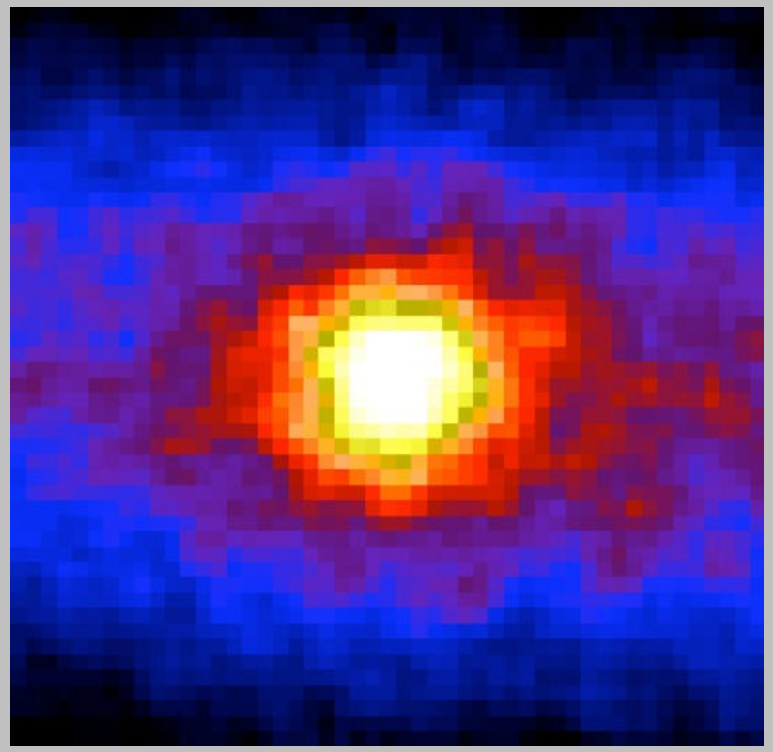
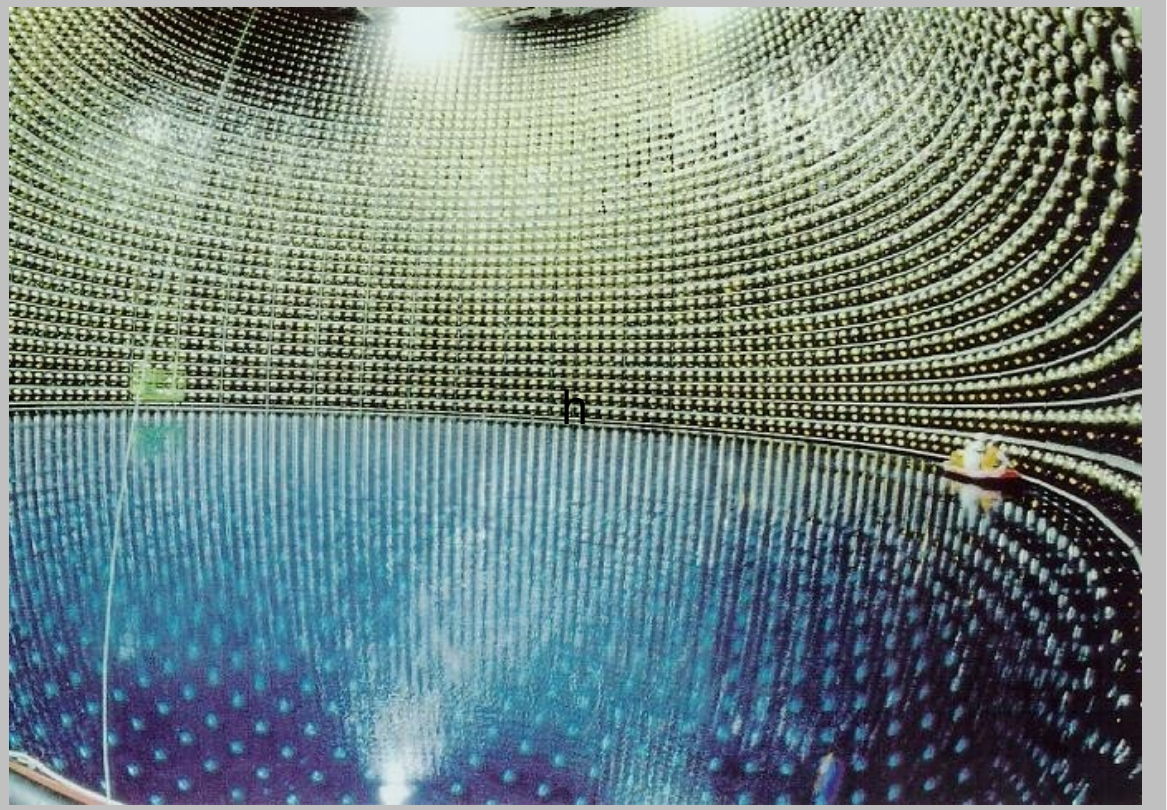


