ESWW10 / PROBA2 splinter

Modelling flare induced ionization enhancements of the lower ionosphere with LYRA data

relating Space LYRA – Earth VLF data

Guest Investigator Program

Fourth Call:Sep 2013- Jun 2014

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OUTLINE   Objectives:

Understand Impact of Flares! On the Lower Ionosphere

50-100 km height

- Observations of the effects of Solar X-ray flares from Earth – VLF transmission
- Correlation: VLF data - space based measurements
- Can we exploit **LYRA** data?
- How to combine data and model: N(t,h), LWPM
- (some) RESULTS – 90 km height
- Prospects

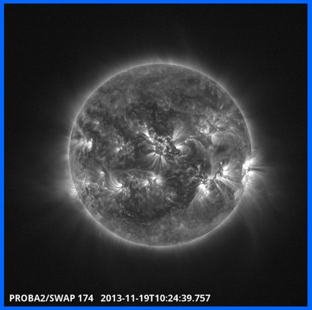
DATA:

SPACE : Solar irradiance

LYRA

ch2-4(Zr); 6 – 20 nm+X-ray(< 2 nm)

(SWAP ?)



GOES 12-15 (0.1-0.8 nm)

Flare classification

LYRA - 4 years in orbit

Dammasch et al. 2012
COSPAR

Dominique et al. 2013
Solar Physics, DOI: 10.1007.

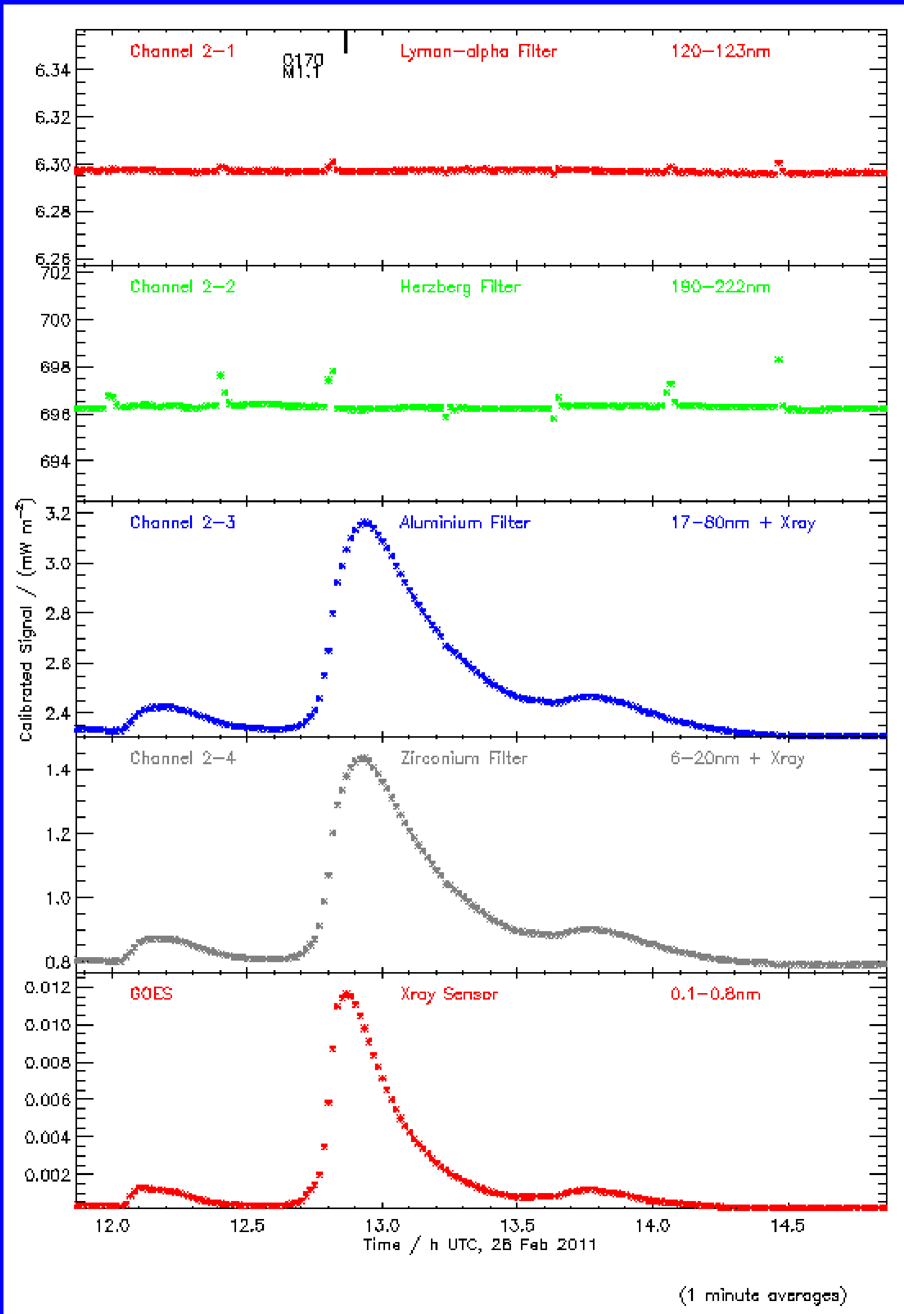
The LYRA Instrument Onboard PROBA2:
Description and In-Flight Performance

Characteristics of the Lyra Irradiance:

- **Lyra peaks after GOES** τ_{LG}

- **Lyra descends slower than GOES**

2011_02_28_M1.1



DATA:

EARTH : VLF data - AMPLITUDE & PHASE

on different sunlit paths from receivers R_x

- **Belgrade** IP VLF Observatory – **Belgrade University**

- **Casey** and **Scott Base** stations, **Antarctica** –

Otago University, Dunedin NZ

BAS, Cambridge, UK

On Earth:

Radiowave propagation

(Supported by NOSC **LWPC)**

Solar Lyman Alpha (121.6 nm)

