Mike Lockwood

University of Reading, RAS President

Life as a Scientist

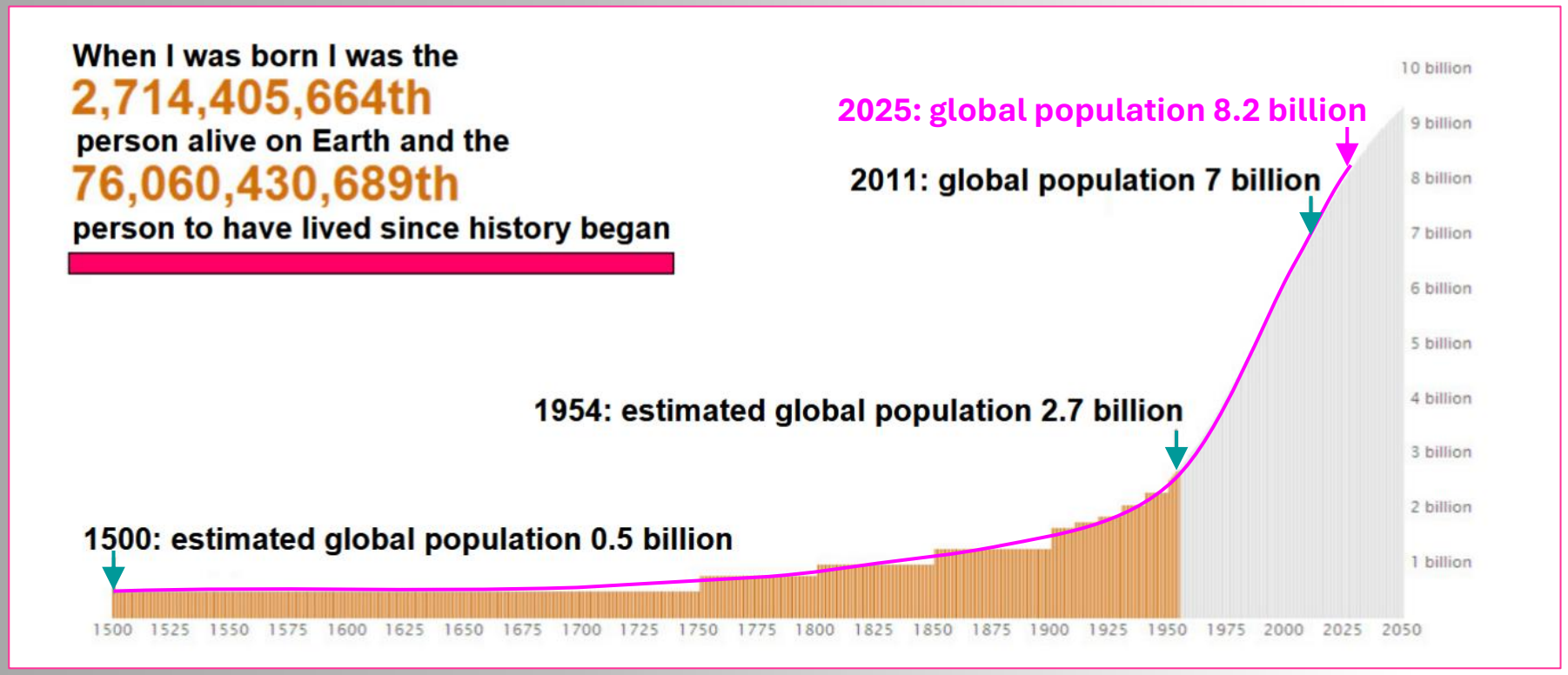
Talk @ Westminster School

25 November 2025

Science for a Better Life

My Life

- 1954: born in Epsom, Surrey



(source: UN population Fund)

My Life

- 1954-1961: grew up (a little bit) in Holmfirth, Leatherhead, Rhinedahlen (Germany)
- 1961-1965: family settled in Tunbridge Wells and I went to primary school in Bidborough village
- 1965: started at The Skinners' School

Polesdon Lacey, Surrey (1957)

Secondary School

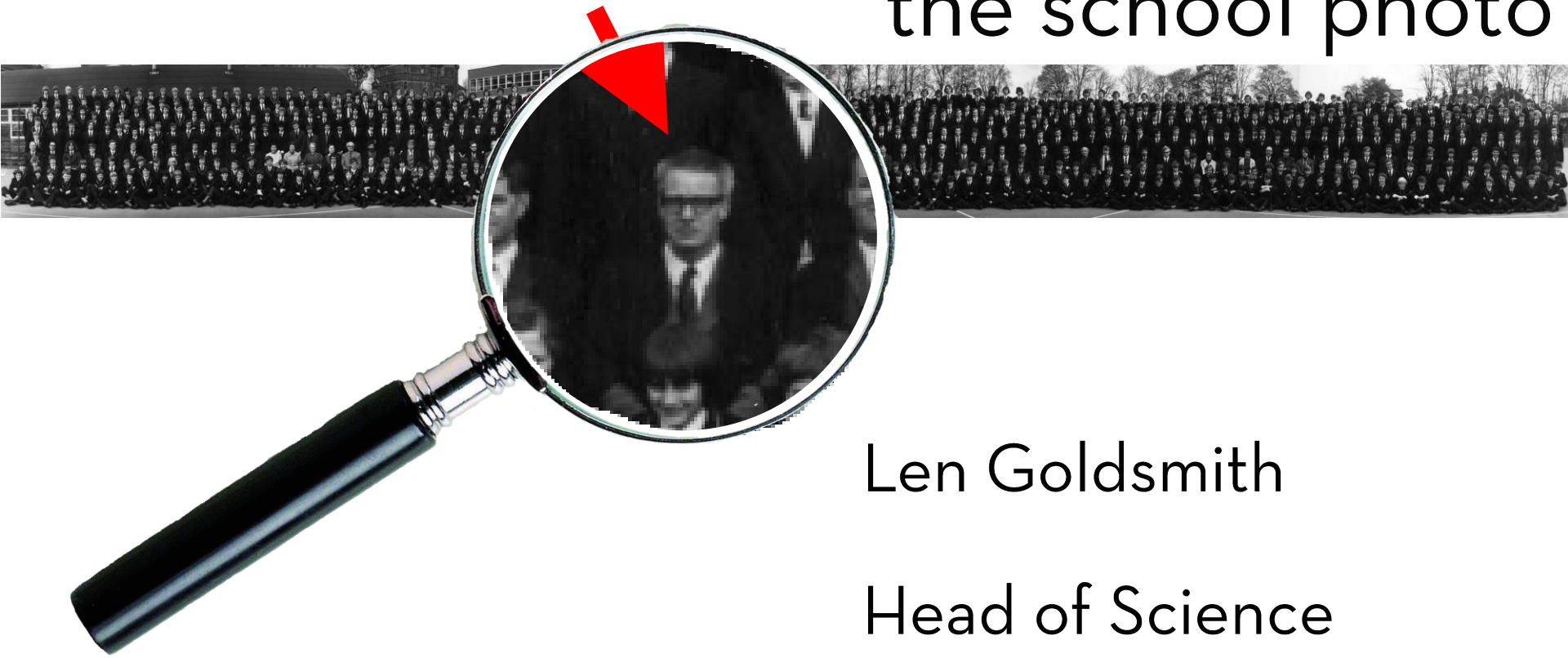
1968 & 1969: “O levels” – notably unremarkable & an undiagnosed dyslexic. Best a “C” in Latin – but at least no “F”s (Fails)

1970: 6th form & “A levels” –still much more interested in rock music, motor racing, & football than school work

… but …

First day at Skinners’, 1965

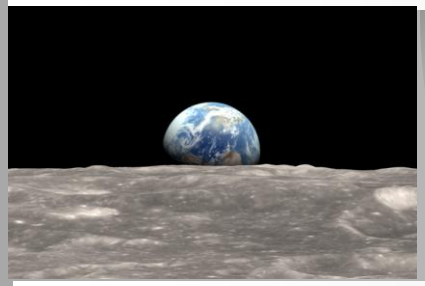
the school photo



Len Goldsmith

Head of Science
Taught me Physics

A brilliant teacher and an interesting, kind, thoughtful and charismatic man



A key moment

(William Anders' Classic Earthrise pictures from Apollo 8, Christmas Eve, 1968)

"We choose to go to the moon, and do the other things - not because they are easy, but because they are hard"

President John F. Kennedy,
speech at Rice University
September 12, 1962

Words written with his brilliant
Speechwriter, Ted Sorensen

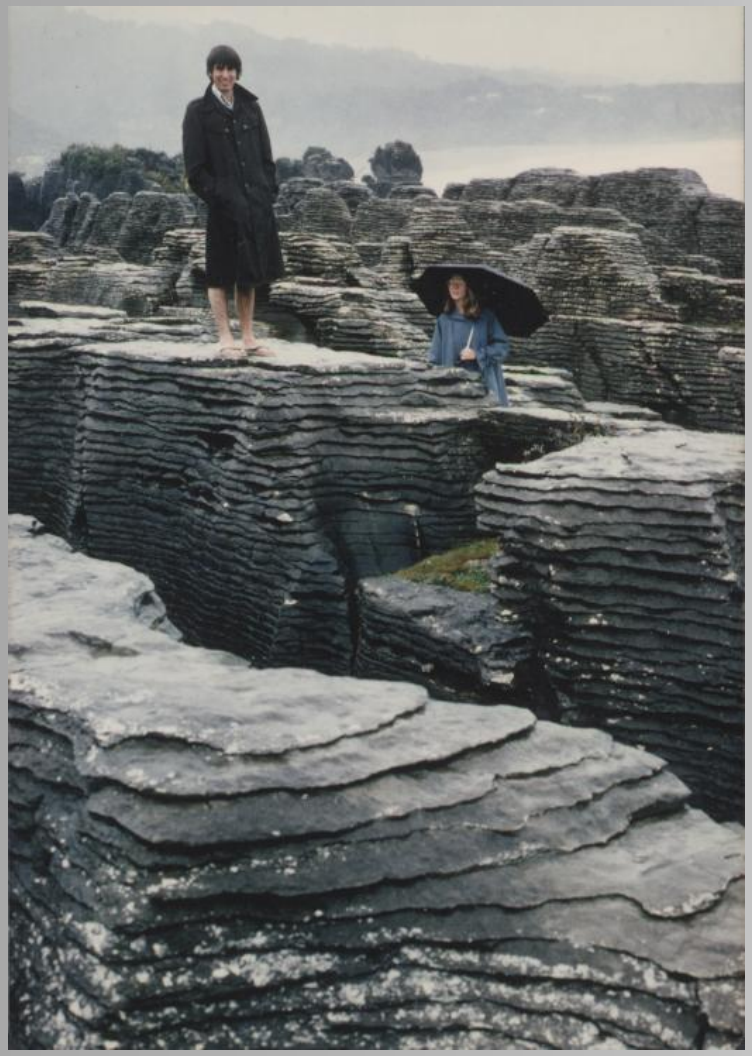
University

1972 - 1975: Exeter University: BSc in Physics

1975 - 1978: Exeter University: PhD in Ionospheric Physics

I started to love the work I was doing

First Job

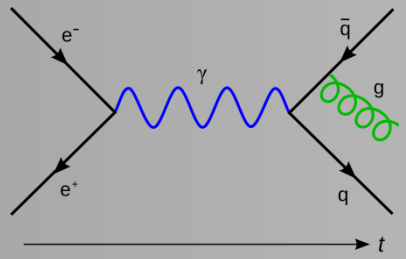


1979 - 1980 Research Scientist, Auckland University, New Zealand

Had a fabulous time – and did the work that turned into 4 my first 6 scientific journal papers

UNIVERSITY OF AUCKLAND
Waipapa Taumata Rau
NEW ZEALAND

Famous Visitor



"The first principle is that you must not fool yourself and yourself is the easiest person to fool"

"reality must take precedence over public relations, for Nature cannot be fooled"

Richard P. Feynman
(1918-1988)

Other Employment

Space Science & Technology Dept.
Rutherford Appleton Lab, UK

RAE, Farnborough

NASA Marshall Space Flight Center, Hunstville, Alabama

University of Southampton

University Centre in Svalbard

Imperial College London

University of Reading

a LOT (>300!) of International Conferences

a favourite: Reykjavik, 1999

My science

- Over the years, I have caried out research using radars and a variety of spacecraft on:
- radiowave propagation (PhD)
- plasma physics
- upflows of ionospheric plasma (NZ & NASA)
- aurora
- magnetic reconnection
- long-term solar change
- solar eruptions (CMEs)
- geomagnetic disturbances
- climate change
- space-weather effects on operational systems

style

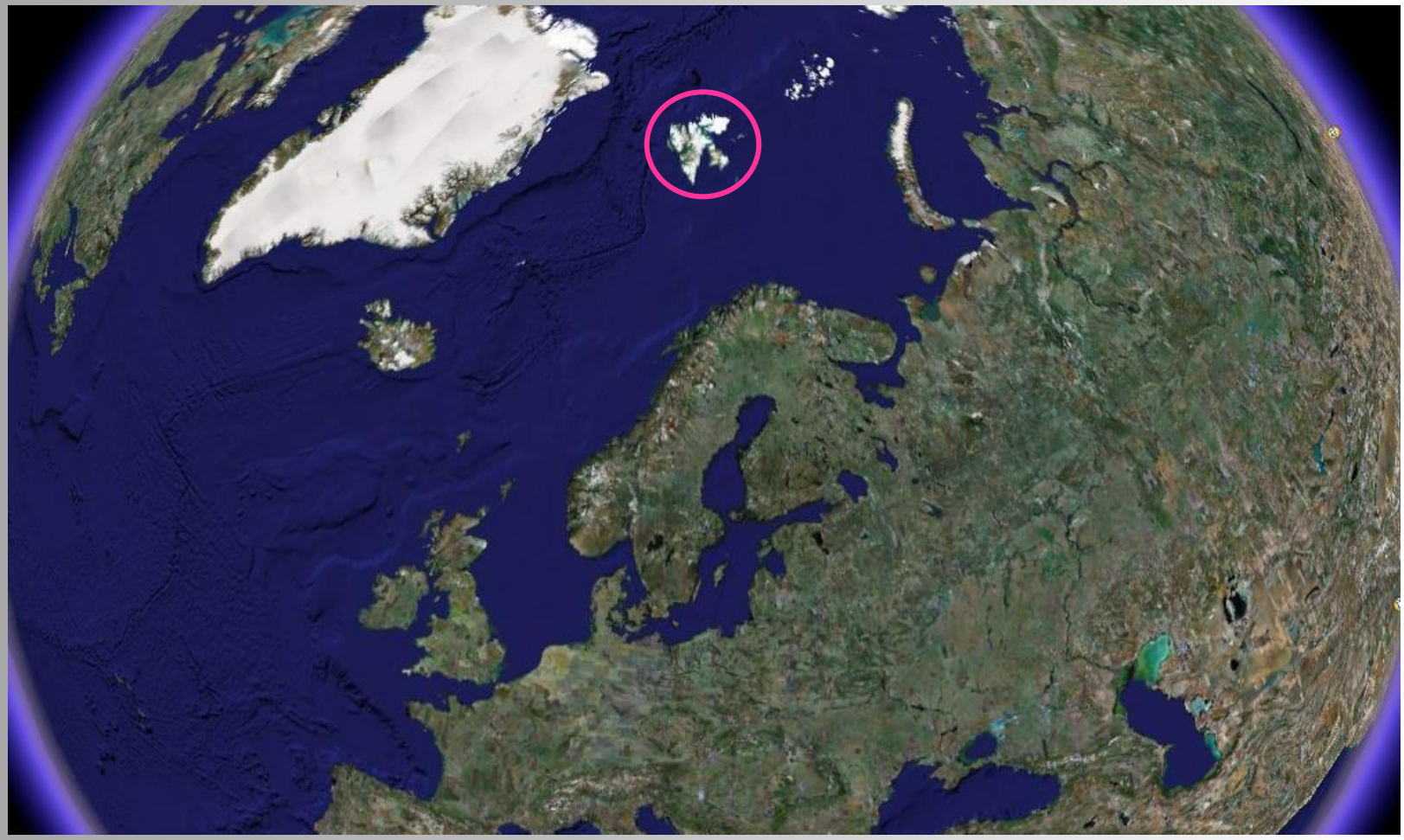
- OVER

content

Dumber Than Chickens

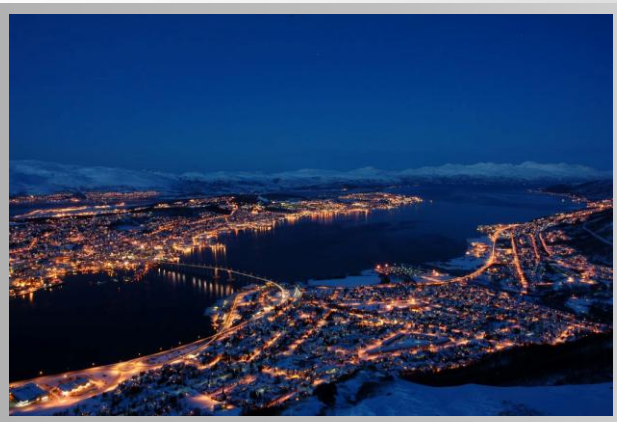
Svalbard

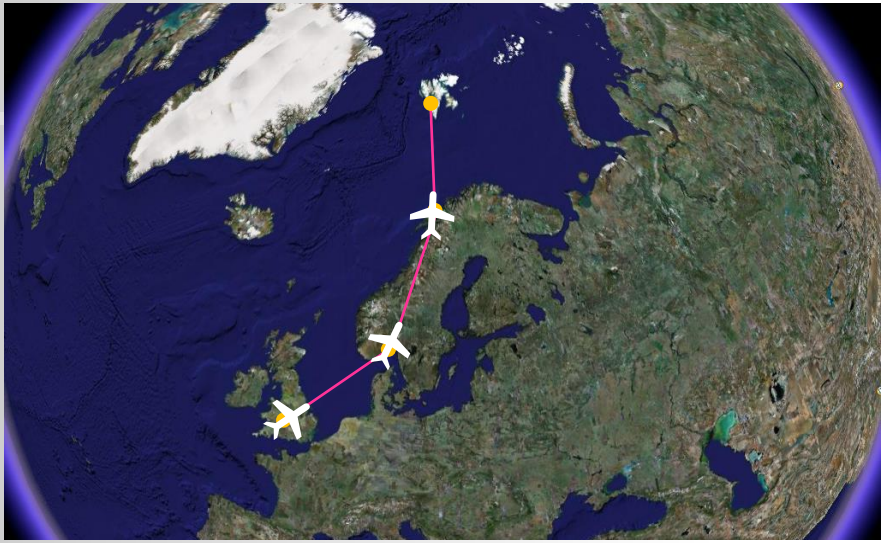
- Where is it?



