Synthetic photometry of M-type AGB stars with JWST & WISE

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Abstract

In this study we present a data set of synthetic photometry of M-type AGB stars for JWST, WISE and a filter set that will be referred to as the generic filter set, consisting of: U_X B_X B V R I J J_{2m} H H_{2m} K_{s2m} K L L' M M'. 106 different models compromised of 4741 spectra have been processed for the three filter sets. We have also fitted the models to eight observations of M-type AGB stars made by WISE, showing that the models fairly well can recreate observations but that there is definitely still room for improvements. The resulting photometric files can be accessed at http://www.astro.uu.se/AGBmodels/ABmags/.

1 Introduction

This study follows the work done in Hjort *et al.* (2016) where a grid of C-stars where processed with the same filter sets and fitted to a set of stars from the AllWISE Multiepoch Photometry Database. In this study a grid of M-type AGB stars have been processed that was provided from Bladh *et al.* (2013). To see if these models could provide a similar fitting quality as the C-star models from Eriksson, K. *et al.* (2014) that where used in Hjort *et al.* (2016) we have fitted the models against a data set of eight M-type AGB stars which have been observed by WISE and are accessible in the AllWISE Multiepoch Photometry Database.

2 Method

In order to rapidly process all spectra a modified version of the MATLAB script used in Hjort *et al.* (2016) was developed. This script recursively searches the data folders for spectra files and assign each model a unique number for future investigations. Information about the different filter sets can be found in Appendix B. For a more thorough walkthrough of how the spectra are being processed please see the method section in Hjort *et al.* (2016). The AGB stars that we have fitted the model against have been selected from Olofsson, H. *et al.* (2002) and consist of eight objects. The data in Olofsson, H. *et al.* (2002) contains 69 M-typs AGB stars but most objects could not be used since they had saturated the sensor onboard WISE. A list of the objects that where used can be found in Appendix C. To further increase the quality we only used observations with a $\chi^2_{\text{red}} > 5$. For a detailed explanation on how the fitting is done please see the method section in Hjort *et al.* (2016).

3 Results

The resulting photometric files are available for download at: http://www.astro.uu.se/AGBmodels/ABmags/. In Appendix A the resulting plots from the SED fit can be seen. In Table 1 the results from the SED fit are summarised together with the observed magnitudes.

4 Discussion & Outlook

We see in Appendix A that many of the models provide good fits. The fits differ between 5.46% − 58.24% from the observed magnitudes. In Hjort *et al.* (2016) the results differed between 3.18% − 8.10%. The average error is 19.22% (and the median 14.84%) whereas in Hjort *et al.* (2016) the average error was 5.37%. It should however be noted that the grid in Hjort *et al.* (2016) consisted of 67 808 spectra whereas the grid used in this study consisted of 4741 spectra. It should also be noted that the distances in Olofsson, H. *et al.* (2002) have been derived by assuming a luminosity $4000 L_\odot$ for all objects.

#	Object Name	$M_{W1\ obs}$	$M_{W1\ mod}$	$M_{W2\ obs}$	$M_{W2\ mod}$	$M_{W3\ obs}$	$M_{W3\ mod}$	$M_{W4\ obs}$	$M_{W4\ mod}$
1	BC And	-5.6661	-5.0972	-3.5971	-4.5886	-2.6721	-3.2038	-2.0631	-1.8514
2	CE And	-5.4632	-5.1308	-4.1992	-4.6839	-3.3642	-3.3455	-3.0852	-1.9826
3	SV Aqr	-4.9665	-5.1876	-2.3135	-4.6587	-3.2315	-3.2916	-2.5085	-1.9442
4	AH Dra	-4.9064	-5.0972	-3.3744	-4.5886	-2.5834	-3.2038	-2.0064	-1.8514
5	SY Lyr	-5.9759	-5.7819	-5.4519	-5.4088	-3.4389	-4.1078	-2.9129	-2.8724
6	TU Lyr	-4.9782	-6.015	-4.8712	-5.4083	-3.2742	-4.0279	-2.8732	-2.846
7	EX Ori	-5.6095	-5.3013	-4.8025	-4.9492	-3.0885	-3.6526	-2.6885	-2.4015
8	OT Pup	-6.2509	-5.6174	-5.3989	-5.0771	3.2379	-3.6476	-3.0079	-2.3765

Table 1: List of the observed (obs) and the model (mod) magnitudes in the different WISE bands. All magnitudes are in absolute AB magnitudes. The average deviation is 7.92% in W1, 16.10% in W2, 34.69% in W3 and 18.17% in W4.

We can also see in Figure 1 that there is some anomaly in W2 that lowers the magnitude that the models can't replicate. It is not clear where this anomaly comes from but it is beyond the scope of this study to further investigate this. A good starting point would be to compare spectrographic data from the objects with the matching models synthetic spectra to see if there is any obvious feature that the model dosen't contain.

5 Conclusion

We have done synthetic photometry for a set of 104 M-type AGB models for three filter sets (see Appendix B). We see from the fits in Appendix A that the models fairly well can reproduce the observed SEDs although there appears to be some features that the models fail to account for. We hope that this data set together with the data from Hjort *et al.* (2016) can prove to be useful for planing observing strategies for JWST.

