National Aeronautics and Space Administration

The Heliophysics Big Year

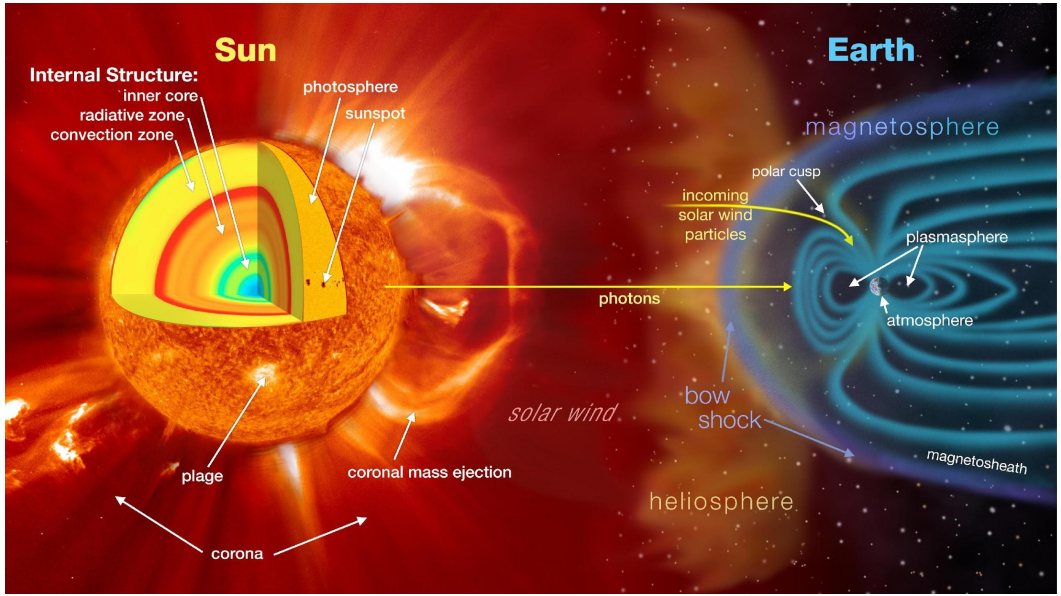
Dr. Sten Odenwald, Astronomer

NASA Heliophysics Education Activation Team

December 2023: What is Heliophysics?

Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

It also studies how the Sun varies and how those changes pose a hazard to humans on Earth and in space



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Heliophysics Big Year Timeline

Annular Eclipse

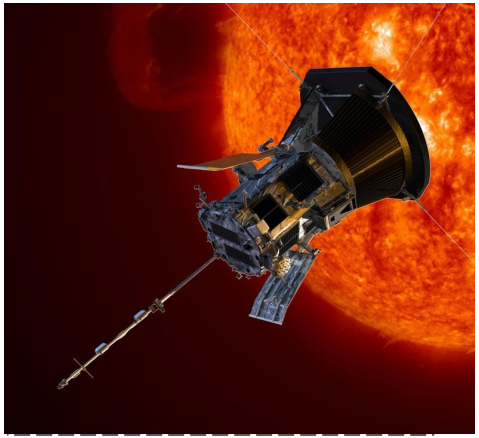
October 14, 2023

Total Eclipse

April 8, 2024

Solar Parker Probe Perihelion

December 24, 2024



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December 2023 : HBY Schedule

December 19 – Citizen Science

January 16 - The Sun Touches Everything

February 20 - Fashion

March 19 - Experiencing the Sun

April 16 - April 8 Total Solar Eclipse

December 2023 : NASA's Big Questions

1. What causes the Sun to vary?
2. How do the Earth and the heliosphere respond?
3. What are the impacts on humanity?

These Big Questions form the basis for the

Framework for Heliophysics Education

https://science.nasa.gov/learn/heat/big-ideas/

December 2023 : The Framework for Heliophysics Education

What are the impacts of the Sun on humanity?

1.1 The Sun is really big and its gravity influences all objects in the solar system. (PS2, ESS1)

1.2 The Sun is active and can impact technology on Earth via space weather. (PS1, PS2, PS4, ESS2, ESS3) <<<<<< Tonight

1.3 The Sun's energy drives Earth's climate, but the climate is in a delicate balance and is changing due to human activity. (PS1, PS2, PS3, LS4, ESS2, ESS3)

How do the Earth, the solar system, and heliosphere respond to changes on the Sun?

2.1 Life on Earth has evolved with complex diversity because of our location near the Sun. It is just right! (PS3, PS4, LS1, LS2, ESS2)

2.2 The Sun defines the space around it, which is different from interstellar space. (PS2, ESS1, ESS2)

2.3 The Sun is the primary source of light in our solar system.(PS1, PS2, PS3,PS4, ESS1)

What Causes the Sun to Vary?

3.1 The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields. (PS1, PS2, ESS1, ESS2)

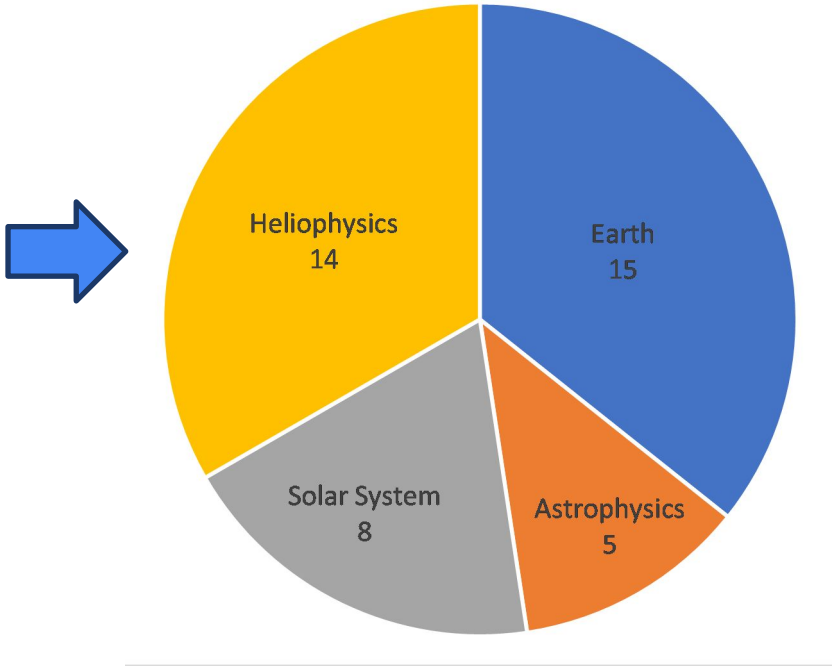
3.2 Energy from the Sun travels outward through the Sun and into the heliosphere. (PS1, PS3, PS4, ESS1, ESS2, ESS3) <<<<< Tonight

3.3 Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)

December 2023: Citizen Science

Citizen science has enabled many heliophysics discoveries, including new types of auroras.

