

Products of AGB-star Mass Transfer Are Likely More Common in Stellar Streams Than Intact Systems

SAM A. USMAN ¹, NEWLIN C. WEATHERFORD ², AND MADELEINE MCKENZIE ²

¹Colgate University, 13 Oak Drive, Hamilton, NY 13346, USA

²Observatories of the Carnegie Institution of Washington, 813 Santa Barbara Street, Pasadena, 91101, CA, USA

ABSTRACT

A growing body of evidence suggests that disrupting stellar systems, such as tidally dissipating globular clusters, tend to host a comparatively high fraction of stars with chemical signatures of mass transfer from an asymptotic giant branch (AGB) companion, sometimes called Ba, CH, extrinsic S-type or (if metal-poor) CEMP-s stars. Such stars can serve as tracers of binary evolution in low-density environments and offer a novel means of exploring binary interaction. In this work, we investigate whether the conditions that favor the formation and long-term stability of binaries capable of AGB mass transfer also increase a stellar system’s vulnerability to tidal disruption by the Galactic potential. We present a literature survey of recent observations of AGB mass-transfer stars in different stellar systems and leverage these data to perform a probabilistic analysis demonstrating that it is extremely unlikely that these rates in stellar streams are a statistical anomaly. We estimate that the rate of these stars in stellar streams is $\sim 6\%$, approximately ten times more common than in globular clusters. We highlight the implications of our findings for upcoming photometric and spectroscopic surveys, recommending that future campaigns systematically search for chemical signatures of AGB mass-transfer stars in stellar streams and disrupting clusters.

1. INTRODUCTION

The chemical abundances of stars are generally determined by the composition of the molecular clouds in which they form and the nucleosynthetic processes within that star over the course of its stellar evolution. Asymptotic giant branch (AGB) stars, for example, are a late stage of stellar evolution in which heavier elements such as strontium, yttrium, zirconium and barium are typically formed through the slow neutron-capture process (*s*-process). However, stars in earlier stages of stellar evolution, such as red giant branch (RGB) stars, are occasionally found to contain highly enriched in *s*-processelements relative to other stars from the same system, despite not having the means to create *s*-processelements (I. Iben & A. Renzini 1983).

It is therefore assumed that these chemically peculiar RGB stars have received ejecta from a binary companion via mass transfer, which was in the AGB phase of its life cycle (I. Iben & A. Renzini 1983). As the stars of unequal mass evolve, the more massive of the two will evolve through core hydrogen and helium fusing phases, and reach the AGB phase prior to its smaller companion. The mass-transfer from the AGB can occur through three different mechanisms: standard Roche-lobe overflow (RLOF), Bondi-Hoyle-Lyttleton accretion (BHL), or *wind* Roche-lobe overflow (WRLOF). In the first situation, the AGB itself expands outside of its Roche lobe and accretes onto the companion as it grows. BHL accretion occurs when the binary is in a very wide orbit, resulting in the companion capturing some fraction of the AGB star’s stellar winds (Z. Chen et al. 2017; M. I. Saladino et al. 2019). WRLOF acts as a middle-ground between these two mechanisms, where the stellar winds from the AGB compan-

ion are funneled through the Lagrange point to the companion star (S. Mohamed & P. Podsiadlowski 2007). The more massive star will eventually lose all of its outer layers, and, in the present-day, may no longer be visible as an optically dim white dwarf star.

