EVIDENCE FOR POLARIZED SOLAR FLARE EMISSION FROM SIMULTANEOUS RADIO OBSERVATIONS IN AUSTRALIA AND VIETNAM

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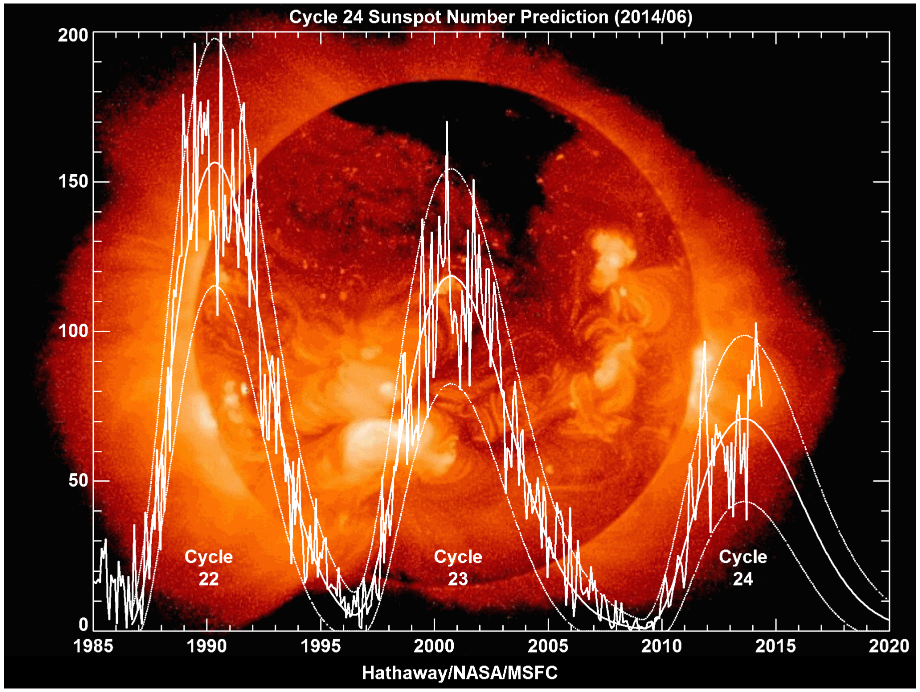
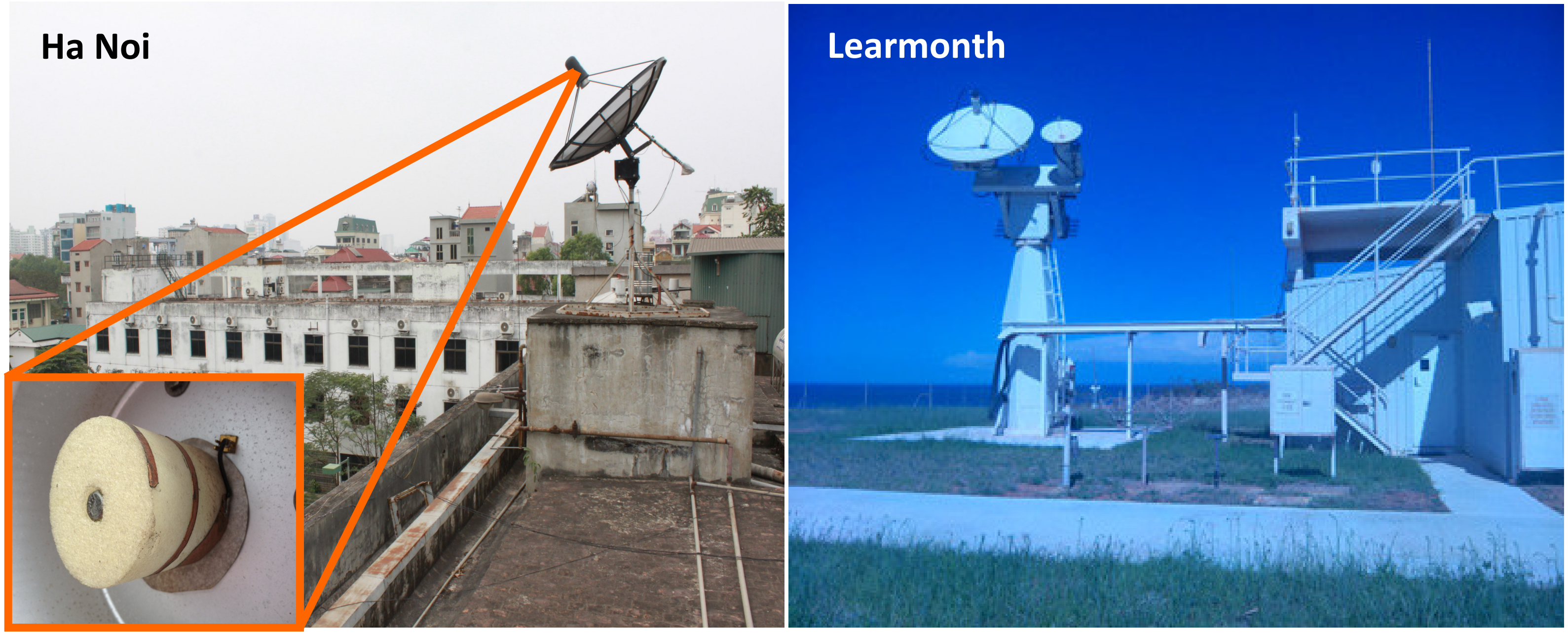
Solar flares are sudden flashes of brightness observed on the Sun. The differential rotation of the Sun surface implies that magnetic field lines trapped in it become closer and closer in an 11-year cycle. Flares are caused by the resulting magnetic reconnection and occur in the vicinity of Sun spots of high magnetic activity. They are observed at all wavelengths from decameter radio waves to gamma rays at MeV scale.



