

The Local Group Symbiotic Star Population and their Weak Relation with Type Ia Supernovae

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Abstract. Here we study the symbiotic stars (SySt) population and its relation with type Ia supernovae (SNe Ia) in the galaxies of the Local Group. SySt are low- and/or intermediate-mass evolved binary systems where a white dwarf (WD) accretes mass from a giant star. A fraction of these WDs can become massive enough to reach the Chandrasekar mass. Therefore, SySt have been considered as potential SNe Ia progenitors. Taking two approaches, one empirical and another statistical, we estimated the SySt population on the Galaxy as having a minimum value of 1.69×10^3 and a expected one of 3.23×10^4 . For Local Group dwarfs galaxies, the computed SySt population ranges from 2 to 4 orders of magnitudes lower. Concerning the SNe Ia with SySt progenitors, our general result is that SySt are not the main SNe Ia progenitors. On the other hand, we still expect that about 0.5–8% of the SNe Ia have symbiotic progenitors in the Milky Way, while the majority of the – low-mass – dwarfs galaxies did not experience a symbiotic type Ia supernova.

Resumo. Apresentamos aqui um estudo da população de estrelas simbióticas (SySt) e sua possível relação com supernovas do tipo Ia (SNe Ia) nas galáxias do Grupo Local. SySt são sistemas binários evoluídos constituídos de estrelas de massa baixa e/ou intermediária, onde uma anã branca (WD) acumula massa de uma estrela gigante. Uma fração dessas WDs pode se tornar massada o suficiente para atingir a massa de Chandrasekar. Portanto, as SySt são consideradas como potenciais progenitoras de SNe Ia. Tomando duas abordagens, uma empírica e outra estatística, derivamos a população SySt na Galáxia como tendo um valor mínimo de $1,69 \times 10^3$ e um valor esperado de $3,23 \times 10^4$. Para galáxias anãs do Grupo Local, os valores correspondentes são de 2 a 4 ordens de grandeza menores. Em relação às SNe Ia com SySt como progenitoras, obtemos, como resultado geral, que as SySt não são as principais progenitoras de SNe Ia. Por outro lado, ainda esperamos que cerca de 0.5–8% das SNe Ia tenham progenitores simbióticos na Via Láctea, enquanto a maioria das galáxias anãs – de baixa massa – não experimentou SNe Ia provenientes de SySt.

Keywords. Binary Stars: Evolution – Symbiotic Stars – Type Ia Supernovae

1. Introduction

Binary star systems can evolve in different ways, which primarily depend on the stars' zero age main sequence (ZAMS) masses, their initial orbital separation and eccentricity (Benacquista 2013). Since a small difference in mass can lead to differences in evolutionary timescales during the main sequence (MS), one of the stars in a binary system will evolve first. If one of the stars becomes a giant and fills its Roche lobe (Roche lobe overflow – RLOF), it will cause a flow of matter from the so-called donor star to its companion. The evolution of the RLOF binaries can be stable or unstable, depending on the donor's envelope structure (radiative or convective), and on the mass ratio of the system (Ge et al. 2010). Stable systems will only experience a change in mass ratio, due to the mass flow and accretion on the companion. However, in unstable systems the feedback of the mass-loss on the effective Roche lobe radius (R_L) and on the envelope of the donor star leads to the disruption of its envelope and the engulfment of the companion, so the system enters a common envelope (CE) phase (Paczynski 1976; Ge et al. 2010). The CE evolution can result in the merge of the stars or in the ejection of the envelope, producing a close evolved binary (Paczynski 1976). In systems without RLOF, the mass transfer is limited to a fraction, due to stellar winds, and the components evolve more likely as if they were single star systems.

Binary stellar evolution can lead to the formation of symbiotic stars (SySt), which are evolved systems composed by low- and/or intermediate-mass stellar objects. In the typical configuration of SySt a white dwarf (WD) accretes matter from a red giant branch (RGB) or asymptotic giant branch (AGB) star, mostly

via winds (Kenyon 2008). However, there are evidences for SySt that have distorted giants, probably because of Roche lobe filling (Mikołajewska 2003). Since SySt have accreting WDs, they have been considered as potential progenitors of type Ia supernovae (SNe Ia; e.g. Kenyon et al. 1993; Liu et al. 2019; Iłkiewicz et al. 2019). However, many SySt have low mass WDs, with RS Oph and T CrB being known exceptions (Mikołajewska 2013), which is a counterargument regarding this type of SNe Ia progenitor. Nevertheless, the fraction of SySt with massive enough ($\geq 1.1 M_\odot$) WDs can be considered as promising progenitors of SNe Ia, contributing to the observed SNe Ia rate.

