Atmospheric and auroral research with sounding rockets

N. Ivchenko
+ Daedalus team
+ SPIDER-2 team
+ IRF, MISU

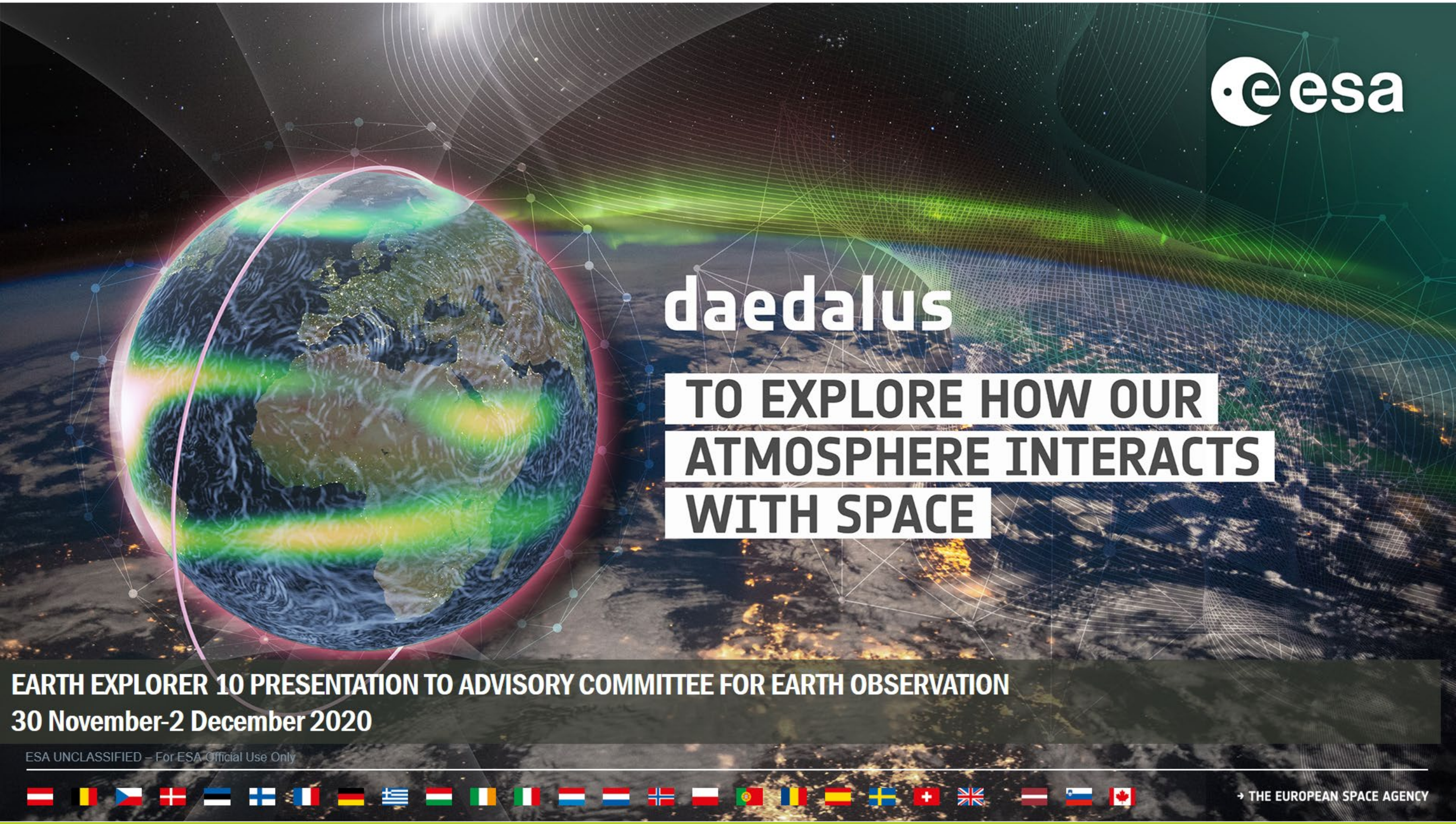
SRS Meeting, March 16, 2021, Virtual Lund

Outline

- Lower Thermosphere and Ionosphere – ESA Daedalus mission

- Some Swedish sounding rocket projects
  - SPIDER-2
  - BROR
  - SYSTER
  - ORIGIN

Daedalus mission candidate for EE10



Daedalus mission candidate for EE10

- Proposal of mission to low thermosphere/ionosphere region
- In situ measurements in the region, with perigee <200 km
- PI T. Sarris (Greece)
- Phase 0 concluded in 2020
- Not selected for phase A for budgetary reasons (Harmony mission continues to phase A as a sole candidate)
- Discussions ongoing on altenative implementation scenarios

Lower thermosphere – Ionosphere (LTI) coupling

LTI coupling mechanisms

1. Waves from below
2. Precipitation from above
3. Current closure and heating from above

Level of driving determined by how much energy each mechanism deposits

1. Solar EUV ~700 GW
2. Quiet: Forcing from below/above, total ~300GW
3. Active: Heating alone exceeds 700 GW!

Lower thermosphere – Ionosphere (LTI) coupling

Upward propagating atmospheric waves

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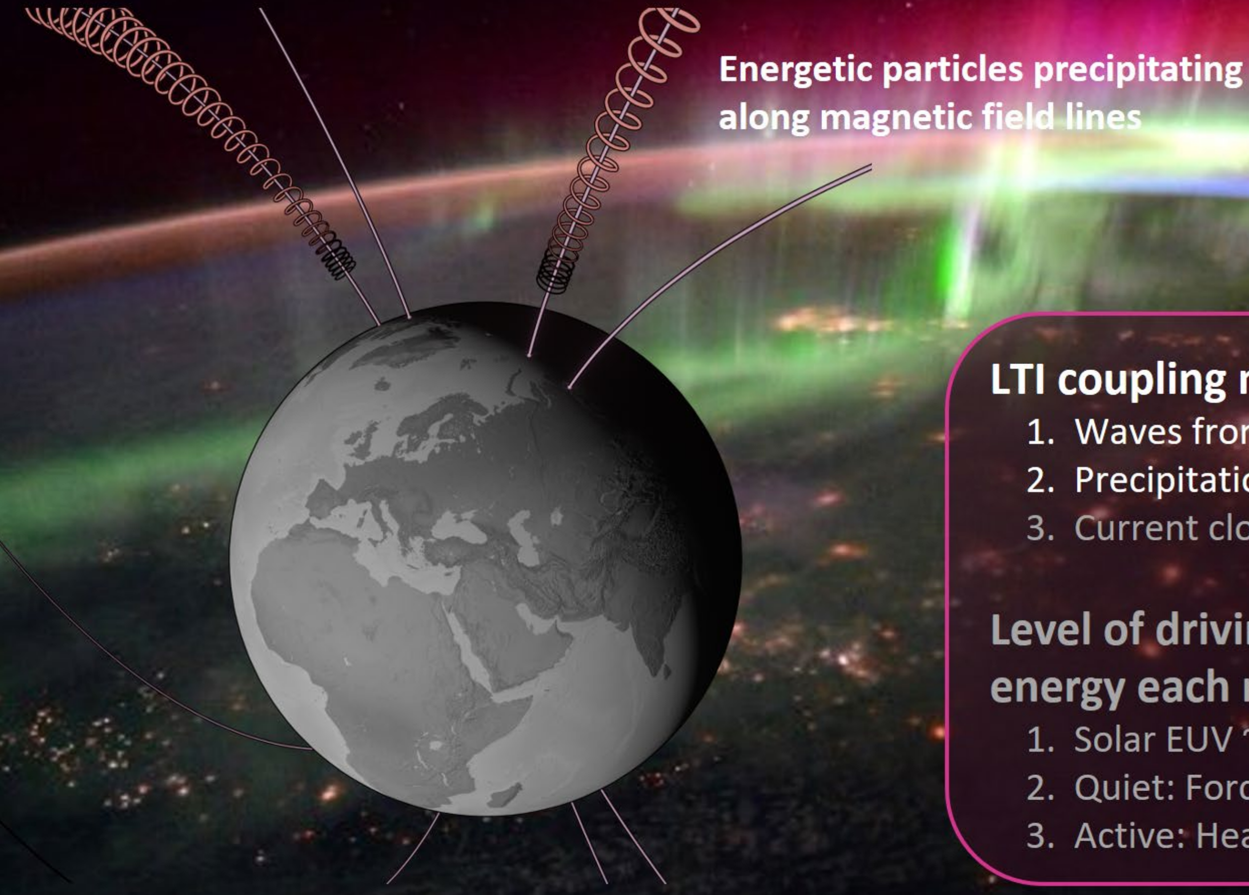

