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OH/IR Star "Death" Statistics

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Abstract. Four dead OH/IR stars are identified in a complete Arecibo sample of OH/IR stars, together with one in the process of dying.

1. Introduction

The "death" of an OH/IR star occurs when it is no longer expected to have detectable 1612 MHz masers. Dead OH/IR stars then follow one of two evolutionary scenarios. The first arises soon after the complete loss of the stellar envelope, when, as a consequence, the circumstellar shell can no longer be replenished by ongoing mass loss. These stars contract to become the central stars of planetary nebulae (PNe), and so first become proto-planetary nebulae (PPNe), before later evolving into PNe. The prototype for this scenario is IRAS 18455+0448, which had a 2.1 Jy maser in 1988 that had faded to a 0.1 Jy maser by 1998: its final, smooth, exponential decline was followed for two years by Lewis, Oppenheimer, & Daubar (2001), until its peak intensity $I_{12} < 2$ mJy. In this case the lack of a long-period pulsational signature in the declining maser and the red IR colors of the shell both suggest that it had become a PPN. Such deaths are normally irrevocable. By contrast the second scenario for dead OH/IR stars occurs when mass-loss into a circumstellar shell declines sharply as the extra luminosity available after a He-shell flash ebbs away, even though the star still has an envelope. The subsequent evolution in the case of a *low-mass* AGB star is to retrace its mass-loss history en route to the next thermal pulse, after which it is resurrected as an OH/IR star again (Wood & Vassiliadis 1992; Lewis 2001).

To confirm the second scenario we needed to find more dead OH/IR stars. This is practical as the net duration of all 1612 MHz emission phases from high latitude OH/IR stars is ~1700 yr (Lewis 2000), so one "death" should occur in a sample of 170 every ten years if they have just one emission phase, while more will be found if many deaths follow the second scenario. We have accordingly made second epoch observations using the Arecibo 305 m telescope of the complete sample of 328 OH/IR stars with a peak first-epoch $I_{12} > 100$ mJy in the Arecibo sky. These are detected if their current $I_{12} > 5$ mJy, while four are now undetectable after ~12 yr (IRAS 18455+0448, 19479+2111, 19529+3634 & 20547+0247 = U Equ). Moreover the masers in IRAS 15060+0947 (= FV Boo) appear to be in terminal decline, as they exhibit the periodicity of an AGB star while their mean flux decays exponentially.

2. Discussion

The blue IR colors of all of the new dead stars, together with their water and SiO masers and the 315 d period of FV Boo suggest that all of them are still on the AGB. So these objects follow the second death scenario, with IR colors that will loop back to a (25-12) μm $\sim$-0.85 before becoming redder again. The discovery of so many dead stars from a general population of OH/IR stars shows that most AGB stars pass through an OH/IR star phase several times.

The positions of the dead OH/IR stars on first-epoch plots of I_{12} v S(25), and on plots of the ratio of these quantities versus IR color, are entirely normal. However all of the dead stars have small, $<$12 km s^{-1}, expansion velocities, and all but one have blue IR colors. When these criteria are used to delimit the sample further, these dead stars imply a mean 1612 MHz emission life $t_e$$\sim$314 yr. This short t_e is readily understood if oxygen-rich stars toward the end of the AGB pass through a brief OH/IR star phase after a thermal pulse, when, as often happens, they are not bright enough to support heavy mass-loss during the luminosity ascent to a thermal pulse. Our estimate for t_e is then the observational signature in oxygen-rich stars for the correlation between $\dot{M}$ and period proposed by Wood & Vassiliadis (1992). Hence copious AGB mass-loss is frequently triggered by events following after a thermal pulse. While an increase in shell density, and thus in $\dot{M}$, is an expected consequence of an increase in luminosity and period, Lewis (2001) argues that the physical trigger for copious mass loss occurs when the density in the circumstellar shell rises past the threshold that abruptly causes newly-formed dust grains to be slowed by collisions with gas molecules, so that grains suddenly start to couple photon momentum to the shell.

It has, however, been a surprise that the very considerable radial extent of the gain path of 1612 MHz masers in a circumstellar shell has not provided them with more longevity. We have seen the 1665 & 1612 MHz masers in IRAS 19556+3423 more than double in intensity and velocity range over the past 12 years, and suspect that this system is thus a recent birth. Now, with the deaths of four systems over a similar interval, we can be certain that such changes in intensity are not due to special *ad hoc* factors within a shell: 1612 MHz masers can clearly be fragile on a decadal timescale.

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