Our goal with this study is to characterize the binary systems with ZAMS properties compatible with the observed evolved of SySt. Then determine the evolutionary paths these systems could have taken, to reach their expected population in the Galaxy and in Local Group dwarf galaxies. This knowledge, combined with our statistical procedure, allows us to find the fraction of SySt with the minimum requirements to be considered progenitors of SNe Ia.

2. Lower Limit of Milky Way's SySt Population

The lower limit in the Milky Way (MW) is obtained by studying the distribution of SySt, as a function of the Galactic height. Right ascension (RA), declination (Dec) and distance from Akas et al. (2019) and the updated online catalog of SySt (Merc et al. 2019) were used to determine the distribution that better describes the data. After transforming the coordinates to the galactocentric ones, (X_G, Y_G, Z_G), and from a series of statistical tests – maximization of log-likelihood, KS, and least squares – we

found that the best representation of the parametrized distribution is a Laplace distribution. From this distribution, we recover the scale height of the Galactic SySt as being $h = 0.654$ kpc.

The above derived parameters allow, via projection of the data on $Z_G = 0$ kpc, to compute the 1σ and 2σ data dispersion ellipses. Through the combination with the scale height of the disk, H , we computed the central SySt density of the MW, $n_0 \sim 1.0\text{--}2.7$ kpc $^{-3}$. This is the central value because it refers to the density at $Z_G = 0$ kpc. The lower limit for the SySt population, N_{\min} , is then given by the integration of the distribution, scaled with n_0 , in the Galaxy's volume, assuming cylindrical symmetry.

We used two values for the MW's disk radius, R_G . The first as four times the scale length of the thin disk, $R_G = 4h_d$, and the other as the truncation radius, $R_G = R_{\text{trunc}}$. Here, $h_d = 2.0\text{--}3.8$ kpc and $R_{\text{trunc}} = 16.1 \pm 1.3$ kpc are given by Amôres et al. (2017). With these values, we found $N_{\min} \sim (1.2\text{--}2.8) \times 10^3$, and for the best fit of 1.69×10^3 as the SySt population in the Galaxy.

3. Statistical Binary Evolution and Expected SySt Population

Our second approach to the problem of counting SySt in the LG relies on the use of observed properties of binary stars. Using them, we can statistically infer which evolutionary channel a given binary will follow in its evolution. From this approach, we can extract the population of SySt. To this end, three steps are needed: 1) finding the ZAMS physical characteristics a binary need to have to evolve to SySt; 2) statistically evolve this ZAMS fraction using pre-defined channels (e.g. Han et al. 2020; Lü et al. 2006); and 3) defining a parameter to scale the fraction computed with the expected population.

3.1. ZAMS Parameters

Since the stars in SySt are evolved stars and of initial low- and/or intermediate-mass ($\sim 0.8\text{--}8.0 M_\odot$), we need to restrict our analysis to this subset of systems. The first important constraint is on the minimum mass, because both stars of the system need enough time to evolve into giant dimensions, in a timescale lower than the age of the Universe, which defines a threshold mass (M_{thr}). The values $M_{\text{thr}} = 0.86\text{--}0.90 M_\odot$ are derived from the MS evolutionary timescale (Harwit 2006), taking the reionization era epoch ($\sim 13.3 \times 10^9$ yr; Schneider 2015) as an upper boundary.

The second ZAMS parameter is a restriction on the mass ratio of the systems. It is defined as $q_{\text{cut}}(M_1) := M_{\text{thr}}/M_1$, being M_1 the primary mass, with mass ratio defined as $q := M_2/M_1$ ($M_2 \leq M_1$). This restriction is used to discard ZAMS binaries with $M_2 < M_{\text{thr}}$.

