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GEOS RR Lyr Survey: FM DEL IS INDEED A CEPHEID

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ABSTRACT

Though FM Del has been considered as a RR Lyr star by Preston et al. in 1959 (following discovery by Huth, 1957), Huth (1960) eventually changed his mind by showing that it is in fact a cepheid of W Vir type of period of 3.95452 days. Various authors since then have considered it as a cepheid indeed, with the exception of Wils et al. (2006) who list this star in their RR Lyr catalog with a period of 0.79688 days. On this basis, FM Del was added to Tarot RR Lyr program. We present here these observations which confirm the cepheid type.

RESUMÉ

Quoique l'étoile FM Del ait été considérée comme une RR Lyr par Preston et al. en 1959 suivant la découverte par Huth (1957), Huth (1960) changea d'idée en montrant qu'il s'agit en fait d'une céphéide de type W Vir de période 3.95452 jours. Plusieurs auteurs ont considéré cette étoile comme une céphéide depuis, à l'exception de Wils et al. (2006) qui la listent dans leur catalogue de RR Lyr avec une période de 0.79688 jour. Sur cette base, FM Del a été ajoutée au programme RR Lyr de Tarot. Nous présentons ici ces observations qui confirment le type céphéide.

RIASSUNTO

Scoperta da Huth (1959), FM Del è stata classificata come una variabile di tipo RR Lyr da Preston et al. (1959). Successivamente, Huth (1960) ha mostrato che si tratta di una Cefeide tipo W Vir con periodo 3.95452 d. Questa classificazione è stata adottata da molti autori ad eccezione di Wils et al. (2006), i quali la riportano nel loro catalogo di variabili RR Lyr con periodo 0.79688 d. Sulla base di questa nuova indicazione, FM Del è stata aggiunta al programma RR Lyr svolto con Tarot. L'analisi delle nuove osservazioni conferma definitivamente che si tratta di una cefeide.

RESUMEN

La estrella FM Del fue clasificada como de tipo RR Lyr por Preston et al. en 1959, tras su descubrimiento por Huth (1957). Posteriormente, Huth (1960) demostró que se trata de una Cefeida de tipo W Vir, con periodo de 3.95452 días. Desde entonces numerosos autores la han considerado como Cefeida, con la excepción de Wils et al. (2006), que la incluyeron en su catálogo de variables de tipo RR Lyr, con un periodo de 0.79688 das. En base a esto, FM Del ha sido añadida al programa de RR Lyr de Tarot. Presentamos aquí estas observaciones, que confirman que es una Cefeida.

1 Introduction

As recalled by Diethelm (1986), FM Del was discovered by Huth (1957) as an RR Lyr of period 0.79739 days and was studied as such by Preston (1959). Preston's study concerned metallicity which was found to be about solar. This pushed Huth to reconsider the type determination and eventually revised (Huth, 1960) its type to cepheid with period 3.95542 days. GCVS (Samus et al., 2007-2012) gives CWB type (population II cepheid) and variation from 12.3 to 13.3 (p) with reference to Huth (1960).
Since then, several authors used FM Del as a cepheid. It was listed cepheid general studies by Petit (1960a, 1960b) and Harris (1985). New observations only appear in Diethelm (1986, 1990) who made a single photometric measurement in Walraven VBLUW system determining a metallicity index [Fe/H]=-0.9. Having only one measurement, Diethelm supposed that it is a cepheid, but with caution. Schmidt et al. (2003) eventually published electronic measurements in V and R filters, followed by spectroscopic observations (2005). Though Schmidt et al. assume the same period as determined by Huth (1960), their light curve leaves no doubt on the cepheid type.
Strangely enough, FM Del appears in Wils et al. (2006) catalog of RR Lyr stars from Rotse measurements with period of 0.79688 days (NSVS 11462023), a period close to Huth's. We may guess that this is an artifact from the time sampling of one measurement per night. It is worth to note that the ratio between the two periods is close to 5 (4.96). A consequence of FM Del being in Wils et al. catalog have been to schedule FM Del in Tarot RR Lyr program.