How do you get there?

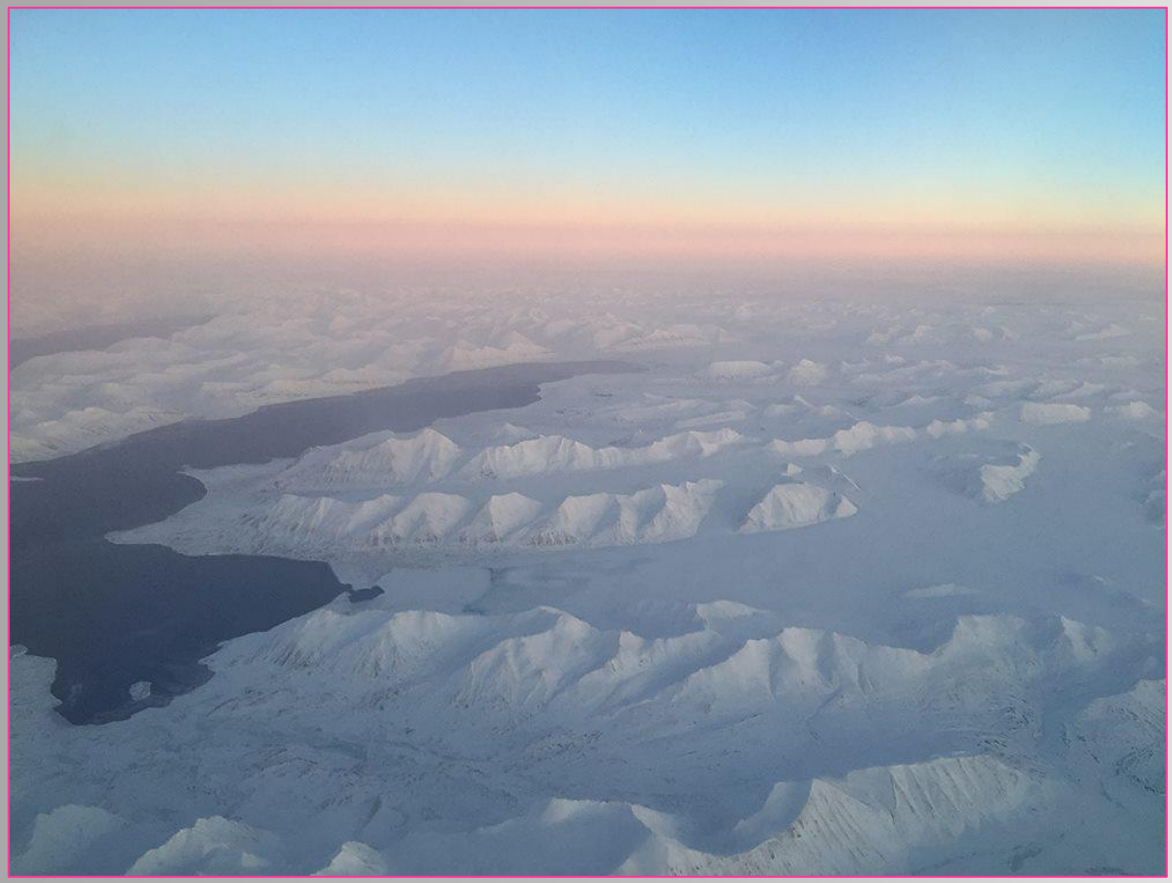
- First fly to Tromsø, northern Norway, via Olso

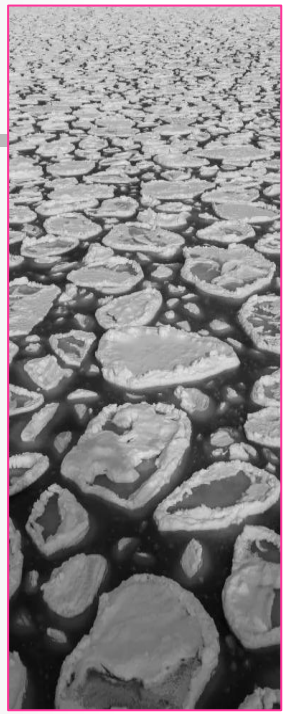




How do you get there?

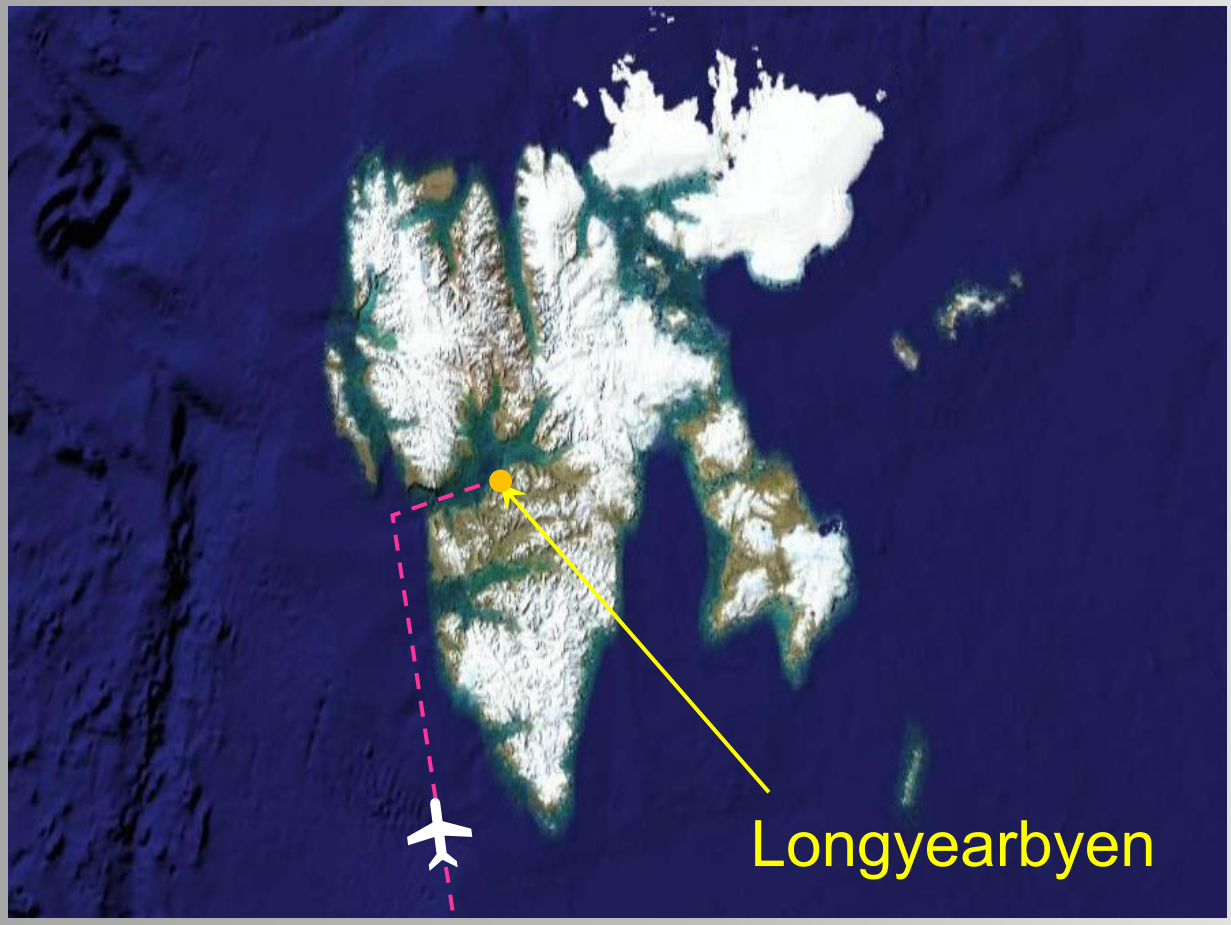
- Commercial daily flights (SAS and Braathens SAFE) from Tromsø, northern Norway





Longyearbyen

- The largest settlement on Spitsbergen, the biggest island of the Svalbard archipelago



- A long way from anywhere

Longyearbyen

Longyearbyen

- The world's most northerly permanent human settlement
- Sited by a lake of drinkable water as it is free of glacial meltwater

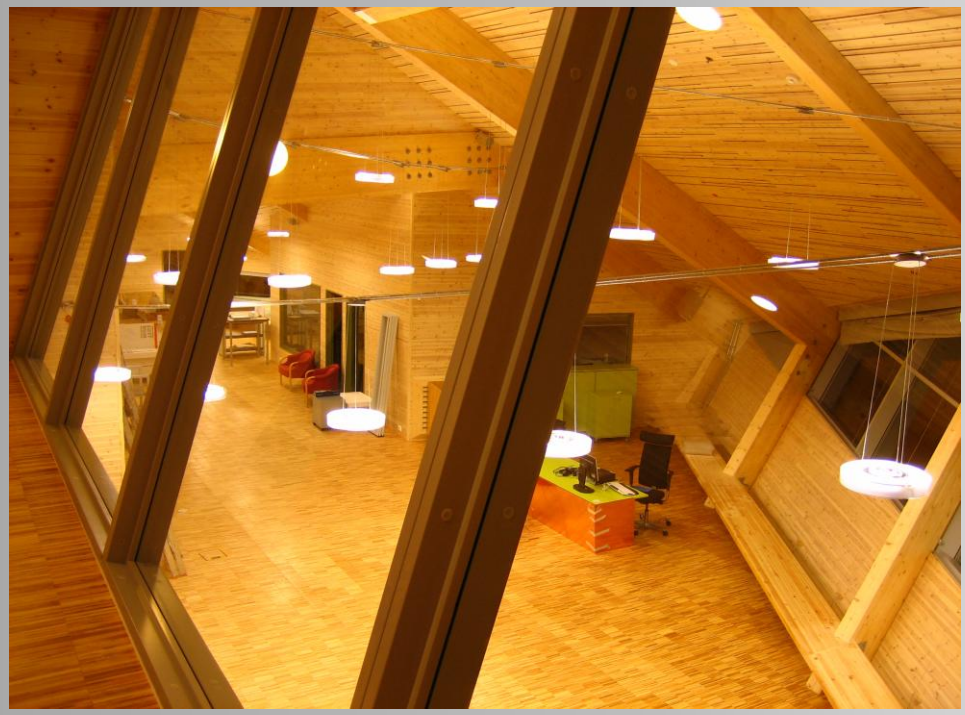
- The "Susselman" ("He who gets things done") is the Governor appointed by the King of Norway
- Ruled under an international treaty that gives anyone the right to go there
- "Huset" ("the House") – a special place

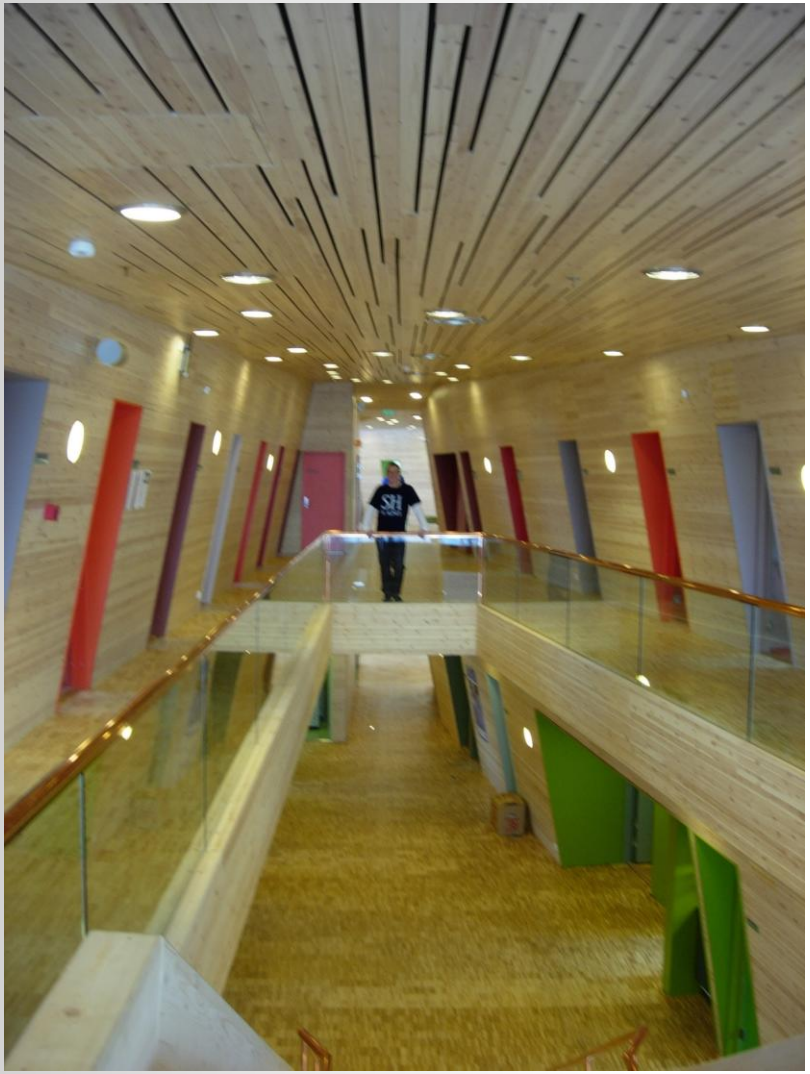
UNIS

- UNIS - the world's most northerly University

Inside UNIS

- "Like a Scandinavian-style interstellar prison ship"





Longyearbyen

▲ A gruvearbeider (miner) at work

▲Taubanesentralen ("the cableway center") was a central hub for the cable car system that brought coal from the mines.

