# Monitoring Precursors' Signs of Large Flares and CMEs in Lyman-Alpha


**L. Damé[1], S. Khaled[1,2], S. UeNo[3], M. Dominique[4], I. Dammash[4], R. Kariyappa[5] and S.T. Kumara[6]**

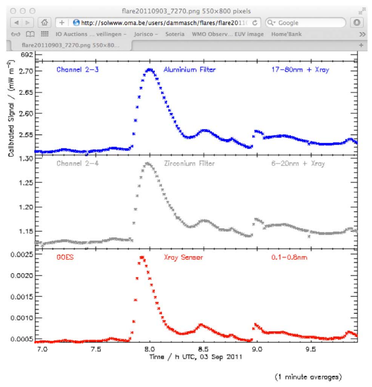
[1]Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), IPSL/CNRS/UVSQ, 11 boulevard d'Alembert, 78280 Guyancourt, France (luc.dame@latmos.ipsl.fr)
[2]SpaceWeather Monitoring Center, HelwanUniversity, Ain Helwan 11795, Egypt
[3]Hida Observatory, Japan
[4]Royal Observatory of Belgium, Uccle, Belgium
[5]Indian Institute of Astrophysics, Bangalore, India
[6]Departement of Physics, ATMA, India

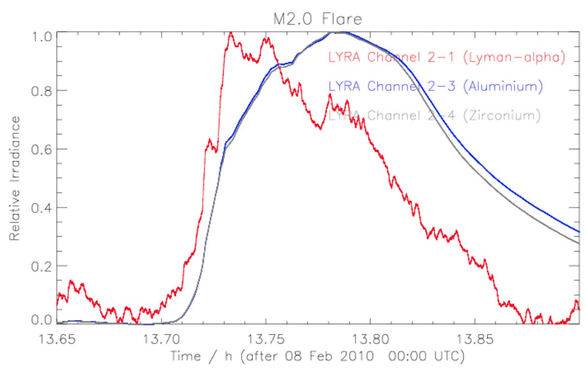

## Introduction

Events preceding the onset of a flare are called "precursors", and one of the prominent precursors is a newly emerging bipolar region at the surface, which may interact with pre-existing magnetic field in the corona and trigger a flare. Another well-known precursor is the activation, or eruption, of a filament that is composed of relatively cool plasma (around 10000 K), floated in the hot coronal plasma. Both emerging regions and filaments are well observed in Lyman-Alpha and H-Alpha and we expect that their combination might lead to a better identification of the changes at the origin of major flares and CMEs.
The objective of the study we present, carried with the LYRA/PROBA-2 instrument (observations of early 2010) and H-Alpha observations (Hida Observatory), is to monitor flares in Lyman-Alpha and to compare sensitivity difference with H-Alpha to develop better precursor indicators on the flaring region. Comparison is also made with classical EUV–X-ray indicators (GOES 1-8 Å but also LYRA channels 2-3, Aluminum 17–80 nm, and 2-4, Zirconium 6–20 nm), showing that Lyman-Alpha flares are equally sensitive and detectable, with the advantage, though, of providing significant precursors. H-Alpha — although 1000 times less intense as a flare than Lyman-Alpha (example of C9.9 February 2010 flare presented) — is indicative of the precursor elements to study.
Many H-Alpha observational sources are available but we preferably use Peru or Hida Observatory data (Flare Monitoring or SMART telescopes) when available since providing velocities (spectroheliograms).
This Lyman-Alpha flares and precursors study will be pursued with new observations campaigns made with a spare Lyman detector of LYRA. But this interesting possibility to open and watch for flares from a promising region implies, accordingly, to rely on good precursors indications to limit filter's degradation.
These observations are pointing the interest for future Lyman-Alpha irradiance measurements coupled, for precursors identification, to full Sun imaging in Lyman-Alpha.

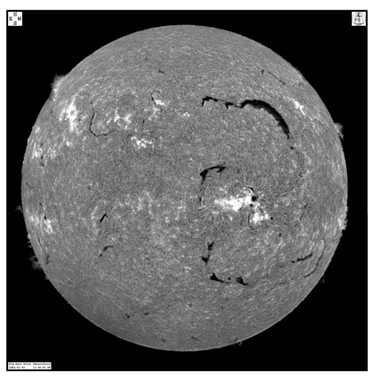
## Predicting and monitoring large flares & CMEs: from X-ray to Hα to Lyα

- Objective is to monitor flares in Lyman-Alpha rather than X-ray or XUV but not only since Lyman-Alpha, much like H-Alpha, is an excellent flares/CMEs precursor indicators since of filaments and emerging bipolar region high visibility (space weather direct application). Furthermore, comparing sensitivity difference with H-Alpha formed slightly below in the chromosphere might lead hopefully to even better and robust flare/CME indicators.
- First, it is worth recalling that Lyman-alpha is EXCELLENT at detecting flares (as shown by LYRA/PROBA-2) with raise in global integrated light curve even slightly before GOES X-ray (1–8 Å) or the LYRA channel 2-3, Aluminium 17–80 nm, or 2-4, Zirconium 6–20 nm.

