



FULL LENGTH ARTICLE

# Signatures of the low-latitude Pi 2 pulsations in Egypt

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**Abstract** To study the activities and the physics of the Earth's magnetosphere, several types of measurements are made with different kinds of instruments both on earth and in space. Ground based data represent the properties of the solar wind, the Earth's magnetic field and currents in the magnetosphere. Many of the activities occurring in the magnetosphere are a result of changes in the solar wind.

It has been known since the 1860s that the Earth's magnetic field is fluctuating and during that times the fluctuations are periodical.

In this study, a special type of magnetic pulsations in the Earth's magnetic field called Pi 2 (from MAGDAS stations in Egypt) is investigated and analyzed statistically.

We carried out our analysis through two different methods: (i) Fourier transformations and (ii) wavelet power spectrum.

The result shows that the Pi 2 observed in the main phase of the geomagnetic storm have larger frequency than those observed in the recovery phase. These results excluded the field line resonance and the plasmopause surface as a possible generation mechanism, and suggest the cavity resonance as a possible generation mechanism of the Pi 2 pulsations at low latitude stations in Egypt.

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## Introduction

Geomagnetic pulsations, Ultra Low Frequency (ULF) waves, are naturally occurring Magneto-Hydrodynamic (MHD) waves in the Earth's magnetosphere. These ULF waves are classified as continuous (Pc) or irregular (Pi) pulsations. Each category is subdivided into period bands that roughly separate a specific type of pulsation. The characteristics of ULF waves observed on the ground contain information not only about the generation processes but also about the regions through which they have propagated (Bol'shakova and Troitskaya, 1968).

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Pi 2 is one of the most important nightside geomagnetic pulsations observed in the Earth's magnetic field in the period range [40–150 s] (Saito et al., 1976). This type of pulsations attracted attention in the last few years due to different methods:

- (1) Low latitude Pi 2 is sensitive to small substorms even extremely ones that hardly detected with the AE index (Sakurai and Saito, 1976). Good indicator to substorm onset at low latitude stations (Yanagihara and Shimizu, 1966).
- (2) A promising tool in the detection of the plasmopause positions in nightside region (Uozumi et al., 2009).
- (3) A promising tool for diagnosing plasma density in different magnetospheric–ionospheric region.

The majority of the ULF wave studies have relied on data obtained from middle or high latitudes, while the low latitudes have received a little attention (Feng et al., 1995). Consequently, the source and propagation mechanisms of the low latitude pulsations are not fully understood. Ghamry et al. (2011) show the first investigation of Pi 2 pulsation observed from MAGDAS stations in Egypt.

The present study reveals the characteristics of the Pi 2 pulsations at two stations in Egypt, Fayum and Aswan (FYM and ASW) in order to identify the generation and propagation mechanisms of the Pi 2.

#### Data sets and analytical methods

Data were obtained from two stations in Egypt (FYM and ASW) belong to the MAGnetic Data Acquisition System (MAGDAS) project. MAGDAS project effectively started in May 2005, with the installation of the first MAGDAS magnetometer in Hualien, Taiwan (Yumoto and MAGDAS Group 2006, 2007). They are distributed along three chains: (1) the 210° Magnetic Meridian (MM) chain, (2) the dip Equator chain, and (3) the 96° MM chain (African chain) as shown in Fig. 1.

MAGDAS system is one of many tools are now being deployed in order to carry out space weather studies in the Space Weather Monitoring Center (SWMC) in Egypt (Mahrous

**Table 1** The geomagnetic and geographic locations of both stations.

Station	Code	G.G Lat.	G.G Lon.	G.M Lat.	G.M Lon.
Fayum	FYM	29.3	30.88	21.13	102.38
Aswan	ASW	23.59	32.51	15.20	104.24

et al., 2010). The geomagnetic and geographic locations of both stations are given in Table 1.

The data filtered in the Pi 2 range using second order Butterworth zero-phase band pass filter to subtract the background magnetic field. The spectral analysis method was performed using two different methods:

- (1) Fast Fourier Transformations (FFT) spectra. The dominant frequency of the Pi 2 pulsations was calculated for a duration time 10 min (600 s) (Kosaka et al., 2002). Dominant frequency was chosen at the peak of the spectra in the  $H$  component, if the spectra have more than one peak we took a peak of the highest power (Nose et al., 2006).
- (2) The wavelet power spectrum, which highlights the frequency/time relationship.