The third ZAMS parameter is the maximum orbital separation a_{max} . The latter is used to discard very wide binaries, which will basically evolve as the stars were singles. Kepler's third law, as a function of the primary mass (M_1) and mass ratio (q), give us the maximum orbital separation, $a_{\text{max}}(M_1, q)$, setting a maximum orbital period, P_{max} , as a fixed parameter. Given that this is a very uncertain parameter, we use a range of values $\log(P_{\text{max}}) \in [3.6, 4.2]$ (P_{max} in days), based on the largests orbital periods known for SySt (R Aqr: $\log(P) = 4.1$ – Gromadzki & Mikołajewska 2009; RR Tel: $\log(P) = 5.0$ – Hinkle et al. 2013). Note that the orbital periods can increase or decrease during the system's evolution.

From Kroupa's initial mass function (IMF; Kroupa 2001) for the primaries, $\xi(M_1)$ – for which we assume that all systems are

resolved –, a binary fraction, $f_{\text{bin}}(M_1)$ (Duchêne & Kraus 2013), and the mass ratio and separation distributions ($\zeta(q)$ and $\zeta(a)$ – Duchêne & Kraus 2013), the fraction of ZAMS binaries with the desired physical characteristics is

$$f_{\text{bin}}^* = \int_{M_{\text{thr}}}^8 \xi(M_1) f_{\text{bin}} \left[\int_{q_{\text{cut}}}^1 \zeta(q) \left(\int_{a_{\text{min}}}^{a_{\text{max}}} \zeta(a) da \right) dq \right] dM_1. \quad (1)$$

3.2. Binary Evolution Channels

Having defined the initial population of binaries, we need to statistically consider their evolution. This is made considering three evolutionary channels:

- I. The primary fills its Roche lobe during the MS phase;
- II. The primary fills its Roche lobe during the giant (RGB or AGB) phase;
- III. There is no RLOF during the entire evolution of the primary.

The selection of the channel for a given ZAMS binary is made by using the effective Roche lobe radius (R_L ; Eggleton 1983)

$$\frac{R_L}{a} \equiv x(q) = \frac{0.49 q^{-2/3}}{0.6 q^{-2/3} + \ln(1 + q^{-1/3})}, \quad (2)$$

and the expected radii of the primary (R_φ), which is computed as the temporal mean of the radius in a given evolutionary phase φ : MS, RGB, or AGB. The condition for RLOF is set as $R_\varphi(M_1) = R_L$, which then gives the restriction on the separation for each of the above channels as $a_{\text{cut},\varphi}(M_1, q) = R_\varphi(M_1)/x(q)$.

The RLOF in channels I and II can lead to a stable or unstable evolution, depending, strictly, on M_1 and q . The critical mass ratio, $q_{\text{crit}}(M_1)$, is computed in channel I based on Ge et al. (2013), and on channel II based on Chen & Han (2008), where we reconstruct $q_{\text{crit}}(M_1)$ with the assumptions made in this work. If $q \equiv M_2/M_1 > q_{\text{crit}}$ the system will have a stable RLOF, on the other hand, if $q < q_{\text{crit}}$ then the RLOF will be unstable.

The evolution through channel I can lead to a direct merger, a contact binary, or to a MS + He-WD (helium white dwarf) system, in the minority of cases. Since without a simulation we can't say exactly the fraction of MS + He-WD systems formed, we introduce a free parameter, $f_\ell^{(I)}$, to stand for this uncertainty. The idea is that the evolution of the secondary, for MS + He-WD systems, can lead to SySt ($f_\ell^{(I)}$ also takes it into account). Channel I gives the function $f_{\text{evol}}^{(I)}(M_1)$, which describes the fraction of ZAMS systems that becomes SySt, as a function of M_1 , through the evolution described.

Evolution through channel II is divided in four sub-channels: RGB and AGB, stable or unstable; where RGB or AGB indicates that the ZAMS binary will fill its Roche lobe during RGB or AGB phases, and stable or unstable refers to their evolution during RLOF. Stable RLOF will lead to the formation of MS + WD binaries, while unstable RLOF will form a CE. The evolution through the CE phase is dynamic and results in the merge of the stars or in the ejection of the envelope. The outcome of CE ejection is a close MS + WD system. If CE is present, another free parameter, $f_\ell^{(II)}$, related to the fraction of systems that do not merge, is introduced. The WD in both scenarios (stable or unstable RLOF) can have a dominant composition of He or C+O, depending on the mass of the Roche lobe filling star and on its evolutionary phase. Analogously to channel I, this channel returns a function $f_{\text{evol}}^{(II)}(M_1)$, for each of its sub-channels.

