Transit events on the Sun observed in VLF, soft X-Ray and FUV

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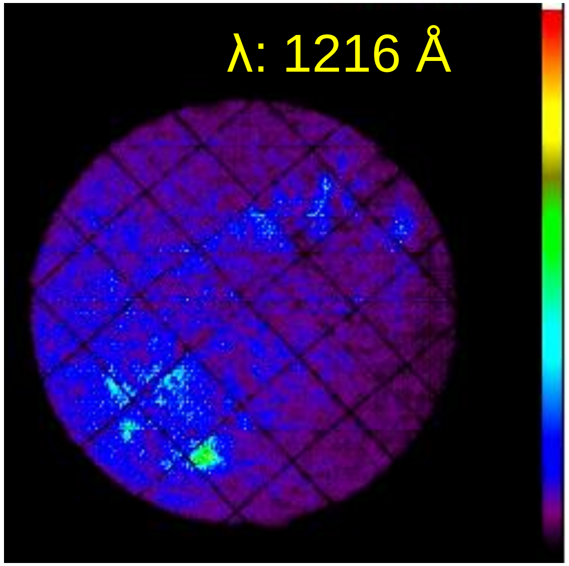
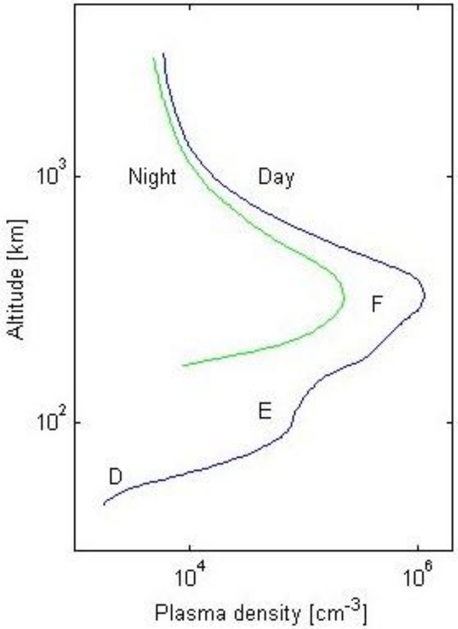
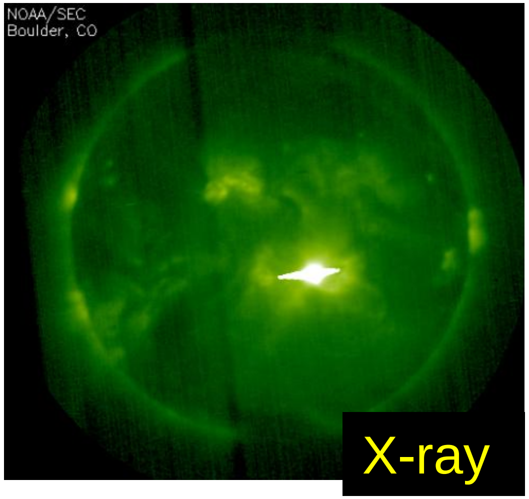
Introduction

Quiescent Lyman-α (**λ: 1216 Å**) is the main responsible for the formation of the D-region (Nikolet and Aikin, 1960)





During solar flares **X-rays** (**λ < 2 Å**) produce ionization excesses in the lower ionosphere (Pacini and Raulin, 2006)