during flares: **Solar X-rays**

D-region

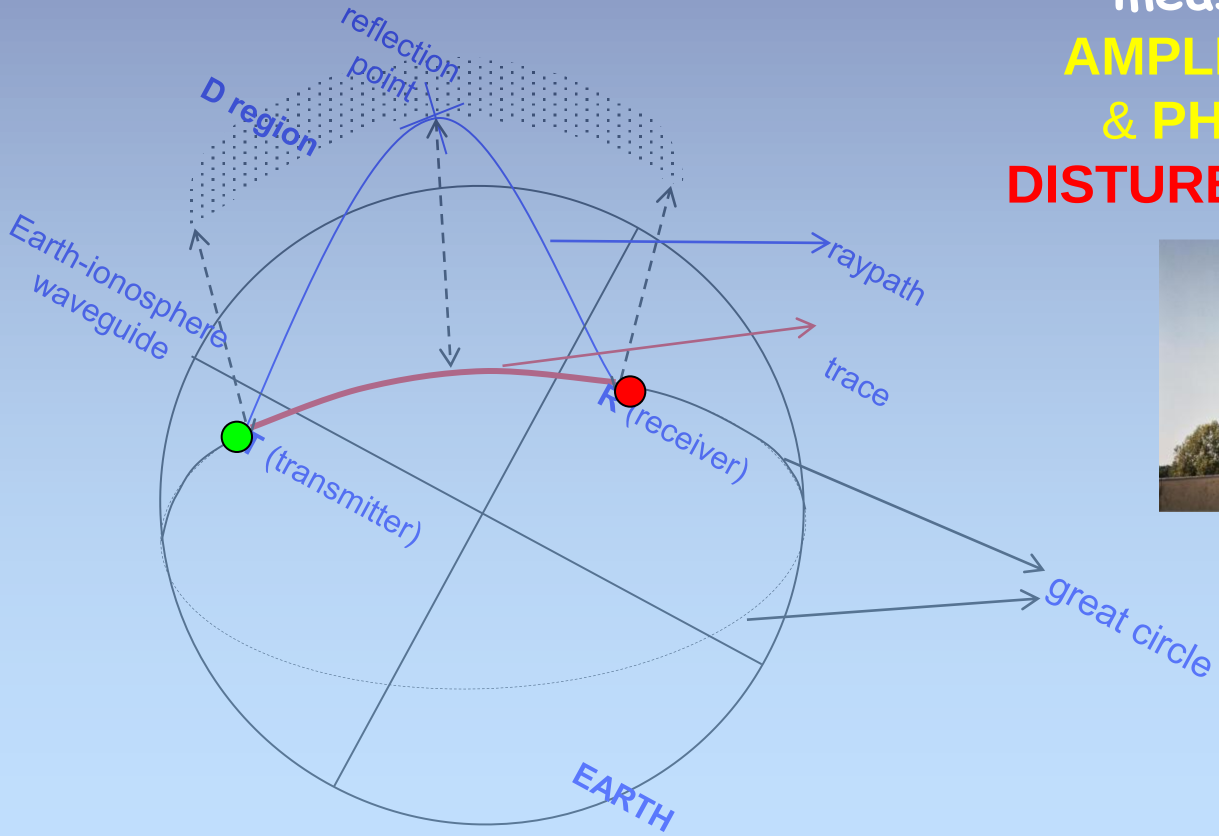
emit

VLF

f < 30 kHz

Transmitter:

NWC/19.8 kHz



measure

AMPLITUDE

& **PHASE**

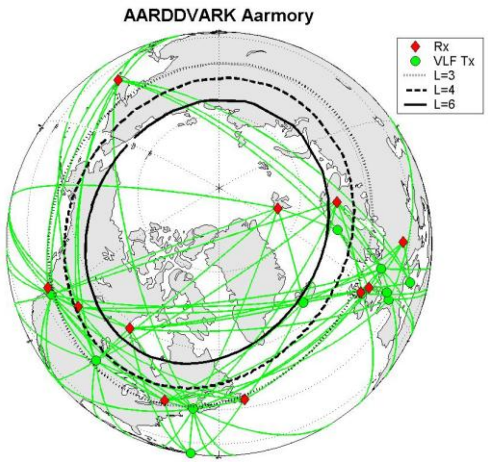
DISTURBANCES

Receiver:

Belgrade

AbsPAL

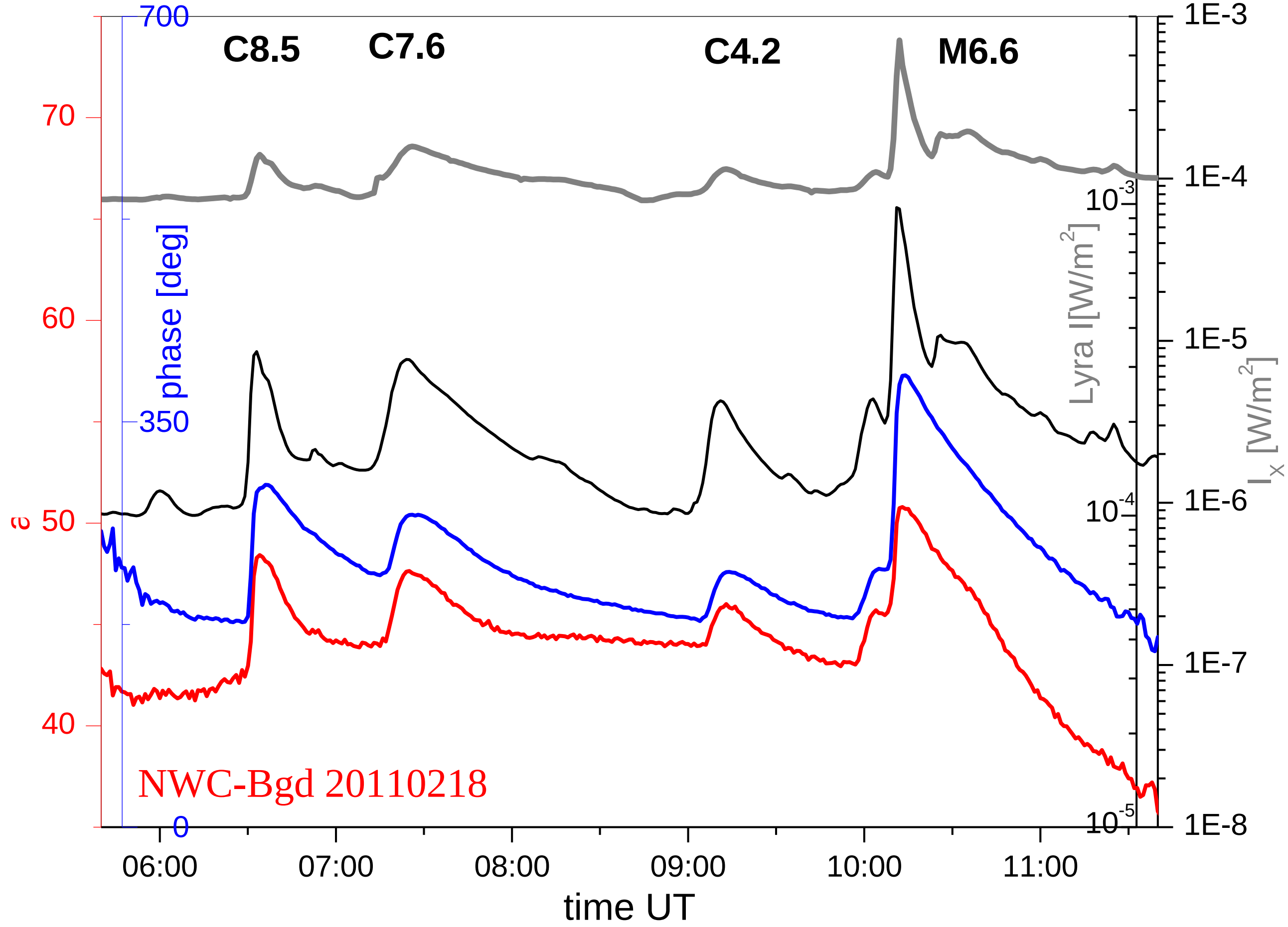
OBSERVATIONS:



NWC – Bgd
11974 km

All data in
1 min
cadence

2011_02_18 NWC - Bgd



MODELLING:

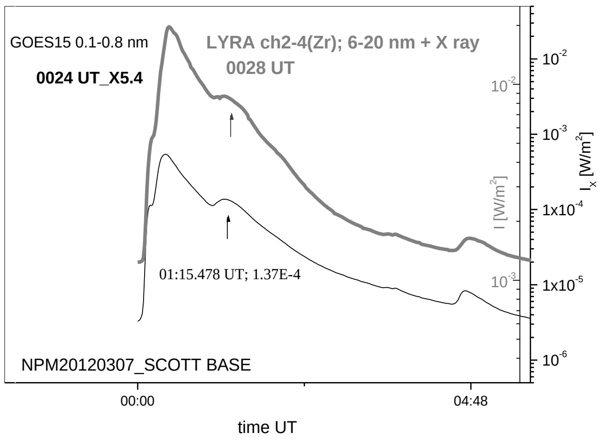
$$\frac{dN}{dt} = \frac{q}{(1+\lambda)} - \alpha N^2 - N\frac{d\lambda}{dt}\frac{1}{(1+\lambda)}$$

time dependence!

$$\boxed{\frac{dN}{dt} = q - \alpha N^2}$$

$$\boldsymbol{q(t) = k\, I\,(t)}$$

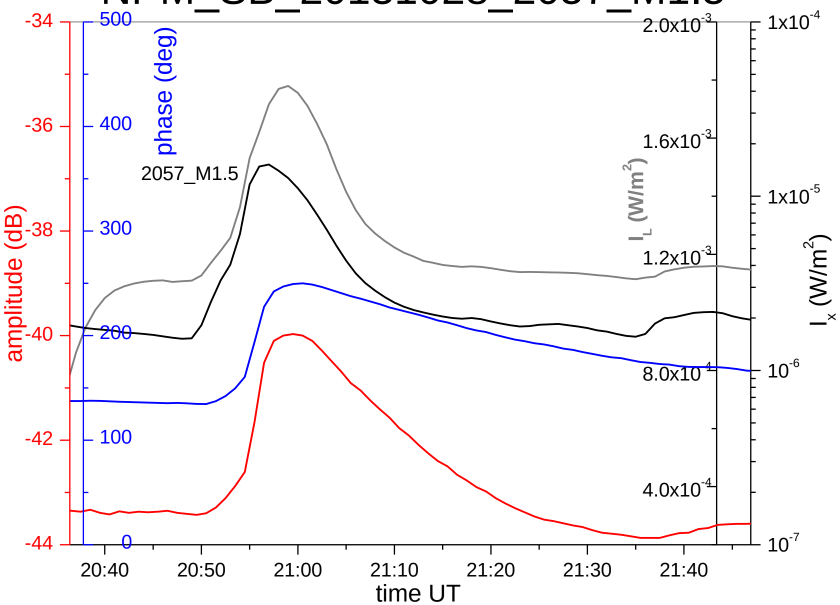
Irradiance *I (t)* 2012_03_07



FROM LYRA!

From Goes

NPM_SB_20131028_2057_M1.5

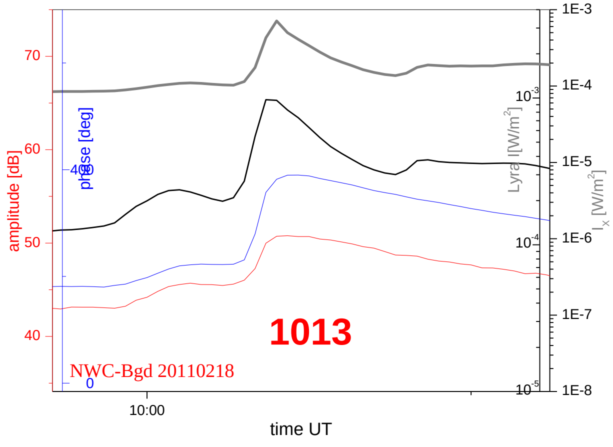


AMP & PHA Time delay!

$$\Delta t = t_{A,P_{max}} - t_{I_{max}} = t(N_{max}) - t(I_{max})$$

NWC- Bgd 20110218_1011_M6.6

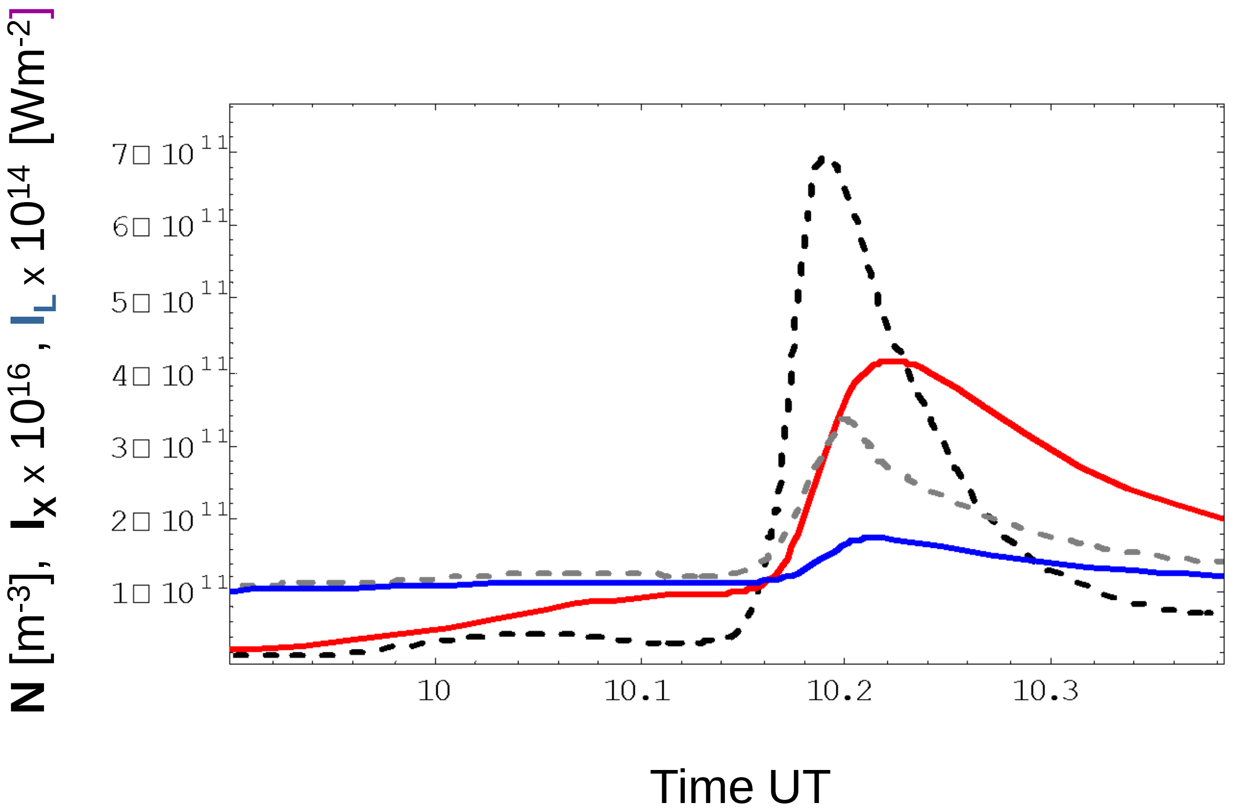
Electron density at 90 km height from **AMPLITUDE** time delay



