Remote sensing of the magnetospheric plasma density by ULF waves recorded at a large array of magnetometer stations in Europe

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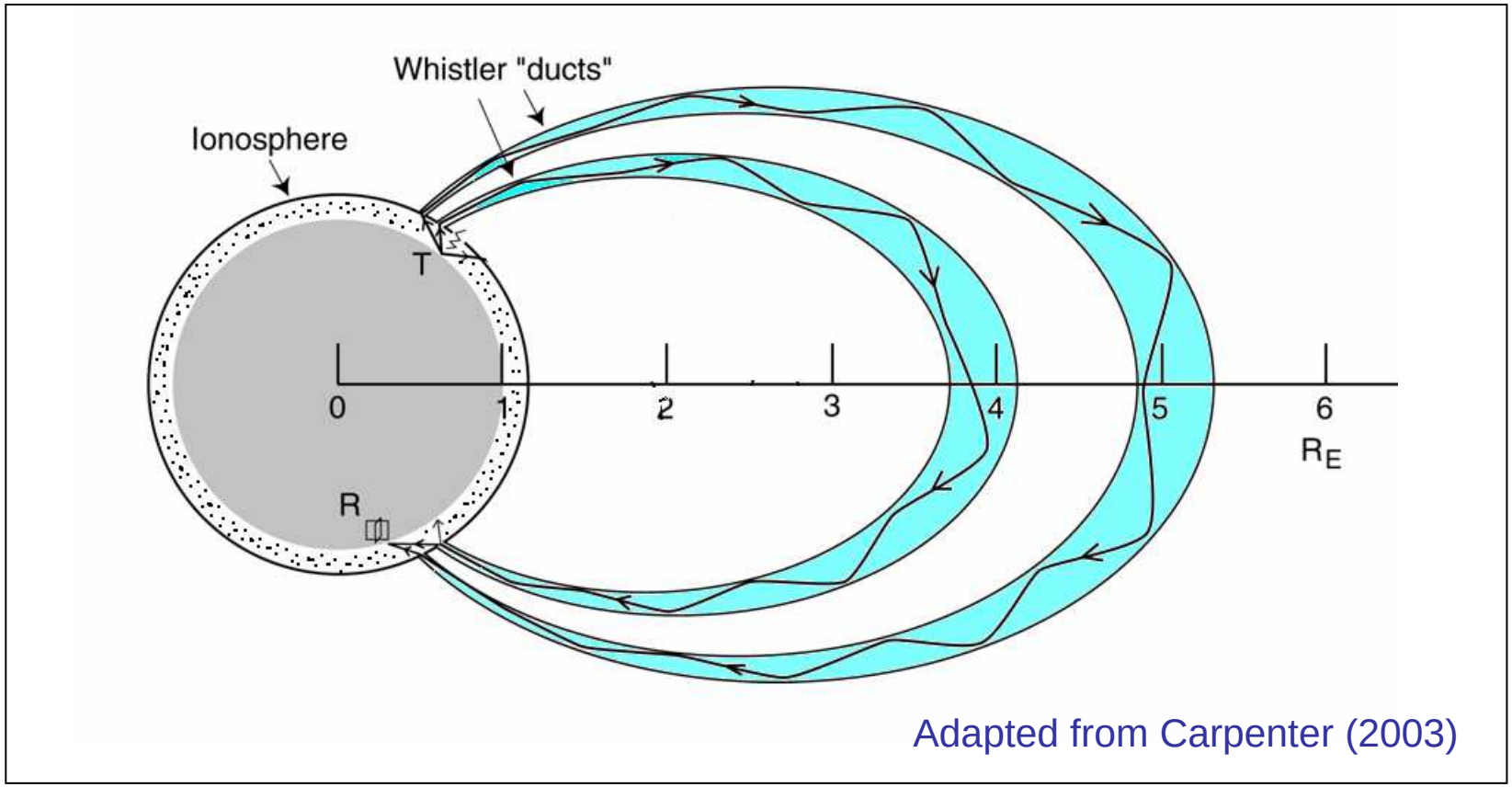
Whistler method for remote sensing the structure and the dynamics of the plasma density in the magnetosphere

