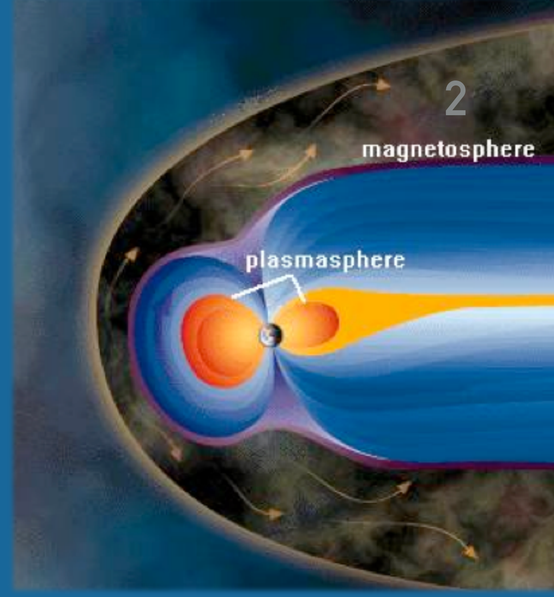
POLAR SYMPOSIUM: SPACE

Fabien Darrouzet / Simona Toscano on behalf of
all colleagues working in *space-related experiments*



STUDY OF THE PLASMAPHERE AT PRINCESS ELISABETH ANTARCTICA

http://www.antarcticstation.org/

AWDA Project - *Fabien Darrouzet (Royal Belgian Institute for Space Aeronomy)*

- Study a sub-region of the Earth's magnetosphere (the plasmasphere) with another way than satellites

  ⇒ Ground-based instrument (cheaper, faster)

- International network of instrument all around the world: AWDA (Automatic Whistler Detector and Analyzer)

  ⇒ Belgian participation (1 instrument in Belgium, since 2010)

- Princess Elisabeth Belgian station in Antarctica : clean electromagnetic environment and at medium magnetic latitude to be able to do interesting measurements (70°S)

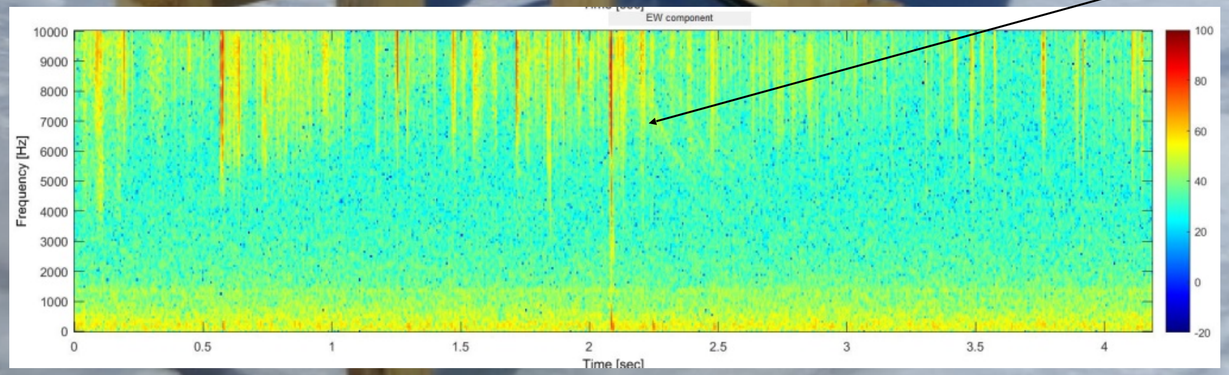
  ⇒ Good location

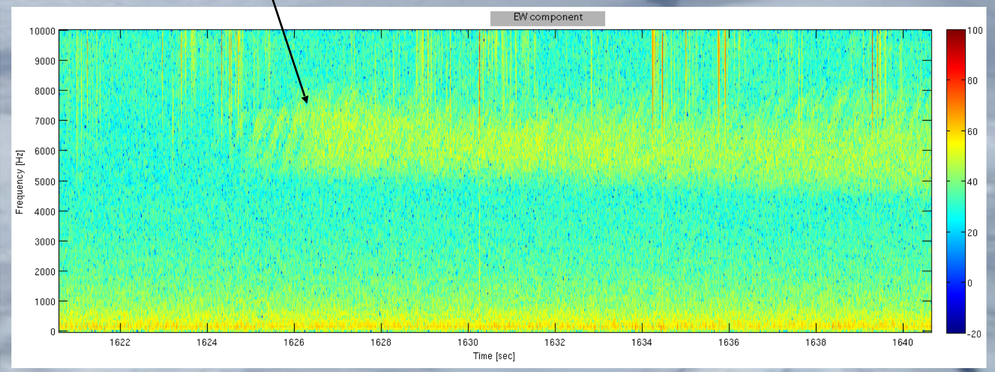
- Compact low frequency (~10 kHz) magnetic antenna installed in 2016

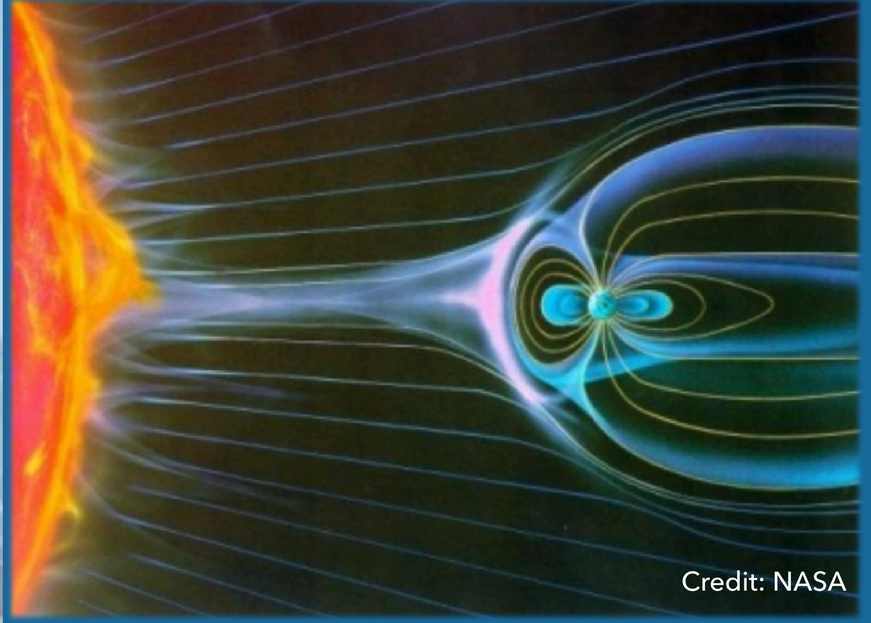
Goal: Detection of natural radio electromagnetic waves, whistlers

- Frequency 5-15 kHz (for reference, human frequency : 20 Hz - 20 kHz)
- Duration ~1 second
- Created by lightning's storm/stroke
- Propagate along magnetic field line from 1 hemisphere to another
- Allows to infer information about the state of the plasmasphere.