Hanoi flare data are collected at maximal solar activity at radio frequency (1415 MHz) and compared with simultaneous data collected in Australia at the same frequency.

Differences due to the different time resolutions
Evidence for the good quality of the measurements
Differences due to the different feeds
Interpretation in terms of the polarization of the flare emission
A spectacular case of high polarization



The two instruments are identical except for two features:

Time resolution is 1 s in Learmonth and 8 s in Ha Noi

The feed is a dipole in Learmonth and an helix in Ha Noi

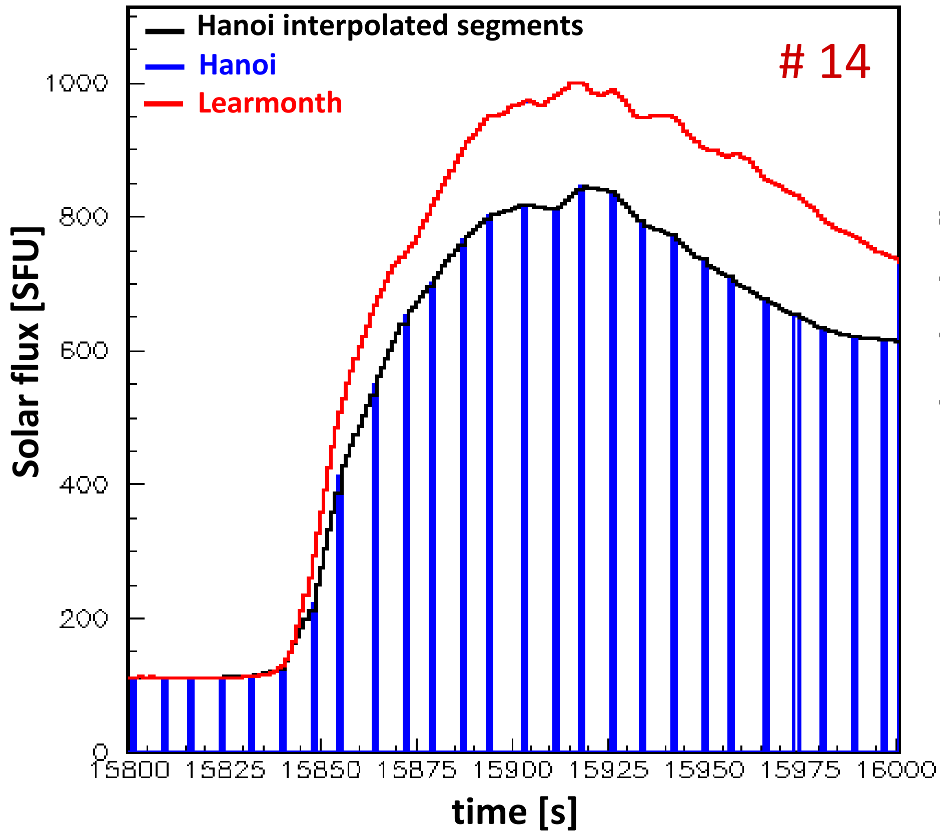
34 solar flares are collected simultaneously in Ha Noi (Viet Nam) and Learmonth (Australia).

Learmonth data is in solar flux unit (1 SFU =10^4 Jy)

Ha Noi data is the antenna temperature (K) averaged over the 138 channels of a same frequency spectrum after having cleaned the data for possible radio frequency interferences. Conversion factor is 12.5 K/SFU

Differences due to the different time resolutions

The Ha Noi telescope is blind to rapid flux variations.
In order to ease comparison between both sets of observations, we interpolate the Ha Noi data into bins of 1 s as in Learmonth.