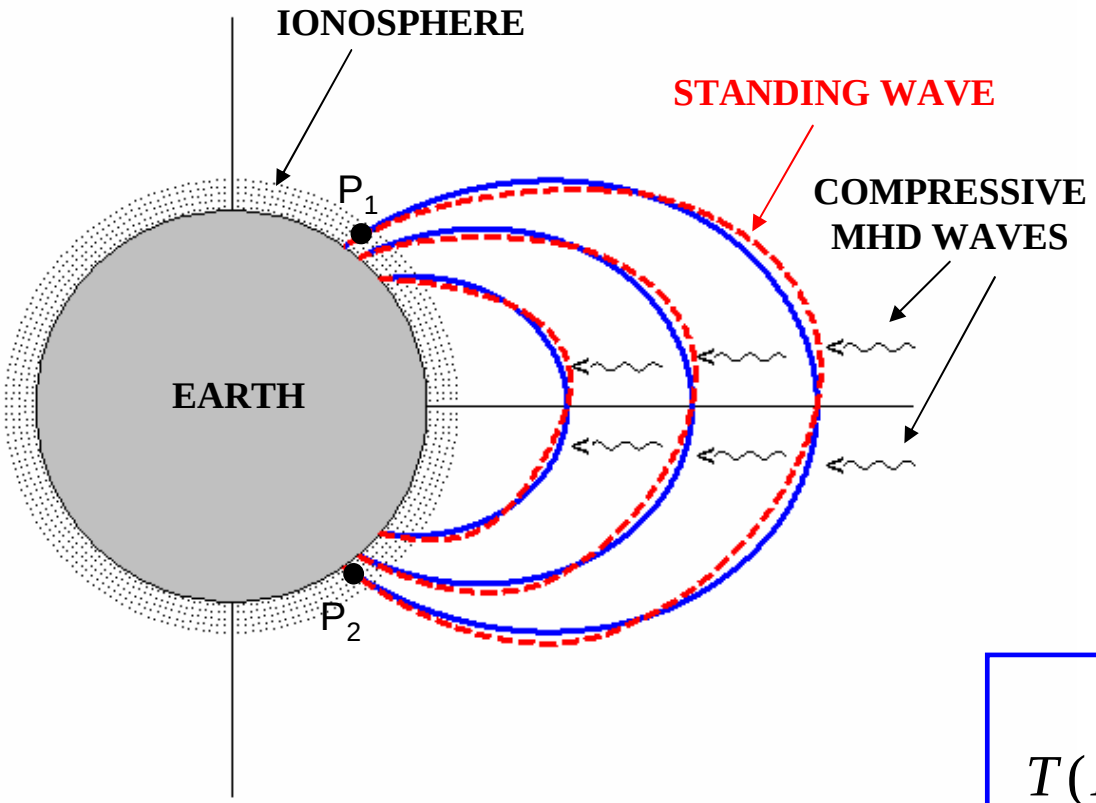


Adapted from Carpenter (2003)

Very important results, such as:

Plasmapause identification, detailed understanding of dynamic processes in the plasmasphere: **erosion** and plasma **refilling** during periods of high geomagnetic acivity

Geomagnetic Field Line Resonances (FLR)



$$T(L) \cong \int_{P_1}^{P_2} \frac{ds}{V_A(s)}$$

$\mathbf{V_A}$: Alfvén velocity

$$T(L) = 2\mu_o \int_{P_1}^{P_2} \frac{\rho^{1/2}(s)}{B(s)}\, ds$$

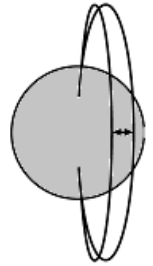
Whistlers → electron density

ULF waves → mass density

Inference of the plasma mass density from field line eigenfrequencies

Standard procedure for low and middle latitudes:

Assumption: Observed FLR frequencies (f_R) correspond to the axisymmetric **toroidal** mode eigenfrequencies in a **dipole** field.



Toroidal Mode

Governing equation:

$$d^2E/dz^2 + \lambda\,(1- z^2)^6\,\rho(z)/\rho_o\,E = 0$$

E : wave electric field
z = cos (θ), **θ**: colatitude
ρ : mass density along the field line
ρ_o: equatorial mass density

Eigenvalues **λ** are found imposing:

1) the boundary condition: **E = 0** at the altitude (100-200 km) where the wave is reflected

2) A given functional form for the mass density along the field line.

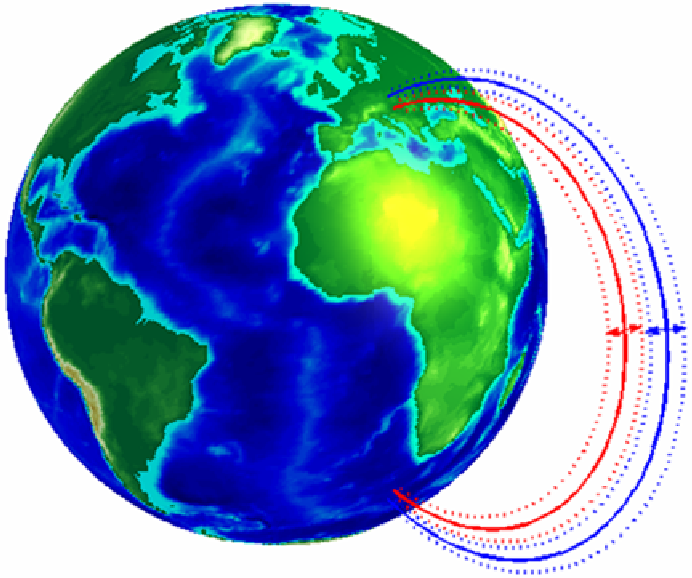
   Common assumption: $\rho(r)/\rho_o = (r / r_o)^{-m}$

For any given **L- shell** and **m** value, the inferred **equatorial** mass density is:

$$\rho_o\,[\text{amu/cc}] = \frac{A_{L,m}}{f_R^{\,2}\,[\text{mHz}]}$$

$$A_{L,m} = \frac{K\lambda_{L,m}}{L^8}, \qquad K = \text{const.} \cong 2.9\times10^8$$

