Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
Proceedings IAU Symposium No. 343, 2019
F. Kerschbaum, M. Groenewegen & H. Olofsson, eds.

doi:10.1017/S1743921318007718

TIG*vival*: High-resolution spectroscopic monitoring of LPV stars

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Abstract. TIG*vival* is a spectroscopic monitoring program of long-period variables (LPV) using our robotic telescope TIGRE. Since 2013, we obtain low-noise, high-resolution spectra (R= 20 000) that cover the optical regime (3800 Å to 8800 Å). We are now continuously monitoring 7 LPVs with different periods and chemical properties. Our 350+ spectra evenly sample the target cycles, as far as ground-based observations allow. Analyzing the TIG*vival* spectra of Mira as a sample case, our measurements indicate that the strength of the TiO-absorption is phase-shifted with respect to the visual light curve.

Keywords. stars: AGB and post-AGB, molecular processes, techniques: spectroscopic

1. Introduction

Our long-term monitoring program TIG*vival* provides spectroscopic time series of currently seven long-period variables: G Her (89 days), BK Vir (150 d), U Hya (183 d), *o* Cet (=Mira, 332 d), W Hya (361 d), R Hya (380 d) and R Lep (445 d) – the corresponding cycle periods are given in brackets. The acronym TIG*vival* illustrates that we plan to continue our monitoring for several more years: TIGRE *vigila variables de largo periodo a largo plazo* = TIGRE long-term monitoring of LPVs. All our time series currently cover almost two continuous years, with a total of more than 350 spectra. They evenly sample the target cycles, as far as visibility from the TIGRE site in central Mexico allows.

TIGRE is a 1.2 meter robotic telescope. It uses a two-armed echelle spectrograph to cover much of the optical range from the near UV to the near IR with a spectral resolution of 20 000. With the exception of R Lep, essentially all TIG*vival* spectra have a signal-to-noise ratio that exceeds e.g. 100 at 7000 Å.

2. Mira's TiO molecular bands: illustrating the potential of TIG*vival*

The formation of molecules (TiO, VO) in the extended atmospheres of Mira variables dominates their visual variations (Reid & Goldstone 2002). Furthermore, molecular absorption also causes the different stellar diameters measured in different optical narrow-band filters (Tuthill *et al.* 1995) – as well as their cyclic variations (Young *et al.* 2000).

The bolometric emission of LPVs is difficult to measure directly. However, the H_2O and SiO maser emission of LPVs are assumed to be directly correlated with the bolometric emission. These maser emissions follow the visual light curve, although with a lag of approximately 0.2 in phase (Pardo *et al.* 2004, Brand *et al.* 2019 in prep.).

As a first step to study the TiO absorption in LPV, we performed a simple analysis: we integrated Mira's spectral flux inside two wavelength bands, each several dozen

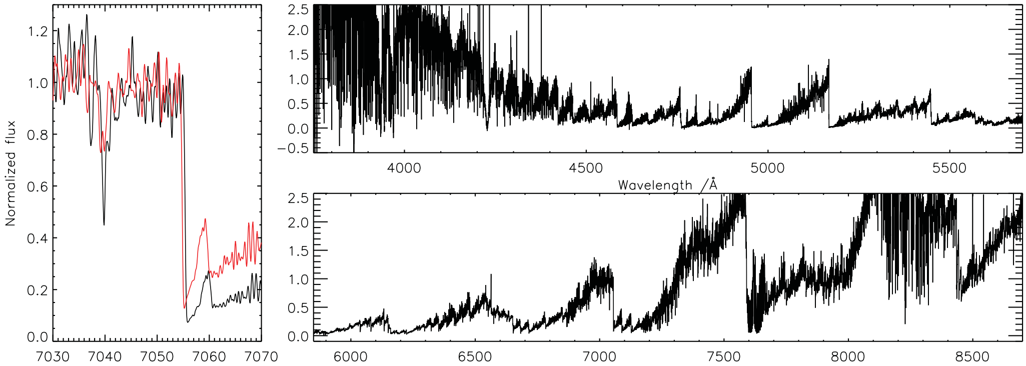

Figure 1. Representative TIG*vival* spectrum of Mira (*o* Ceti) taken near visual phase 0.3 (black graph, see also Fig. 2). The panels on the right show the entire spectrum, while the left panel zooms in on the same spectrum as well as on a second spectrum taken at about visual phase 0.16 (red). Note that above a wavelength of ∼4500 Å no signal noise is visible in this figure.

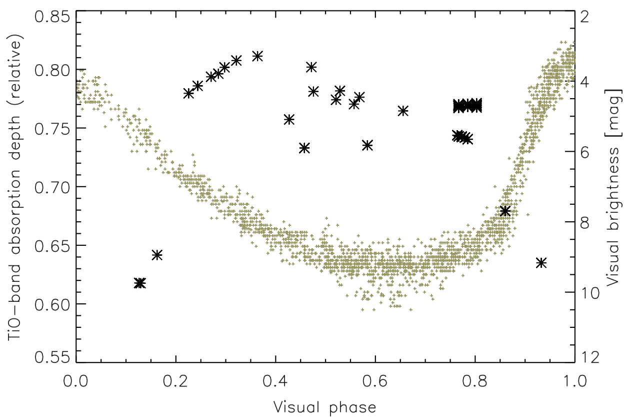

Figure 2. Depth of the 7062 Å TiO absorption for Mira (asterisks), in units of the nearby pseudo-continuum. Phase zero represents maximum visual brightness, the AAVSO magnitudes (January 2014 to September 2018) are shown in gray for comparison.

Ångströms wide, situated near the TiO bandhead at ∼ 7055 Å (Fig. 1). We measure the strength of the TiO absorption, using the ratio of the flux redward of this bandhead (TB) divided by the pseudo-continuum TC directly blueward of the bandhead as a proxy. Here we define the *arbsorption depth* as $(1 - TB/TC)$. The phases we use here were estimated from visual AAVSO measurements spanning more than a decade.

Our result is shown in Fig. 2. We find the weakest TiO absorption close to visual phase zero. While the TiO band depth largely seems to follow the visual light curve, it shows a substantial lag. It reaches its maximum later, at approximately phase 0.35. We will continue our TIG*vival* monitoring of Mira to check the reality of this delay.

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https://doi.org/10.1017/S1743921318007718 Published online by Cambridge University Press