

# Multi instrument radio diagnostics



**H. Rothkaehl**

Centrum Badań Kosmicznych PAN

Warsaw LOFAR Ionospheric workshop

# Space Research Centre

Polish Academy of Sciences



**Established in 1977**

- **Staff: 200 persons**
- **Scientists: 50**
- **Engineers, technical staff, students, others**



**Heliosphere**

**Planetary Research**

**Solar Physics**

**Space Plasma Physics**

**Geodynamics, Time**

**Reference Systems,**

**Remote Sensing**

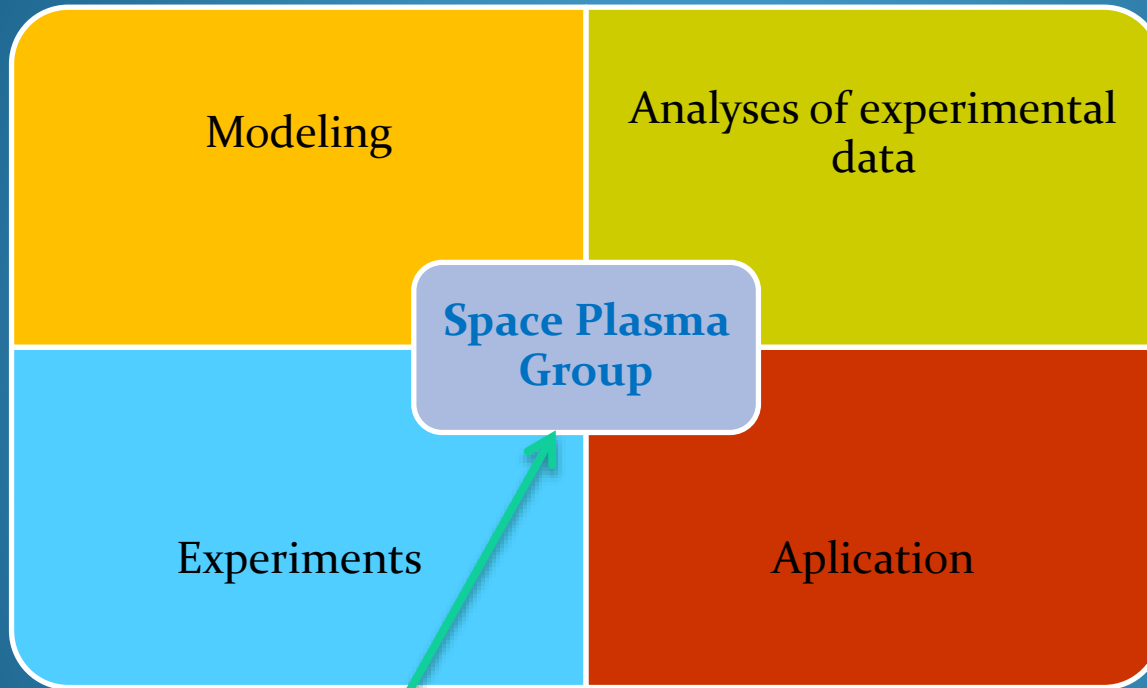
**Instrumentation,**

- **About 50 instruments built**



# Space Plasma Group

Heliogeophysical Prediction Service Laboratory

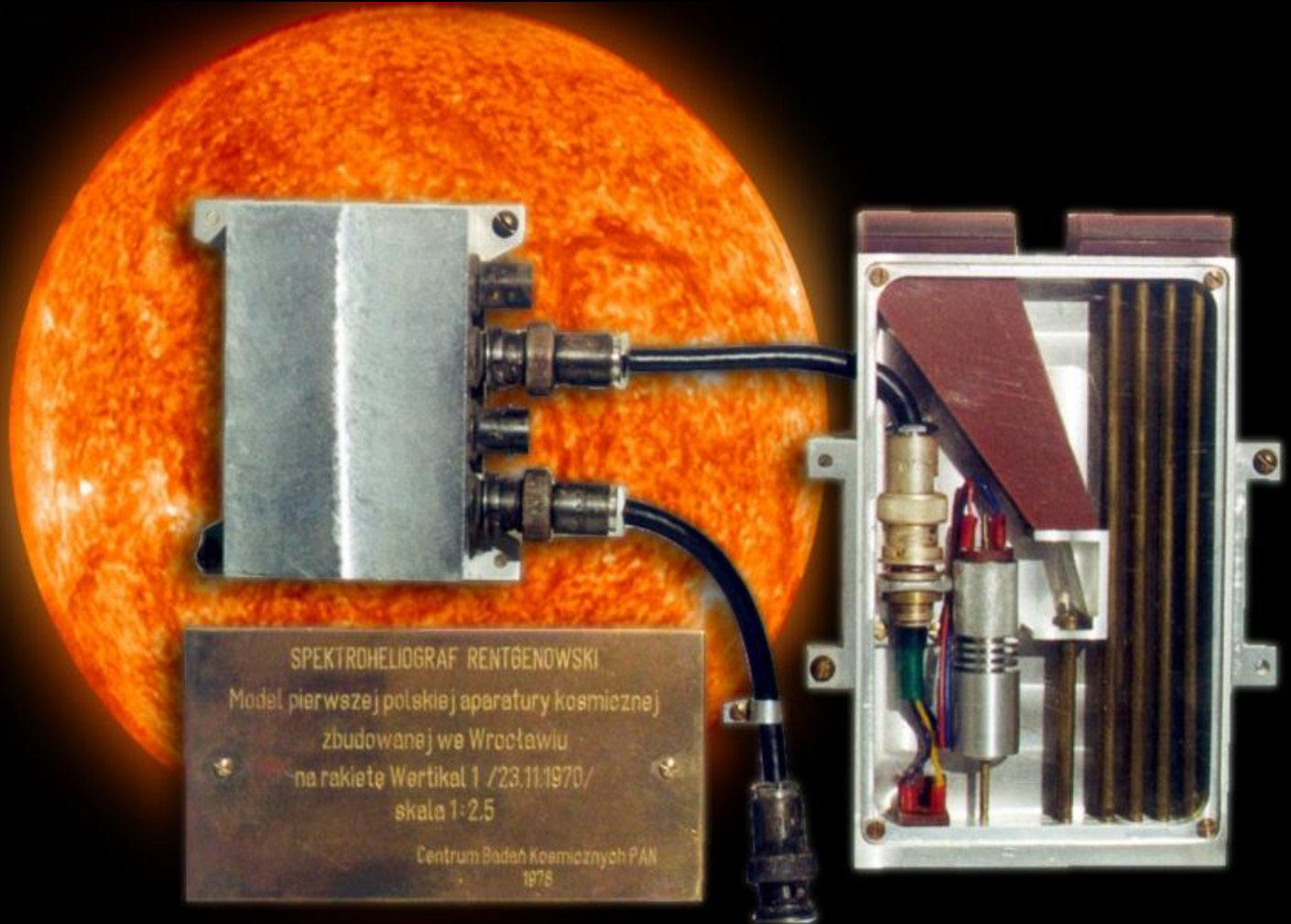


Total around 25 person

Head Ass Prof. Hanna Rothkaehl

Close cooperation with  
Electronic Constructions Laboratory

**The first Polish instrument launched into space**  
pin-hole camera launched on VERTICAL-1 Soviet rocket on November 28, 1970





# PLASMA PHYSICS EXPERIMENTS

**SATELLITE EXPERIMENTS, 28 instruments; 21 missions already completed,**

27.02.1979	INTERCOSMOS-19	Radiospectrometer IRS-1
25.12.1980	PROGNOZ-8	Spectrum Analyzer BUD-A
15.12.1984	VEGA-1	Spectrum Analyzer APV-N
21.12.1984	VEGA-2	Spectrum Analyzer APV-N
18.12.1986	COSMOS 1809	Radiospectrometr AVCz-2F, Antenna Impedance Meter
7.07.1988	PHOBOS-1	Spectrum Analyzer APV-F1
12.07.1988	PHOBOS-2	Spectrum Analyzer APV-F2
28.09.1989	INTERCOSMOS-24 ( <i>ACTIVE.</i> )	Radiospectrometer PRS-2, Antenna Impedance Meter, Spectrum Analyzer
28.09. 1989	INTERCOSMOS-24 ( <i>SUBS.</i> )	Radiospectrometer PRS-2S
18.12.1991	INTERCOSMOS-25 ( <i>APEX</i> )	Radiospectrometer PRS-3, Antenna Impedance Meter
		Radiospectrometer ISKRA , Electrostatic Energy Analyzer
18.12.1991	INTERCOSMOS-25 ( <i>SUBS.</i> )	Radiospectrometer PRS-3S
2.03.1994	CORONAS-I	Radiospectrometer SORS
3.08.1995	INTERBALL-1	Plasma Wave Analyzer ADS
3.08.1995	INTERBALL-1 ( <i>SUBS.</i> )	Plasma Wave Analyzer SAS-1
16.11.1996	MARS 96	DCDC, Low Frequency Analyzer and EGSE for ELISMA PWC
29.08.1998	INTERBALL-2	Radio-spectro Polarimeter POLRAD
29.08.1998	INTERBALL-2 ( <i>SUBS.</i> )	Plasma Wave Analyzer SA-2
10.12.2001	COMPASS	Radiospectrometer RFA-2
29.02.2004	DEMETER	DCDC for Plasma Wave Complex
25. 05 2006	COMPASS-2	Radiospectrometer RF

## ROCKET EXPERIMENTS

18.09.1981 VERTICAL-Gruzya 60-S  
Radiospectrometer PRS-1

Radiospectrometer ISKRA

21.12.1981 VERTICAL-10

Frequency Spectrum Analyzer ASIN

20.05.1983 VOLNA-1 MR-12 Low

Frequency Spectrum Analyzer

Langmuir

Probe

18.03.1985 PLASMA-1 MR-12

Radiospectrometer PRS-2E

15.05.1985 PLASMA-2 MR-12

Radiospectrometer PRS-2RP

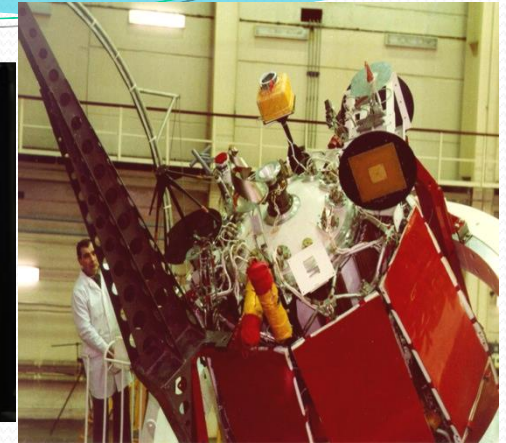
June 1992 NASA Terrier-Black AC-  
Electric Field Spectrometer

