Mem. S.A.It. Vol. 88, 777

Memorie della

Eruptive variable protostars from VVV

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Abstract. The search for high-amplitude infrared variable stars with the Vista Variables in the Via Lactea (VVV) survey yields 106 likely YSOs with eruptive light curves, increasing the number of known eruptive variable YSOs by a factor of about 5. Spectroscopic follow-up confirms 19 objects as new additions to the variable class. These differ from FUors and EXors as they are generally optically obscured systems at earlier stages of evolution, show 1 to 4 year duration of the outbursts and have a mixture of the spectroscopic characteristics of both subclasses.

1. Introduction

Episodic accretion has been invoked to solve long-standing problems in star formation: 1) the luminosity problem (Kenyon et al. 1990), and 2) the scatter observed around the best fitting isochrones in pre-MS clusters (Baraffe et al. 2012). Observational support for the idea of episodic accretion arises from the observation of young stellar objects (YSOs) displaying sudden rises in luminosity, of up to 6 magnitudes, that last from months to 100 yrs (Hartmann & Kenyon 1996). These outbursts are caused by the abrupt increase of the accretion rate onto the central star due to instabilities in the accretion disc (Audard et al. 2014). The young eruptive variables are usually divided into 1) FUors, which show long-lasting outbursts (t>30 yrs) and strong CO absorption in their near-IR spectra, and 2) EXors, which display lower amplitude and shorter duration outbursts, as well as near-IR spectra with Brγ emission and CO emission/absorption depending on bright/quiescent state. In order to characterise eruptive variability and to try to establish the incidence of episodic accretion among YSOs, we have searched for high-amplitude variability in the near-IR multi-epoch survey VVV (Minniti et al. 2010).

2. The VVV survey search

The analysis uses the 2010-2012 Ks photometry from VVV. We analysed disc tiles with $|b| < 1^\circ$ which amounts to 76 tiles in total, with at least 14 epochs per tile. For the selection we required objects to be classified as star in each catalog, and that $\Delta K_s = K_{s,max} - K_{s,min} >$ 1 mag and ΔK_s to be 3σ above the mean ΔK_s observed at its magnitude level. This method yields 5085 variable candidates; visual inspection of images confirms 816 true variable stars (Contreras et al. 2017a). Most of the variables stars are unknown in the literature.

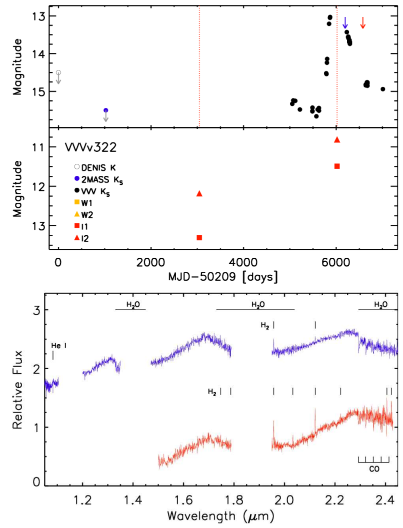

Fig. 1. Near- and mid-IR light curve (top), and near-IR spectrum (bottom) of VVVv322. The object shows a classical FUor spectrum, however the outburst duration is shorter than expected for this class.

3. SFR association, follow-up and classification (MNors)

We searched for association with star forming regions (SFRs) using SIMBAD, WISE, Vizier and the Avedisova catalog of SFRs (Avedisova 2002). We estimate that 54% of the sample is likely associated with SFRs. The SEDs of the objects in these areas support a YSO classification, with most objects having SEDs of class I or flat-spectrum sources. We conclude that YSOs are the commonest type of high amplitude infrared variable stars in the Galactic disc. The large amplitudes observed in our SFR–associated variables are likely due to accretion or extinction related variability. To gain insight into the physical mechanism causing the variability, we visually inspected the light curves of these variable stars. In here we find several classes: long-term variability (often periodic, t>100 d), short-term variability (t<100 d), eclipsing binaries and aperiodic variability (faders, dippers). Among the latter, we classify 106 objects as eruptive YSOs. In these objects, the near-IR colour variation argues against extinction-related variability. We find that the majority are class I YSOs, and by considering the ratio of class II to class I YSOs observed in SFRs we find that eruptive variability is 13-17 times more common in class I than class II objects. The duration of the outbursts appear in the range 1-4 years. We obtained medium-resolution spectroscopy for 37 VVV objects between 2012-2015, using FIRE (R~6000) at the Baade Telescope in Las Campanas Observatory. We find that 28 objects display the typical characteristics of YSOs, such as Brγ or H_2 lines in emission or CO in emission or absorption (Contreras et al. 2017b). Fifteen objects show spectroscopic characteristics of being eruptive variables, whilst other four have additional data that support this classification. We find that the properties of most of the sample differ from the classical EXor and FUor classification scheme (see Fig. 1). The sample shows longer duration of the outbursts compared to classical EXors but shorter than FUors. They are also at earlier stages of evolution than classical EXors and FUors. Given this we propose a provisional classification as MNors, following V1647 Ori the illuminating source of the McNeill Nebula (MNO).

Acknowledgements. This work was supported by STFC grants ST/J001333/1, ST/M001008/1 and ST/L001403/1. Support was also provided by the Ministry of Economy, Development, and Tourism's Millennium Science Initiative through grant IC120009. DM is also supported by the CATA PFB-06 and Fondecyt No. 1130196. CCP acknowledges support from the Leverhulme Trust.

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