Microvariability of Red Giant Stars

N. Mowlavi
Observatoire de Genève, CH-1290 Versoix, Switzerland

A. Jorissen
Chercheur Qualifiè F.N.R.S., Institut d'Astronomie et d'Astrophysique, U.L.B., Boulevard du Triomphe, CP 226, B-1050 Bruxelles, Belgium

Abstract Light variations are a common feature of red giant stars. Recent studies have shown that the amplitude of the light variations steadily increases along the giant branch, from microvariable and irregular K giants to semiregular and Mira-type M giants. Recent accurate photoelectric studies actually suggest that *all* stars among late K and M giants are variable to some degree. In particular, Jorissen *et al.* (1997) provide evidence that there is a *minimum* variability amplitude for a given spectral type, which increases with decreasing stellar surface temperature (or later spectral type). We summarize their results in this paper. The first light curves of microvariable K giants, with semi-amplitudes ~10 millimag (in the Strömgren *y* band) on time scales of 5 to 10 days, are also presented. Such patterns could characterize all microvariable K giants, but need tight time sampling and high photometric accuracy to be revealed.

1. Introduction

Photometric variability is a common feature among red giants. Three classes of variables are usually identified among those stars, namely the irregular, semiregular, and Mira variables. They exhibit variations of increasing amplitudes and improving cycle repeatability (see Gautschy and Saio 1996 for a discussion of their pulsational characteristics). How these different groups relate to each other is still a matter of debate, as is the evolutionary link between them—if any.

The use of photomultipliers in recent years has allowed researchers to monitor red giant stars with unprecedented accuracy, and has led to the introduction of the class of *small amplitude red variables* (SARVs; Percy *et al.* 1994, 1996). This class comprises K and early M giants with variations on the order of 0.1 magnitude (in the *V* band), with time scales of 20–200 days. Pushing accuracies down to a few millimagnitudes in *V* over several years, Geneva photometry has unravelled *microvariable* red giant stars (Rufener and Bartholdi 1982; Burki 1984). These are K and M giants with statistically significant variations on the order of a few 0.01 magnitude. From the analysis of the whole *Geneva Catalogue*, Grenon (1993) has shown that the average amplitude of the variations continuously increases from the microvariable K giants to the M Miras. This variability sequence parallels the spectral-type sequence. This picture has been refined by Eyer *et al.* (1994) and Eyer and Grenon (1997), with the use of the HIPPARCOS photometry. Microvariables were also uncovered by Edmonds and Gilliland (1996) among K giants in the globular cluster 47 Tuc.

The Long-Term Photometry of Variables (LTPV) project (Sterken 1983) has investigated, among other topics, microvariability in more than fifty different red giant stars over a decade. The LTPV project is a collaborative effort involving several groups of astronomers interested in the long-term monitoring of various classes of variable stars, and has operated since 1982 at the European Southern Observatory (ESO). The data used by this paper and by Jorissen *et al.* (1997) for the study of microvariability in red giants were obtained with the Danish 50-cm telescope in the Strömgren *uvby* system, with a frequency ranging from one observation per night to one per month. Observing runs are typically one month long, with an average of six runs per year. The complete database is available at the *Centre de Données Stellaires* (Strasbourg, France), and is documented in Sterken *et al.* (1995).

The observation time sampling allows researchers to investigate variations on time scales from days to years, and the accuracy reaches 2 to 3 millimag (in the Strömgren *y* band) over the whole monitoring. Such high accuracies result partly from the differential nature of the observations (each observation consists of a sequence such as *APB* or *APBPBPA*, where *P* designates the program star, and *A* and *B* nearby comparison stars), and partly from the multi-night reduction algorithm (Sterken and Manfroid 1992), which prevents offsets between different observing runs. The results, described in detail by Jorissen *et al.* (1997, hereafter JMSM), confirm that the average amplitude of variability increases towards later spectral types, in agreement with previous studies. They suggest, in addition, that *all* red giants are variable to a level exceeding some minimum value (called *minimum-variability boundary* by JMSM) which depends on the spectral type. This property is detailed in the next section below. In the third section, JMSM presents, for the first time, the light curves of two microvariable red giants.