2 TAROT observations

A description of TAROT telescopes may be found in Klotz et al. (2008) and GEOS RR Lyr survey, including TAROT RR Lyr program in Le Borgne et al. (2007, 2012). To summarize, let us say that

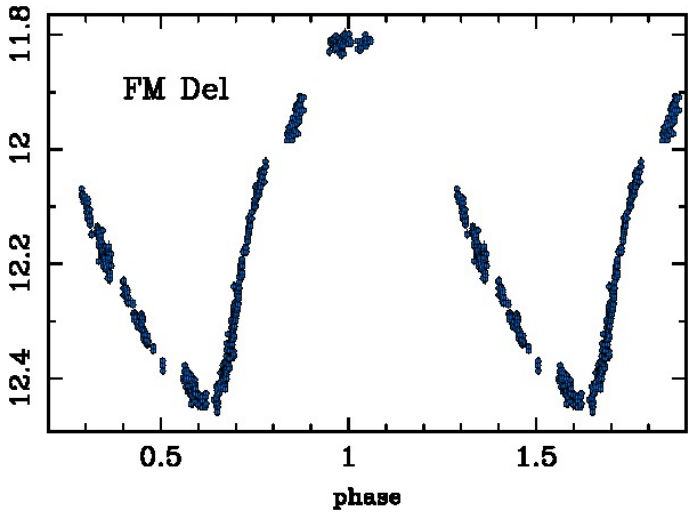

Figure 1: Folded light curve of FM Del (TAROT) using elements (1).

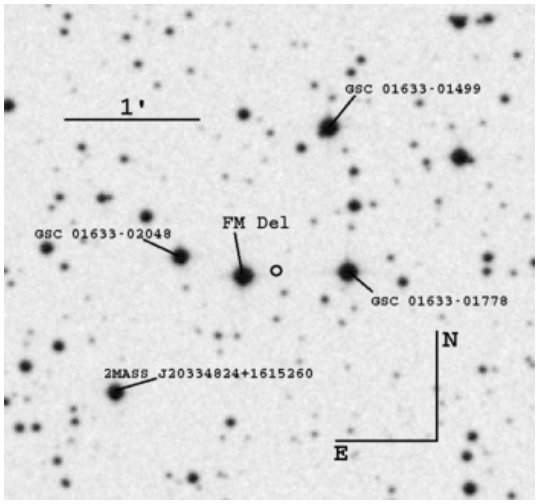

Figure 2: Star field around FM Del.

TAROT telescopes are robotic 25cm telescopes aimed to the observation of optical counterparts of events triggered by γ-ray satellite alerts or astro-particles detectors (neutrinos, gravitational waves). One is located in France (Calern Observatory) and the other in Chile (La Silla Observatory). Between alerts, the telescopes are used for several programs, one of them being to contribute to GEOS RR Lyr survey.
FM Del has been observed by the northern TAROT telescope at Calern Observatory from JD 2455401.414

(23 July 2010) to 2456162.582 (23 August 2012). 872 measurements spread over 29 nights have been obtained. As for the other stars of TAROT RR Lyr program, data reduction, from bias subtraction and flatfielding to photometry using SExtractor (Bertin and Arnouts, 1996), is performed automatically.
In TAROT RR Lyr program, observations are scheduled in order to obtain times of maximum during selected nights. For FM Del, the nights where selected according the elements given in Wils et al. (2006). It appeared that no maximum was observed during the selected nights, and furthermore, the star varied very few during all of them, and at different mean brightness. This is not typical of a RR Lyr star. We then plotted a folded light curve with the period given by Huth and later used by Schmidt et al. (Figure 1). We first used the elements given in GCVS (Samus et al., 2011) but the maximum of the light curve did not correspond to phase 0. We then adjusted the origin of the elements:

3 Discussion

One fact is to be noted: there is no reference to Wils et al. (2006) in CDS/SIMBAD entry for FM Del, nor NSVS 11462023 is given as cross identification. The question is then to investigate if these are 2 different stars. The coordinates of FM Del given in GCVS are the same as those given in SIMBAD. The coordinates of NSVS 11462023 from ROTSE are 0.2 arc minutes from GCVS FM Del coordinates. Figure 2 shows the star field around FM Del. The circle shows the position of NSVS 11462023 from Wils et al. (203343.42+161619.2). There is no star at ROTSE position and the closest 12th magnitude star is FM Del. Then it is most probable that FM Del and NSVS 11462023 are the same star.