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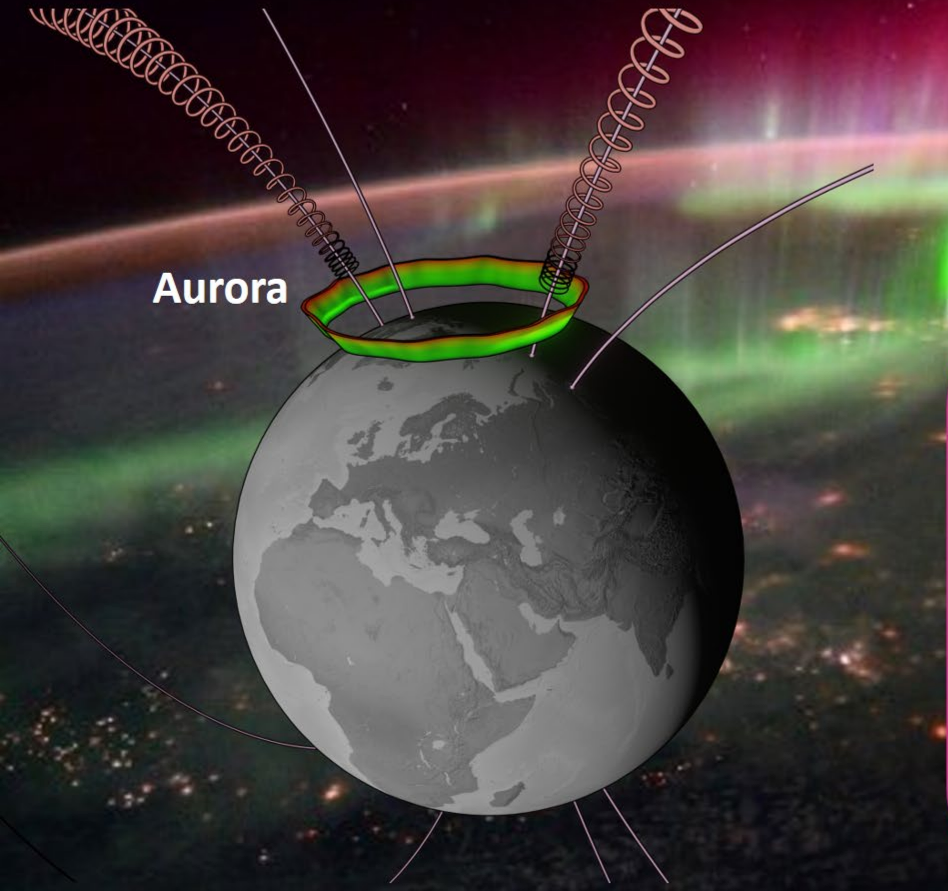

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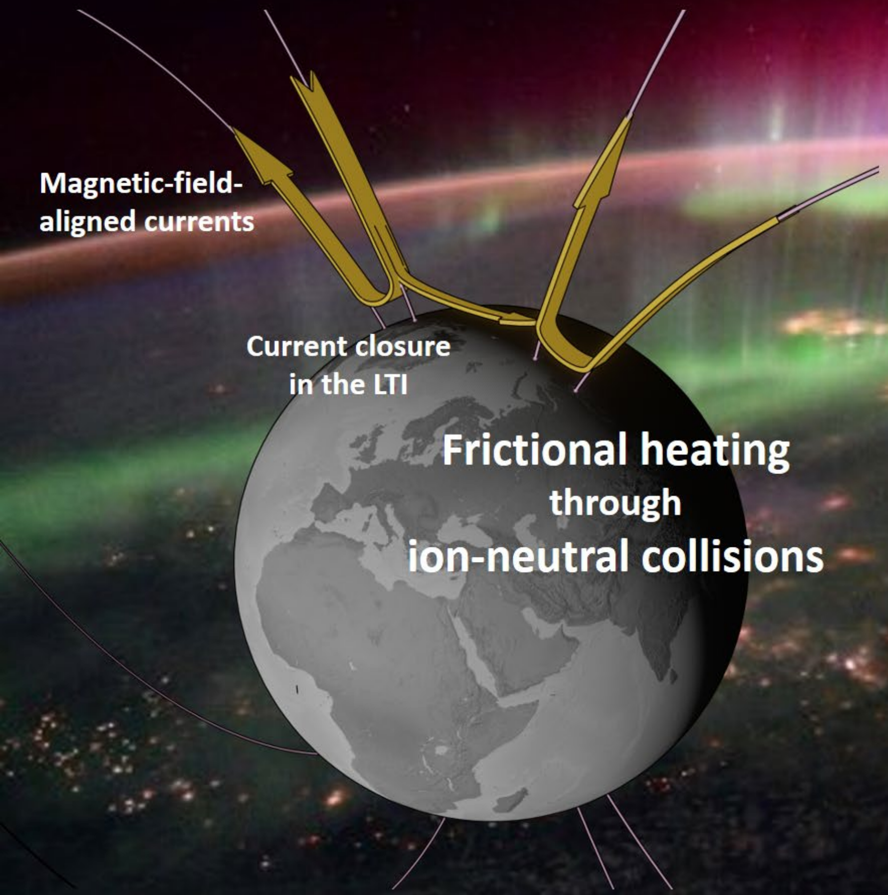