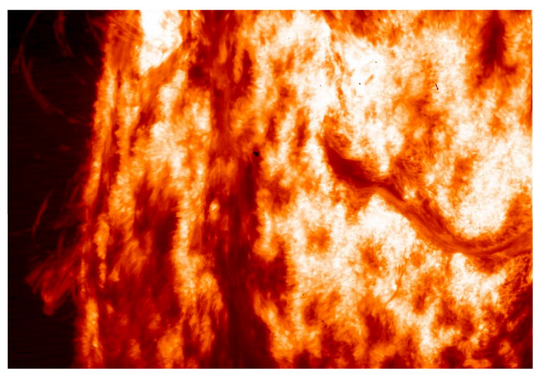



- But even better is that filaments and emerging bipolar region (the two major flare's precursors) are EXTREMELLY well seen in Lyman-Alpha allowing their detection and tracking for a more than easier prediction of large flares happening (the only ones leading to the Space Weather annoying Interplanetary Coronal Mass Ejections, ICMEs, the ones towards the Earth) that, for example, their delicate identification in He II 304 Å (see work of Eric Buchlin with SDO).



*Filaments are cool, dense chromospheric material maintained in equilibrium in the hot corona thanks to the magnetic field, up to instability leads to a flare or CME (Hcfiltregram from BBSO)*

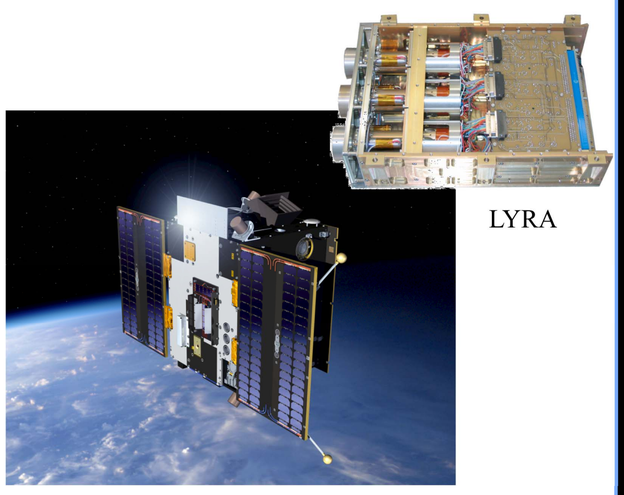


*High resolution image of the Sun in Lyman-Alpha taken by the VAULT rocket program of NRL and nicely showing prominences and filaments (prominences seen in absorption on the disk)*

## LYRA Lyman-Alpha flare data available

The list of potential candidates is very limited due to degradation of sensitivity of the UV channels: available data are from very early 2010 where channel 2-1 was still strong:

- event 5800 (M1.8) 20 Jan 2010
- event 6590 (C4.0) 06 Feb 2010
- event 6880 (C9.9) 07 Feb 2010
- event 7080 (C4.2) 07 Feb 2010
- event 7510 (C6.8) 08 Feb 2010
- event 7650 (M2.0) 08 Feb 2010
- event 7790 (M1.0) 08 Feb 2010

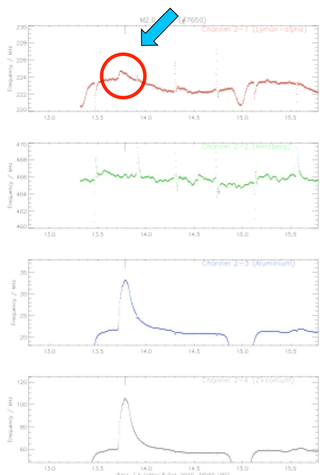


LYRA

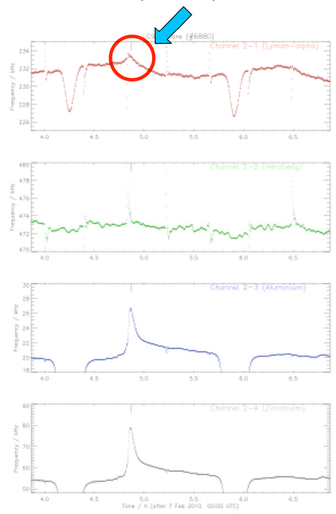
***ESA/PROBA-2**: LYRA, SWAP, Magnetometer and Ionospheric instrument*