8 instruments in 6 missions

# CBK PAN

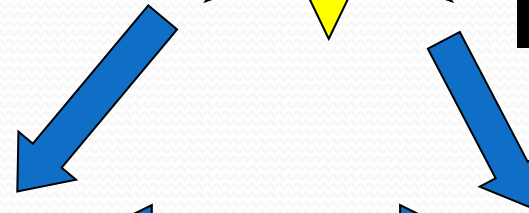
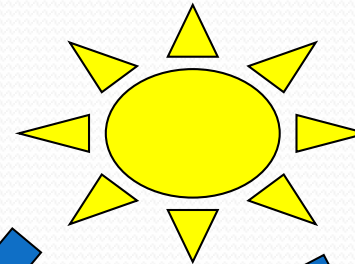
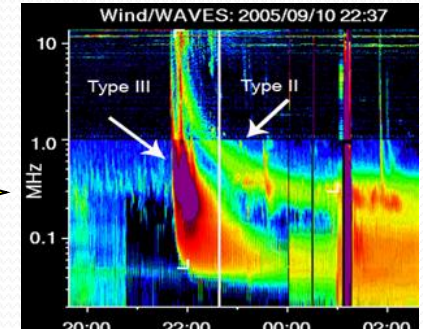
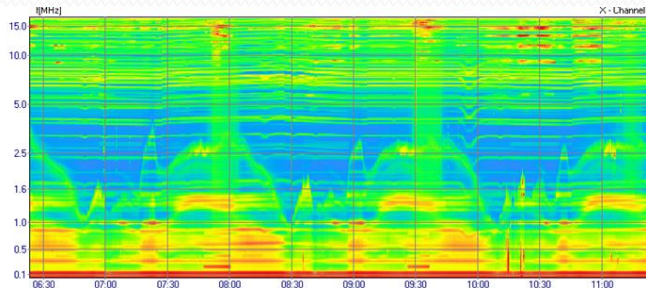
past experiment -RF diagnostics

<b>IK-19</b> 1978-1981	<b>500-980 Km</b> inc. 74 deg	<b>0.1-6. MHz CBK</b>
<b>IK-24 Activn</b> 1989-1990	<b>500-2500 Km</b> inc. 82.5 deg	<b>0.1- 10. MHz CBK</b>
<b>IK-25 Apex</b> <b>Magion-3</b> 1991-1992	<b>430-3100 Km</b> inc. 82.5 deg	<b>0.1-10. MHz CBK</b>
<b>Coronas-I</b> 1994	<b>500 Km</b> inc. 82.5 deg	<b>0.1-30. MHz CBK</b>
<b>Compass-2</b>	<b>600km, inc 79</b> <b>deg</b>	<b>0.1-15 MHz</b> <b>CBK+IRF-u</b>
<b>Obstanovka</b> <b>on ISS</b>	<b>300 km</b>	<b>0.1 -30 MHz electric</b> <b>and magnetic field</b>



# Global chain

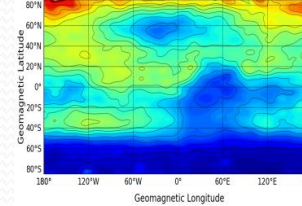
radio wave diagnostics



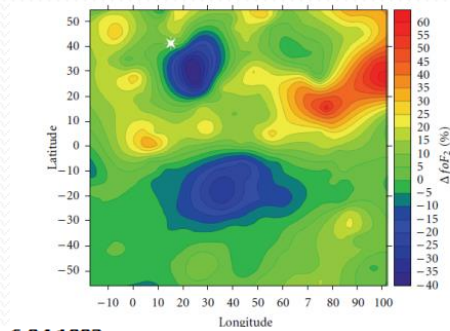
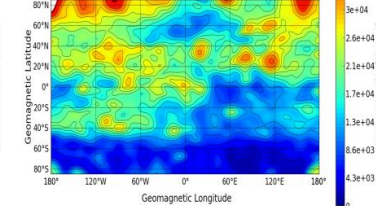
ionosphere

magnetosphere

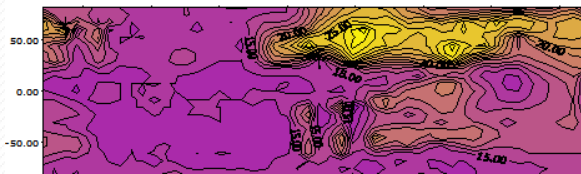
Electron density map from COSMIC data  
Kp index = 0-2, May-July 2007



Electron density map from COSMIC data  
Kp index = 4-6, May-July 2007

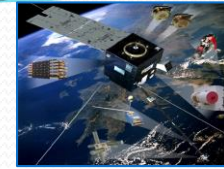


6.04.1992



Earth  
natural processes and human activity

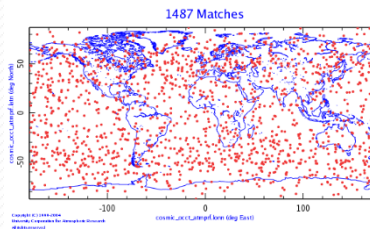
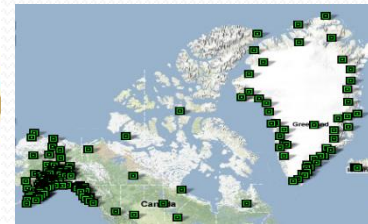
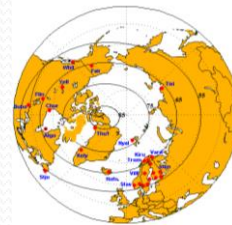
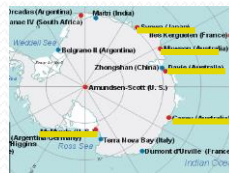
# Multi instruments diagnostic



- In situ diagnostics LO satellite; waves and plasma diagnostic **DEMETER RELEC**

- TEC measurements IGS, **Antarctic and Arctic**

- RO satellite diagnostics **FORMOSAT-3/COSMIC**



- grand based Ionosondes, radars, LOFAR (radio telescope interferometer)

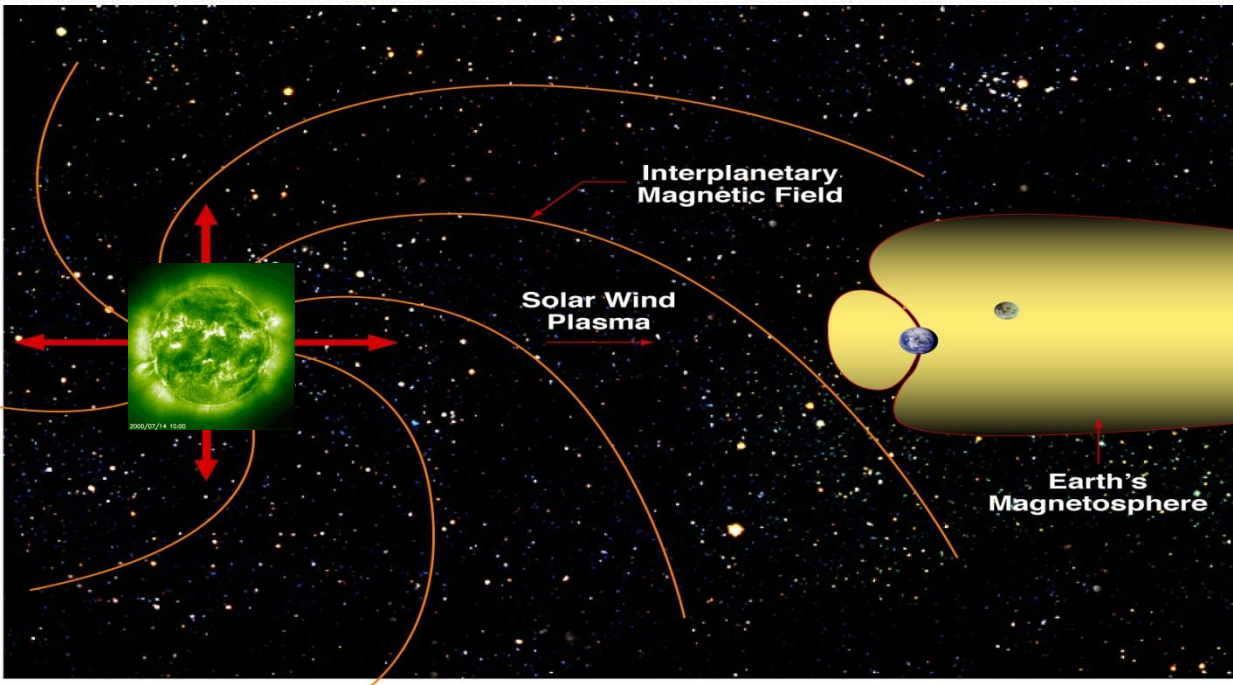


High temporal and spatial resolution: topside in situ waves and plasma diagnostics, and remote diagnostics (limited area)

General description of large scale structures :TEC measurements, ground base ionosonde network



# Wave diagnostics



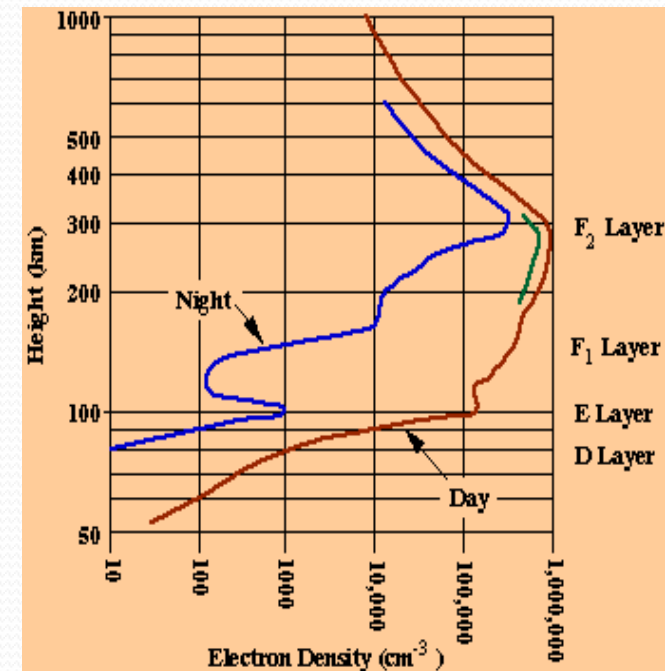
Local plasma frequency = local electron density  
kHz up to few MHz

Local gyro-frequency proportional to the intensity of magnetic field  
tens kHz up to MHz

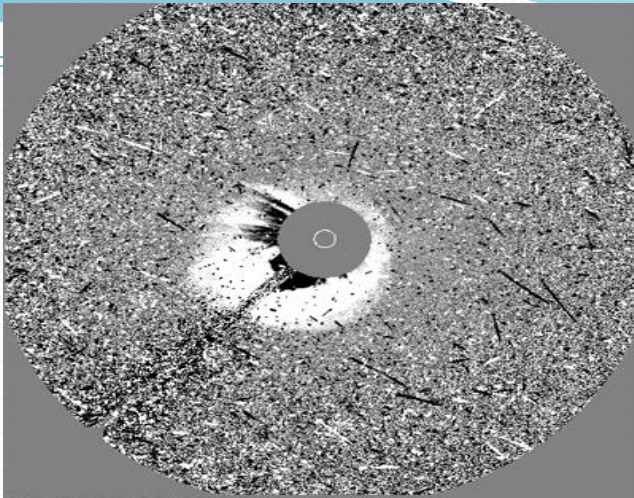
**ULF and LF ion**  
plasma diagnostics, E  
B field fluctuations.

