Observational evidence of pre-flare quasi-periodic Pulsations

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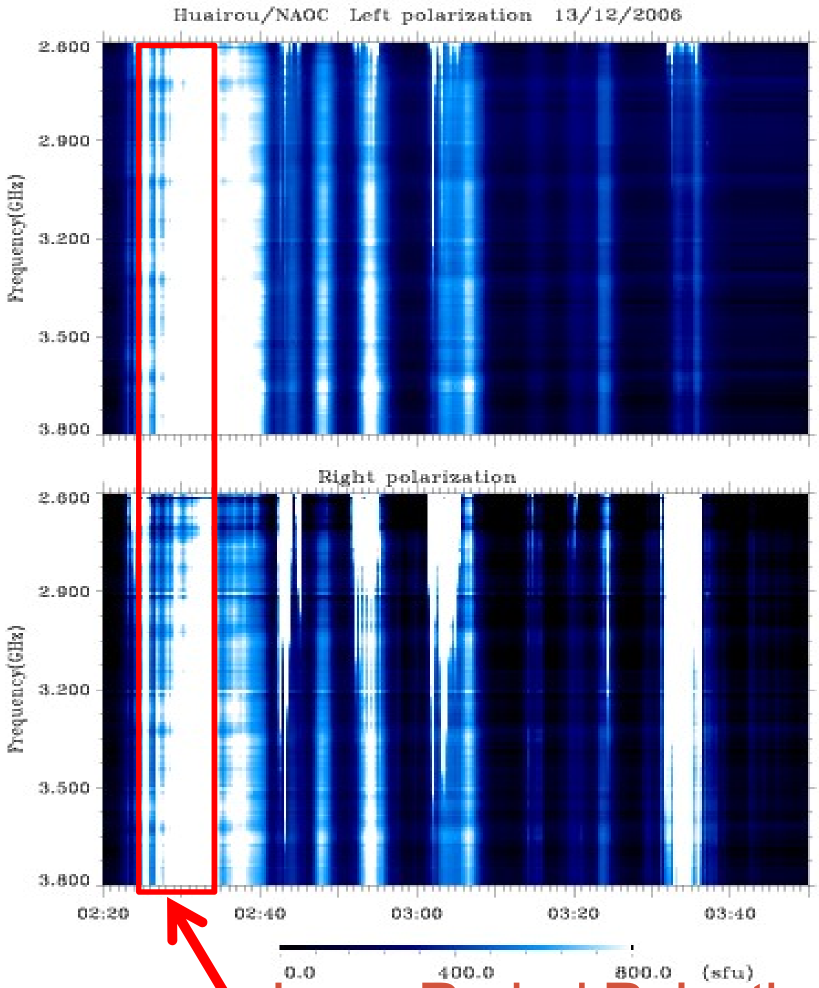
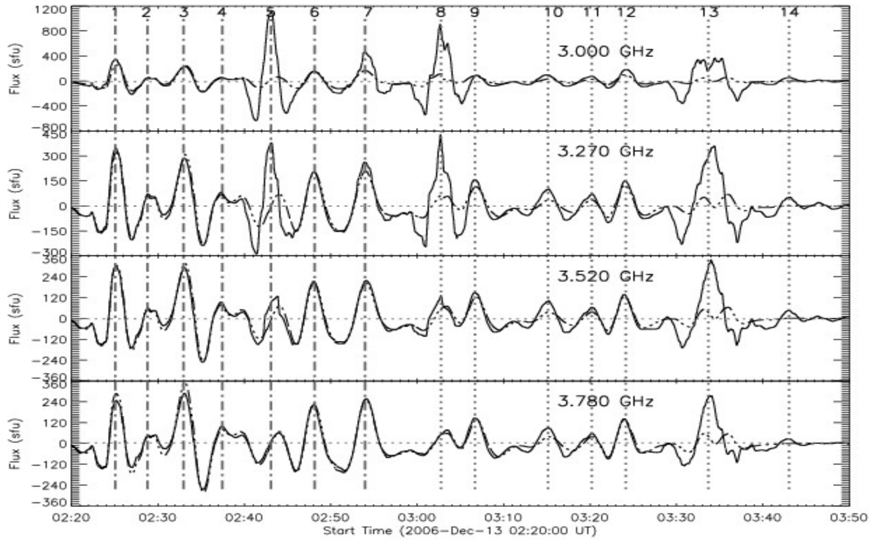
Multi-timescale QPP on 2006-12-13