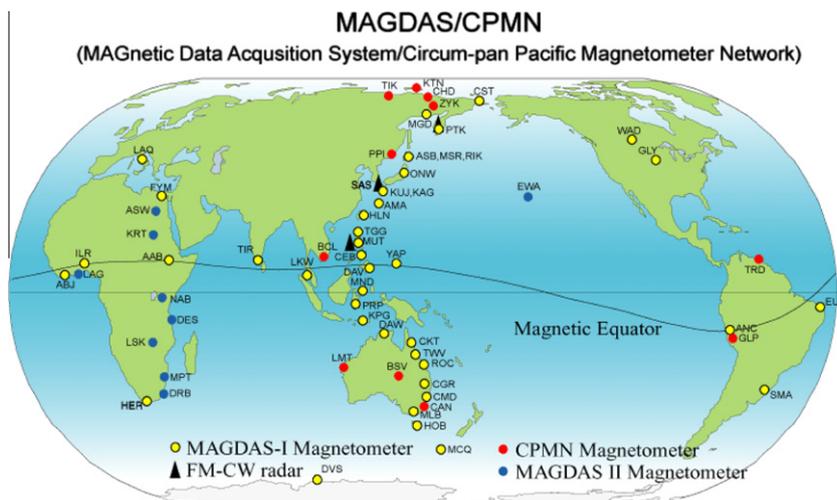
The absolute value of the maximum amplitude of the Pi 2 event was chosen to make a statistical study of the amplitude–local time dependence, this results not shown her in the paper. It was found that the Pi 2 amplitude increase toward the midnight.

The geomagnetic data used for this study were recorded from December 2008 up to November 2009.