This month will explore ongoing citizen science projects in heliophysics

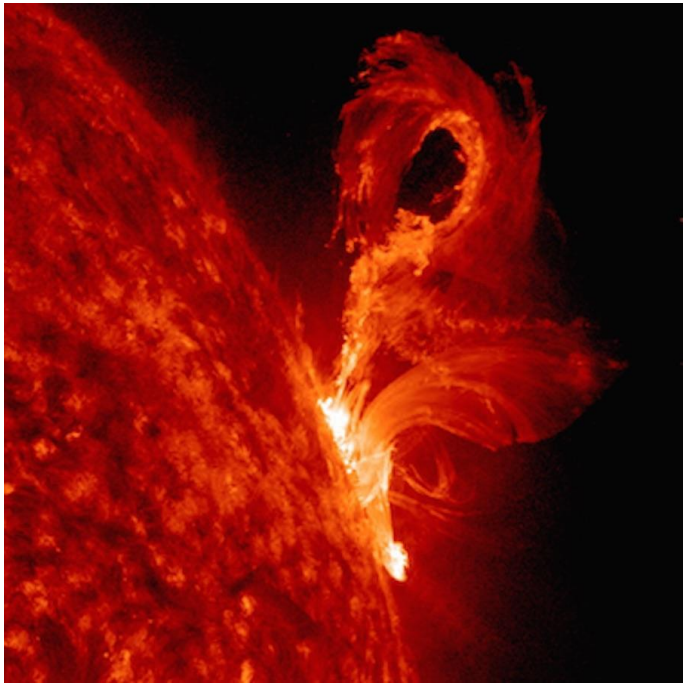


https://science.nasa.gov/heliophysics/programs/citizen-science

December 2023: Citizen Science

Projects about the sun:

- Sungrazer
- Solar Active Region Spotter
- Solar Jet Hunter
- Sunsketcher
- Megamovie
- RadioJOVE
- CATE



December 2023: Citizen Science

Projects about solar impacts

- Aurorasaurus
- HamSci
- EZIE-Mag
- DEB Initiative
- Soundscapes
- Eclipse Ballooning Project
- HARP

December 2023: Citizen Science

Sungrazer.....	https://sungrazer.nrl.navy.mil/
Solar Active Region Spotter.....	https://www.zooniverse.org/projects/eimason/solar-active-region-spotter
Solar Jet Hunter.....	https://science.nasa.gov/citizen-science/summary/solar-jet-hunter/
Sunsketcher.....	https://sunsketcher.org/
Megamovie.....	https://eclipsemegamovie.org/
RadioJOVE.....	https://radiojove.gsfc.nasa.gov/
CATE.....	https://science.nasa.gov/sciact-team/citizen-cate-experiment/

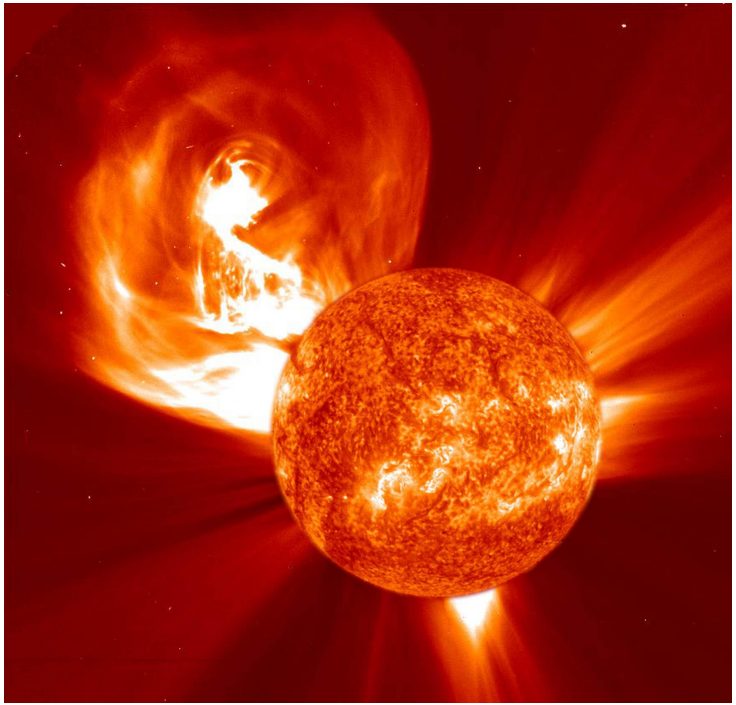
December 2023: Citizen Science

Aurorasaurus.....	https://science.nasa.gov/citizen-science/summary/aurorasaurus/
HamSci.....	https://science.nasa.gov/citizen-science/summary/ham-radio-science-citizen-investigation/
EZIE-Mag.....	https://ezie.jhuapl.edu/outreach/ezie-mag/
DEB Initiative.....	https://debinitiative.org/
Soundscapes.....	https://eclipsesoundscapes.org/
Eclipse Ballooning Project.....	https://science.nasa.gov/sciact-team/nationwide-eclipse-ballooning-project/
Heliophysics Audified HARP.....	https://listen.spacescience.org/

December 2023: Aurora Science

Step 1:

Solar storms produce clouds of plasma called coronal mass ejections

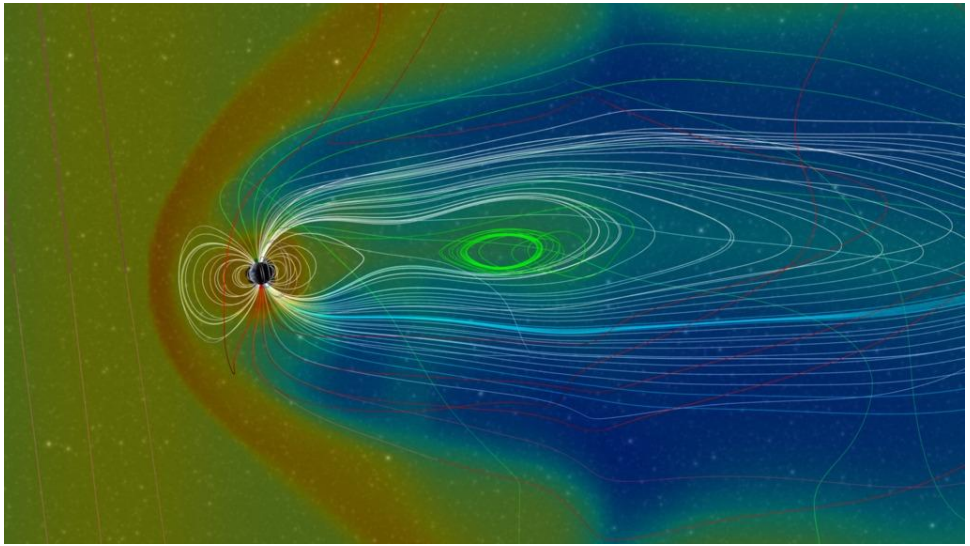


The Sun is active and can impact technology on Earth via space weather. (PS1, PS2, PS4, ESS2, ESS3)

December 2023: Aurora Science

Step 2:

Coronal mass ejections can impact Earth's magnetic field causing magnetic reconnection.