Very Long-period Pulsation (VLP), P>100s

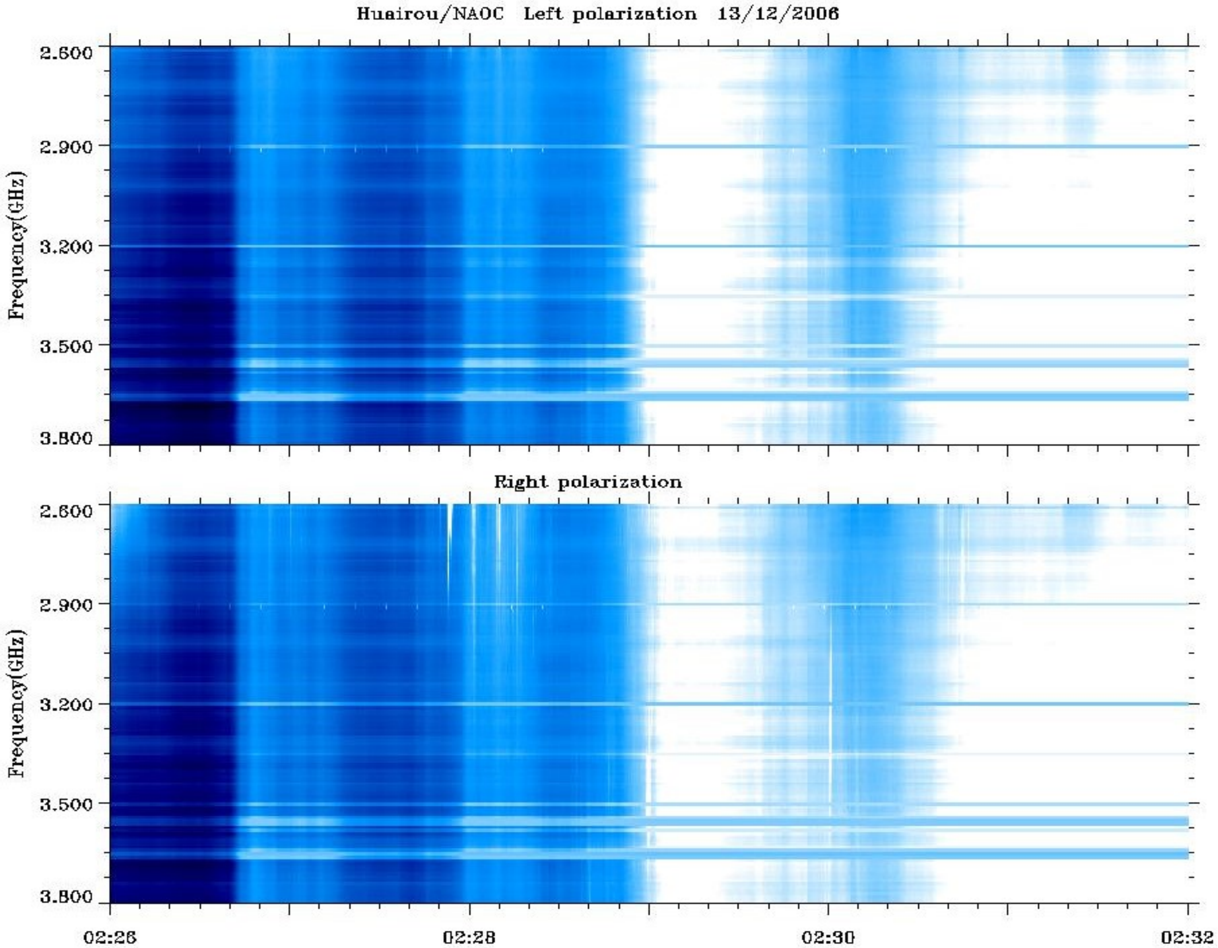


Long Period Pulsation



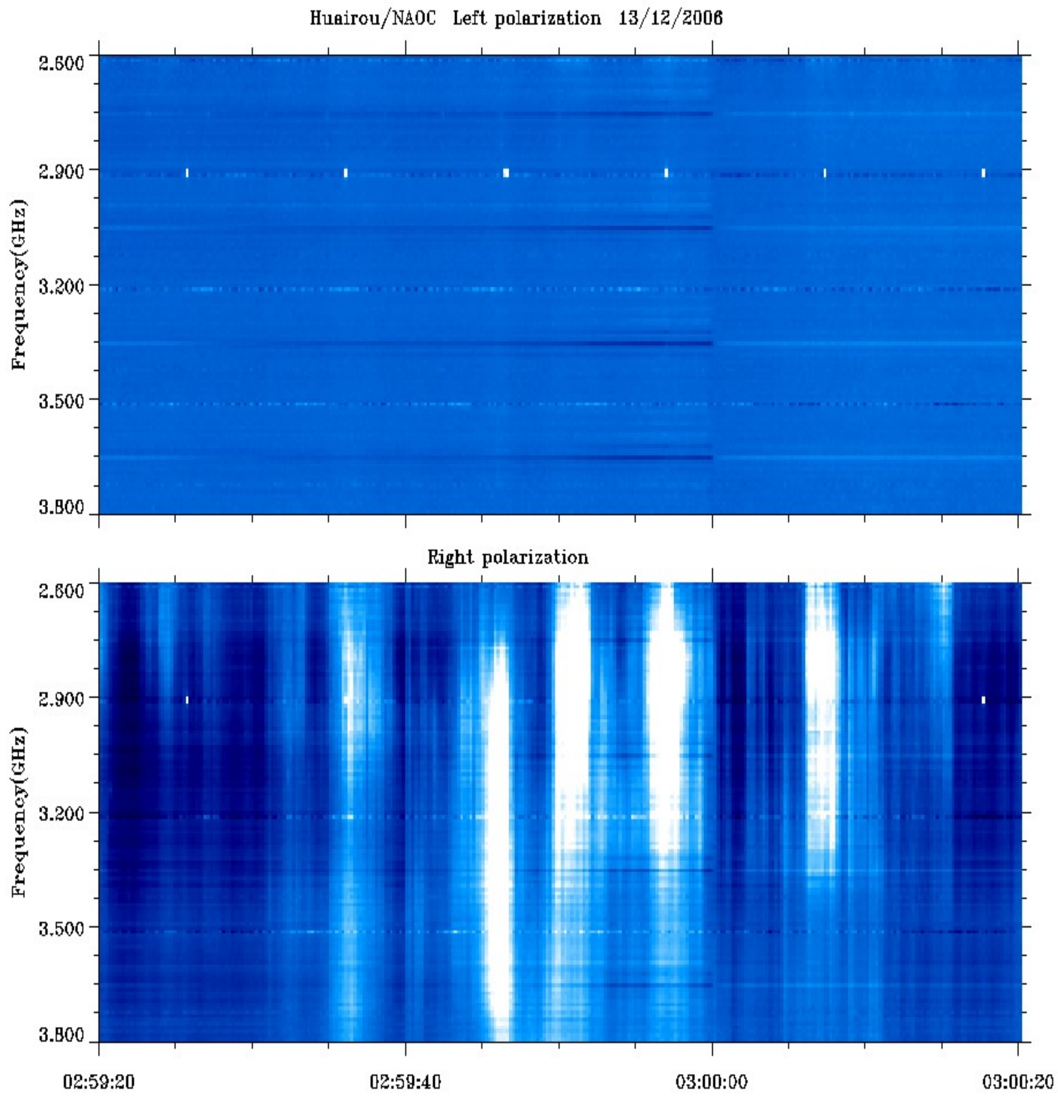
Bandwidth >1200MHz,
Period: 4-9 minutes,
weak polarization