In this work, we refer to the chemically peculiar stars as *AGB mass-transfer stars* (AGB-MT stars). However, stars with these unique signatures have been found in many different contexts and masquerade under many different names depending on how they were found and for what purpose. These stars can be red giants, but also main sequence or sub-giant stars (the fact that to-date most AGB-MT stars observed are giants simply reflects a selection effect). One of the earliest iterations of these stars is referred to as an extrinsic S-type star. S-type stars were first defined by P. W. Merrill (1922) by their unique zirconium oxide molecular band (see also P. C. Keenan 1954; J. Piccirillo 1980). However, some S-type stars contain technetium, an unstable element whose half-life within massive stars is just 2×10^5 years. The occurrence of this short-lived element indicates that the observed S-type star is actively producing *s*-process elements, i.e. are currently in the AGB phase, and have *not* undergone mass-transfer (unless the mass-transfer had happened very, very recently, $< 50,000$ years). In I. R. Little-Marenin & S. J. Little (1979), the authors studied 90 spectra of late-type stars obtained from Kitt Peak observatory and found that many Tc absorption features. A few years later, J. M. Scalo & G. E. Miller (1981) found that 30% of these S-type stars contained *no* technetium, indicating the stars are neither in the AGB phase nor currently producing *s*-process elements. I. Iben & A. Renzini (1983) postulated that these stars had instead

received enhanced s -process material from an AGB binary companion.

CH stars or carbon stars were first defined by P. C. Keenan (1942) due to their marked absorption in molecular carbon bands such as CH, C₂ and CN, though their spectra also contained marked absorption in barium and strontium. Similar to these stars, the authors of W. P. Bidelman & P. C. Keenan (1951) note that some G- and K-type stars have significant barium absorption, but do not appear to be giant stars. They refer to these stars as *Ba stars*, and note that these appear related to both carbon stars and S-type stars. For a while, the cause for differences was not well understood; E. M. Buridge & G. R. Burbidge (1957) suggested temperature was the key difference between Ba stars and S-type stars, though we now know the difference is due to changes in metallicity (A. Jorissen et al. 1993).

Among metal-poor stars (i.e. stars with metallicity $[Fe/H] \leq -1$), there are some stars which exhibit either carbon- or nitrogen-enhancement (T. C. Beers et al. 1992). These metal-poor variants are therefore referred to as carbon-enhanced metal-poor (CEMP) or nitrogen-enhanced metal-poor (NEMP) stars, respectively. However, there are multiple mechanisms which can enhance carbon or nitrogen. CEMP and NEMP stars are thus broken up into different subcategories, including those that contain no enhancements to neutron-capture elements (CEMP-no) and those that contain elements like europium created through the rapid neutron capture process, or r -process (CEMP-r) (W. Aoki et al. 2002). The metal-poor AGB-MT stars are therefore the subset of these stars which additionally contain s -process elements, denoted CEMP-s or NEMP-s stars. Additionally, a smaller number of stars are enhanced in both s -process and r -process elements, and are denoted CEMP-s/r. These may also be the result of AGB-MT, and are often classified with CEMP-s stars.

Despite their variety of names, all of these stars enhanced in both carbon and s -process elements (extrinsic S-type, CH, carbon, Ba, CEMP-s and NEMP-s), are considered the result of AGB-MT (A. Jorissen et al. 2019). The AGB binary mass-transfer process as a solution to explain the overabundances of these chemically peculiar stars (I. Iben & A. Renzini 1983). Later studies showed these stars are commonly found in binary systems, supporting the scenario where a now-extinct AGB companion transferred enriched material via Roche-lobe overflow or wind accretion (G. W. Preston & C. Sneden 2001; C. Sneden et al. 2003; S. Lucatello et al. 2005). Radial velocity monitoring has shown that a large number of CEMP-s / CH / Ba stars are in binary systems, consistent with a past AGB-MT event, while CEMP-no stars show no consistent pattern of binarity, underlining their different chemical histories (E. Starkenburg et al. 2014; T. T. Hansen et al. 2016).

When first identified decades ago, AGB-MT stars were considered very rare, but more recent studies have found them at higher rates. D. J. MacConnell et al. (1972) estimated that they occur at a rate of about $\sim 1\%$ in G and K giant stars near the Sun. R. E. Luck & H. E. Bond (1991)

similarly found that AGB-MT subgiants occur at a rate of about $\sim 1\%$.

