Activity prepared by the KCL EPAP group
Experimental Particle and Astroparticle Physics

The Sun is a massive neutrino (ν) generating nuclear reactor

How many of those neutrinos reach you?

In this activity you will be working with very large numbers and very small probabilities to calculate how many of the neutrinos created in the Sun might pass through your own body.

Mathematical concepts used:

- Place value and indices
- Area of a sphere
- Speed = distance / time
- Probability
- Estimation

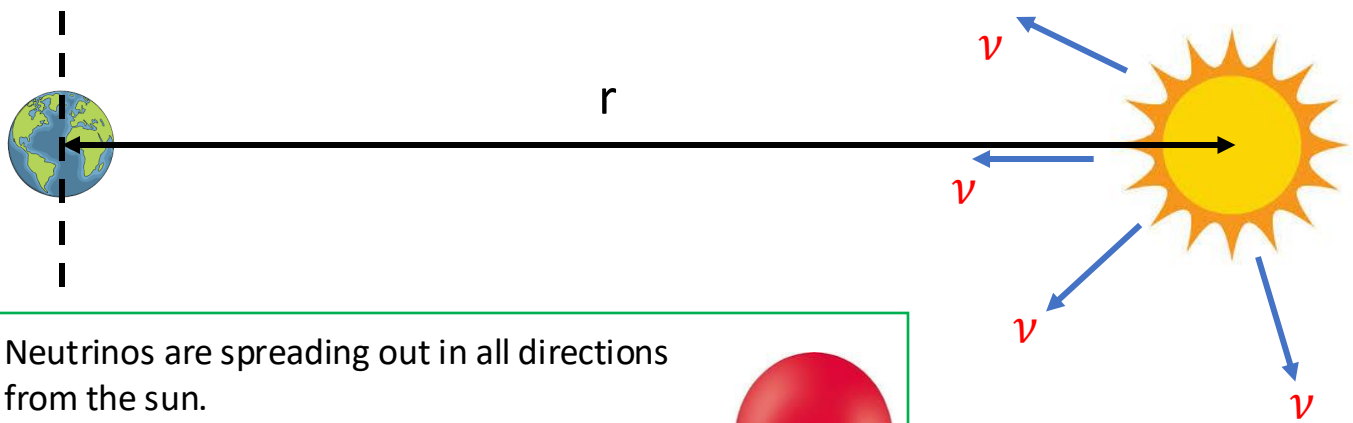
1. Calculate the neutrino flux at Earth

- The Sun produces 10^{35} neutrinos per second!
  - These are emitted in all directions (isotropically) so consider them spreading out on the surface of a sphere
- The Sun is 152 million kilometers away from Earth

Flux, ϕ = rate of particles passing through a given area (1m^2) in a given time (1s) .

Surface area of a sphere
$A = 4\pi r^2$

How many neutrinos per second pass through a 1m^2 area here?

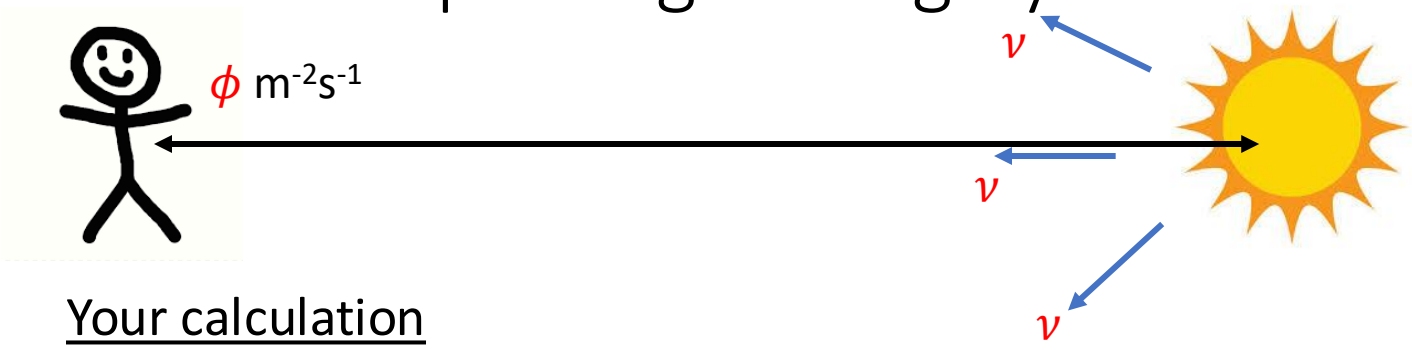


Neutrinos are spreading out in all directions from the sun.
Consider a balloon with spots on the surface – as you blow the balloon up there are the same number of spots but they get further away from the centre and more spread out.

Your calculation

Quantity	Symbol	Your Answer	Units
Distance neutrinos travel from the Sun to the Earth	r		m
Area of sphere with radius r	A		m^2
1m^2 unit area on the surface of Earth as a fraction of area A	$f = \frac{1}{A}$		
The neutrino flux at Earth is this fraction f times the total number of neutrinos produced in the sun each second	ϕ		m^{-2}s^{-1}

2. Calculate the number of neutrinos passing through you



Your calculation

Quantity	Symbol	Your Answer	Units
Estimate your area	a		m^2
Number of neutrinos passing through you in one second	$N_1 = a \times \phi$		s^{-1}

Does it make a difference if you are standing up or lying down?