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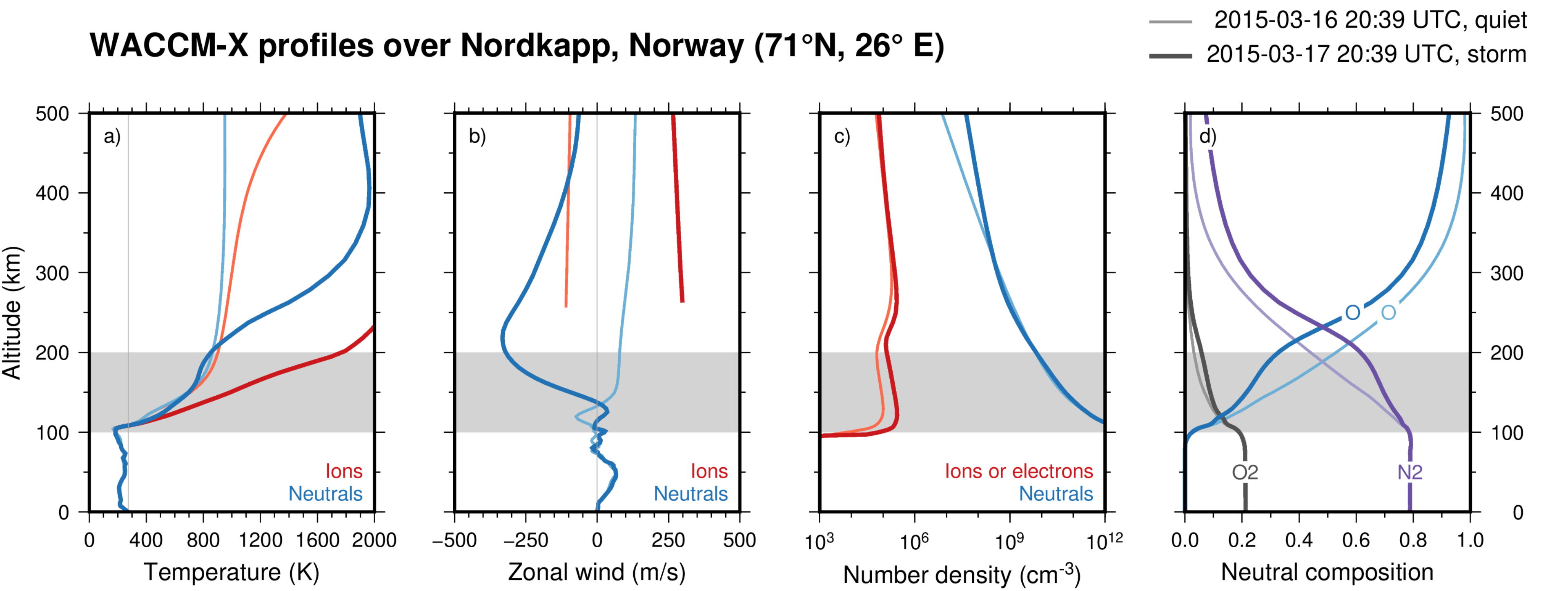
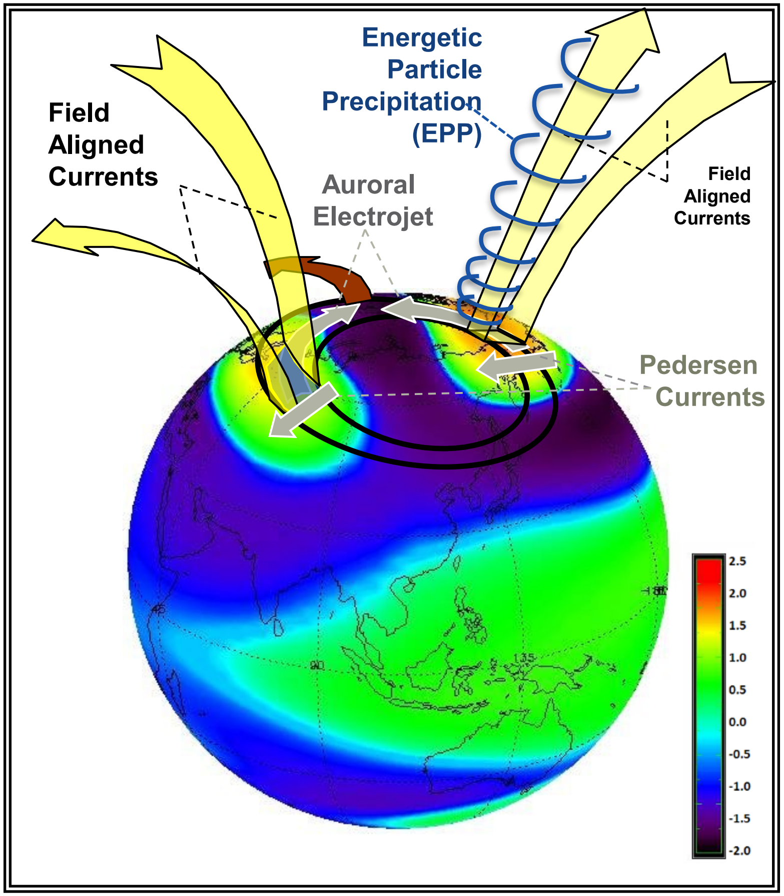
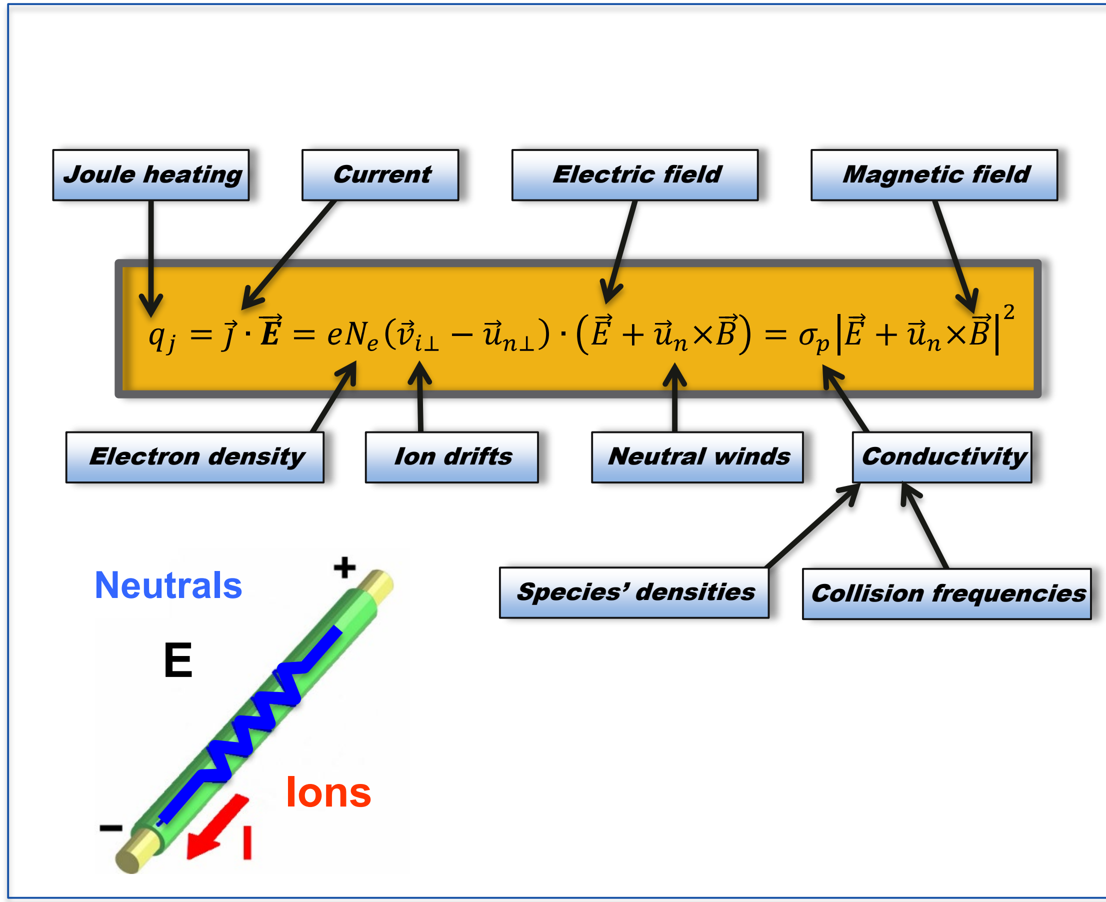
LTI conditions change substantially with geomagnetic activity