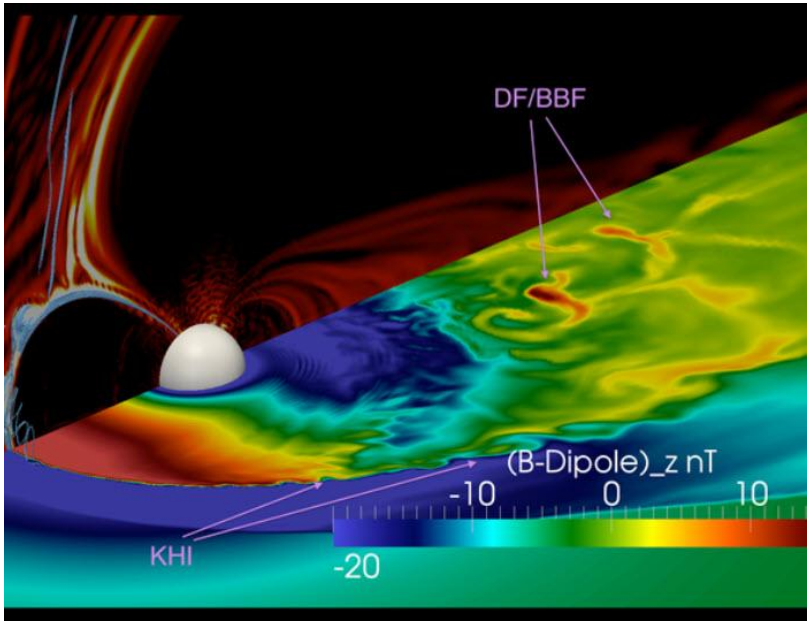


The Sun is active and can impact technology on Earth via space weather. (PS1, PS2, PS4, ESS2, ESS3)

December 2023: Aurora Science

Step 3:

Magnetic reconnection releases energy stored in the magnetic field, which causes charged particles to flow into the polar regions



The Sun is active and can impact technology on Earth via space weather. (PS1, PS2, PS4, ESS2, ESS3)

December 2023: Aurora Science

Step 4:

These energetic particles, mostly electrons, collide with the atmosphere to produce the aurora

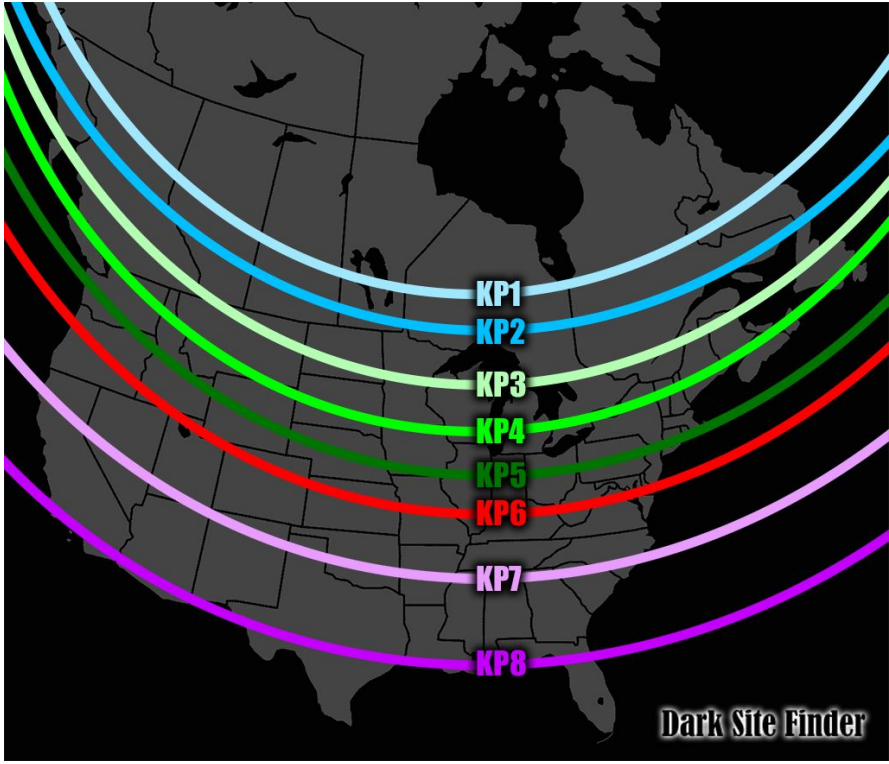
The Sun is active and can impact technology on Earth via space weather. (PS1, PS2, PS4, ESS2, ESS3)

December 2023

When to look:

There are many online sites that give forecasts for aurora sightings in the next few days. Typically the Kp index is used to gauge geomagnetic activity.

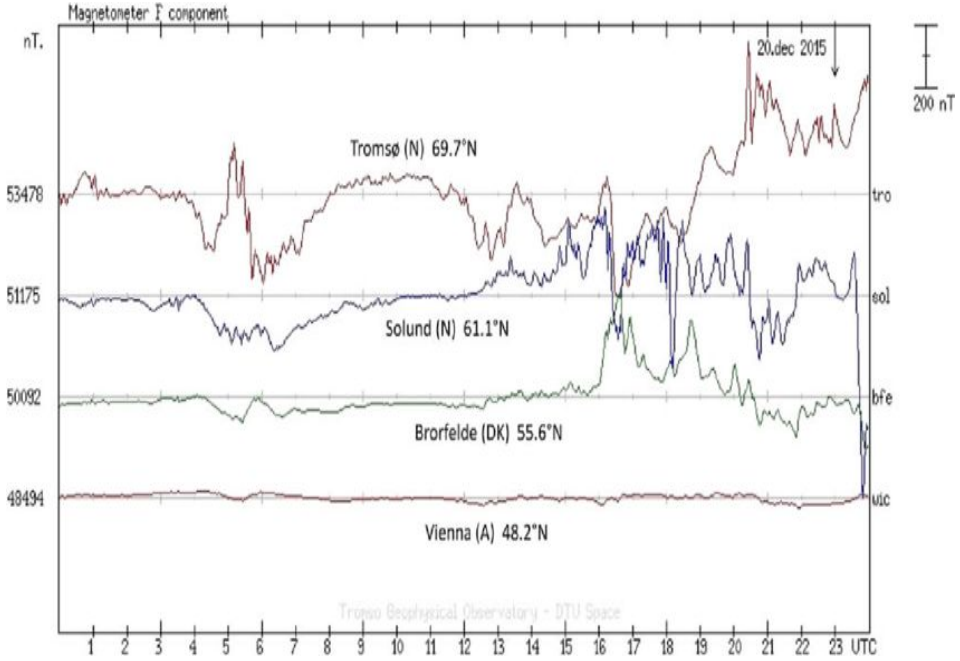
NOAA Space Weather Prediction Center: https://www.swpc.noaa.gov/



December 2023

Once a coronal mass ejection aimed towards Earth is sighted by NASA spacecraft (SOHO, SDO), magnetic storms are soon to follow in a few days.

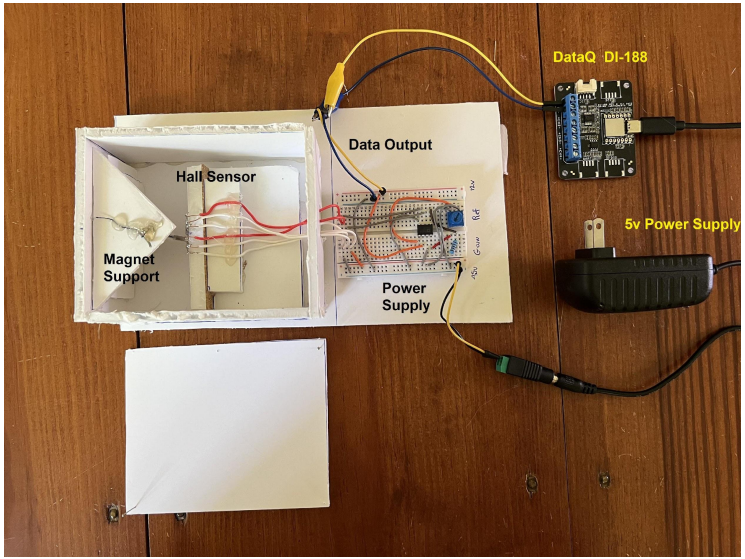
They often happen in the daytime so by looking at geomagnetic disturbances (Kp index) you can tell if the storm is strong enough to produce an auroral event that evening.