A picture of the Sun as seen in *neutrinos*. (Many of those neutrinos passed through the Earth before being detected.)

(Note: actual size of sun is <1 pixel. This is a blurry image!)

Super-Kamiokande, the detector that took the above picture.

(Only half-filled; usually has about 50 million kg of very pure water.)



Converting between Distance and Time...

distance = speed × time

How long it takes depends on how fast you are going...

LIGHT : Universal speed $c = 3.00 \times 10^8$ m/s

The father away something you observe is, the further back in time you are looking.

Astronomers have a time machine!
(Well, a time viewer.)

“Lookback Time”

= how far back in time you are looking

= how long it took the light you are seeing to reach you from the object you're observing

= (distance to object) / (speed of light) **

** *for very distant objects, the expansion of the Universe complicates this, but don't worry about that for now!*

The Speed of Light

$c = 3.00\times10^{8}$ m/s

$c = 670{,}000{,}000$ mph $= 6.7\times10^{8}$ mph

$c = 1$ light-year/year

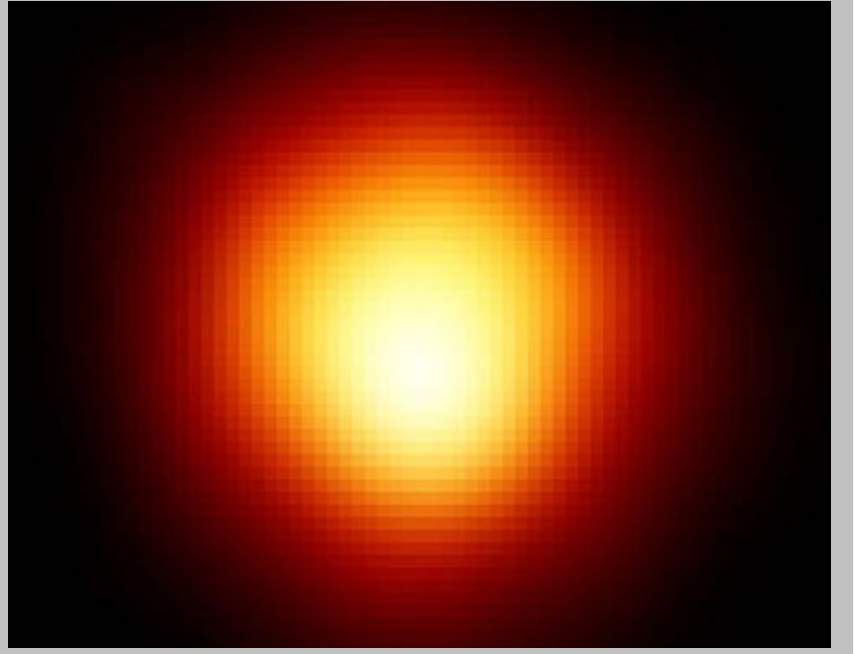
$c = 1/3.26$ pc/year $= 0.306$ pc/year

$c = 0.984$ feet/nanosecond (1 ns $= 10^{-9}$ s)

$c \approx 1$ billion feet/second

Betelgeuse (an HST image of which is shown to the right) is a supergiant star of $M \approx 12 M_{\odot}$.

