Flaring Miras

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Abstract

Long-term monitoring of AGB stars at the Nancay Radio Telescope (NRT) led to the discovery of a new class of OH masers towards Miras. The 2 main characteristics of these events are their high degree of polarisation and indications that the OH flaring regions are located in a more internal part of the circumstellar envelope than the standard OH shell. This latter fact has been confirmed by recent mapping towards o Ceti. These flaring events have now been recorded towards stars believed to be isolated as well as towards stars belonging to a binary system. The overall characteristics of such events and the implications with respect to the standard models are presented here.

Standard Miras

- Miras are AGB stars with an optical counterpart
- The **standard OH shell**, created by the photodissociation of H_2O by external ambient UV radiation, is found in the outer part of the circumstellar envelope (CSE) at a typical distance of 100-1000 AU
- This OH shell can produce 3 out of 4 ground-state maser transitions at 1612, 1665 & 1667 MHz. Miras are called **"type I"** emitters **if their main lines** (1665 & 1667 MHz) **are stronger than the 1612 MHz** satellite line or **"type II" in the opposite case**.
- Their OH spectra usually exhibit a so-called **"standard" two-peaks profile** generally more complicated than the one of OH/IR objects. The **expansion velocity** estimated as half of the width between the two peaks of the spectrum **increases with the period of pulsation of the star** and lies in the range 2 to 10 km/s.
- Their **OH variations follow** the **infrared and optical periodicity with a delay of** some tens of days corresponding to **10 to 20%** of the period.
- The **pumping** of their OH maser lines is **achieved by far infrared radiation** coming **from the dust** of the CSE.

Flaring Mira characteristics
illustrative case: O Ceti

cf. Etoka & Le Squeren (1997) for a full description

- The **flaring emission** also **follows the optical light curve with a typical phase delay of 10-20%** of the period.

➥ the phases corresponding to the beginning of the flare events are all quite close to zero

➥ the **duration** of these events **varies greatly** from one star to another: from only few months to several optical cycles (i.e., >10 years)

- The flaring emission is **strongly polarised**
- **OH flaring emission originates from a region closer to the star than the OH maser emission in the standard model**

➥ The recent analysis of O Ceti flaring emission has shown that its **OH flaring emission and H_2O masers are emitting in similar velocity ranges &** multi-epoch **mapping has revealed** that its **flaring** regions occur within a **zone** less than **~400 mas (~40 AU) from the central star** *(cf. Fig 1)*.

- All the **flaring Miras** are **characterized by very low [60-25] and [25-12] IRAS colour indexes** with their **[25-12]** colour indexes **less than -0.70** *(cf. Fig.2)*.
- There is a correlation between ($V_{star} - V_{flare}$) and the **[25-12] colour-index** *(cf. Fig.3)*.

➥ there is a hint that *o* Ceti flaring zone is even more internal than anticipated, which could be due to the influence of the companion.