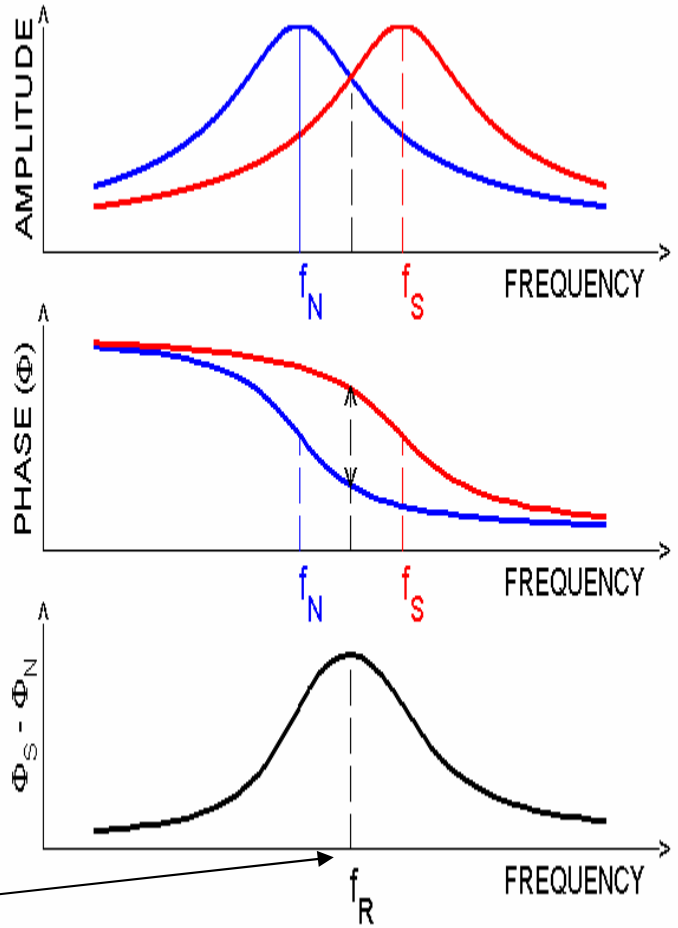
GRADIENT METHOD FOR DETECTING FIELD LINE RESONANCES FROM GROUND-BASED ULF MEASUREMENTS



Higher latitude field line → Lower resonance frequency (f_N)

Lower latitude field line → Higher resonance frequency (f_S)

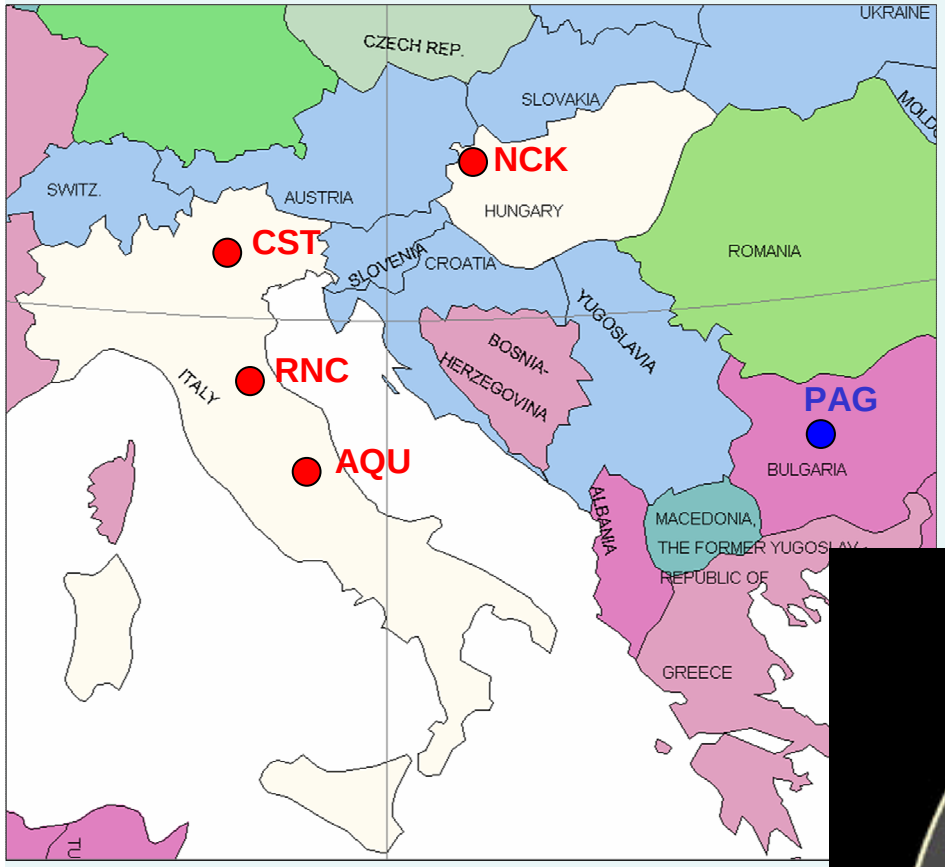
FREQUENCY RESPONSE OF TWO OSCILLATORS



CROSS-PHASE TECHNIQUE

Resonance frequency at the middle point.
Identified by a maximum in the phase difference

SEGMA (South European GeoMagnetic Array)
(1.56 < L < 1.88)

