DETECTION OF RAPID PHOTOMETRIC VARIATIONS IN MIRA-TYPE VARIABLES

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ABSTRACT

The accuracy of the Hipparcos photometric measurements and the exceptional repetition of observations of a star during the mission lifetime lead to an unexpected result: the first detections from space of photometric jumps in Mira variables over timescales ranging from a few hours to a few days. We report on these brightness variations and discuss their possible correlation with the spectral types of the stars and other physical parameters.

Key words: stars: variables: Miras; stars: AGB; space photometry.

1. INTRODUCTION

Mira-type variables are stars with more or less regular large amplitude light curves with periods ranging from $\sim$ 50 days to more than a few thousand days. They pulsate at the top of the Asymptotic Giant Branch.

Short-term variations, over timescales of days or even less, in any case much smaller than the period of these variables, have been suspected for several years in LPV. We list in Table 1 the most interesting detections from ground. The number of observed rapid variations in Miras is rather low and no systemic study of them have been done so far because of the lack of adequate data. In order to check if these variations are real and try to analyze them, we have looked for such events in the photometry collected by the Hipparcos satellite during the 37 months of the mission. The analysis of the Hipparcos photometry and the selection of events are described in the following section. The detected short-term variations are described in Section 3 and possible correlations with relevant stellar physical parameters are sketched out in Section 4. A more extensive presentation of this work and its results can be found in de Laverny et al. (1997b).

2. SEARCH OF SHORT-TERM VARIATIONS

2.1. Hipparcos Photometry

Hipparcos collected on the average 110 individual photometric observations of more than 10^5 stars including 239 Long-Period Variables of Mira type. The periods range from 100 to 550 days and 195 of them are oxygen-rich stars, 26 carbon-rich and 11 are classified as S-type.

The Hipparcos filter Hp covers almost completely the Johnson B and V filters. The reduction was performed by two independent consortia FAST and NDAC.

The time sampling of the Hipparcos observations is rather intricate: typically a star is observed over a grid-crossing, then again 20 minutes later. Usually this sequence is repeated several times, every two hours. Eventually the whole scheme returns after three to six weeks on a very different scanning direction. This allows the detection of rapid variations with timescales ranging from hours to few days.

2.2. Analysis of the Reduced Data

We have analyzed 17 613 observations of oxygen-rich Miras, 2890 of carbon-rich, 924 of S-type and 754 of Miras with unknown spectral type. Most of the measurements are found between 8 and 11 magnitude with a rather low uncertainty. The typical error, at 8 mag, is indeed around 0.015 mag on the individual measurements and 0.08 mag for a 11 mag star.

In order to eliminate all the instrumental effects and to check the validity of our procedure, we also considered a sample of 150 stars classified as photometric standards after the Hipparcos mission. We analyzed 15 521 observations of these standards whose magnitude range is comparable to the mean magnitude of the Miras sample.

Sequences of at least three consecutive observations of a given star were investigated to determine the evolution of Hp with time and therefore to look for any

Table 1. Previous ground based detections of short-term variations in Miras.

Source	Stars	Amplitude	Timescale
Odell et al. (1970)	o Cet	ΔW_λ (Hδ, Hγ, TiO)	10 days
Kovar et al. (1972)	o Cet	ΔW_λ (Pβ)	2 days
Smak & Wing (1979)	R Aur	$\Delta V = 1$ $\Delta K = 0.57$ $\Delta L = 0.36$	2 days
Schaeffer (1991)	11 Miras	All bands	$\sim$ min $< \Delta$ t $< \sim$ hours
Maffei & Tosti (1995)	18 LPV	$0.5 < \Delta$ B < 1.0 $0.5 < \Delta$ I < 1.0	1 day $< \Delta$ t $<$ 1 month
de Laverny et al. (1997a)	R Oct, R Hyi, S Pic	$\Delta V \sim \Delta B \sim \Delta I \sim 1$ $\Delta U \sim \Delta R \sim 0.7$	12 hours

rapid variation. The amplitude of a rapid variation was then defined as the largest difference between one observation and the mean of all the neighbouring ones. Only variations with an amplitude larger than 0.2 mag have been considered as a real event.

Finally, the light curve of each suspected rapid variation has been carefully examined and especially the variations of the *Hp* magnitudes around the jumps. Furthermore, the numbers of events for which the Miras undergo a sudden increase or decrease in brightness are of the same order of magnitude. This indicates that only a very small number of detections could be due to an accidental pollution by a star of the conjugated field. All the selected events are also confirmed by the data given by the two consortia FAST and NDAC and we can assert with confidence that they are not linked to any instrumental effect.

We eventually selected 51 short-term variations of 39 Miras. The list of these events together with their amplitude, time scale and some characteristics of the stars can be found in de Laverny et al. (1997b).

3. DESCRIPTION OF THE DETECTED EVENTS

The 51 detected short-term variations in Miras are characterized by:

1. their amplitude, which ranges from 0.23 mag to 1.11 mag;
2. their duration, which extends from 2 hours to almost 6 days;
3. the fact that 36 of these Miras are M-star. No short-term variations are therefore detected for Miras with spectral types S or C in contrast to what could be expected;
4. for some stars, several short-term variations are found:
   - twice for 8 Miras: half of them had their jumps at almost the same phase;
   - three times for 2 Miras: two of the three jumps have the same phase.

Examples of such short-term variations are shown in Figure 1.

4. SEARCH FOR PHYSICAL INTERPRETATIONS

We did not find any peculiar characteristics (period, amplitude, spectral type ranges,...) of the Miras for which short-term variations were detected, except that all of them are oxygen-rich.

From their AAVSO light curves, we estimated their phases in their duty cycle when the variation occurs. No clear link between rapid variations and phases is visible. If it exists, the phase of appearance depends on the star; at the moment the number of detections for each star is too small to conclude.