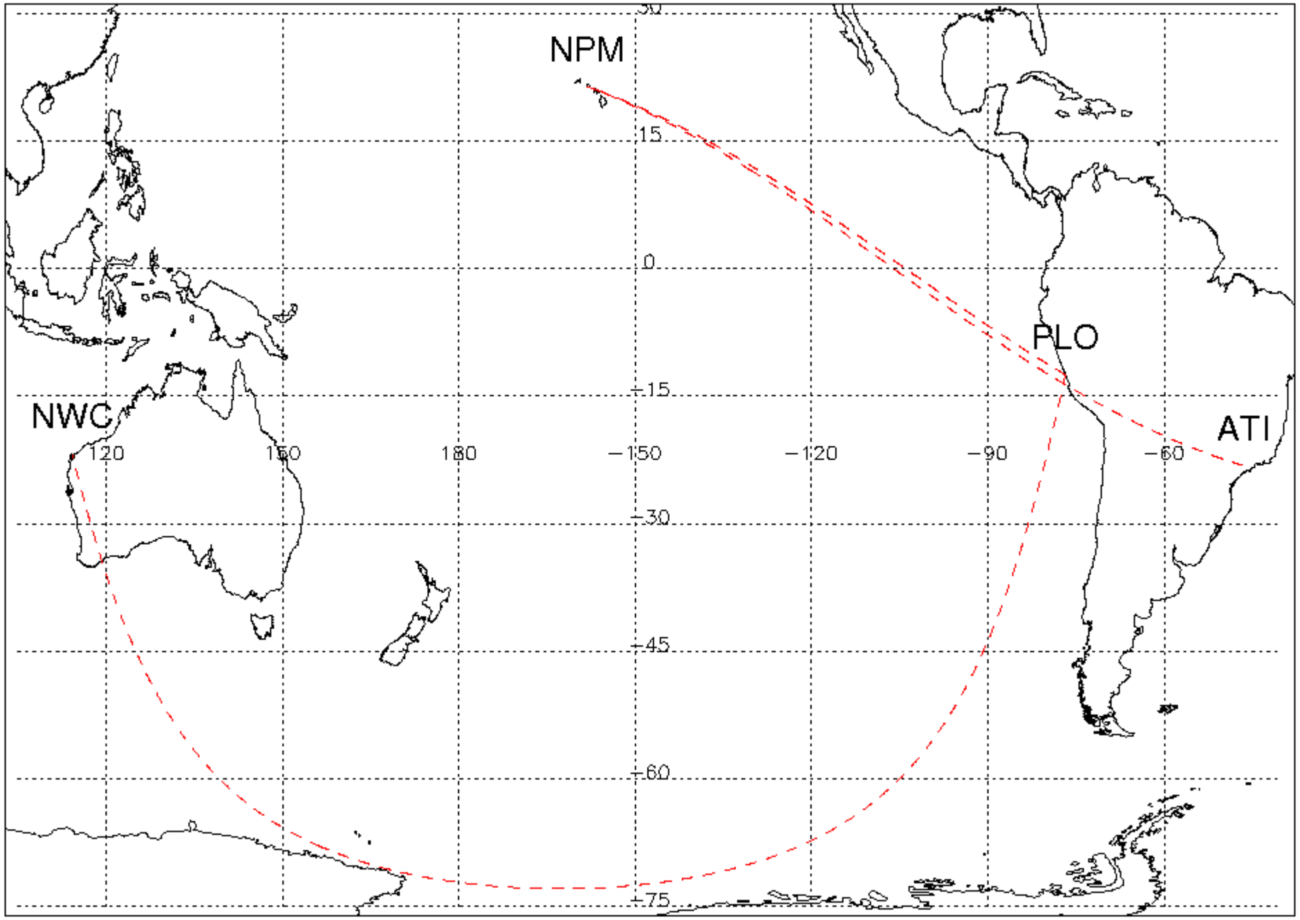
Objective: Find out the response of the lower ionosphere as VLF phase advances, due to X-rays and Lyman-α excesses produced **during solar flares**

Instrumentation and data analysis

Three data set: VLF (SAVNET), X-ray (GOES) and
Lyman-α (PROBA2)

SAVNET
(Raulin et al (2009,2010))