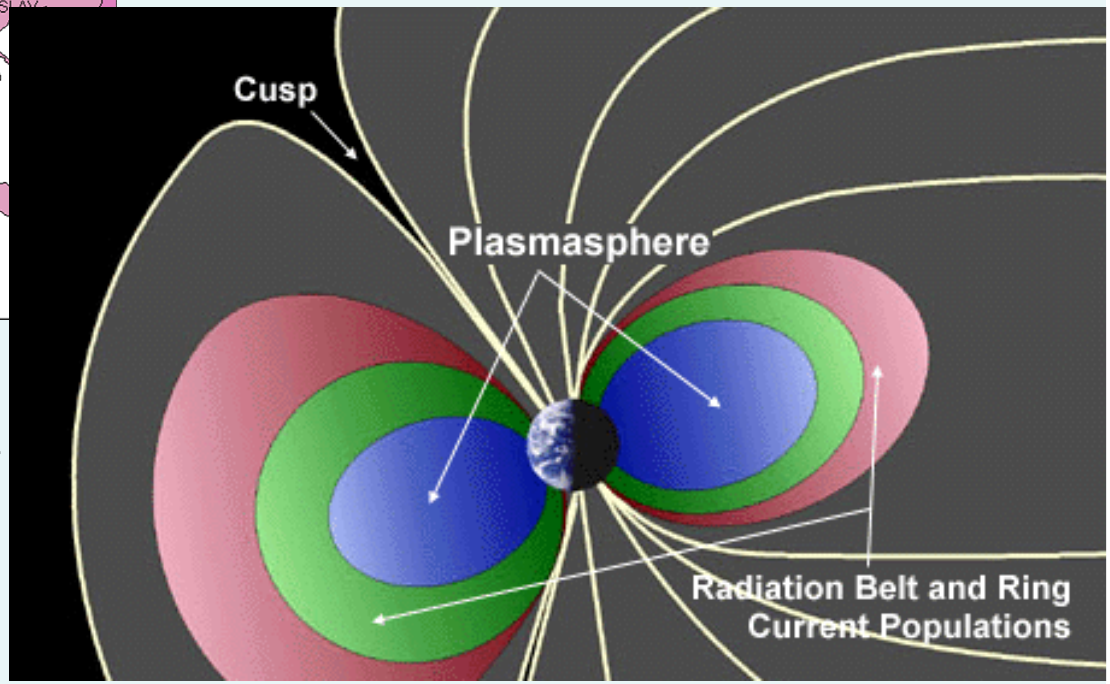


3 gradient installations

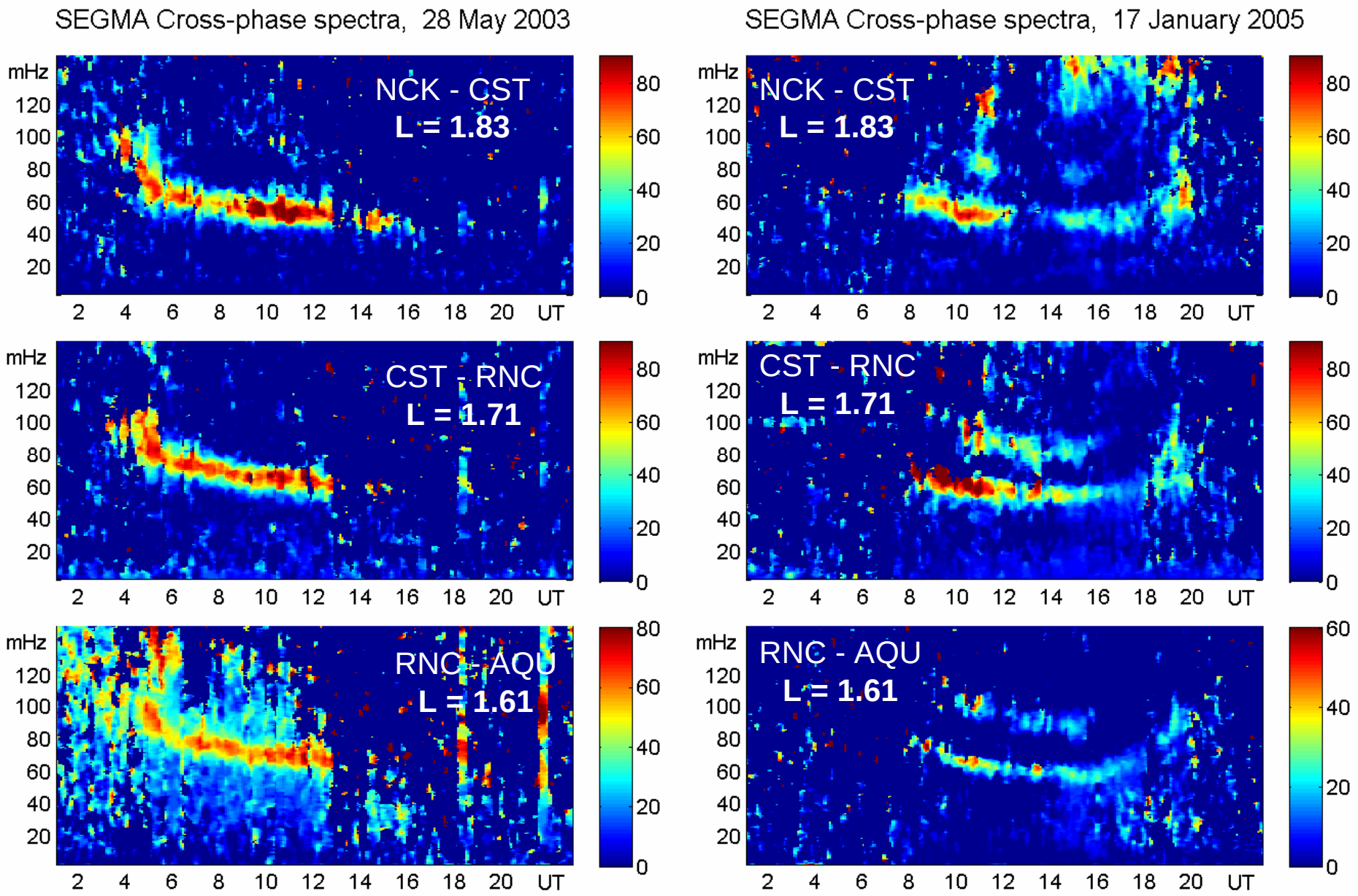
Stations	Latitud. separ.	L
NCK - CST	1.9°	1.83
CST - RNC	2.5°	1.71
RNC - AQU	1.9°	1.61

Cooperation between:

- **Physics Department, University of L'Aquila**
- **Space Research Institute of Graz (Austria)**