▲ The miners' memorial

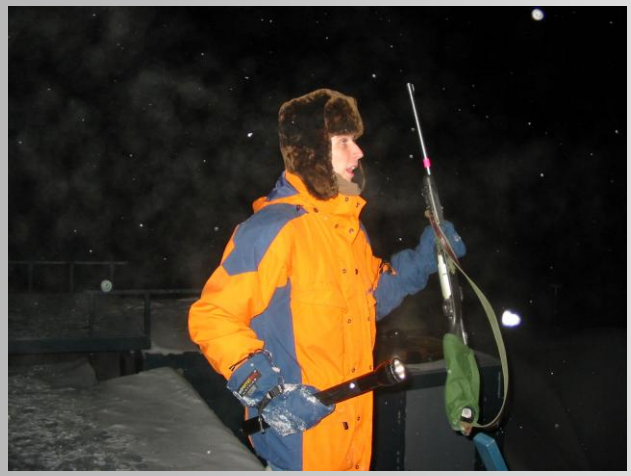
Bears: very cute

Bears: very curious

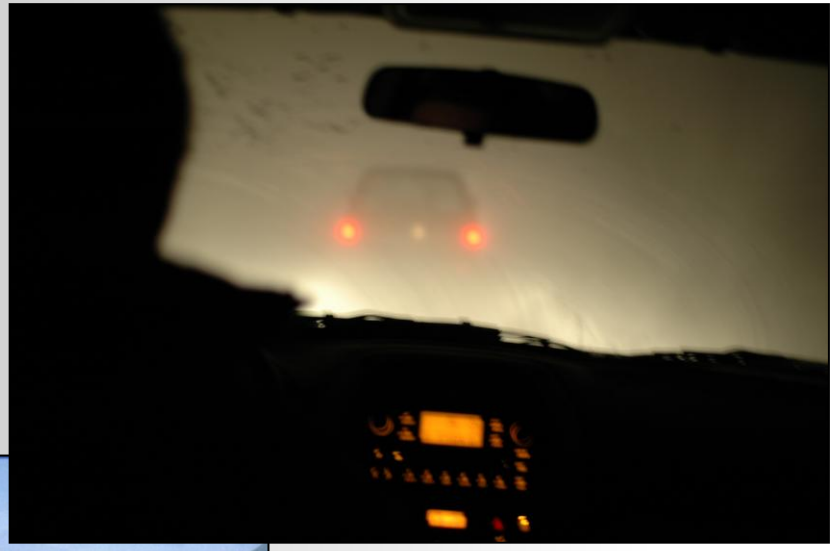
Bears: very dangerous

Bears: staying safe

The sign says “Gjelder Hele Svalbard” which means “Over All of Svalbard (keep a watch for polar bears)”.



Svalbard



The EISCAT Svalbard radars

EISCAT

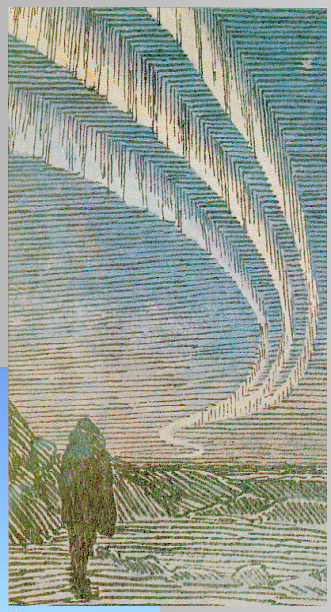
European
Incoherent Scatter

- Sited in Svalbard, mainland Norway, Sweden & Finland, EISCAT is a collaborative venture.

% shares:	to 2006	2007-2012	Now
UK	23%	19%	20%
Norway	10%	25%	26%
Sweden	9%	21%	22%
Finland	5%	10%	11%
Germany	23%	-	-
France	23%	6%	-
Japan	7%	10%	11%
China	-	9%	10%

EISCAT

EISCAT Svalbard Radar



- Adventdalen, Longyearbyen, Svalbard: 42m fixed and 32m steerable antennae, 1050 MHz)

EISCAT

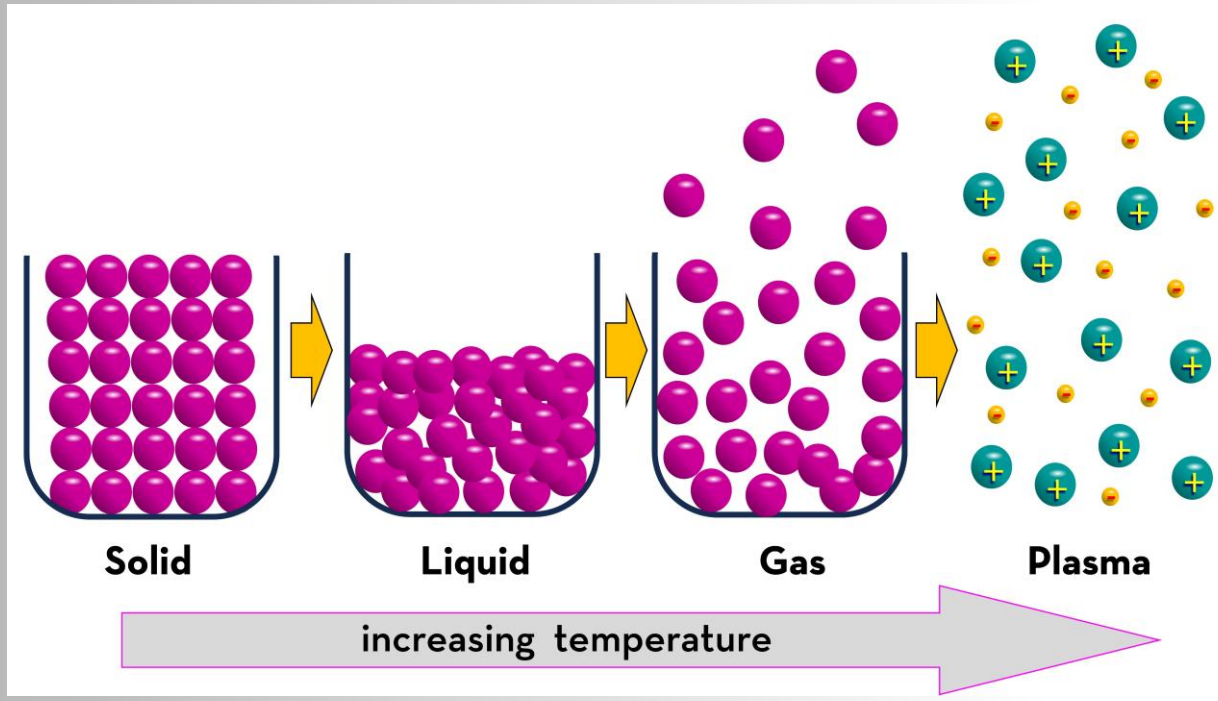
EISCAT Svalbard Radar

- Me in 1996, after the 32m radar was tested and working well
- As chair of the governing EISCAT Council, I was a happy and relieved man



Plasma

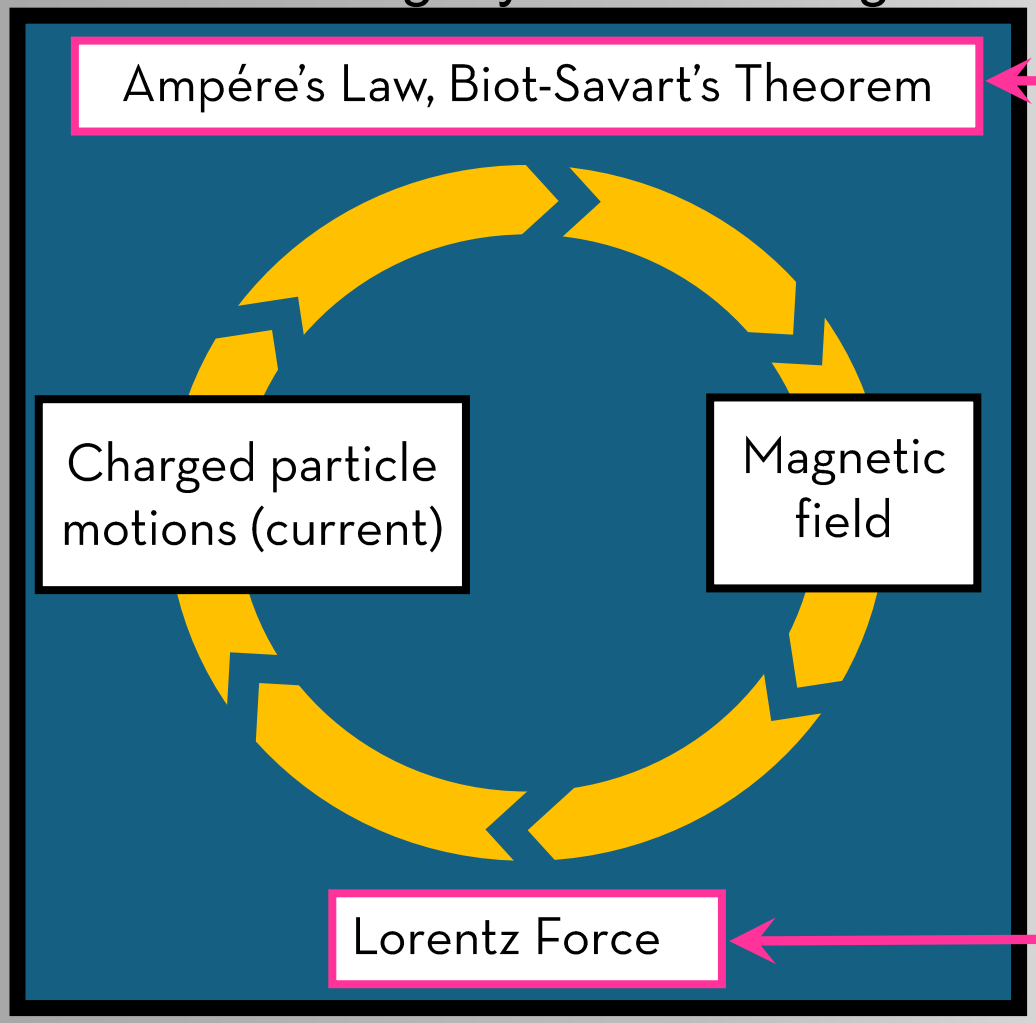
- Plasma is an ionised gas ("4th state of matter")
- as temperature rises: solid → liquid → gas → plasma
- last step is called "ionisation" and occurs because electrons have enough energy to leave gas atoms & form free electrons and positive ions
- 99% of matter in the visible cosmos is in the plasma state (even though it is very rare in Earth's biosphere)

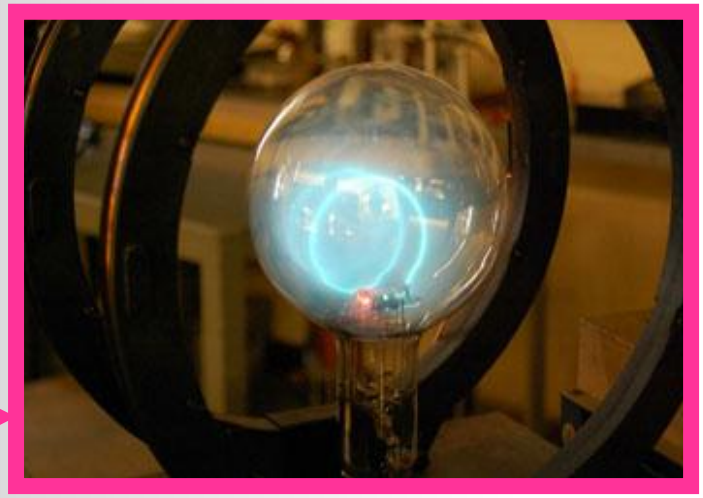




Plasma

- Plasma is tightly linked to magnetic field





The solar Atmosphere (Corona)

- corona is seen in scattered sunlight in eclipses
- corona temperature very high (~ 10^6 K) so it is a fully ionised plasma
- we see magnetic field lines because they give structure the to the plasma

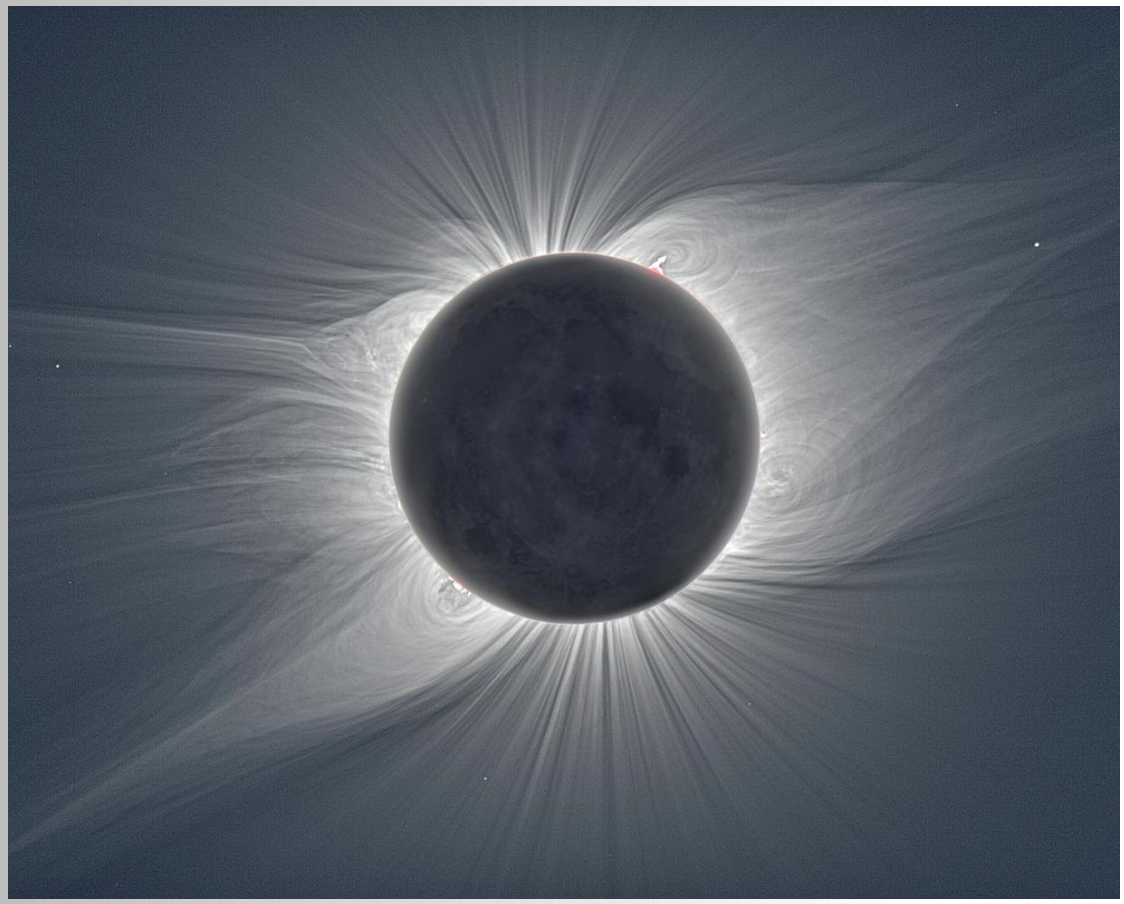
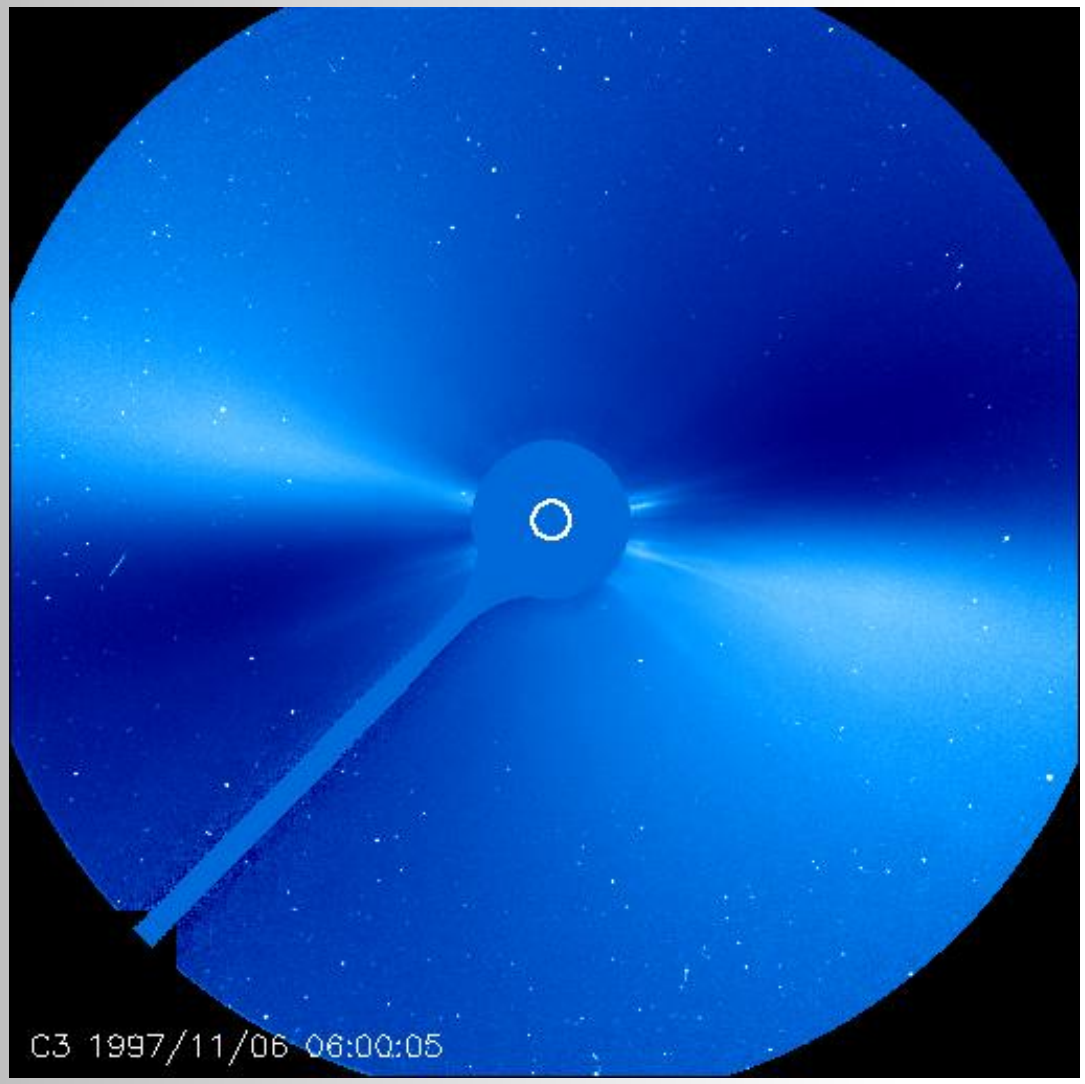
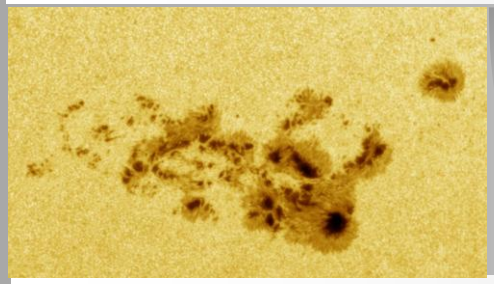