LTI energetics





Sounding rockets

So far, sounding rockets are the only way to do in situ measurements in the LTI region

They also provide ground truth for remote sensing (optical imaging, radars, lidars, etc)

Rockets will be needed to complement LTI satellite data with vertical profiles

SPIDER-2

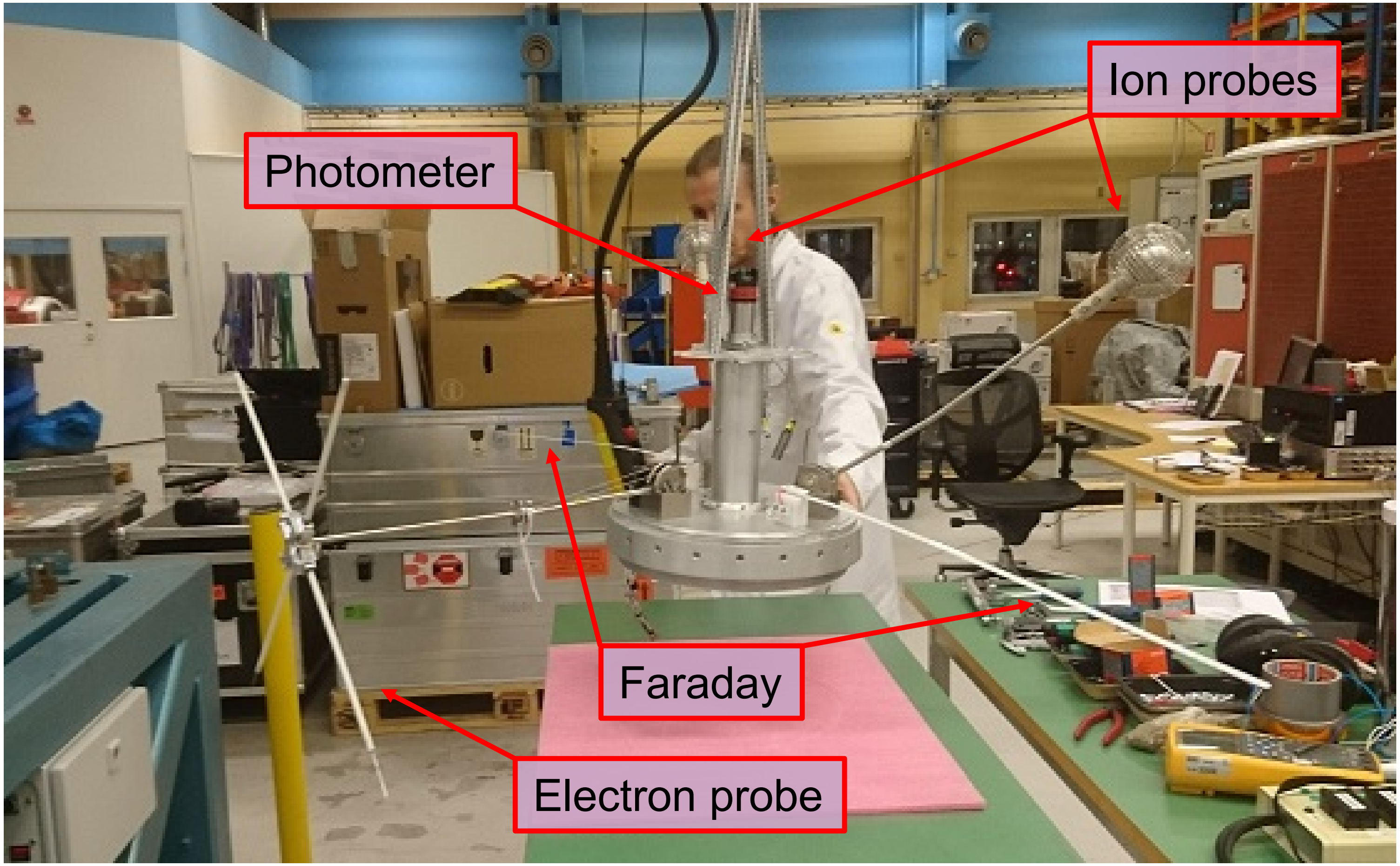
Main rocket:
- UV Photometer (MISU)
- Ion probes (IAP Kühlungsborn)
- Faraday rotation (TU Graz/IAP Kühlungsborn)
- Electron probe (KTH)

SPIDER-2 free fliers (x8):
- 4x E-field probes
- 4x Langmuir probes
- SMILE

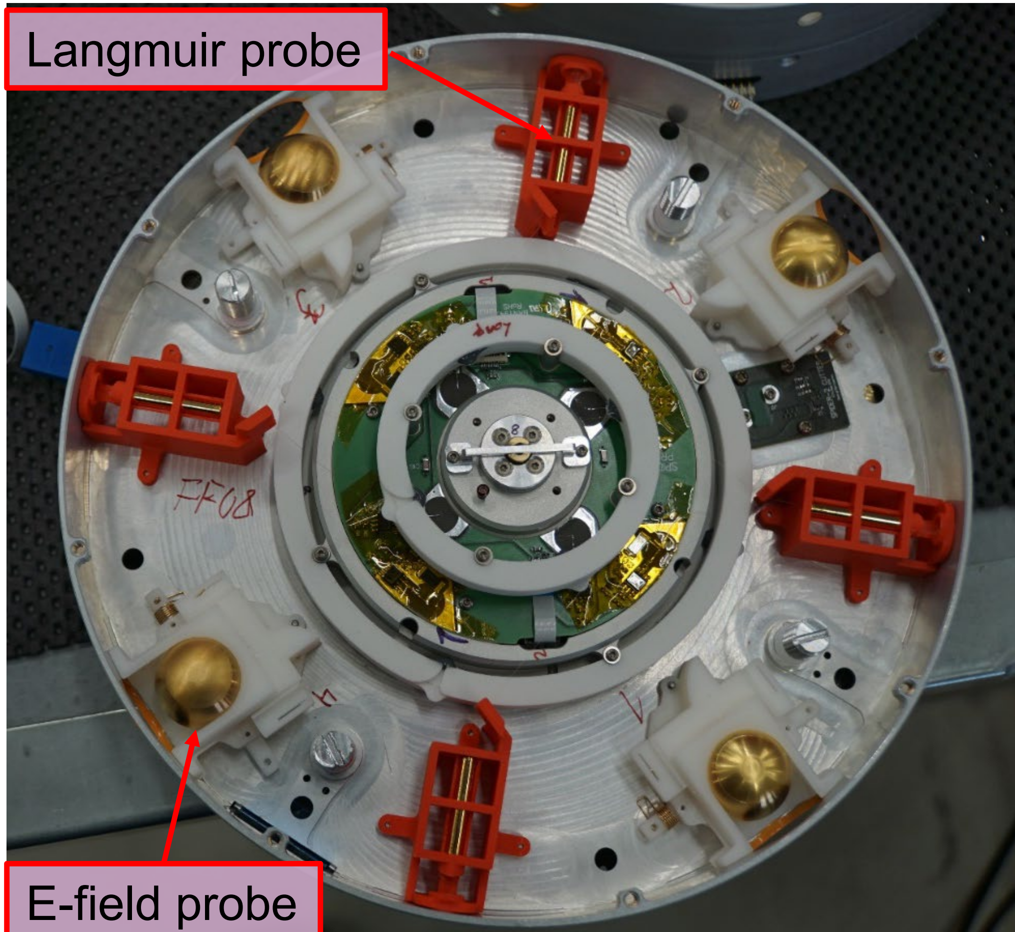
MUSCAT free fliers (x4):
- raw GPS
- accelerometers