Results: Observations and statistical analysis of whistler and chorus waves





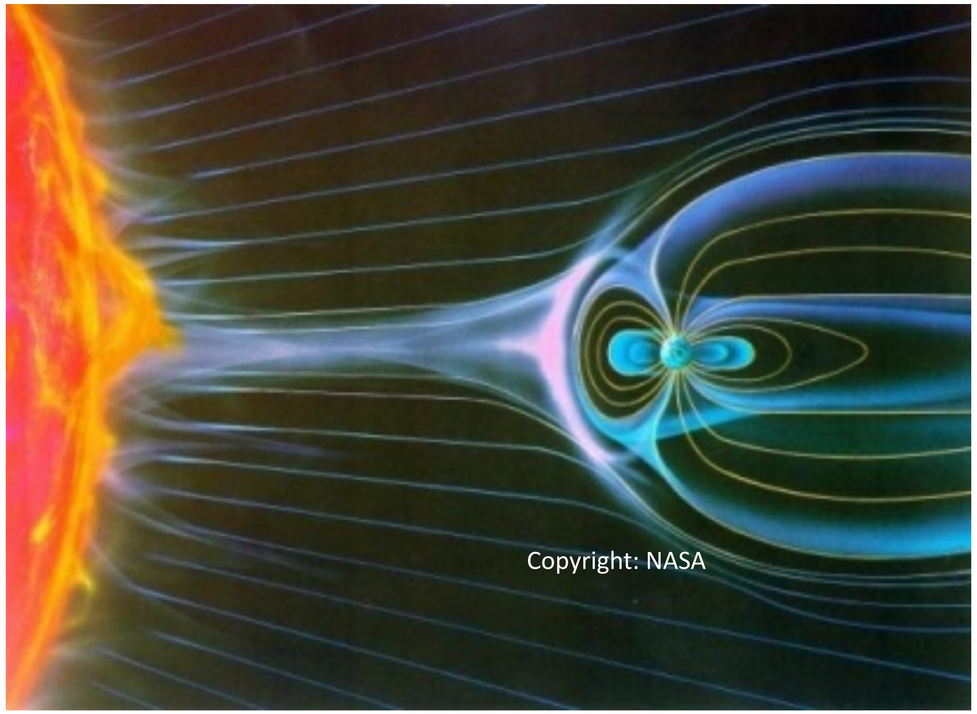


Credit: NASA

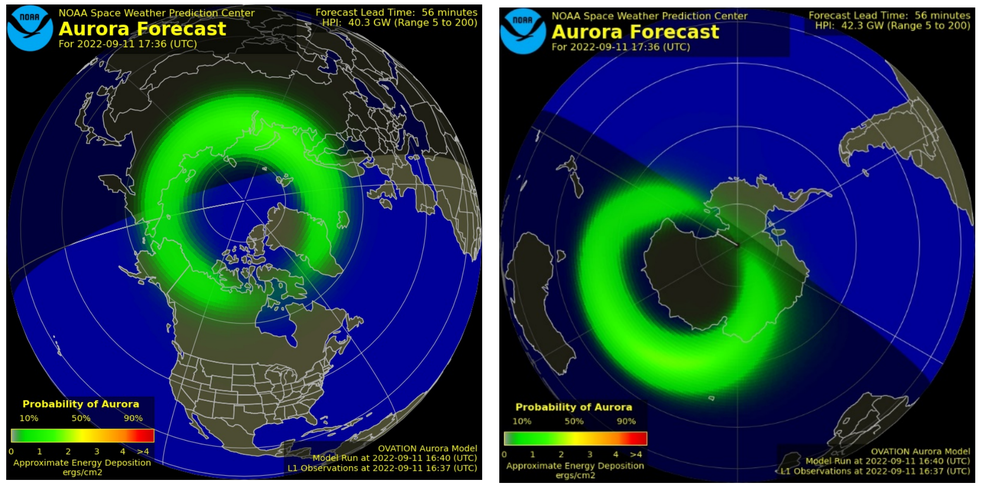
AURORAL STUDY AT PRINCESS ELISABETH ANTARCTICA

http://www.antarcticstation.org/

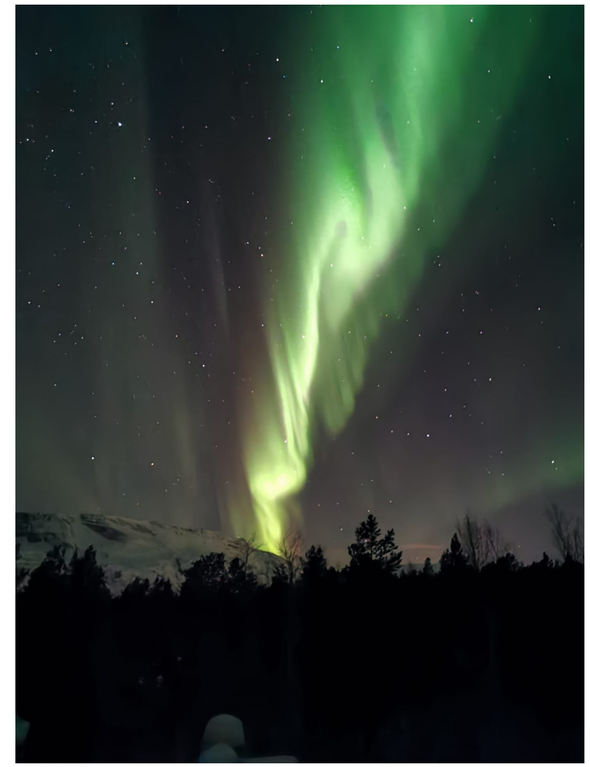
Study of auroras



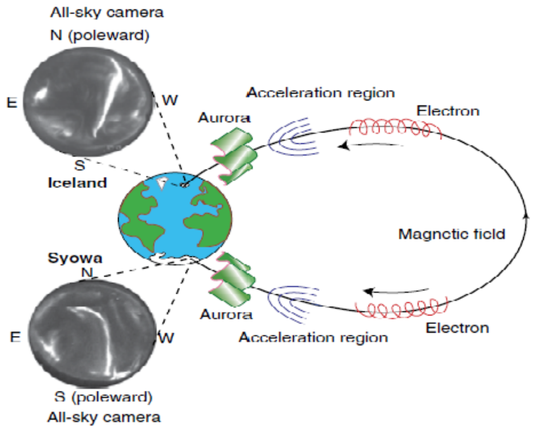
- Auroras are the most spectacular manifestation of the complex solar wind-magnetosphere-ionosphere coupling.
- Solar wind forcing creates perturbations in the Earth's magnetosphere leading to acceleration of electrons along the magnetic field lines towards the ionosphere where they hit and excite atmospheric oxygen atoms and nitrogen molecules, which produce the blue, green and red emissions by de-excitation.
- Auroras occur in the so-called auroral ovals, a belt around the magnetic poles of the Earth, whose size and latitude extension strongly depends on solar activity.



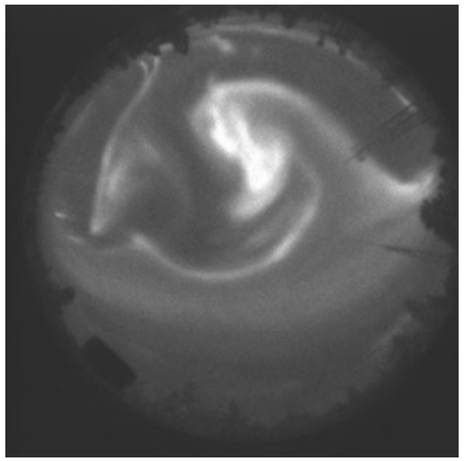
From OVATION Auroral Forecast



Auroral study at PEA - *H. Lamy (Royal Belgian Institute for Space Aeronomy)*



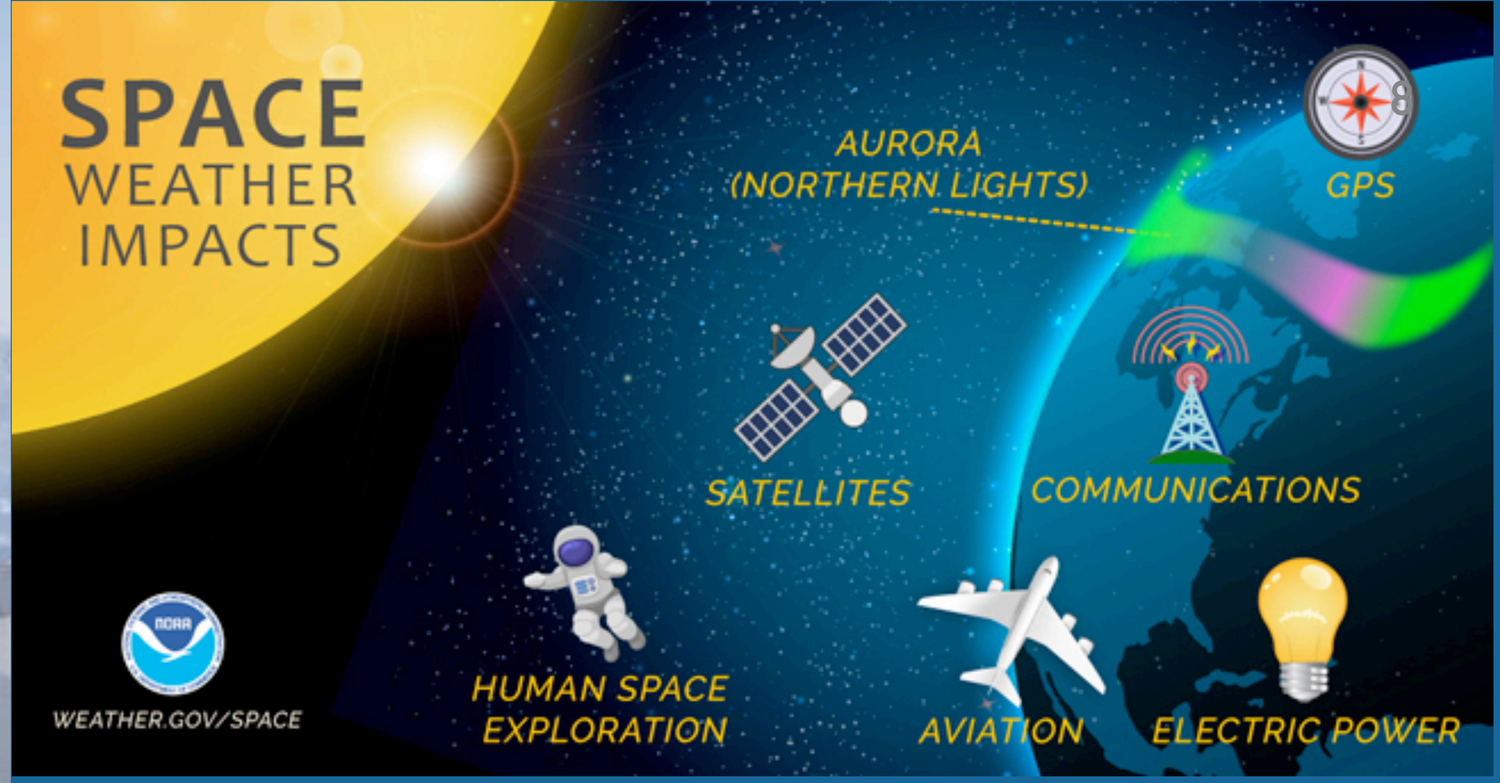
From Sato et al. (2012)