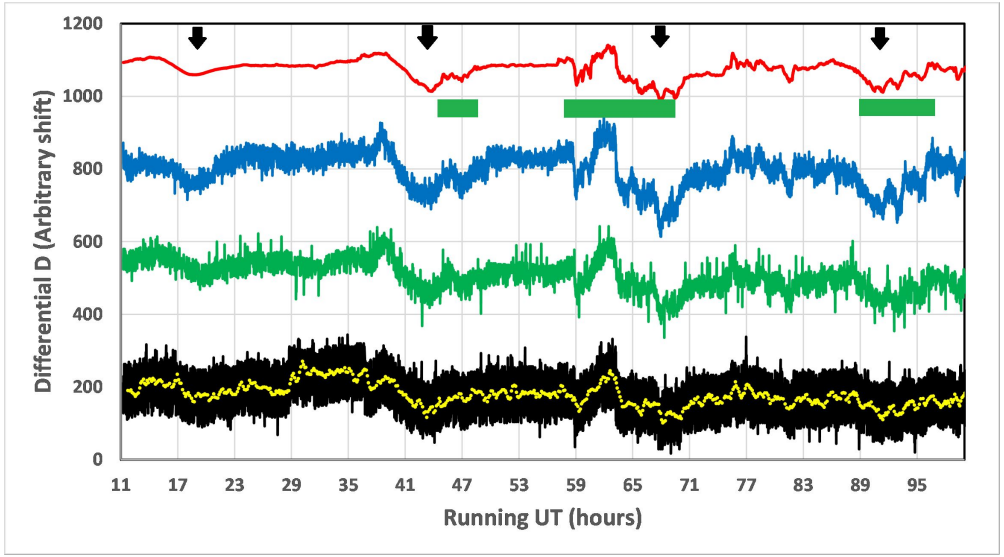


Magnetic storm beginning on 20 December 2015

December 2023

DIY magnetometers can be built to track them yourself for under $50.





See ‘DIY Magnetometers’ by Sten Odenwald
Email me for details: odenwald@astronomycafe.net

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December 2023: Aurora Math

Aurora science provides some interesting opportunities to see how math is used in the Real World (Earth-1).

SpaceMath@NASA has developed over 1000 math problems designed for grades 3-12.

Main webpage: http://spacemath.gsfc.nasa.gov

Search engine: https://spacemath.gsfc.nasa.gov/Search.html

December 2023: Aurora Questions Answered by Math

How high up are aurora?

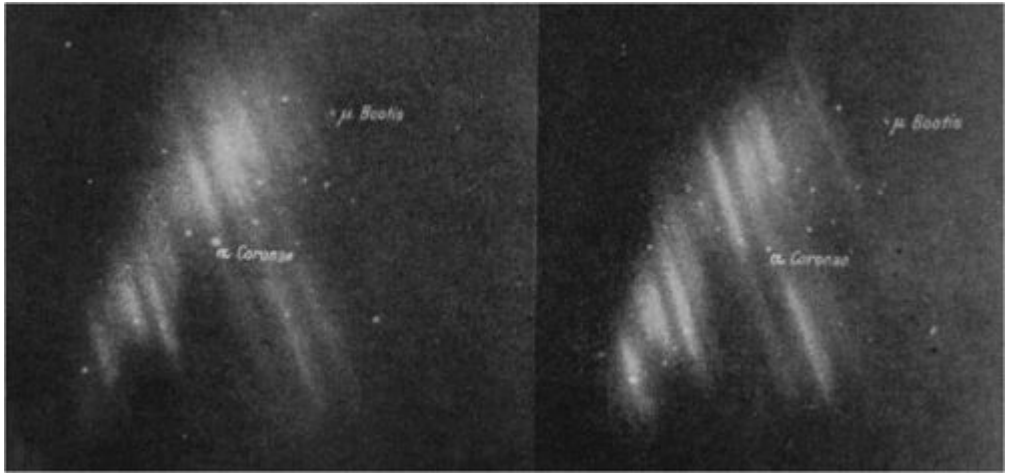
Do they ever reach the ground?

Can you hear an aurora?

December 2023: Aurora Heights

In the early 1900s, Norwegian scientist Carl Stormer and an assistant donned fur coats and braved freezing Arctic temperatures in order to take simultaneous photographs of auroral features from different locations in Norway.

By comparing pairs of pictures, Stormer could triangulate the height of portions of the aurora



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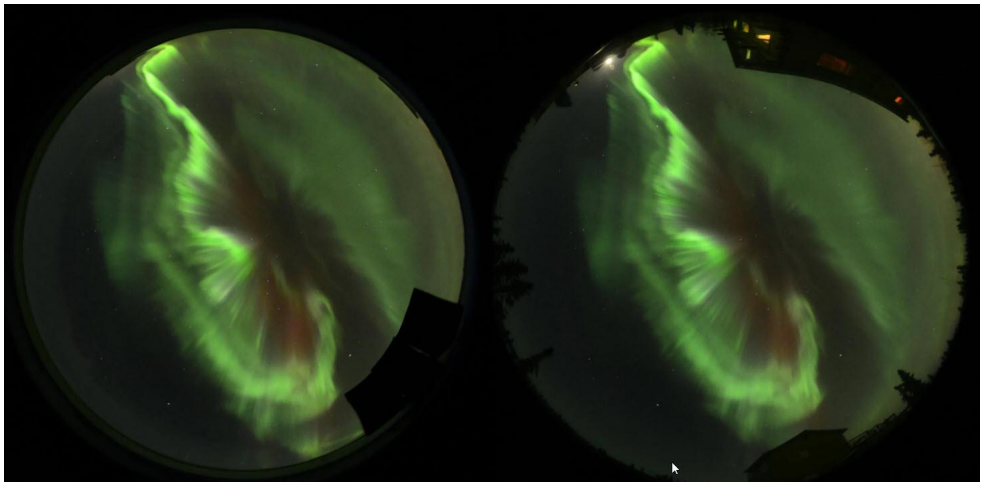
December 2023: Aurora Heights – By Parallax

