MASYS – The AKARI spectroscopic survey of Symbiotic Stars in the Magellanic Clouds

Rodolfo Angeloni\textsuperscript{1,2}, Stefano Ciroi\textsuperscript{1}, Paola Marigo\textsuperscript{1}, Marcella Contini\textsuperscript{2,1}, Francesco Di Mille\textsuperscript{1} and Piero Rafanelli\textsuperscript{1}

\textsuperscript{1} Department of Astronomy, University of Padova, Italy
\textsuperscript{2} School of Physics & Astronomy, Tel Aviv University, Israel

Abstract. MASYS is the AKARI spectroscopic survey of Symbiotic Stars in the Magellanic Clouds, and one of the European Open Time Observing Programmes approved for the AKARI (Post-Helium) Phase-3. It is providing the first ever near-IR spectra of extragalactic symbiotic stars. The observations are scheduled to be completed in July 2009.

1. Introduction

Symbiotic stars (hereafter SSs) are long-period interacting binaries composed of a hot compact star - generally but not necessarily a white dwarf - and an evolved giant star, whose mutual interaction via accretion processes is at the origin of extended emission recorded from radio to X-rays. Nowadays, 173 Galactic SSs are known, plus 26 suspected ones (Belczynski et al. 2000). Nonetheless, this value is in striking contrast with the predicted total number of SSs in the Galaxy that, according to different estimates, oscillates between $3 \times 10^3$ (Allen 1984) and $4 \times 10^5$ (Magrini et al. 2003). The actual consistency of symbiotic population is thus a key-point to be investigated and has recently triggered specific observational campaigns (Corradi et al. 2008).

Whatever the case, SSs represent unique laboratories for studying a variety of important astrophysical problems and their reciprocal influence: e.g. nova-like thermonuclear outbursts (Munari et al. 1997), formation and collimation of jets (Tomov 2003), PNe morphology (Corradi 2003), and variable X-ray emission (Mukai et al. 2007). As binary systems, they offer a powerful benchmark to study the effect of binary evolution on the nucleosynthesis, mixing and dust mineralogy which characterize the AGB companion, likely different from what expected in single AGB stars (Marigo et al. 2007, 2008); moreover, they have even been proposed as potential progenitors of Supernovae Ia (Munari et al. 1992; Hachisu et al. 1999, Lv et al. 2009).

The energetics operating these binaries is a basic ingredient for a meaningful understanding of the physical processes at work in SSs, but it relies on accurate knowledge of the distance. Unfortunately, the distances to Galactic SSs are largely uncertain, preventing reliable calibration of absolute stellar luminosities. As a matter of fact, such luminosities are of vital importance for evaluating the evolutionary status of SSs and the energy budget involved in the observed outbursts.

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2. Extragalactic Symbiotic Stars

The specific stellar nature of symbiotic systems places them amongst the intrin-
sically brightest variable stars, easily detectable in nearby galaxies, in particular
in the Magellanic Clouds (hereafter MCs). At present, 17 extragalactic SSs are
known, 14 of which belonging to the MCs: 6 in the Small and 8 in the Large
MC. It is clear that observations of Magellanic SSs remove the primary ambi-
guity in studying these interacting stars, namely the lack of reliable distances.
It has even been suggested to use them as standard candles for the calibration
of Galactic objects (Vogel et al. 1994), as already done with Novae.

Magellanic SSs (hereafter MSSs) are also interesting in themselves, because
they differentiate from Galactic SSs in several aspects. SSs were classified into
S- and D-types according to whether the cool star (S-type) or dust (D-type)
dominated the near-IR spectral range (Webster & Allen 1975). In our Galaxy,
D-type SSs host invariably a Mira variable, while RGB stars are generally found
in S-types. As their Galactic cousins, MSSs contain low mass ($\leq 3 M_\odot$) giants
as cool components. However, in MSSs, only AGB stars are found (Kniazev et
al. 2009). In LMC, 4 out of 8 SSs are classified as D-type systems (50%, much
higher than the Galactic ratio of $\sim 20\%$), while no D-types have been found in
SMC. These results are intriguing, because S-type Galactic SSs rarely contain
AGB stars. Furthermore, the position in the H-R diagram of the hot component
reveals that in MSS they are amongst the hottest and the brightest within
the known symbiotic population (Mikolajewska 2004, Fig.2c). It is probable
that some of these results stem directly from the nature of the present sample,
strongly biased toward the brightest objects we have been able to detect so far.