Channel III is the simplest one. It takes into account the ZAMS binaries that do not experience RLOF during the evolution of the primary. It is only limited by the parameter a_{\max} . Again, as channels I and II, this one returns the function $f_{\text{evol}}^{(\text{III})}(M_1)$.

Finally, all channels are brought together to compute the fraction of SySt formed:

$$f_{\text{ss}} = \int_{M_{\text{thr}}}^8 \frac{df_{\text{bin}}^*(M_1)}{dM_1} \sum_i f_{\text{evol}}^{(i)}(M_1) dM_1, \quad (3)$$

where the super index i in $f_{\text{evol}}^{(i)}$ refers to the evolutionary channel it represents.

3.3. The Scaling Parameter

To obtain the SySt population, from the relative fraction derived above, we adopt the approach given by Kenyon et al. (1993), which is based on formation rate of planetary nebulae (PNe). Thus, it is assumed that this rate closely represents the rate which stars with masses $> 0.6 M_{\odot}$ and $< 8 M_{\odot}$ complete their evolution. The scaling parameter is expressed as $\mathcal{N} = \mathcal{R}_{\text{PN}} \tau_{\text{ss}}$. Here $\mathcal{R}_{\text{PN}} = N_{\text{PN}}/\tau_{\text{PN}}$ is the formation rate of PNe and $\tau_{\text{ss}} \approx 5 \times 10^6$ yr (Kenyon et al. 1993) is the timescale of the symbiotic phenomenon. For the Galaxy, we use this PNe rate as a density and combine it with the volume, V , of the disk, as $\mathcal{R}_{\text{PN}} = V \nu_{\text{PN}} = 2\pi R_{\text{G}}^2 H \nu_{\text{PN}}$, where $\nu_{\text{PN}} \approx 2.4 \times 10^{-12} \text{ pc}^{-3} \text{ yr}^{-1}$ is the formation rate density of PNe (Phillips 1989).

For the Local Group dwarf galaxies, we use a bolometric absolute magnitude approach for \mathcal{R}_{PN} . The PN population in a galaxy can be associated with the so called α -ratio, which gives the number of PNe per unit bolometric luminosity of the galaxy (Buzzoni et al. 2006). Thus, the scaling parameter is given by

$$\mathcal{N} = \mathcal{B} \tau_{\text{ss}} L_{\odot, \text{bol}} \times 10^{0.4(M_{V, \odot} + \text{BC}_{\odot} - M_V - \text{BC})}, \quad (4)$$

being $\mathcal{B} \approx 1.8 \times 10^{-11} L_{\odot, \text{bol}}^{-1} \text{ yr}^{-1}$ the specific evolutionary flux (Buzzoni et al. 2006), $M_{V, \odot} = 4.85$, $\text{BC}_{\odot} \approx -0.1$, M_V the visual magnitude of the galaxies, and BC their bolometric correction (-0.2 ; Reid 2016).

3.4. Results for the Galaxy

Since the majority of the multiple star systems are binaries, according to (Duchêne & Kraus 2013), we adopt the binary fraction as the multiplicity frequency (MF); $f_{\text{bin}}(M_1) = \text{MF}(M_1)$. The MF gives the fraction of systems that are multiple, in this case as a function of the primary star's mass. We used the $\text{MF}(M_1)$ as given by (Duchêne & Kraus 2013).

From an analysis of their impact on the final results, the free parameters were fixed to $f_{\ell}^{(\text{I})} = 0.25$ and $f_{\ell}^{(\text{II})} = 0.5$. In comparison with $f_{\ell}^{(\text{II})}$ the parameter $f_{\ell}^{(\text{I})}$ changes very little the expected number of SySt (up to few percents; $\sim 4\%$). The choice for $f_{\ell}^{(\text{II})}$ is simply related to the difficulty in inferring a realistic value. As for $f_{\ell}^{(\text{I})} = 0.25$ we just assumed a non-dominant fraction, since the formation of SySt through channel I is unlikely. The metallicity to compute the stellar radii from models, per evolutionary phase, in the Galaxy, was an average of $Z = Z_{\odot} \approx 0.0134\text{--}0.0140$ from the models given by Lagarde et al. (2012) and Claret (2019).

