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Periodicity in the light curve of P Cygni – indication for a binary companion?

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ABSTRACT

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Keywords: (stars:) binaries: general — stars: massive — stars: individual (P Cyg)

1. INTROCUTION

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In the year 1600 The Luminous Blue Variable (LBV) P Cygni has undergone a major eruption (de Groot 1969, 1988), also known as "Supernova Impostor". The eruption (at the time referred to as a nova) caused the star to increase in visible magnitude from XXXX to XXXX (de Groot 1969, 1988) Being the nearest LBV, at a distance of 1.7 kpc (Najarro et al. 1997a), the 3rd magnitude eruptions were seen by naked eye (de Groot 1969)

Later on in the seventeenth century the star underwent a series of 4 more eruptions.

P Cygni was commonly considered to be a single star. Its eruption was associated with single LBV star processes (e.g., Humphreys and Davidson 1994; Lamers & de Groot 1992). The peculiar morphology of the nebula which was formed by the eruption of P Cygni (Nota et al. 1995) lead Israelian & de Groot (1999) to suggest that a different physical process is responsible to the eruption of η Car and P Cygni. On the other hand, Kashi et al. (2009) showed that the eruption of P Cygni lies on a strip in the total energy vs. timescale diagram together with other intermediate luminosity optical transients, including the two 19th century eruptions of Eta Carinae. This suggests that the same physical mechanism that is applicable to the eruptions of η Car and the other transients, accretion onto a MS companion and liberation of gravitational energy, is responsible to the eruption of P Cygni as well.

These kinds of pre-supernova eruptions are though to occur in the final evolutionary stages of a star. The best investigated example of a very massive star that had gone such eruptions and survived is η Car. But η Caris at least 90 $M_\odot$, probably twice this value, while P Cyg is only ≈ 25 $M_\odot$.

Kashi 2010 ..... I show that the 17th century eruption of the massive luminous blue variable (LBV) star P Cygni can be explained by mass transfer to a B-type binary companion in an eccentric orbit, under the assumption that the luminosity peaks occurred close to periastron passages. The mass was accreted by the companion and liberated gravitational energy, part of which went to an

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increase in luminosity. I find that mass transfer of ~ 0.1 M$_\odot$ to a B-type binary companion of $\sim 3-6$ M$_\odot$ can account for the energy of the eruption, and for the decreasing time interval between the observed peaks in the visual light curve of the eruption. Such a companion is predicted to have an orbital period of ~ 7 years, and its Doppler shift should be possible to detect with high resolution spectroscopic observations. Explaining the eruption of P Cygni by mass transfer further supports the conjecture that all major LBV eruptions are triggered by interaction of an unstable LBV with a stellar companion.

Smit?

Richardson et al. (2011) performed spectroscopic analysis over a 15-year period but found no periodic radial velocity variation. As they state, the radial velocity variation in the Hα line they observed cannot be caused by the companion as the line is formed in a volume much larger than the semi-major axis of the companion predicted by Kashi (2010). Richardson et al. (2013) count the non-detection of Richardson et al. (2011) as an argument disfavoring the existence of the companion, but this is inconsistent with the statement of Richardson et al. (2011) regarding the large Hα volume

2. OBSERVATIONS

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XXXX remember to add AASVO!

3. ANALYSIS OF OBSERVATIONS

We use P Cyg photometry data from three different sources at the V band. The data contain magnitude relative to different reference stars. First, we quantify the data such that we average same-night observations to obtain a single observation per-night, for each source. We zero pad the signal at times were no observations have been taken. The next step is to remove DC from the signal (per source). We than renormalize the data using the following technique. We identify similar measurement points for the three sources sources, and use them to normalize all data. We do that by re-quantifing the data to generate a normalized unified signal that will have one point for each night. All our analysis done on this unified renormalized data from our three sources.

Next, we analyze the spectrum using two method. The first is conventional Fourier transform by performing FFT and the second method is calculating the power spectrum density (PSD) which is defined as the spectrum power of the auto-correlation of the unified signal. In order to validate our technique, we add a synthetic signal with a period of 1 Year and intensity equal to the variance of the unified signal. Inthe upper panel of Fig. **??** we show the unified signal. The time axis .... (where is 0?) Units of y.... The lower panel shows the synthetic signal, defined as the unified signal with the added 1-year period signal. At times where no data is available for the unified signal we did not add the 1-year period signal. The inset zooms on part of the signal to illustrate the way the synthetic signal was constructed.