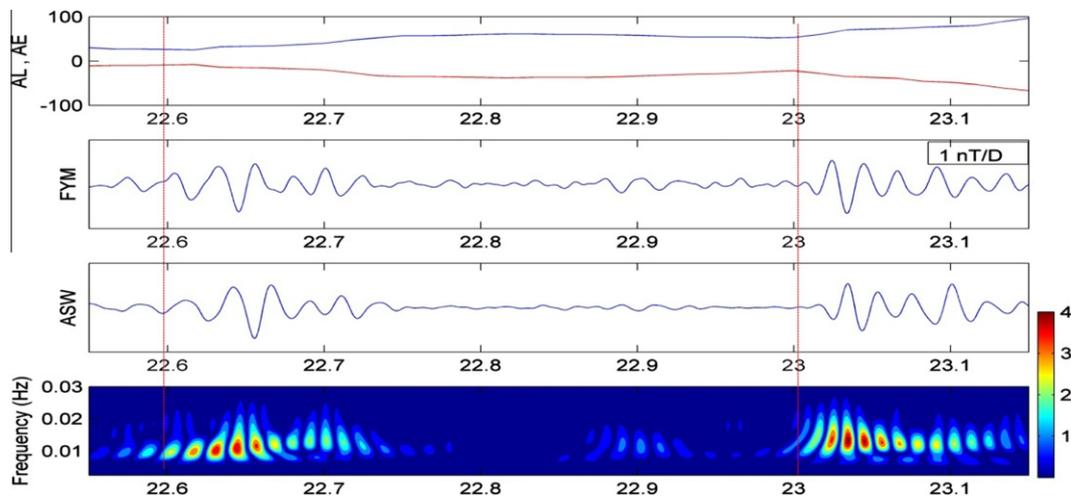
#### Case study

##### Successive Pi 2 events

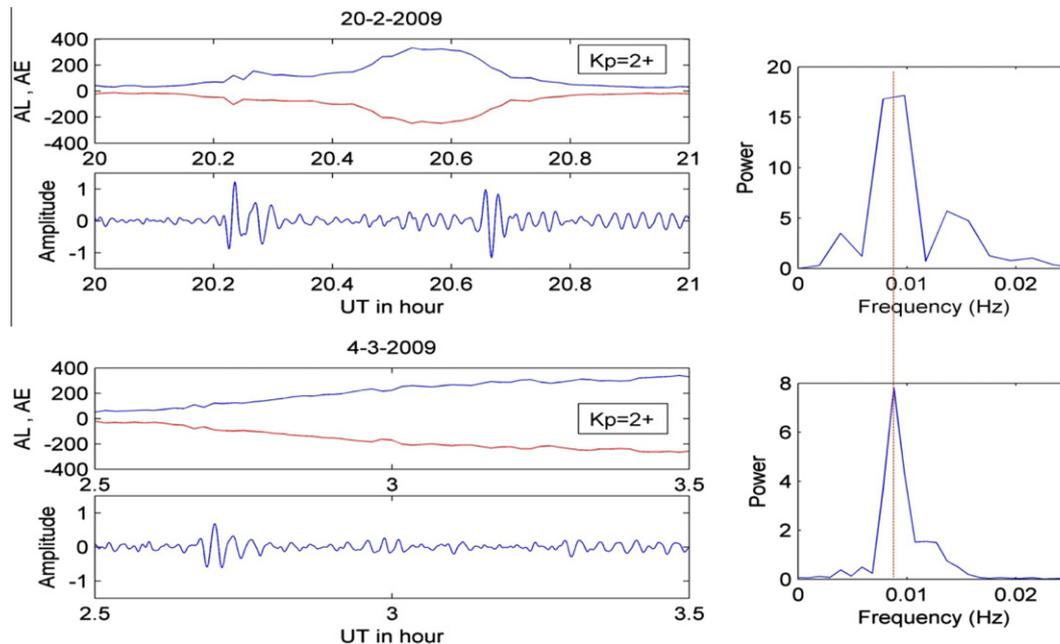
Ten cases for successive Pi 2 events observed in a successive form have showed a larger frequency of the second Pi 2 event



**Fig. 1** MAGDAS/CPMN (MAGnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network) system of the SERC, Kyushu (Yumoto and MAGDAS Group, 2006).



**Fig. 2** Two pulsation events recorded at FYM and ASW stations on 27 March, 2009 through two successive substorms. Frequency of the first and the second events are 11.7 and 13.7 mHz, respectively. Upper panel shows AE and AL index, two middle panels show the filtered data in the (40–150 s) period band and the lower panel shows wavelet power spectrum.