In the search for AGB-MT stars, many studies generally identify CEMP stars, then use s -process enhancement to categorize CEMP-s (or CEMP-r/s) and CEMP-no stars. More recently, V. M. Placco et al. (2014) studied CEMP-no stars in the halo using publicly available spectroscopic data. While filtering out extrinsic AGB-MT stars, the authors found about half of identified CEMP halo stars were in fact CEMP-s, at a rate of about 13%. Similarly, J. Yoon et al. (2018) identify CEMP-s stars using AAOmega spectroscopy, finding that their rate does not change significantly as a function of metallicity, with fractions staying roughly around $\sim 10\%$ between $-4 < [Fe/H] < -1$.

For giants, however, it appears the rate is similar: (H. Li et al. 2022) found in a study of 192 metal-poor giants, 0.5% are enhanced in s -process elements. The same study found that among turnoff stars the rate increases significantly, with 5.8% of metal-poor turnoff stars being s -process-enhanced. The authors suggest that the envelopes of giant stars could dilute contributions from AGB companions, resulting in the lower rate of CEMP-s stars among giants relative to turnoff stars. More recently, among stars observed by the Galactic Archaeology with Hermes (GALAH) survey (S. Buder et al. 2025), $\sim 0.6\%$ of stars contain the chemical fingerprint of AGB-MT (though this does not account for selection effects; J. Levine et al. 2026).

However, these rates appear largely dependent on the environment in which they're found. Almost half a century ago, R. D. McClure & J. Norris (1977) noted a tendency for AGB-MT stars to occur in low central concentration clusters relative to denser clusters. This reflects the higher survival rates of binary systems in low-density environments. Indeed, binary stars are disrupted very easily in dense environments like globular clusters (GCs; C. J. Lada & E. A. Lada 2003). AGB-MT stars are thus even more uncommon inside GCs, with some surveys estimating of a rate of about $\sim 0.4\%$ (V. D'Orazi et al. 2010).

It has therefore been an unexpected discovery that recent chemical analyses of disrupted GCs appear to have a comparatively high rate of AGB-MT stars: for example, an AGB-MT star was found among a sample of just eight red giant branch members of the 300S stellar stream (S. A. Usman et al. 2024). Again, more recently, the GD-1 stellar stream was also found to contain an AGB-MT star (J.-K. Zhao et al. 2025; S. A. Usman In Prep) in a total sample of 12 stars. This may indicate that the low-mass, low-density GCs which dissolve into stellar streams are an ideal environment for the survival and evolution of AGB-MT stars.

In this paper, we take a three-pronged approach to revealing AGB-MT stars in GC stellar streams: first, in Section 2 we perform a literature survey of chemical analyses of GC stellar streams and look for stars which have identified overabundances of s -process elements. We calculate the probability of identifying multiple AGB-MT stars, assuming a rate similar to the field ($\sim 1\%$). We then estimate the rate

of AGB-MT in stellar streams, given current observations. We discuss our conclusions and in Section 4.

2. AGB MASS-TRANSFER STARS IN STELLAR STREAMS

Chemical analyses of GC stellar streams have become increasingly common in recent years, due in part to the identification of these streams using the *Gaia* survey (Gaia Collaboration et al. 2018; K. Malhan & R. A. Ibata 2018; A. P. Ji et al. 2020; R. Ibata et al. 2024). Here, we compile current chemical analyses of GC stellar streams which specifically measure *s*-process elements such as barium and strontium. Table 1 lists the full compilation of systems, including GC streams, dwarf galaxy streams, intact GCs and the field. Here, we exclude stellar streams at metallicities below $[\text{Fe}/\text{H}] < -3.0$, as studies such as J. Yoon et al. (2016) found that CEMP-no stars dominate at $[\text{Fe}/\text{H}] < -3.0$, while most CEMP-s/r stars occur above this metallicity.

