MASS EJECTION FROM OLD STARS - AN EXAMPLE OF A POSSIBLE MECHANISM

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The basic ideas in this paper are described in recently published papers by Ahern et al. (1977) and Kwok (1977). There are two main points to be made in addition, which remove the differences between these two papers.

1) If smaller dust grains are used, say of 0.1 μ instead of the 1 μ grains of Kwok, then the dust is more efficient in absorbing the uv radiation from the star. While we have not carried out detailed calculations yet, we believe that such a medium will produce a cut-off to the HII region in a $\rho \sim r^{-2}$ density distribution, so that Kwok's previously ejected nebula is not necessary, provided the star ejected material moderately uniformly for a period of say 10,000 years. For a total mass $\sim 0.3\ M_\odot$, it appears this model will fit the detailed grain calculations and the radio outer cut off well.

As time goes on the inner radius expands, along with the whole nebula which becomes more ionized. Eventually we can expect, after say a further 10,000 years, to see a fully fledged, ionized, planetary, whereas at present we see all the dust, but only a small fraction ($\sim 0.02\ M_\odot$) of the gas, that is the ionized component.

2) From the work of Cahn and Wyatt (1976) and also Wood and Cahn (1977) we see that the birth rate and death rate of planetaries, the death rate of stars with $1M_\odot < M < 5M_\odot$ the production rate of white dwarfs, and the death rate of Miras are all of the order of $3 \times 10^{-3}\ \mathrm{kpc}^{-3}\ \mathrm{yr}^{-1}$. Hence we expect to see about 1 planetary formed every 10 years within $\sim$ 5 kpc of the sun. V1016 Cygni and HM Sge are suitable candidates and understanding the physics for them could be a major clue to understanding mass ejection.

Our conclusion is that the V1016 Cygni phenomena is representative of the way a planetary nebula is formed. We may summarize it as follows:

1. Mass ejection at $\sim 3 \times 10^{-5}\ M_\odot\ \mathrm{yr}^{-1}$ for $\sim 10^4$ years of a dusty envelope from an LPV. This gives a density distribution of

$\rho \sim r^{-2}$.

2. Cessation of the ejection process, producing an observable "stellar" HII region ~ 3 years later.

3. The size of the HII region is limited by dust grain absorption of uv and reradiation in the infrared, but eats its way out into the surrounding medium over several thousand years, producing a fully fledged resolvable planetary eventually.

4. Planetary Nebula formation is not the result of a single isolated event, but the result of a steady stellar wind such as is found in late type giants. Dust seems to be intimately involved in the process.

References:

Ahern, F.J., FitzGerald M.P., Mark K.A., Purton C.R., 1977, Astron. Astrophys. 58, 35.

Cahn, J.H., Wyatt S.P., 1976, Astrophys. J. 210, 508.

Kwok, S., 1977, Astrophys. J., 214, 437.

Wood, P.R., Cahn J.H., 1977, Astrophys. J., 211, 499.

D I S C U S S I O N of paper by FITZGERALD:

R.N. THOMAS: Which is the final model to produce a PN - continuous ejection over some time, or abrupt ejection?

FITZGERALD: This model indicates a continuous mass ejection process over some 10,000 years, with no abrupt ejection. The nebula "appears" after the ejection process ceases, at which time the hot stellar core is able to ionize the expanding nebula, certainly out to the point at which all the UV photons are absorbed by dust and re-radiated in the infrared. One feature of this model is that it predicts no EUV flux from young planetaries, but does from old ones.

R.N. THOMAS: I am always fascinated by the different types of central stars of planetary nebula: from "dwarf" WR stars on "down" in Teff. Could you speculate, on your model, as to how such a sequence of central stars might arise?

FITZGERALD: We have not looked at this sequence, but we can say that some planetary nebula nuclei have an emission line component in this spectrum displaced about 100 km s^{-1} to the blue with respect to the system's velocity. In this sense the stellar core of V 1016 Cygni appears similar to one type of planetary nebula nucleus.

SWINGS: Your model star V 1016 Cyg seems to be also applicable to the ex-symbiotic star RX Puppis (for details see Klutz,

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Simonetto and Swings, paper submitted to Astron. Astrophys.).

OLNON: If I remember correctly, the model of a r^{-2} density distribution with an outer boundary was applied to two other objects as well, and both had roughly the same outer radius. Could you comment on this surprising result?

FITZGERALD: I do not recall which objects there were in particular, but I think one was also a protoplanetary candidate; as such, it is probably not too surprising that the same general conditions are present at the same stage. The actual details could be found from Dr. C.R. Purton, York Univ., Ontario, Canada.

SURDEJ: Because of this suggested slow process in formation of PN, would you not expect to see more of such objects like the one concerned here?

FITZGERALD: We would not expect to see a large number because of the expected number of roughly 1 every 10 years at this stage. However, we do also have HM Sge as a similar candidate; also many stellar planetaries of apparently low total mass. On our model as the object continues to expand more material will be ionized as the relative grain area decreases with respect to the surface area of the inner radius. Eventually the object should appear as a full-fledged planetary in about 10,000 years.

In a discussion with Dr. G. Shaviv at lunch, he advised me that two features of V 1016 Cygni that we had not previously understood were consistent with that to be expected theoretically. Namely: If the hydrogen-rich material is stripped from an LPV fairly quickly (over 10,000 years and less) the remnant core will continue to pulse with the LPV period. Our conclusion is that this is what causes the observed variation in the infrared (P about 450^d). Since the emission lines are produced by recombinations and the radio by free-free collisions, variation here will be either strongly changed or not present. However, the dust will respond since it rapidly re-radiates any absorbed UV radiation in the infrared.

The apparent increase in T_e of the core and radius decrease is consistent with that to be expected from a recently stripped core.

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