2. The Minimum-variability boundary of red giants

The variability of red giants in the LTPV dataset is analyzed from the standard deviation σ_y of their *differential* magnitudes in the *y* band (which offers the highest accuracy for those objects). Figure 1 presents the standard deviation of the differential magnitude y_G–y_{Xi} (where *G* designates the reddest giant star in the *APB* triplet, and *Xi* is any of the remaining two stars) as a function of the *b–y* index of *G*. Actually, only those red giant stars having more than twenty measurements in the LTPV database and spanning at least 1,000 days are retained, to ensure a certain homogeneity in the sample. The *minimum-variability boundary* is represented by the dashed line. It clearly delineates a minimum variability level for all giants redder than $(b–y)_0 = 0.8$ (unreddened index) monitored by the LTPV project. The minimum standard deviation increases from ~2.5 millimag at *b–y* = 0.8 to ~7 millimag at *b–y* = 1.1. It is interesting to note that the stars labelled 1, 2, and 3 in Figure 1, which fall *below* the *minimum-variability boundary*, are in fact heavily reddened by interstellar absorption. Their de-reddened $(b–y)_0$ index locates them above the *minimum-variability boundary* in the $(\sigma_y, b–y)$ diagram, as expected (see JMSM).

The minimum σ_y of ~2.5 millimag observed in Figure 1 for stars with $b–y < 0.8$ reflects the overall accuracy of the LTPV data (due to photometric measurement error sources such as photon and scintillation noise, de-centering effects, short-term transparency variations, etc.).

3. Light curves of microvariable K giants

JMSM argue that the lack of (de-reddened) red giant stars below the *minimum-variability boundary* is real and does not result from instrumental effects which may cause a loss of accuracy for stars with extreme colors. In order to validate that statement, light curves of two microvariable stars with $\sigma_y = 7$ millimag (and labelled *4* and *5* in Figure 1), lying along the *minimum-variability boundary*, are presented in Figure 2. Those two stars have been observed once or twice per night during fifteen consecutive nights. They clearly exhibit low-amplitude variations with a time scale of 5 to 10 days. Moreover, the light curves of the two microvariables are uncorrelated and their comparison stars remained stable during the observing period, thus dismissing instrumental drifts as the origin of the observed variations.

The similarity of the variations exhibited by HD 60197 and HD 44896, both in terms of amplitude and time scale, is remarkable, and parallels the similarity of their *b–y* indices.

4. Final remarks

The existence of the *minimum-variability boundary* and the presence of well-defined low-amplitude variations in microvariable red giants are the two main novelties brought to the study of microvariability by the LTPV project.

The analysis of the LTPV data set moreover brings to light the following properties of red giant variables:

- the time scale of the variability increases with increasing light amplitude (or, equivalently, with increasing *b–y*), reaching ~100 days for σ_y ~0.1 magnitude;

- the variations become less irregular as their time scale increases, and well-defined periods emerge above about 100 days.

The overall picture which emerges from these studies suggests that photometric variability arises (or, at least, becomes detectable with current techniques) in red giants at $b–y \simeq 0.8$, and grows at lower stellar temperatures (or higher luminosities). At the onset of variability, light variations are irregular—albeit with well-defined patterns—with time scales of a few days and semi-amplitudes of a few millimagnitudes. There seems to be a continuous sequence, in terms of increasing amplitudes and time scales of variations, from these microvariables to the Mira variables.

Stellar oscillations may be responsible for the light variations observed in microvariable stars, as suggested by the detection of radial-velocity jitter (on the order of 1.5 km s^{-1} r.m.s.) associated with photometric variability. More observations of red giants, with accuracies of a few millimags and tight sampling, are required to refine the picture offered by the existence of a *minimum-variability boundary*.

References

Burki, G. 1984, in *Space Research in Stellar Activity and Variability*, eds. A. Mangeney, and F. Praderie, Observatoire de Paris, Paris, 69.

Edmonds, P. E., and Gilliland, R. L. 1996, *Astrophys. J.*, **464**, L157.