$N_{\max}$ [m^{-3}]		$(\Delta t_A, \Delta t_A')$ [min]
4.14 10^{11}	**GOES**	(2, 1.92)
1.74 10^{11}	**LYRA**	(1, 0.79)

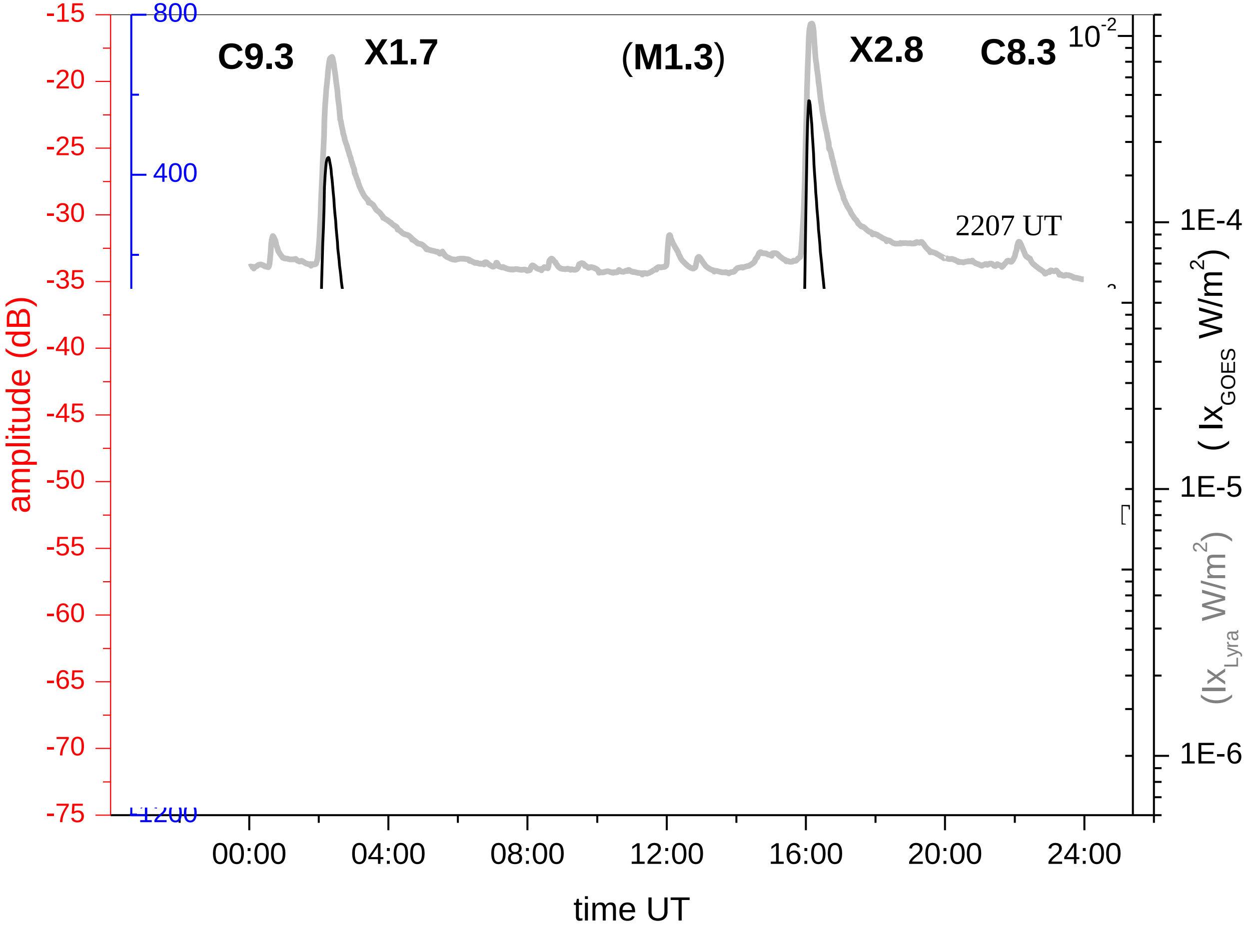
LYRA I_{max}
1012 UT , 3.35 mW/m^2

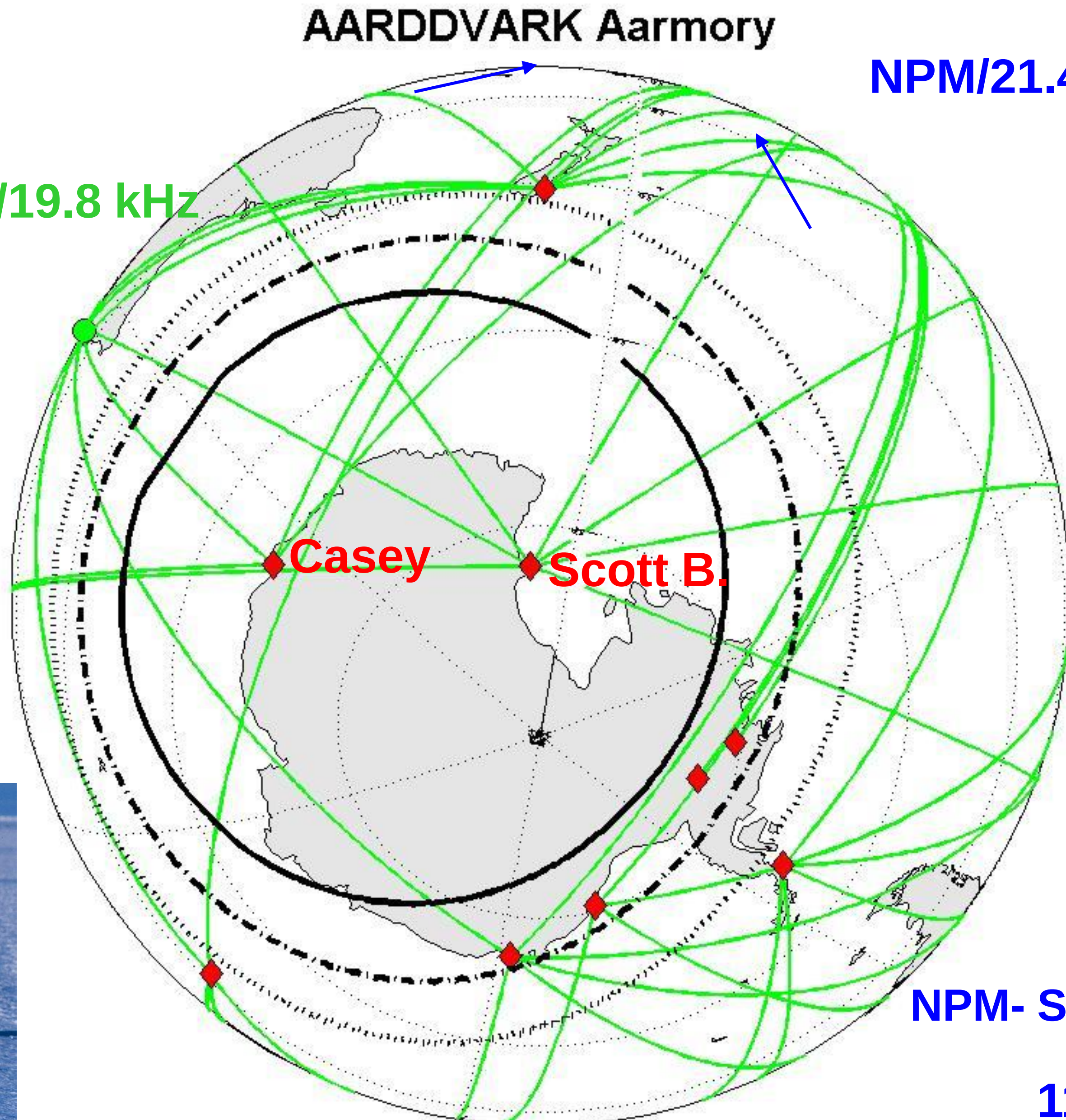
$$\tau_{LG} = 1 \ \text{min}$$



OBSERVATIONS:

2013_05_13 NPM – Scott Base



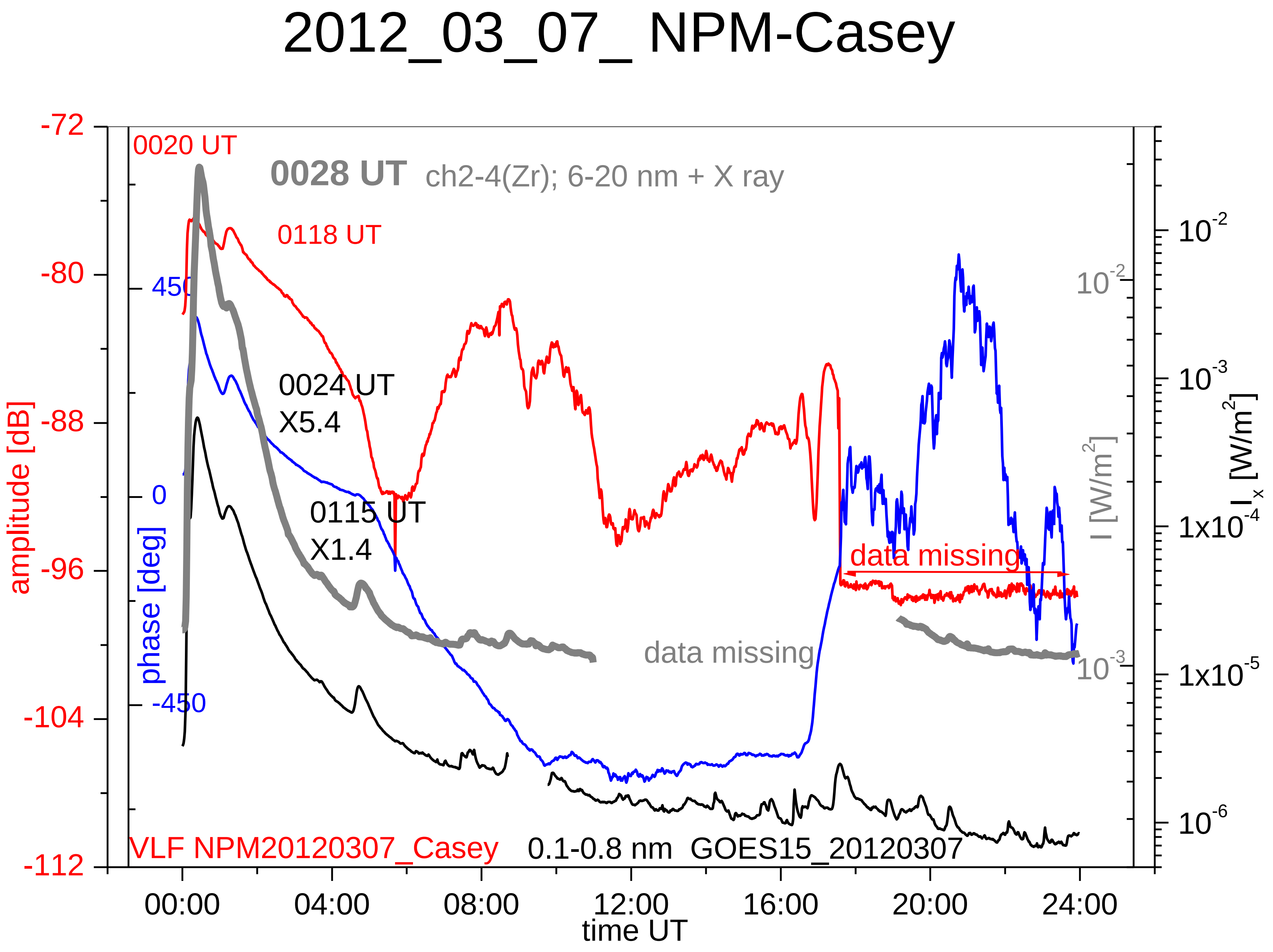


NWC/19.8 kHz

NPM/21.4 kHz

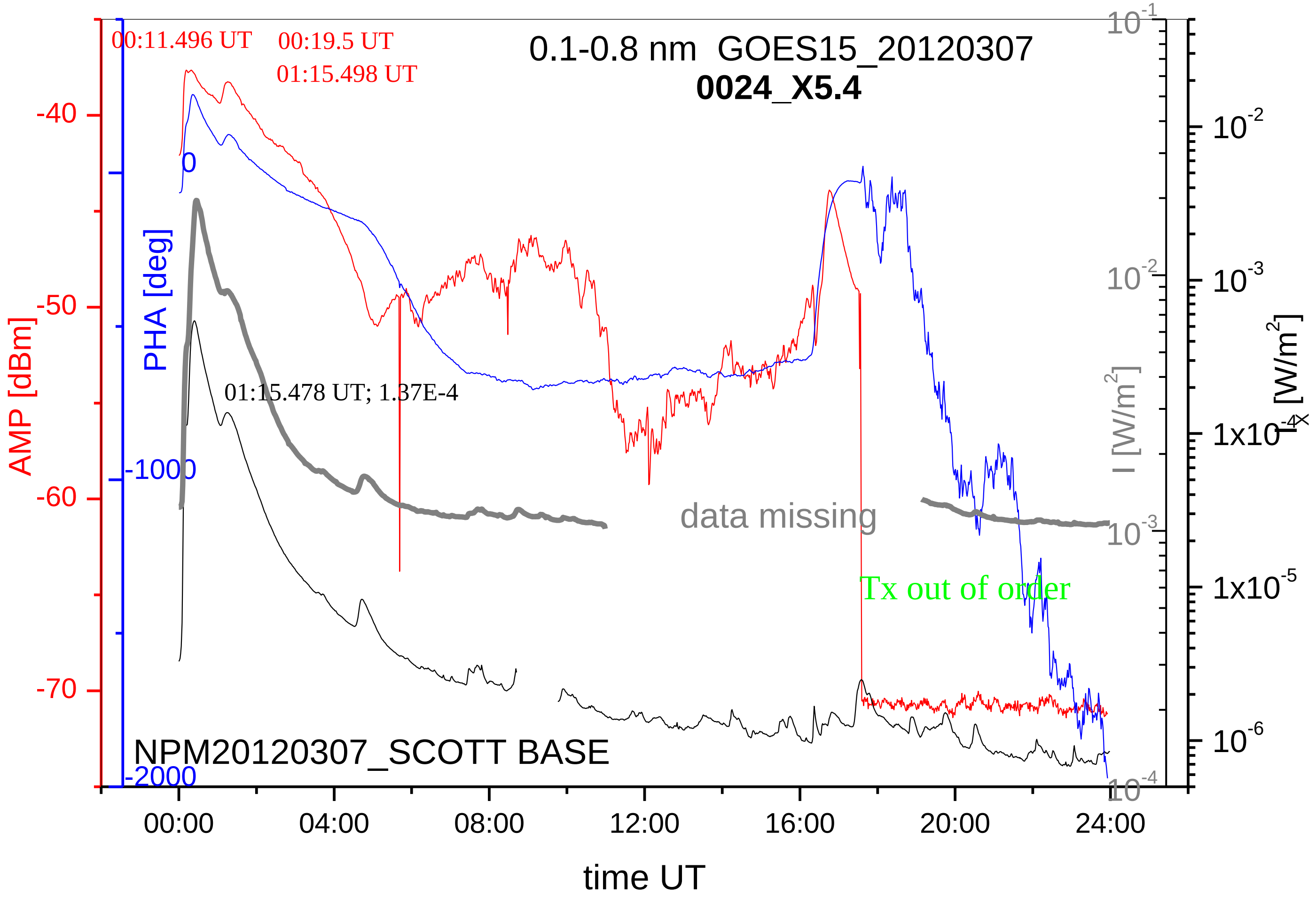
NPM- Scott Base

11260 km

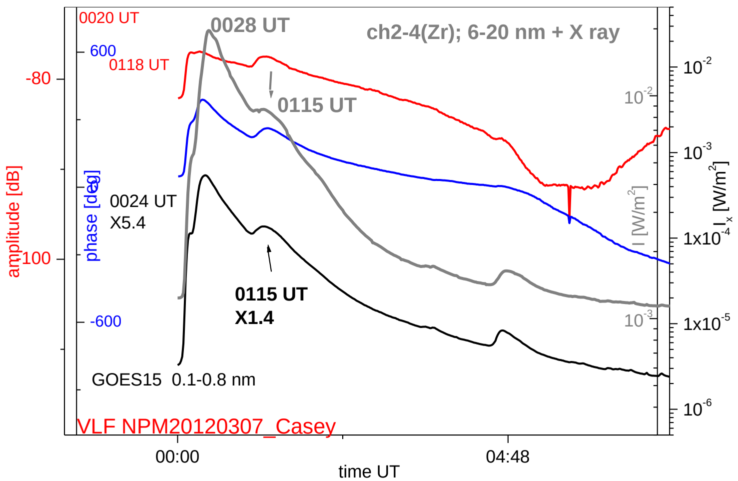


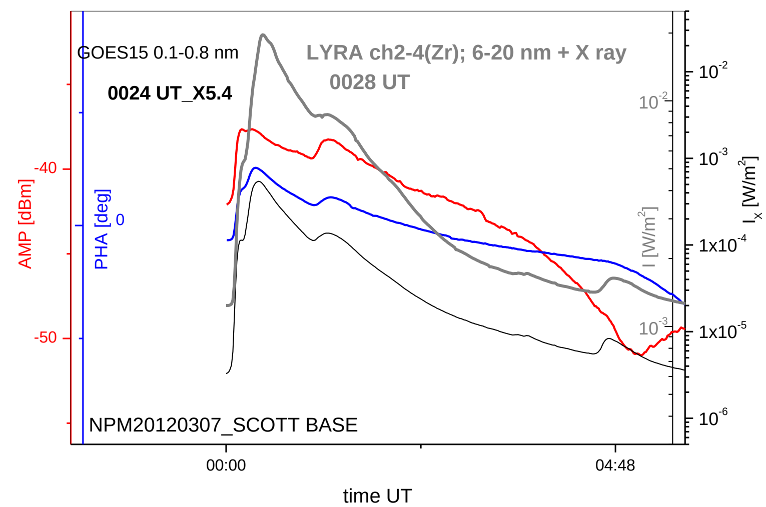
2012_03_07_ NPM-Casey
0020 UT
0028 UT ch2-4(Zr); 6-20 nm + X ray
0118 UT
0024 UT
X5.4
0115 UT
X1.4
data missing
data missing
