Gravitational redshift / time dilation

- light escaping from a gravitating body is redshifted
- clocks deep in a gravitational potential run slow

Descriptions of light

Particles (photons) or packets of energy
Travel at speed c, have energy E

e.g. detect X-rays from Jupiter on a CCD – each photon deposits energy in one spot
Electromagnetic waves travelling through vacuum travel at speed $c$, have wavelength $\lambda$ and frequency $\nu$.
Quantum mechanics

Light behaves as *both* a wave and as a particle

\[ \lambda = \frac{c}{\nu} \]  
*wave* – higher frequencies mean shorter wavelength

\[ E = h\nu \]  
*particle* – energy is proportional to frequency

\( h \) is Planck’s constant: measures how small quanta of energy are...

Gravitational red shift

gravity extracts energy from escaping mass (conservation of energy)
**Gravitational red shift**

Gravity extracts energy from escaping light

\[ E = h\nu \]

Consider as photons, means lower frequency

\[ \lambda = \frac{c}{\nu} \]

As waves, longer wavelength, “redshift”

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**Gravitational time dilation**

Wavelength is longer but speed the same, c, so time ticks slower

Measure time as light crests pass
Gravitational time dilation

...same answer from thinking of light pulses in an accelerating but gravity-free experiment

Special vs general relativistic time dilation

Bob: “Alice’s clock is slow”

Alice: “Bob’s clock is slow”

symmetric...
light is blueshifted falling in

light is redshifted escaping

all agree: clock deep in the gravity field is slow, clock far away runs faster

small, measurable effect for Earth, infinitely strong at horizon of a black hole