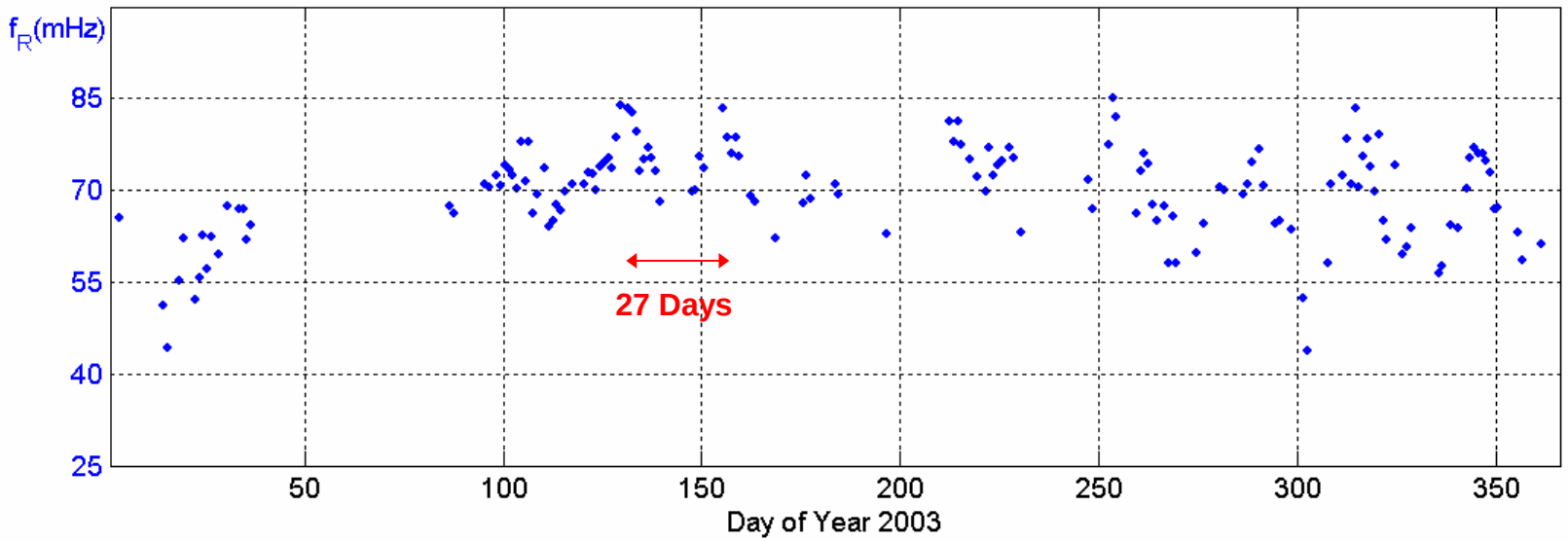


Diurnal variation



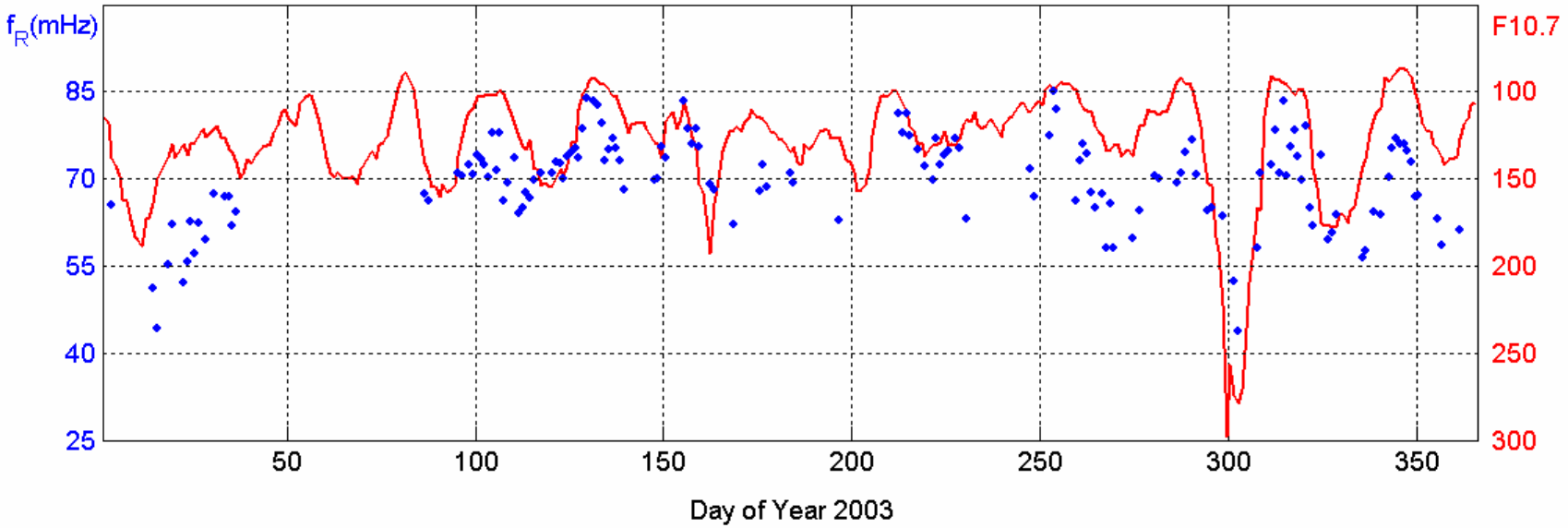
ANNUAL VARIATION OF THE FLR FREQUENCY AT L = 1.61, YEAR 2003

DAILY AVERAGES (0900 – 1600 LT)