Example of B&W ASC obtained in Sodankylä, Finland. Credit: MIRACLE project

- Proposal submitted by the Space Physics group at Royal Belgian Institute for Space Aeronomy to recent Polar Research call : **IRMA** (Inter-Hemispheric Monitoring of Aurora)
- Technical goal : procure and install a sensitive all-sky camera (ASC) equipped with narrow interference filters at PEA.
- Scientific goals :
  - monitoring the auroral activity in the Southern hemisphere above PEA (energy fluxes, dynamics, …)
  - monitoring the inter-hemispheric auroral activity with ground-based observations. Collaboration with Japanese scientists from NIPR who have a long-term expertise in this field and several stations located in Iceland, not far from the magnetically conjugated point of PEA.
  - monitoring the inter-hemispheric auroral activity by comparing with future UV observations from the upcoming ESA/CAS joint mission SMILE (Solar Wind Magnetosphere Ionosphere Link Explorer) to be launched in 2024 (Belgium is strongly involved in the UVI instrument).

http://www.antarcticstation.org/



SPACE WEATHER RESEARCH

Space weather research and forecasting

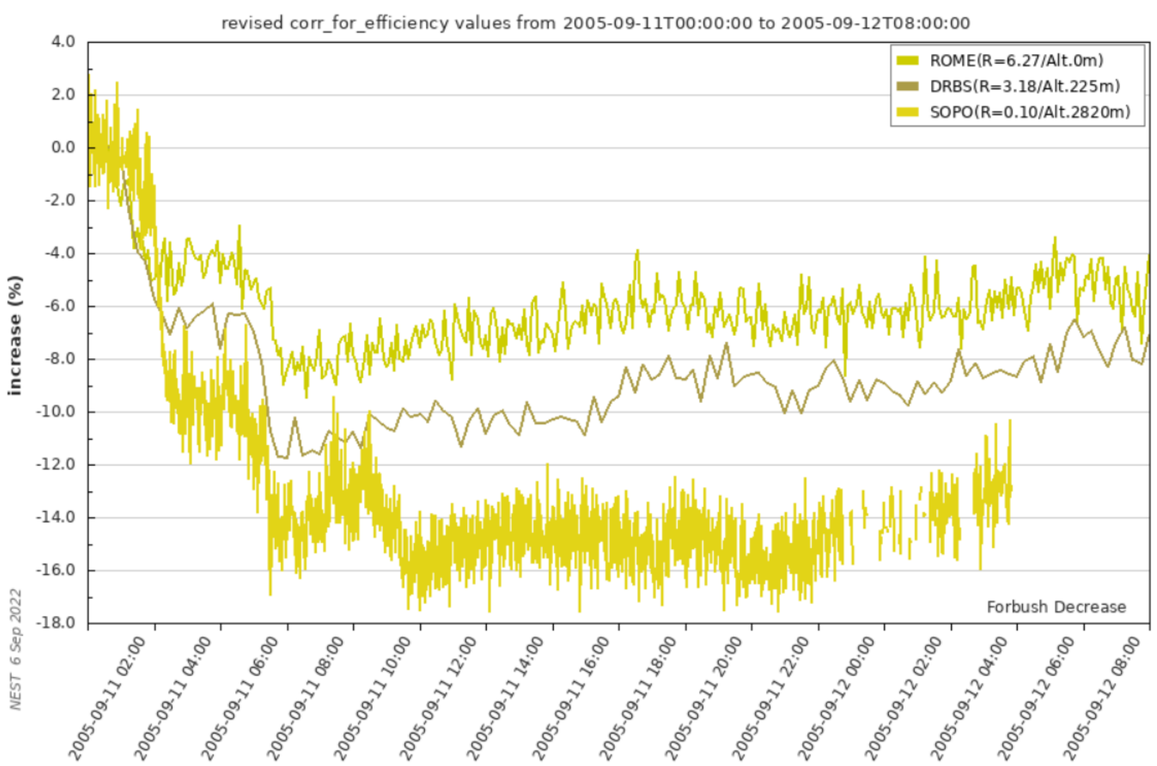
1. Polar regions offer the unique opportunity to measure cosmic rays particle without the effect of the Earth's magnetic field:
   a. Neutron monitors operate at the south pole since the 1960s (USA, USSR, Australian stations). Initially to monitor the solar activity only, now largely used for space weather monitoring and applications.
   b. These instruments are aging and stations are being closed.
   c. Newly installed instruments are either smaller or situated away from the GM poles; the data and data transfer is not suitable for real-time applications.

Space weather research and forecasting in Belgium - *Danislav Sapundjiev, RMI*

1. In the last decade, Belgium has established itself as a space weather hub - concerning research and forecasting services.
2. Royal Meteorological Institute of Belgium (RMI), under the hood of the STCE project, participate as data provision and services:
    i. Two neutron monitors (operating since 1968 and January 2021)
    ii. A Muon Telescope for space weather applications (under construction, expected December 2023)
3. An important part of this infrastructure is a real-time data from a polar observatory at PEA including a standard Neutron Monitor for real-time Solar Cosmic Rays observations.

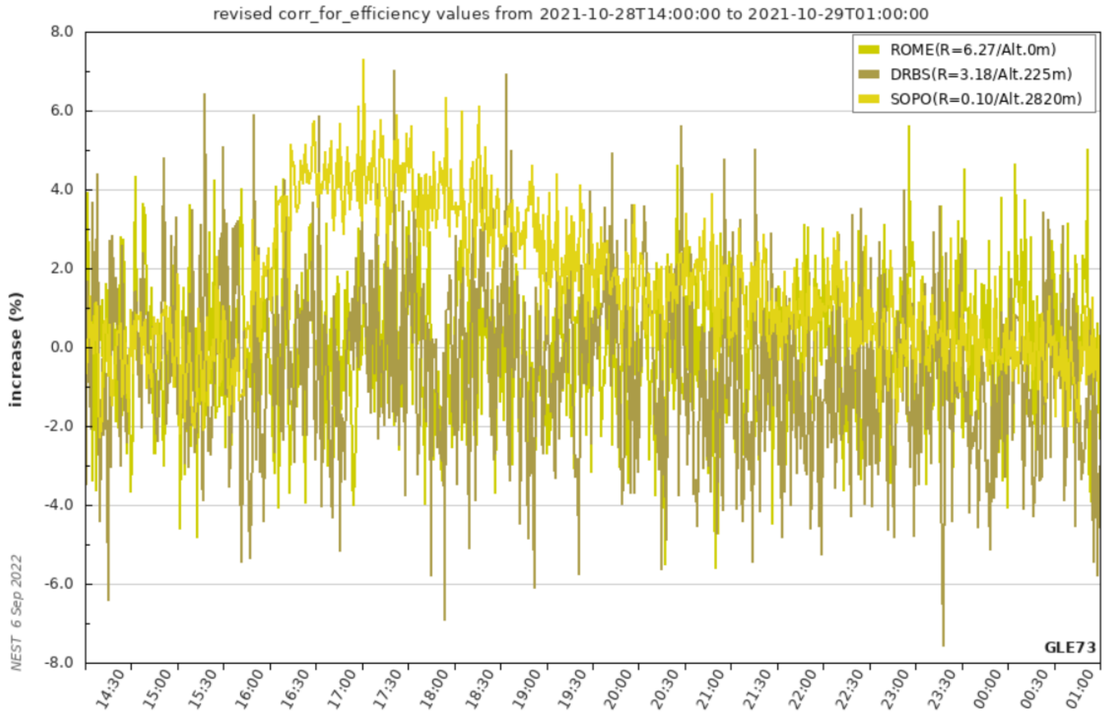
Neutron monitor data - *Danislav Sapundjiev, RMI*

Forbush Decrease



[FD 51 from 2005-09-11, data from www.nmdb.eu]

Ground Level Enhancement (GLE)