Photo: Miroslav Druckmüller (Brno University)

The solar Atmosphere (Corona)

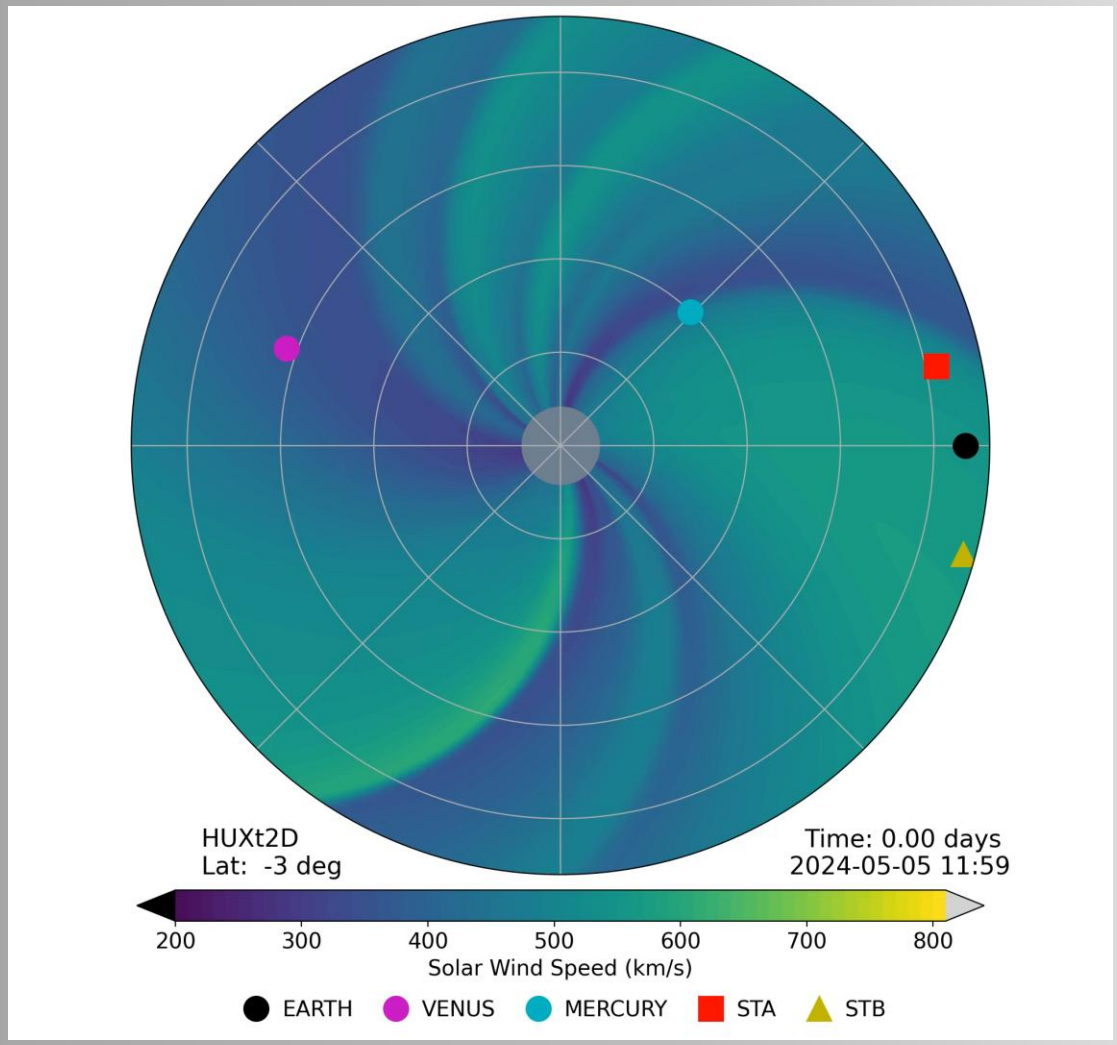
- the same principle is used by a coronagraph
- in the above eclipse example we can see the field loops of a coronal mass ejection (CME) erupting
- CME also seen in coronograph movie – the “snow” is strikes of the detector by Solar Energetic Particles (SEP) generated by the CME



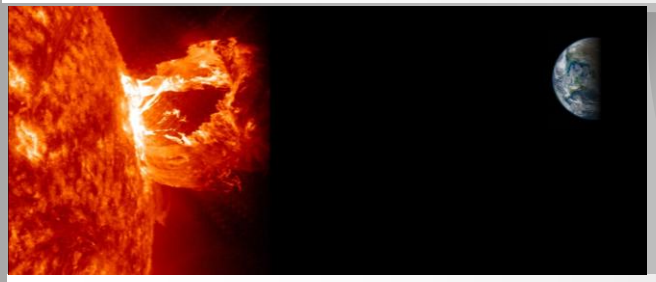


Coronal Mass Ejection

Launched from AR 3664

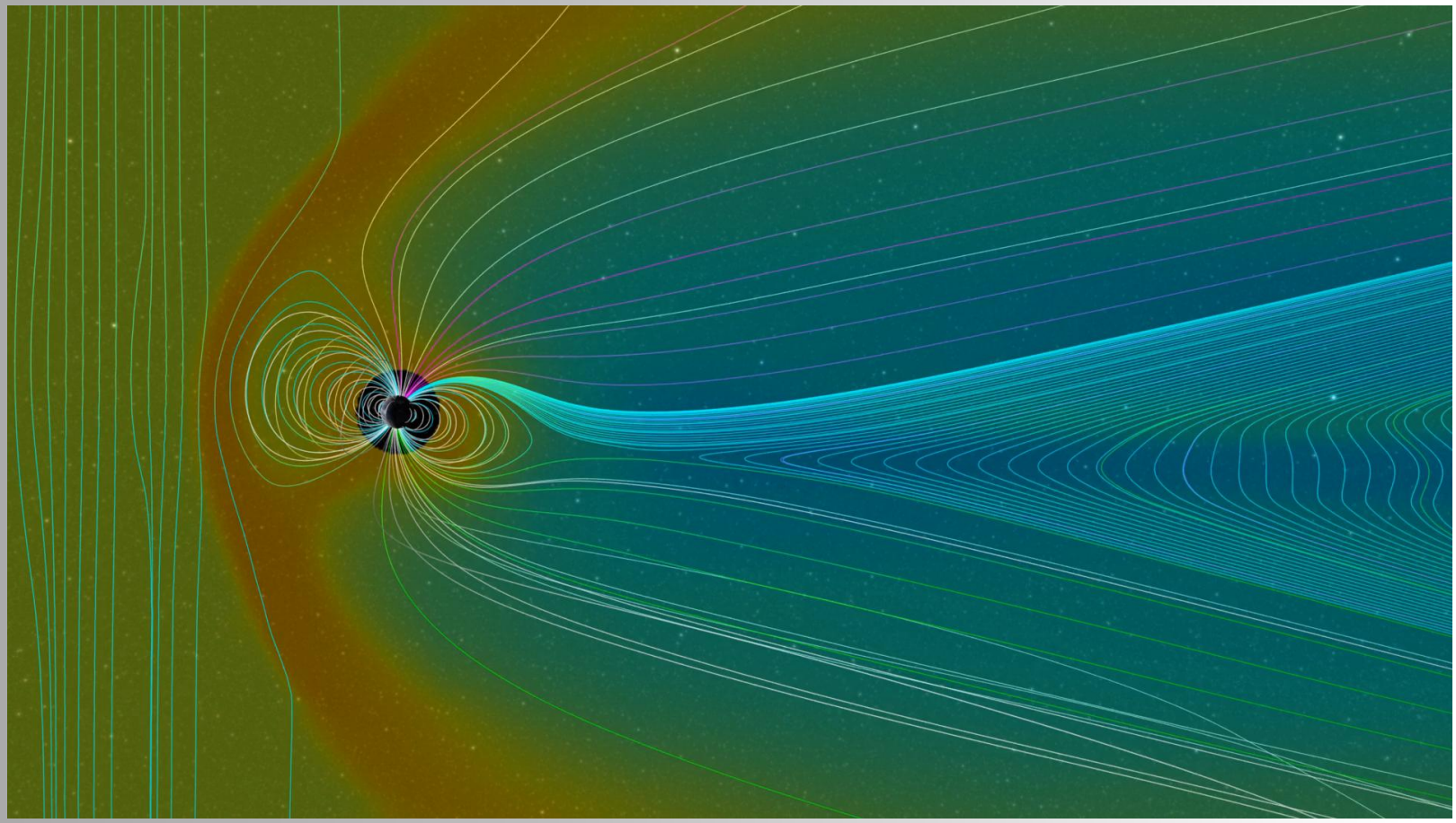


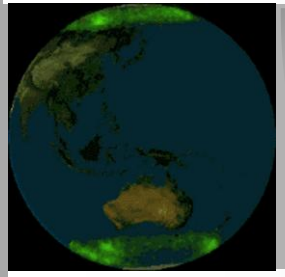
- Forecast made 00 UT 10 May 2024
- Uses the reduced-physics HUXt model (Mat Owens & Luke Barnard at UoR)
- Can be run many times to give large ensemble of predictions and hence probabilities of effects at Earth
- Storm commenced 17 UT, as predicted



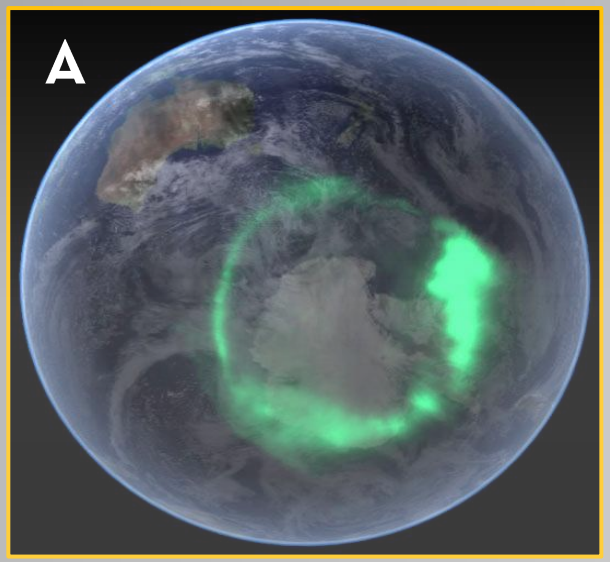
Simulation of when a CME Hits the Earth

- Numerical Computer "MHD" (MagnetoHydroDynamic) simulation of Earth's "magnetosphere" when it is hit by a CME