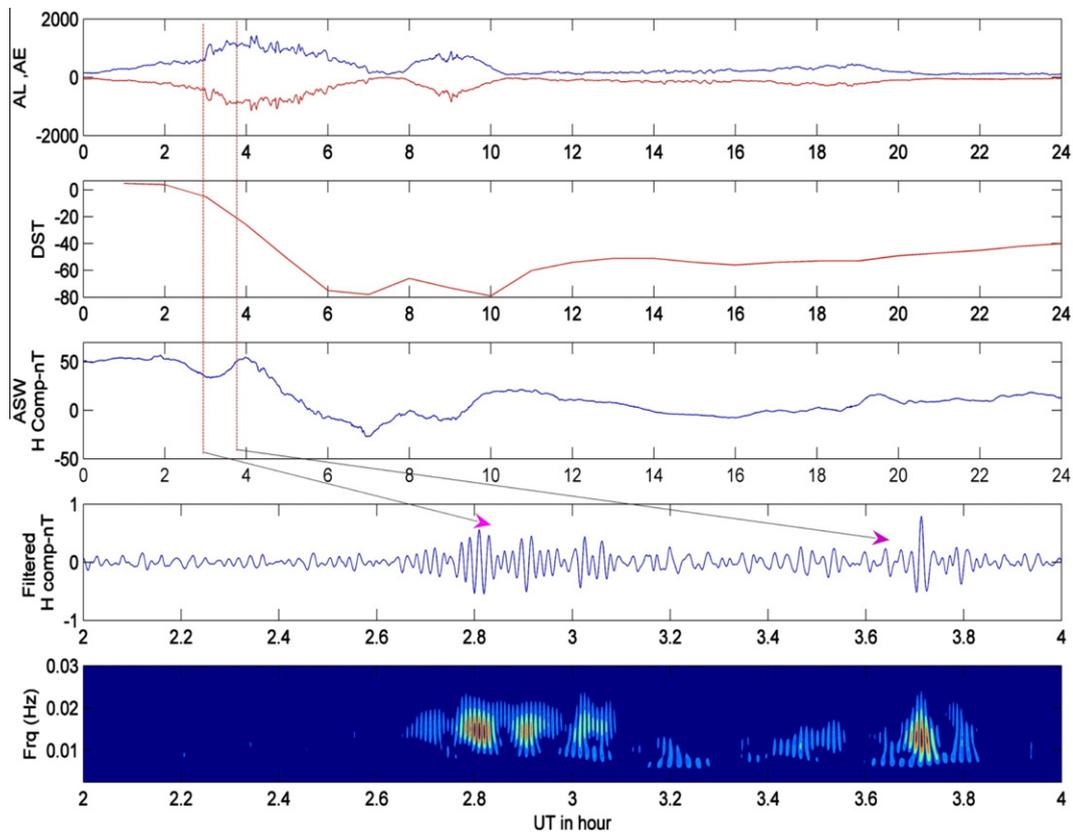


**Fig. 3** Two pulsation events recorded at FYM station. Left column, upper two panels show the Pi 2 event on 20 February, 2009 which observed in the duskside but lower two panels show the Pi 2 event on 4 March, 2009 which observed in the dawnside. The Fourier transformation in the right column of the corresponding events respectively have the frequency of both Pi 2 events are 9.7 mHz.

than the first. These discrete frequencies observed for successive Pi 2 have a multiple harmonics 7.8, 9.7, 11.7 13.7 and 15.6 mHz. Kuwashima and Saito (1981) presented that, Pi 2 period increases with increasing the latitude of auroral breakup. In some multiple auroral breakup events, the breakup locations moved poleward (Lopez et al., 1990). Summarizing those observational results, it is expected that the later Pi 2s tend to have longer dominant periods.

The case study presented in Fig. 2 showed that the frequency of the second Pi 2 which has 13.7 mHz is larger than the first event which has frequency 11.7 mHz.

In order to suggest a possible generation mechanism of the Pi 2 pulsations, we have to specify the characteristics of the Pi 2 in our study near the dawnside and the duskside, we have chosen two events the first near the duskside during 20/2/2009, and the second near the dawnside during 4/3/2009. The characteristic, which the Pi 2 have been shown for those two events under the condition of the same level activity determined by  $K_p = 2$ , as shown in Fig. 3 illustrate that both events have a same frequency. This result precludes the field line resonance (plasmopause surface wave) as a possible generation mechanism to the Pi 2 pulsations.



**Fig. 4** Main phase of 22-7-2009 geomagnetic storm. The AE and the AL index in the upper panel. The three middle panels are, the DST index, the raw data of  $H$  component at ASW and the filtered data in the range [40:150]. The wavelet power spectrum in the lowest panel.

#### *Pi 2 during a geomagnetic storm*

Pi 2 pulsations observed in the main phase of a moderate geomagnetic storm ( $Dst = -81$  nT), showed extremely higher frequency of 15.6 mHz than those observed in the recovery phase of frequencies 12.7, 15.6 and 11.7 mHz, respectively.

In the inner magnetosphere the field lines have a fixed length (Young et al., 1982), so that if the FLR is the generation mechanism of the low latitude Pi 2 pulsations, the frequency of Pi 2 pulsations would be extremely low during geomagnetic activity. According to Figs. 4 and 5, the discrete high frequencies observed in the main and the recovery phases could be interpreted in terms of plasmopause position relative to geomagnetic level activity measured by  $K_p$  index.

The discrete spectrum of successive events as shown in Fig. 2 could be interpreted in terms of shifting (displacement) of the plasmopause position.

These properties reflect the possibility of Cavity Resonance Mode (CRM). In other word, the most appropriate generation mechanism of the Pi 2 pulsations observed in the geomagnetic field data at low latitude stations in Egypt is the plasmaspheric cavity resonance.

#### **Analysis and results**

More attention has been attracted toward different phenomena observed at the low latitude region especially the Pi 2 pulsation. The statistical analysis of the Pi 2 events are interest to identify its generation and the propagation mechanism at

different latitude regions (Uozumi et al., 2009; Kosaka et al., 2002; Liou et al., 2000; Fan et al., 2000).