Suppose Betelgeuse supernovas tomorrow. If you're outside in lab next week, when this star rises, what will you see?



A An intensely bright point of light where the star is going supernova.

B Betelgeuse will be brightening as it the supernova heads towards its peak brightness in a week or so.

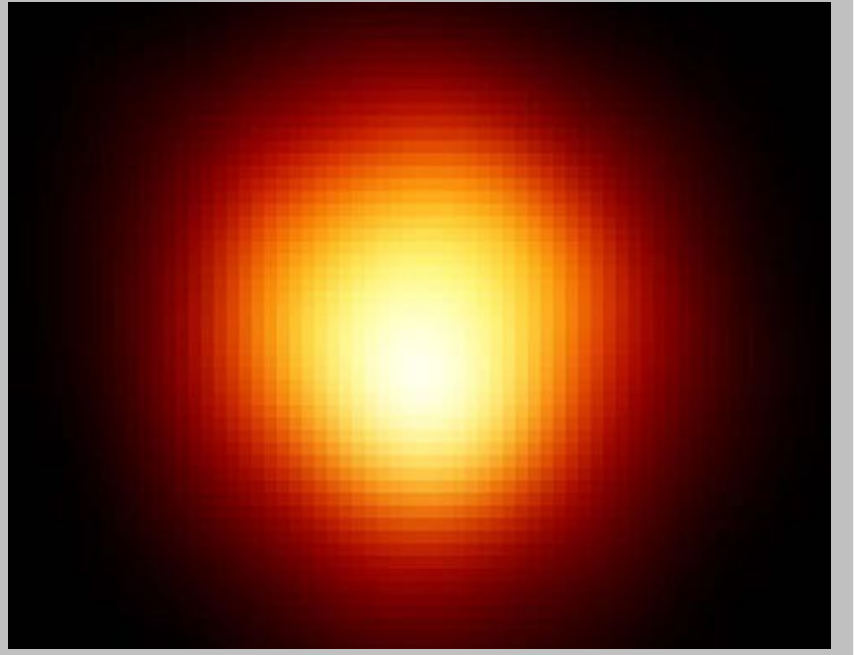
C A red star just like we saw this week.

D A supernova remnant with a neutron star at the center.

E There is not enough information to answer this question.

Betelgeuse is a supergiant star of $M \approx 12 M_{\odot}$, and is 130pc away.

Suppose we see Betelgeuse go supernova tomorrow. If we were to see that, when would it really have exploded?



A Around when the dinosaurs went extinct (65 million years ago).

B During the European Dark Ages (around 1,000 AD)

C When Sir Francis Drake was circumnavigating the world (late 16th century).

D During post Civil-War reconstruction (Civil War ends 1865)

E Tomorrow.

Lookback Times

Object	Lookback Time
Sun	8 minutes
Alpha Centauri	4 years
Andromeda Galaxy	2 million years
Virgo Cluster	65 million years
Quasar 3C273 at z=0.158	2 billion years
Galaxy at z=1	7 billion years
Age of Universe	13 billion years

Suppose you look at a Galaxy that is so distant that light from that Galaxy takes half of the age of the Universe (i.e. about 7 billion years) to reach us. What is true about the population of stars you see in that Galaxy (as compared to the population of stars you see when observing the Milky Way)?

A You are looking at a younger stellar population.

B You are looking at a stellar population not substantially different from that of the Milky Way.

C You are looking at an older stellar population.