**VLF** low density  
plasma diagnostics

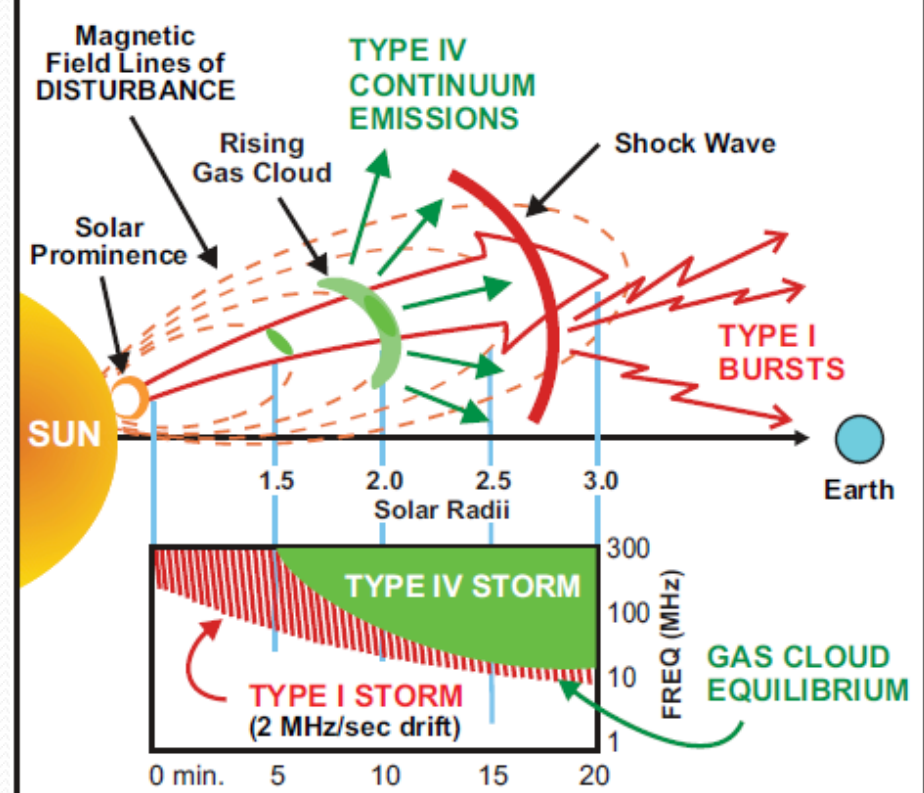
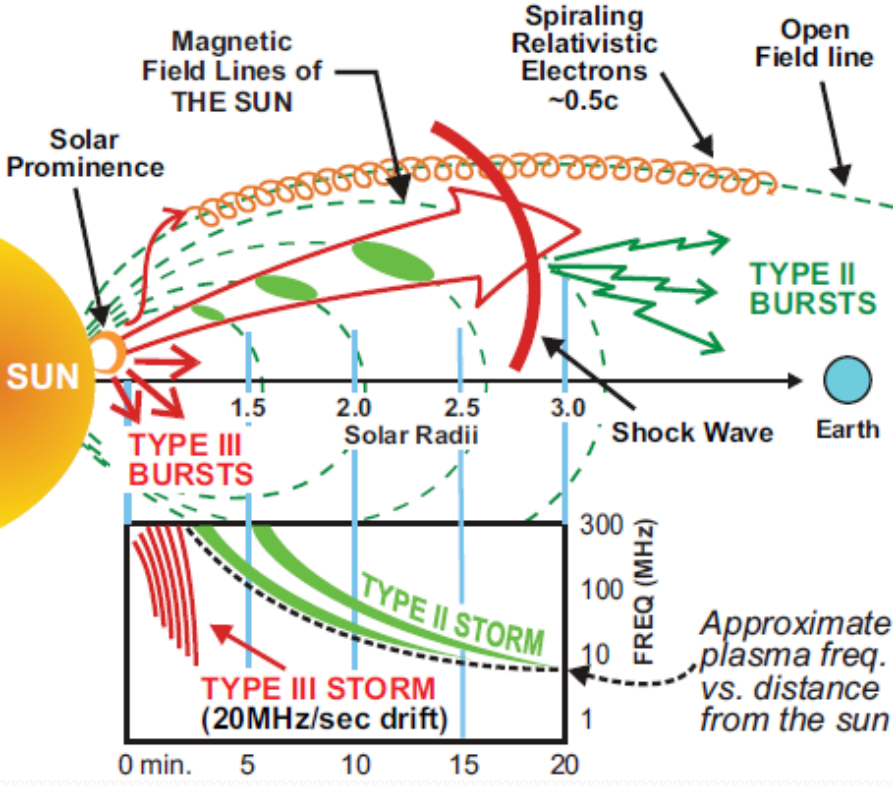
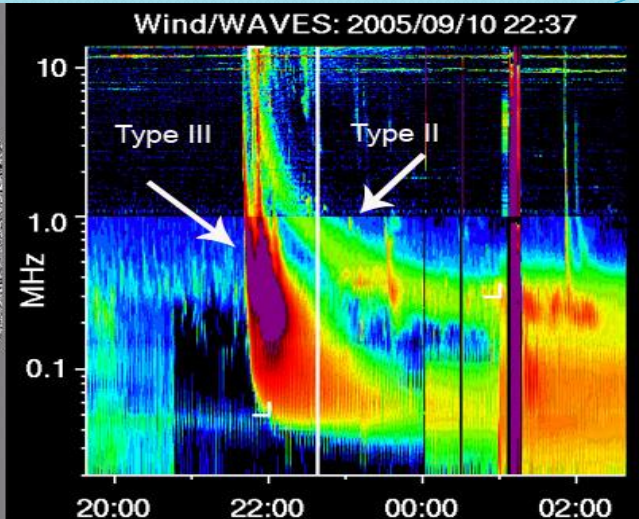
**HF** electron plasma  
diagnostics, Solar  
radio burst



# SUN RADIO Emissions



C3: 2005/09/10 22:37:47



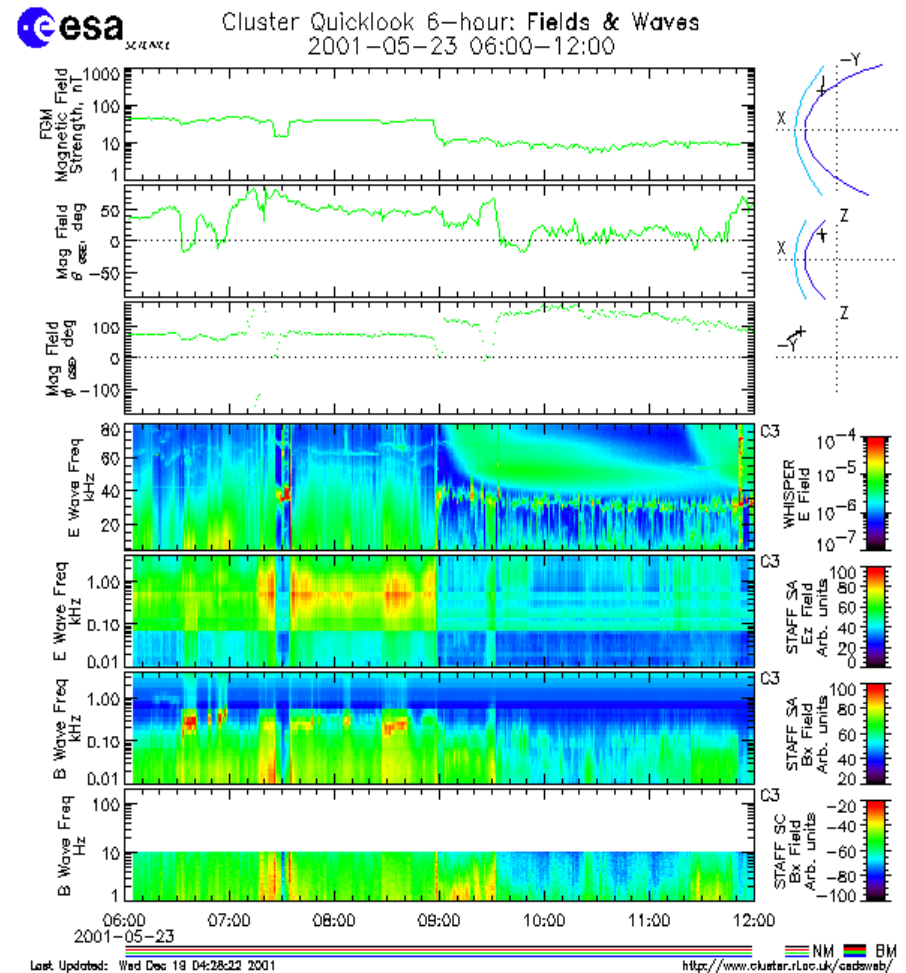
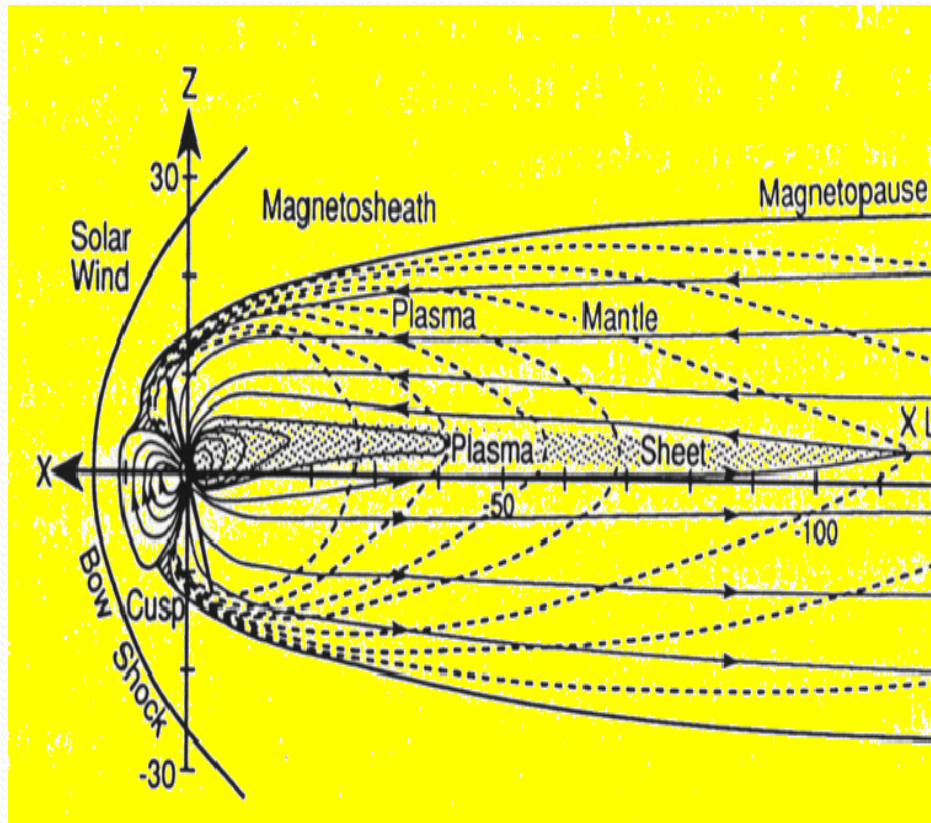
# Magnetosphere