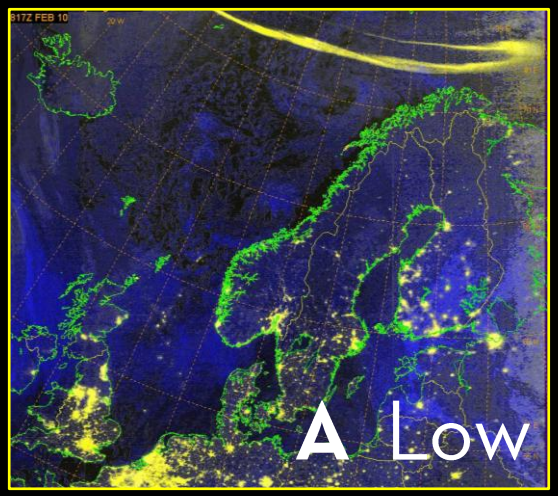


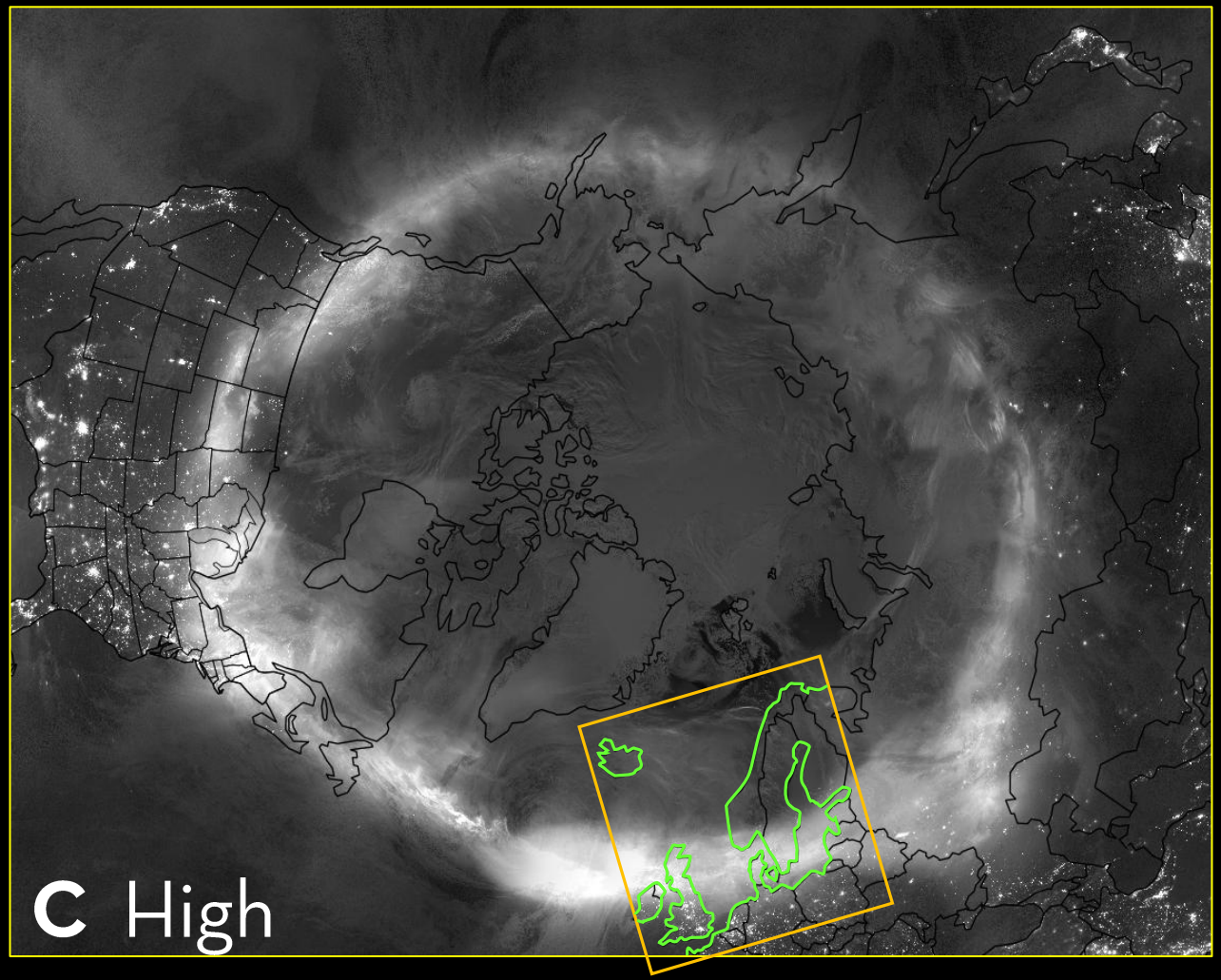


Aurora

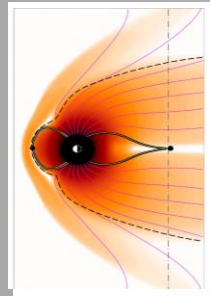


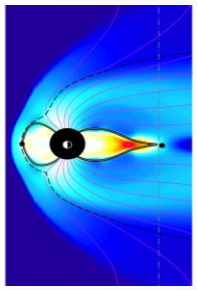
Aurora and Activity Level





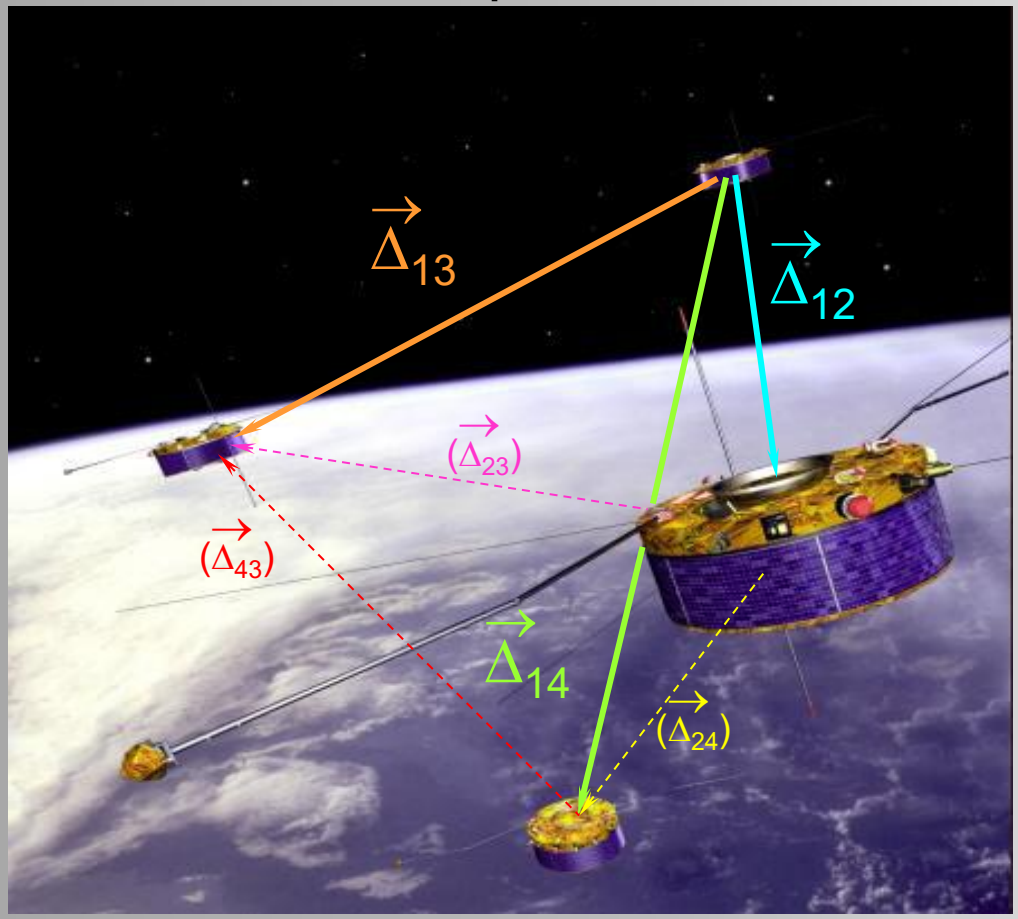
Aurora: fascinating and beautiful



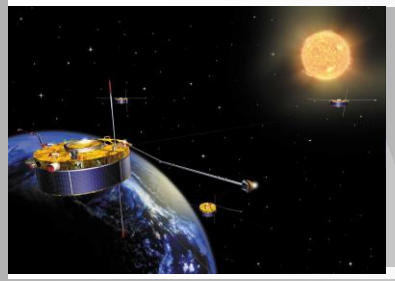


Cluster

- the first 3-dimensional observations of space

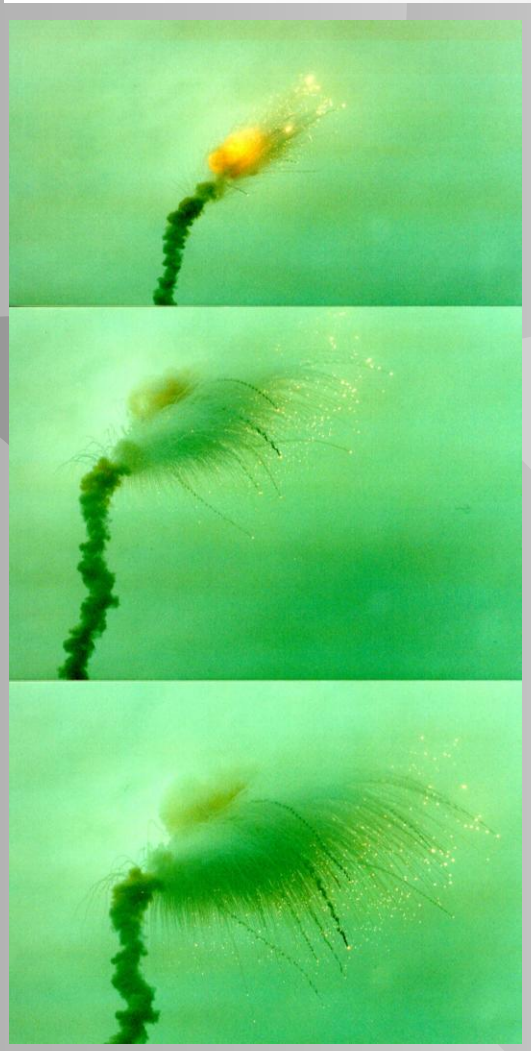


- a cornerstone mission of the European Space Agency (ESA)
- we use timing at 4 craft to find motion, orientation, thickness and curvature of boundaries in space for the first time



Cluster: the first attempt in 1996

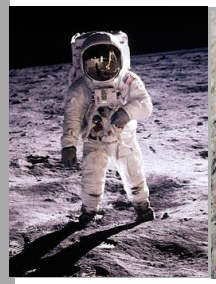
University of Reading



- was to be launched on the first test flight of Arianne 5
- used of software borrowed from Arianne 4
- caused rocket to blow up
- it took 4 years to rebuild instruments and craft an launch on 2 Russian rockets

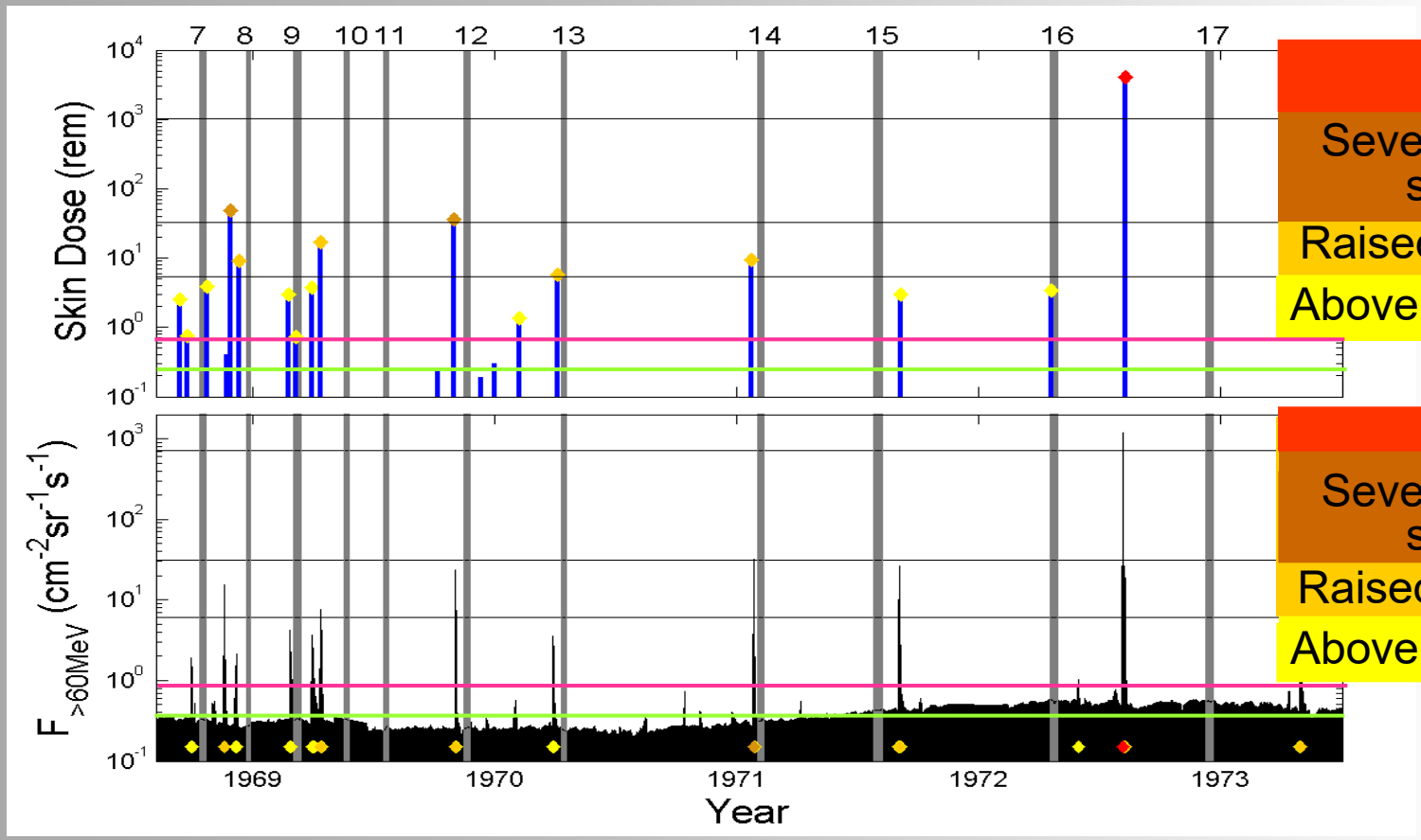
Photos: Andre Balogh (ICL)

The Apollo Missions



SEPs: just how lucky were the lunar astronauts?

- SEPs during the era of the Apollo Missions



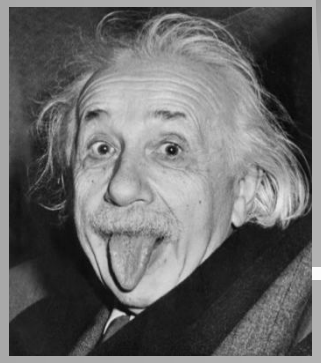
Max. annual dose for a radiation worker

Average annual dose at Earth's surface

Space is a very hostile environment

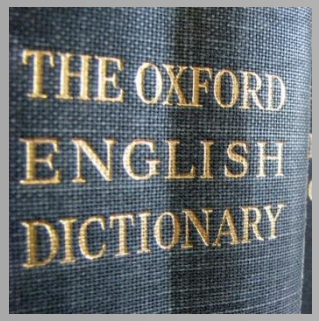
- For equipment, electronics and humans
- Revival of interest in manned space flight to the Moon and Mars
- Energetic particles pose a real threat

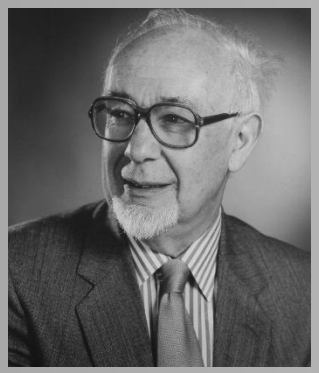
- *artists' impressions of manned bases on our Moon and on a Martian moon*



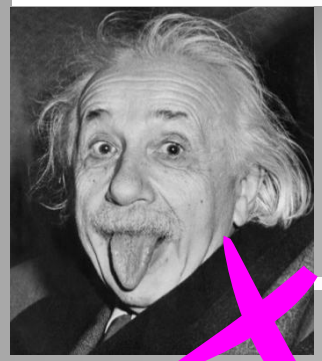
Science

/ˈsʌɪəns/
(noun)





- Cambridge Dictionary: “(knowledge from) the careful study of the structure & behaviour of the physical world, especially by watching, measuring, and doing experiments, and the development of theories to describe the results of these activities”
- Wikipedia: “(from Latin *scientia*, meaning knowledge) is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe.”
- OED: “A systematically organized body of knowledge on a particular subject.”
- John Michael Ziman (1925-2005): “**consensus**, is the touchstone of reliable science”



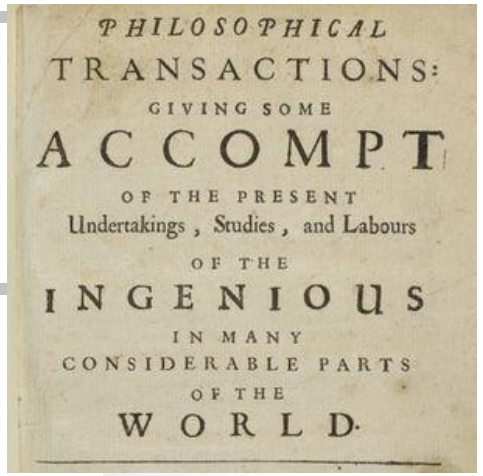
Science Consensus

/ˈsʌɪəns kən ˈsɛnsəs/
(compound noun)

- Wikipedia: “the collective judgment, position, and opinion of the community of scientists in a particular field of study. Consensus implies general agreement, though not necessarily unanimity”

The solar science community at the STEREO-3/SOHO-22 Workshop: “Three Eyes on the Sun: Multi-spacecraft studies of the corona and impacts on the heliosphere” Bournemouth, UK April/May 2009

How we arrive at a scientific consensus: peer review


PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.

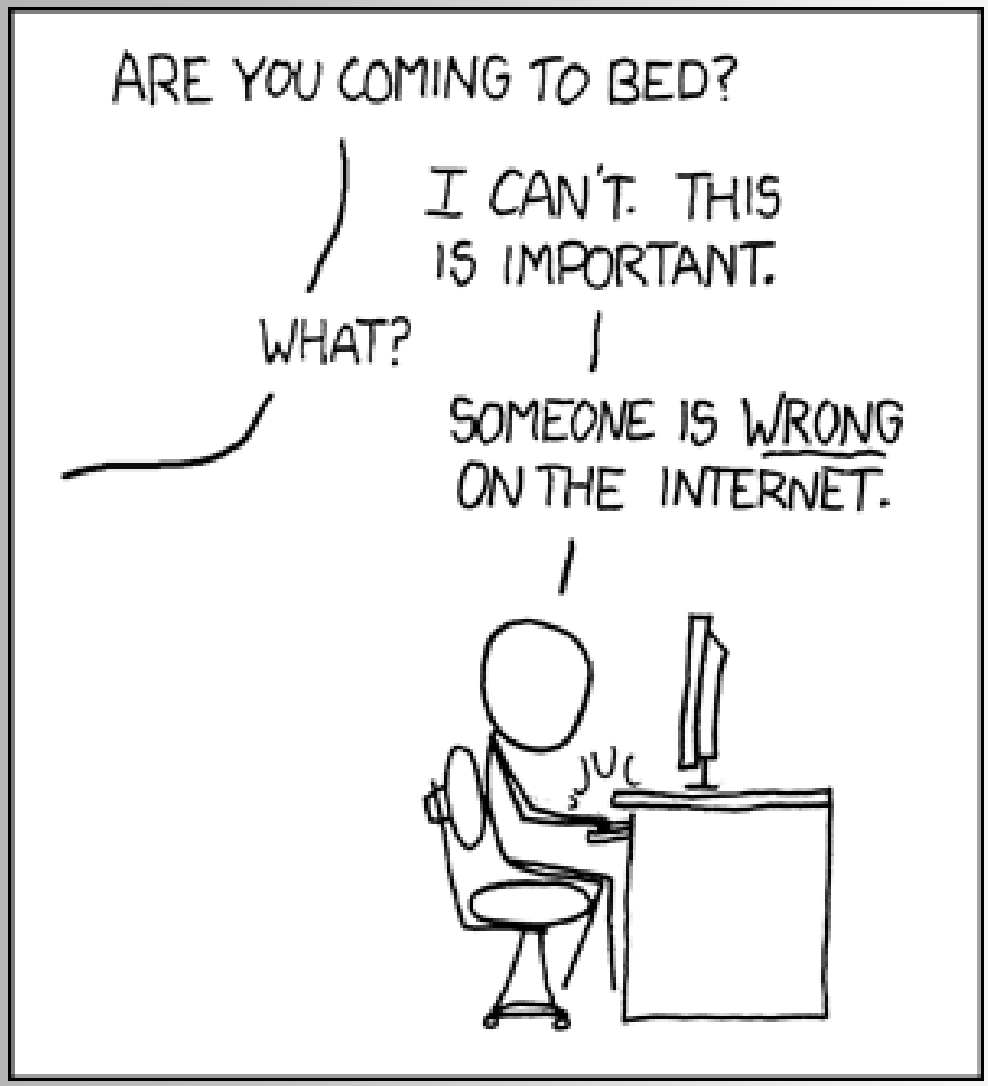
- Peer review is Britain's single greatest contribution to science - bar none!