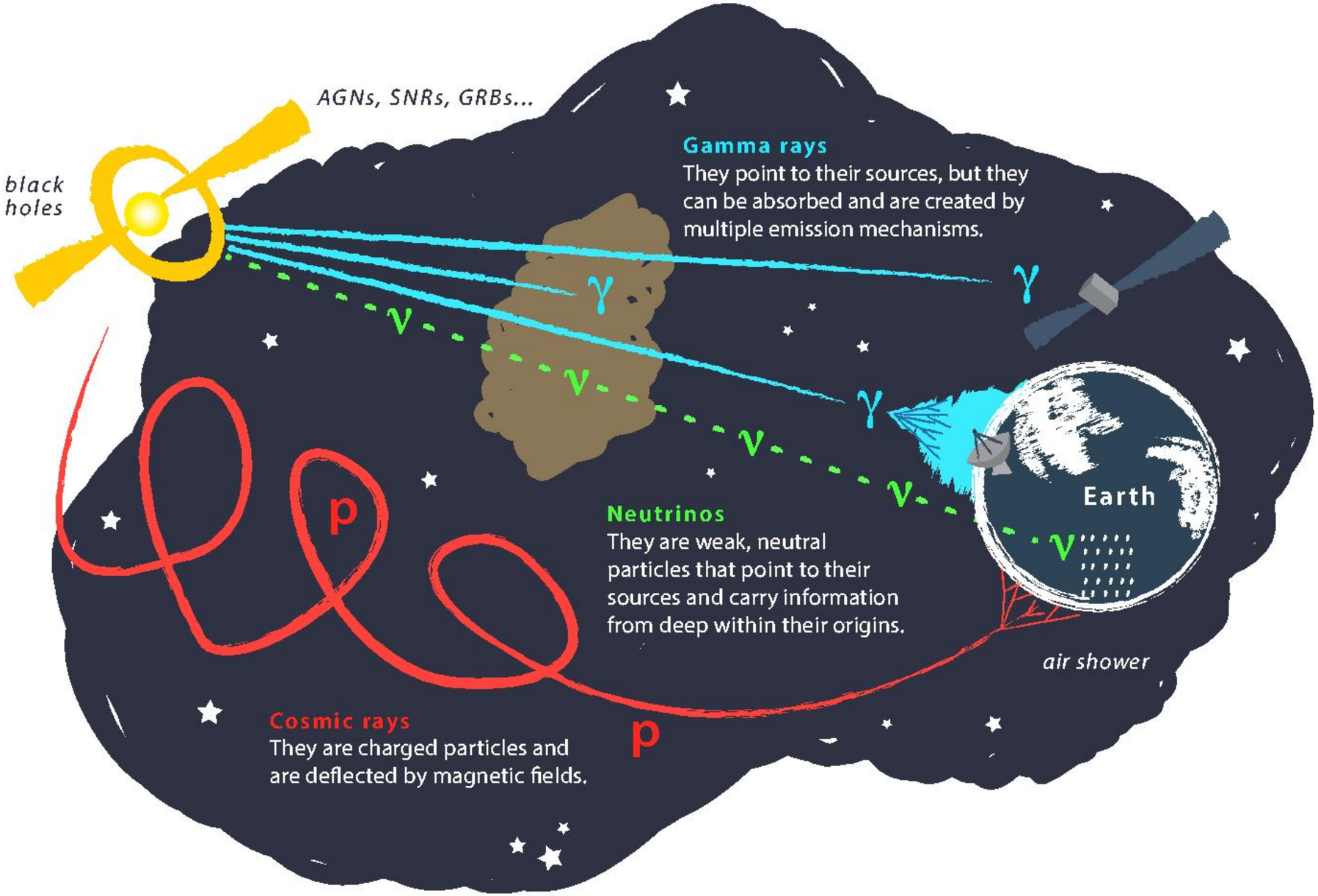


[GLE73 from 2021-10-29, data from www.nmdb.eu]

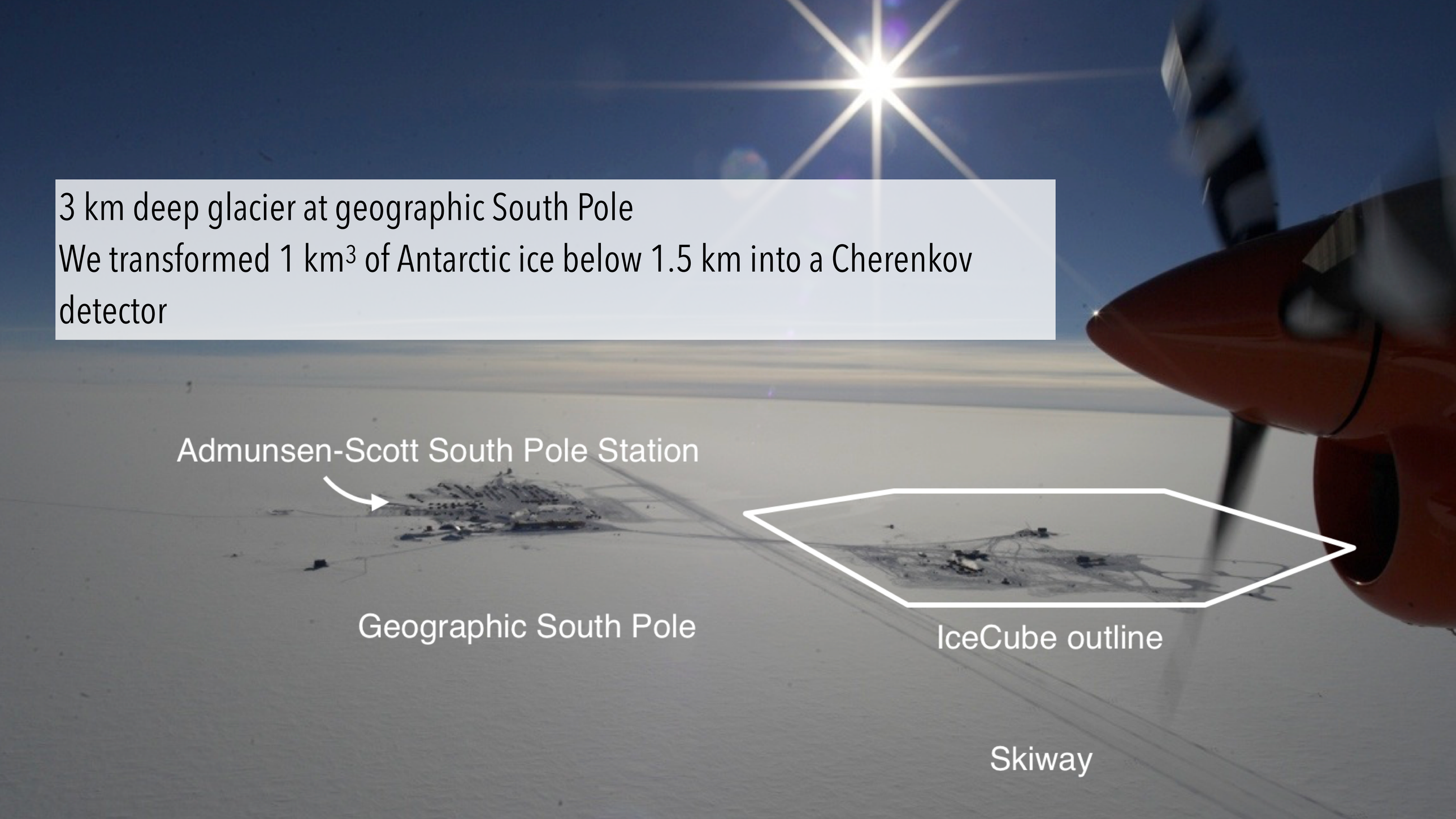
Data from neutron monitors located at the polar region (SOPO) and at regions with stronger Geo-Magnetic Field (Dourbes
and Rome). The latter two failed to detect the last GLE from 29 Oct 2021.

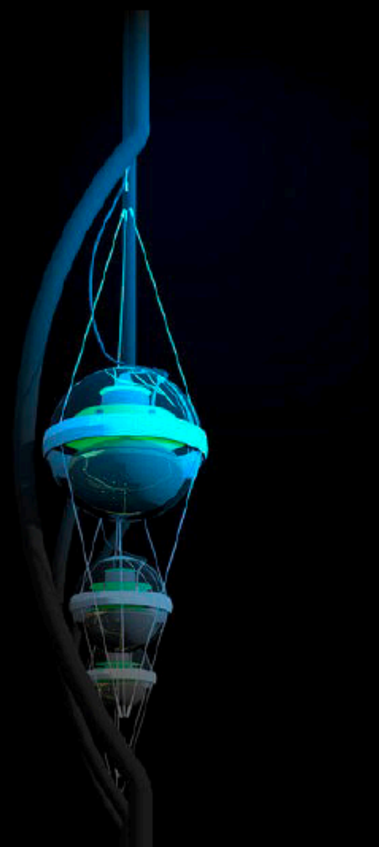
NEUTRINO ASTRONOMY AT THE SOUTH POLE

Neutrino astronomy: the physics case



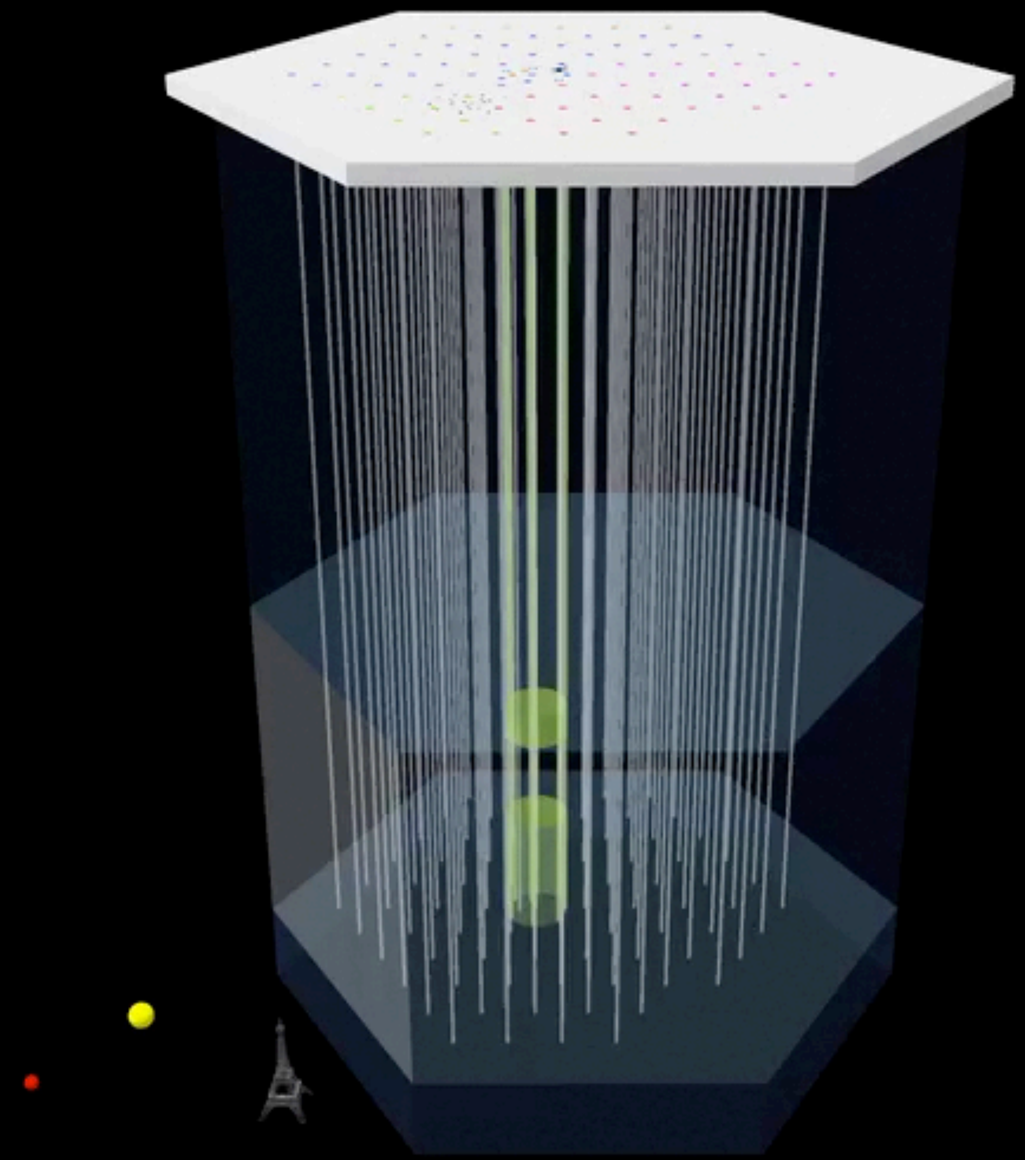
3 km deep glacier at geographic South Pole
We transformed 1 km^3 of Antarctic ice below 1.5 km into a Cherenkov detector