Long Period Pulsation (LPP): 10<P<100 s



P: ~70 s, df/dt: from –610 to 78.5 MHz/s, weak polarization

Short Period Pulsation (SPP): 0.5<P<10 s



Bandwidth: 600-900 MHz

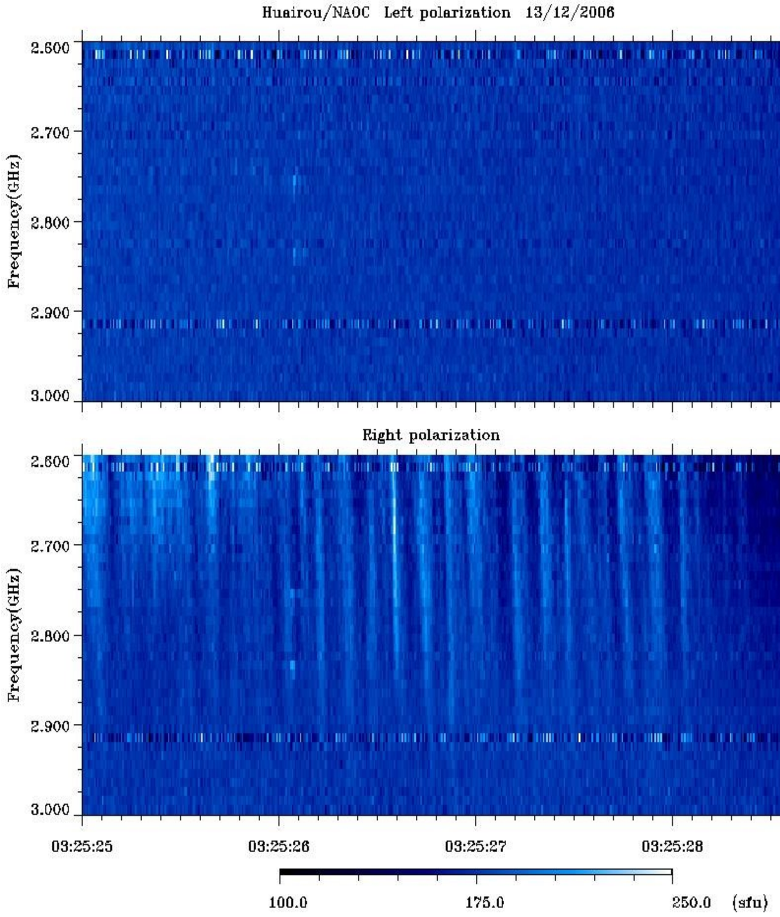
P: ~7.5 s

Strong polarization

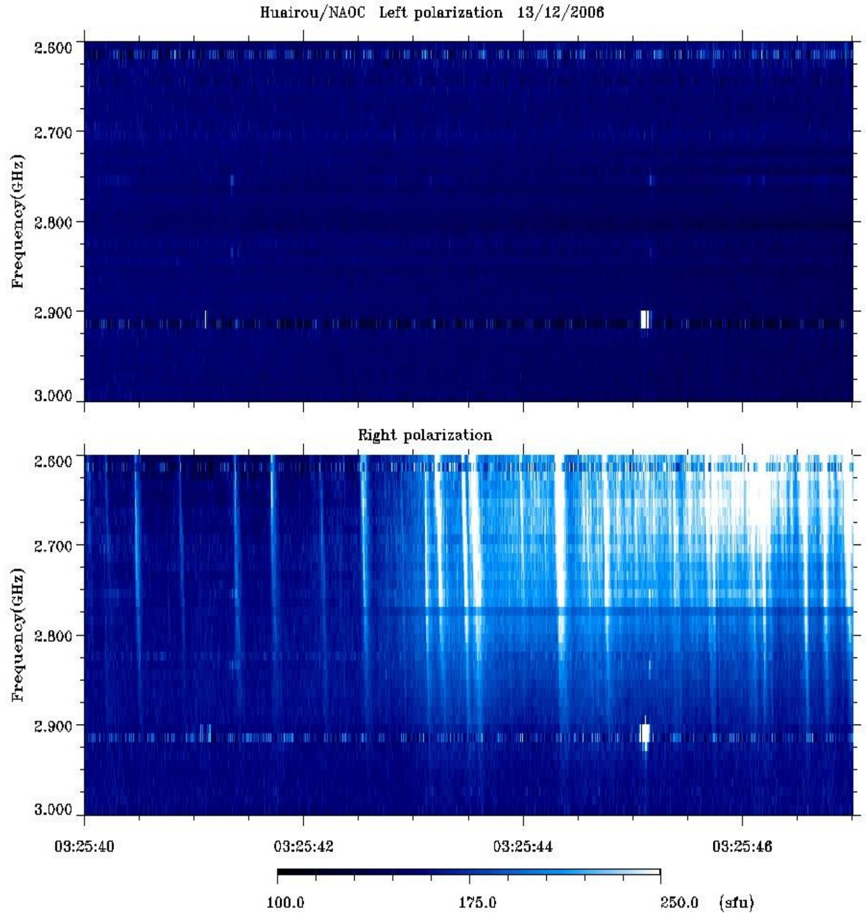
df/dt: –4.0 GHz/s

to 3.5GHz/s

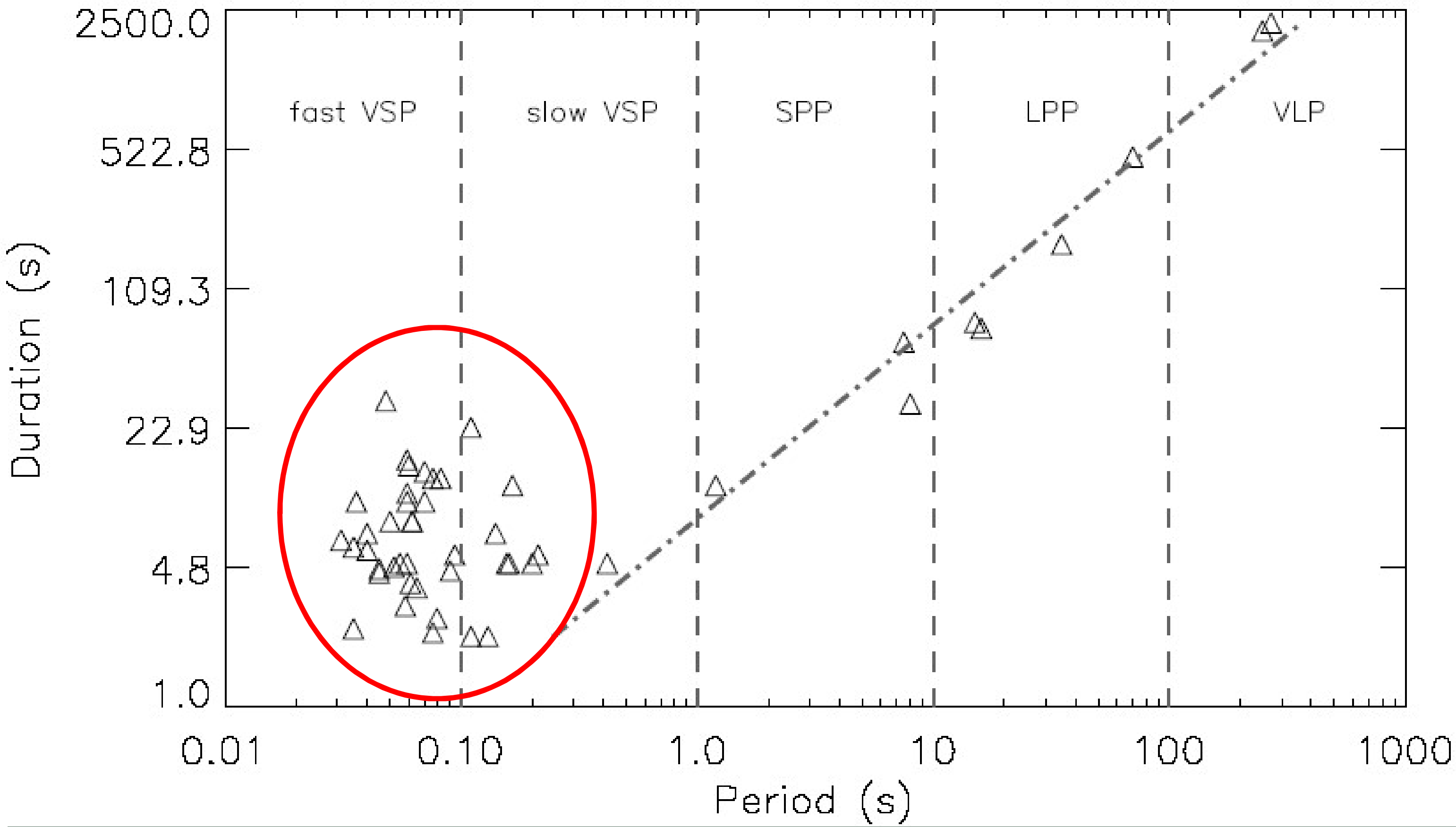
Very Short Period pulsation (VSP): P<0.5s



Type I



Type II



It seems that the short fast QPP may have different mechanism from the relatively long period QPPs.

