THE WIND OF EG ANDROMEDA IS NOT DUST-DRIVEN

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ABSTRACT

The symbiotic star EG And has recently been the subject of several studies investigating its wind properties. The red giant primary has been considered to have a wind driven by radiation pressure on dust, indeed, the derived wind velocity law fits this model. We point out here that there is no appreciable dust in the wind of EG And using constraints from extinction limits (IUE) from and far infrared fluxes (IRAS). An alternate mechanism must operate in this star. We suggest that the wind can be driven by the effect of the radiation on molecular lines.

J. INTRODUCTION

Dust driven winds are believed to be the mass loss mechanism for late type giants (Salpeter 1974, Goldreich & Scoville 1976; Gail & Sedlmayr 1987; Netzer & Elizur 1993, for a review on mass loss mechanisms in evolved stars see Lafon and Berruyer 1991). Heavy elements condense Mow $T \simeq$ I 0001< forming dust which becomes accelerated by radiation pressure. Dust momentum is transferred to the gas by collisions. As the dust grains condense at low temperatures, the acceleration zone predicted by this mechanism is a few radii away from the stellar surface. Since the radiative transfer problem is coupled to the hydrodynamical problem, the solution of the complete problem is complicated.

An order of magnitude estimate for the dust optical depth needed to drive the wind can be obtained by simple arguments (e.g. Knapp 1986, Berruyer 1991 , Netzer & Elizur 1993), ie the momentum semi in the wind was originally present in the radiation field. Then if $\dot{M}$ is the mass loss rate, v_∞ is the asymptotic wind velocity, L is the bolometric stellar luminosity, τ_∞ is the flux weighted mean dust optical depth of the acceleration zone and c is the speed of light this is expressed as (cf Mihalas 1978),

$$\dot{M} = \frac{L\tau_\infty}{v_\infty c}, \qquad (1)$$

$$= 2 \times 10^{-5} \left(\frac{L}{10^4 L_\odot}\right) \left(\frac{v_\infty}{10 km\ s^{-1}}\right)^{-1} M_\odot\ yr^{-1}.$$

Substituting the values $\dot{M} = 1 \times 10^{-8}\ M_\odot\ yr^{-1}$, $L = 1000 L_\odot$ and $v_\infty = 30\,\mathrm{km\,s^{-1}}$, assumed for EG And (see Vogel,Nussbaumer & Monier 1992), we obtain $\tau_\infty \sim 0.01$

Vogel (1991) presented an empirical velocity law for the cool giant of EG And. The UV radiation from the hot component is Rayleigh scattered in the wind of the cool giant. The column density for Rayleigh scattering varies with the orbital phase and an empirical density structure is derived. Assuming a final velocity of $30\,\mathrm{km\,s^{-1}}$ for the wind a mass loss rate $\dot{M} \sim 10^{-8} M_\odot\,\mathrm{yr}^{-1}$ was derived for the cool giant. From the continuity equation and the density structure he derived a velocity law. The derived velocity law suggests a narrow acceleration zone at a few stellar radii. This velocity law is consistent with the dust driven wind mechanism because dust cannot form closer to the stellar surface.

Wind velocities for field giants have long been known to be ~ 20 - $30\,\mathrm{km\ s^{-1}}$ (see e.g. Linsky 1984) and therefore, it is assumed to be the case for the cool companion in symbiotic stars. For EG And high dispersion *IUE* and Hα spectroscopic observations indicate that the wind from the entire symbiotic system is $\sim 74\,\mathrm{km\ s^{-1}}$ (Oliversen, Anderson, Stencel & Slovak 1985), and it could be as high as $\sim 150\,\mathrm{km\,s^{-1}}$ (Stencel, private communication). The fact that in the CIV 1548/50 Å emission line, the P Cygni feature disappears during the eclipse of the primary (Oliversen et al. 1985), strongly suggests that this wind velocity refers to the hot companion. Although the effects of the cool wind are detected in the nebular lines as a function of phase (Pesce, Stencel & Oliversen 1987), the velocity of the cool wind has not been directly measured.

2. NO DUST IN EG AND'S WIND

2.1 IUE Flux Incompatible With Dust

Archival IUE low dispersion spectra of EG And were analyzed by Vogel (1991). These data, taken near phase zero of the system when the white dwarf is viewed through the red giant's wind show the strong signature of H resonant absorption at Lyman α and Rayleigh scattering off atomic hydrogen at longer wavelengths. At phase 0.04 the estimated hydrogen column in the wind is 10^{24} cm^{-2}, which would imply at normal dust to gas ratios an ultraviolet extinction of thousands of magnitudes.

Knapp (1985) obtained a dust to gas ratio of 1.5×10^{-3} for carbon stars and 5×10^{-3} for oxygen stars. The mere fact that Rayleigh scattering is important precludes a dust to gas ratio this large, given that for the dust mechanism to operate the (cool star) flux-weighted mean dust optical depth must be of the order of 0.01. Applying a typical dust extinction curve, the 1500 A optical depth must then exceed 0.2 or so. With even this small a dust optical depth, the signature of the 2200 A bump should appear in the IUE spectra, but it dots not seem to be present. We conclude that on the basis of the ultraviolet satellite data the EG And wind appears to be 99.9% dust-free, ie any dust present comprises an abundance less than 0.1% normal.