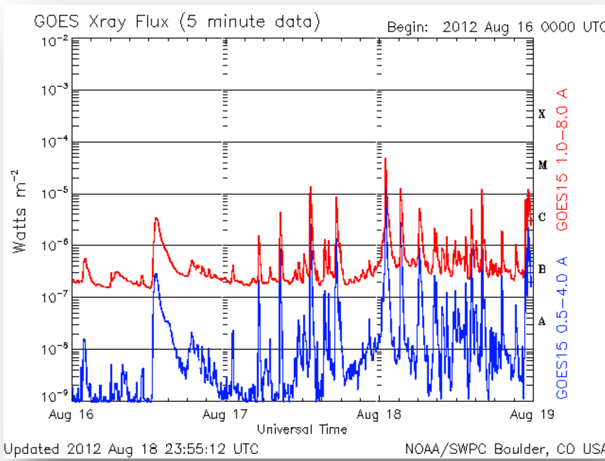
VLF treatment:
1) $\Delta\phi/d$
2) $[\cos(\chi)^{-1}]$
3) $\Delta\phi \cdot (2.88\ \mathrm{Mm})$



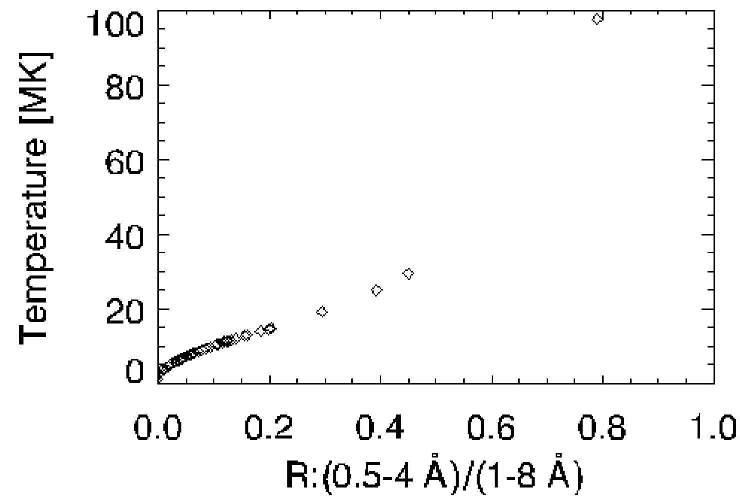
VLF propagation paths

Instrumentation and data analysis

GOES

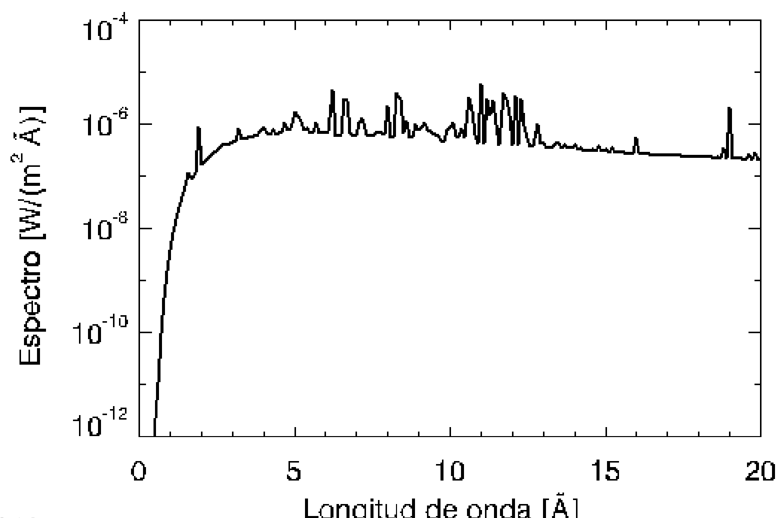


(Pacini and Raulin, 2006)