Eyer, L., and Grenon, M. 1997, in *Hipparcos Venice '97*, ed. B. Battrick, ESA-SP 402, ESA Publ., Noordwijk, The Netherlands, 467.

Eyer, L., Grenon, M., Falin, J. -L., Froeschlè, M., and Mignard, F. 1994, *Solar Physics*, **152**, 91.

Gautschy, A., and Saio, H. 1996, *Ann. Rev. Astron. Astrophys.*, **34**, 551.

Grenon, M. 1993, in *Inside the Stars*, eds. W. W. Weiss, and Baglin, A., IAU Coll. 137, ASP Conf. Ser. 40, Astron. Soc. Pacific, San Francisco, 693.

Jorissen, A., Mowlavi, N., Sterken, C., and Manfroid, J. 1997, *Astron. Astrophys.*, **324**, 578.

Percy, J. R., Desjardins, A., Yu, L., and Landis, H. J. 1996, *Publ. Astron. Soc. Pacific*, **108**, 139.

Percy, J. R., *et al.* 1994, *Publ. Astron. Soc. Pacific*, **106**, 611.

Rufener, F., and Bartholdi, P. 1982, *Astron. Astrophys., Suppl. Ser.*, **48**, 503.

Sterken, C. 1983, *The Messenger*, **33**, 10.

Sterken, C., and Manfroid, J. 1992, *Astronomical Photometry, a Guide*, Kluwer, Dordrecht.

Sterken, C., *et al.* 1995, *Astron. Astrophys., Suppl. Ser.*, **113**, 31.