This event shows that QPP is ubiquitous in solar flares….

(Tan et al. ApJ, 2010, 723, 25)

outline

1. Introduction
2. Observation of preflare-VLPs
3. Why is there QPP in pre-flare phase?
4. Summary

1. Introduction

It is very important to investigate the **precursor** of solar flares for understanding the **origin** and **predicting** their occurrence.

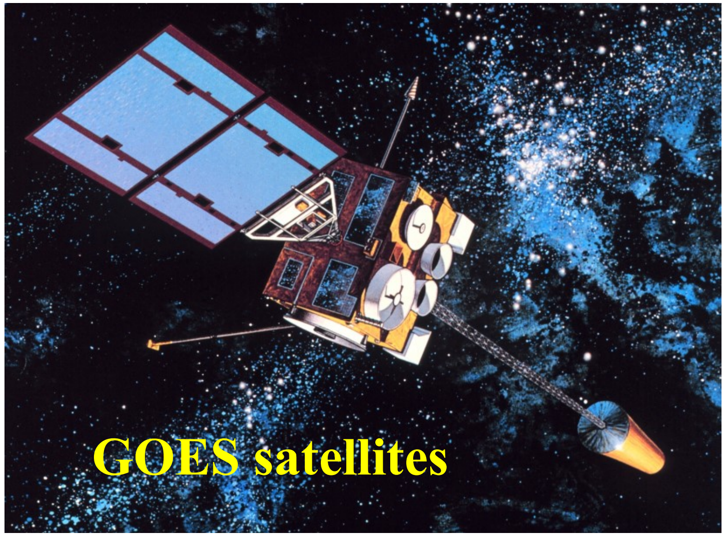
So far, many evidences are reported as precursor of solar flares