Our main results for the Milky Way SySt are as in what follows: Figure 1 displays the relative contribution per channel; Figure 2 shows the expected chemical composition of the SySt's WDs found; and Table 1 gives the expected SySt population.

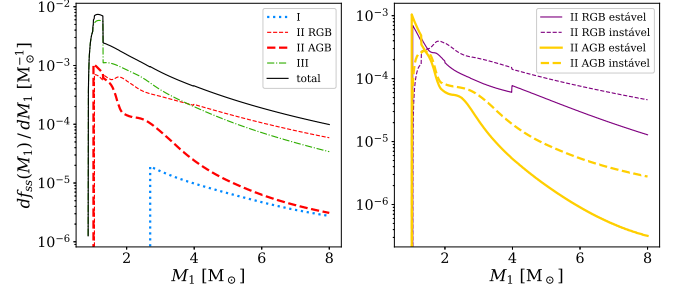


FIGURE 1. Example of the contribution from each evolutionary channel to f_{ss} density (in mass space). In the left panel, we have: the blue dotted line as channel I, the red thin dashed line as channel II RGB, the red thick solid line as channel II AGB, the green dash-dotted line as channel III, and the black solid line as the sum of them all. On the right panel we have the contributions from each subset of channel II: yellow for the AGB and purple for the RGB channel; solid lines for the stable components and dashed for the unstable ones. For this plot, we used fixed $Z = Z_{\odot}$, $\log(P_{\max}) = 4.2$, and $M_{\text{thr}} = 0.86 M_{\odot}$.

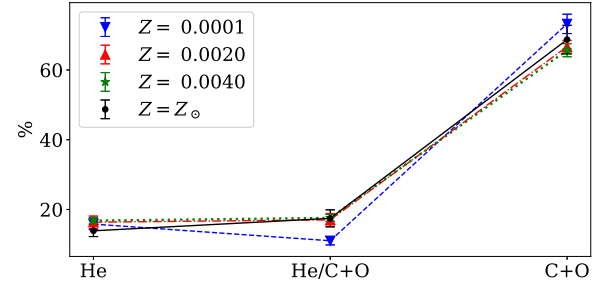


FIGURE 2. Composition of SySt's WDs obtained per metallicity model. The column He/C+O represents the percentage of SySt where we couldn't set an expected composition for the WD, or the composition is mixed

As with the empirical approach, when the disk dimension is set to $R_{\text{G}} = R_{\text{trunc}}$, the resulting SySt population is an upper limit. When using $R_{\text{G}} = 4h_d$ we get the better fit, since it follows from the behavior of the galactic disk. Therefore, our best fit implies 3.23×10^4 , with an upper limit of 6.18×10^4 , SySt in the Galaxy.

Comparing our results with other authors' (e.g. 3×10^5 – Munari & Renzini 1992; 3.3×10^4 – Kenyon et al. 1993; 4×10^5 – Magrini et al. 2003; $1.2\text{--}15.0 \times 10^3$ – Lü et al. 2006), we note that it is in agreement with the previous estimations, and it is also very close to the value obtained by Kenyon et al. (1993), when using $R_{\text{G}} = 4h_d$. This is not a coincidence, since we used an approach very similar to theirs in the computation of the scaling parameter. However, our stellar evolution considerations are more complex.

3.5. Results for the Local Group Dwarf Galaxies

We need to know the metallicity of the galaxies in order to study their Z -dependent characteristics. For that we use the converted $[\text{Fe}/\text{H}]$ to Z , adopting $Z = Z_{\odot} 10^{[\text{Fe}/\text{H}]}$ (see comment on table 6 of Mateo 1998), and assign, per galaxy, the stellar evolution model with the closest Z . From Lagarde et al. (2012) we have the following metallicities available: $Z = 0.0001$; $Z = 0.0020$; $Z = 0.0040$. The IMF from Kroupa (2001) and the mass ratio

TABLE 1. Results for the Galactic SySt population, given the different parameters.