amplitude [dB]
phase [deg]
I [W/m2]
Ix [W/m2]
VLF NPM20120307_Casey
0.1-0.8 nm GOES15_20120307
time UT
-72
-80
-88
-96
-104
-112
450
0
-450
10-2
10-3
1x10-4
1x10-5
10-6
00:00
04:00
08:00
12:00
16:00
20:00
24:00

2012_03_07_ NPM-Scott Base



20120307_0115_ NPM-Casey X1.4 NPM_Scott Base





$(\Delta t_A, \Delta t_P)$ min

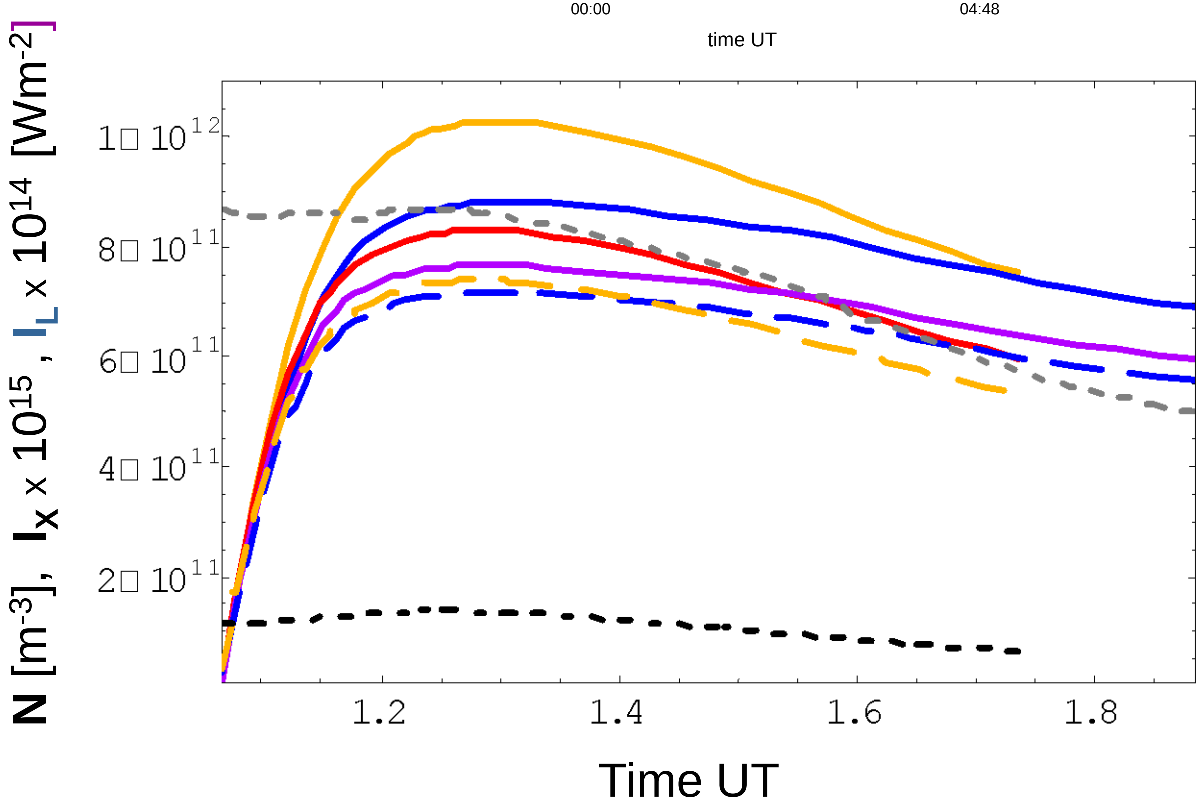
(2.5, 3.5)

