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X-Ray AGB Stars in the 4XMM-DR9 Catalog: Further Evidence for Companions

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Abstract

Single AGB stars are not normally expected to be X-ray emitters due to the lack of a corona capable of powering a hot plasma. Therefore, the detection of X-ray emission in AGB stars by the ROSAT, Chandra, and XMM-Newton observatories has been interpreted as evidence for binarity. The number of X-ray-emitting AGB stars is, however, very small, and statistically sound conclusions shall be considered tentative. In this paper we aim at increasing the number of X-ray-emitting AGB stars and at providing a consistent analysis of their X-ray emission to be compared to their UV and optical properties. The XMM-Newton 4XMM-DR9 catalog has been searched for X-ray counterparts of various types of AGB stars: nearby (i.e., listed in Hipparcos), mass-losing, and S- and C-types. Seventeen X-ray counterparts of AGB stars have been found in the 4XMM-DR9. Nine of them have pointed XMM-Newton observations, whereas eight are genuine serendipitous discoveries. Together with the AGB stars detected by ROSAT, this increases the number of X-ray AGB stars to 26. Most of their X-ray spectra can be fit by the emission from an optically thin single-temperature thermal plasma with temperatures typically larger than 10^7 K. There is no obvious correlation between the X-ray and bolometric luminosity of these stars, but the X-ray luminosity generally increases with the amount of far-UV excess. The high temperature of some X-ray-emitting plasma in AGB stars and the correlation of their X-ray luminosity with the far-UV emission supports the origin of this X-ray emission from accretion disks around unseen companions.

Unified Astronomy Thesaurus concepts: Close binary stars (254); Asymptotic giant branch stars (2100); Late-type giant stars (908); Single x-ray stars (1461); Symbiotic binary stars (1674); X-ray binary stars (1811)

1. Introduction

UV emission lines and continuum of single late-type giants are formed in their extended stellar chromospheres (Carpenter et al. 1988; Luttermoser et al. 1989; Judge 1990). Near- and far-UV spectra of AGB stars often exhibit various emission lines of low-ionized species, such as FeII, MgII, SiII, CII, and CIV that are considered as typically chromospheric (Johnson & Luttermoser 1987; Judge 1990; Ortiz et al. 2019). On the other hand, highly ionized emission lines like NV and O VI, which are generally associated with the stellar corona, require higher temperatures to be formed ($10^5 \sim 10^6$ K), and are generally absent in the spectra of M-type giants. The lack of these higher ionized species suggests that a corona is absent around these stars (Linsky & Haisch 1979). In fact, Schrijver (1987) showed that the basal intensity of various chromospheric emission lines (i.e., their lower-limit value) steadily decreases toward the later spectral types, even though individual values can be strongly affected by the intensity of the chromospheric activity. Likewise, soft X-ray emission, commonly attributed to the stellar corona, becomes rare. The coronal dividing line (CDL) delimitates the region on the right side of the H-R diagram where soft X-rays are no longer detected (Linsky & Haisch 1979; Ayres et al. 1981). Pace (2013) and more recently Dixon et al. (2020) obtained a relationship between the chromospheric activity and the stellar rotation that can be used to estimate the stellar age. According to these findings, as a star ascends the AGB, the decrease in rotation resulting from the angular momentum conservation causes a strong decrease of coronal activity on the right side of the CDL.

The first searches for X-ray coronal emission toward red giant stars did not result in reliable detections (Vaiana et al. 1981). Eventually, among 4330 X-ray sources inspected by Lin et al. (2012) in the XMM-DR3 catalog only 101 were classified as "variable stars," and among these, none could be reliably associated with an AGB star. Until now, the search of X-ray counterparts of AGB stars in various surveys (e.g., ROSAT and XMM-Newton; Boller et al. 2006; Webb et al. 2020) have resulted in a few detections (Jorissen et al. 1996; Hunsch et al. 1998a; Ramstedt et al. 2012). In the majority of these cases the X-ray source has been attributed to the presence of an accretion disk around a companion, like in symbiotic stars, for example (Sahai et al. 2015).

In this paper we describe a search for X-ray counterparts of AGB stars in the 4XMM-DR9 catalog using a sample including nearby, mass-losing, S- and C-type AGB stars. Their X-ray, UV, and optical characteristics are compared with those of symbiotic stars with AGB primary components.

2. The AGB Sample

The search for X-ray counterparts was based on various lists of AGB stars:

1. *Hipparcos AGB stars*. This list is biased toward nearer stars, mostly within 1 kpc. McDonald et al. (2012) obtained effective temperatures and luminosities of 107,619 Hipparcos stars (ESA Publications Division 1997) based on photometric data covering from the UV to the far-IR. Our search was limited to Hipparcos stars restricted to $T_{\rm eff} < 3500$ K and $1000 < (L/L_\odot) < 54{,}000$, which eventually reduced the number of candidates to 801 objects. The maximum temperature and minimum luminosity (Salaris & Cassisi 1997) are criteria intended to reduce the contamination of the sample by RGB stars, while the upper limit of luminosity corresponds to the tip of the AGB