Plasma Sheet

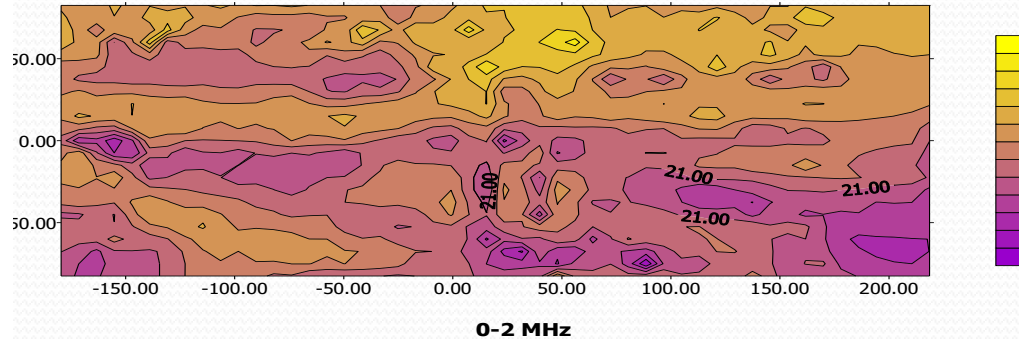
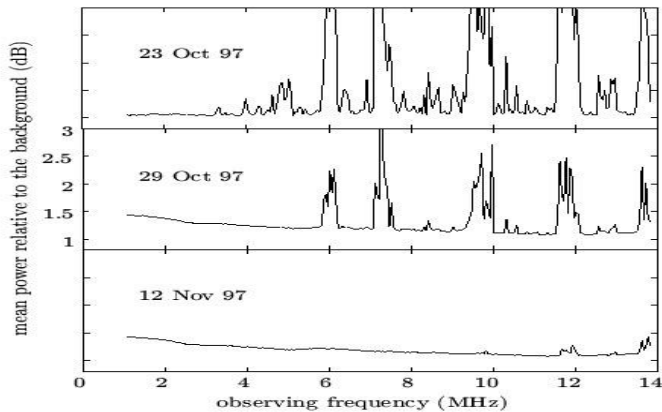
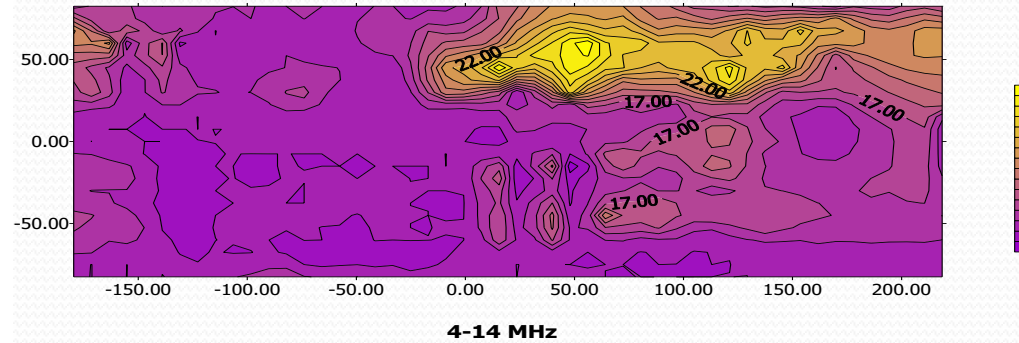
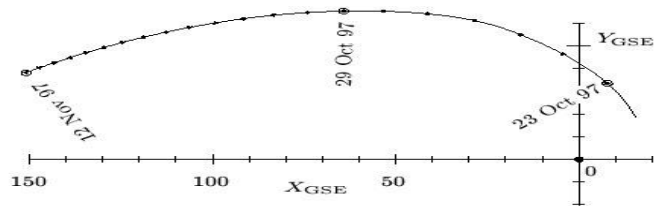
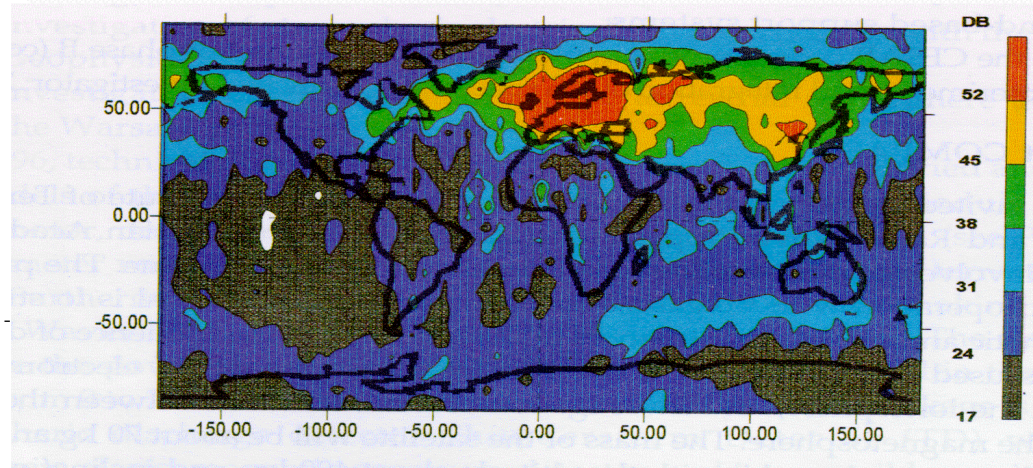
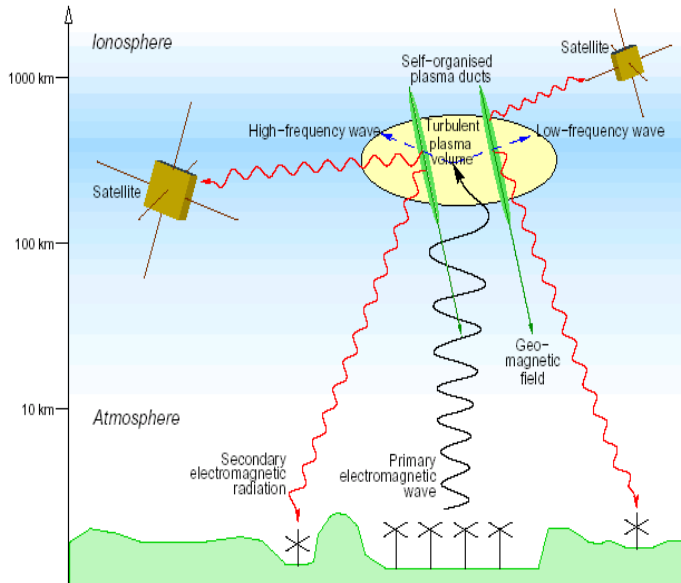
Plasma Mantle

Magnetopause

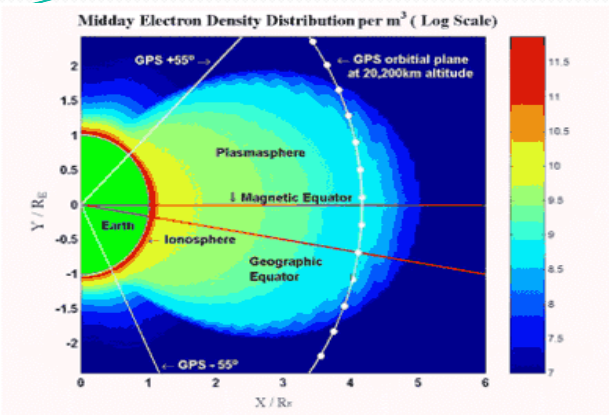
Bow Shock



# Human activity can perturb Earth's environment.



# IONOSPHERIC TROUGH

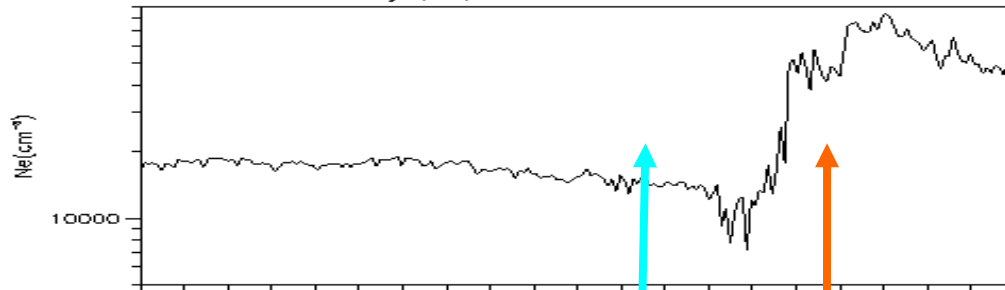


DEMETER

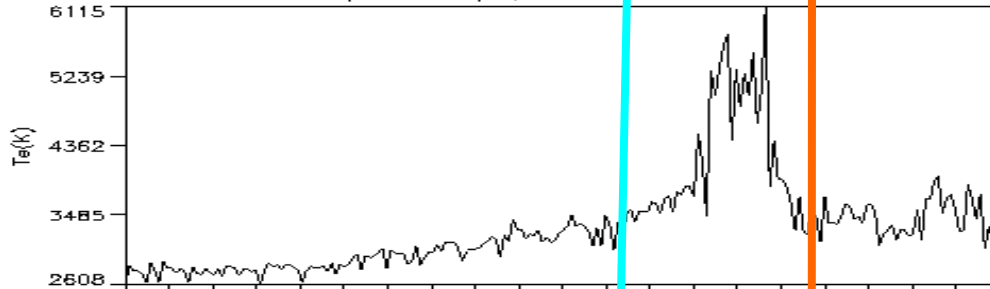
Date (y/m/d): 2004/11/07

Orbit: 01865\_1

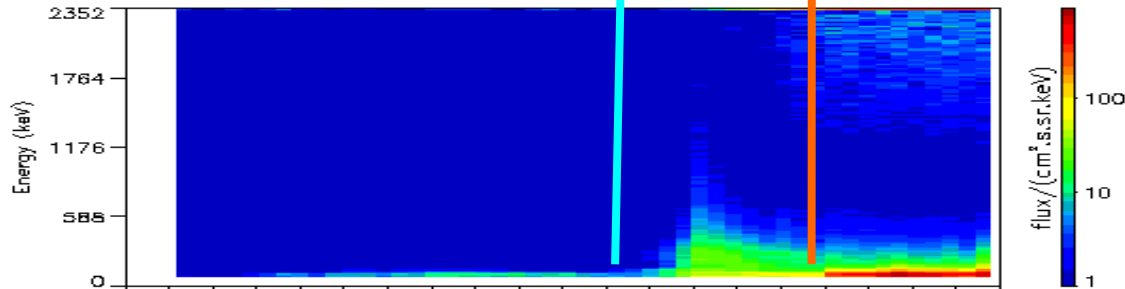
ISL Electron density ( $N_e$ )



ISL Electron temperature ( $T_e$ )



IDP Electron flux



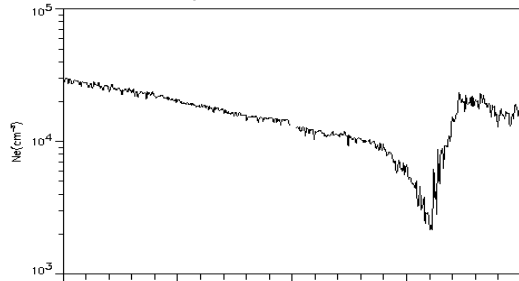
UT	17:47:30	17:48:22	17:49:15	17:50:07	17:51:00
Lat.	52.80	55.87	58.93	61.97	64.88
Long.	55.64	54.07	52.27	50.17	47.67
Inv. Lat.	50.02	52.96	55.87	58.75	61.62
MLT	22.32	22.31	22.30	22.28	22.26