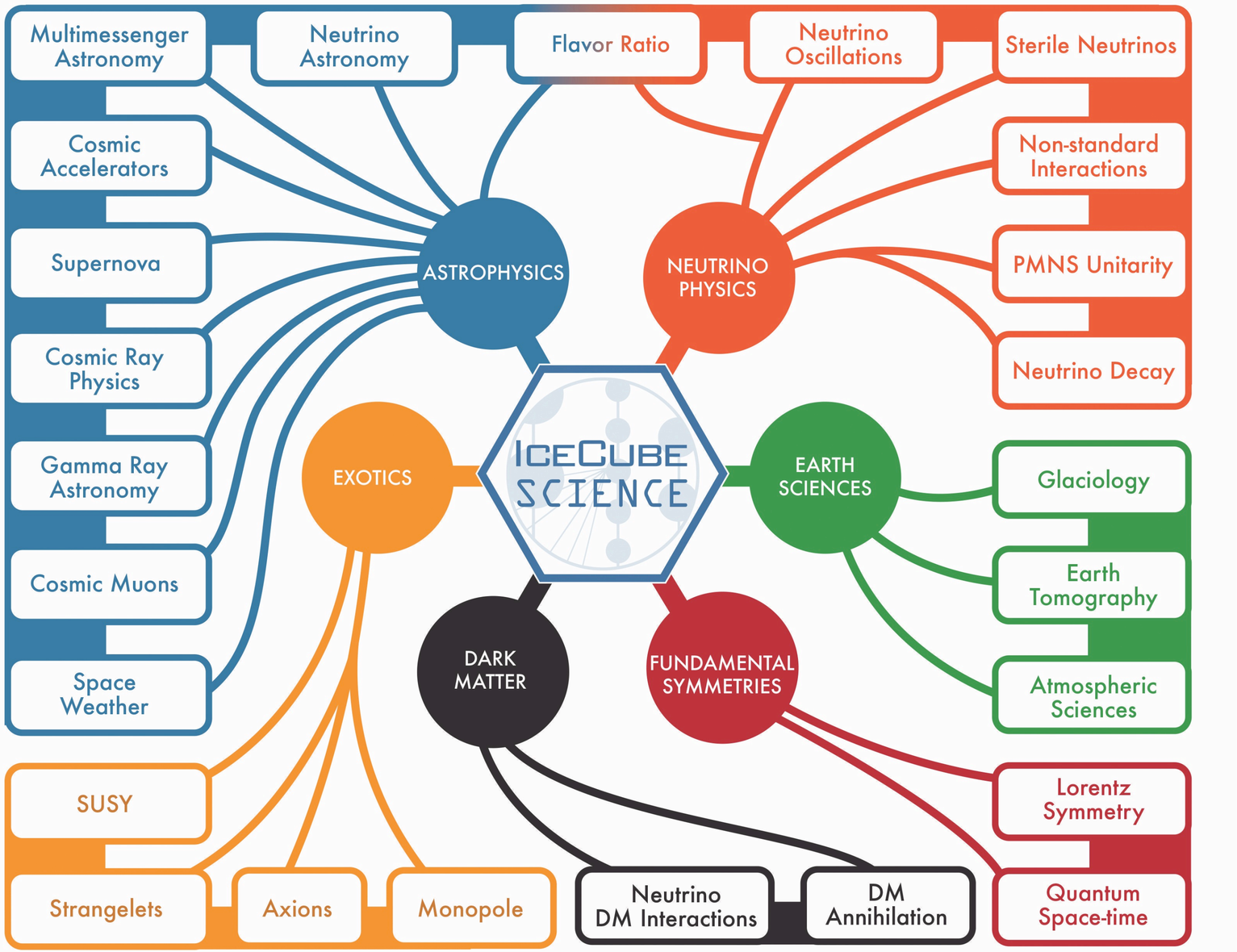


5160 DOMs
instrumenting 1 km^3
(1 GT) of clear ice

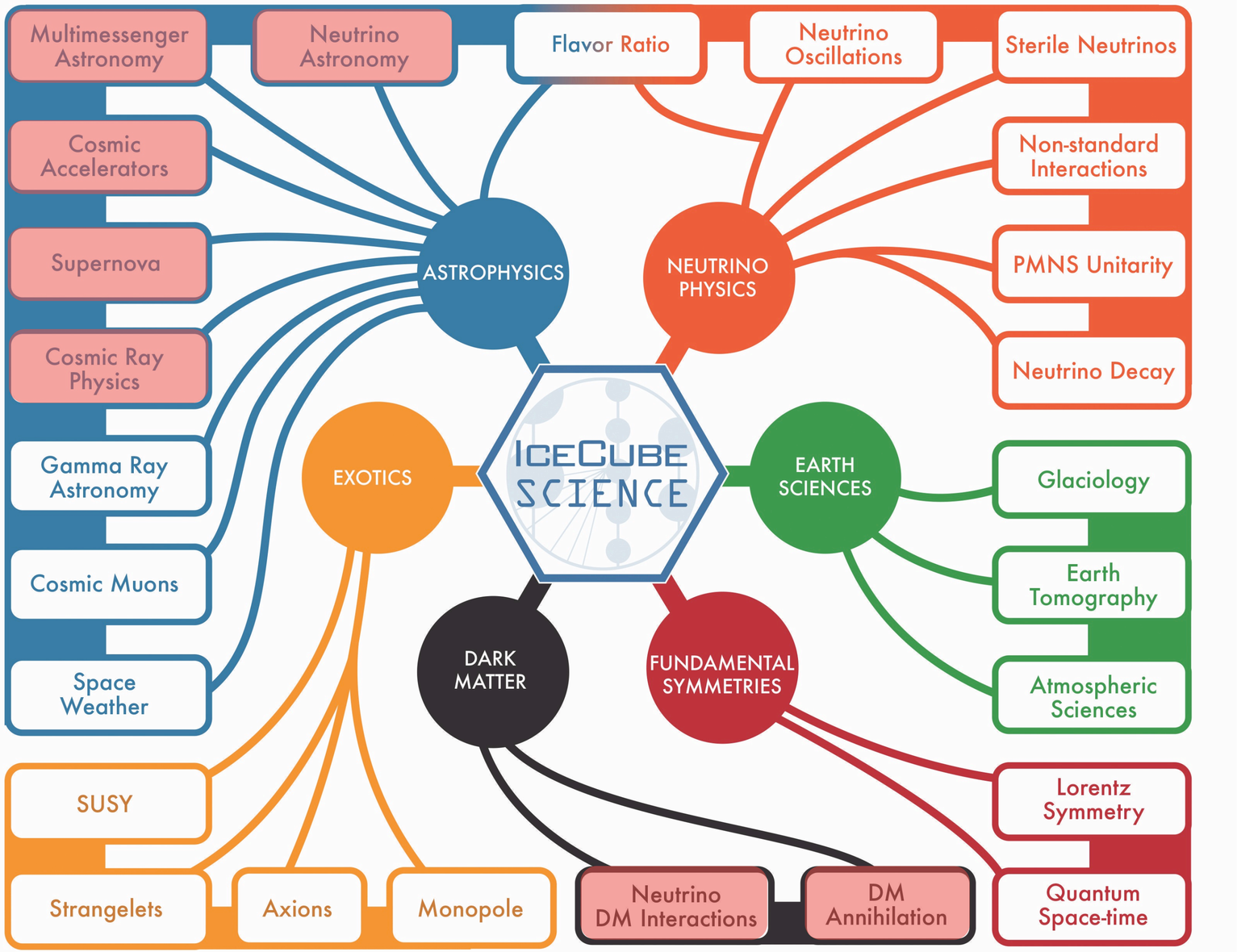
2 ns time resolution



Physics reach



Physics reach



A discovery instrument

2010

IceCube construction completed

2013
IceCube discovers astrophysical neutrinos with energies greater than 10^{14} eV

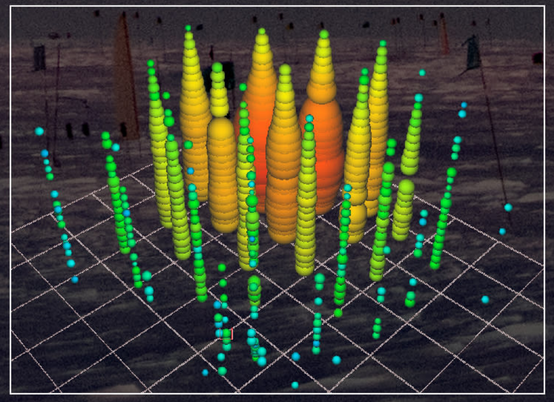
2014
IceCube discovers highest energy neutrino to date, nicknamed Big Bird (2×10^{15} eV)