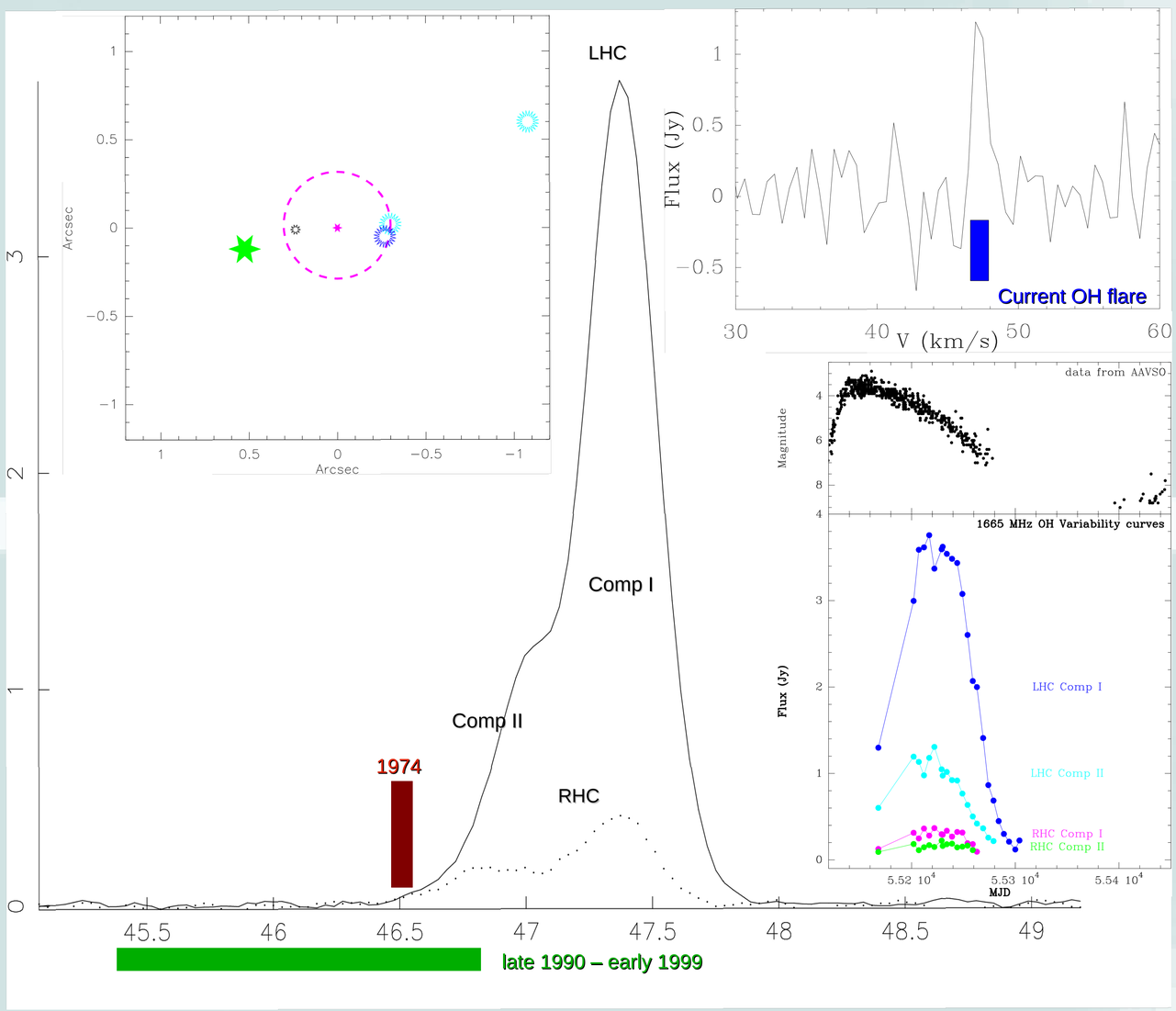

Fig. 1 : Main panel: average NRT[1] spectrum of the current OH outburst in Mira Ceti at 1665 MHz (December 2009 - February 2010). The vertical bar gives the velocity of the OH peak in 1974, and the horizontal bar gives the OH emission velocity spread in 1990-1999. Top-left insert panel: Relative positions of the OH emission detected by the EVN[2]-(e)MERLIN[3] in February 2010 (black), MERLIN In the 1990s (light blue: 1995 / dark blue: 1998) and the stars of the Mira AB system (purple star: Mira A /green star: Mira B), taking Mira A as the reference position, and correcting all the positions for proper motion (van Leeuwen 2007). Top-right insert panel: Medicina H_2O maser emission during the rise of the OH maser emission towards the maximum in December 2009. The vertical bar gives the current OH emission velocity spread. Lower-right insert panel: Variability curves of the individual components after Gaussian spectral decomposition. (Etoka et al. 2010 & *2015 in preparation*)

1: Nancay Radiotelescope *http://www.nrt.obspm.fr/*
2: European VLBI Network *http://www.evlbi.org/*
3: Multi-Element Radio Linked Interferometer Network *http://www.e-merlin.ac.uk/merlin*