The Parallax Method

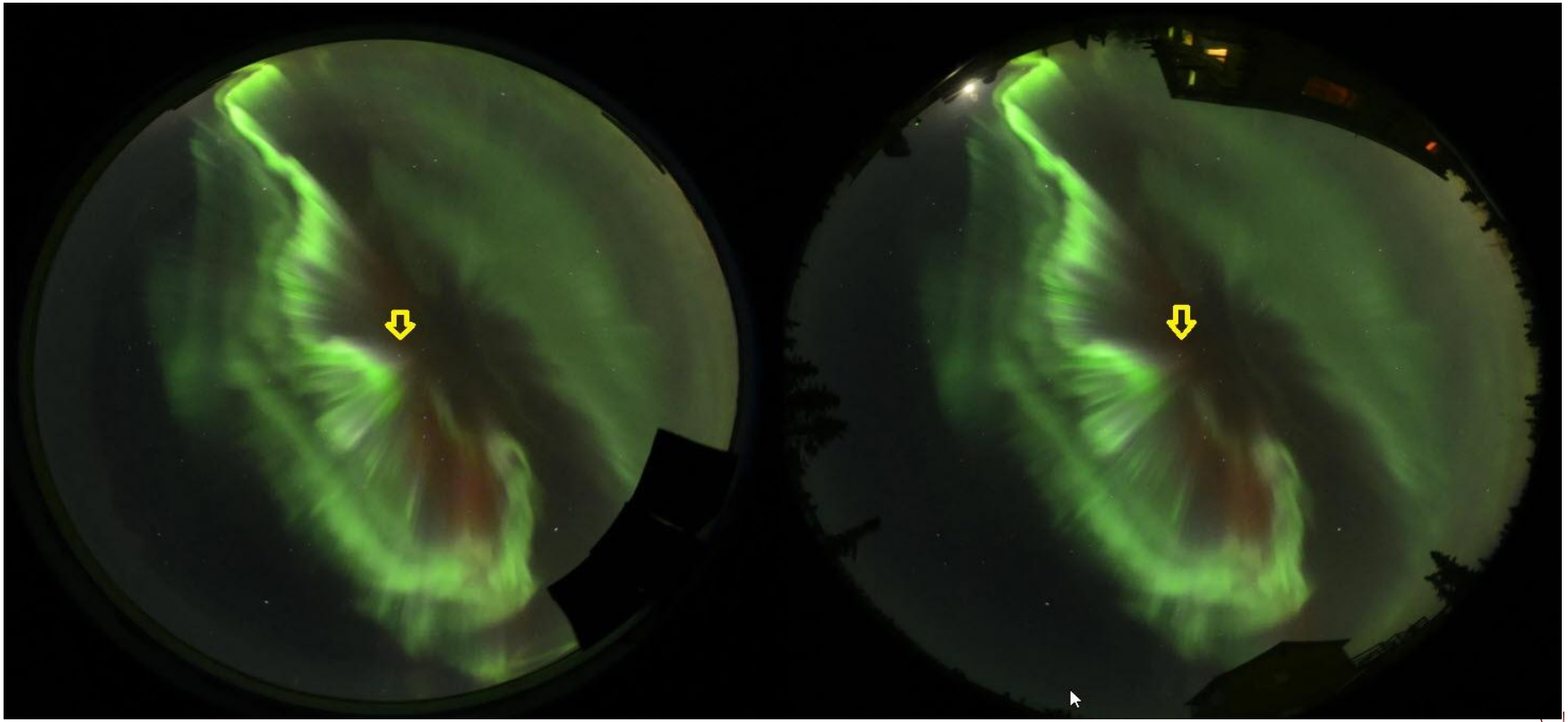
The technology that Ryuho Kataoka, an associate professor at the National Institute of Polar Research in Tokyo, and his colleagues used provides more precise measurements.

They set up digital Nikon cameras—equipped with wide-angle fisheye lenses capable of capturing expanses of sky in Alaska.

https://www.sciencefriday.com/articles/a-double-take-on-the-northern-lights/

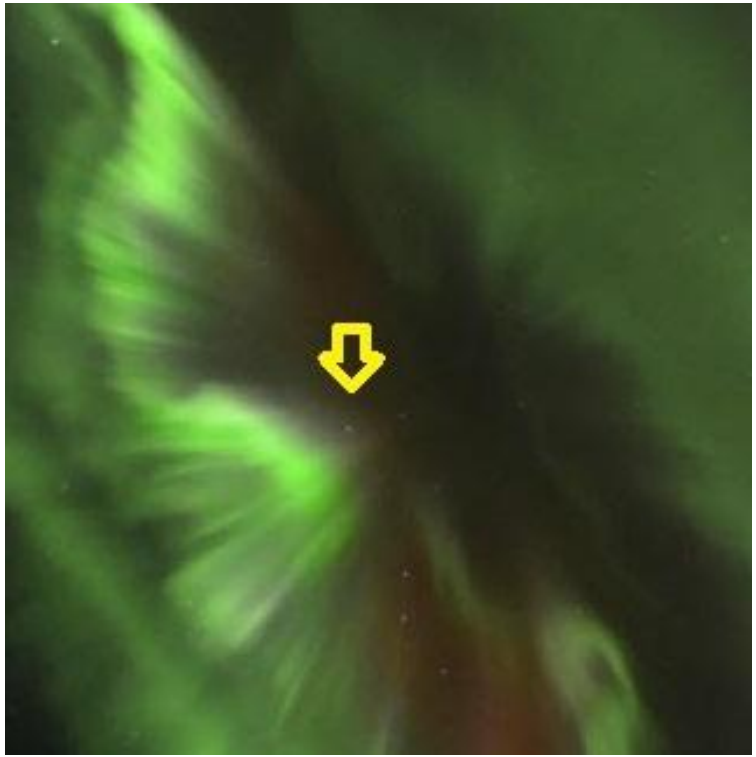


December 2023: Aurora Heights - Introductory



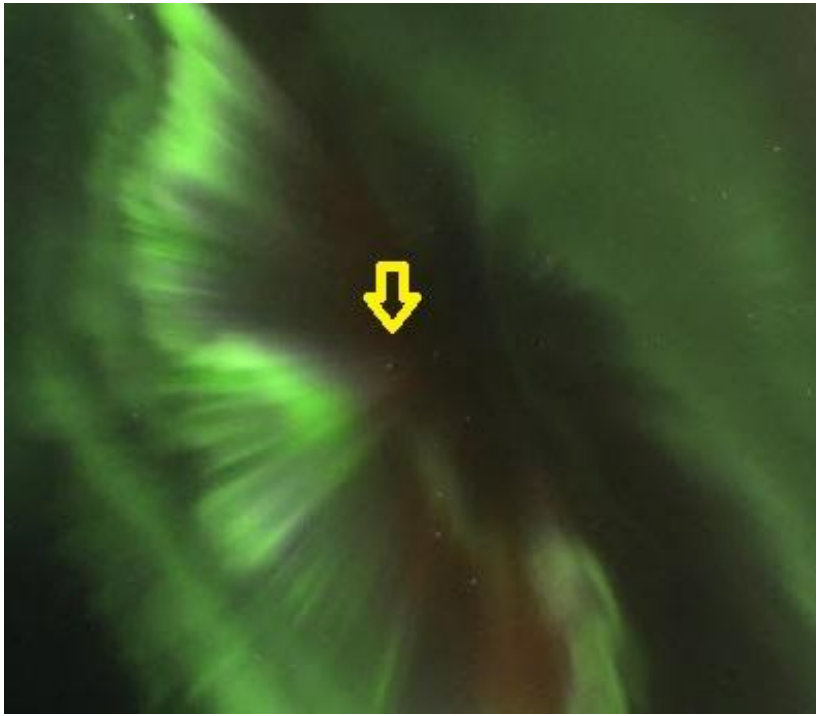
December 2023: Aurora Heights - Introductory