DEMETER

Date (y/m/d): 2005/09/10

Orbit: 06335\_1

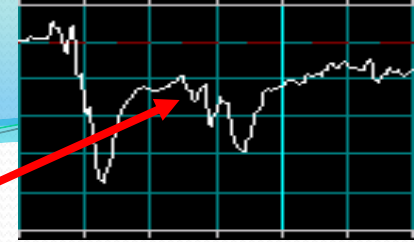
ISL Electron density ( $N_e$ )



Alfven waves, EMIC,  
LHR, UHR

Frozen emissions,  
turbulent regions

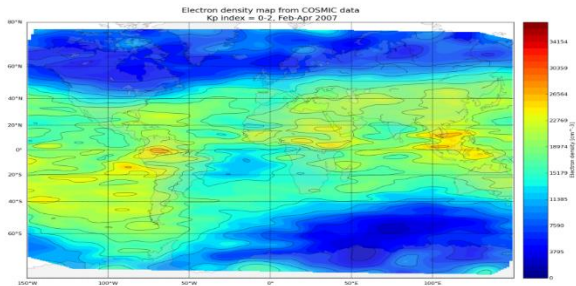
# „First” recovery phase



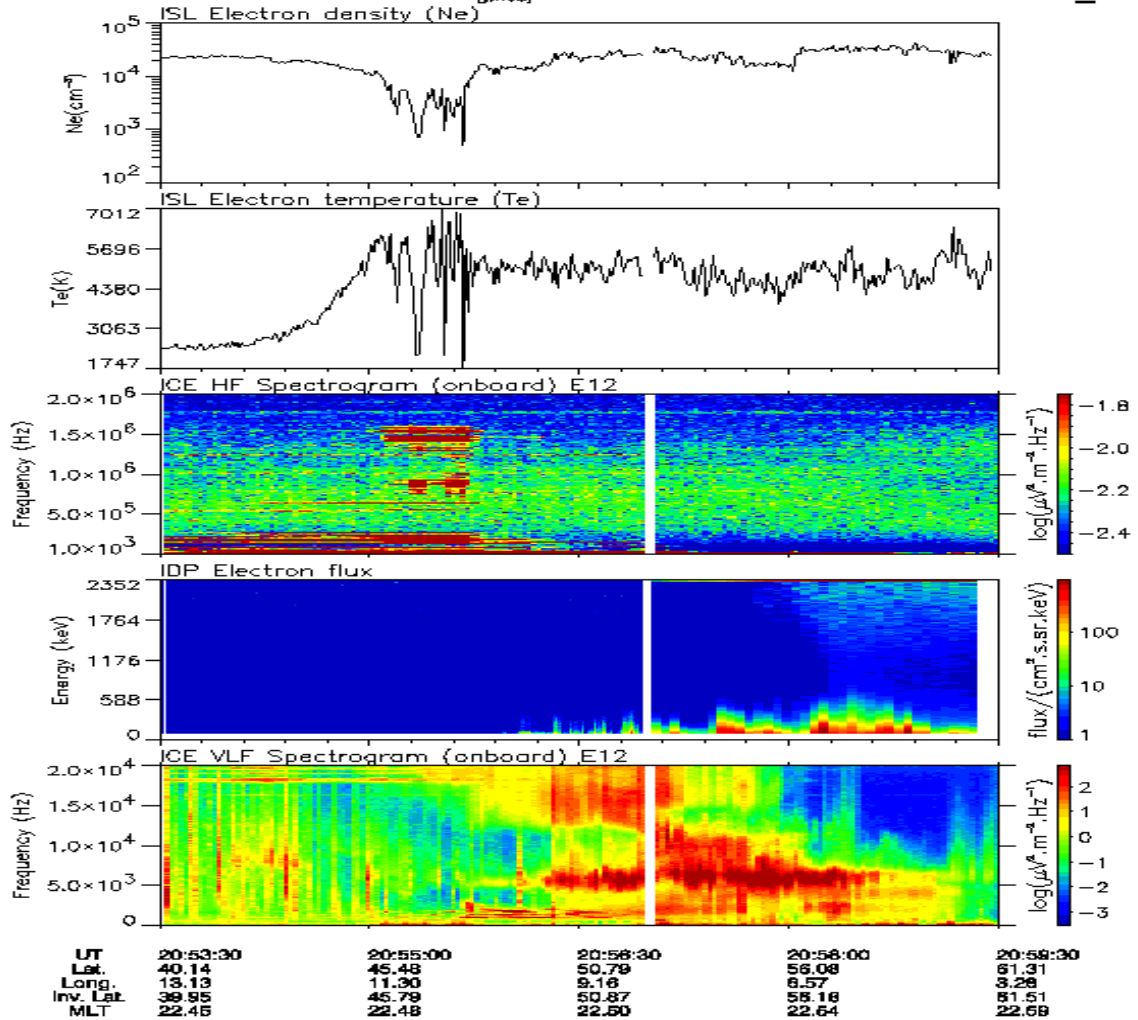
Emissions in auroral oval

VLF emissions „frozen”

The width of trough around 5 deg

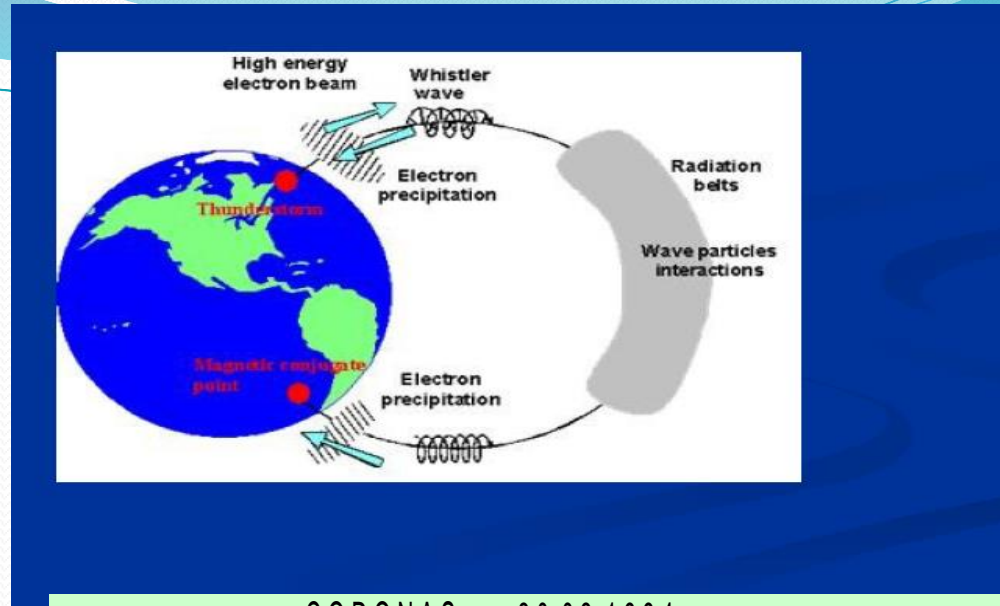
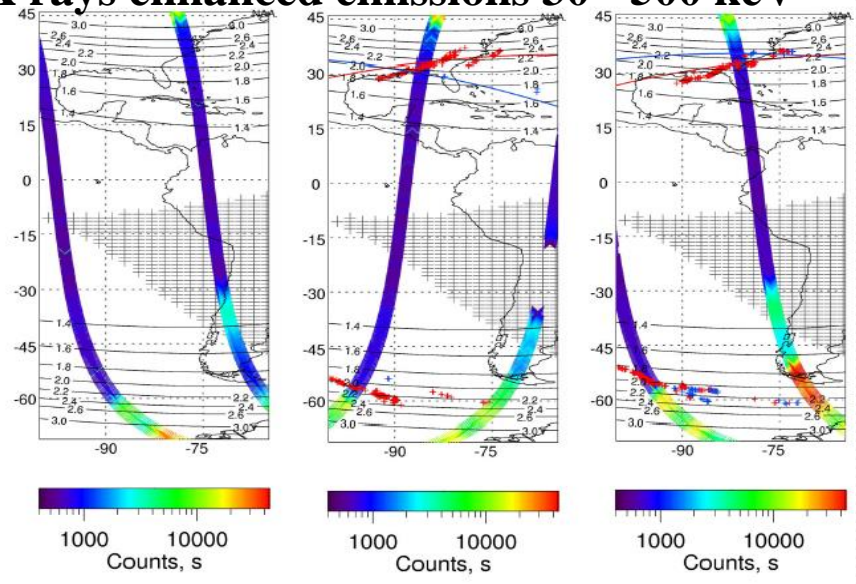


DEMETER Date *yy/mm/dd*: 2004/11/09 Orbit: 01896\_1

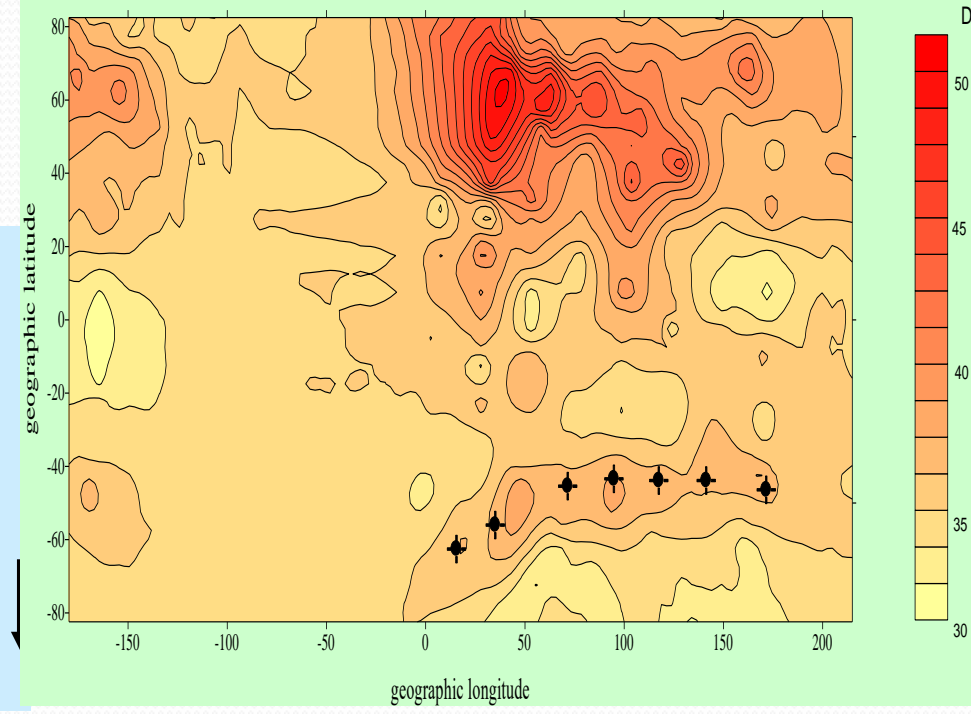


# LIGHTNING INDUCED HARD X-RAY FLUX ENHANCEMENTS: CORONAS-F OBSERVATIONS,

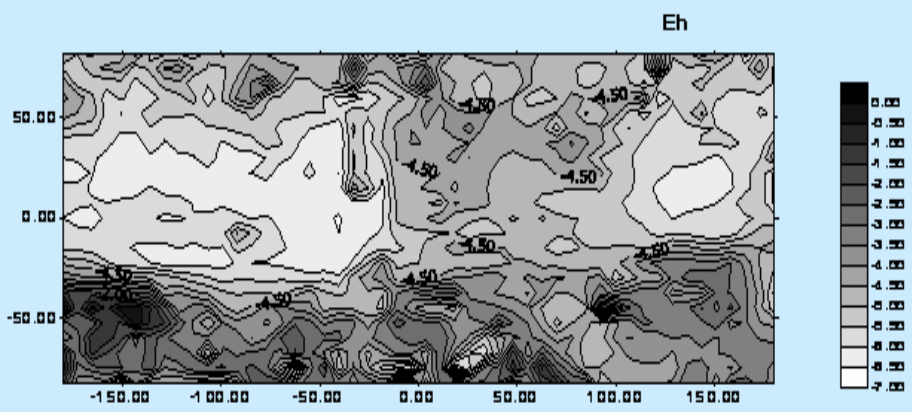
## X rays enhanced emissions 30 - 500 keV