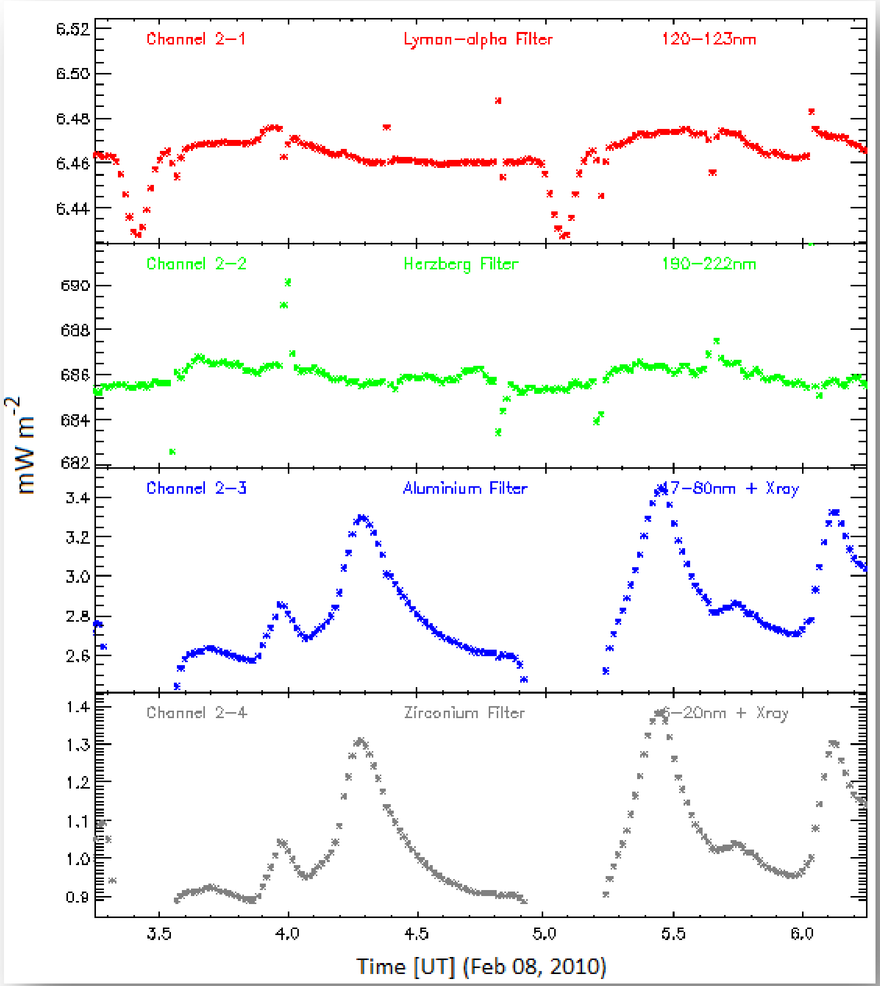
Treatment:

1) We assume that X-rays are emitted by the hot isothermal plasma associated with the flaring active region.
2) T(t) and EM(t) of the emitting plasma are derived as a function of time.
3) Using T(t) and EM(t) the source isothermal spectrum is calculated and then, integrated between 0.5 - 2 Å (fluence).



Instrumentation and data analysis

Large Yield RAdiometer (LYRA)