	$M_{\text{thr}} = 0.86 M_{\odot}$		$M_{\text{thr}} = 0.90 M_{\odot}$	
	$R_G = 4h_d$	$R_G = R_{\text{trunc}}$	$R_G = 4h_d$	$R_G = R_{\text{trunc}}$
$\log(P_{\text{max}})$	N_{ss}	N_{ss}	N_{ss}	N_{ss}
$\log(\text{days})$	$[\times 10^4]$	$[\times 10^4]$	$[\times 10^4]$	$[\times 10^4]$
3.6	3.02 ± 0.30	5.82 ± 0.98	2.76 ± 0.28	5.32 ± 0.90
3.9	3.38 ± 0.34	6.50 ± 1.10	3.07 ± 0.31	5.91 ± 1.00
4.1	3.63 ± 0.36	6.98 ± 1.18	3.29 ± 0.33	6.34 ± 1.07
4.2	3.75 ± 0.37	7.23 ± 1.22	3.40 ± 0.34	6.56 ± 1.11

TABLE 2. The results for the LG dwarf galaxies and the chosen parameters. Morphological type and metallicity are given by McConnachie (2012), M_V by Reid (2016), and the known SySt population is given by the 2022 updated version of Merc et al. (2019) SySt catalogue.

galaxy	type	M_V [mag]	[Fe/H] [dex]	Z used [$\times 10^{-3}$]	f_{bin}	N_{ss}	known
LMC	Ir	-18.5	-0.5	4.0	0.30^{\dagger}	685–849	10
SMC	Ir	-17.1	-1.0	2.0	0.30^{\dagger}	187–232	12
NGC 205	Sph	-16.4	-0.8	2.0	$(0.25-0.55)^*$	82–223	1
IC 10	Ir	-16.3	-1.28	0.1	$(0.25-0.55)^*$	75–203	1
NGC 6822	dIr	-16.0	-1.0	2.0	$(0.25-0.55)^*$	56–154	1
NGC 185	Sph	-15.6	-1.3	0.1	$(0.25-0.55)^*$	40–107	1
IC 1613	dIr	-15.3	-1.6	0.1	$(0.25-0.55)^*$	30–81	0
NGC 147	Sph	-15.1	-1.1	2.0	$(0.25-0.55)^*$	25–67	0
WLM	dIr	-14.4	-1.27	0.1	$(0.25-0.55)^*$	13–35	0
Sagittarius	dSph	-13.8	-0.4	4.0	$(0.36-0.40)^{\ddagger}$	11–15	0
Fornax	dSph	-13.1	-0.99	2.0	$0.44^c-0.87^a$	7–17	0
Leo II	dSph	-10.1	-1.62	0.1	$0.33^b-0.36^a$	0	0
Sculptor	dSph	-9.8	-1.68	0.1	$0.58^a-0.59^c$	0–1	0
Sextans	dSph	-9.5	-1.93	0.1	$0.68^c-0.71^a$	0–1	0
Carina	dSph	-9.4	-1.72	0.1	$0.14^c-0.20^a$	0	0
Draco	dSph	-8.6	-1.93	0.1	0.50^a	0	1
Ursa Minor	dSph	-8.5	-2.13	0.1	0.78^a	0	0
Hercules	dSph	-6.6	-2.41	0.1	0.47^d	0	0
Leo IV	dSph	-5.5	-2.54	0.1	0.47^d	0	0

*: Range of values used on absence of observed ones.

† : Assumed based on the mean binary fraction value for LMC globular clusters (Milone et al. 2009), and in accordance with stellar formation history for SMC and LMC as commented by Rubele et al. (2011) and references therein.

‡ : Derived from radial velocity dispersion, but with high uncertainty (Bonidine 2022).

a: Spencer et al. (2018); b: Spencer et al. (2017); c: Minor (2013); d: Geha (2013).

and separation distributions from Duchêne & Kraus (2013) are also adopted here.

Table 2 contains the results obtained for the Local Group dwarf galaxies. We note that the expected value of the SySt population for this group is orders of magnitude lower than for the MW, which is expected, since, correspondingly, their masses are also orders of magnitude smaller. Moreover, from our analysis, the expected SySt population of a number of the LG dwarf galaxies is null. A way of interpreting these results is as an indicative that the formation rate of SySt, for the galaxies with $N_{\text{ss}} = 0$, is lower than the rate at which they cease to exist ($\sim 1/\tau_{\text{ss}}$). Draco is a good example of such an interpretation, since its SySt contradicts the expected value we obtained. For the remaining galaxies, the SySt population scales with their absolute magnitude in the V band, reaching a maximum of hundreds of SySt for the most luminous galaxies.