$\tau_{LG} = 0$

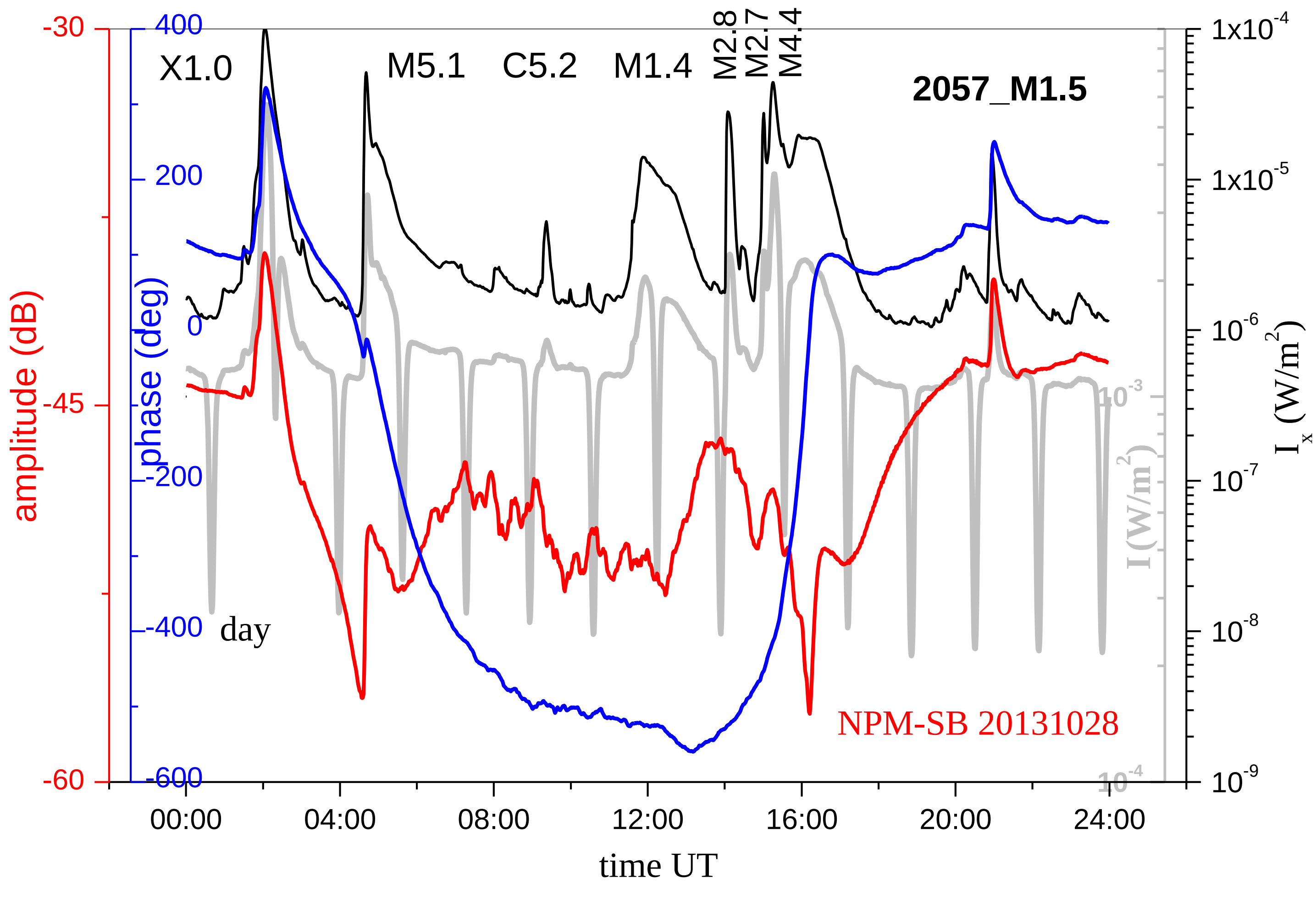
Overall: at **90** km

$N_{\max}$

($7.4\ 10^{11}$, 10^{12}) m^{-3}

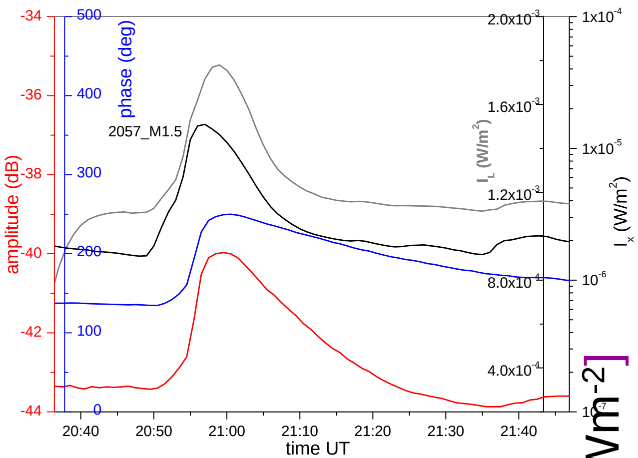


2013_10_28_ NPM-Scott Base



NPM-Scott Base 20131028_2057_M1.5

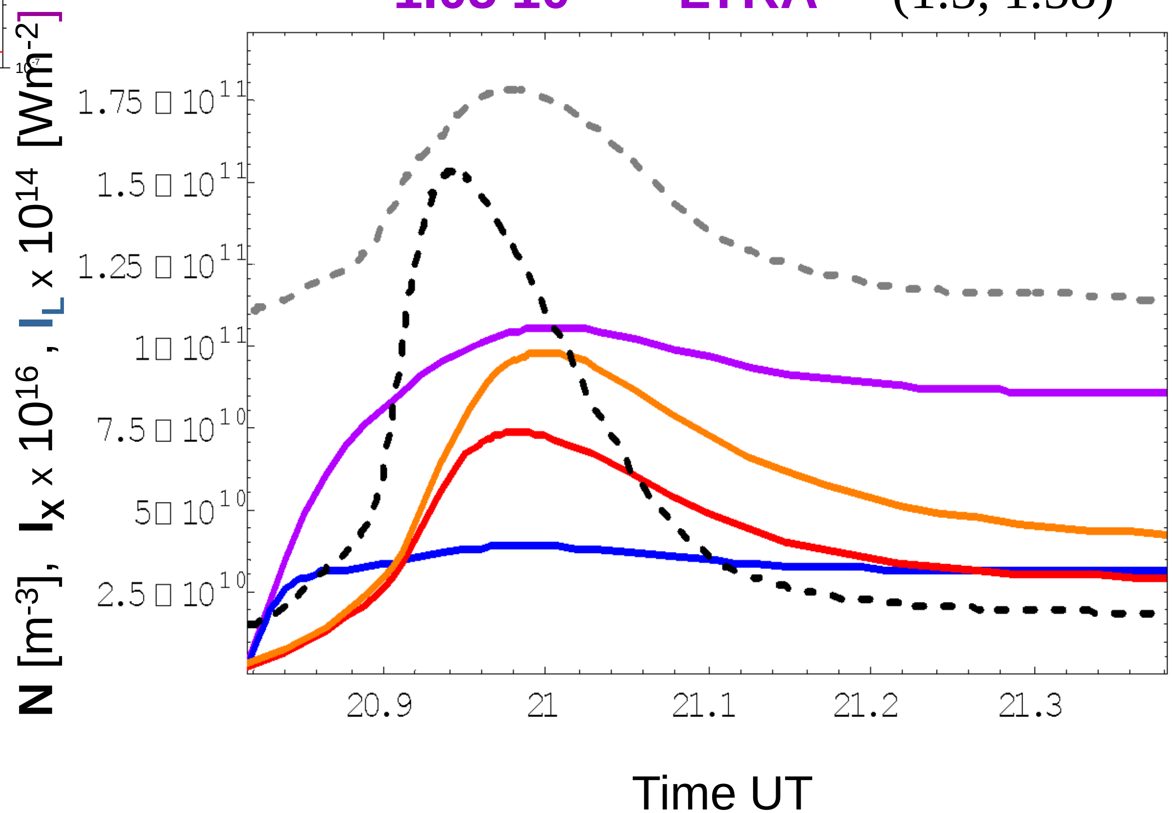
Electron density at 90 km height from **AMPLITUDE** & **PHASE** time delay



	N_{max} [m^{-3}]		$(\Delta t, \Delta t')$ [min]
AMP	**7.36 10^{10}**	**GOES**	(2.5, 2.32)
	3.89 10^{10}	**LYRA**	(0.5, 0.52)
PHA	**9.76 10^{10}**	**GOES**	(3.5, 3.30)
	1.05 10^{11}	**LYRA**	(1.5, 1.58)

LYRA I_{max}
2059 UT , 1.78 mW/m^2

$$\tau_{LG} = 2 \ \ \text{min}$$



Summary

- **LYRA data** can be used to assess the flare enhanced electron density at the ceiling of the D-region - 90 km.