In Fig. 2 we see the spectrum of the unified signal obtained from our FFT analysis. We can see different periods in the signal at times $P_1 = xxx$ days, $P_2 = xxx$ days. The most evident period in the signal is XXXX. We can clearly see that the synthetic signal produced both the peaks of the unified signal, and the 1-year period signal.

4. RESULTS

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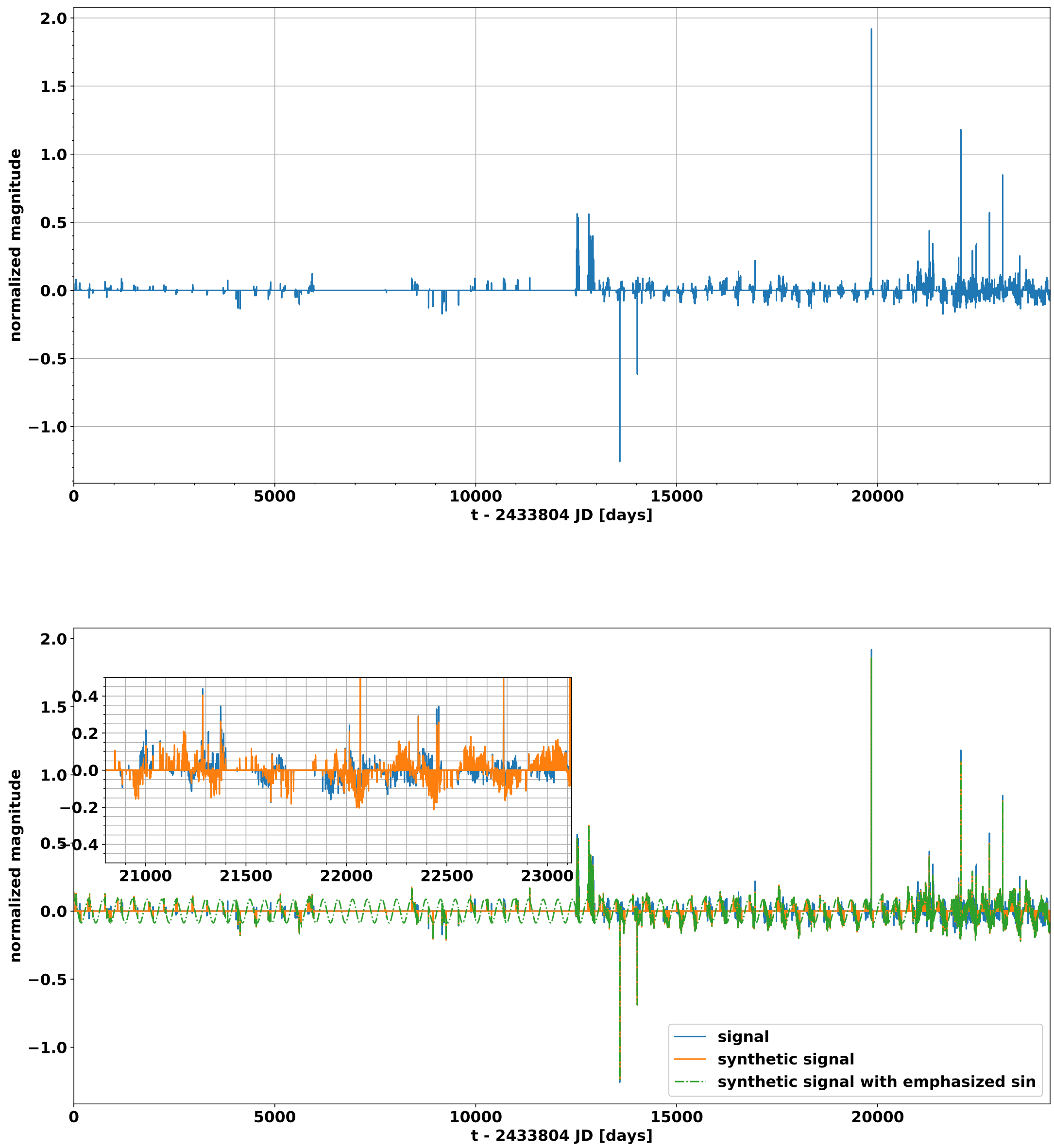

Figure 1. Upper panel:XXXXX Lower panel: synthetic....xxxxx

That way we can identify the effect of such signal and the similarity between this synthetic and real ~ 1736 days signal.