- first introduced in 1665 by German immigrant, Henry (formerly Heinrich) Oldenburg, the founding Editor of *Philosophical Transactions of the Royal Society*

- formal peer-review procedures as we know them today, developed from his ideas by Sir Francis Bacon & applied to *Medical Essays and Observations* published by the Royal Society of Edinburgh in 1731.

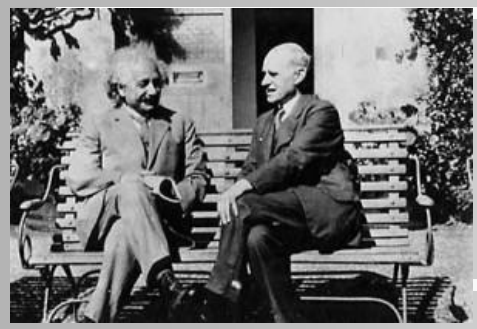
- It is how science expunges "fake news"

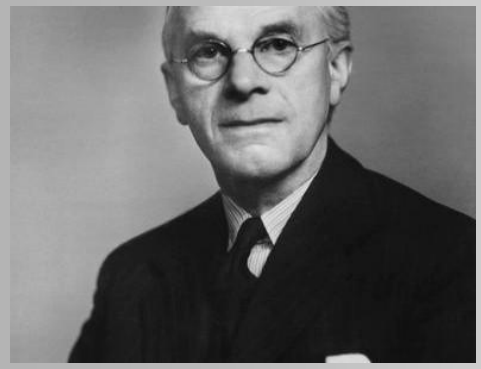
Peer review avoids the information “wild west” we now have on the internet



- As famously observed by xkcd (Randall Munroe)

“Duty Calls”
1st December 2011

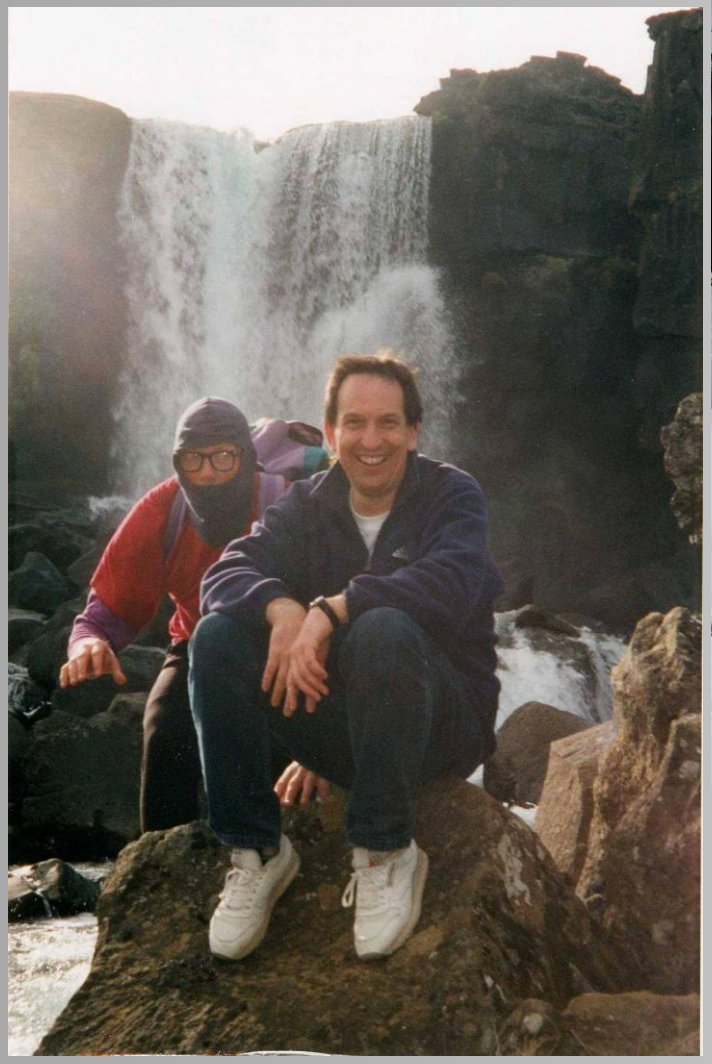


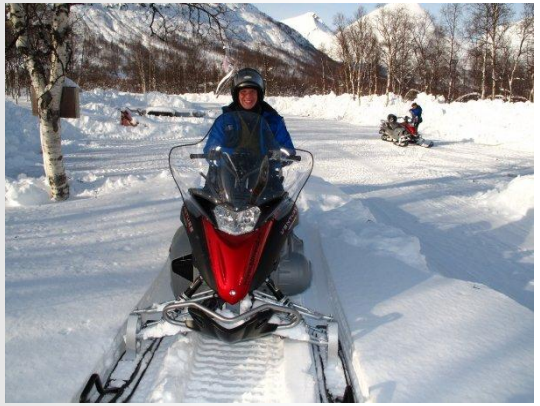


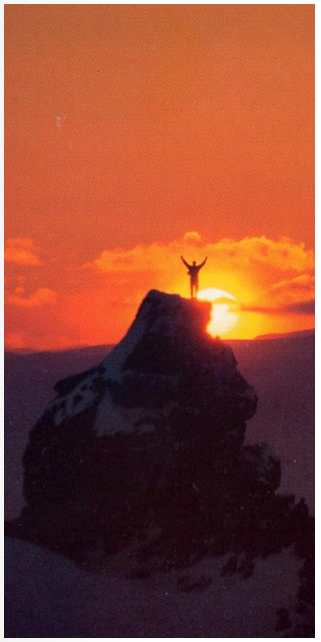
Scientific Consensus at work: Einstein's relativity & GPS

- Objections started to fall away after Eddington's 1919 eclipse observations, consistent with general relativity (GR)
  - Herbert Dingle – spectroscopist who from his 1939 Nature letter to his death in 1978 published or tried to publish articles about why Einstein's special relativity (SR) was wrong. Still invoked on the internet
  - Sat-Nav: GPS (designed 1973, first launch 1978) use corrections for both SR and GR on its satellite clocks. 1ns timing error → 30cm position error, Without SR and GR error grows at 2km and 13 km per day, respectively! **Consensus matters**.

Scientific life is also (lots of) fun







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(University of Reading, UK)

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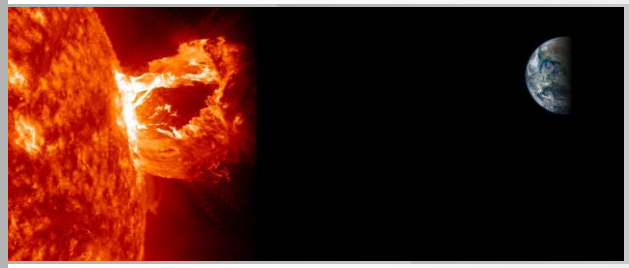
(University of Reading, UK)

SPARES!



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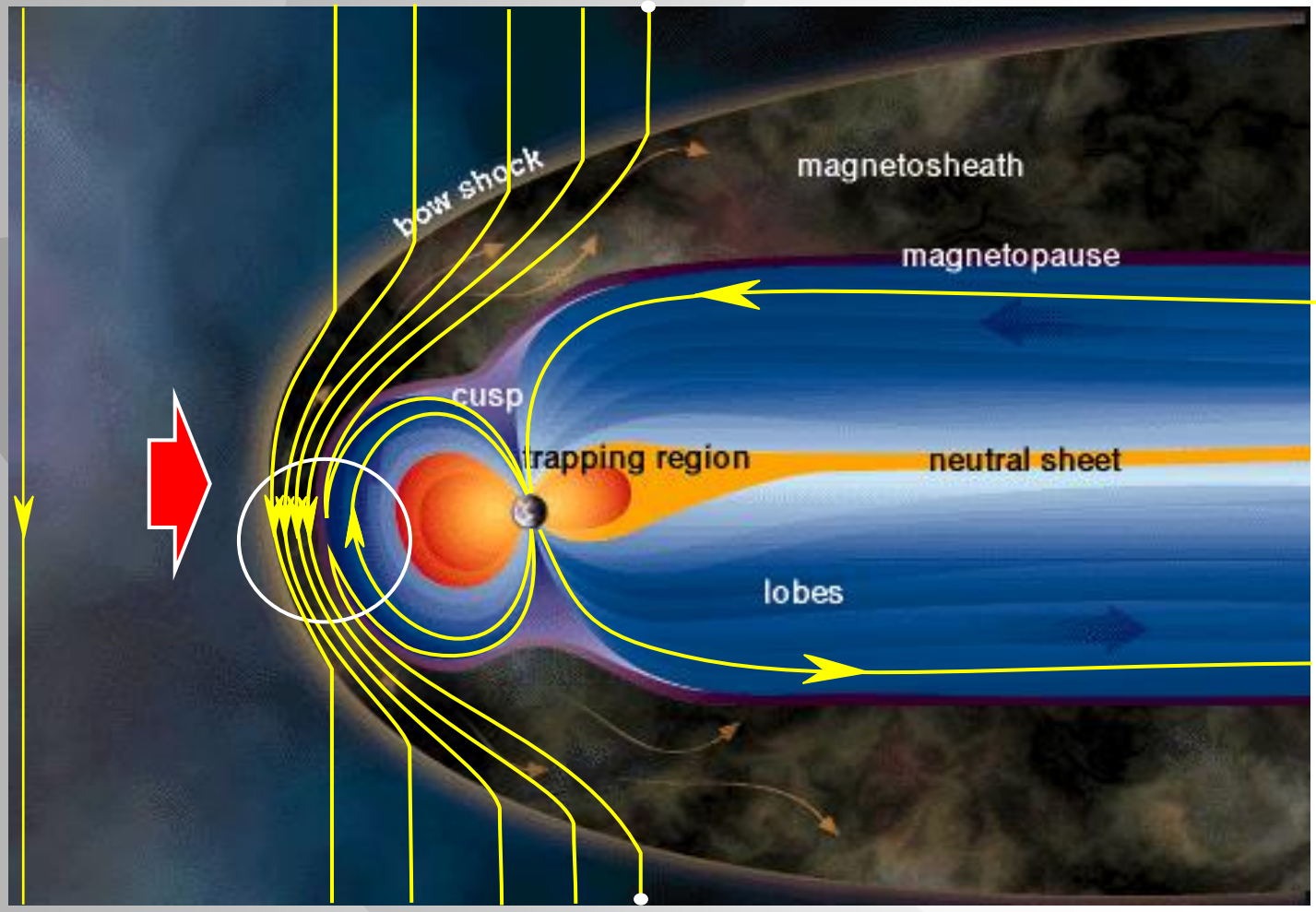
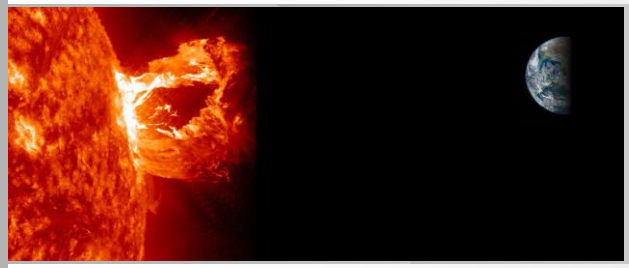
The Magnetosphere during southward IMF





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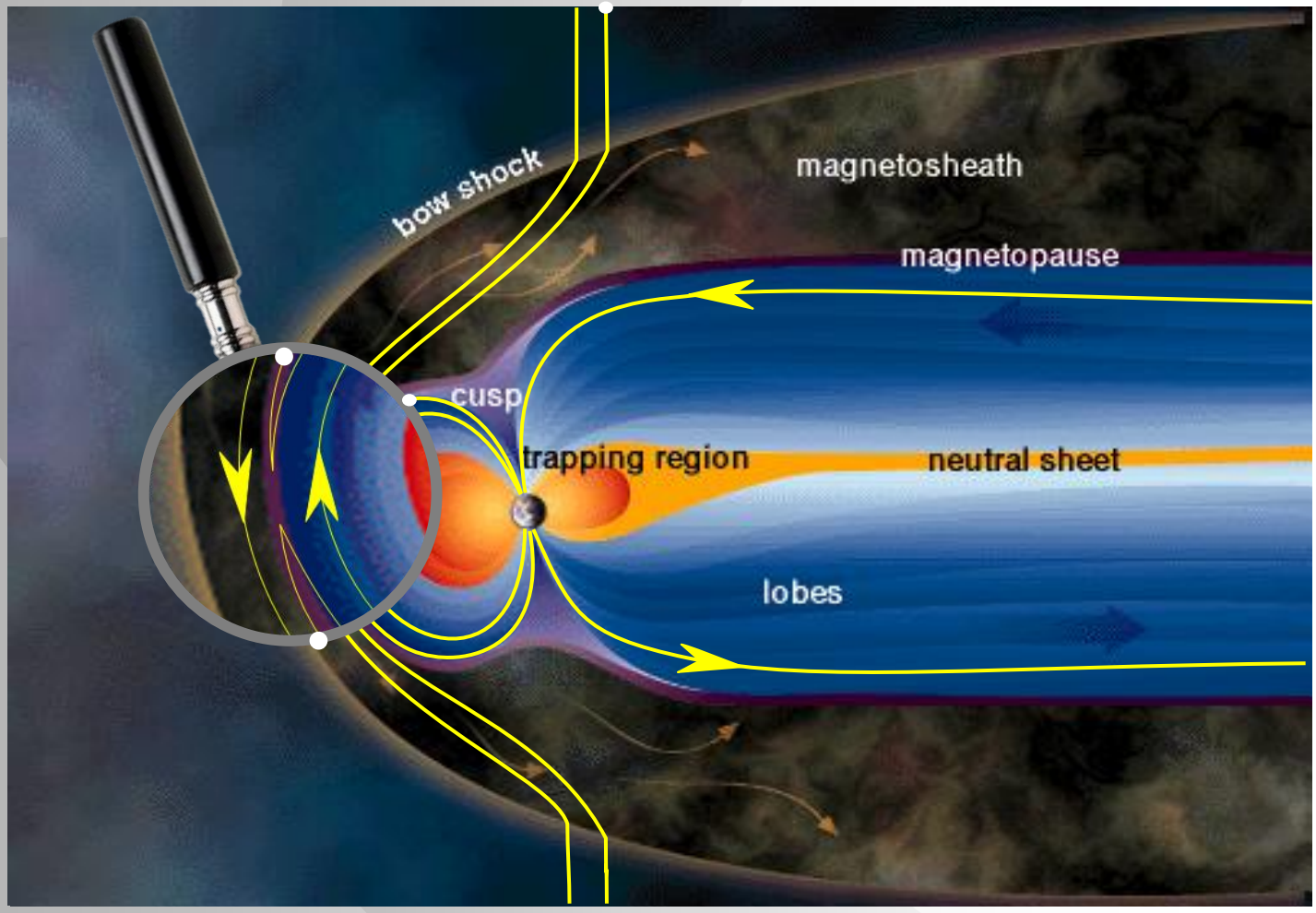
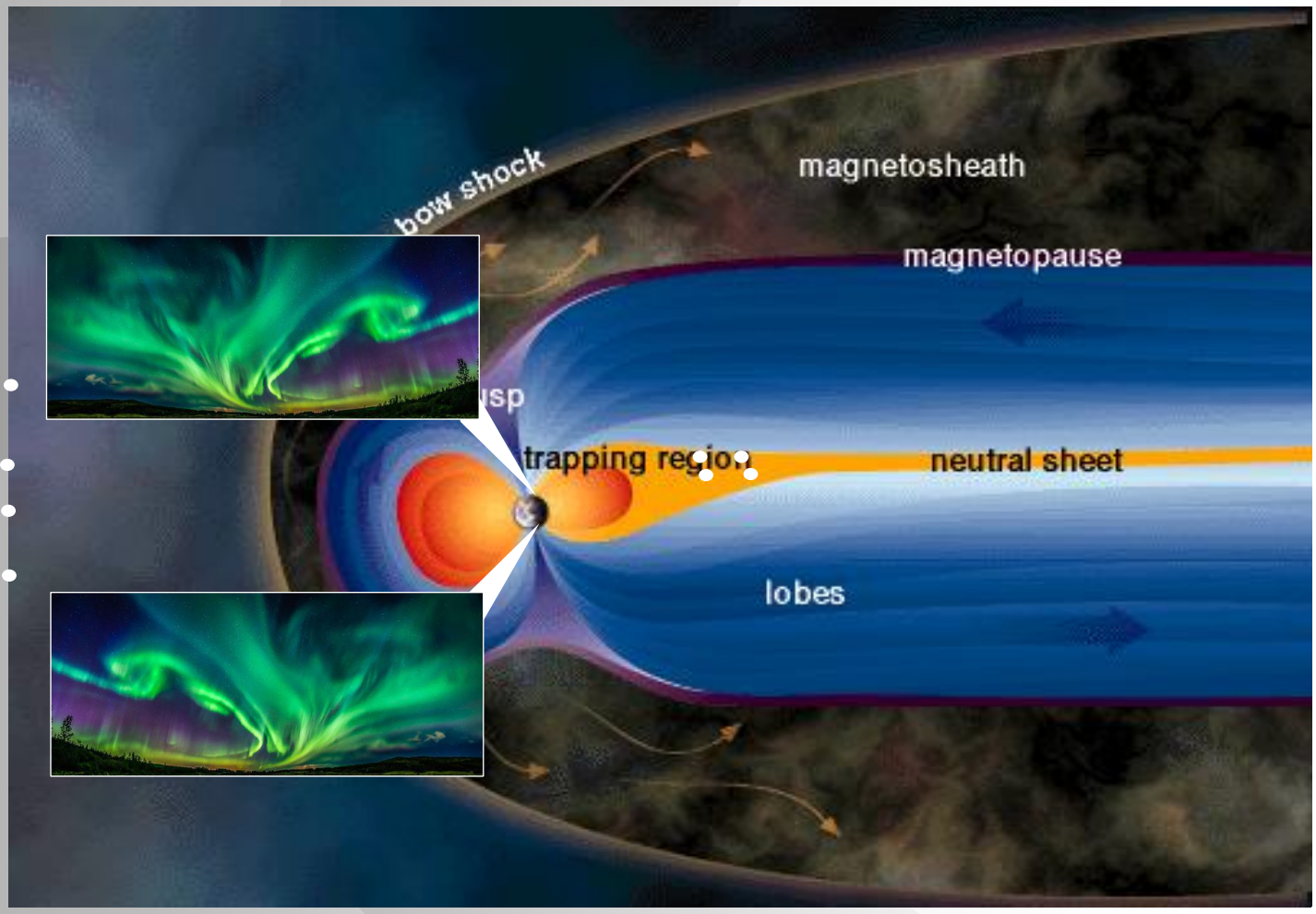
Reconnection near the nose of the magnetosphere