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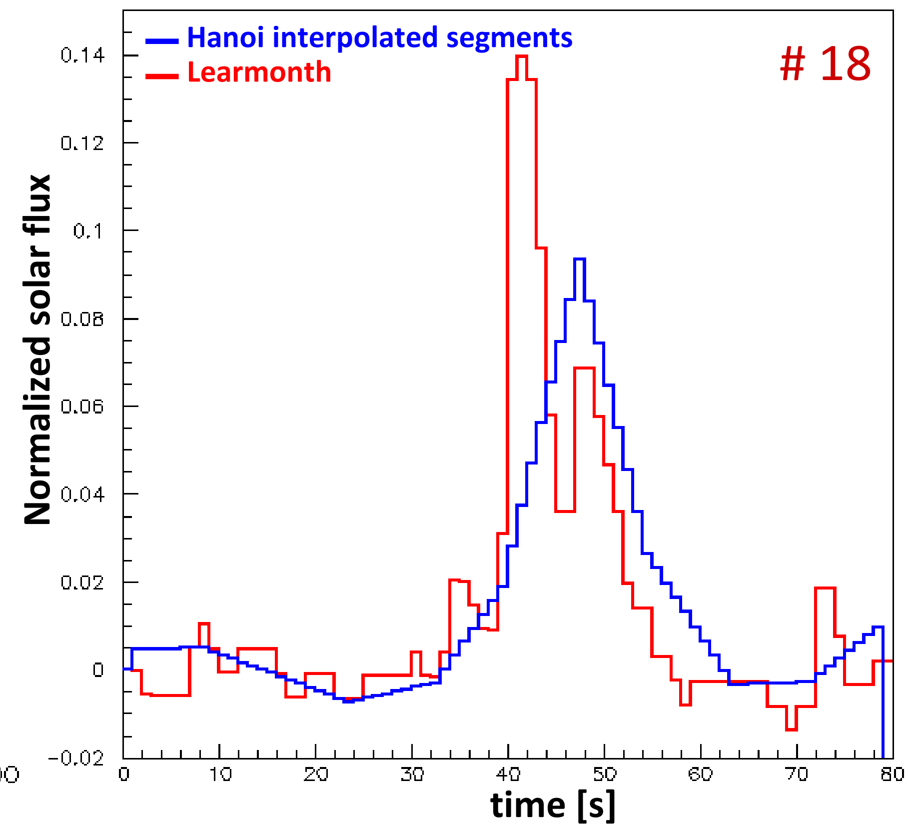

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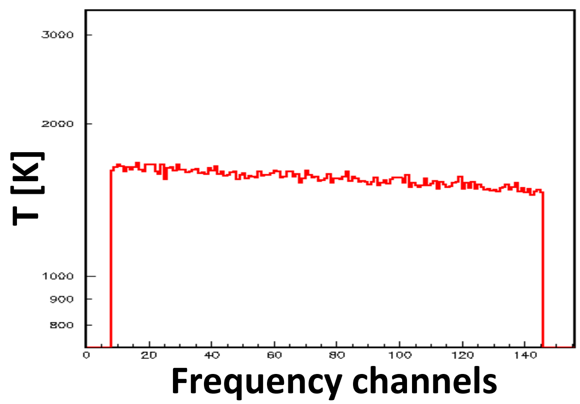
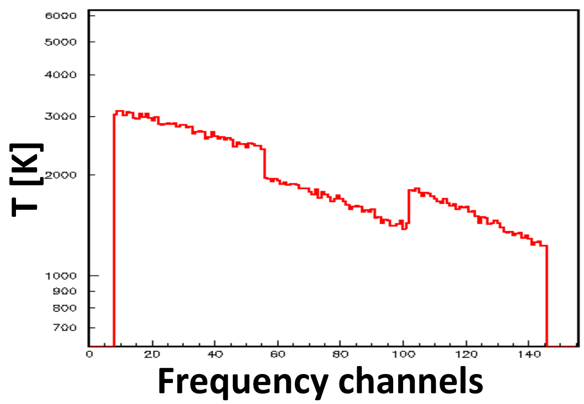
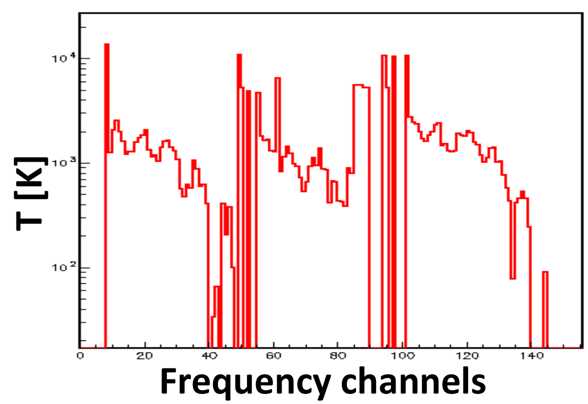
Differences due to the different time resolutions

Very rapid variations of the flux cause distortions of the Ha Noi measured frequency spectrum, which is made of three independent sub-bandwidths read-out in succession. However, the different time resolutions do not affect significantly the quality of the measurement beyond the obvious averaging effect.







Normal behavior, the slope is small and instrumental.