However, from the phases and the spectral types at the extrema of the light curves, we managed to estimate the spectral type at the time of appearance of the rapid variations. The distribution of these spectral types is shown in the upper panel of Figure 2. In the lower panel, we show the distribution of the spectral types of Miras performed at any time of their cycle. The comparison of the two histograms clearly reveals that short-term brightness variations do occur preferentially at late spectral types (75 per cent of the events are found at spectral types later than M6.5). de Laverny et al. (1997b) have also shown that all the jumps previously detected from the ground occured at similar spectral types.

These late spectral types are characterized by the presence of lines of the VO molecule. We therefore propose that short-term variations in Miras variables might be related to opacity changes linked to this molecule and then to variations in the physical conditions of the regions where these lines originate. However, the cause of these unstabilities is still unknown but hydrodynamics effects might be invoked. A better understanding of these short-term variations in Miras will be obtained only if new photometric and spectroscopic detections are made in the future.

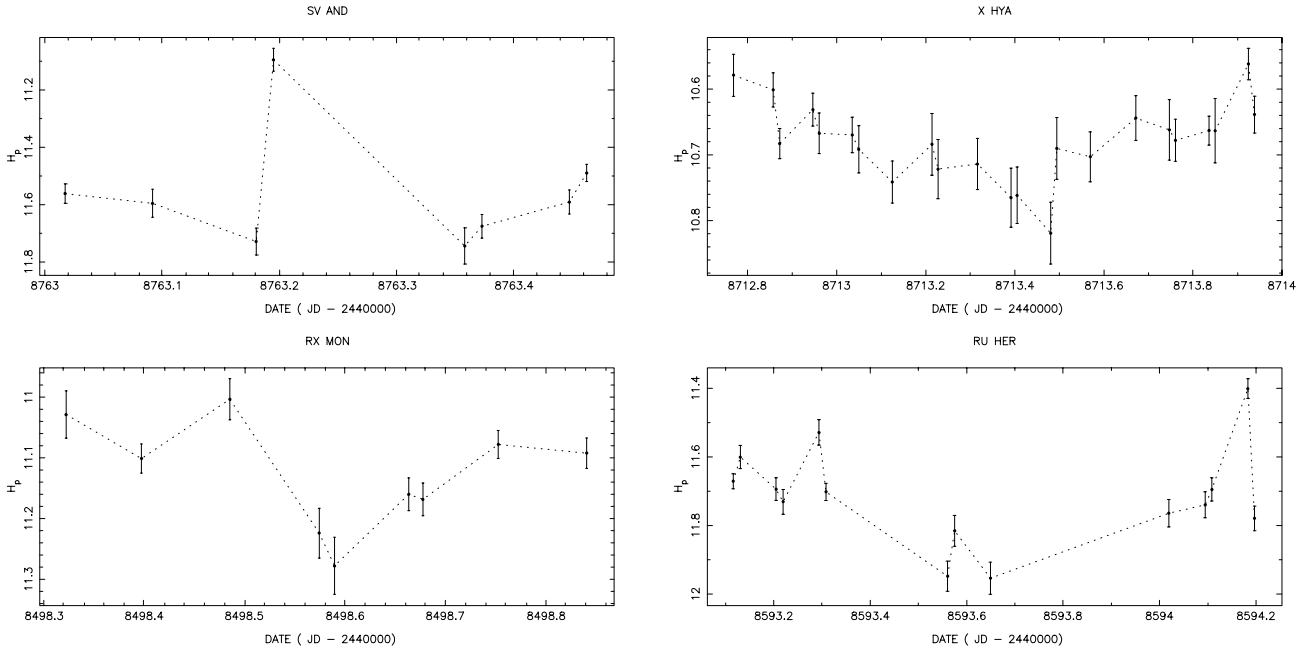

Figure 1. Examples of short-term variations in Miras detected by Hipparcos.

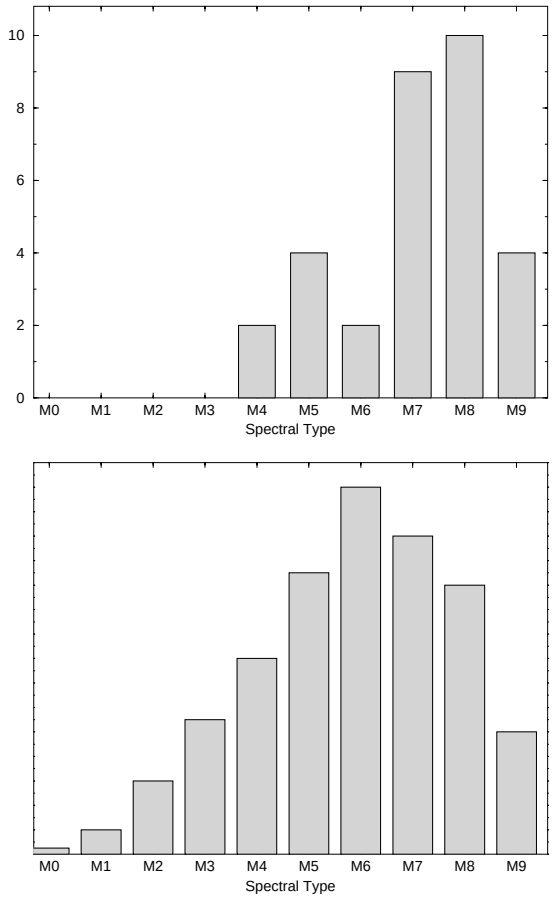

Figure 2. Spectral types corresponding to a rapid change in brightness (upper panel) and distribution of all the possible spectral types of a Miras sample during their cycle (lower panel).

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