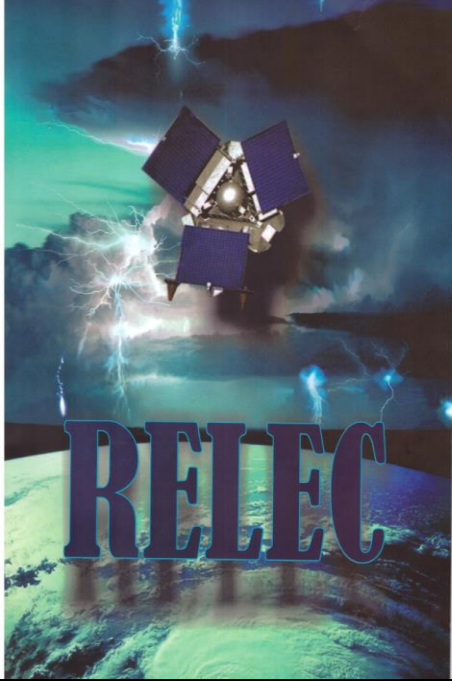


CORONAS 30.03.1994



11 12 13 0 1982 ARCAD-3





# RELEC

## Relativistic ~~ELEC~~trons

START 08 06 2014



**Orbit:**

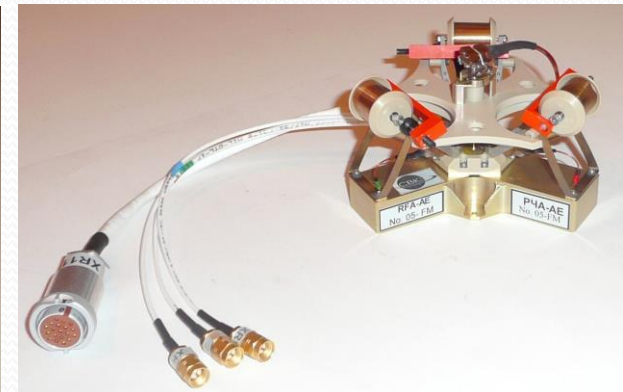
apogee: 830 km.

perigee: 640 km.

inclination: 98,4 deg.

- **DRG-1 & DRG-2** - two identical detectors of X-, gamma-rays and high-energy electrons of high temporal resolution and sensitivity
- **DRG-3** - three axe directed detectors of energetic electrons and protons
- **MTEL** - optical imager
- **DUV - UV** detector
- **BChK** - module of charge and neutral particle detectors
- **NChA** - low-frequency analyser
- **RFA** - radio-frequency analyser
- **DOSTEL** - dosimeter module
- **BSKU** - module of commands and data collection

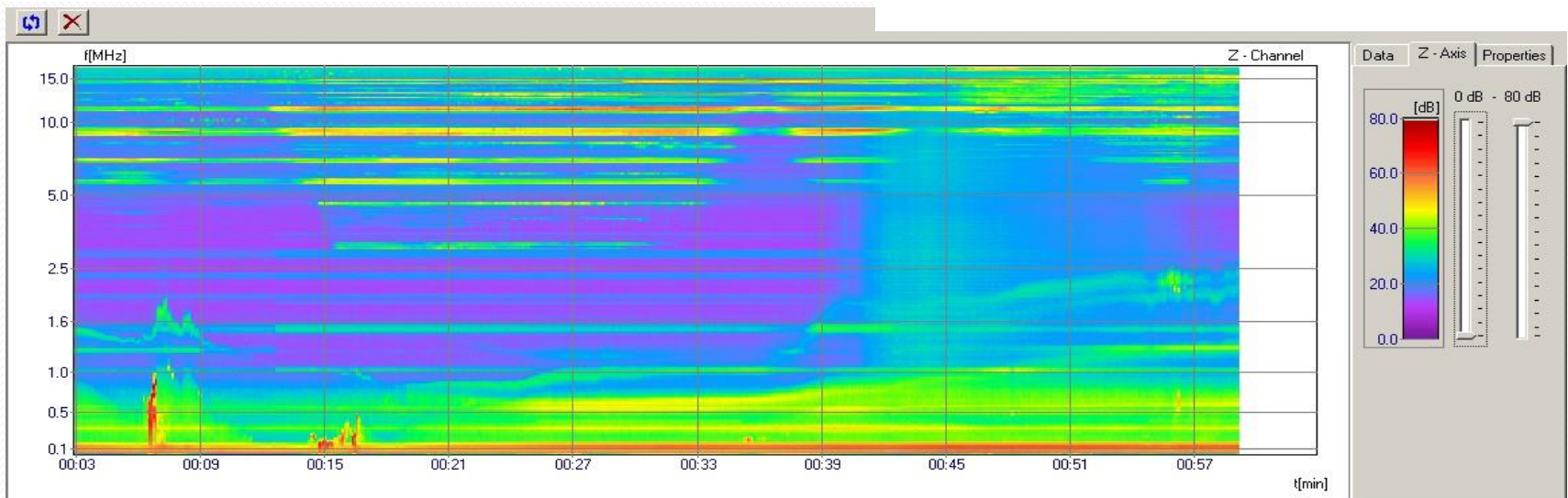
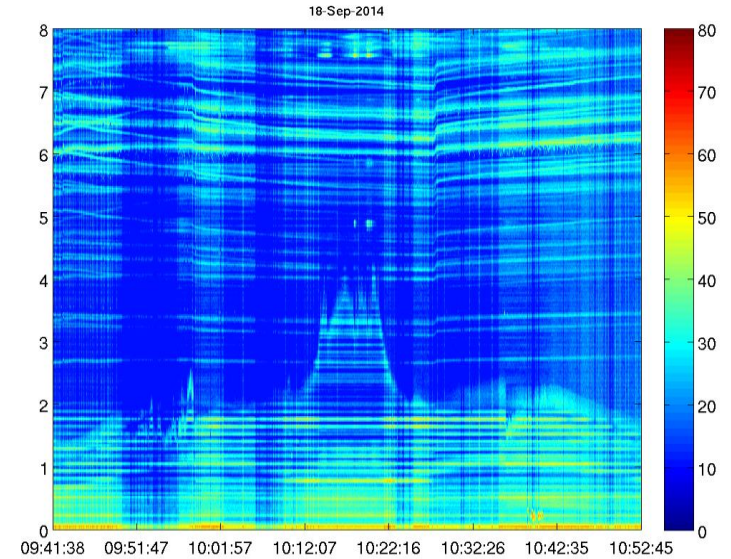
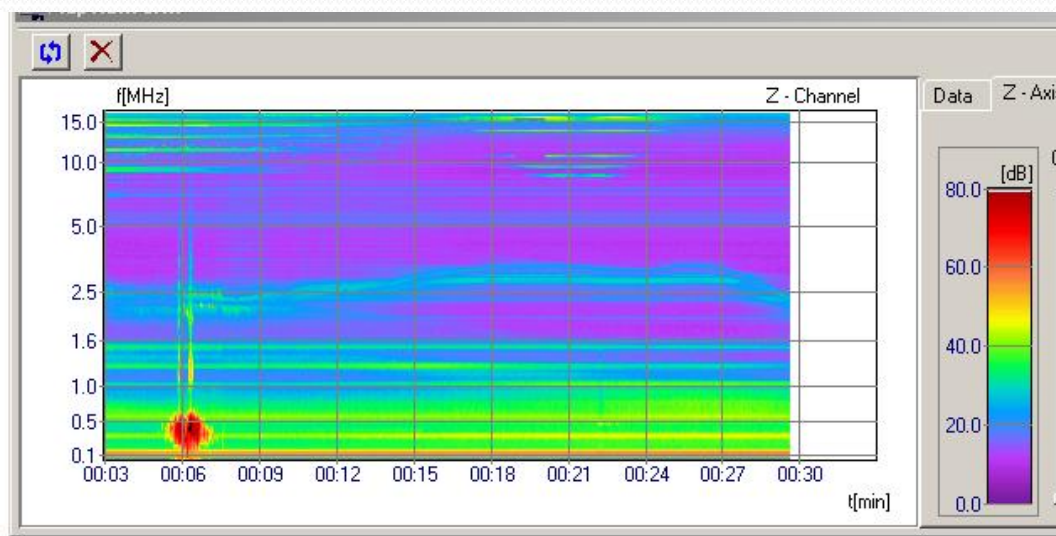
Parameter	Value
<b>General</b>	
Mass [kg]	1.3 (+10% / - 30 %)
Power [W]	10.0 (+20% / - 30 %) - full operational ~2.5 (+25% / - 50 %) - standby (TM Dump)
Supply voltage [V]	28.0 ( +/- 4 [V])
Dimension [mm]	190.0x160.0x92.0 (TBC)
<b>Functional</b>	
Number of channels	3 for E-field components
Frequency range	50.0 [kHz] to 15.0 [MHz] - E-field
Spectrum resolution	~1.0 [kHz] (50 to 1000 kHz) ~20.0 [kHz] (1.0 to 15.0 MHz)
Time resolution (wave mode)	25.0 [ns]
Dynamic range	80.0 [dB] (spectrum mode) 65.0 [dB] (wave mode)
<b>Operational</b>	
Discrete commands	NONE
TM/TC interface	RS 422
TC stream	2 - 3 commands/session (orbit)
TC packet length	16 bytes
TM stream	~2 - 4 kB/ sec
TM packet length	256 byte
Internal memory buffer	2MB (minimum ~10 minutes of measurement without TM dump)