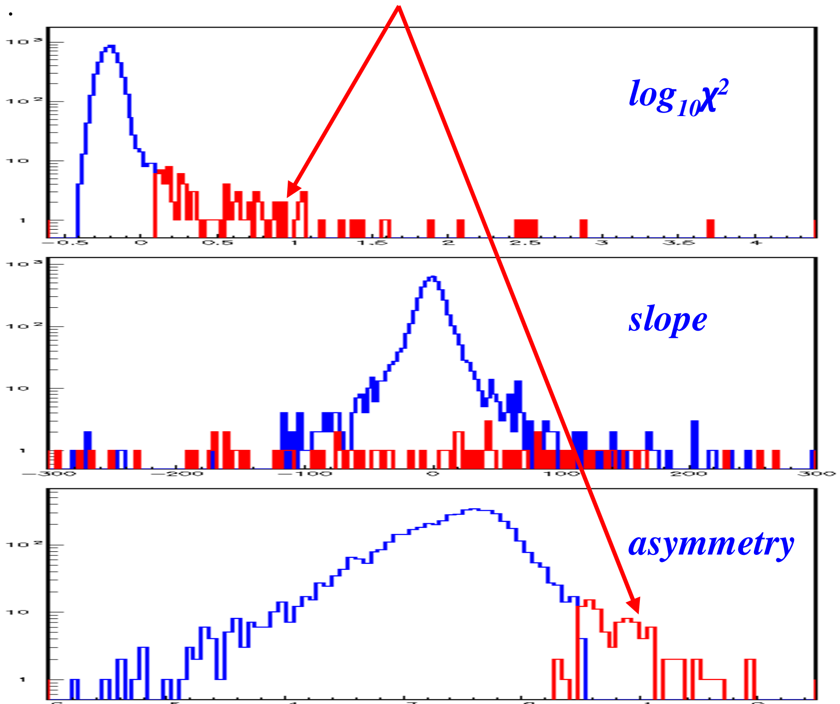
Rapid flux variation, the slope is now large and/or the three sub-bandwidths are at different levels. The total flux measurement is essentially unaffected.

3 out of ~5000 spectra show dysfunctions caused by the very high amplitude and very fast variation of the flux. They are discarded from the subsequent analysis

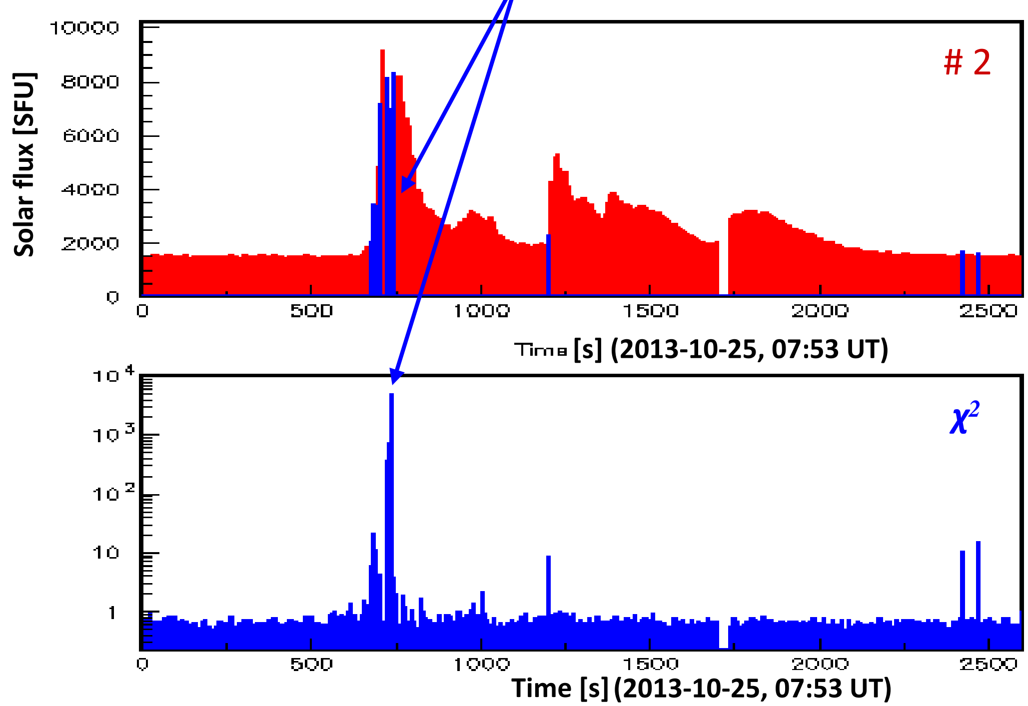
Evidence for the good quality of the measurements

In order to assess the quality of the Ha Noi data we define a χ^2 of the fit of the frequency spectra to a straight line. The distributions of the slope of the frequency spectra and of the asymmetry between the three sub-bandwidths confirm that the data are well behaved, the only source of bad fits resulting from the difference in time resolutions.