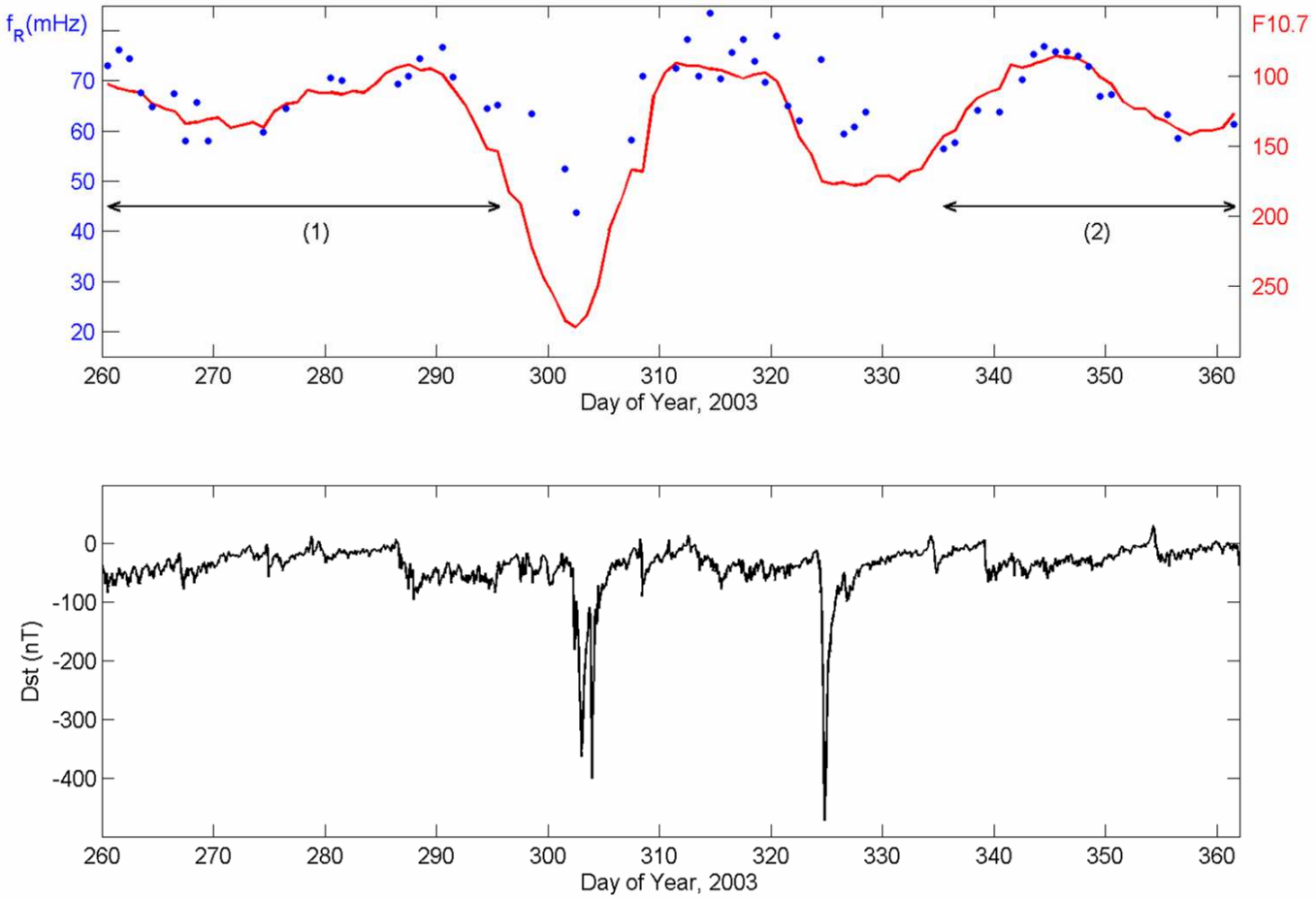


- **a nearly 27-days modulation appears which must be connected to the recurrence of active regions of the Sun**

SOLAR IRRADIANCE DEPENDENCE OF THE FLR FREQUENCY (L = 1.61)



Combined effects of solar and geomagnetic activity



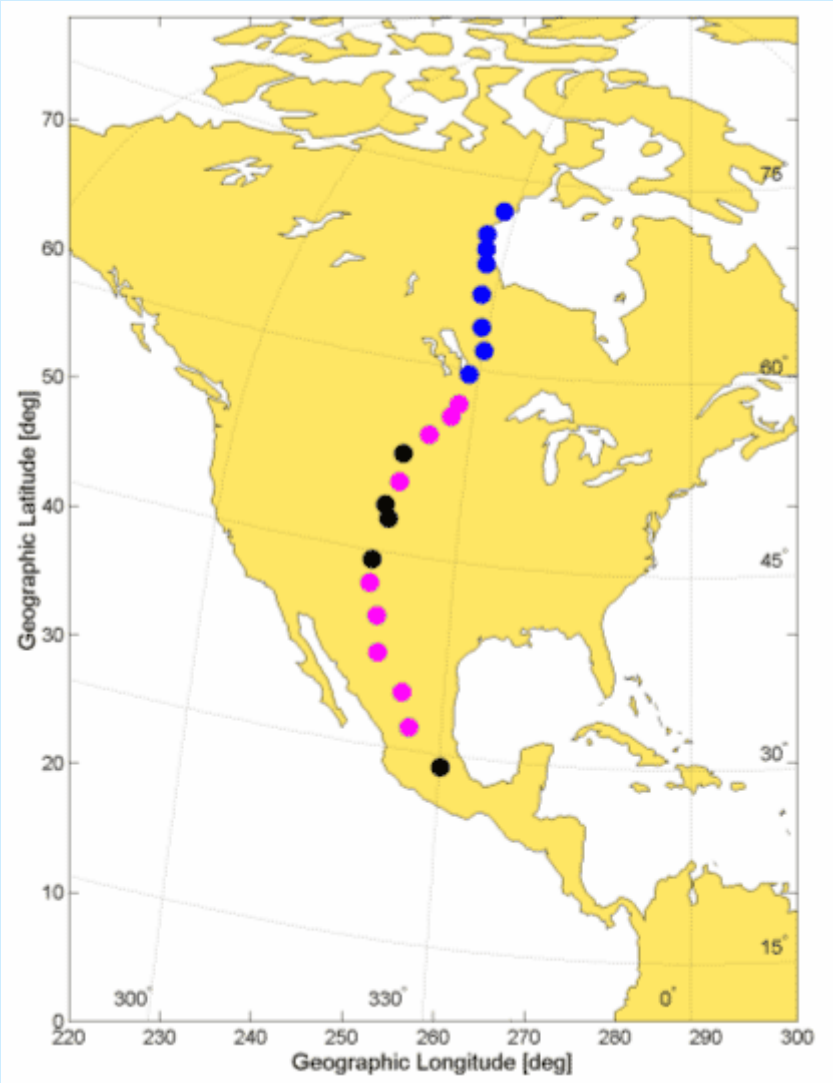
Under quiet magnetospheric conditions (intervals 1 and 2), the plasmaspheric density (as inferred by the FLR frequency: $\rho \sim f_R^{-2}$) is strongly controlled by the solar EUV radiation (F10.7 index).