Launched: 2020-02-19 23:14 UTC / 2020-12-20 00:14 LT

Nosecone payload – “plasma package”



Boom deployment system

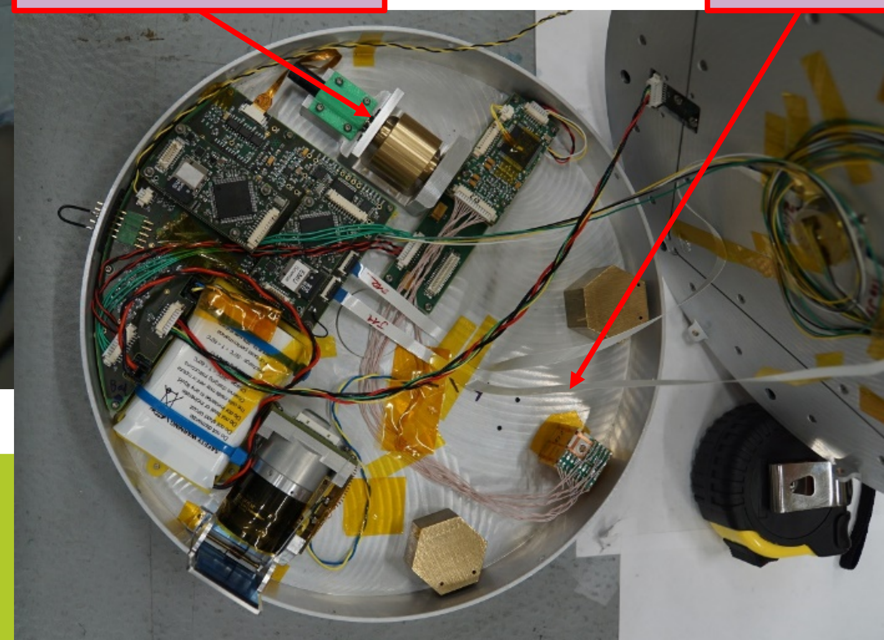


Cylindrical Langmuir probes

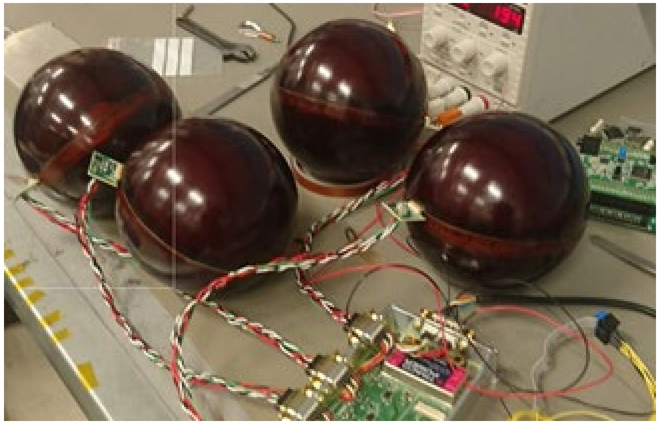
Spherical E-field probes

1.5 m wire booms

SMILE magnetometer

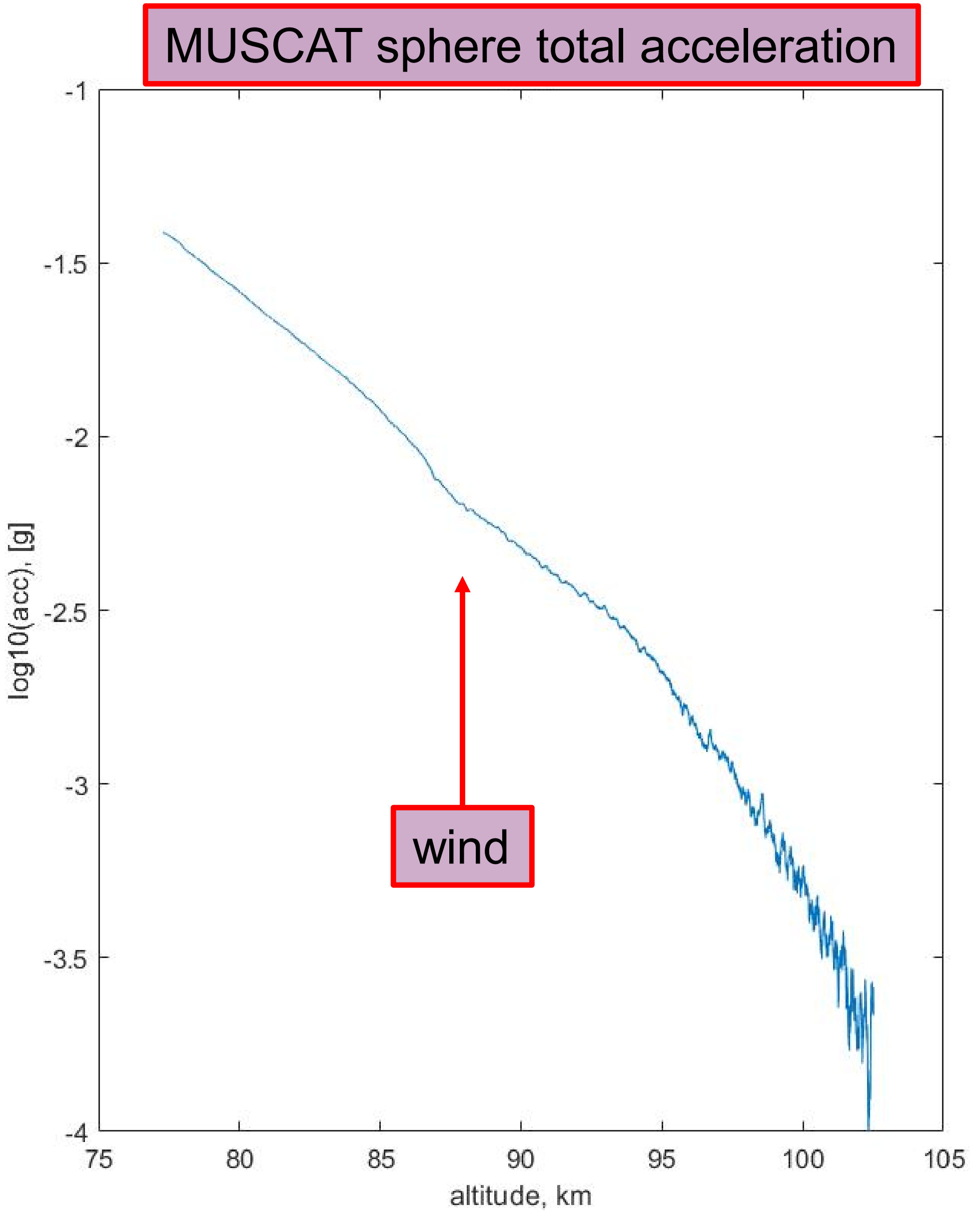


MUSCAT free fliers



Falling spheres to retrieve density, temperature and wind profiles.