Bad χ^2 have unequal sub-bandwidths



Bad χ^2 are related to rapid flux variations



Differences due to the different feeds

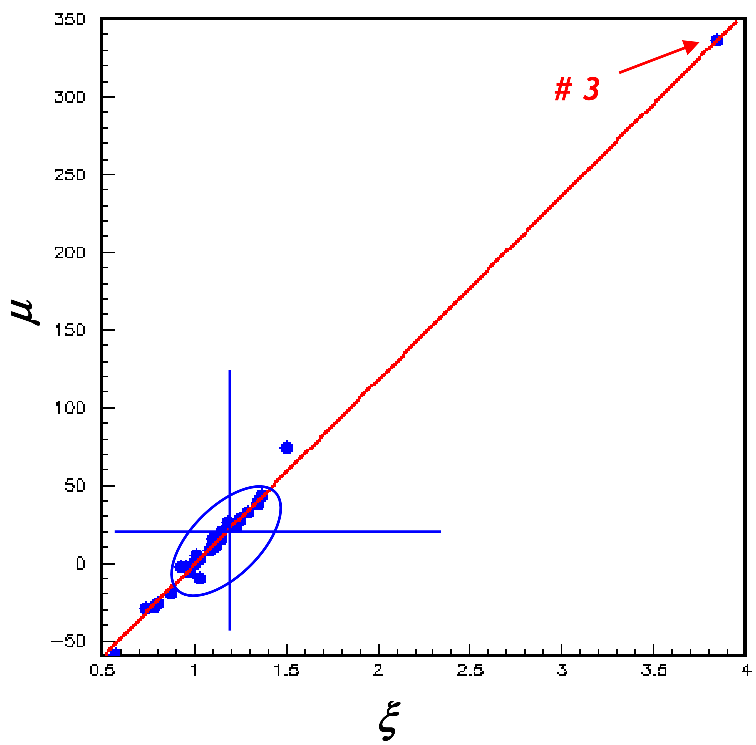
$$S_{LM} = \xi S_{HN} - \mu$$

S_{LM} and S_{HN}: flux densities measured in Learmonth and Ha Noi respectively.

μ: difference in system temperature, ξ-1: difference in gain

As the two flux densities were normalized before the flare to a common quiet Sun value S_0, they must obey the relation

$$\mu = (\xi - 1) S_0$$



$\langle S_0 \rangle$ = 120 SFU

$\langle T_{sys(HN)} \rangle$ = 220 K

We find evidence for overall consistency of the two sets of data. However it does reveal occasional significant differences. Particularly spectacular is the case of a small flare (#3) that erupted ~1 hr after a major flare (#2).

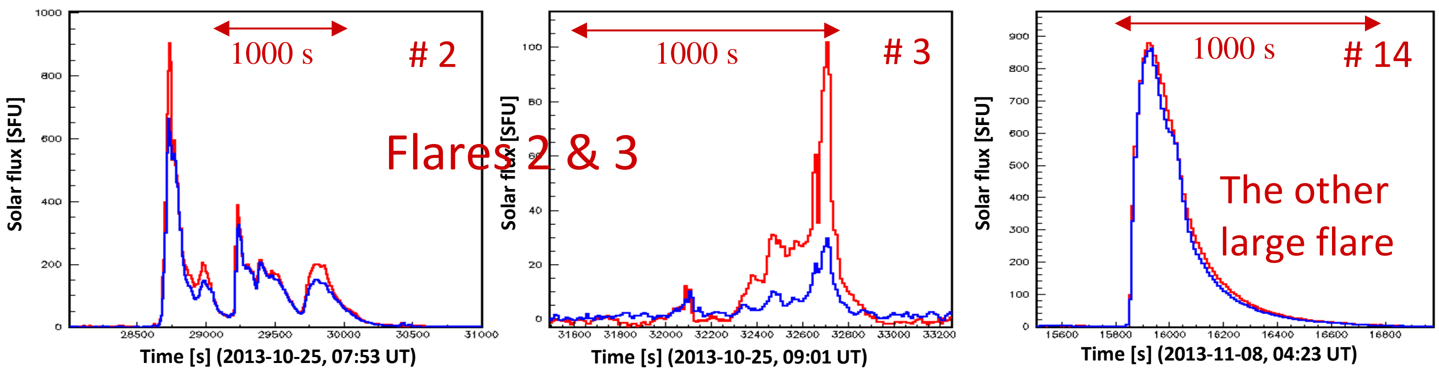
Interpretation in terms of the polarization of the flare emission

In order to compare flare emissions, F, we subtract quiet Sun emission from total emission. The use of a dipole feed in Learmonth rather than helical feed in Ha Noi implies detection of the average flux density rather than that of the right-handed component of the incident wave.