$$HJD\ 2456111.65 + 3.95452\ E. \tag{1}$$

Next step is to check by our self the frequencies present in Rotse measurements which are available at

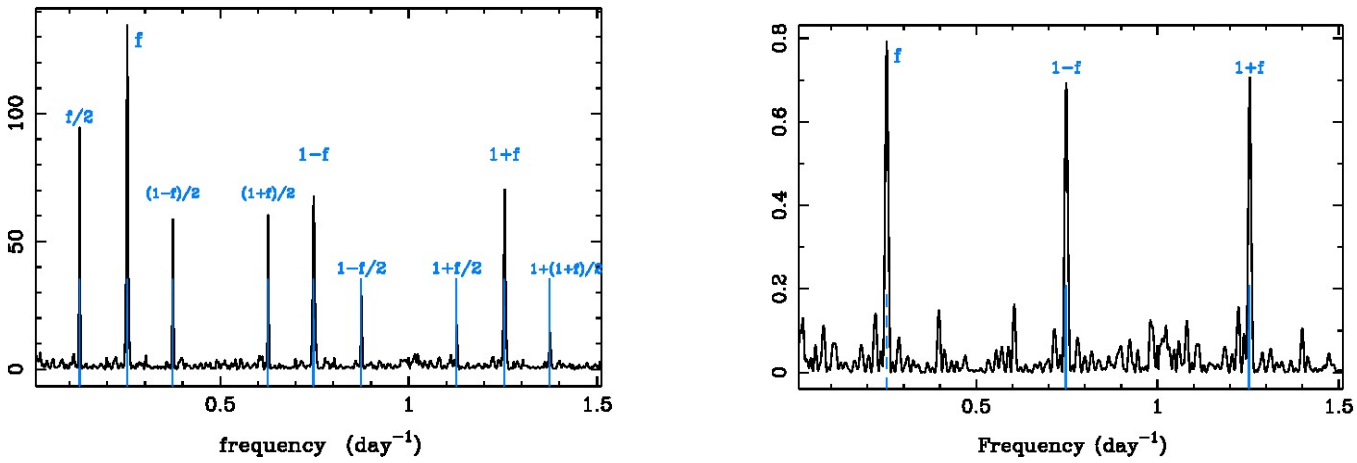

Figure 3: Periodograms of Rotse measurements. left: Schwarzenberg's method. Right: Vaniĉek's method.

the web site http://skydot.lanl.gov/ (Wozniak, 2004). Rotse database contains 103 measurements for NSVS 11462023 between JD 2451420.746 (30 August 1999) and 2451511.631 (29 November 1999). A periodogram of these data (Figure 3, left), using multiharmonic Fourier series method (Schwarzenberg-Czerny, 1996), gives a main frequency f at 0.25307 d^{-1}, that is 3.95147 days. We also see aliases at $1-f$ and $1+f$, as well as their half frequencies $f/2$, $(1-f)/2$ and $(1+f)/2$. Other aliases appear at $1-f/2$, $1+f/2$ and $1+(1+f)/2$. Note that because f is close to 0.25, $5f$ is close to $1+f$. As noted above, 5 is the ratio between the GCVS cepheid period and the period given by Wils et al.. Obviously, they used the alias $1+f$ as the main frequency. In principle, since the time sampling of Rotse is about one measurement per day, they should have considered such a frequency only with caution.

We also use a second method, the iterative sine–wave least–squares method (Vaniĉek, 1971) to build a second periodogram (Figure 3, right) the frequency f found is 0.25274 d^{-1}, corresponding to a period of 3.95663 days. As with the former method, we see aliases at $1 - f$ and $1 + f$ which is expected with the time sampling of the measurements. However, none of the other aliases appears.