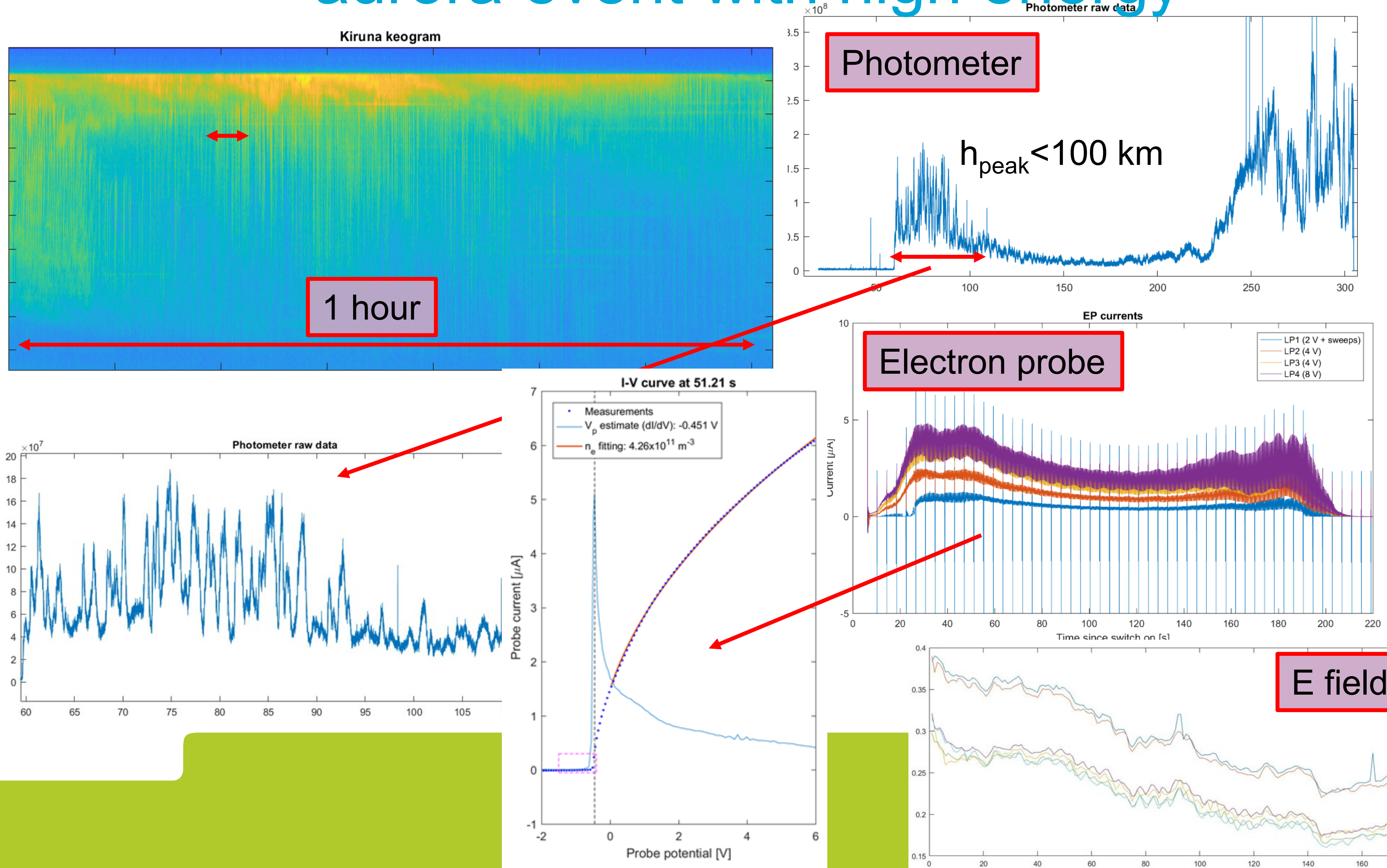
Design based on MUSCAT REXUS experiment (2013) and LEEWAVES (2016)



Launch – Feb 19, 2020, 23:14 UTC

Photo: SSC, M. Lindh et al

SPIDER-2 observations – pulsating aurora event with high energy



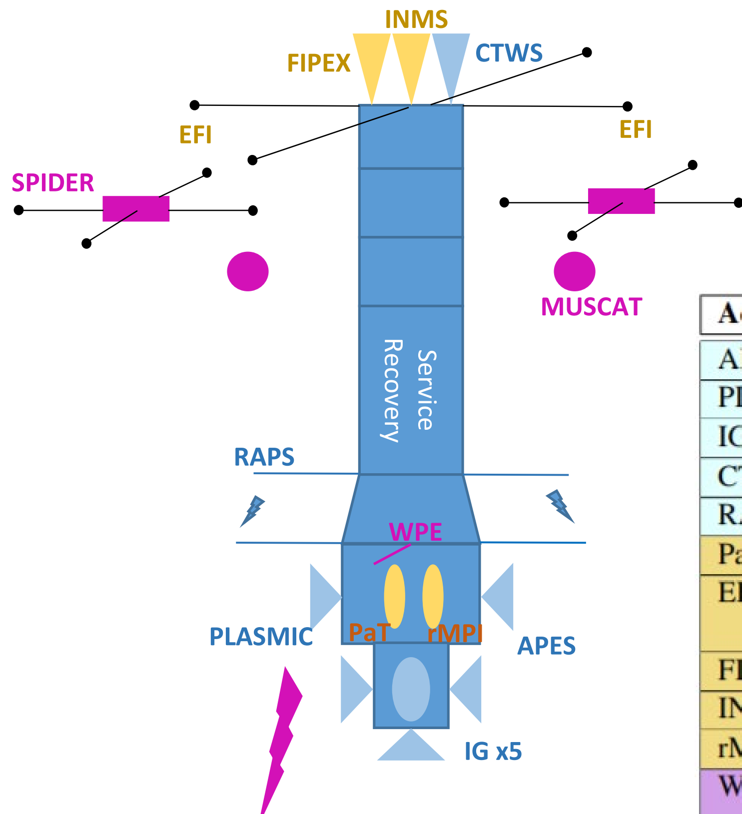
SYSTER & BROR

SYSTER: Proposed by KTH in situ rocket with comprehensive suite of instrumentation, for **quantitative characterisation of the energetics of Joule heating in the auroral region through in situ measurements of the parameters of ionized and neutral components in the lower thermosphere**.