2.1. Probability of Observing an AGB Mass-transfer Star

To ensure our measured rate is not an accidental occurrence, we calculate the probability of identifying the same number of AGB-MT stars in the total sample assuming the rate matches that of intact GCs. We assume the cluster is a simple binomial distribution, with a given rate of AGB-MT stars, θ . The probability of finding X AGB-MT stars in a sample of n stars would therefore be:

$$p(y|\theta) = \theta^X (1-\theta)^{n-X} \binom{n}{X}. \quad (1)$$

To calculate the significance of this detection, we calculate the probability of observing fewer than X stars:

$$p(< X|\theta) = \sum_{i=0}^{X-1} p(i|\theta) = \sum_{i=0}^{X-1} \theta^i (1-\theta)^{n-i} \binom{n}{i}, \quad (2)$$

then take the complement to find the probability of identifying X stars or more:

$$p(\geq X|\theta) = 1 - p(< X|\theta). \quad (3)$$

We apply this calculation to GC streams with $[\text{Fe}/\text{H}] \geq -3$, as described in Table 1. Among the 48 stars chemically tagged in GC stellar streams, three have been identified as AGB-MT stars. If we assume the rate of AGB-MT stars in streams matches the rate observed in intact GCs, $\sim 0.4\%$ (V. D’Orazi et al. 2010), the probability of identifying three or more AGB-MT stars is approximately 0.01%. It is therefore extremely unlikely that these stars are at a higher rate from a statistical anomaly alone.

We next calculate the observed rate of AGB-MT stars within GC stellar streams. We measure the likelihood of identifying X AGB-MT stars in a sample of n stars:

$$\mathcal{L}(\theta|X) = \theta^X (1-\theta)^{n-X} \binom{n}{X}. \quad (4)$$

We sample the likelihood with θ varying from 0 to 1, and find the most likely rate is $6\%_{-2}^{+5}$, more than ten times more likely than the rate of AGB-MT stars in intact GCs. Observing and chemically tagging GC stream stars will allow us to increase our sample size and more tightly constrain this rate.

We additionally calculate the observed rate of AGB-MT stars within each GC stream. For streams in which an AGB-MT star is found, we use the same method as above to calculate the predicted interval for each stream. For streams in which no AGB-MT stars are found, we estimate the fraction using a Jeffreys interval with 1σ confidence. The results of these interval estimates are displayed in Fig. 1. We show a clear higher fraction of AGB-MT stars among fully disrupted globular clusters relative to intact systems.

2.2. Selection Biases

Our estimated rates of AGB-MT stars within streams may *underestimate* how often these stars appear due to selection biases. One of the key difficulties in cataloging and chemically tagging stellar streams is identifying stream member candidates among large datasets. Identifying streams often involves clustering large datasets such as the *Gaia* survey to find stars with similar ages and kinematic behavior. Two common culling techniques in particular may cause AGB-MT stars to be excluded: radial velocity and color cuts.

Stellar streams exhibit coherent kinematic signatures, with radial velocities that are either approximately consistent or vary smoothly along the stream. As a result, stars with inconsistent radial velocities with respect to other potential stream members are commonly rejected. However, AGB-MT stars are expected to reside in binary systems, where orbital motion can produce radial-velocity variations that temporarily shift a genuine stream member away from the expected velocity. As a result, radial-velocity-based membership criteria may preferentially exclude AGB-MT stars, introducing a potential selection bias against these systems.

Similarly, GC streams are expected to have similar chemistry and fall along the same isochrone in color-magnitude space. As previously discussed, the presence of carbon in AGB-MT stars causes significant absorption in the CH, CN and C_2 bands, which occur at bluer wavelengths around $\sim 4000\text{--}6000\text{ \AA}$. The loss of flux at these blue wavelengths gives AGB-MT stars a redder appearance, potentially shifting them outside the color-selection criteria used to identify candidate stream members. Combined with the radial-velocity variations described above, these color and kinematic selection criteria may therefore cause genuine AGB-MT stream members to be excluded from stellar stream observations.