The ratio of flare emissions, interpreted in terms of polarization (P) is

$$F_{HN}/F_{LM}=2R/(R+L)=1+(R–L)/(R+L)=1+P$$

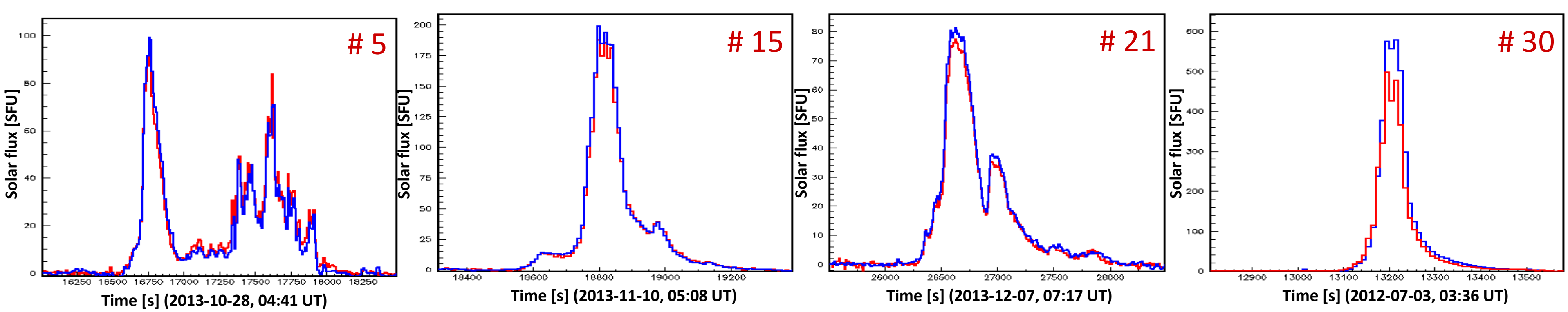
R and L stand for the right-handed and left-handed flux densities respectively



$\Delta P < 15\%$

$F_{LM} > 25$ SFU

Four smaller flares

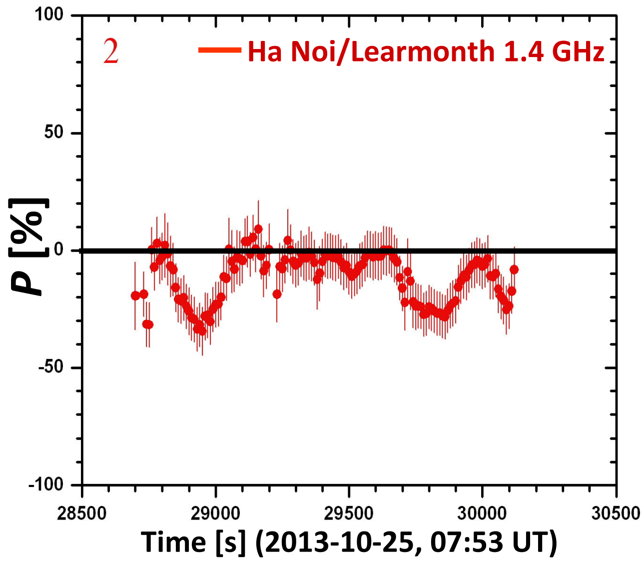


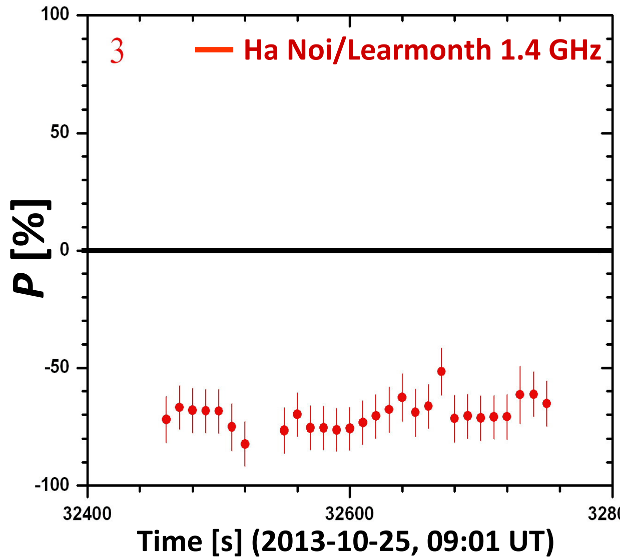
Interpretation in terms of the polarization of the flare emission

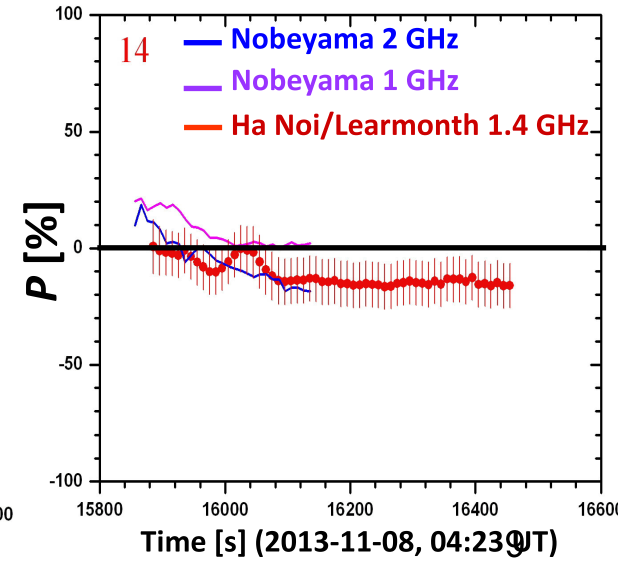
Polarizations are also measured in Nobeyama (Japan) at 1 and 2 GHz. The fast and irregular dependence of polarization on frequency makes a precise comparison difficult and prevents obtaining strong support to our result. Unfortunately, the Sun had set in Japan when flares 2+3 occurred. Large polarizations are not uncommon, associated with the magnetic field direction in the flaring solar plasma.