BROR: Proposed by IRF Kiruna/Clemson Universty, to study **neutral winds and ion drifts in the ionosphere and effects of scale structure**

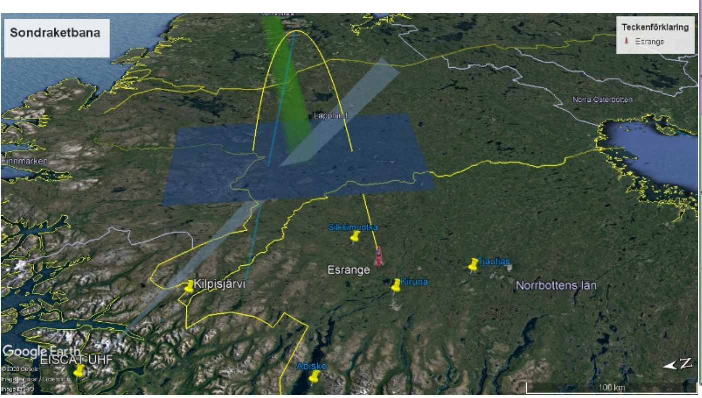
Multiple Barium releases @ 120 km, 140 km, 160 km, 180 km & ground based optical tracking of neutral and ion clouds

SYSTER



- Proposal submitted to SNSA spring 2020
- NASA contribution funded, conditioned on SYSTER approval
- Discussion with ESA on potential co-funding ongoing

Acronym	Meas. Type	Meas. Quantities	Provider
APES	Main payload in-situ	Auroral e-	COUSIN / GSFC
PLASMIC	Main payload in-situ	Energetic e-	COUSIN / U. Iowa
IG	Main payload in-situ	Neutral (n, T, $\vec{v}$) along-track	COUSIN / UNH
CTWS	Main payload in-situ	Neutral (n, T, $\vec{v}$) cross-track	COUSIN / UTD
RAPS	Main payload in-situ	e- density	COUSIN / CU-LASP
PaT	Main payload in-situ	i+ velocity	Stockholm U. Sweden
EFI	Main payload in-situ	Electric field	KTH, Sweden and U. Oslo, Norway
FIPEX	Main payload in-situ	O, O_2 density	U. Stuttgart, Germany
INMS	Main payload in-situ	$\vec{v}$, composition (i+, neutral)	MSSL, U.K.
rMPI	Main payload in-situ	i+ velocity	U. Calgary, Canada
WPE	Ground to payload, integrated	e- density	IAP Kühlungsborn, Germany
SPIDER	Free-flyer (4x)	E-field, B-field, e- density, e- temperature	KTH, Sweden
MUSCAT	Falling sphere	Neutral $\vec{v}$	KTH, Sweden
ALIS4D	Imaging	Multi-spectral	IRF Observatory, Esrange, Sweden
VIPR	Ionosonde	Bottom-side e- density	IRF Observatory, Esrange, Sweden
Other ground assests	Magnetometer chain, riometers, GNSS stations	B-field, total e- content, radio absorption	IRF Observatory, Esrange, Sweden



BROR – Barium Release Optical and Radio experiment

- What is the role of small- and medium-scale (from a few to tens of km) ionospheric disturbances in the magnetosphere-ionosphere interaction?
- What is the mechanism of cross-scale energy transfer between the auroral ionosphere and the thermosphere?
- How are the plasma waves generated by the ionospheric plasma instability transformed into radio waves?

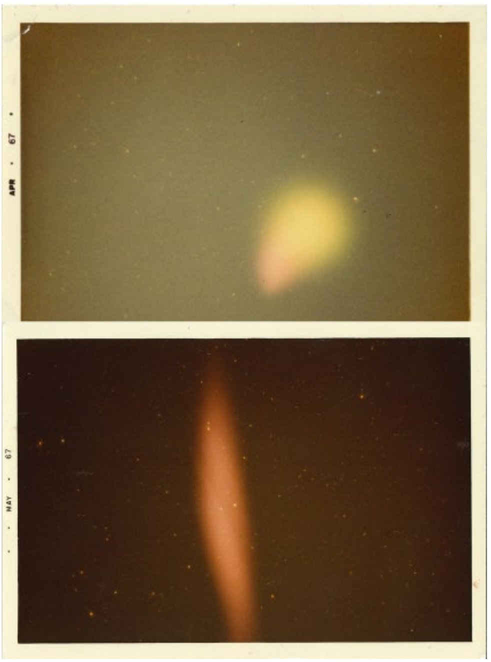
SSC

IRF INSTITUTET FÖR RYMDFYSIK Swedish Institute of Space Physics

CLEMSON PHYSICS AND ASTRONOMY

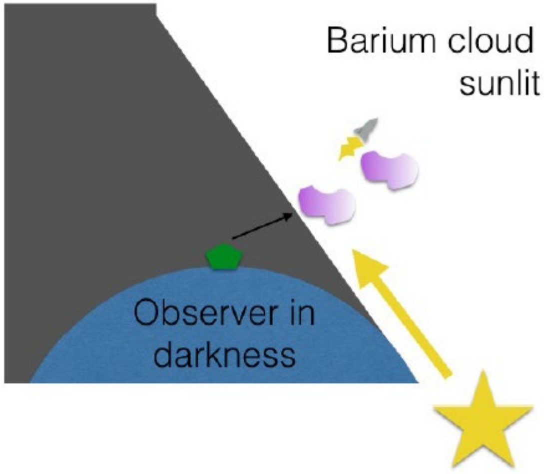
Rymdstyrelsen Swedish National Space Agency

BROR – funded for flight 2022/23!