2015
IceCube confirms cosmic neutrino flux with muon neutrinos traversing Earth, including a 7×10^{15} eV neutrino

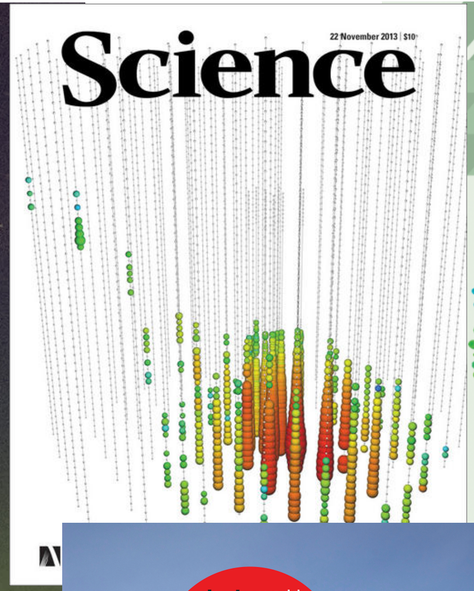
2018
Science papers describe first detected source of neutrinos—active galaxy TXS 0506+056, identified in 2017 by first successful multimessenger campaign

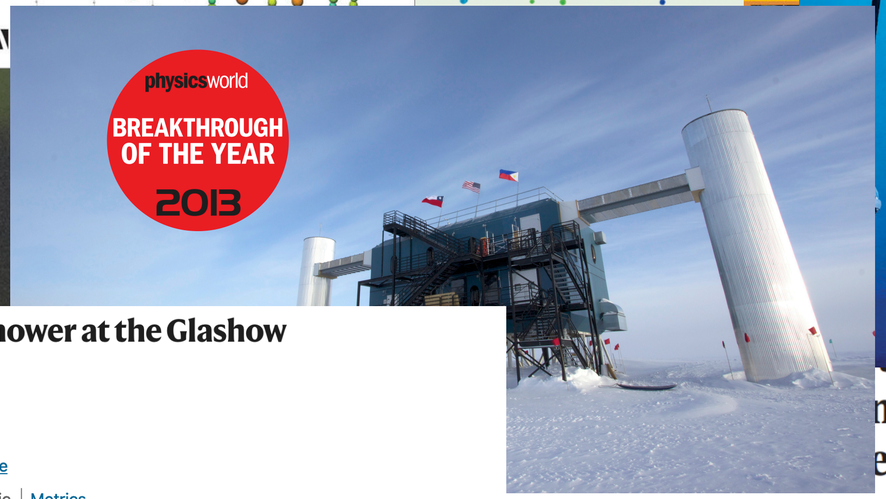
2021

IceCube announces the detection of a 6.3 PeV neutrino via the Glashow resonance



PHOTOGRAPHY: YUYA MAKINO, ICECUBE/NSF • ROBERT SCHWARZ, NSF





Detection of a particle shower at the Glashow resonance with IceCube

The IceCube Collaboration

Nature **591**, 220–224 (2021) | Cite this article

Abstract

The Glashow resonance describes the resonant formation of a W^- boson during the interaction of a high-energy electron antineutrino with an electron[1], peaking at an antineutrino energy of 6.3 petaelectronvolts (PeV) in the rest frame of the electron. Whereas this energy scale is out of reach for currently operating and future planned particle accelerators, natural astrophysical phenomena are expected to produce antineutrinos with

nt with
eCube-170922A

ube Collaboration, *Fermi*-LAT, MAGIC, *AGILE*, ASAS-SN, HAWC, H.E.S.S, IL, Kanata, Kiso, Kapteyn, Liverpool Telescope, Subaru, *Swift/NuSTAR*, , and VLA/17B-403 teams*†

ARCH ARTICLE

NO ASTROPHYSICS

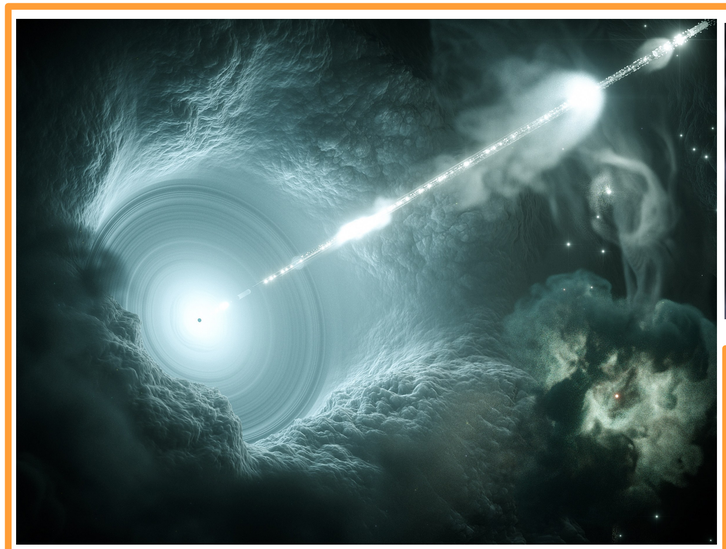
trino emission from the direction ne blazar TXS 0506+056 prior to IceCube-170922A alert

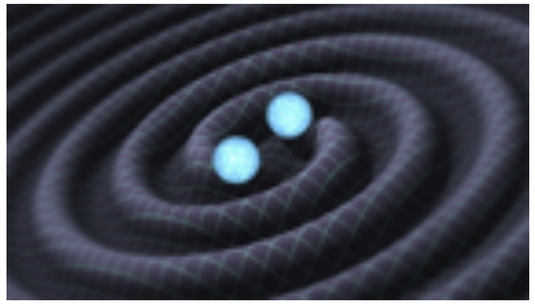
Collaboration*†

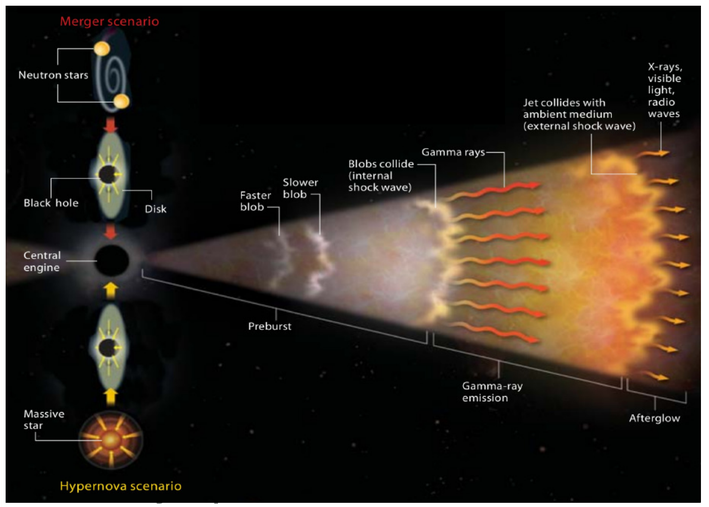
Belgian contribution

Belgium is one of the 4 countries that contributed to the construction of the IceCube detector