Magrini et al. (2003) also present results for the SySt population in some LG galaxies. However, they use an approach based on the galaxies' $K-B$ color to estimate their red giant population. Assuming that 0.5% of this population is in fact SySt. Their val-

TABLE 3. SNe Ia results. The second column gives the computed fraction of potential SySt progenitors. The third, the formation rate of symbiotic supernovae. And the fourth, the timescale between each supernova event.

galaxy	f_{prog} %	$r_{\text{SNe Ia-SySt}}$ [yr^{-1}]	Δt_{exp} [yr]
Milky Way	1.22–1.70	$(7.37-24.6)\times 10^{-5}$	$(4.05-13.6)\times 10^4$
LMC	4.00–5.28	$(5.48-8.94)\times 10^{-6}$	$(1.11-1.82)\times 10^5$
SMC	4.02–5.29	$(1.50-2.46)\times 10^{-6}$	$(4.06-6.64)\times 10^5$
NGC 205	4.82–6.35	$(0.79-1.29)\times 10^{-6}$	$(7.74-12.6)\times 10^5$
IC 10	2.74–2.92	$(0.86-1.12)\times 10^{-6}$	$(8.89-9.93)\times 10^5$
NGC 6822	4.82–6.35	$(0.55-0.89)\times 10^{-6}$	$(1.12-1.83)\times 10^6$
NGC 185	2.74–2.92	$(4.52-5.90)\times 10^{-7}$	$(1.7-1.9)\times 10^6$
IC 1613	2.74–2.92	$(3.43-4.48)\times 10^{-7}$	$(2.2-2.5)\times 10^6$
NGC 147	4.82–6.35	$(2.38-3.90)\times 10^{-7}$	$(2.56-4.19)\times 10^6$
WLM	2.74–2.92	$(1.50-1.95)\times 10^{-7}$	$(5.1-5.7)\times 10^6$
Sagittarius	3.34–3.96	$(7.22-11.90)\times 10^{-8}$	$(8.48-13.8)\times 10^6$
Fornax	1.82–2.74	$(3.78-6.17)\times 10^{-8}$	$(16.2-26.4)\times 10^6$
Leo II	4.19–4.35	$(2.85-3.72)\times 10^{-9}$	$(0.27-0.30)\times 10^9$
Sculptor	2.47–2.55	$(2.16-2.82)\times 10^{-9}$	$(0.35-0.39)\times 10^9$
Sextans	2.11–2.12	$(1.64-2.14)\times 10^{-9}$	$(0.46-0.52)\times 10^9$
Carina	7.53–10.25	$(1.50-1.95)\times 10^{-9}$	$(0.51-0.57)\times 10^9$
Draco	2.87–3.01	$(0.71-0.93)\times 10^{-9}$	$(1.19-1.07)\times 10^9$
Ursa Minor	1.84–1.93	$(0.65-0.85)\times 10^{-9}$	$(1.17-1.30)\times 10^9$
Hercules	3.05–3.21	$(0.11-0.15)\times 10^{-9}$	$(6.74-7.53)\times 10^9$
Leo IV	3.05–3.22	$(0.04-0.05)\times 10^{-9}$	$(18.6-20.7)\times 10^9$

ues are, in average, 100 times higher than ours. The discrepancy between their work and ours probably lies in the assumption of the 0.5% fraction, which can be interpreted as related with our \mathcal{N} parameter. Again exposing the difficulty in finding a proper scale for the SySt population, with respect to the total stellar population of a galaxy.

4. Can SySt be SNe Ia Progenitors?

This open question has been treated by a number of authors. A fairly good discussion with respect to this problem can be found, for example, in Mikołajewska (2013).

We can argue that WDs in SySt could accrete mass, from their giant companion, during the symbiotic phase, in a range of $0.05-0.25 M_{\odot}$ (Mikołajewska 2013). This implies that SySt with massive ($\gtrsim 1.1 M_{\odot}$) WDs could approach the Chandrasekhar mass limit ($M_{\text{Ch}} \approx 1.4 M_{\odot}$), then (possibly) experiencing nuclear instability and give rise to a SN Ia event, according to the classic SNe Ia model – see Hillebrandt & Niemeyer (2000) for a review.