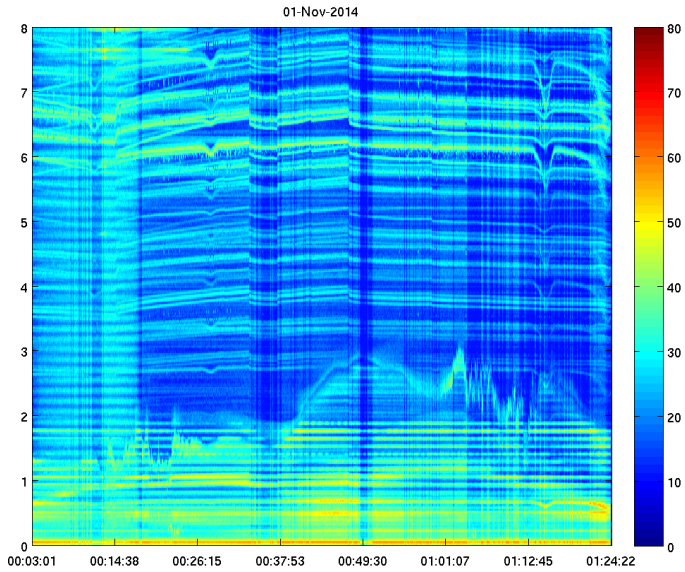




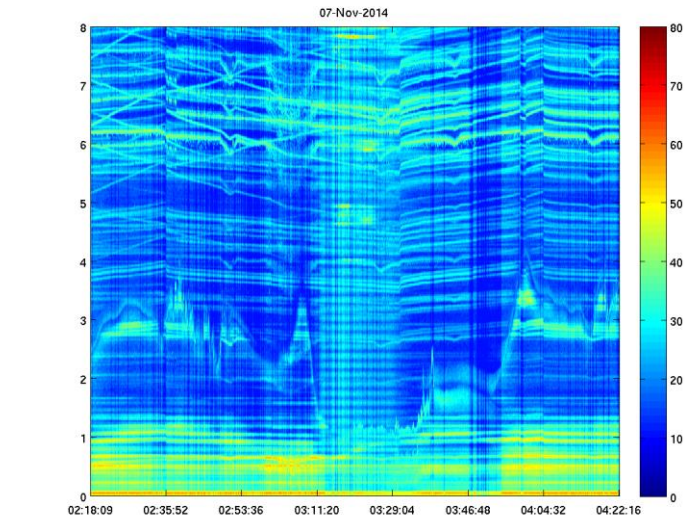
# First results – spectra high latitude structures

# equator structure



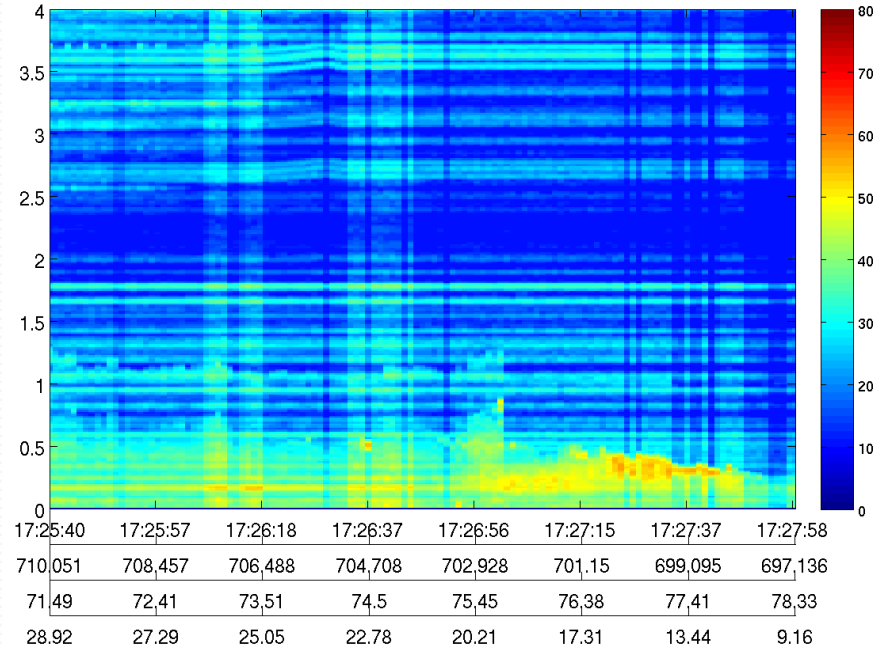


Auroral region structure

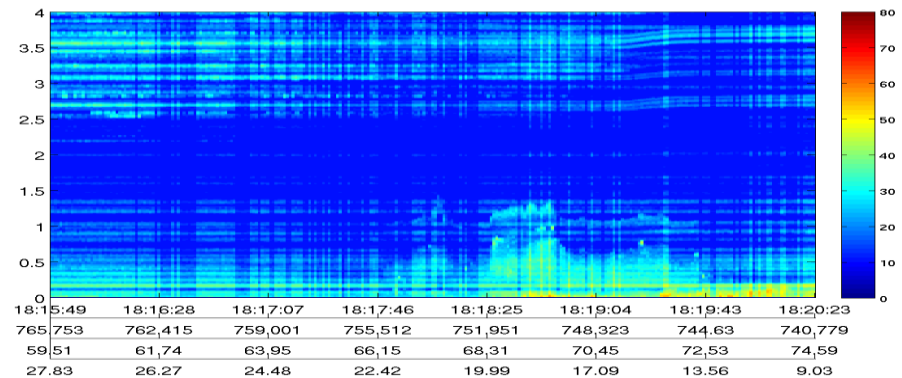


# Heating over Tromso

26-Nov-2014



19-Nov-2014



**FUTURE**

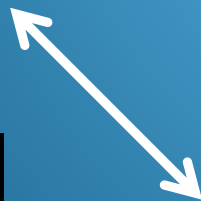
**Synergy**

**ground based radio astronomy  
and satellite diagnostics**

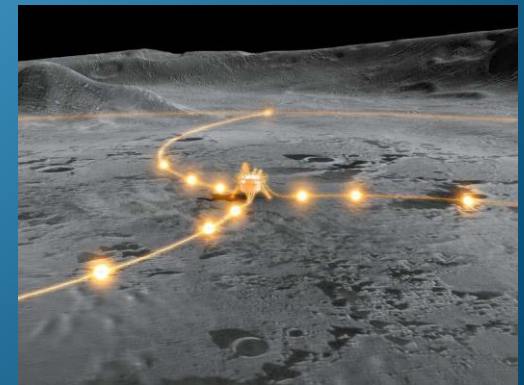
LOFAR

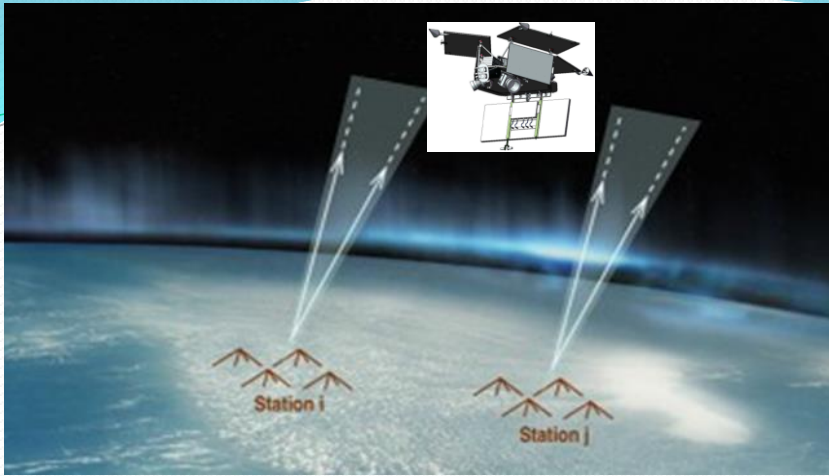


SKA



Cluster radio  
diagnostics near L<sub>2</sub>  
MOON FAR SIDE





## LOFAR and topside satellite in situ diagnostics and COSMIC/FORMOSAT

Solar science and space weather

- Ionospheric and magnetospheric environmental diagnostics
- Sun diagnostics
- Service of ionospheric modelling and corrections
- Ground support for planetary mission JUNO



PL610 Borowiec

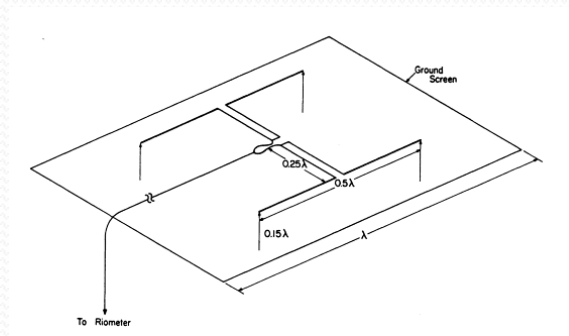
# Additional Diagnostic

1. Scintillation receiver



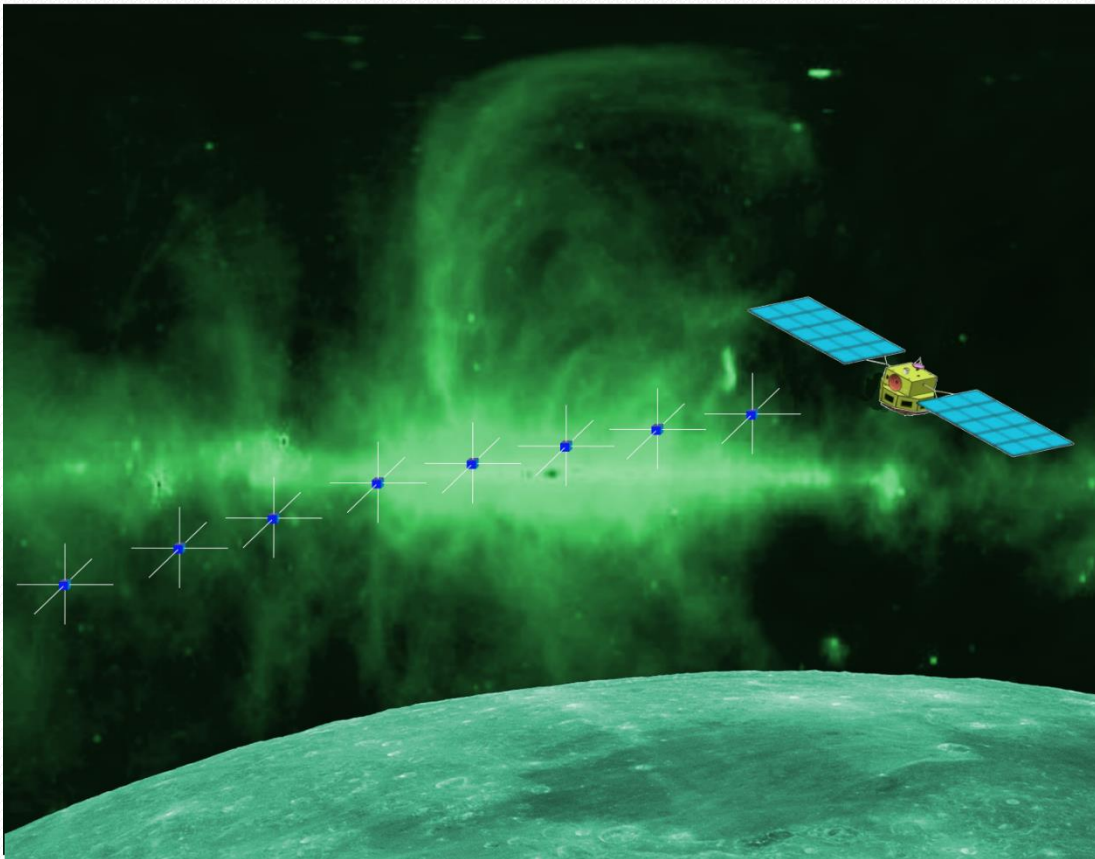
2. Radio receiver for ionosonde and DAB *Digital Audio Broadcasting*

3. Riometr

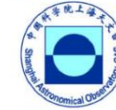


# Discovering the Sky at the Longest Wavelengths

proposal for China ESA call and **now Chang-4**



China



Nsfc



Europe

Radboud University 

ASTRON

TU Delft Delft University of Technology

UNIVERSITY OF TWENTE.