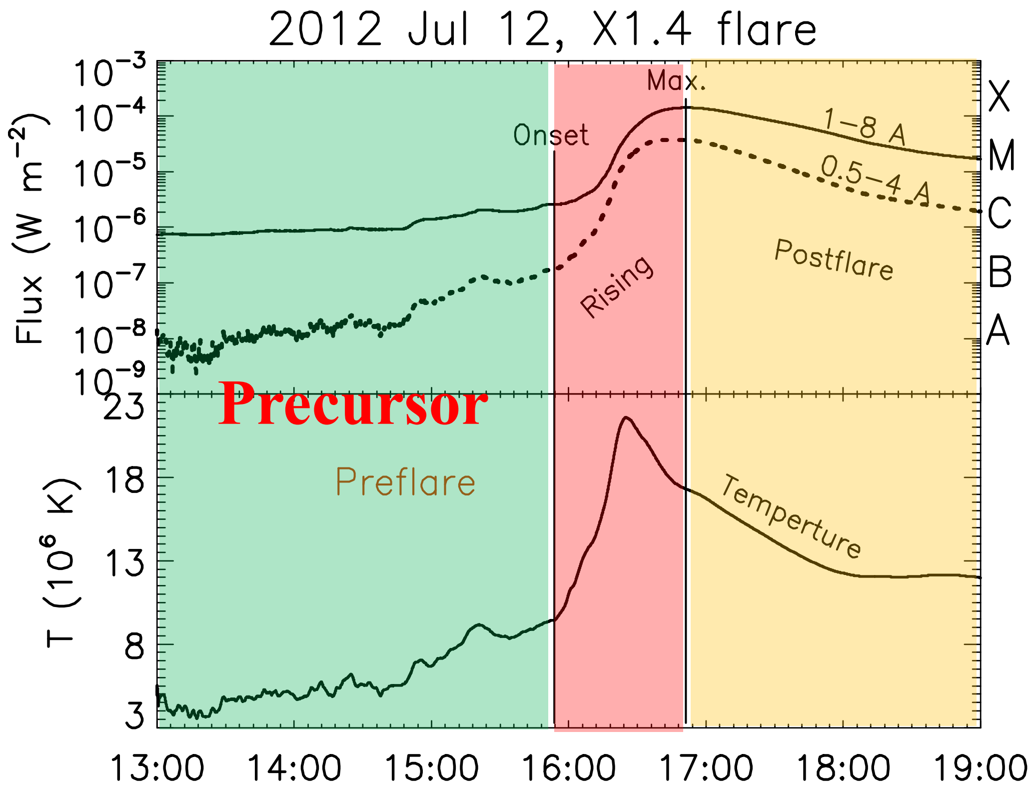
- Filament activities (Chifor et al. 2006, etc.)
- Weak SXR bursts (Tappin 1991, etc.)
- Magnetic helicity accumulations (Zhang et al. 2008, 2009)
- Radio spectral fine structures (Zhang et al. 2015)
- Fast MHD oscillations of magnetic flux rope (Zhou, et al. 2016)
- low-atmospheric small-scale energy release (Wang et al. 2017)
- ……

However, most of them are very weak with considerable uncertainties, and some of them are too complicated...

Is it possible to find out relatively simple precursors?

Since 1975, **GOES** satellite series provide uninterrupted observation data of **SXR** at 1-8 Å and 0.5-4 Å with cadence of 2-3 s.



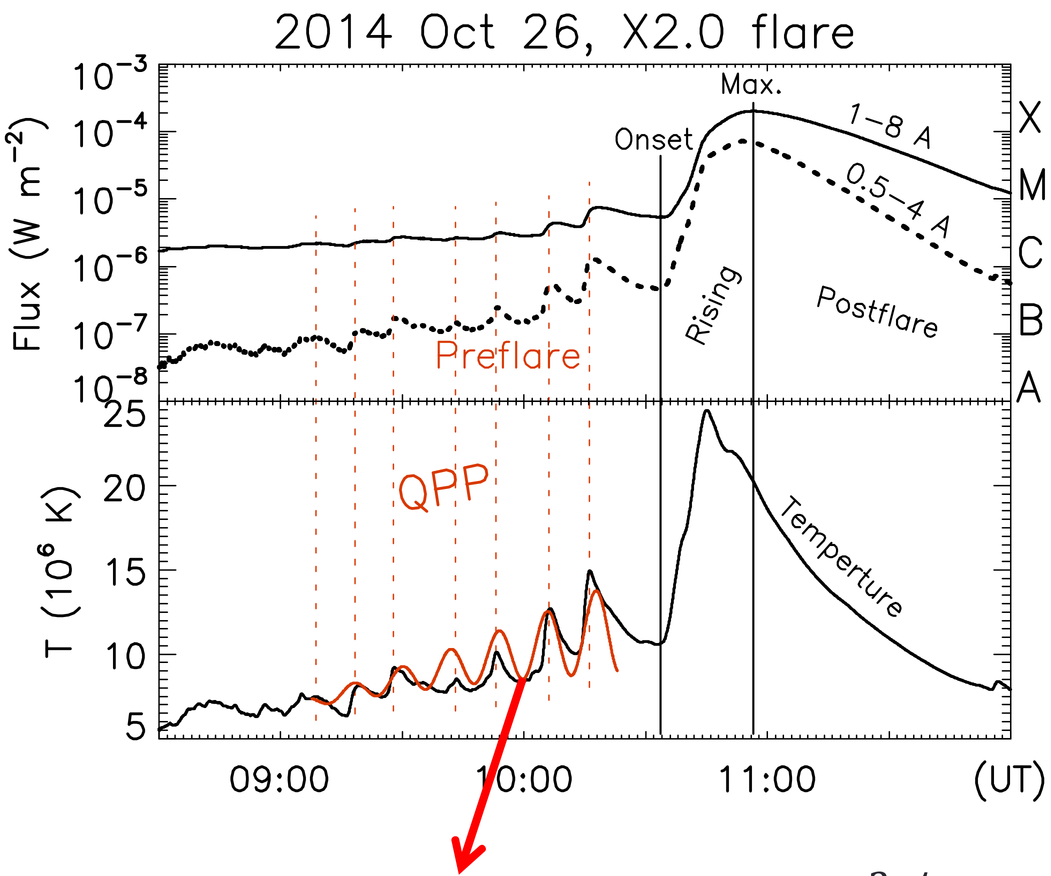


Phase partition of a solar flare

It is interesting to revisit the GOES SXR records of **isolated solar flares** in solar cycle 24