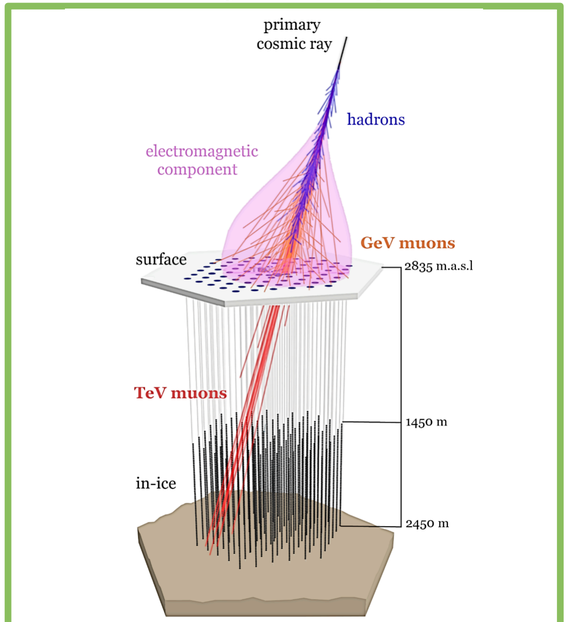
Cosmic neutrinos from GeV to TeV



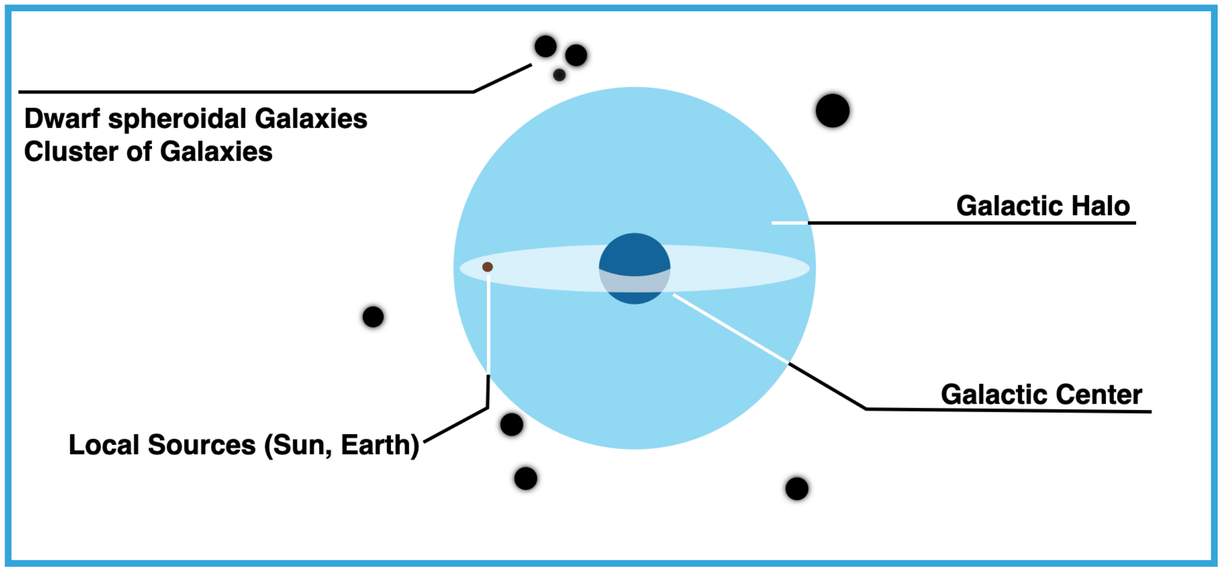




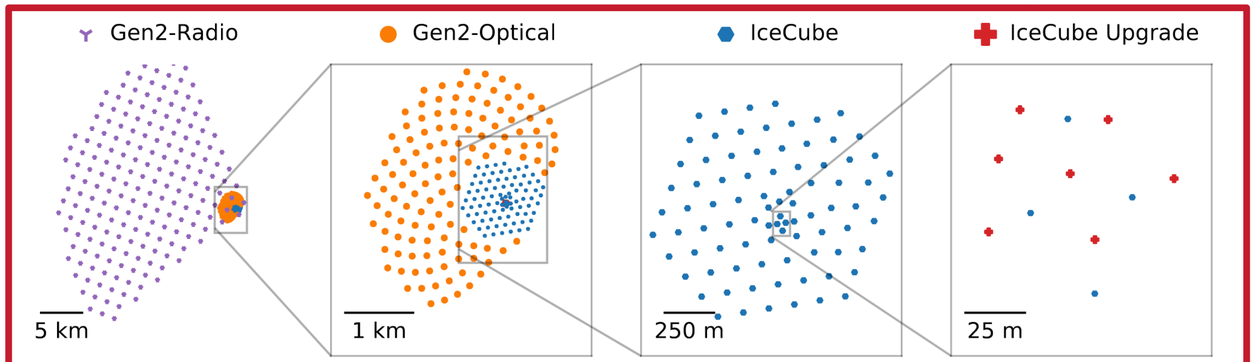
Cosmic rays composition



Dark matter searches



IceCube-Gen2: the future of neutrino astronomy at the SP



BUILDING A NEW HIGH ENERGY NEUTRINO DETECTOR IN GREENLAND (SUMMIT STATION)

The Radio Neutrino Observatory in Greenland (RNO-G)

Station design

Credit: Bob Oeyen

RNO-G [2010.12279]

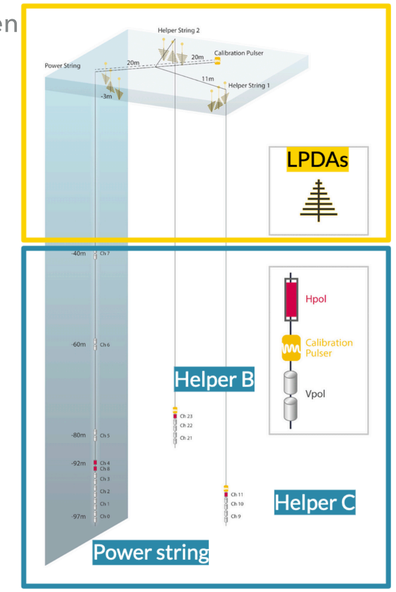
Surface component:

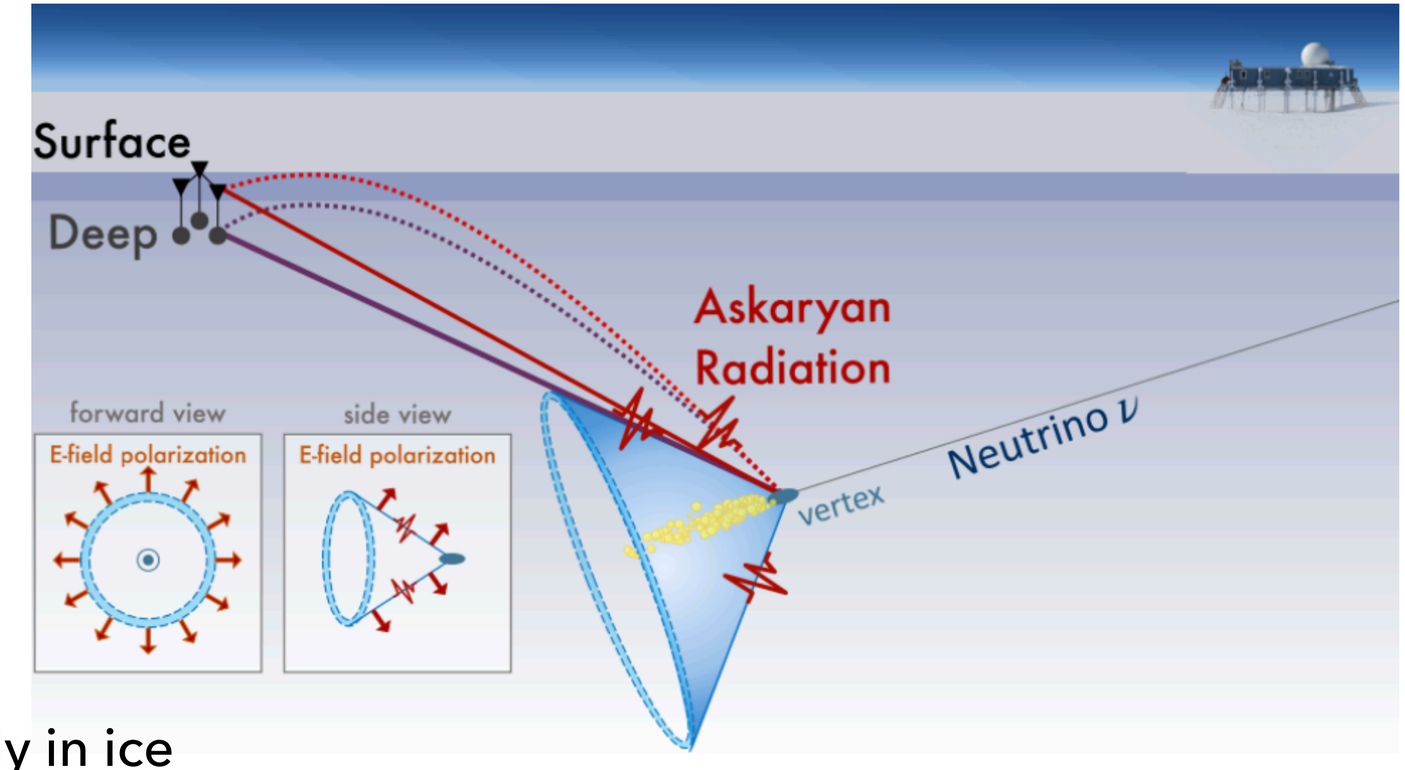
Cosmic rays, veto, ν detection, more channels for reconstruction

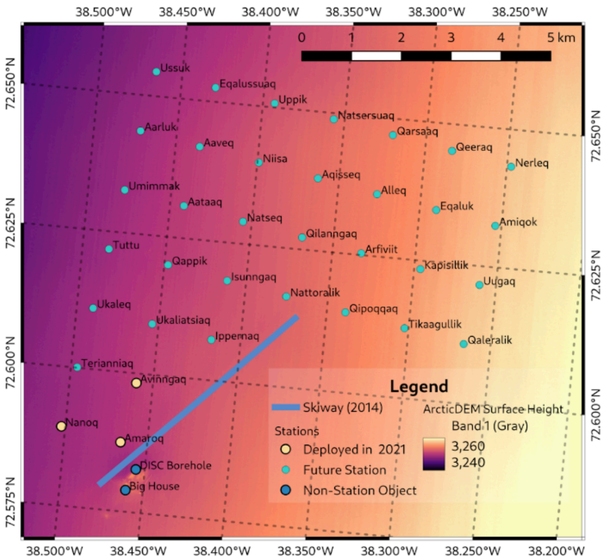
Deep component:

Effective volume neutrinos

Designed to be **scalable**
→ Informs array design **IceCube-Gen2**







- 7 stations already in ice
- LTE Comms
- Solar/Wind powered

Journal of Glaciology, Vol. -, No. -, - 1

***In situ*, broadband measurement of the radio frequency attenuation length at Summit Station, Greenland**

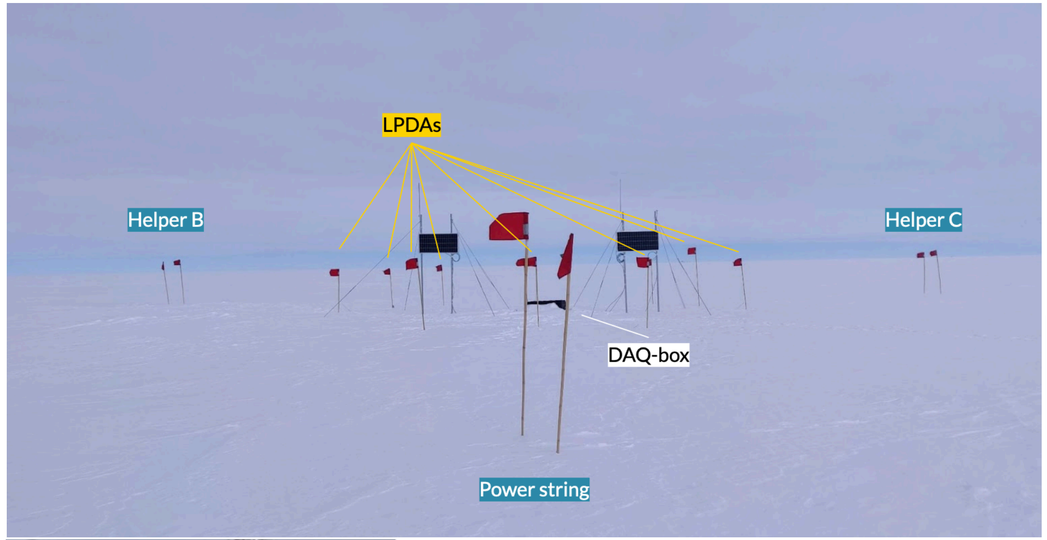
J. A. Aguilar[1], P. Allison[2], J. J. Beatty[2], D. Besson[3,4], A. Bishop[5], O. Botner[6], S. Bouma[7], S. Buitink[8], M. Cataldo[7], B. A. Clark[9], Z. Curtis-Ginsberg[10], A. Connolly[2], P. Dasgupta[1], S. de Kockere[11], K. D. de Vries[11], C. Deaconu[10], M. A. DuVernois[5], C. Glaser[6], A. Hallgren[6], S. Hallmann[12], J. C. Hanson[13], B. Hendricks[14], C. Hornhuber[3], K. Hughes[10], A. Karle[5], J. L. Kelley[5], I. Kravchenko[15], R. Krebs[14], R. Lahmann[7], U. Latif[11], J. Mammo[15], Z. S. Meyers[12,7], K. Michaels[10], K. Mulrey[16], A. Nelles[12,7], A. Novikov[3], A. Nozdrina[3], E. Oberla[10], B. Oeyen[17], Y. Pan[18], H. Pandya[8], I. Plaisier[7,12], N. Punsuebsay[18], L. Pyras[12,7], D. Ryckbosch[17], O. Scholten[11,19], D. Seckel[18], M. F. H. Seikh[3], D. Smith*[,10], D. Southall[10], J. Torres[2], S. Toscano[1], D. Tosi[5], D. J. Van Den Broeck[11,8], N. van Eijndhoven[11], A. G. Vieregg[10], C. Welling[7,12], S. Wissel[14,20], R. Young[3], A. Zink[7]

RNO-G
Radio Neutrino Observatory - Greenland

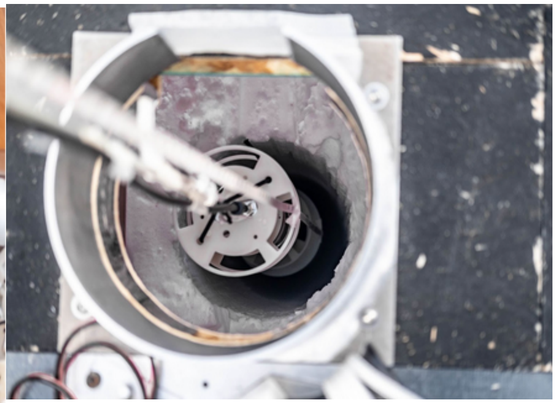
Belgian contribution

fwo fnrs
LA LIBERTÉ DE CHERCHER

Main fundings coming from IRI program of FWO - N. Van Eijndhoven (VUB)



1. Hardware production
2. Construction, commissioning and calibration
3. Real time alert system for transients

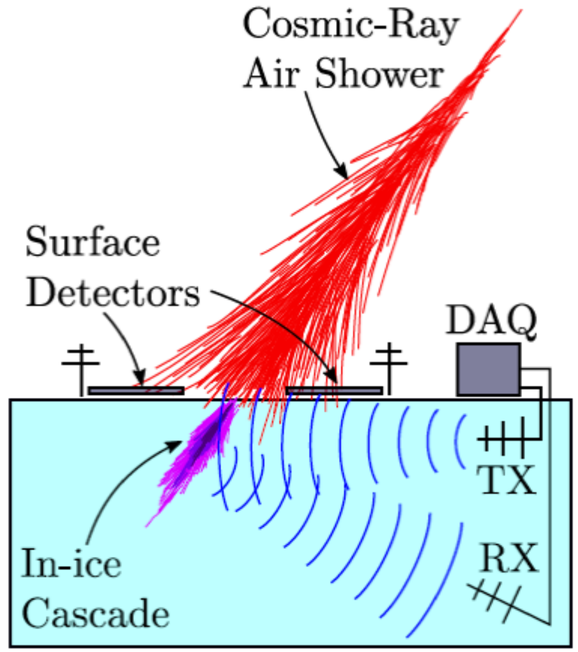


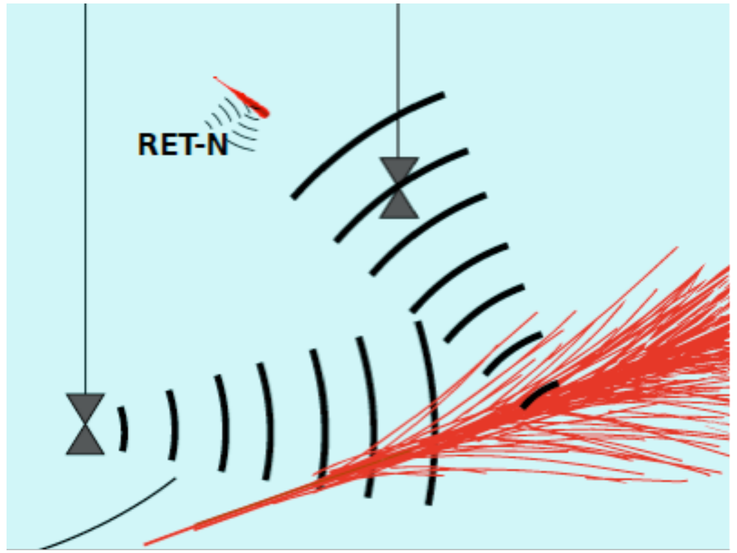
The RADAR ECHO TELESCOPE (RET)

Leadership: Belgium / US - K. de Vries (VUB) funded with ERC Starting Grant

the RADAR ECHO TELESCOPE for COSMIC RAYS

the RADAR ECHO TELESCOPE for COSMIC RAYS for NEUTRINOS





RET-CR paper: arXiv: 2104.00459
ICRC Contributions 1032,1039,1147,1329
Funded by NSF (NSF/PHY-2012980) and the EU/ERC HORIZON2020 PROGRAM.
www.radarechotelescope.org

Antarctica as an analogue for manned spaceflight

Environment	e.g. vacuum, microgravity, radiation, no day/night	e.g. no day/night, monotonous landscape, constant light or constant darkness, cold
Mission	e.g. workload, mission duration, emergencies, isolation for many months	e.g. workload, mission duration, emergencies, isolation for many months
Habitat	e.g. noise, confinement, LSS, limited resources	e.g. confinement, LSS, limited resources
Social situation	e.g. small crew, restricted communication with earth	e.g. small crew, restricted communication

See talk on Anthropology and Health

RNO-G

Radio Neutrino Observatory - Greenland

SPACE WEATHER

AURORAL STUDY

STUDY OF THE PLASMAPHERE

NEUTRINO ASTRONOMY

ICE PROPERTIES STUDIES

COSMIC RAY DETECTION

RMI

BIRA-IASB

UCLouvain

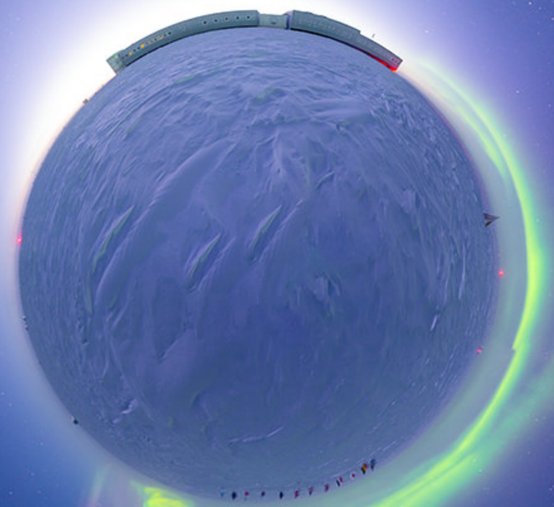
GHENT UNIVERSITY

ULB UNIVERSITÉ LIBRE DE BRUXELLES

VUB VRIJE UNIVERSITEIT BRUSSEL

IceCube Neutrino Observatory

THANK YOU



Credit: SPT/Aman Chokshi