During disturbed magnetospheric conditions (high **Dst** index) f_R is higher than what expected.

The inferred plasmaspheric density depletion is possibly due to plasmasphere erosion by the enhanced magnetospheric convection electric field and/or to enhanced ion loss rate in the ionosphere.

Mid-continent MAgnetoseismic Chain (McMAC):

A Meridional Magnetometer Chain for Magnetospheric Sounding



$1.3 < L < 11.7$

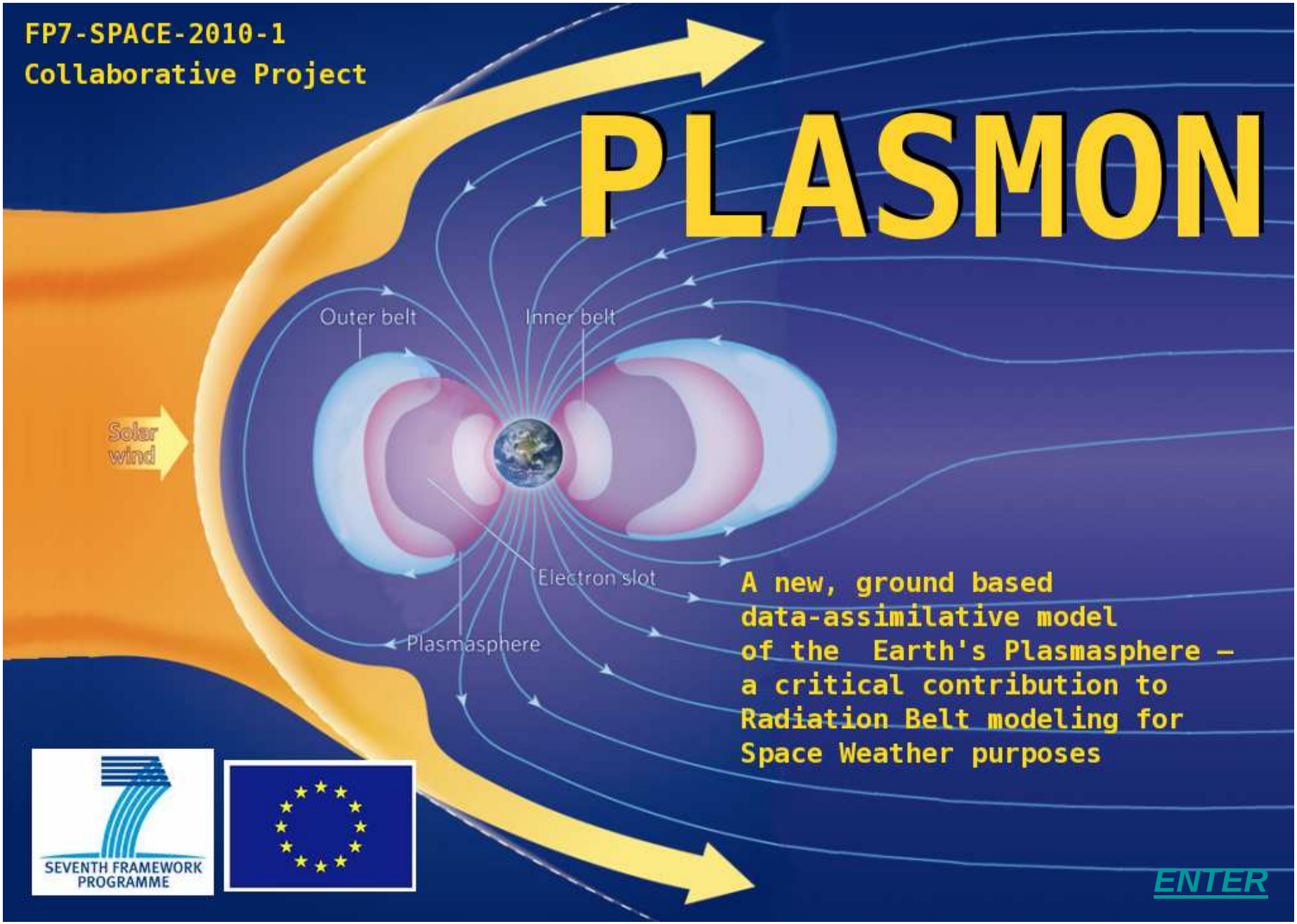
Map of operating / planned EMMA stations (1.6 < L < 6.7)

Δ SEGMA

\+ MM100

IMAGE

■ planned new stations



Tematica di riferimento: Security of space assets from space weather events

Scopo del progetto

Realizzazione di un monitoraggio remoto e continuo delle condizioni della plasmasfera terrestre mediante misure di onde ULF / VLF rilevate da una rete internazionale di stazioni.