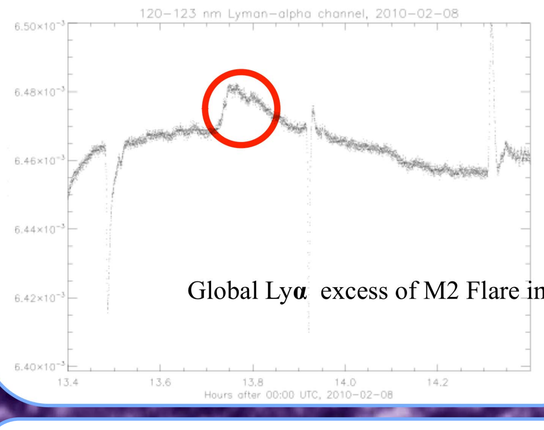
## Lyα flares: 1000 times more intense than in Hα

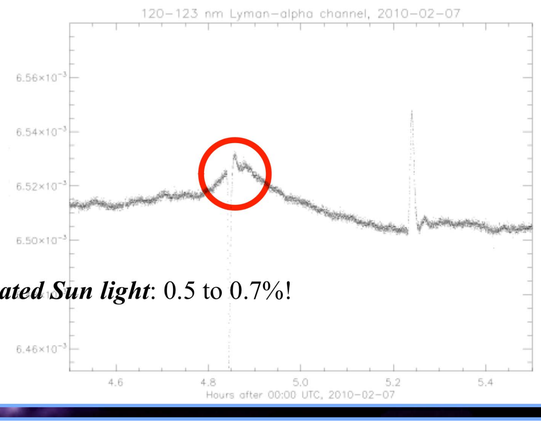
**Event 7650 (M2.0) 08 Feb 2010**



**Event 6880 (C9.9) 07 Feb 2010**






Global Lyα excess of M2 Flare in ***integrated Sun light***: 0.5 to 0.7%!

## Ground support observations from Hida Observatory

There are Mauna Loa, Peru, Big Bear, Pic-du-Midi, and Hida Observatory data available depending of the time of the day (and cloud coverage). We prefer Peru or Hida Observatory data when available since providing velocities (spectroheliograms) also (Flare Monitoring Telescope at Hida and Peru; SMART at Hida).

In January and February 2010 the FMT Peru was not active yet but the SMART Telescope of Hida Japan was. They have data for:

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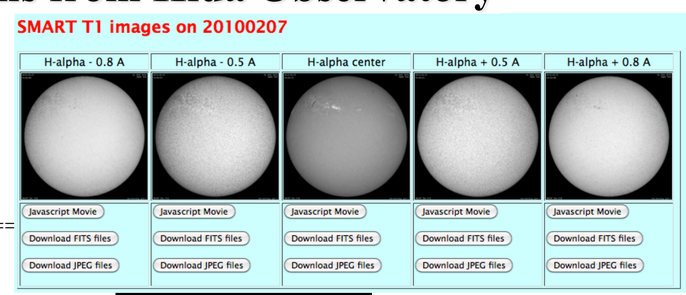
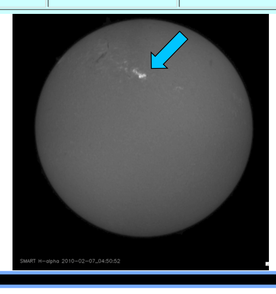
- 2010 01 17 5450 22:12 22:33 22:41 C2.1 1040 (*)
- 2010 01 19 5710 23:17 23:26 23:38 C2.2 1041 (+)
- 2010 01 20 5720 00:10 00:22 00:30 C4.0 1041 (+)
- 2010 01 20 5730 02:47 02:53 03:02 C1.7 1041 (+)
- 2010 02 07 6810 02:20 02:34 02:39 M6.4 1045 (#)
- 2010 02 07 6870 03:25 03:29 03:33 C1.1 1045 (#)
- 2010 02 07 6880 04:42 04:52 04:54 C9.9 1045 (#) <= Best
- 2010 02 12 8750 07:18 07:25 07:28 C7.9 1046 ($)



*7 Feb. 2010 C9.9 flare in Hα (Hida, SMART)*

## Conclusions/perspectives

Excellent news for Lyman-Alpha flares is that LYRA/PROBA-2 made recent observations campaigns with the spare Lyman detectors (opening reserved unit3 — not calibrated though — in parallel to unit2 for a limited duration to regain sensitivity!).
This possibility is to be used in the coming weeks with the increase of activity foreseen, knowing that a compromise is to be found between long openings to "watch for flares" from a promising region and limited openings after a first flare to limit filter's exposition (and, thus, degradation…). This second strategy was used up to now but with limited success.
A follow-up of LYRA/PROBA-2 is proposed with more FUV-MUV-UV bands (and also a full Sun Lyman-Alpha and 200-220 nm telescope): the **Space Weather & Ultraviolet Solar Variability (SWUSV) Microsatellite Mission**.

*Background illustration: Lyman Alpha filtregram obtained in 1979 during the first rocket flight of the Transition Region Camera (TRC) and yet the best resolution (1 arcsec) full Sun Lyman Alpha image of the Sun.*