Blink Image A



December 2023: Aurora Heights - Introductory

Blink Image B



December 2023: Aurora Heights - Introductory

Parallax Shift

Image is 0.5º x 26 moons = 13º

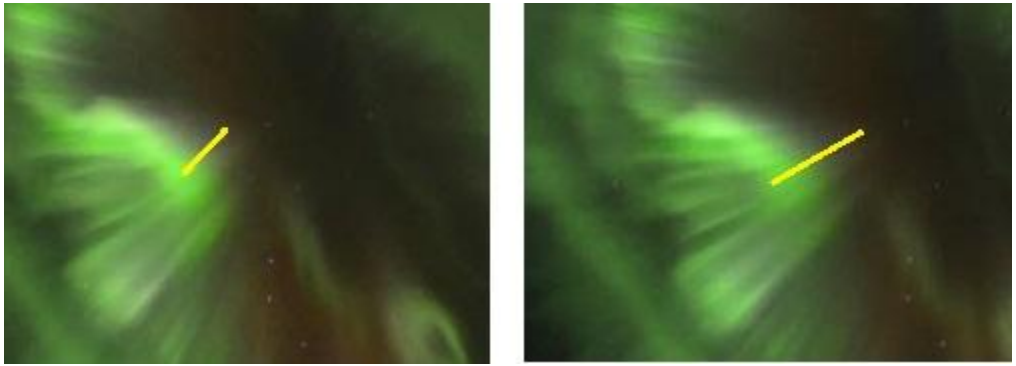
From the scale of the image:

Using the star as a reference:

Length A = 2 degrees

Length B = 3 degrees

Difference Angle = 1.0 degrees



The field of view of this picture is cropped so that its width on the sky is about 26 times the full moon.

December 2023: Aurora Heights - Introductory

Parallax Geometry

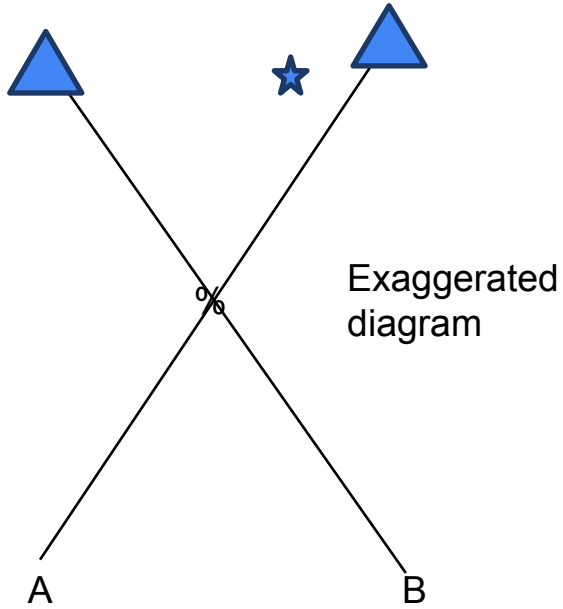
Length A = 2 degrees

Length B = 3 degrees

Parallax Angle: B – A = 1 degree

Base line = 2 km from A to B

Distance = 2 km x (57.3º/1º) = 114 km



December 2023: Aurora Heights - Introductory

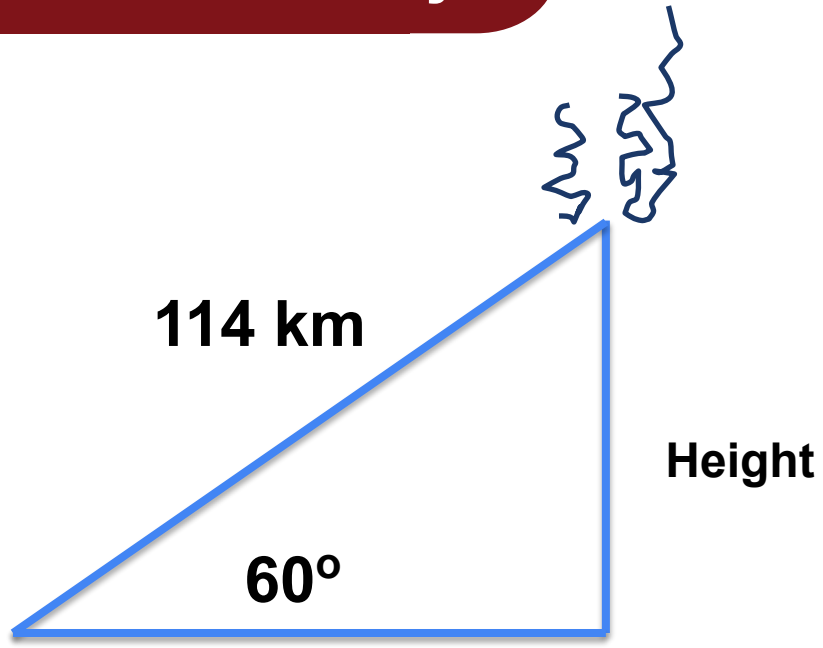
Distance to Height:

Distance = 2 km x (57.3/1) = 114 km

Height = 114 x sin(60º)

Height = 114 x 0.866

Height = 99 kilometers.



December 2023: Angular height and scale drawing

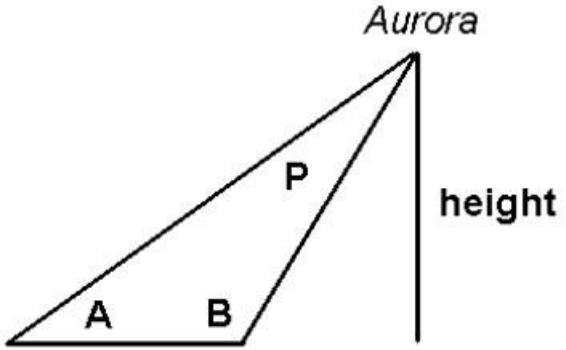
Method 2: Scale Drawing

Suppose that two observers were located 30 kilometers apart (length of AB).

Observer A measured an angle A of 53°
Observer B measured an angle B of 114°.

By making a scaled drawing of this triangle, what was the height of the auroral feature they were studying?

About 100 km.



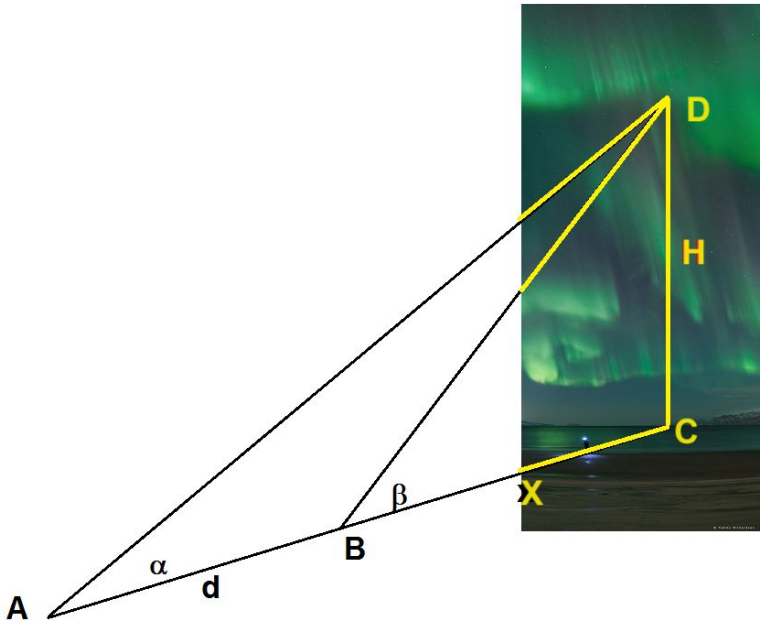
https://spacemath.gsfc.nasa.gov/weekly/Page11.pdf

December 2023: Height by Trigonometry

Method 3: By trigonometry

The basic idea is that two observers will be spotting the same feature on an aurora.