From our statistical binary evolution algorithm, with the lower WD mass limit of $M_{\text{WD,min}} = 1.1 M_{\odot}$, we fixed an upper limit to the fraction of SySt that could potentially be SNe Ia progenitors (f_{prog}). We limit ourselves to channels II AGB and III, since they are the only ones that, certainly, will produce SySt with C+O WDs. The integration limit $M_1(M_{\text{WD,min}})$ gives the minimum ZAMS mass of a star that generate a $1.1 M_{\odot}$ WD, which was identified as $\sim 6.0 M_{\odot}$ using the initial-final mass relations (IFMR) given by Cummings (2018) and references therein. Thus, we compute the rate of SNe Ia with SySt progenitors as $r_{\text{SNe Ia-SySt}} = \mathcal{N} f_{\text{prog}} / \tau_{\text{ss}}$, and the respective timescale between consecutive SySt supernovae as $\Delta t_{\text{exp}} = 1/r_{\text{SNe Ia-SySt}}$. Table 3 displays the results.

We note that f_{prog} (Table 3) is, on average, higher for the Local Group dwarf galaxies than for the Galaxy. This is easily explained by the use of f_{bin} as a function of the primary mass for the Galaxy, but as a constant in the case of the LG dwarf galaxies. Since, in the Galaxy, the higher values MF are associated with the higher stellar mass population, which are the minority.

It is also interesting to note that the expected rate of SNe Ia from SySt is very low, even for the Galaxy. Considering the total SNe Ia rates estimated in the literature (e.g. $3 \times 10^{-3} \text{ yr}^{-1}$, Kenyon et al. 1993; $(5.4 \pm 1.2) \times 10^{-3} \text{ yr}^{-1}$, Li et al. 2011; $14.1_{-8.0}^{14.1} \times 10^{-3} \text{ yr}^{-1}$, Adams et al. 2013) we compute a contribution of about 0.5–8% from SySt to the SNe Ia rate. By comparing ours with the previous results, we conclude it is very unlikely that SySt are the main SNe Ia progenitors. Nevertheless, SySt still cannot be ruled out as SNe Ia progenitors in the classic SNe Ia formation scenario, because a fraction of them will have massive enough accreting WDs (RS Oph and T CrB are well known examples – Mikołajewska 2013).

Regarding the result for the Local Group dwarf galaxies, there exists the possibility that some of them experienced a SNe Ia from SySt during their evolution. At least in cases where $\Delta t_{\text{exp}} < 10^9 \text{ yr}$, since it is well restricted within the age of the Universe. For the remaining dwarf galaxies Δt_{exp} is too high, and we conclude that no SNe Ia from SySt has ever occurred on these galaxies.

5. Conclusions

This work is dedicated to the study of the population of symbiotic stars (SySt), with the goal of finding a robust way to estimate such population in the Milky Way and in the dwarf galaxies of the Local Group. Moreover, since SySt can satisfy the required characteristics for developing a SN Ia event, we used our own algorithm to compute this specific fraction of SySt.

Using observational data, we adopted two approaches for the SySt population, one empirical and the other theoretical. We found that the SySt population in the Galaxy has a minimum value of 1.69×10^3 , while its expected and upper limits are 3.23×10^4 and 6.18×10^4 , respectively. For the dwarf galaxies, the value obtained ranged from zero to hundreds of SySt, which depended mostly on their bolometric absolute magnitude, with a weaker dependence on their metallicity.

Regarding the SNe Ia, we obtained as a general result that SySt are not the main progenitors. Mostly due to the fact that the great majority of the WDs in SySt have masses below $1.1 M_{\odot}$. This implies that the accretion rates in SySt are insufficient for them to reach the M_{Ch} . However, we found that a small fraction of the total SySt population could be progenitor of SNe Ia: in the Galaxy $\sim 1.5\%$; and $\sim 3\%$ in the Local Group dwarf galaxies. By calculating the formation rate of SNe Ia with SySt as progenitors, we show that 0.5–8.0% of the SNe Ia in the Galaxy could come from SySt, and that most of the dwarf galaxies of the Local Group have not yet experienced SNe Ia from SySt.

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