2.2 FIR Flux Shows No Excess Over Photosphere

We have reviewed the IRAS survey data for EG And being careful only to use scans that passed closest to the star and verify the fluxes of Kenyon, Fernandez-Castro and Stencel (hereafter KFS, 1988) within five percent, except that we reduce the 100 micron upper limit to 0.26 Jy from 0.7 Jy.

Vogel, Nussbaumer and Monier (1992) use IUE data from the 1992 eclipse of EG And to determine physics] properties of the system. They find that the total bolometric luminosity is 966 solar luminosities for a distance of 400 pc. The far infrared colors are consistent with a the Rayleigh-Jeans end of a T> 2000 K blat.khdy while the giant's classification of M 2.4111 suggests an effective temperature of 3800 K (Ridgeway et al. 1980). As an extreme upper limit we may associate all the far infrared with re-radiation from dust. In that case the optical depth to absorption (which is within a factor of a few of the total optical depth), is $L_{FIR}/L_{BOL} = 3.4/966 \sim 3.5 \times 10^{-3}$. The threshold optical depth for a dust-driven wind is 0.01, so the scattering cross section would have to be 2.8 times the absorption] cross section to begin being consistent with the dust-driven wind picture.

The absorption scattering ratio depends 011 the grain size, It is uncertain what size the grains in the wind have. If the size is smaller than 0.1 μm the absorption dominates.

Although the grain size can be as big as 0.3 μm (Snow, Buss, Gilra & Swing (1987), most grain sizes are ~ 0.05 μm (Netzer & Elizur 1993). Larger grains would drift very fast reducing their space density. In addition the high drift would cause sputtering of the grains (Drain & Salpeter 1979).

We thus conclude that it is a stretch to make the dust- driven wind model work for EG And based on the far infrared fluxes, and thus that the model as presently formulated is not a plausible candidate for the wind mechanism of this star.

3. ALTERNATIVE WIND MECHANISMS FOR EG AND

The inherent problems in dust-radiation wind models, particularly the need for dust to form at both low temperatures and high densities, have lead to the search for alternative and/or additional mechanisms. Some of these include Alfven and sound waves (Hartmann & McGregor 1980), shocks driven by stellar pulsation (11 owen 1988), 'stochastic winds' driven by the accumulative effect of random shocks (Cuntz 1992) and 'molecular winds' driven by radiation effects on molecular lines (Elitzur, Brown & Johnson 1989).

For Alfven waves to be effective requires mass loss rates higher than 1 x 10^{-7}, magnetic fields >10 Gains and a particular form of damping, as to reach the observed wind velocities (Hartman & MacGregor 1 980). Although polarization measurements have been carried out to determine the presence or absence of a magnetic field (Schulte-Ladbeck et al. 1990), the results for EG And are inconclusive. The observed polarization is small, ~ 0.2- 0,4 %, with a relative weak dependence 011 wavelength, i.e. could be due either to scattering or magnetic fields, and it may not be related to the giant star at all (Schulte-Ladbeck et al. 1990). A magnetic driven wind is not totally ruled out by the observations.

Plausible evidence of non-magnetic processes (i.e. sound waves or shocks waves driven by pulsation) taking place in M giants has been recently published (Judge ct. al 1993). Although the stars in question have circumstellar envelopes, it was determined from the profiles of their Mg 11 and Ca II lines that chromospheric activity took place below the circumstellar matter. This suggests that the acoustic or hydrodynamic processes alone may drive the wind and mass loss observed (for details see Judge & Stencel 1991; Cuntz 1990).

A less explored scenario is the effect of the radiation 011 molecular lines. This mechanism has been considered as a way to produce a subsonic wind near the photosphere that carries mass up to coder regions where dust can form. Detailed numerical models using line opacities of CO, H_2O and OH (see e.g. Maciel 1975, 1977; Elitzur, Brown & Johnson 1 989) have been relatively successful in initiating the wind.

The transfer of momentum from the radiation field to the gas via line absorption has been calculated in detail for massive early type stars, where UV resonant lines are very efficient (see e.g. Cassinelli & Castor 1973). An order of magnitude of the effect can be obtained, for instance, by comparing the relative fraction of stellar flux necessary to accelerate the flow using the same argument as presented in the Introduction for a continuous absorption process.

As for the case of dust absorption one obtains the result that if molecular lines can trap a hundredth of the stellar luminosity, they can in principle drive the cool wind. If the molecular opacity increases in such a way that the radiation pressure force is less than gravity at low altitudes where the flow is subsonic, but then becomes great enough to exceed gravity above some critical radius, then a consistent wind solution will exist (Marlborogh and Roy, 1970, Cassinelli and Castor, 1973). Given that kT rapidly decreases below the dissociation energy of common molecules as one moves outward from the continuum-forming photosphere, this possibility remains open. Strong CO absorption features are clearly seen in the 2 micron spectrum of EG And (Schild, Boyle & Schmid 1992).

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