start of Quantum Mechanics

All Objects can act as particles or as waves.



This wave has a definite λ
but an indefinite position



wavepacket

sum of a lot of sine waves
with different λ s.

Position fairly well-defined.

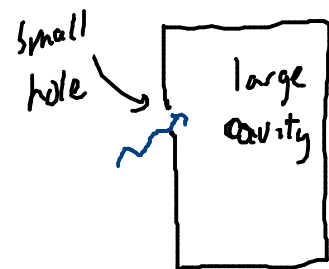
"Particle-like"

Blackbody Radiation

A "blackbody" is an object that doesn't reflect EM radiation.

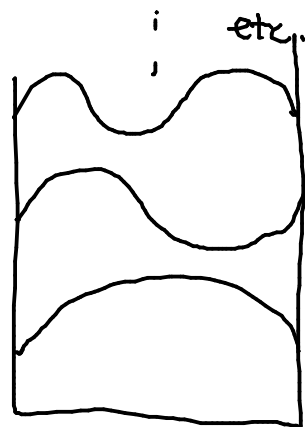
e.g. the Sun ?!?!?

light doesn't reflect off the Sun
but all objects emit light according to
their temperature



hole is the blackbody
doesn't reflect light

in a 1D box (model for this blackbody)
light inside is a sum of standing waves



Each standing wave
has a particular amplitude
 $\rightarrow A^2 \rightarrow$ particular energy
associated with it

∞ # of standing waves