3. What is the chance that one of those neutrinos will interact in your body during your lifetime?

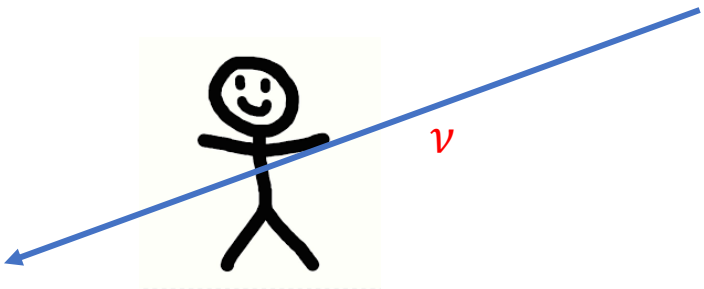
We can only 'see' neutrinos if they interact. The chance, of any single neutrino interacting with you is 1 in 10^{22}. $C = 10^{-22}$

Your calculation

Quantity	Symbol	Your Answer	Units
Estimate your lifetime in years	T_y		y
Calculate your lifetime in seconds	T_s		s
Calculate the number of neutrinos that will pass through you in that time	$N_{lifetime} = T_s \times N_1$		
Calculate the probability that any of those neutrinos will interact	$P = N_{lifetime} \times C$		

Thinking Further: How likely is it that somebody in your class has already had an interaction with a neutrino?

4. Calculate the probability that there is a neutrino inside you at any one instant



Neutrinos travel at virtually the speed of light,
$c = 3 \times 10^8 \text{ms}^{-1}$

Speed = distance / time
$$c = \frac{d}{t}$$

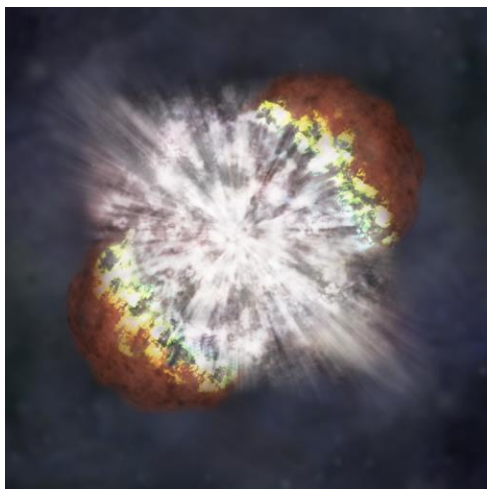
Your Calculation

Quantity	Symbol	Your Answer	Units
Estimate the average distance through your body	d		m
Calculate the time each neutrino spends in you	$t = \frac{d}{c}$		s
Total time of neutrinos inside your body each second	$T_{total} = t \times N_1$		s
This time, divided by 1s, gives the number of neutrinos inside you at any one time	$N_{instant} = \frac{T_{total}}{1}$		

Values < 1 can be taken as the probability of a neutrino being inside you right now, Values > 1 are the expected number at any one time.

5. In the event of a supernova, how many neutrinos could pass through you?

A supernova is a powerful explosion when a star runs out of fuel. It could produce 10^{58} neutrinos in just a few seconds!



IK Pegasi B is the nearest know supernova candidate, located 150 light years away.

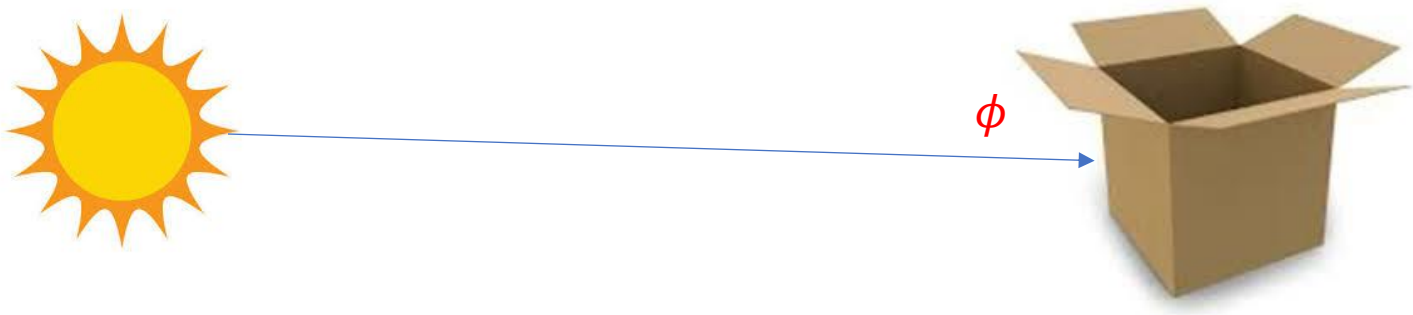
Candidate means a star that we think might go supernova

A light year is the distance that light travels in 1 year, $d = ct$
Remember $c = 3 \times 10^8$ms^{-1}

Your Calculation

Quantity	Symbol	Your Answer	Units
The distance between IK Pegasi and Earth in metres	d		m
Area of a sphere with this radius (ie at Earth's surface)	A		m^2
The number of neutrinos passing through 1m^2 of that sphere	ϕ		
Using your estimated area, a, calculate the number of neutrinos passing through you from the supernova	N_{SN}		

Thinking further: What volume box do you need to be sure there is always a neutrino from the Sun in it?



<u>Your Calculation</u>