Metallicity is also anti-correlated with binarity (D. Raghavan et al. 2010); the extreme metal-poor regime may therefore have a significantly different rate of AGB-MT star compared to higher-metallicity systems.

2.3. Mild *s*-process Enrichment?

Dwarf galaxy stream Elqui (denoted with $\dagger$) contains a star that has $[\text{Ba}/\text{Fe}] = +0.5$, 1.5 dex more abundant than the other

Table 1. Stellar Systems Containing AGB Mass-transfer Stars

GC Streams					
System	Observed Rate	N_{stars}	[Fe/H]	Density ($M_{\odot} \text{pc}^{-3}$)	Reference
300S	12.50%	8	-1.39	—	S. A. Usman et al. (2024)
Jet	14.28%	7	-2.38	—	A. Mura (In Prep)
GD-1	8.33%	13	-2.38	—	S. A. Usman (In Prep) & J.-K. Zhao et al. (2025)
ATLAS/Aliqa-Uma	0.00%	12	-2.45	—	A. P. Ji et al. (2020)
Phoenix	0.00%	8	-2.75	—	A. P. Ji et al. (2020)
Intact GCs					
System	Observed Rate	N_{stars}	[Fe/H]	Density ($M_{\odot} \text{pc}^{-3}$)	Reference
ESO 280-SC06	0.07%	1527	-2.47	0.73	J. D. Simpson & S. L. Martell (2019)
NGC 104 / 47 Tuc	0.91%	110	-0.74	2.61	V. D’Orazi et al. (2010)
NGC 288	1.33%	75	-1.22	1.26	V. D’Orazi et al. (2010)
NGC 1904 / M79	0.00%	49	-1.54	2.43	V. D’Orazi et al. (2010)
NGC 3201	0.00%	104	-1.46	1.55	V. D’Orazi et al. (2010)
NGC 4590 / M68	0.00%	93	-2.23	2.59	V. D’Orazi et al. (2010)
NGC 5904 / M5	0.00%	108	-1.35	2.43	V. D’Orazi et al. (2010)
NGC 6121 / M4	0.00%	80	-1.20	2.25	V. D’Orazi et al. (2010)
NGC 6171 / M107	0.00%	27	-1.07	2.15	V. D’Orazi et al. (2010)
NGC 6254 / M10	0.95%	105	-1.56	2.32	V. D’Orazi et al. (2010)
NGC 6397	0.97%	103	-1.99	2.50	V. D’Orazi et al. (2010)
NGC 6752	0.94%	106	-1.56	2.47	V. D’Orazi et al. (2010)
NGC 6809 / M55	0.00%	112	-1.97	1.88	V. D’Orazi et al. (2010)
	1.39%	72	—		G. S. Da Costa & T. Nordlander (2025)
NGC 6838 / M71	0.00%	29	-0.81	1.61	V. D’Orazi et al. (2010)
NGC 7078 / M15	0.00%	56	-2.34	3.09	V. D’Orazi et al. (2010)
NGC 7099 / M30	0.00%	48	-2.36	2.28	V. D’Orazi et al. (2010)
DG Streams					
System	Observed Rate	N_{stars}	[Fe/H]	Density ($M_{\odot} \text{pc}^{-3}$)	Reference
Elqui	25%	4	-2.44	—	A. P. Ji et al. (2020)
Indus	0.00%	7	-2.13	—	A. P. Ji et al. (2020)
Jhelum	0.00%	8	-2.17	—	A. P. Ji et al. (2020)
Orphan/Chenab	0.00%	3	-2.05	—	A. P. Ji et al. (2020)
Intact DGs					
System	Observed Rate	N_{stars}	[Fe/H]	Density ($M_{\odot} \text{pc}^{-3}$)	Reference
Sag dSph	0.9%	111	—		S. Vitali et al. (2025)
Field					
System	Observed Rate	N_{stars}	[Fe/H]	Density ($M_{\odot} \text{pc}^{-3}$)	Reference
Michigan Spectral Survey	0.5%		—	—	B. Warner (1965)
G & K Giants	1.0%		—	—	D. J. MacConnell et al. (1972)
Subgiants	1.0%		—	—	R. E. Luck & H. E. Bond (1991)
CEMP-s Halo, $-2 < [\text{Fe}/\text{H}] < -1$	$\sim 4-9\%$		—	—	J. Yoon et al. (2018)
CEMP-s Halo, $-3 < [\text{Fe}/\text{H}] < -2$	$\sim 8\%$		—	—	J. Yoon et al. (2018)
CEMP-s Halo, $-4 < [\text{Fe}/\text{H}] < -3$	$\sim 10\%$		—	—	J. Yoon et al. (2018)
CEMP-s Giants	0.5%	194	—	—	H. Li et al. (2022)
CEMP-s Turnoff	5.0%	172	—	—	H. Li et al. (2022)
GALAH Survey	0.6%		—	—	J. Levine et al. (2026)