Flares 2 & 3
Polarization measured
from Ha Noi/Learmonth
comparison

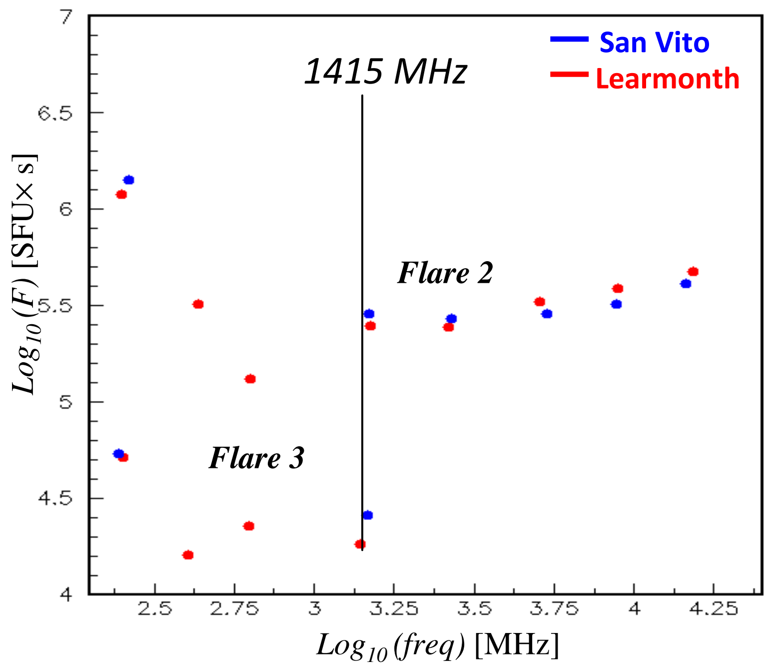
comparison with Nobeyama
on the other 1000 SFU flare