This is like the previous method but relies on computation and not scale drawings so is more general.

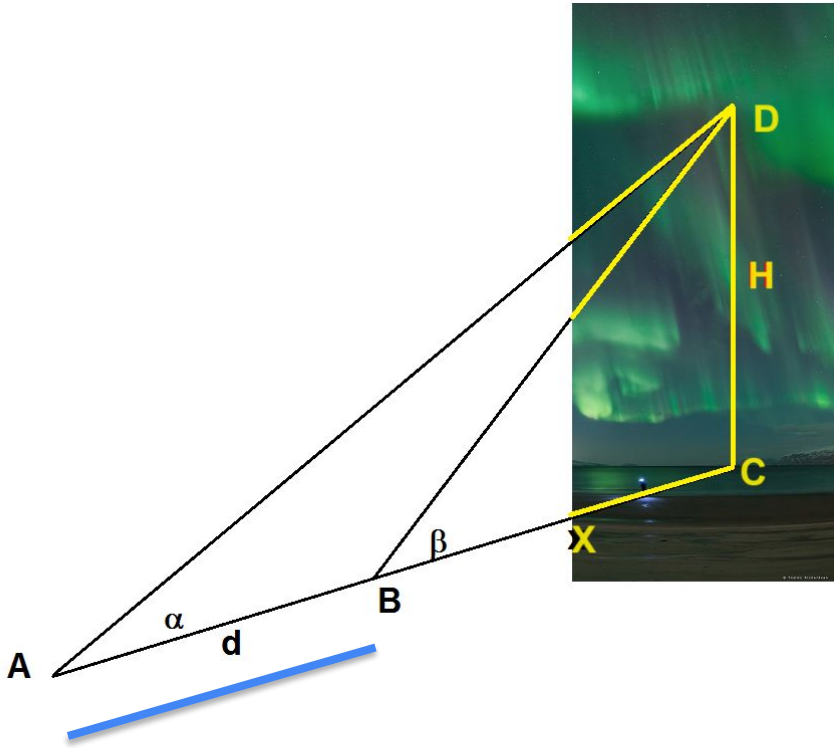


December 2023: Height by Trigonometry

The simplest geometry occurs if you have two observers, A and B, located along the same line ABC as the direction towards the auroral feature.

Observers A and B measure the elevation angles α and β and are standing a distance d apart.

Amazingly, we don't need to know the length x=BC to determine H!



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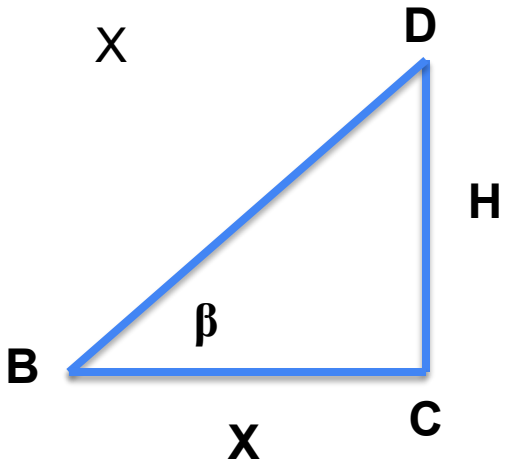
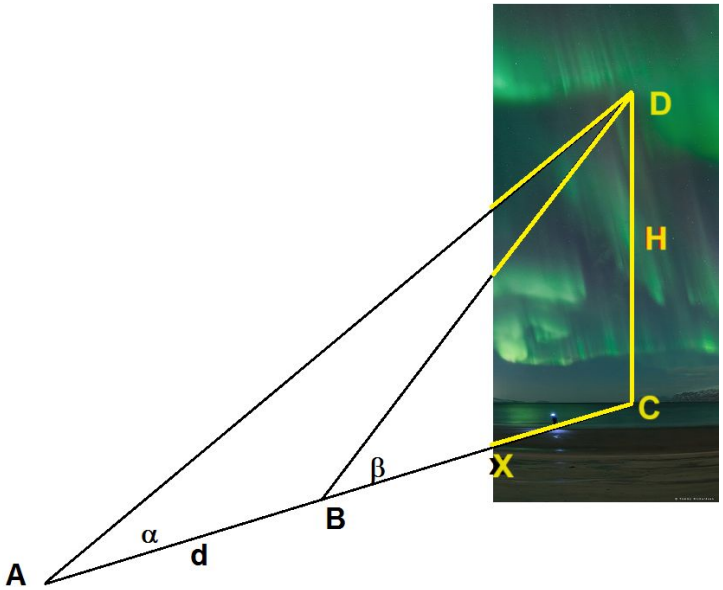
December 2023: Height by Trigonometry