NOTE—The Sagittarius dwarf galaxy has a widely variable metallicity ranging from $[\text{Fe}/\text{H}] = -2.0$ to $[\text{Fe}/\text{H}] = +0.5$ due to multiple bursts of star formation (M. H. Siegel et al. 2007). We therefore exclude its average metallicity from this table.

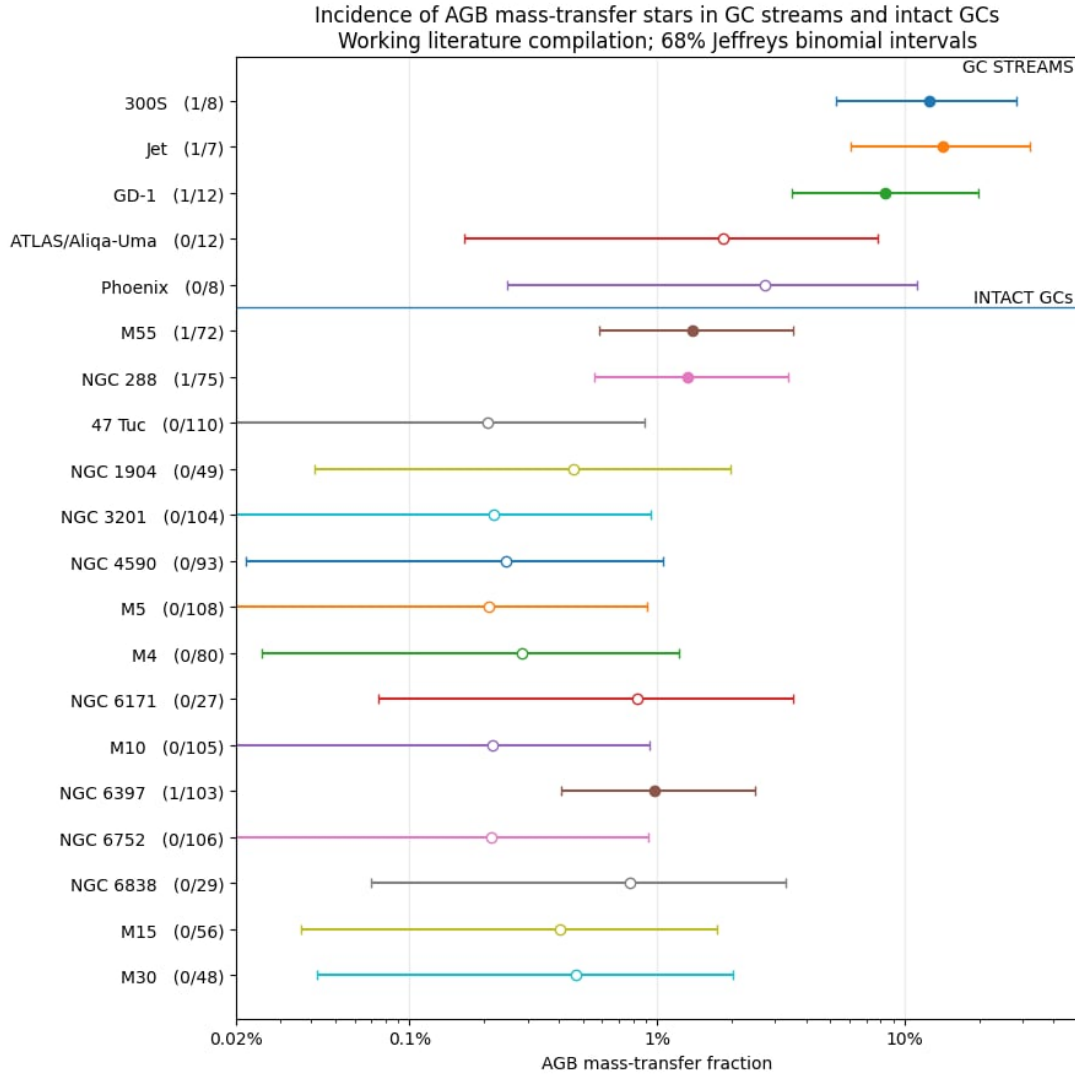


Figure 1. Estimated fraction of AGB-MT stars in different stellar systems given current observations. Systems with and without detected AGB-MT stars are represented with filled circles and hollow circles, respectively. Intervals are estimated using Jeffreys intervals. The predicted fraction of AGB-MT stars is predicted to be higher in globular cluster stellar streams than in intact clusters.

observed Elqui members. While the relative barium enrichment in this star compared to other Elqui members is as significant as the relative enrichment found in the 300S AGB-MT star, the absolute abundance of +0.5 is too low to generally be flagged as a barium star. This could be indicative of a need to compare AGB-MT stars to their own stellar systems, as absolute abundances may not be significant enough to immediately flag as an AGB-MT star. We similarly discuss this with the identification of C-enhanced stars in spectroscopic surveys in Subsection 2.4.

Alternatively, it may be worth considering what relative mild enrichment could teach us about AGB-MT. For example, due to the low barium abundance, we could consider the barium-enhanced Elqui star to be a "mild" AGB-MT star, indicating the enhanced AGB stellar material either did not transfer efficiently or was significantly diluted in the observed star. For example, if the binary was at a large distance, the mass-transfer may have happened inefficiently due to BHL accretion, resulting in less material transfer than in RLOF or WLROF. If the observed star was instead rather massive prior to receiving the accreted material, the AGB enhancement would be more diluted relative to the rest of the star.