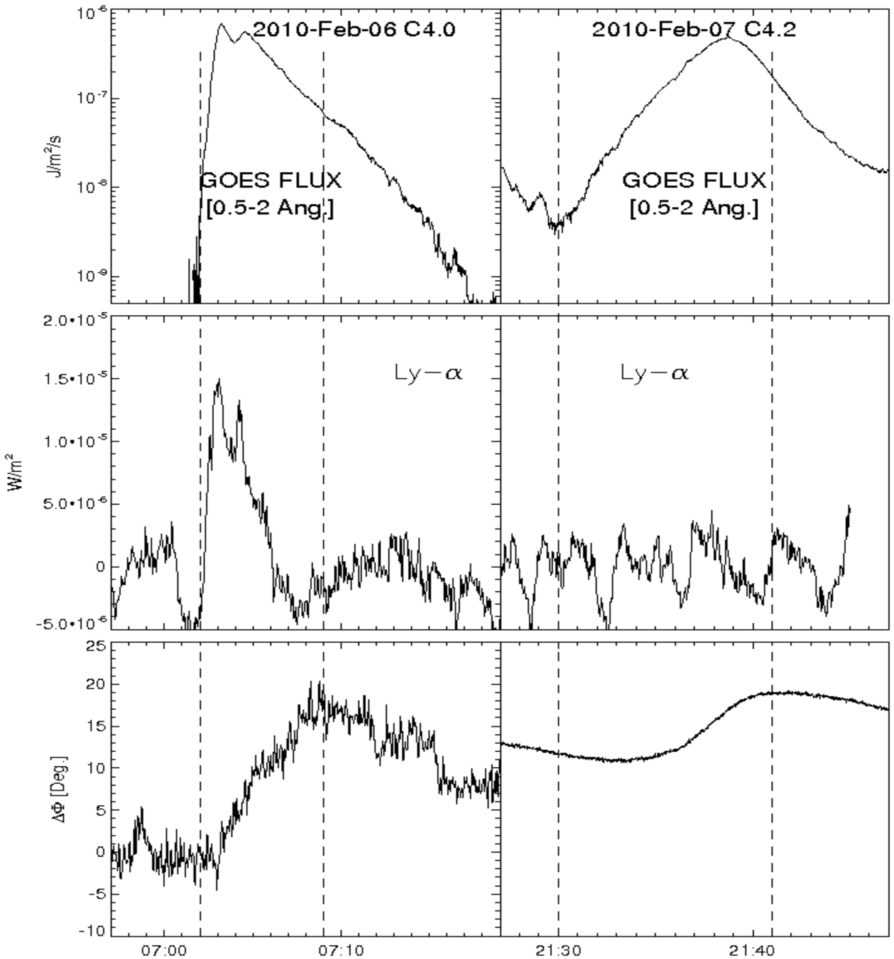
PROBA2 spacecraft (ESA)

Lyman-α channel experienced strong degradation early in the mission: 2-3 months of observation

Use: LYRA level 1 data

Treatment:

1) removed a dark current excess that is observed during some periods early in the PROBA2 missions
2) corrected for the LYRA channel degradation with a multiplicative factor
3) used the absolute value given by the SORCE/SOLSTICE instrument to convert count rates in physical units (W/m^2).