. As the signal continue in time toward period of about 5 years we can see a pick of about 30 dbm. From this point onward the signal decline.

5. SUMMARY

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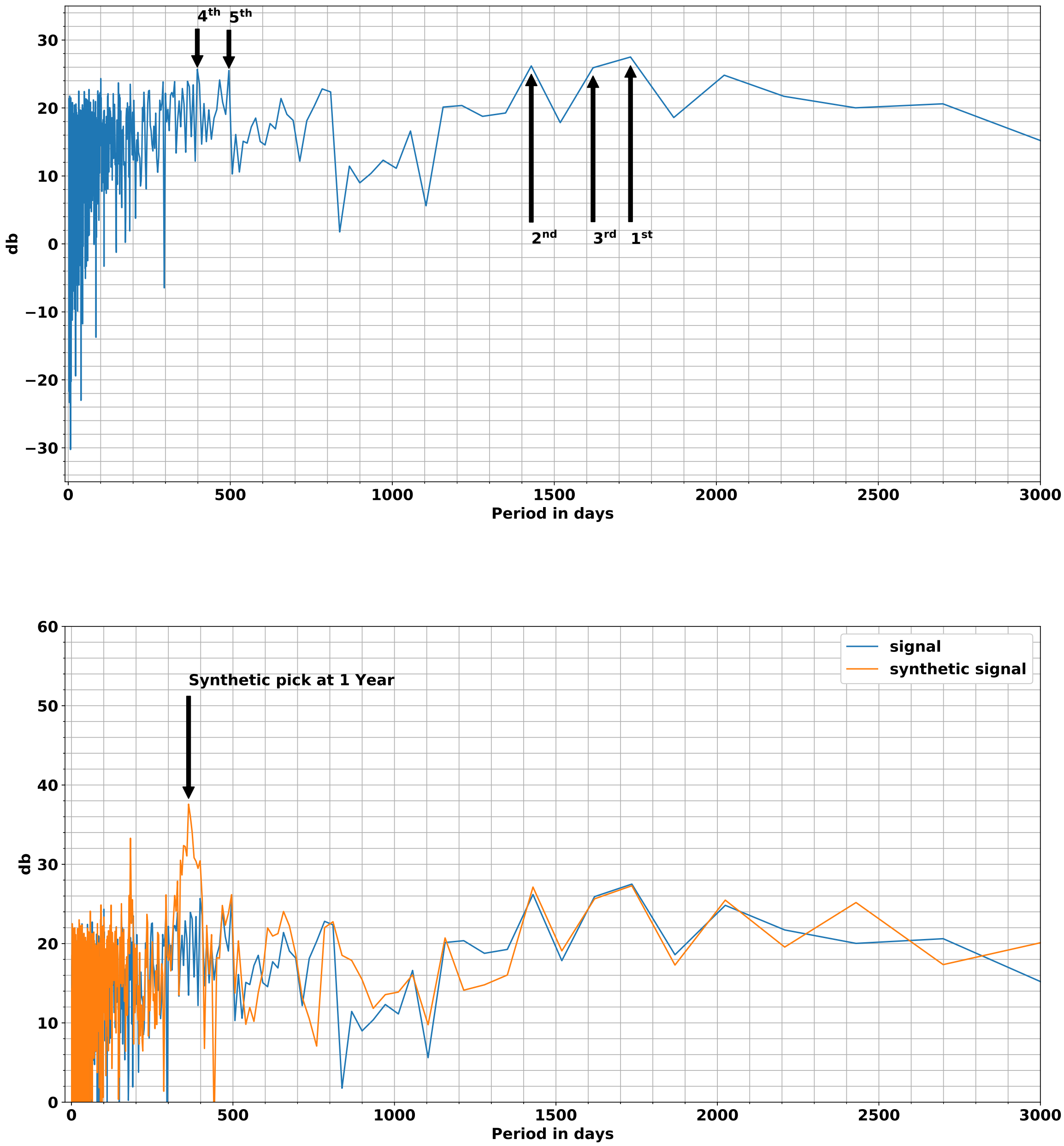