The folded light curve of Rotse measurements are plotted with the same elements as TAROT mea-

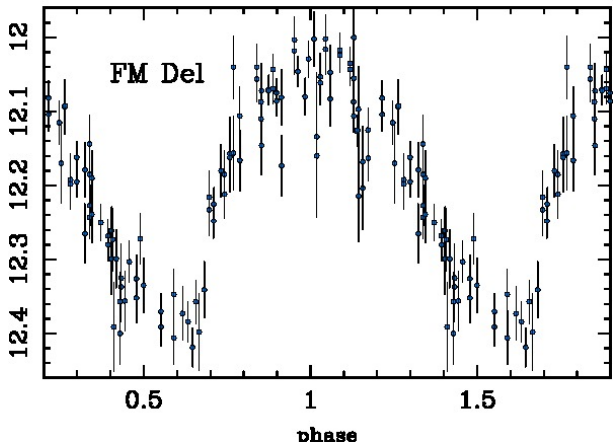

Figure 4: Folded light curve of Rotse measurements using elements (1).

surements in figure 4.

As a comparison, periodograms of Tarot data obtained with the two methods are given in figures 5. Thanks to TAROT time sampling and duration, only f and $f/2$ appear in periodogram obtained with Schwarzenberg-Czerny's method while only f is found with Vaniĉek's method. However, Vaniĉek's periodogram is noisier. The remaining lines are aliases of 1 d^{-1} frequency.

All these periodograms, on Rotse and Tarot data, give an uncertainty on period of about 0.003 day. This does not allow to improve the period given in GCVS. Note that FM Del is not in Catalina Survey

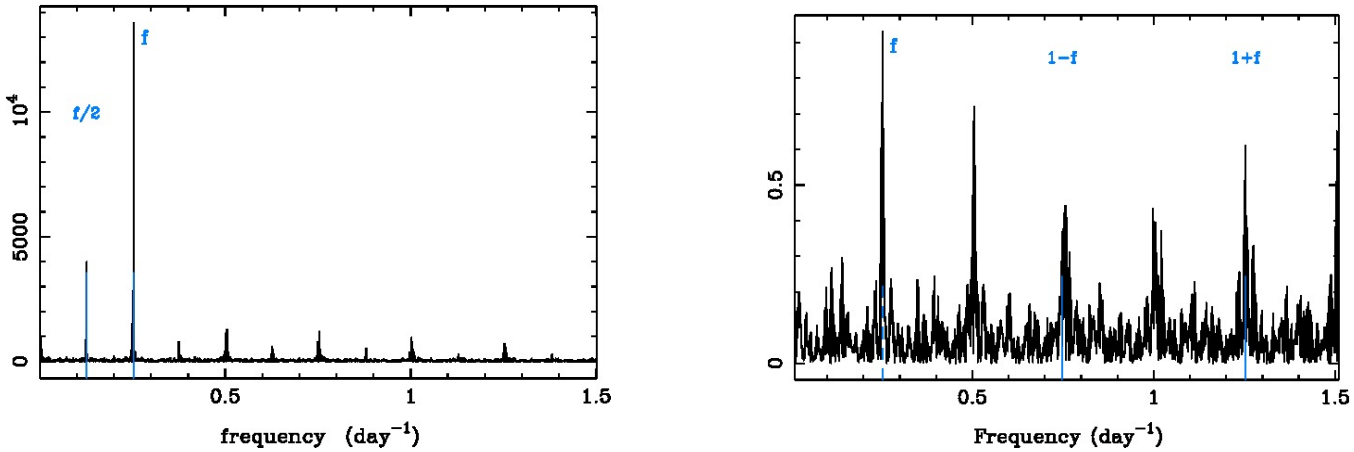

Figure 5: Periodograms of Tarot measurements. left: Schwarzenberg's method. Right: Vaniĉek's method.

database.

4 Conclusion

We have confirmed that FM Del is a cepheid as it was supposed to be since 1960 although it was first identified as an RR Lyr at its discovery in 1957. It was erroneously added to Wils et al. (2006) RR Lyr catalog with a period which is 5 times less than true one. Included in RR Lyr TAROT program on this basis, it clearly appeared not to be a RR Lyr star. TAROT data fit nicely Huth's 1960 period, as do ROTSE measurements which were at origin of Wils et al. paper.

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