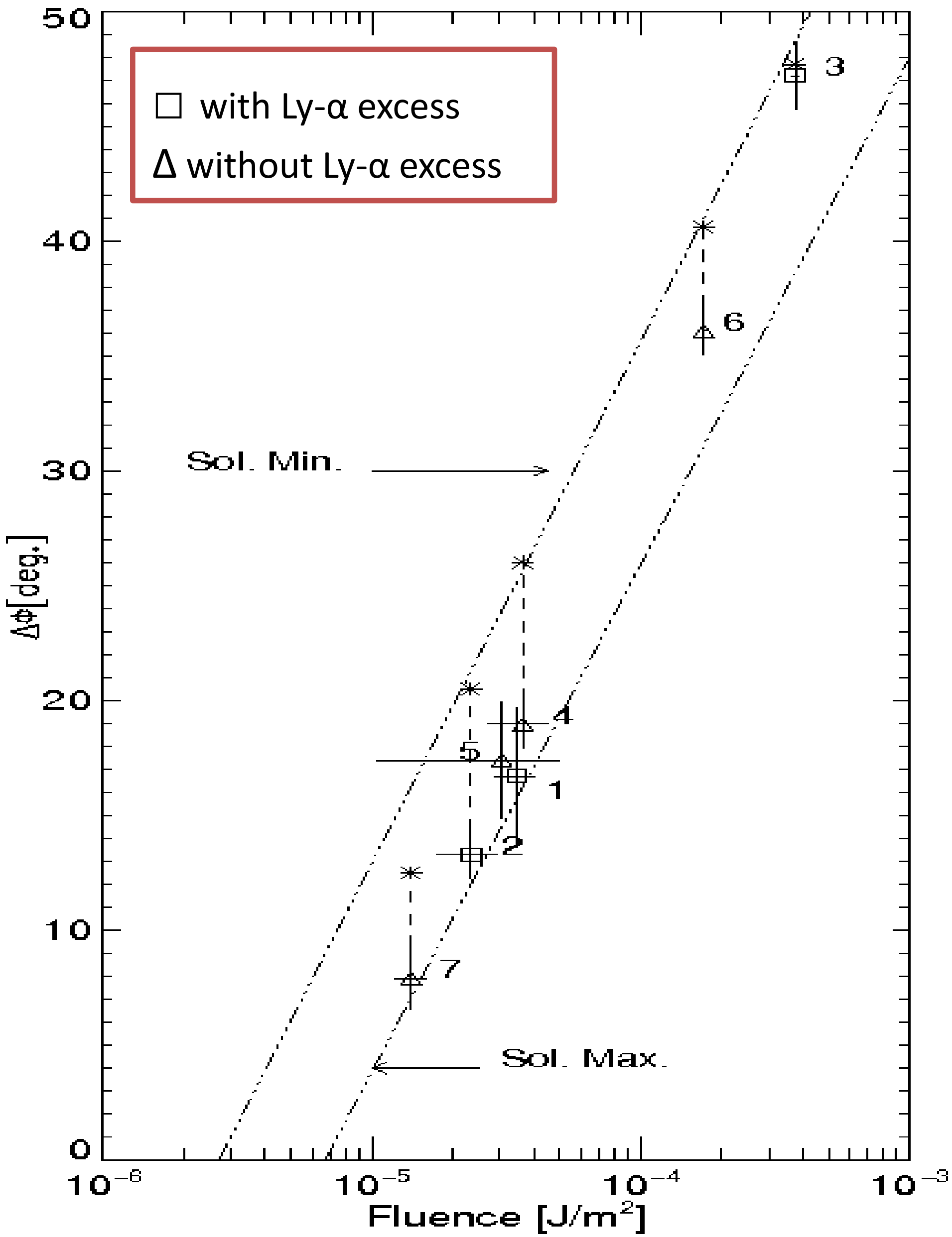


Results

Some solar flares are clearly associated with Lyman-α excesses, and others are not, independently of their X-ray peak flux.

	Date	Time [UT]	VLF path	X-ray flux (10^{-6} W/m^2)	Lyman-α (10^{-5} W/m^2)	Fluence (10^{-5} W/m^2)	Δφ [deg.]
(1)	06-Feb-10	0705	NWC-PLO	4.00	Y - 1.20	3.47	16.70 ± 6
(2)	07-Feb-10	2115	NPM-PLO	4.20	Y - 2.00	2.34	13.30 ± 2
(3)	08-Feb-10	1347	NPM-PLO	20.00	Y - 4.55	37.80	47.20 ± 3
(4)	07-Feb-10	2140	NPM-PLO	4.20	N - < 0.15	3.64	19.00 ± 2
(5)	13-Feb-10	0752	NWC-PLO	4.30	N - < 0.12	3.04	17.40 ± 5
(6)	13-Feb-10	1240	NPM-ATI	9.60	N - < 0.09	17.16	33.30 ± 2
(7)	26-Feb-10	2110	NPM-PLO	2.50	N - < 0.10	1.40	7.90 ± 3

Results

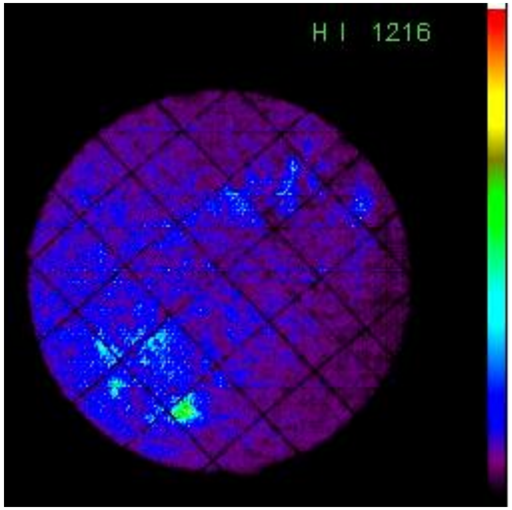


- All the studied events do present a VLF phase advance within the range of values inferred by *Pacini and Raulin [2006].*
- For the 3 events of similar X-ray fluence there is no significant difference between the observed Δϕ's whether they are associated with Lyman-α excesses (event 1) or not (events 4 and 5).