Figure 2. Upper panel:XXXXX Lower panel: synthetic....xxxxx

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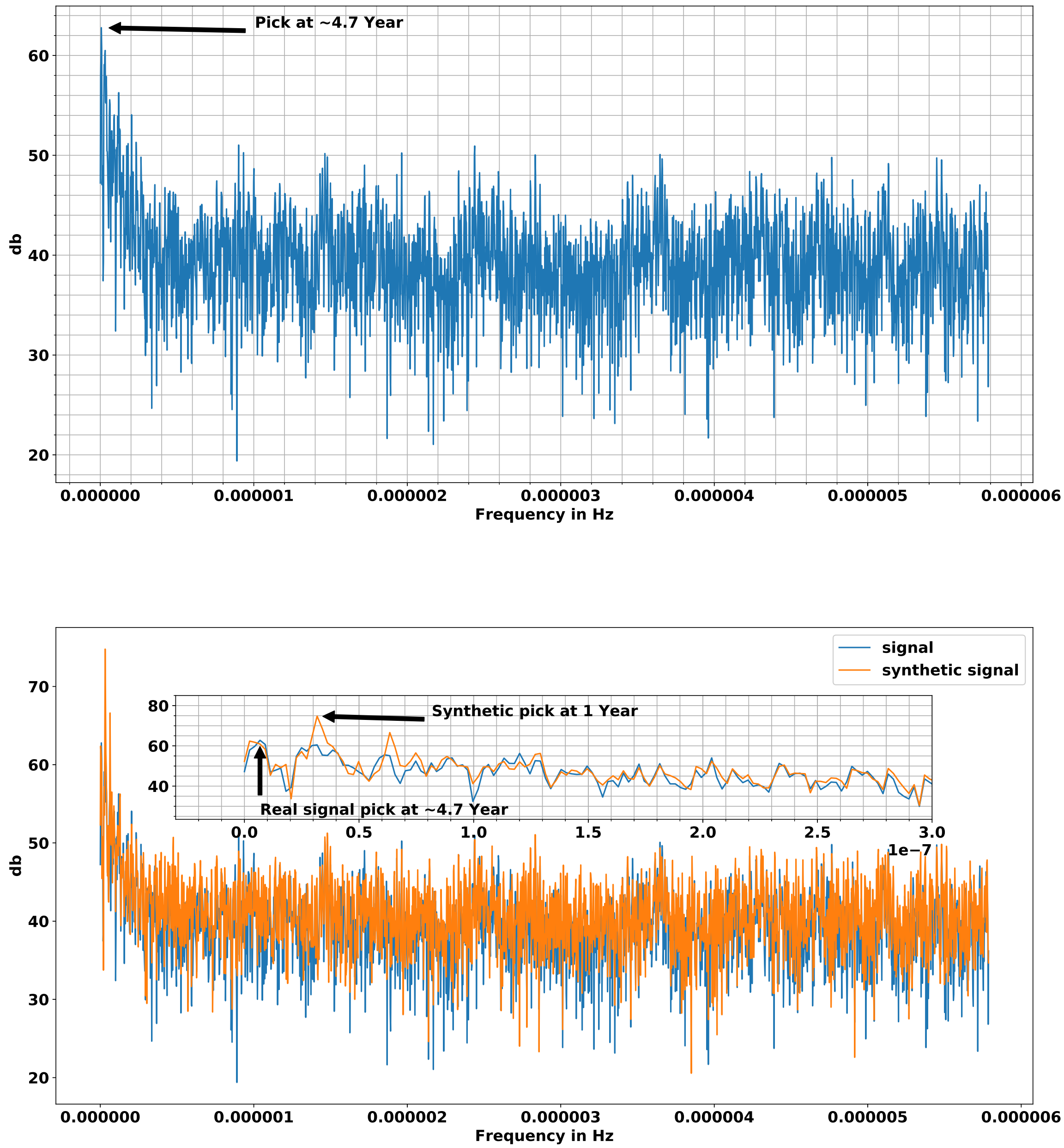

Figure 3. Upper panel:XXXXX Lower panel: synthetic....xxxxx

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