2. Observation of preflare-VLP

Typical event 1



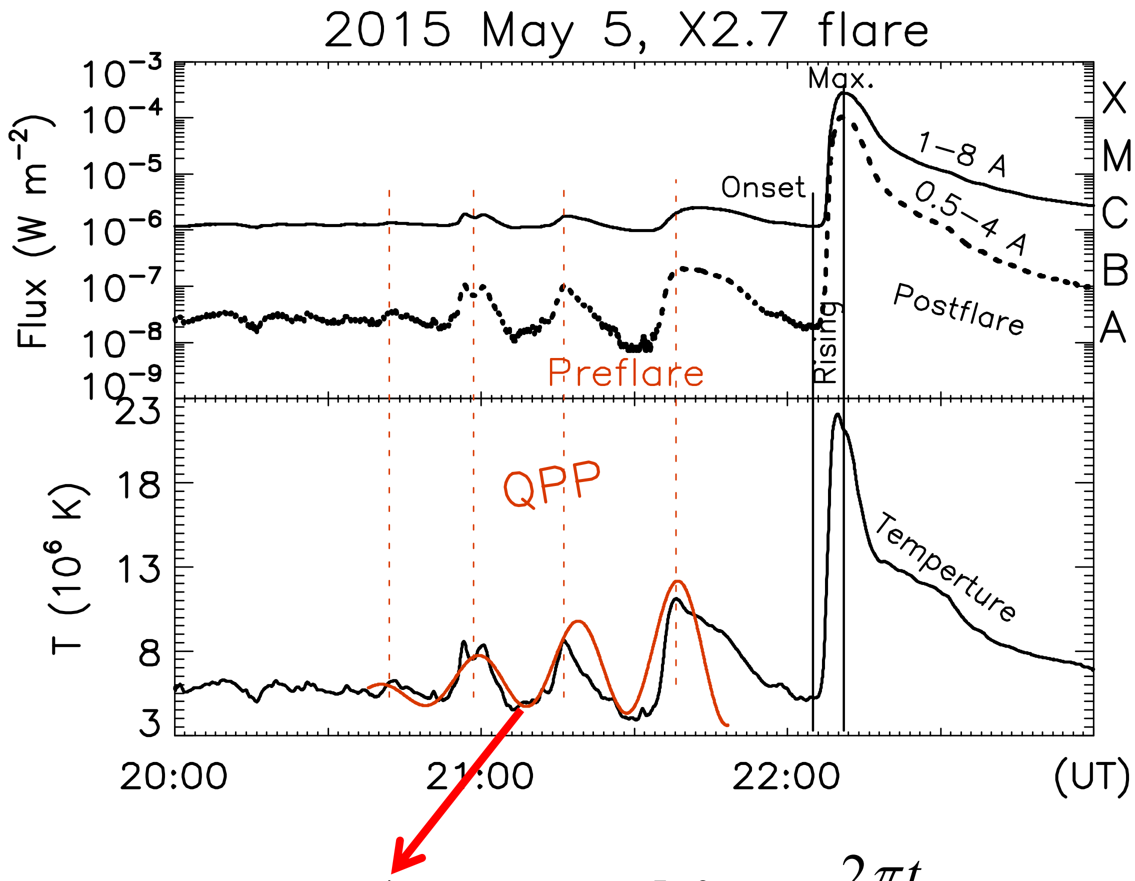
$$T \approx 5.0 + 10^{-3}t + 6.1 \times 10^{-8}t^2 \cos(\frac{2\pi t}{684})$$

Period is 684 s (11.4 min), lasts for about 1.5 hours

Very long-period pulsation in preflare phase

(abbreviate: **preflare-VLP**)