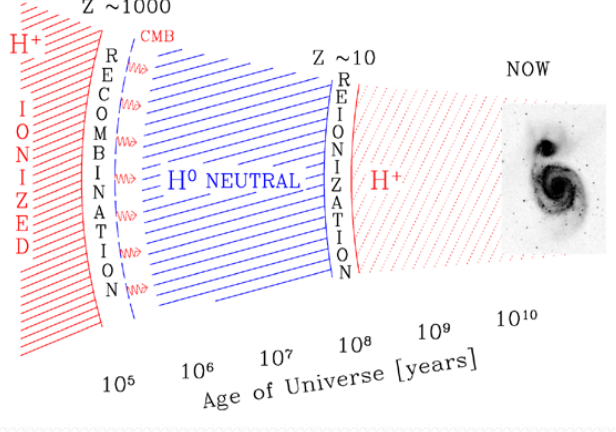
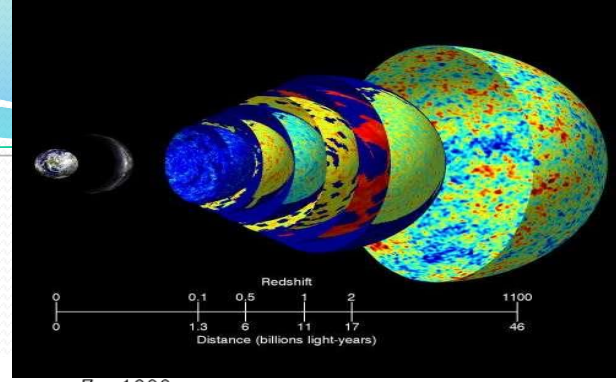
JOINT INSTITUTE FOR VLBI IN EUROPE



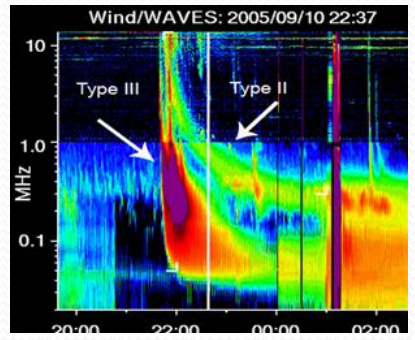
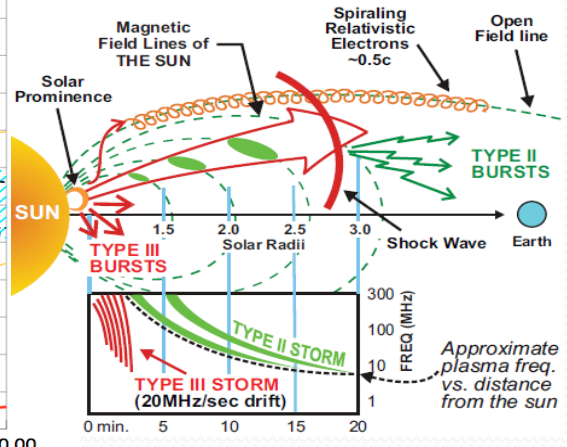
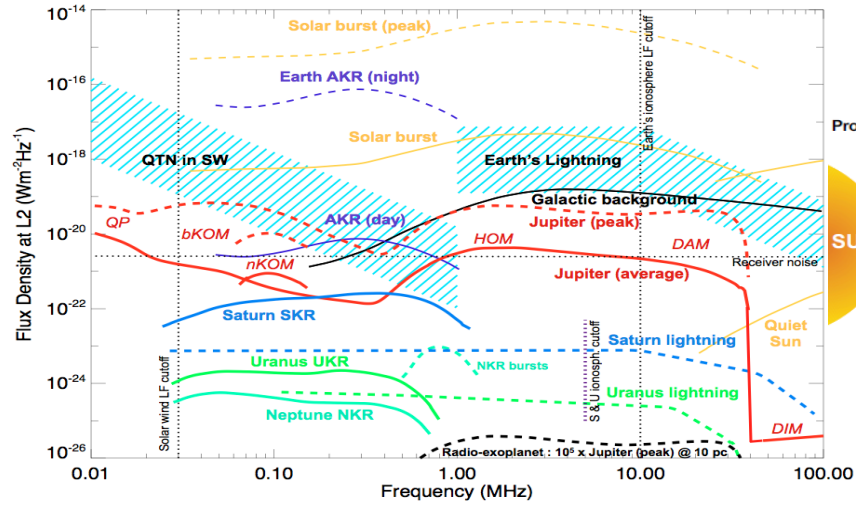
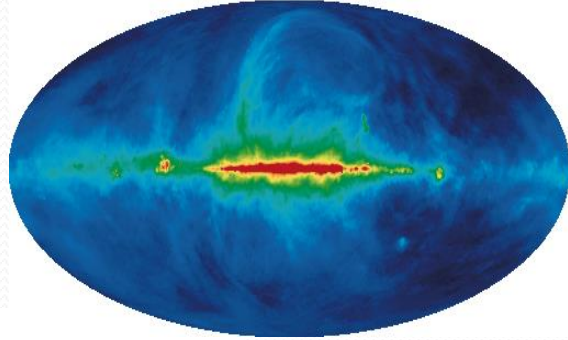
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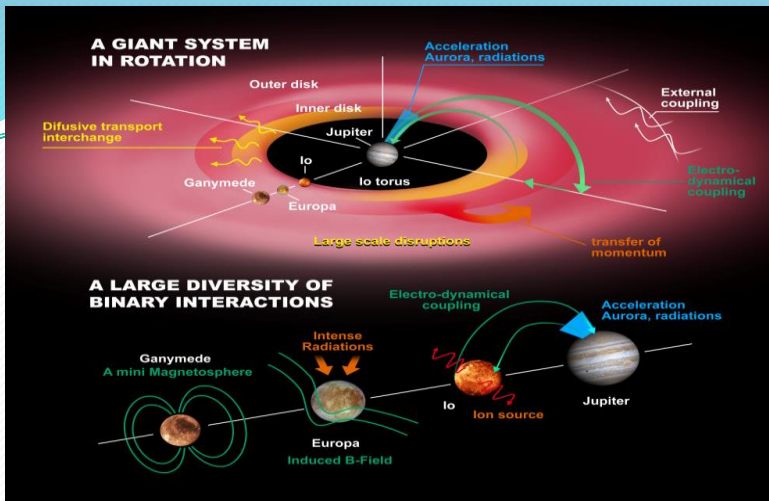


# Main goals – Exploration of the Unknown



- Dark Ages
- The Extragalactic sources
- The Galactic Interstellar Medium and Cosmic Rays
- Transients and Variable Sources and Other Sciences
  - Heliophysics and Solar science
  - Planetary Radio Emissions
  - Pulsars



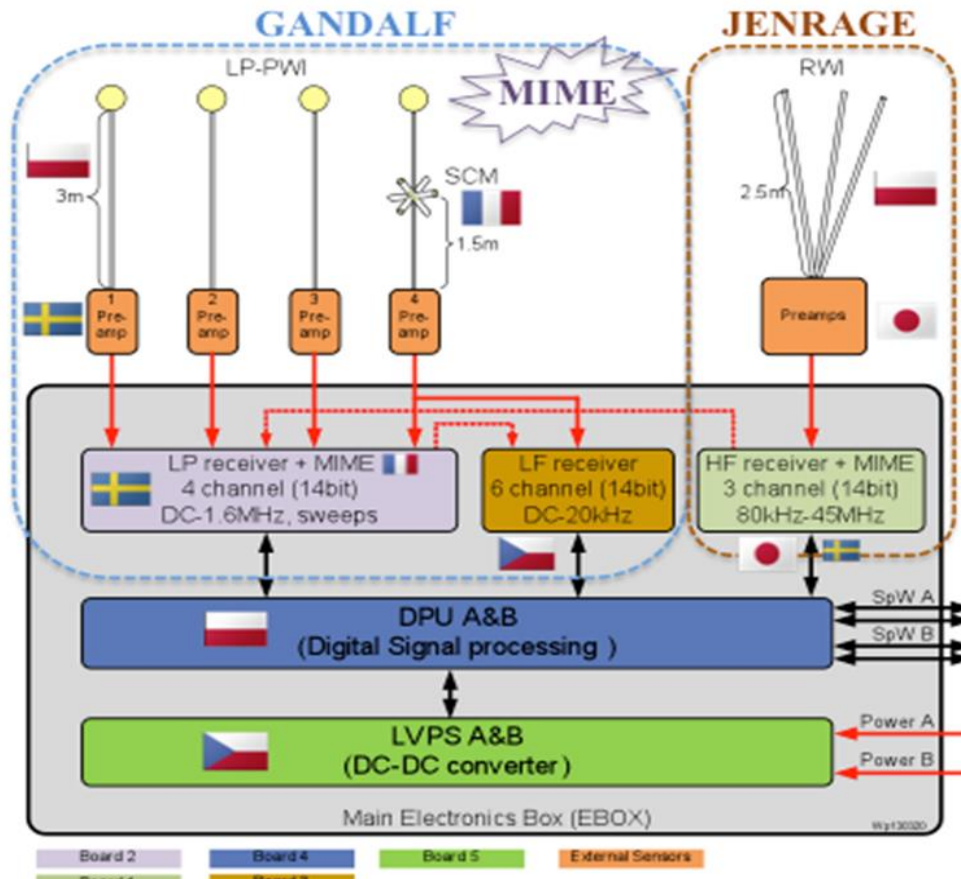


# JUICE

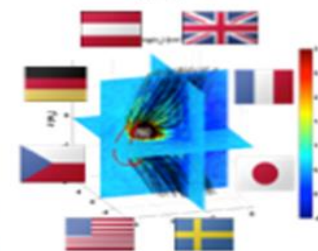
## JU piter ICy Moon Explorer

### ESA L class mission

## 2022



Science/  
Archive/  
Software/  
Operations/  
Calibration/  
Public Outreach  
Support





# RESONANCE

The HF radio analyzer designed and build by the polish team is an electronic module devoted to measure electrical and magnetic components of radio frequency emissions in the frequency range from 10 kHz up to 1.0 MHz and phase difference measurement of two monochromatic signal on frequency 5.0 MHz and 15.0 MHz transmitted from “RIC” instrument.



# JONOSOND

The four identical spacecrafts will be located at the polar circular orbit at the altitude 600 km and 800 km. In the frame of contract with Russian side the **four ionosonds LAERT**, dedicated for top-side in situ active diagnostics were designed in SRC PAS.