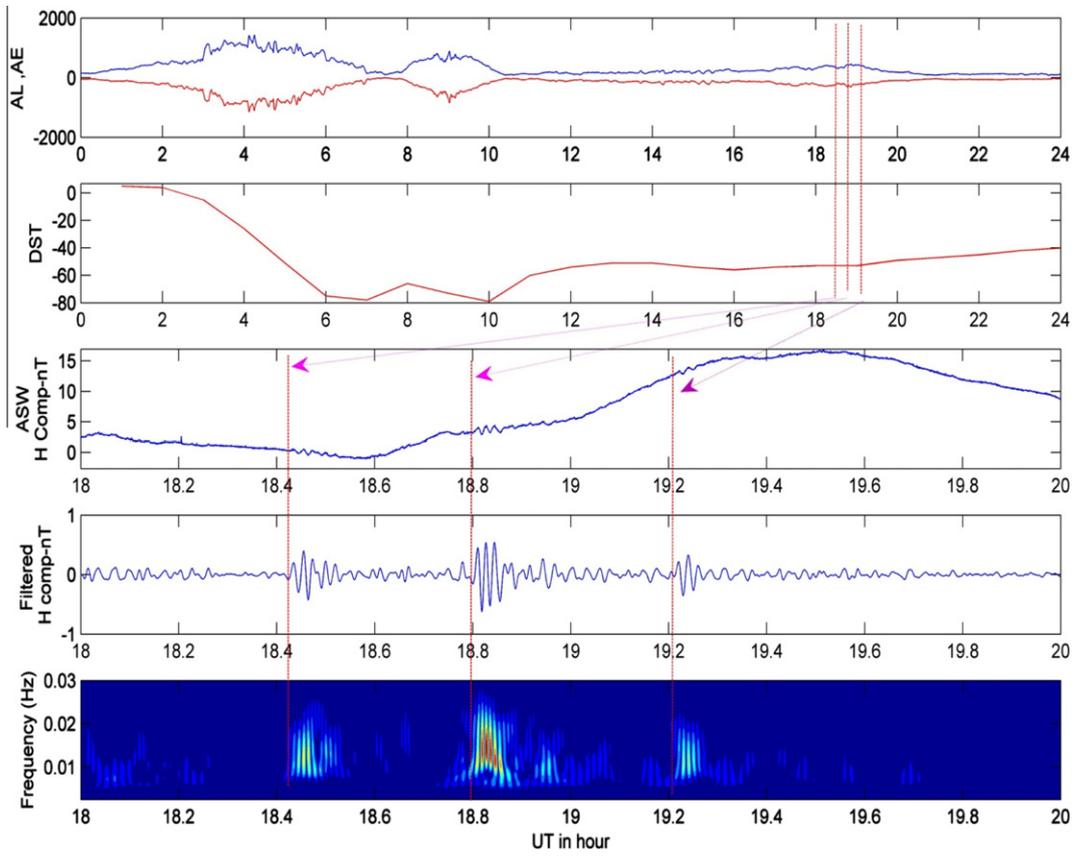
The average hourly frequency variation  $H$  component versus local time for  $K_p \leq 3$  presented in Fig. 6. The dominant frequency approximately varies around 9.7 mHz in almost local time sectors. This result suggests that the CRM is the possible generation mechanism for the low-latitude Pi 2 pulsation.

The local time/frequency dependence for lower and higher level activities was studied in Fig. 7. The average hourly frequency variation in solid line has a maximum value near the dawn at 5 AM local time. This behavior suggests that the plasmopause surface waves may be a possible generation mechanism but the behavior of the plasmopause surface waves had not been completed yet, because we could not detect enough events near the duskside 19 LT. This result is consistent with the result derived by (Lee, 1998).