1967 @Esrange

AZURE rockets, NASA
2019 @Andøya

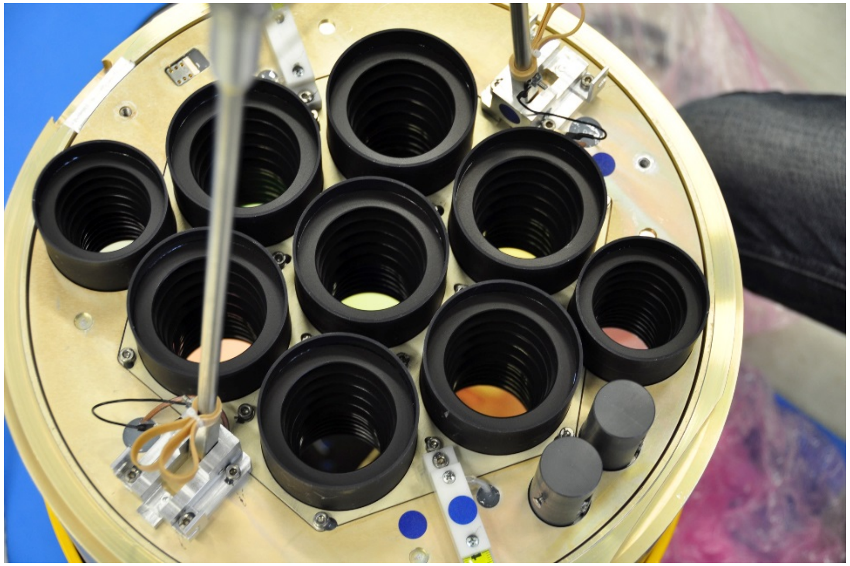


Facility	
ALIS4D	0.1-10 km ~10s ms
Riometer	1-60 MHz 10 ms
EISCAT	2 km 0.44 s

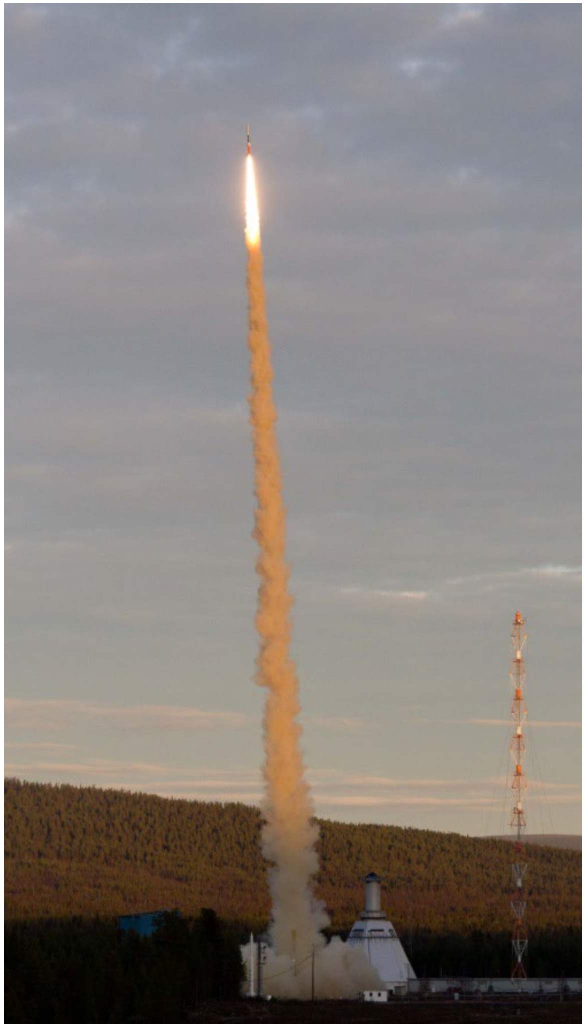
ORIGIN

Oxygen and its Role In Generating and Influencing Nightglow

J. Gumbel, J. Hedin, L. Megner (MISU)
N. Ivchenko (KTH), D. Murtagh (Chalmers)K. , Kalogerakis (SRI)



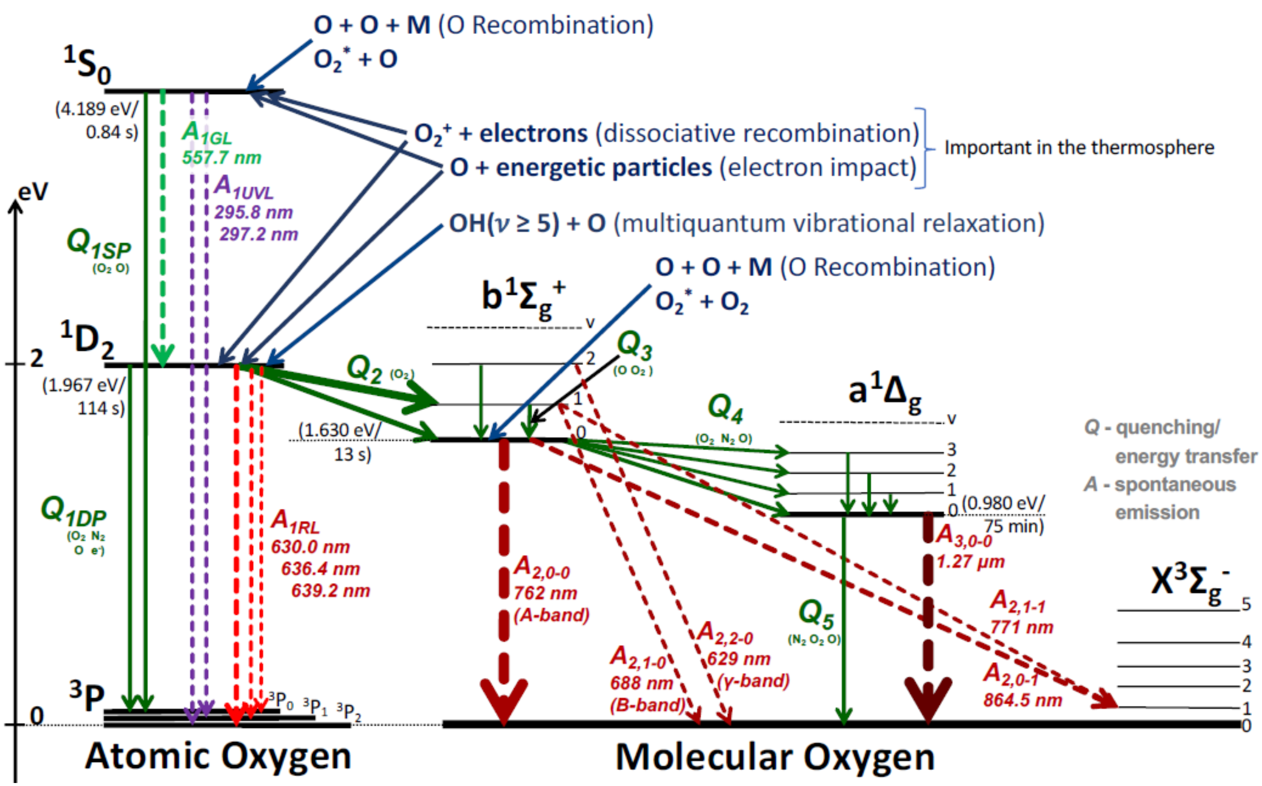
MISU's UV/Visible/IR photometer package



Heritage: O-STATES campaign (Esrange, October 2015)

Revisiting the physics of nightglow emissions

- new lab results on O and H reaction paths
- consequences for energetics and remote sensing



Rocket-borne:

- UV/Vis/IR photometry
- Microwace radiometry
- active O-, H-probes
- CONE temperature
- Ionospheric probes

Ground-based:

- Imaging photometry
- Spectrographs
- Esrange lidar
- EISCAT_3D

J. Gumbel & ORIGIN team

Recent focus on the LTI…

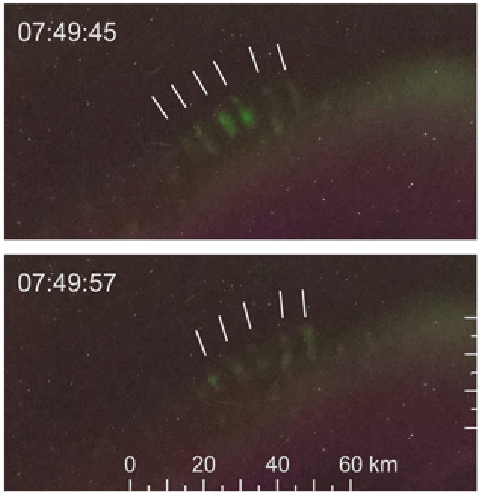
STEVE

Image: ESA/David Markel Photography

Emissions associated to Sub-Auroral Ion Drifts, spectra different from aurora, possibly local generation

E. MacDonald et al, 2018

FAE



Possibly local generation

J. Dreyer et al., 2021

Dune aurora

100 km altitude,
~50 km wavelength

M. Palmroth et al, 2020

Outlook…

- Sounding rockets are a unique research tool
- Esrange has perfect facilities for research using sounding rockets
- There is revived interest in LTI, both scientifically and in space weather context
- Opportunities for great collaboration within Grand Challenge Initiative
- Hopefully Sweden continues contributing actively

NASA GDC mission (@ 300-400 km) is targeting magnetosphere-IT coupling

Daedalus mission may be pursued outside EE program

PhD position (SNSA-funded) to be announced at KTH to work with SPIDER-2 data