Nightside auroral particles from the solar wind



Nightside auroral particles from the ionosphere

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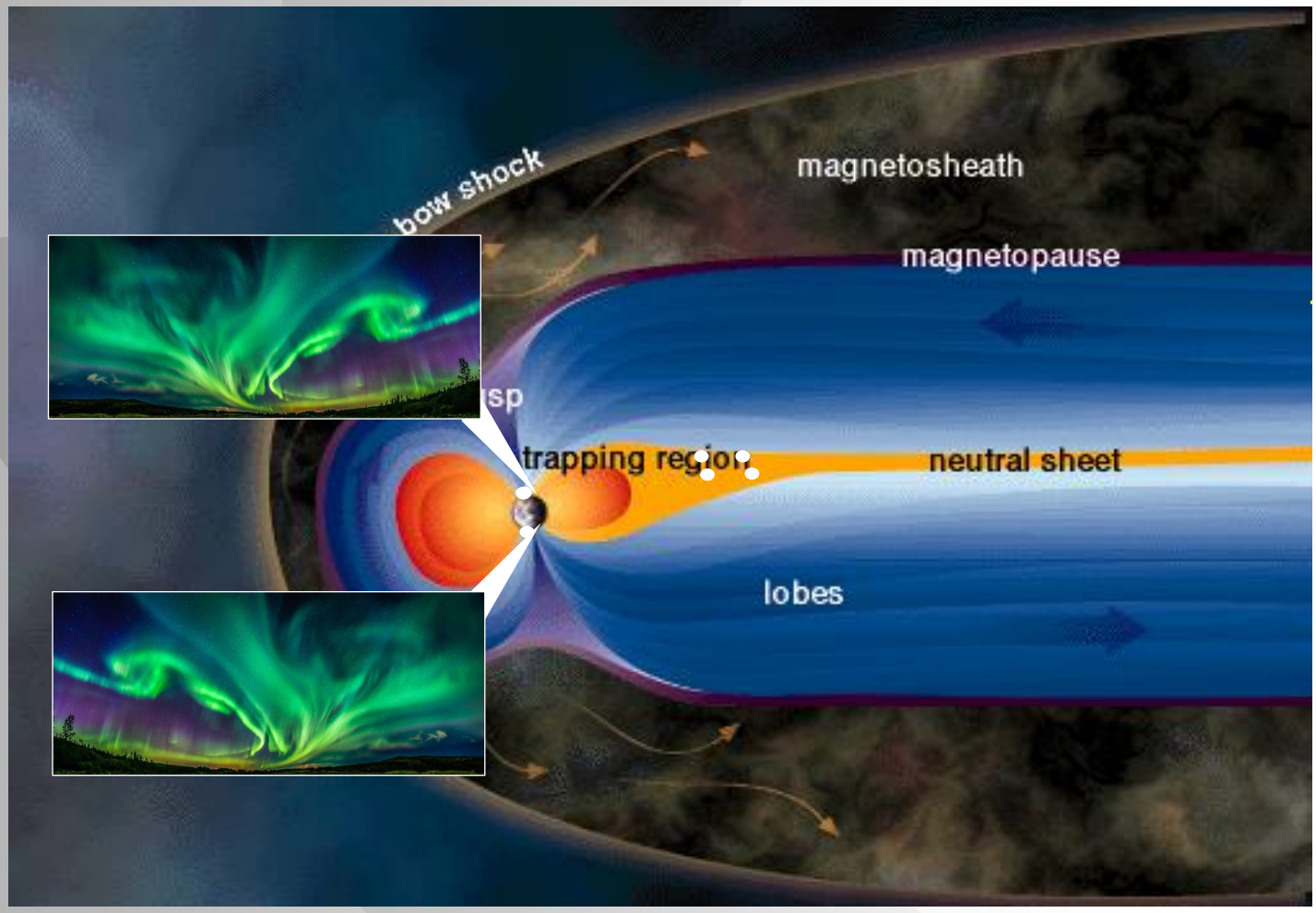

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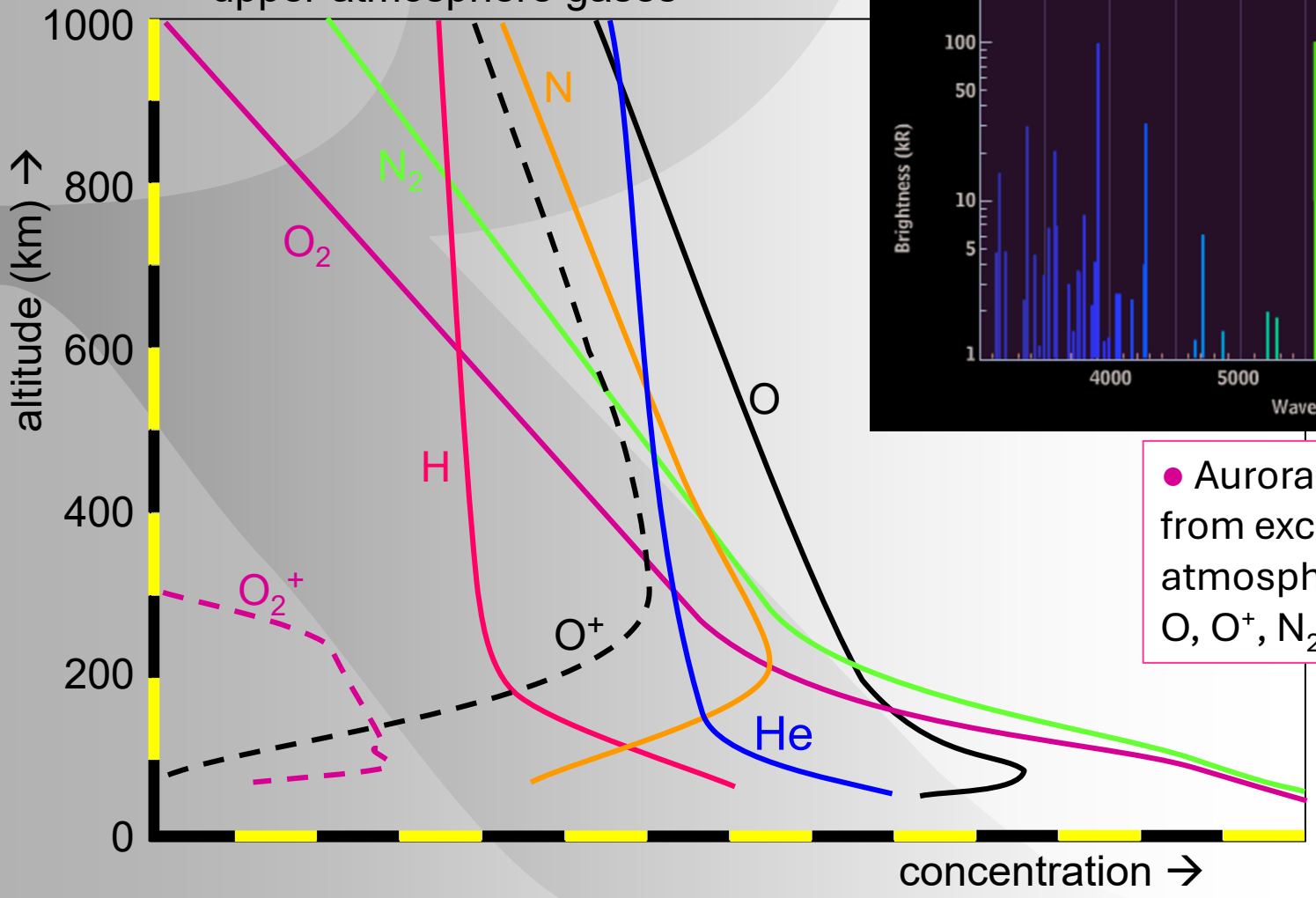
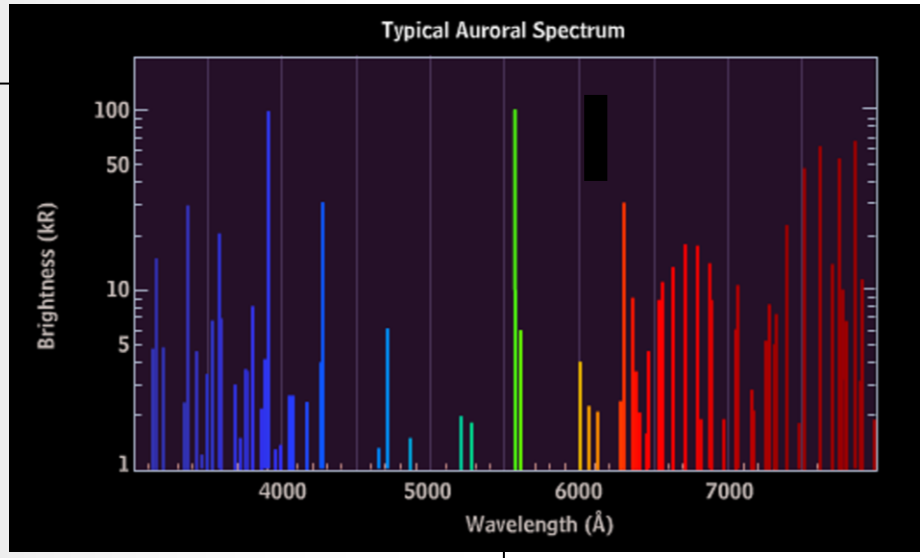
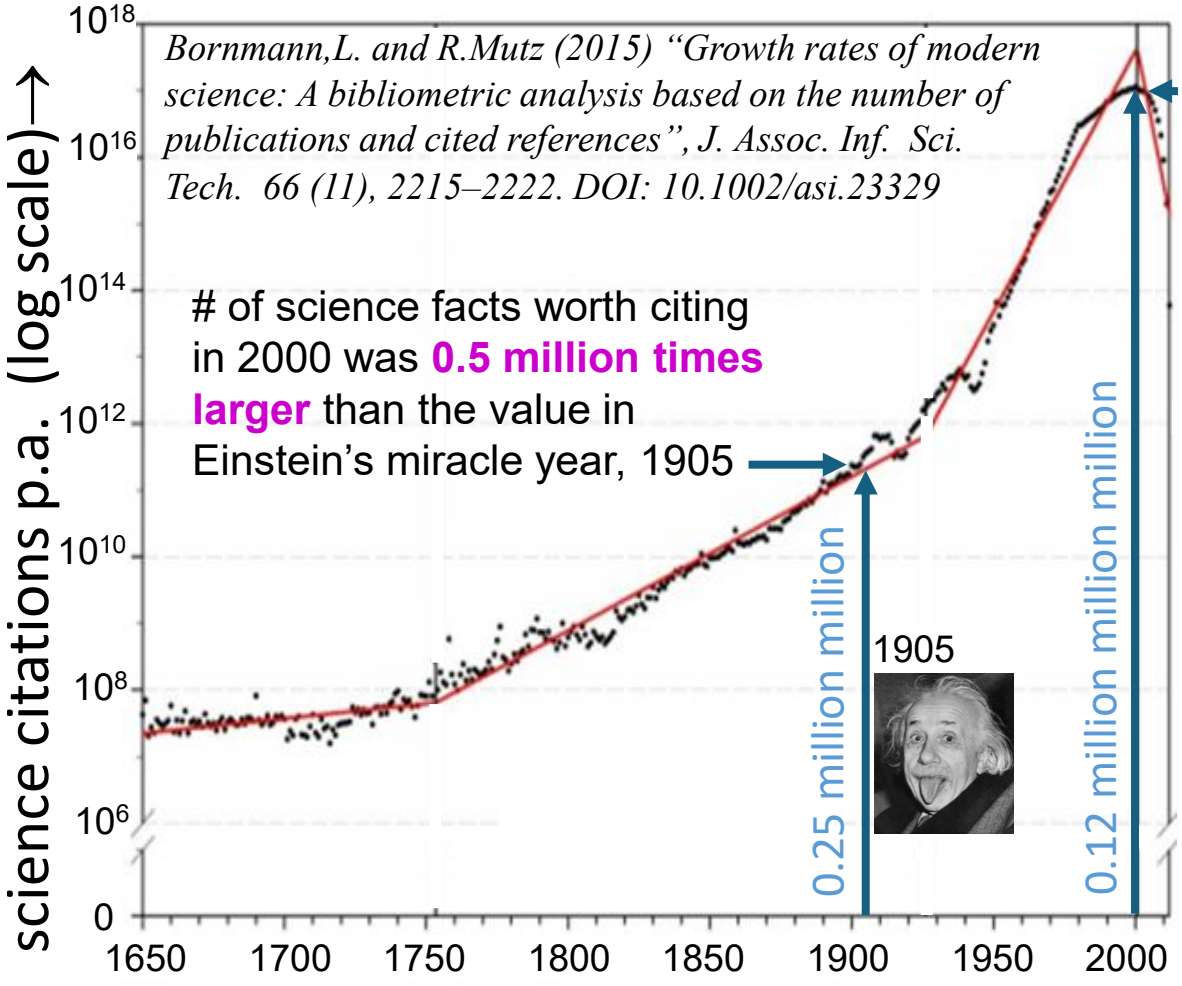
Origins of auroral colours