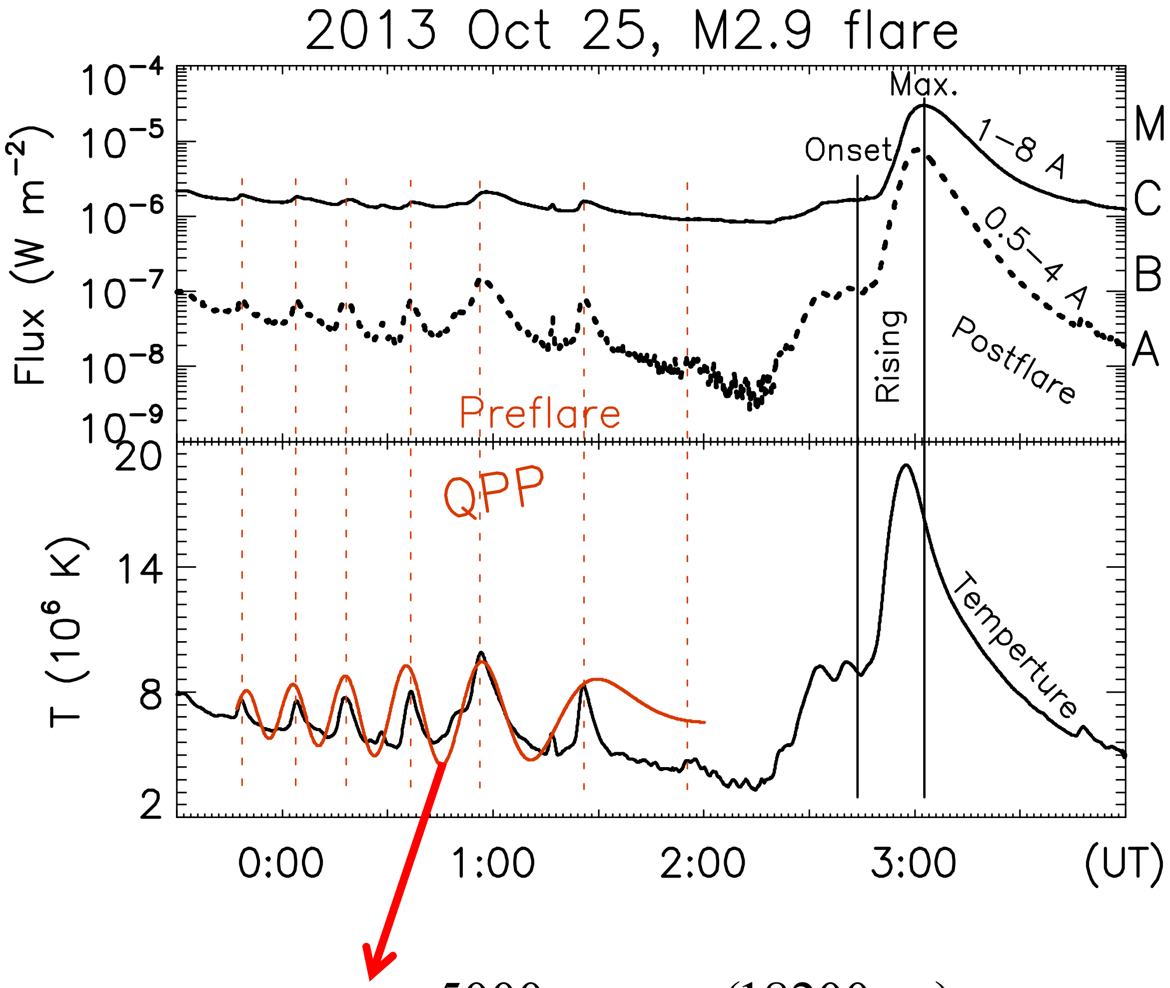
Typical event 2



Period is 1104 s (18.4 min), lasts for about 1.2 hours

$$T \approx 3.5+8.0\times10^{-4}t+1.2\times10^{-7}t^2\cos(\frac{2\pi t}{1104})$$

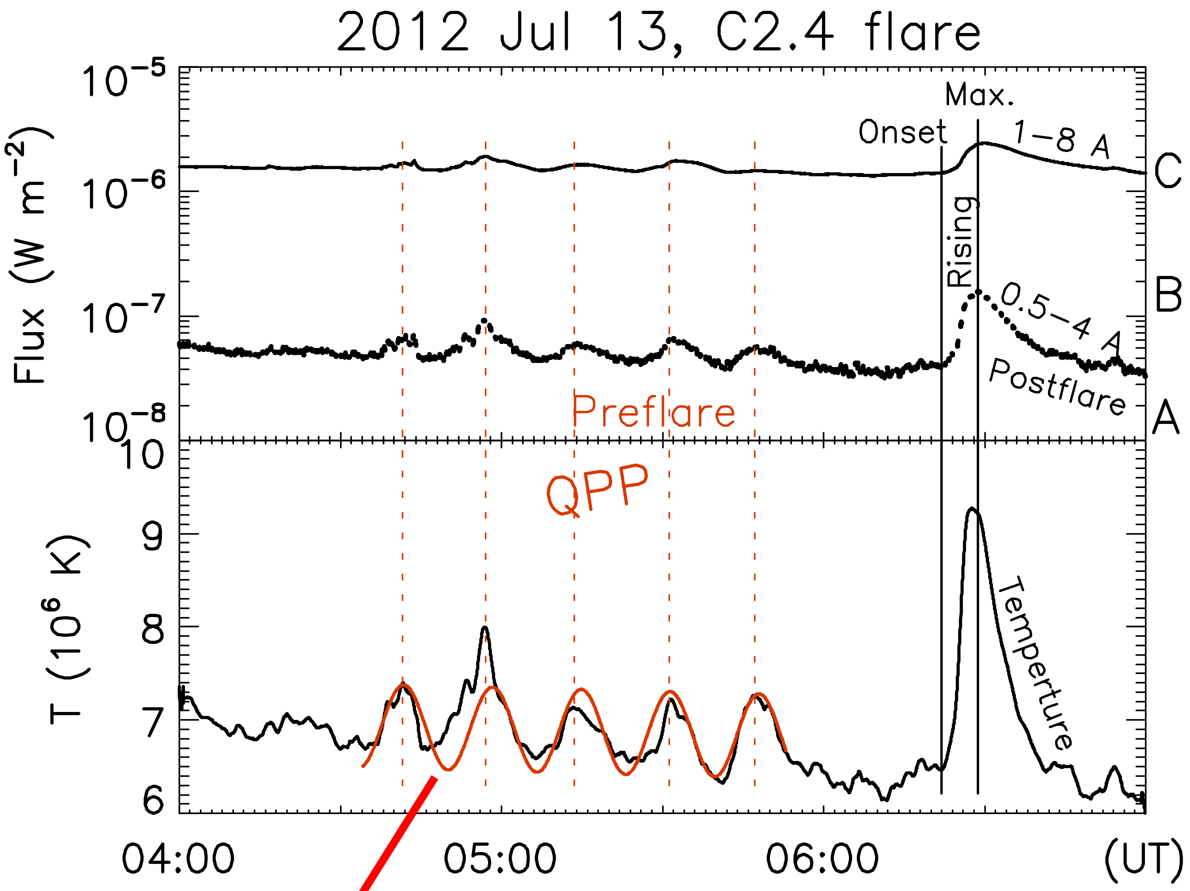
Typical event 3



$$T \approx 7.0\text{-}5.0\times10^{-5}t+\left(\frac{5000}{t-4800}\right)^2\cos\left[\frac{(18200-t)\pi}{2.88\times10^6}(t+200)\right]$$