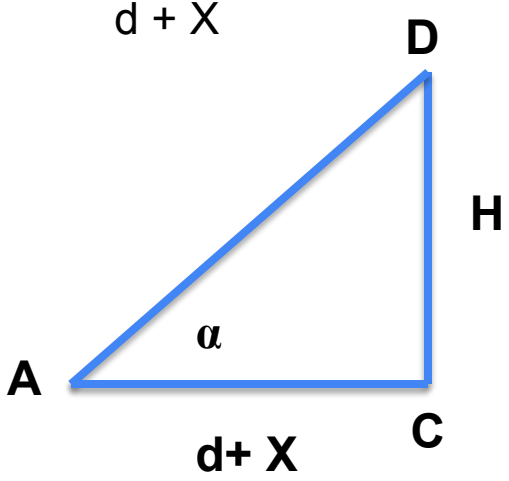
$$\tan \beta = \frac{H}{X}$$

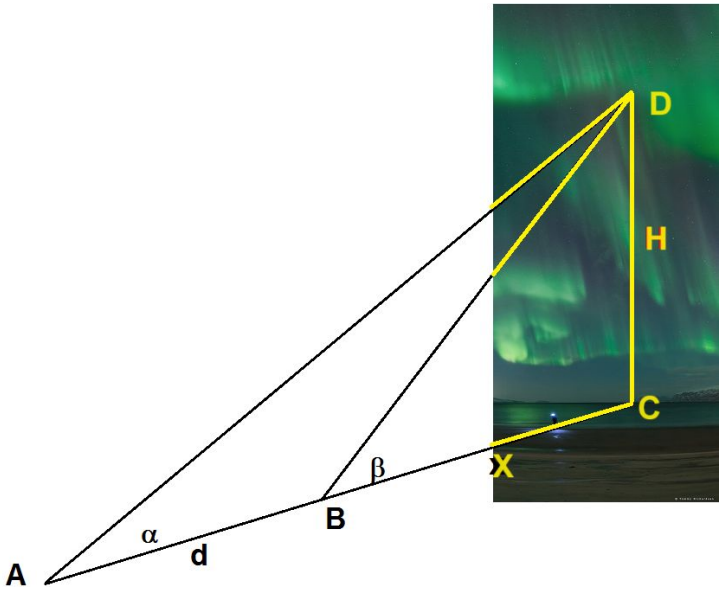




December 2023: Height by Trigonometry

$$\tan \alpha = \frac{H}{d + X}$$





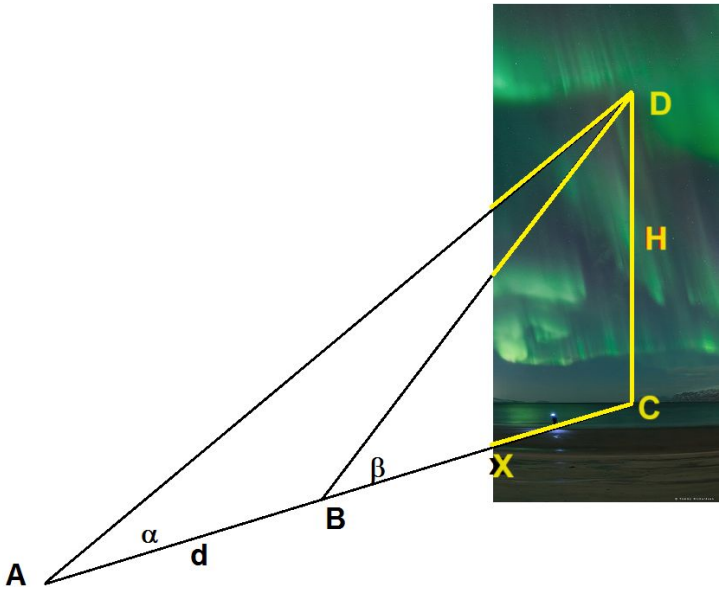
December 2023: Height by Trigonometry

$\tan \alpha = H \ / \ (d+x)$

Multiply both sides by (d+x) and cancil

$H = (d+x)\tan \alpha$

$H = d \tan \alpha + x\tan \alpha$



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December 2023: Height by Trigonometry

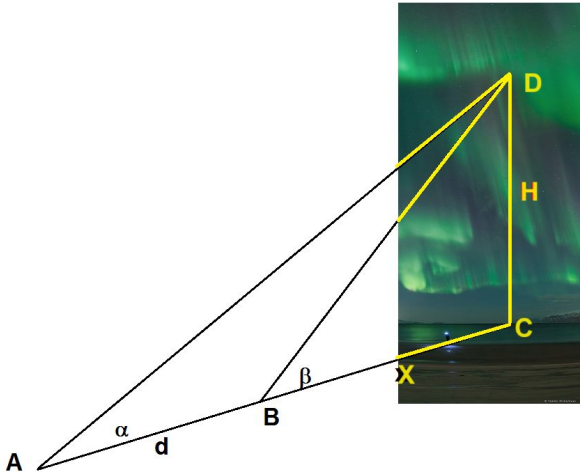
But $\tan\beta = H/x$ so $x = \mathbf{H/\tan\beta}$

Since $H = d\tan\alpha + \mathbf{x}\tan\alpha$

Eliminate x: $H = d\tan\alpha + \mathbf{(H/\tan\beta)}\tan\alpha$

Put Hs on same side: $H - H(\tan\alpha/\tan\beta) = d\tan\alpha$

Simplify: $H(1 - \tan\alpha/\tan\beta) = d\tan\alpha$



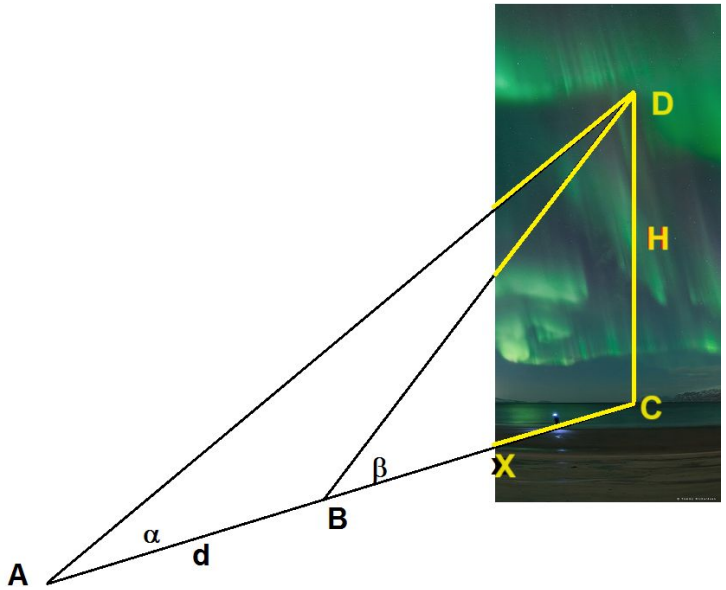
December 2023: Height by Trigonometry

Put H on the one side:

$$H = \frac{d \tan \alpha}{1 - \tan \alpha / \tan \beta}$$

so

$$H = \frac{d \tan \alpha \tan \beta}{\tan \beta - \tan \alpha}$$



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December 2023: Height by trigonometry

Example.

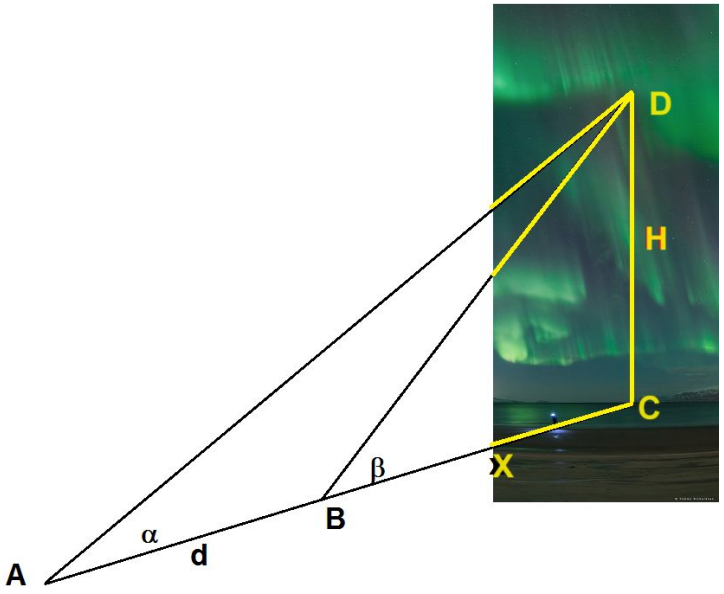
Observer 1 measures α = 35 degrees

Observer 2 measures β = 45 degrees

d = 75 km

$$H = \frac{75\ (0.70)(1.0)}{1.0 - 0.7} = 175\ \text{km}$$

Can you find the length of X?



December 2023: Aurora Math Answers to Questions

How high up are aurora?	Minimum altitude 90 km
Do they ever reach the ground?	Never
Can you hear an aurora?	Nope. Too far away

January 2023: The Sun Touches Everything

Next Time!

From agriculture to economics, the Sun touches all parts of our lives. By far the biggest way is through its sunlight, which allows crops to grow but also provides electrical power for spacecraft and your home.

Math: Solar electricity calculations for your home and your spacecraft!