Tale informazione verrà utilizzata per modellizzare processi fisici che avvengono nelle fasce di radiazione importanti nell'ambito dello Space Weather.

Durata del Progetto: 42 mesi (1 Febbraio 2011 - 31 Luglio 2014)

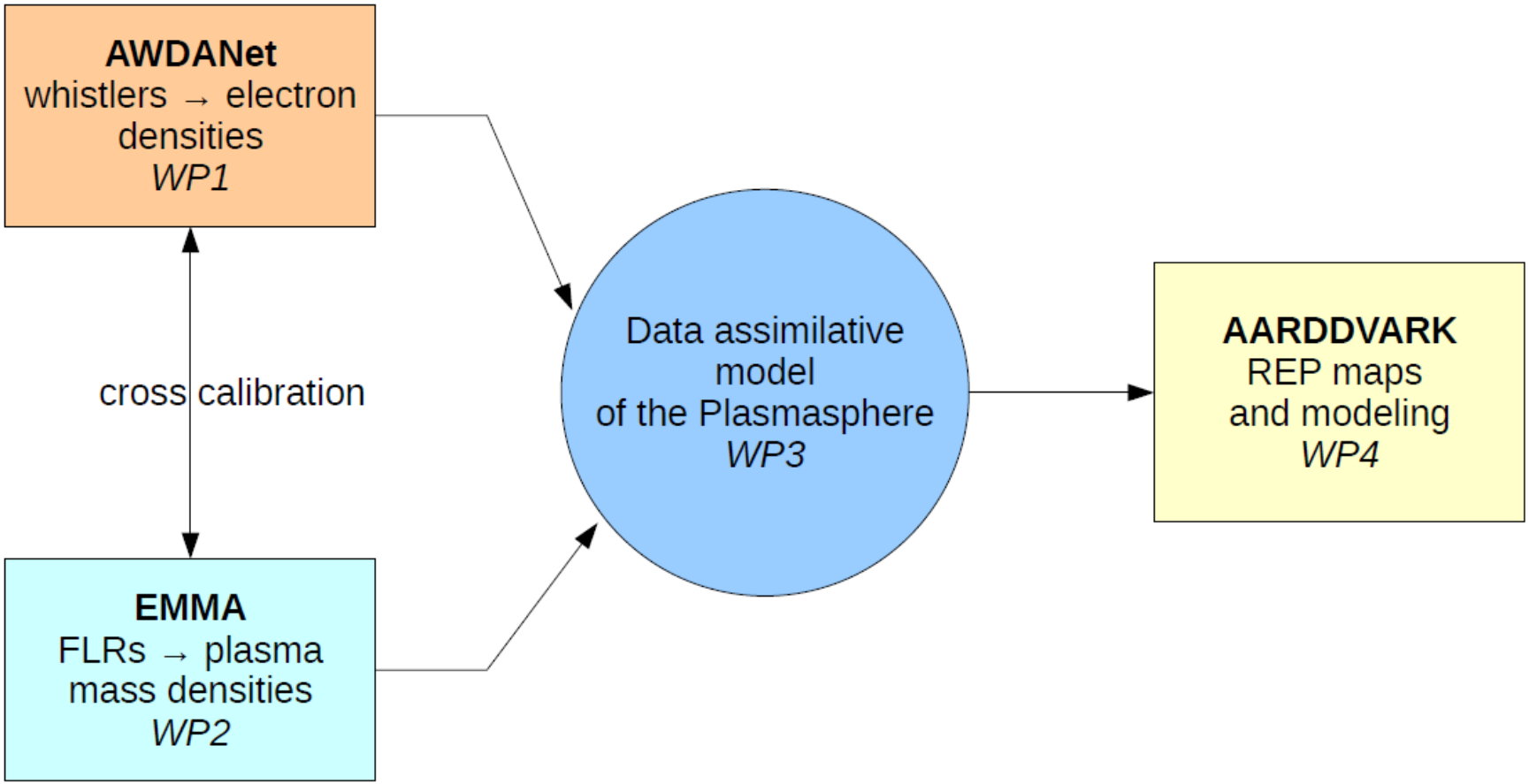
Istituzioni partecipanti

Short name	Institution	Country
1 ELTE (Coordinator)	Eötvös Loránd University	Hungary
2 NERC-BAS	British Antarctic Survey	UK
3 ELGI	Eötvös Loránd Geophysical Institute	Hungary
4 UNIVAQ	University of L'Aquila	Italy
5 UOULU	Sodankyla Geophysical Observatory	Finland
6 UO	University of Otago	New Zealand
7 HMO	Hermanus Magnetic Observatory	South Africa
8 NMT	New Mexico Inst. of Mining and Technology	USA
9 IGPAS	Inst. of Geophysics, Polish Acad. of Scien.	Poland
10 UW	University of Washington	USA
11 LANL	Los Alamos National Laboratory	USA

Work packages

	Title	Lead participant
WP1	Automatic retrieval of equatorial electron densities and density profiles by Automatic Whistler Detector and Analyzer Network (AWDANet)	**Eotvos University**
WP2	Retrieval of equatorial plasma mass densities by EMMA magnetometer array and cross-calibration of whistler and FLR method	**L'Aquila University**
WP3	Data assimilative modeling of the Earth's plasmasphere	**New Mexico Inst.**
WP4	Modeling REP losses in radiation belts based on AARDDVARK network	**BAS**
WP5	Dissemination and exploitation of the results	**Otago University**
WP6	Management of the consortium	**Eotvos University**

PLASMON structure



Acknowledgments

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