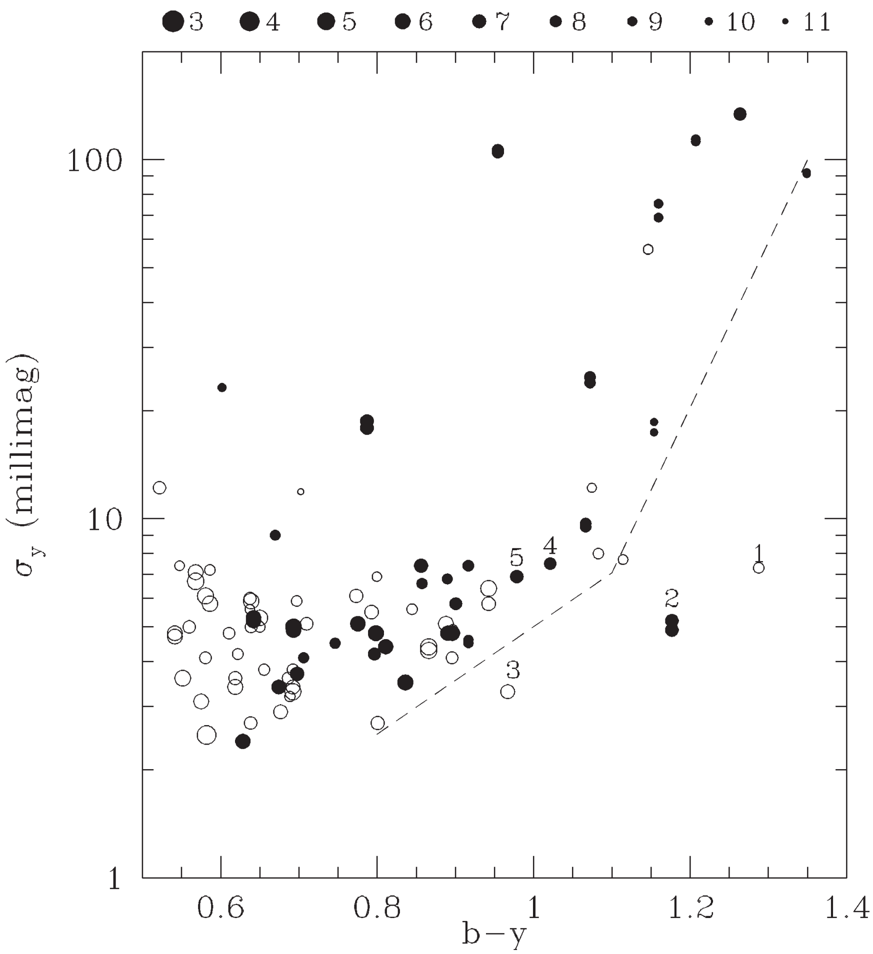

Figure 1. The (σ_y, *b–y*) diagram for the sample of red giant stars extracted from the LTPV database, σ_y being the standard deviation of the *differential y* magnitude *G–Xi*. Filled symbols refer to chemically-peculiar red giant stars (barium, S, or C stars). The size of the symbols reflects the magnitude of the faintest star in the pair, as illustrated on the top line. The dashed line corresponds to the lowest standard deviation found at a given *b–y* index (the *minimum-variability boundary*). Stars 1 (=HD 161406), 2 (=HD 178717), and 3 (=HR 7007) are strongly reddened stars, and move above the *minimum-variability boundary* after correcting for their color excess (see Jorissen *et al.* 1997). The light curves of stars 4 (=HD 60197) and 5 (=HD 44896), falling along the *minimum-variability boundary*, are presented in Figure 2.

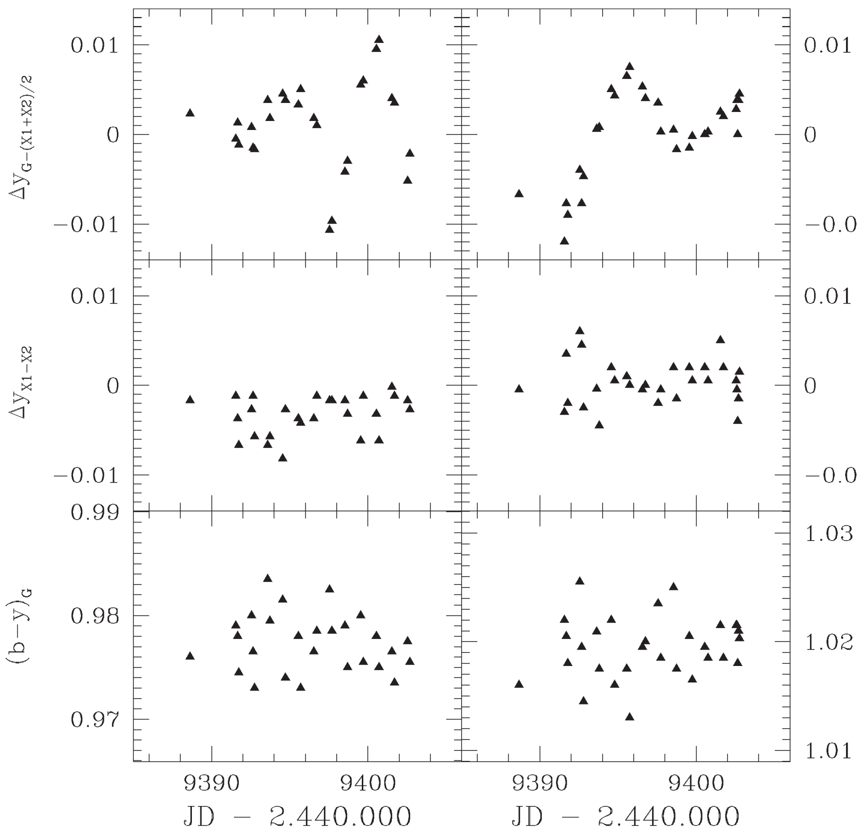

Figure 2. Light curves of HD 44896 (left panel) and HD 60197 (right panel) in February 1994. *Upper panel*: differential magnitude $\Delta y_{G-(X1+X2)/2}$ in the *y* band. Negative values of $\Delta y_{G-(X1+X2)/2}$ correspond to the star *G* being fainter, whereas the zero point corresponds to the average differential magnitude over the whole monitoring. *Middle panel*: same as the upper panel, but for the differential magnitude Δy_{X1-X2}. *Lower panel*: light curves for the color index *b–y* of the program star *G*.