N_{max}, N(t)

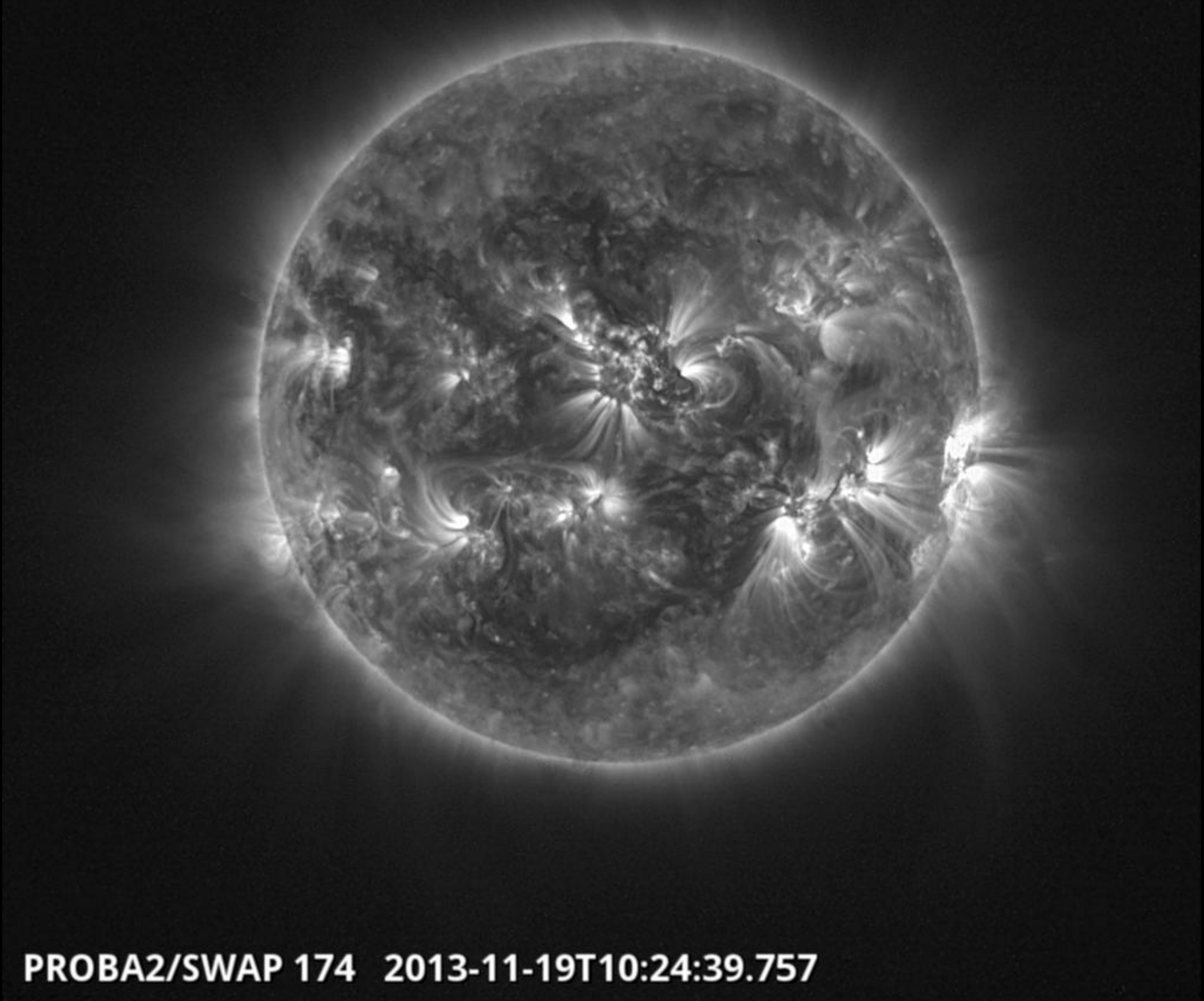
- N(t) according to **LYRA** decreases slower than according to GOES.
- The predictions of the maximal flare induced electron density at **90 km** height are in reasonabe agreement.

	M1.5	**M6.6**	**X1.4**
N_{max} [m^{-3}]	($7.4\ 10^{10}$, 10^{11})	2 - $4\ 10^{11}$	($7.5\ 10^{11}$, 10^{12})

Prospects:

- Can the lower ionization efficiency be compensated by higher irradiance ?

- Assessment with Long Wavelength Propagation Capability LWPC (NOSC)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Thanks to

Proba2 Science Centre

D. Berghmans

M. Dominique

M. West

LYRA Team

NOAA/SWPC

Antarctica logistic providers

The Audience !