2.4. Surveys

Recent efforts to look at the impact of binaries on galactic chemical evolution have lead to broad searches of optical surveys to identify potential AGB-MT stars. For example, the recent study (A. Arden-Arentsen et al. 2025) leveraged publicly-available low-resolution optical surveys such as *Gaia* XP (Gaia Collaboration et al. 2023) and the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST, X.-Q. Cui et al. 2012) in order to identify CEMP stars, assumed to be the results of AGB-MT. In this paper, the authors leverage the definition of CEMP as per W. Aoki et al. (2007) which defines a CEMP star as having $[C/Fe] > 0.7$ and $[Fe/H] < -2.0$. This boundary may ignore stars which exhibit significant evidence of enrichment relative to their peers, without reaching the cutoff in absolute abundance.

For example, the AGB-MT star in the 300S stellar stream has enhancement in Sr, Y, and Ba, all clear indications of having undergone AGB-MT, with significant enrichment compared to other stream members. The C abundance is also enhanced relative to its peers by about 0.65 dex, with an estimated significance of 2.8σ away from the cluster mean. The absolute carbon abundance, however, falls short of the $[C/Fe] > 0.7$ cutoff, at just $[C/Fe] = -0.09$. We therefore may require more nuance when identifying AGB-MT stars, specifically by identifying stars with high *relative* abundances rather than absolute abundances. Further identification of AGB-MT stars should prioritize stars within known systems, such as stellar streams and globular clusters.