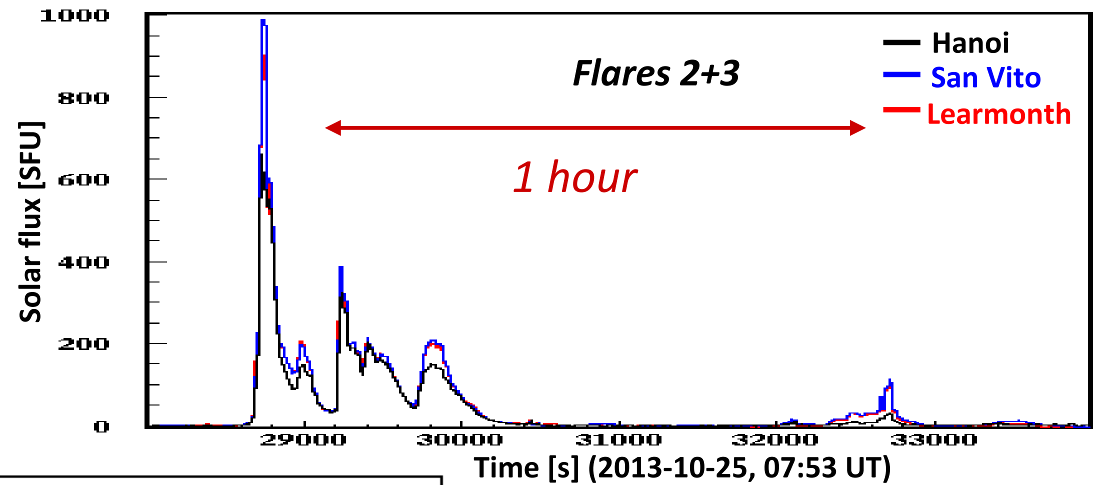


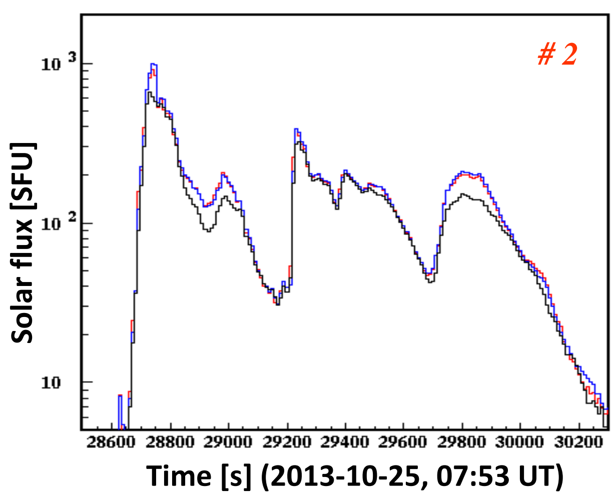


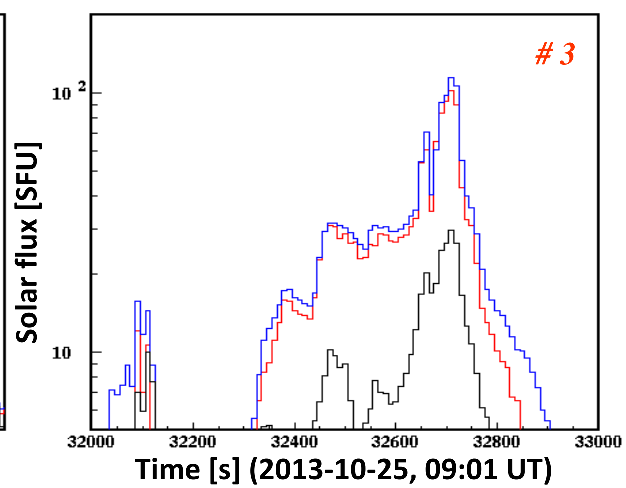
A spectacular case of high polarization



Flares 2 and 3 are measured in Learmonth and San Vito at other frequencies.
Flare 3 is undetected beyond 2 GHz
Flare 2 keeps smoothly increasing
They are of different natures

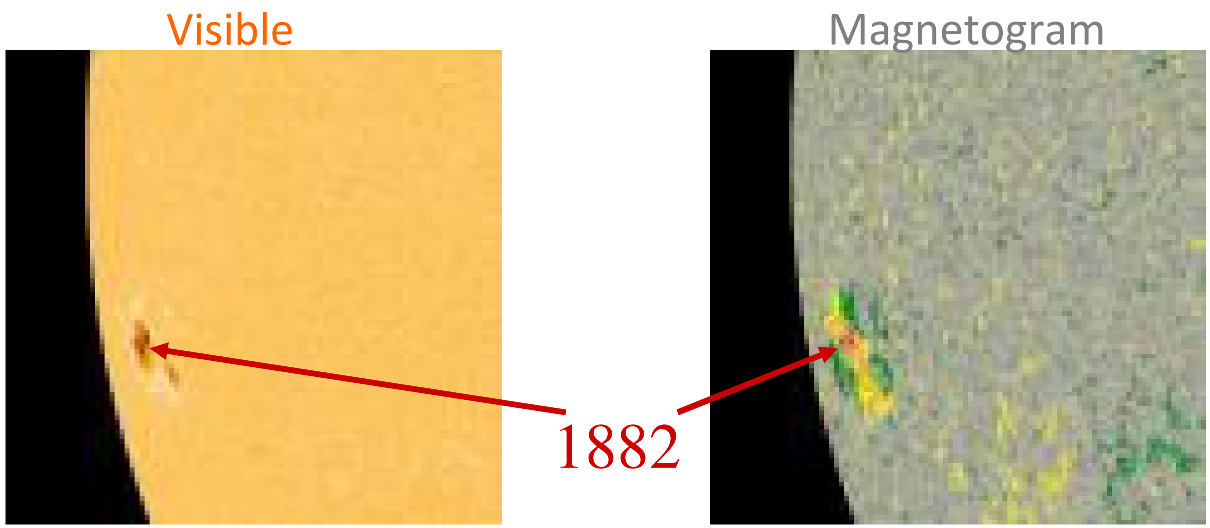






The quiet Sun antenna temperature returns to its earlier level between flares 2 and 3 and after flare 3, making it difficult to invoke another effect than a strong polarization of flare emission.

A spectacular case of high polarization



Flare 2 is an X1.7 flare that erupted from active region 1882, just after it had emerged from the eastern limb of the Sun. It displays a rich time structure. It was followed seven hours later by an X2.9 flare erupting from the same Sun spot, too late however to have been caught by our and Learmonth telescopes.

Flare 3 erupted about one hour after flare 2, again from the same spot, and reaches very large *P* values.

Major radio bursts, of the Tenflare type, meaning more than twice quiet Sun at 10 cm wavelength, were active during the periods covered by flares 2, 3 and 14.

Summary

The study of 34 flares simultaneously observed in Ha Noi (Viet Nam) and Learmonth (Australia), two of which reach 1000 SFU, has given evidence for the perfect performance of both telescopes.

The effect of their different time resolutions has been studied in detail.

Their different feeds, dipole in Learmonth and left-handed helix in Ha Noi, have allowed for polarization measurements of the flare emission at 1.415 GHz.

A spectacular pair of flares, reaching respectively ~1000 and ~100 SFU, has been interpreted as caused by a polarization of up to 70%.

We are indebted to the Learmonth Solar Observatory staff, who are making their data available to the public. We are deeply grateful to Dr Owen Giersch and Dr Alan Rogers for having kindly and patiently answered many of our questions and made us benefit of their experience by making several very useful suggestions and comments. N.H.P. Thanh and B.V. Tuan, master students at the University of Sciences and Technology of Ha Noi, who spent a two month internship in the laboratory, took part in the early phase of the analysis. We thank Dr Sujin Kim for help in accessing Nobeyama data and Pr Kiyoto Shibasaki for having introduced us to the physics of decimetric flares. Financial support is acknowledged from the Institute for Nuclear Science and Technology (VINATOM/MOST), the Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number 103.08-2012.34, the World Laboratory, the Odon Vallet Foundation and the Rencontres du Viet Nam.

Thank you for your attention