Nevertheless, it is remarkable that the lack of dusty SSs in SMC may some-
how reflect the very low Z in SMC, and that the Galactic SS with the lowest mea-
sured Z $\sim 0.002$ - AG Dra - is also amongst the hottest systems. Another point
that makes MSSs interesting to study is that they offer a direct determination of
chemical abundances in extragalactic giants, being the chemical composition of
the cool component reflected in the emission line spectrum of the nebula (Nuss-
baumer et al. 1988). In the past years, this opportunity triggered several studies
which, thanks to sparse X/UV/optical observations, tempted to constrain the
nebular conditions and the chemical abundances of MSSs (Vogel et al. 1994,
1995; Mürset et al. 1996), leading to surprising yet unconfirmed results. For
example, the nebular chemistry and dynamics as derived from the N and Ne
emission lines suggest in some objects a recent mixing of stellar winds in the
interbinary interaction zone that might be representative of a recent outburst
activity; while the already mentioned lower Z in MCs with respect to Galactic
values, along with the suggestion that in several MSSs silicon seems not to be
depleted (Vogel et al. 1994), have been presented as an indication that none of
these systems would have an appreciable amount of dust. Today, this interpre-
tation appears too simplistic, as it has been shown that dust can actually form
also at low metallicity (also in the same MCs, van Loon et al. 2008; Matsuura
et al. 2009), and even in potentially adverse conditions like those found within
strongly shocked environments (Williams 2008).

The issue is that any metallicity effect on the symbiotic phenomenon is vir-
tually unknown.
Therefore, it sounds as a kind of a paradox that the only wavelength range where a single spectrum may allow a direct investigation of nebular conditions, chemical abundances of stellar components, and dust grain properties such as temperature and composition - namely the Infrared - is also the one for which there is no data. The same classification between S- and D-type SSs, that by original definition was introduced accordingly to the SED profile in the range 1-5 $\mu$m, in the case of MSSs is established rather tentatively on the basis of a few optical emission line ratios, relying on the fact that a larger binary separation (as in D-types) should turn into a lower electron density.

3. **MASYS**

The *AKARI* ([Murakami et al. (2007)](murakami2007)) spectroscopic survey of MAgellanic SYmbiotic Stars (MASYS – Phase-3 approved proposal in the European Time – PI: Angeloni) is observing the whole sample of known MSSs (Table 1) in both the moderate (NP) and high resolution (NG) spectroscopic mode of IRC ([Onaka et al. (2007)](onaka2007)). We emphasize that these observations will provide the first ever NIR spectra of Symbiotic Stars in the Magellanic Clouds, giving a fundamental and unique contribution to the understanding of the symbiotic phenomenon in its diverse appearance and, in general, of dust properties in complex environments at different metallicity. Bearing in mind the diverse morphology of symbiotic spectra in this wavelength region, at the present time only hypothesis can be made about the detectable spectral features we are going to detect. Hopefully, these data would allow, among others, 1) to look for photospheric molecular bands (e.g. OH, HCl, H$_2$O, CO), that can inform about the nature of the cool component, so far mainly inferred by means of optical spectra; 2) look for emission lines (e.g. [Si VII]2.48$\mu$m, [Fe VII]2.62$\mu$m, HBr$\gamma$ 2.626$\mu$m, [Mg IV]4.49$\mu$m, [Ar VI]4.52$\mu$m) which help constrain the physical conditions in the photoionized, shocked nebula (as done for Galactic SSs in Angeloni et al. 2007a); 3) look for specific dust bands, whose strengths and profiles are capable of revealing the chemical composition of dust grains and the physical conditions of the dust condensation environment (Angeloni et al. 2007a,b).

**MASYS** observations are scheduled to be completed in July 2009.

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Table 1. Magellanic symbiotic stars in the literature.

| Symbiotic name  | Coordinates α [J2000] δ | Type | K mag. | Integrated flux in the K band [mJy] |
|-----------------|---------------------------|------|--------|-----------------------------------|
| SMC 1           | 00:29:10.800 -74:57:39.91 | S    | 12.64  | 5.86                              |
| SMC 2           | 00:42:47.975 -74:41:59.88 | S    | 13.10  | 3.83                              |
| SMC 3           | 00:48:20.05 -73:31:52.2  | S    | 10.80  | 31.9                              |
| SMC-N60        | 00:57:05.867 -74:13:16.27 | ?    | 12.62  | 5.99                              |
| LIN 358        | 00:59:12.259 -75:05:17.50 | S    | 11.46  | 17.3                              |
| SMC-N73        | 01:04:39.289 -75:48:24.78 | S    | 11.6a  | 15.3                              |
| LMC-S154       | 04:51:50.3 -75:03:36     | D    | 10.1a  | 60.8                              |
| LMC-S147       | 04:54:04.6 -70:59:34.0   | S    | 11.9a  | 11.6                              |
| LMC-N19        | 05:03:24.0 -67:56:35.0   | ?    | -      | -                                 |
| LMC 1          | 05:25:01.080 -62:28:48.67 | D    | 10.71  | 34.8                              |
| LMC-N67        | 05:36:07.653 -64:43:22.46 | S    | 11.4a  | 18.04                             |
| Sanduleak's star | 05:45:19.741 -71:16:07.08 | D    | 13.0a  | 4.21                              |
| LMC-S63        | 05:48:43.502 -67:36:10.60 | S    | 11.33  | 19.6                              |
| SMP LMC 94     | 05:54:10.4 -73:02:39     | ?    | -      | -                                 |

a from Belczynski et al. 2000;
b from 2MASS.

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