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Influence of a Close Companion on the Variability of a Mira-Type Star

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Abstract. The effects of a low-mass companion (a planet?) revolving around a red giant at a short distance (inside its circumstellar envelope) are discussed. Calculations are given for a conical shock wave, induced by the orbital motion of the companion. Consequences for the stellar spectrum and light curve are derived, and predictions for the evolution of such a system are made.

Binarity is indeed a crucial factor for the stars' evolution, even after the AGB stage and formation of a planetary nebula (see, e.g., Harpaz & Soker 1995). Evolution of a red giant having a compact stellar companion (a brown/black dwarf with a mass of $\gtrsim 0.02 M_{\odot}$, or possibly a neutron star) was considered in series of papers on 'double-core evolution' (Soker 1998 and references therein). The fate of a lower-mass companion ($\lesssim 0.001 M_{\odot}$ – a planet), embedded in the atmosphere of star that has become a red giant, was considered in a number of papers. In particular, Soker (1999) proposed to search for Uranus-Neptune-like planets in planetary nebulae, formed in the course of post-AGB evolution. Soker (1999) also considered some physical effects, based on interaction of the planet with the surrounding nebula and fast stellar wind: a tail strongly emitting in the Hα line could form behind the moving planet.

In this poster I consider some effects a planet can cause when revolving around a red giant that has not yet lost its envelope; this may explain some peculiarities in the periodic variability of Miras and emission lines in their spectra.

If a red giant possessed a planetary system prior to inflating to a 1 AU radial size, then the planets – at least the most massive ones (similar to Jupiter, $M_{\rm pl} \sim 0.001 M_{\odot}$) – can survive for a significant time during the red-giant stage (Struck-Marcell 1988). The orbital motion of the planet with a period $T_{\rm orb} \sim 1$ yr at a velocity $V_{\rm orb} \sim 30$ km s^{-1} (if placed at a distance of 1 AU from the center of a $1 M_{\odot}$ star) would engender a conical shock trailing behind. The shock may add to light variations and account for the observed emission in the Balmer lines and lines of metals, appearing in the spectra of Mira stars.

The pulsations of red giants may be intrinsically weak and chaotic; the example case is semiregular variables. SRs seldom display emission lines; their light variations are not strictly periodic. I interpret these stars as having no massive planets, which could impose more regular brightness variability and regular appearance of the emission lines. There also may be cases where the orbital plane is almost perpendicular to the line of sight. Then the periodicity effects (if any) may be much less pronounced.

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This model is proposed as an alternative to the pulsation-driven shocks as sources of optical emission in Miras, because recent optical spectroscopy (Castelaz & Luttermoser 1997, Esipov et al. 2000) and radio continuum data (Knapp et al. 1995; Reid & Menten 1997; Chapman & Rudnitskij 1999) suggest that such shocks are probably much weaker than it was believed, and their velocities do not exceed $\sim$15–20 km s^{-1}. The effects of a hot spot migrating over the disc of the red giant may also explain asymmetry in brightness distributions over the discs of some Miras (Bedding et al. 1997; Lattanzi et al. 1997; López et al. 1997), peculiarities in the light curves and in the velocity structure of emission line profiles of Mira-type variables, e.g. doubling at some phases of the light curve (Derviz & Savanov 1978, Udry et al. 1998).

Detailed calculations concerning the effects of a conical shock in the atmosphere of a red giant are now in progress.

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