Period increases from 15 min to 30 min, lasts for more than 2 hours

Typical event 4



Period is 984 s (16.4 min), lasts for about 1.5 hours

$$T \approx 7.0\text{-}2.5\times10^{-5}t + 0.45\cos(\frac{2\pi t}{984}+1.5)$$

Empirical fitting

We may use an unified expression fitting the above pre-flare VLP

$$\mathrm{T} \approx T_0 + bt + M(t)\cos(\frac{2\pi}{P}\mathrm{t})$$

T_0 Background temperature

b: Change rate of the background temperature

M(t): magnitude of VLP

P: period of VLP

Statistics

Flare	Parameter	X-class	M-class	C-class
With preflare-VLP	Number	18(46%)	76(42%)	50(26%)
	Period (min)	16.1±10.7	16.2±7.9	16.4±7.4
	Duration(min)	85.6±33.7	98.5±35.8	97.4±33.2
	Rising(min)	14.7±9.1	11.7±9.5	9.8±8.3
Without preflare-VLP	Number	21(54%)	107(58%)	140(74%)
	Rising(min)	25.2±23.0	16.7±16.5	13.2±11.8

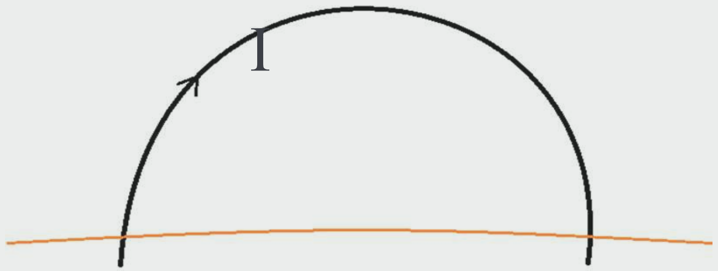
- Pre-flare-VLP: P ≈ 16±9 min, D ≈ 90±34 min (about 1-2 hours)
- No obvious difference in timescale of preflare VLPs among X-, M-, and C-class flares.
- The flares without preflare-VLP tend to have longer rising-time than that with preflare-VLP.

3. Why is there QPP in pre-flare phase?

MHD oscillations is a plausible candidate to explain the formation of Pre-flare-VLP. For example, standing wave of fast magnetoacoustic kink oscillations of magnetic flux rope (e.g. Zhou, et al. 2016, ApJ)

Here, we would like to discuss it in a new way:

LRC circuit



$$L = \frac{\mu_0 l}{\pi}\left(\ln \frac{8l}{\sqrt{\pi S}} - 1.75\right)$$

$$C = \frac{8\pi\rho S^2}{\mu_0^2 l I^2}$$

(Zaitsev et al. 1998)

LRC oscillations may modulate the emission in the plasma loops, and produce pulsations:

$$P = 2\pi\sqrt{LC} \approx 2.75\times10^4 \frac{S\sqrt{\rho}}{I} \quad \Rightarrow I \approx 2.75\times10^4 \frac{S\sqrt{\rho}}{P}$$

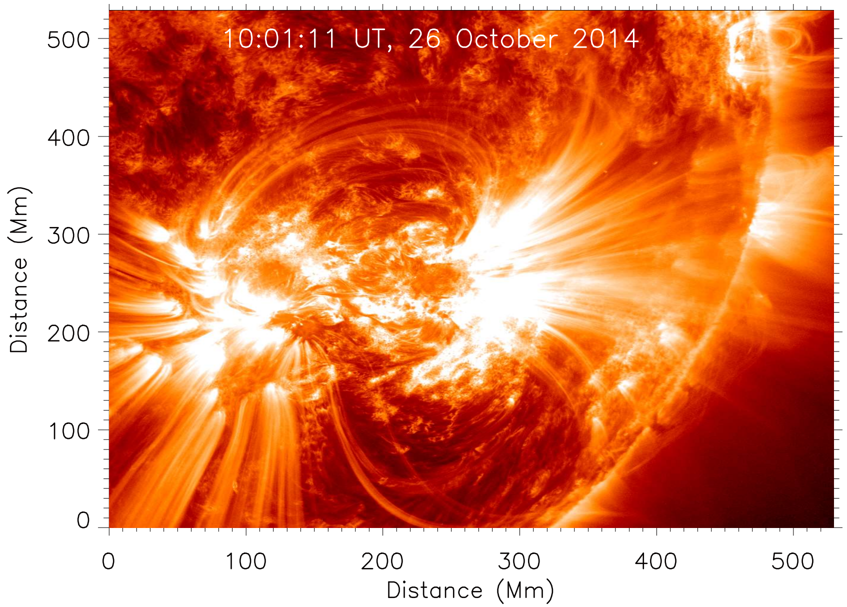
Considering the period of preflare-VLP: 1.9-47 min, n $= 10^{16}m^{-3}$, loop length 5×10^{7}m, section radius 5×10^{6}m. Then, the estimation of **electric current** is about:

$$\boldsymbol{I \sim 3.1 \times 10^{9} - 7.6 \times 10^{10}\ A}$$

Observations of vector magnetograph show the maximum current in active region is in order of :$\boldsymbol{10^{12}\ A}$ (Canfield et al. 1993, Tan et al. 2006, etc.)

In fact, active region is always composed of several decades or hundreds of loops, a single loop should have current of about $\boldsymbol{10^{10}\ A}$.

Spangler (2007, ApJ) developed a new method to measure electric current of single coronal loop and obtained:$\boldsymbol{10^{8} - 10^{9} A}$



Consistent with each other

4. Summary

- Nearly half of isolated flares are accompanying with **preflare-VLP**. Their periods distributed in the range of 8-30 min, lasted for about 1-2 hours.
- The stronger and shorter-rising flares have higher probability to produce pre-flare-VLP.
- The pre-flare-VLPs are possibly associated to **the electric current** in the plasma loops before the flare onset, and may provide some clues to the flare triggering mechanism.
- Pre-flare-VLP may be regarded as a **precursor** of solar flares.

(Tan, Yu, Huang, et al., 2016, ApJ, 833, 206)

Thanks for your attention!