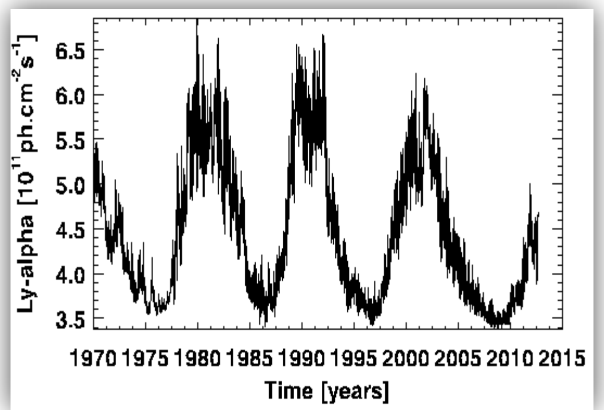
Conclusion

- By comparing the response of the lower ionosphere to seven solar flares from moderate to mid sizes, we have shown that the impact of transient solar Lyman-α excesses on the D-region is negligible.
- In terms of VLF phase measurements, the Lyman-α flare excesses reported here would produce phase changes about 20 times below the sensitivity of the present VLF measurements.

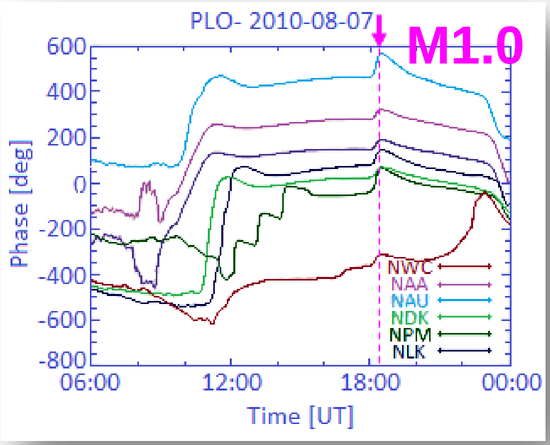
Explosive Lyman-α emission comes from localized regions and is superimposed on to the quiescent Lyman-α emission



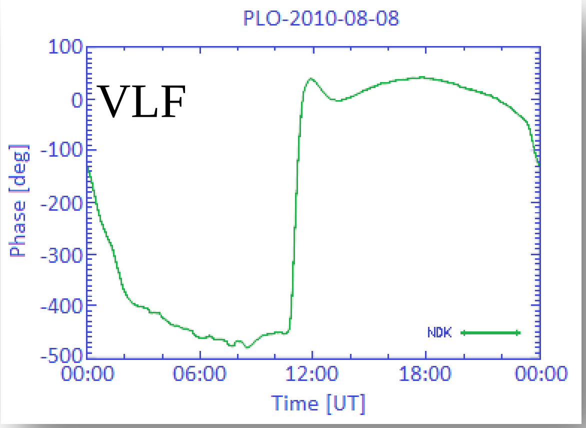
Quiescent Lyman-α emission comes from the whole solar disk



Ly-alpha [10^11 ph.cm^-2 s^-1]
6.5
6.0
5.5
5.0
4.5
4.0
3.5
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Time [years]



PLO- 2010-08-07
M1.0
Phase [deg]
600
400
200
0
-200
-400
-600
-800
NWC
NAA
NAU
NDK
NPM
NLK
06:00
12:00
18:00
00:00
Time [UT]



PLO-2010-08-08
VLF
Phase [deg]
100
0
-100
-200
-300
-400
-500
NDK
00:00
06:00
12:00
18:00
00:00
Time [UT]