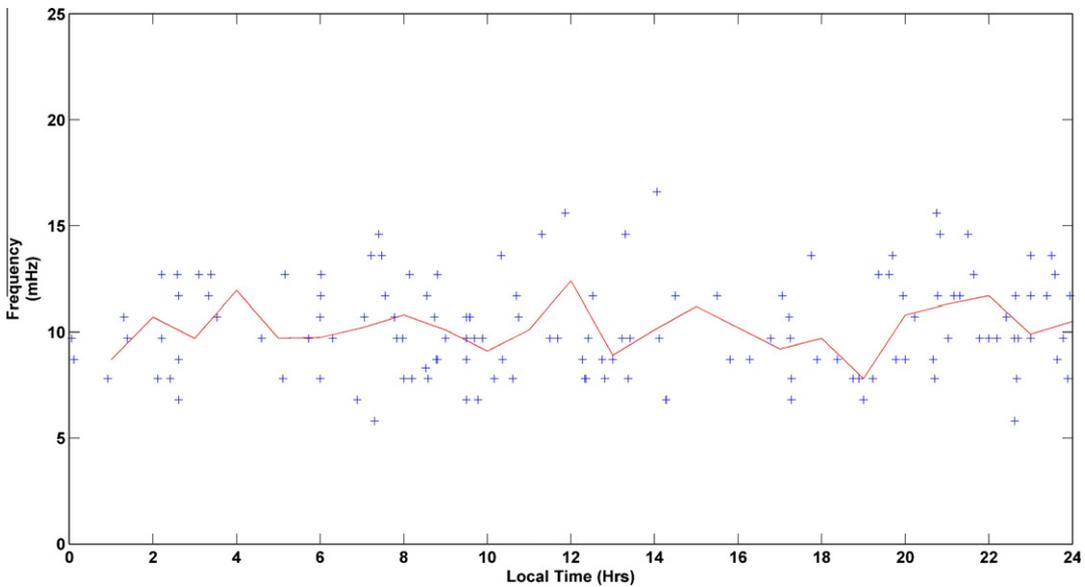
#### **Summary and conclusion**

In this study the statistical analysis of the Pi 2 pulsations observed at low latitude stations in Egypt have been studied to clarify the generation mechanism, and its propagation.

The frequency–local time relationship for the quiet time showed a comparable frequency at all local time sectors, while during the active and quiet time Pi 2 frequency showed a relative increase near 5 AM local time. To suggest a possible generation mechanism, the signature of the field line resonance, plasmopause surface waves and the cavity resonance have been



**Fig. 5** Illustrate three successive Pi 2 pulsations observed during the recovery phase of the geomagnetic storm, with frequencies 12.7, 15.6 and 11.7 mHz, respectively.



**Fig. 6** The relations between the frequency versus local time for  $K_p = 0.3$ . The red line shows the average hourly frequency variation.

studied. To study the frequency of the Pi 2 events near the dawn side and dusk side, two events were chosen at the same level activity the first near the duskside and the second near the dawnside. We found that both of them have the same

frequency. We study the frequency of the low latitude Pi 2 pulsations in successive form during a magnetic storm phases. The result shows that the low latitude Pi 2 observed in the main phase of the geomagnetic storm have larger frequency

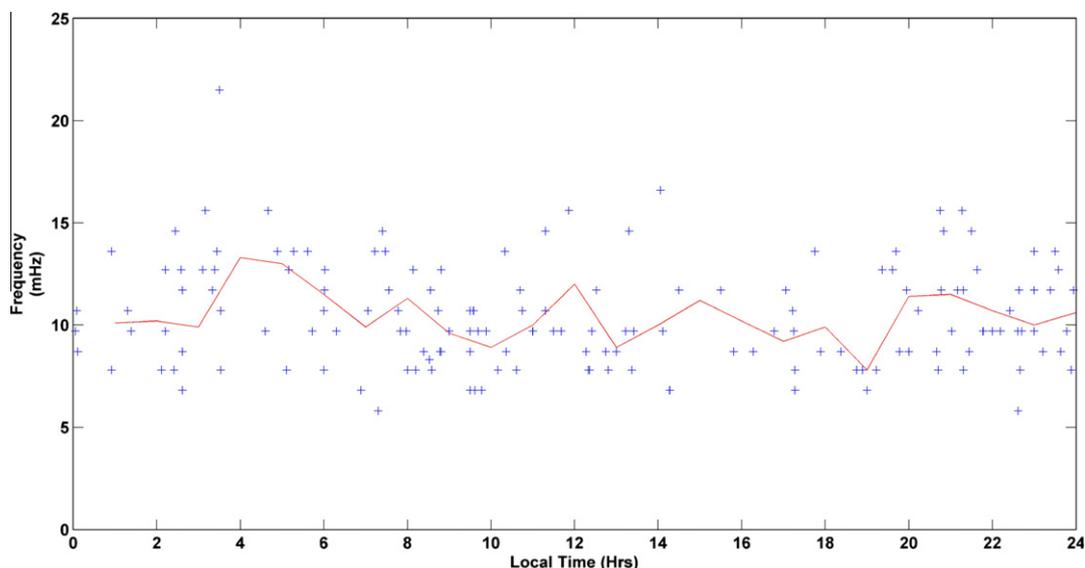


Fig. 7 Frequency versus local time for all Pi 2 pulsations. The solid red line represents the average hourly variations.

than those observed in the recovery phase. These results excluded the field line resonance and the plasmopause surface as a possible generation mechanism, and suggest the cavity resonance as a possible generation mechanism of the Pi 2 pulsations at low latitude stations in Egypt.

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