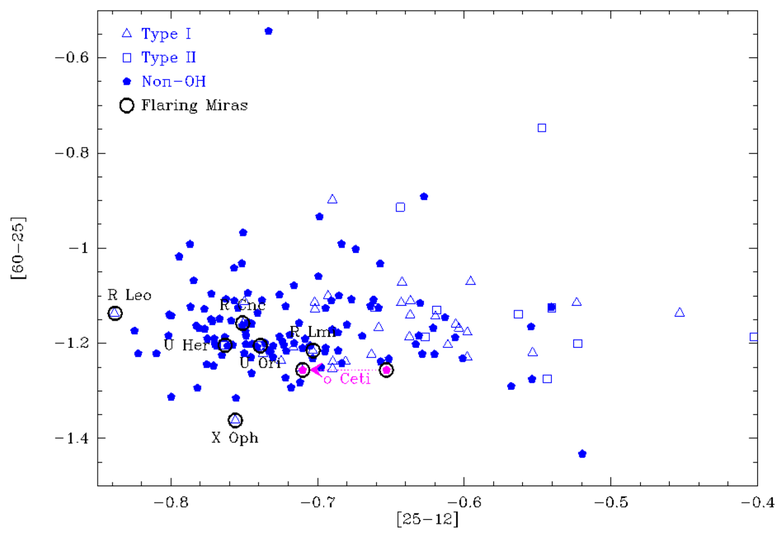

Fig. 2 : Adapted from Fig. 10 of Etoka & Le Squeren (1997) showing the [60 − 25] vs [25 − 12] IRAS colour-colour diagram of the nearby Miras (distance < 1 kpc) with the location of all the flaring Miras indicated. "type I" stands for Miras which are emitting predominantly in the 1665/67 MHz main lines; type II' stands for Miras which show their strongest emission in the 1612 MHz satellite maser line and "non-OH" stands for Miras which have not been detected in any of the ground-state OH maser transitions. Note that 2 positions are given for *o* Ceti in this diagram. The "redder" one corresponds to the uncorrected value as calculated from the fluxes given in the IRAS Catalogue (i.e., corresponding to the overall binary system), while the "bluer" value is corrected for the mid-infrared excess due to the accretion disk heated by Mira A, identified by Ireland et al. (2007). The arrow shows the direction of the correction.

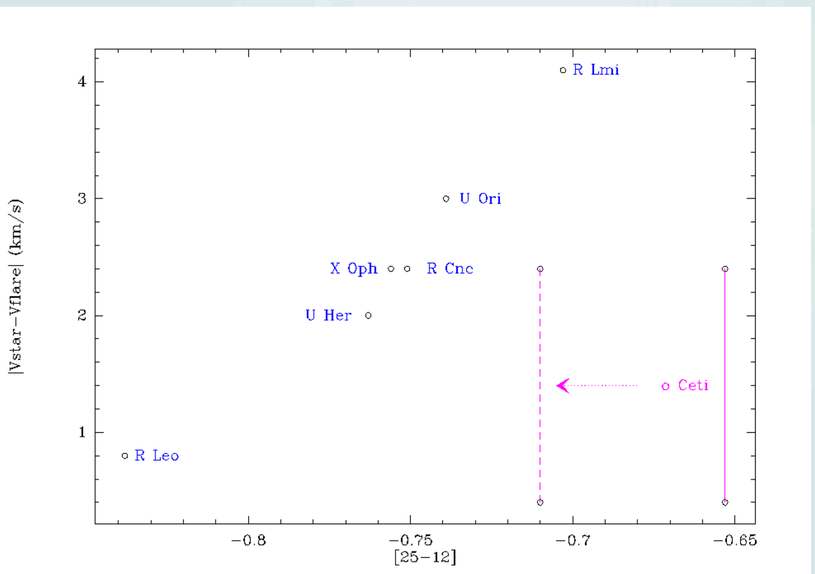

Fig. 3 : Adapted from Fig. 11 of Etoka & Le Squeren (1997) showing the relation found between $|V_{star} - V_{flare}|$ and the [25 − 12] IRAS colour of the flaring Miras. Note that the actual location of *o* Ceti in this diagram is rather poorly constrained due to, on the one hand, the contamination of its [25 − 12] colour by the presence of its companion Mira B and, on the other hand, its poorly constrained stellar velocity, illustrated here by the 2 vertical lines taking into account these 2 effects.

Conclusion

The general flaring characteristics observed towards all the flaring Miras known so far are similar in terms of IRAS colour-colour properties, velocity range in relation to the stellar velocity, spectral characteristics and polarisation behaviour as described by Etoka & Le Squeren (1997), which are quite distinct from what is observed towards standard Miras (Etoka & Le Squeren 2000). These common characteristics suggest that the flaring locations in terms of radius in the CSE is similar for all these events and all indicate that these regions of transient OH maser activity are distinct from the standard OH maser shell. Yet, in the case of *o* Ceti there are also hints that the presence of the companion is playing a role in the flares, most probably in producing "episodic" H_2O photodissociation in preferential zones.

References

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