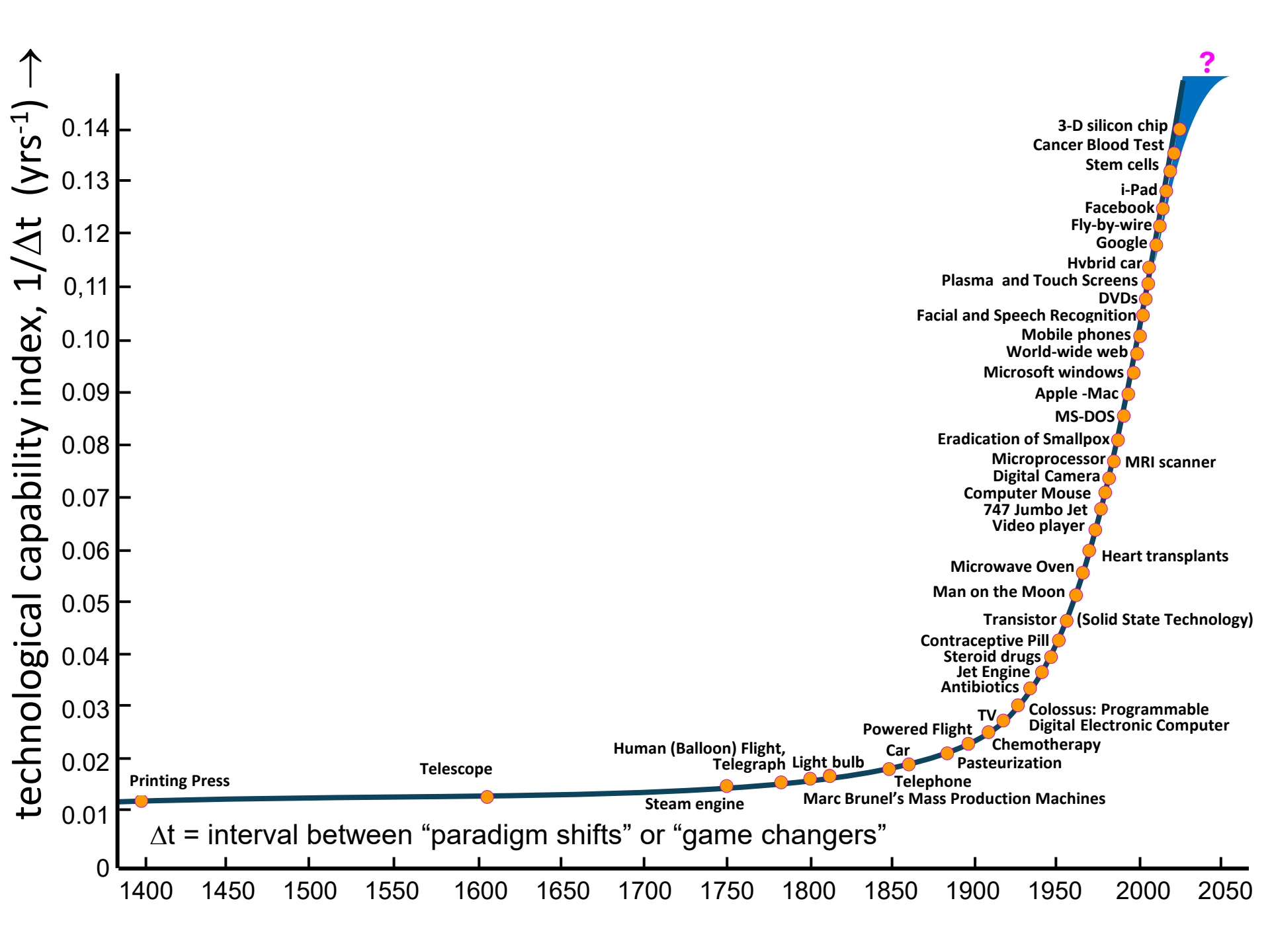
- upper atmosphere gases

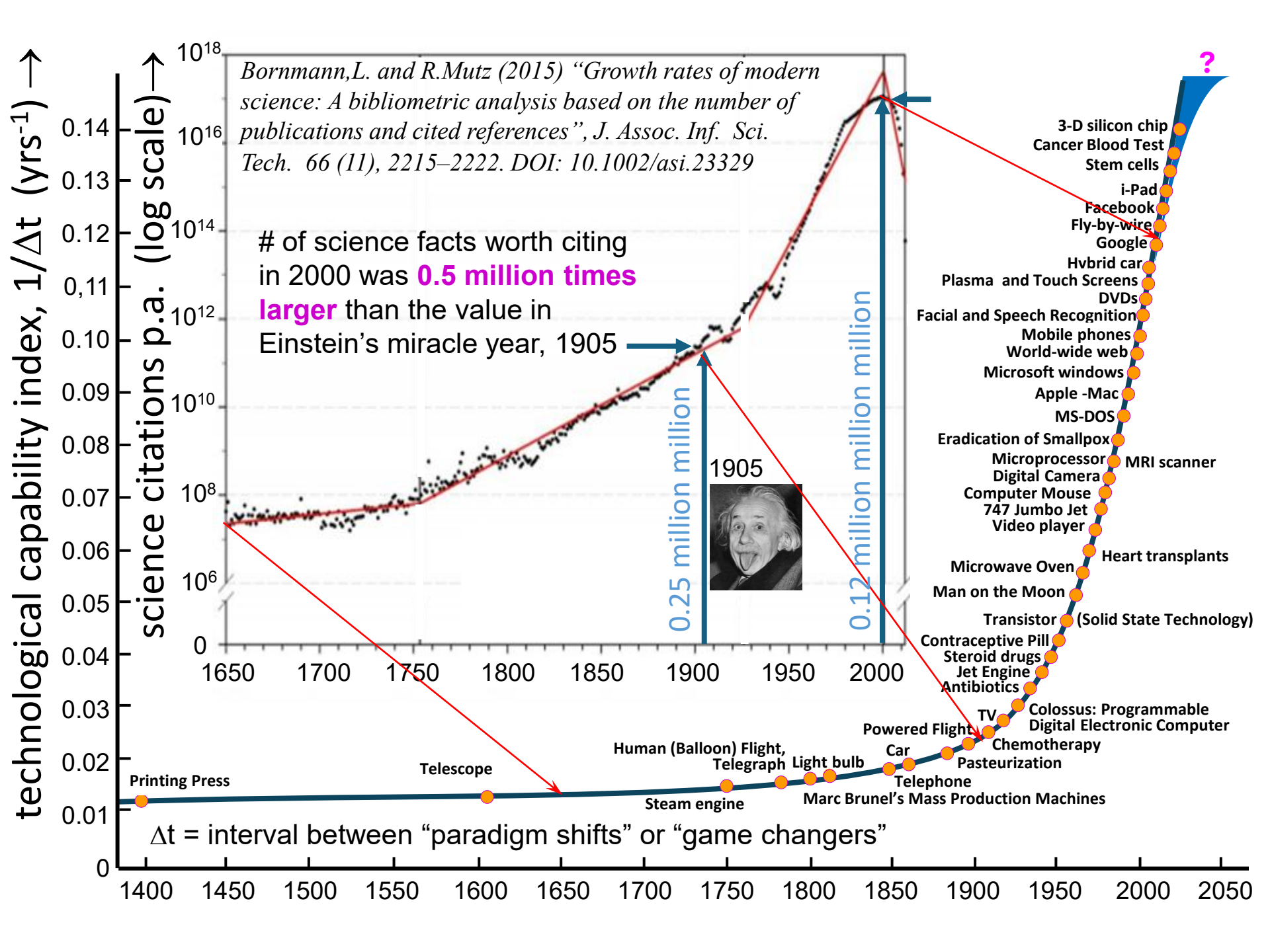




- Auroral emissions arise from excitation of upper atmosphere gasses H, N, O, O^+, N_2, N_2^+, O_2, and O_2^+


Bornmann,L. and R.Mutz (2015) "Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references", J. Assoc. Inf. Sci. Tech. 66 (11), 2215–2222. DOI: 10.1002/asi.23329
# of science facts worth citing in 2000 was 0.5 million times larger than the value in Einstein's miracle year, 1905
science citations p.a. (log scale)→
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
10^{8}
10^{6}
0
1650
1700
1750
1800
1850
1900
1950
2000
1905
0.25 million million
0.12 million million million


technological capability index, 1/Δt (yrs-1) →
0.14
0.13
0.12
0,11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
2050
?
3-D silicon chip
Cancer Blood Test
Stem cells
i-Pad
Facebook
Fly-by-wire
Google
Hybrid car
Plasma and Touch Screens
DVDs
Facial and Speech Recognition
Mobile phones
World-wide web
Microsoft windows
Apple -Mac
MS-DOS
Eradication of Smallpox
Microprocessor
MRI scanner
Digital Camera
Computer Mouse
747 Jumbo Jet
Video player
Heart transplants
Microwave Oven
Man on the Moon
Transistor
(Solid State Technology)
Contraceptive Pill
Steroid drugs
Jet Engine
Antibiotics
Colossus: Programmable
Digital Electronic Computer
TV
Powered Flight
Chemotherapy
Car
Pasteurization
Telephone
Human (Balloon) Flight,
Telegraph
Light bulb
Marc Brunel's Mass Production Machines
Steam engine
Telescope
Printing Press
Δt = interval between "paradigm shifts" or "game changers"


technological capability index, 1/Δt (yrs⁻¹) →
science citations p.a. (log scale) →
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0.25 million million
0.12 million million million
1905
Printing Press
Telescope
Steam engine
Human (Balloon) Flight, Telegraph
Light bulb
Marc Brunel's Mass Production Machines
Telephone
Car
Powered Flight
TV
Pasteurization
Chemotherapy
Colossus: Programmable Digital Electronic Computer
Antibiotics
Jet Engine
Steroid drugs
Contraceptive Pill
Transistor (Solid State Technology)
Man on the Moon
Microwave Oven
Heart transplants
MRI scanner
Microprocessor
Digital Camera
Computer Mouse
747 Jumbo Jet
Video player
Eradication of Smallpox
MS-DOS
Apple -Mac
Microsoft windows
World-wide web
Mobile phones
Facial and Speech Recognition
DVDs
Plasma and Touch Screens
Hybrid car
Google
Fly-by-wire
Facebook
i-Pad
Stem cells
Cancer Blood Test
3-D silicon chip
?
Δt = interval between "paradigm shifts" or "game changers"

Svalbard

Aurora and Activity Level

Lower latitudes

Tends to be more diffuse and sluggish but more varied in colour (seen more clearly by digital cameras than the human eye)

High latitudes

tends to be more structured and dynamic, with multiple arc curtains and fast-changing curls. Dominated by atomic oxygen green line.

GREEN 557.7nm 1-10 keV electrons excite atomic oxygen at 120-180 km (τ=0.5s)

RED 630.0nm ~100eV electrons excite atomic oxygen at 250-500 km (τ=110s)

MAUVE ~5 keV electrons excite ionized molecular nitrogen at 100-120 km (τ=0, "prompt")

BLUE 427.8 nm ~ 1keV electrons excite molecular nitrogen at 300-400 km

PALE GREEN & BLUE 656.3nm & 486.1nm ~10keV protons at 110-120km

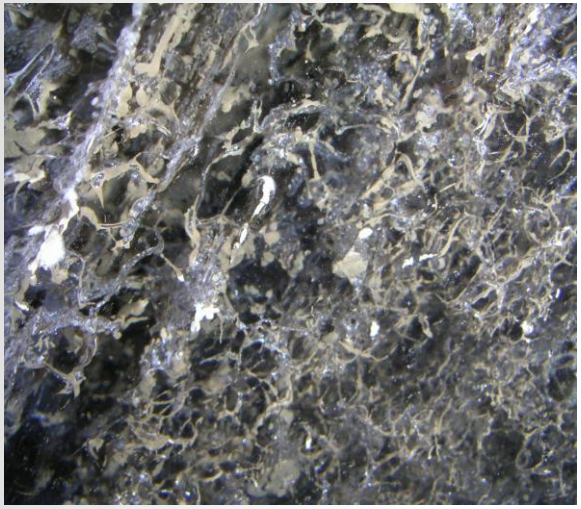
Other colours (WHITE, PINK, PURPLE , ORANGE) come from mixtures of above emissions

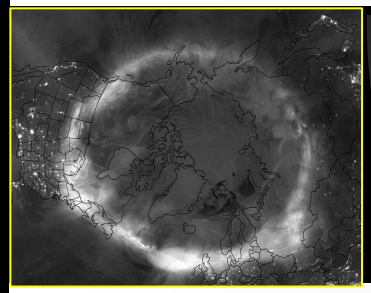
EISCAT

EISCAT Svalbard Radar

Svalbard

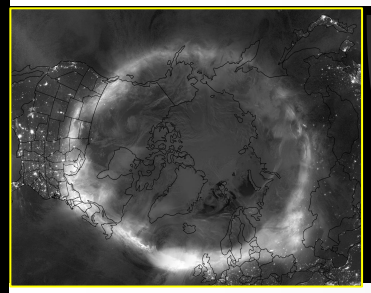
Svalbard





Aurora of 10-11 May, 2024

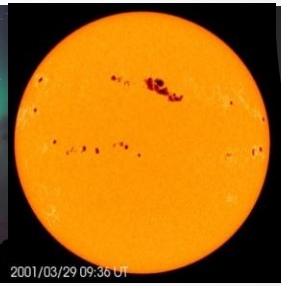
St Mary's Lighthouse in Whitley Bay, Tyne and Wear (photo byOwen Humphreys)



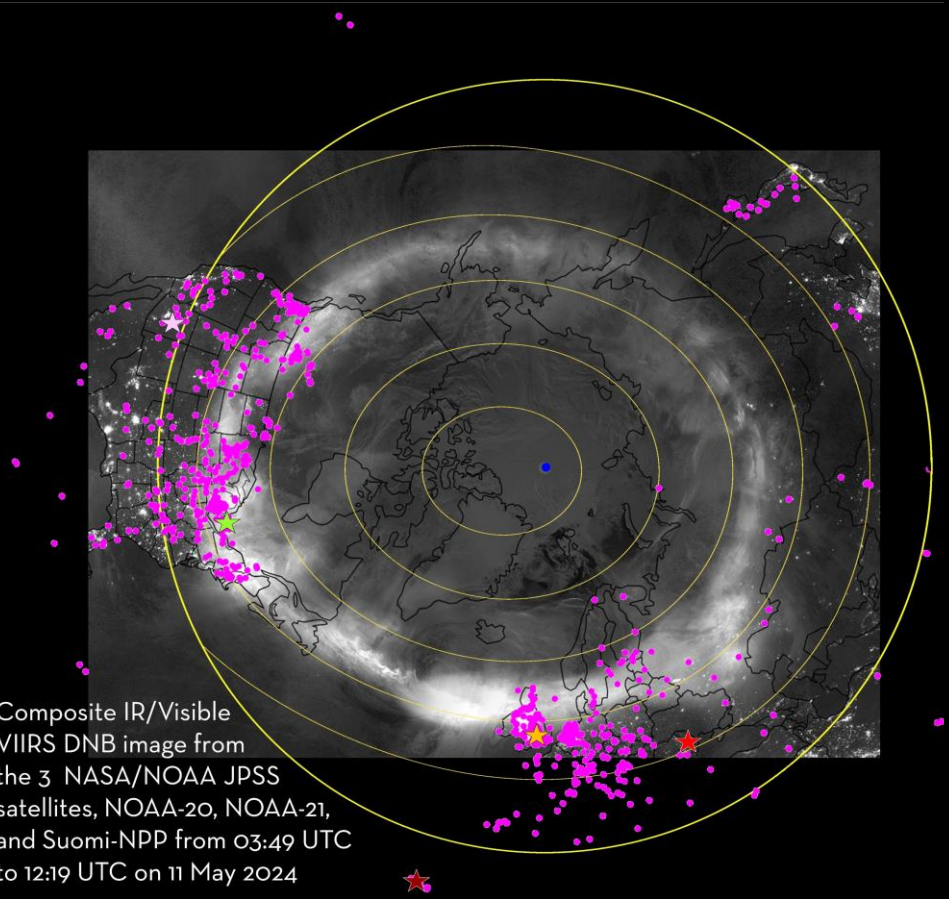
Aurora of 10-11 May, 2024

Crosby beach, Liverpool (Anthony Gormley statue, photo by Peter Byrne)

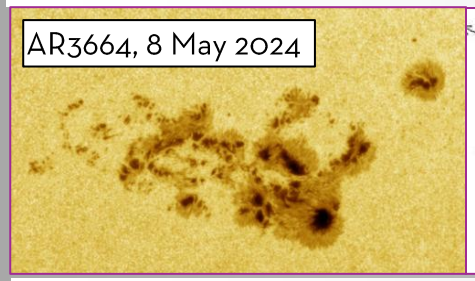
Whiteford Burrows, Gower Peninsula, Wales (photo by David Spencer)

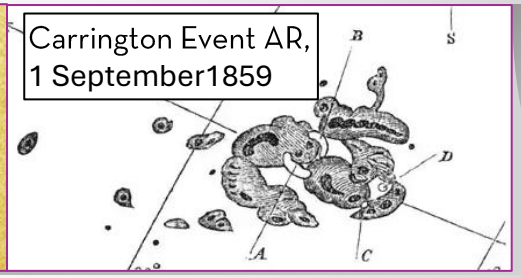


Aurora of 10-11 May, 2024



Composite IR/Visible VIIRS DNB image from the 3 NASA/NOAA JPSS satellites, NOAA-20, NOAA-21, and Suomi-NPP from 03:49 UTC to 12:19 UTC on 11 May 2024





Solar & Auroral Activity

Survey of 0.2 million auroral sightings in Europe between 1650 and 2010

magnetic latitude of auroral sightings

sunspot number