Large-scale surveys may under-identify AGB-MT stars. For example, J. Yoon et al. (2018) identifies CEMP stars in the halo using medium resolution spectroscopy from AAOmega. The authors define CEMP-s stars as having

$[C/Fe] > +0.7$, $[Fe/H] < -1.0$ and $[Ba/Fe] > +1.0$, which again may discount stars such as the 300S AGB-MT.

2.5. An Exception: Omega Centauri

2.6. Future Observations

3. DISCUSSION

3.1. Theoretical Interpretation

There are good dynamical reasons to expect AGB-MT stars to be more prevalent in stellar streams than intact GCs. As pointed out by P. Côté et al. (1997); G. S. Da Costa & T. Nordlander (2025) to explain why AGB-MT stars appear most common in the most diffuse GCs, strong encounters in a GC's core are not conducive to survival of the wide binaries most likely to undergo AGB-MT. Repeated strong encounters in the core can either disrupt a binary before AGB-MT can occur, or shrink its semi-major axis (e.g., D. C. Heggie 1975) enough that common envelope occurs instead, preventing detectable enrichment of the accretor's surface. The rate at which encounters should shrink a binary's semi-major axis a at the center of a GC is (F. S. Phinney 1996)

$$\frac{d \ln a}{dt} \approx \frac{-2\pi G a \rho_c}{\sigma_c}, \quad (5)$$

4. CONCLUSION

In this paper, we have extensively discussed the observation of AGB-MT stars in GC stellar streams. We have shown that:

- the number of stars enhanced in carbon and s -process elements are statistically higher in GC stellar streams, at a rate of about $\sim 6\%$, compared to $\sim 0.6\%$ in field stars and $\sim 0.4\%$ in intact GCs

We may be underestimating the rate of AGB-MT stars due to selection effects, namely caused by radial velocity and color discrepancies in AGB-MT stars. Since these stars are in binary systems, their radial velocities may differ from the predicted value for the stellar stream. Similarly, the absorption in bluer wavelengths due to molecular carbon will make these stars appear redder than their peers. AGB-MT stars may therefore be rejected in chemical analyses of stellar streams, leaving our estimated 6% occurrence rate to be lower than the true value.

One additional constraint which may or may not affect this value is the metallicity of the system. It is difficult to predict whether AGB-MT would be either possible or observable at low metallicities ($[Fe/H] < -3.0$), due to limitations of the s -process and the inefficiency of mass-transfer. The impact of this limitation on our conclusions is unclear.

Lastly, the simulation used in this work, COSMIC, cannot currently fully disrupt GCs. We therefore are unable to follow a cluster through its entire life cycle; for example, we cannot determine whether stars that have undergone AGB-MT will retain their companion star after the cluster's complete tidal dissipation. However, since the chemical imprint

of mass-transfer remains, it does not impact our conclusions of AGB binary survival in early systems.

In the future, observing and chemically tagging stars in GC stellar streams is necessary for more strongly constraining this rate. By comparing the rates within other natal environments, we can better understand the process of mass-transfer inside these binaries. Exploring these unique systems will allow us to better understand an early phase of evolution that is otherwise difficult to observe in the present-day.

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AUTHOR CONTRIBUTIONS

S.A.U. led the project and contributed the observational data analysis. N.C.W. contributed the GC modeling data analysis. M.M. contributed much of the discussion on AGB-star mass transfer physics.

Software: CMC (C. L. Rodriguez et al. 2021), COSMIC (K. Breivik et al. 2020), Astropy (Astropy Collaboration et al. 2013, 2018, 2022), matplotlib (J. D. Hunter 2007), SciPy (P. Virtanen et al. 2020), NumPy (C. R. Harris et al. 2020), pandas (J. Reback et al. 2022).

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