The data set is available online in conjunction to this study and at http://www.astro.uu.se/AGBmodels/ABmags/.

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Bibliography

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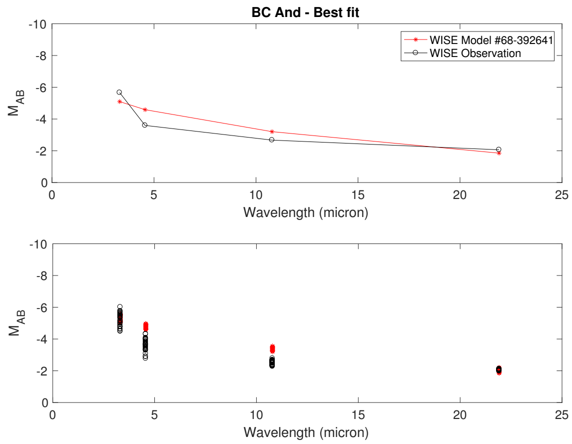
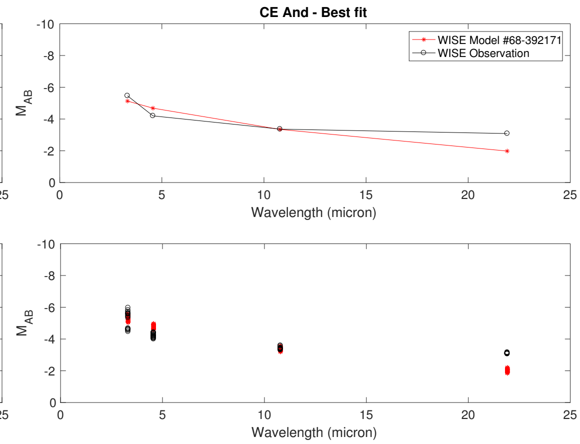
Spanish Virtual Observatory 2012, *Filter Profile Service.*

A Results from SED fit

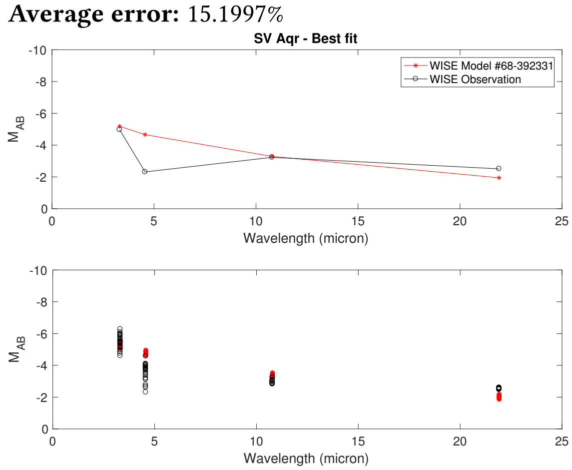
The resulting plots from the SED fit are presented on the following two pages.



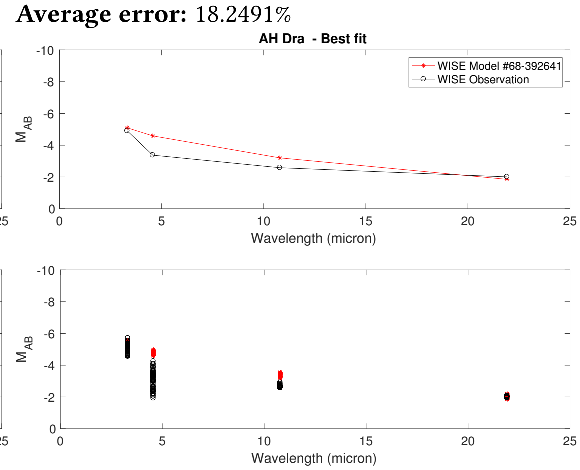
(a) **Object:** BC And
Model: l50t29m10r1_bari20_olx1mg2_td3_nd316_u3_400000
Spectrum: 392641
Average error: 15.1997%



(b) **Object:** CE And
Model: l50t29m10r1_bari20_olx1mg2_td3_nd316_u3_400000
Spectrum: 392171
Average error: 18.2491%

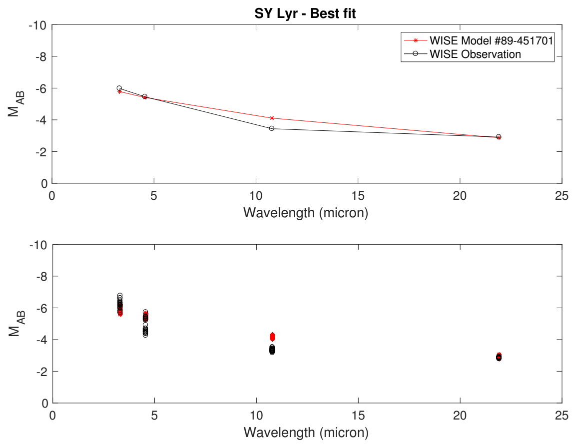


(c) **Object:** SV Aqr
Model: l50t29m10r1_bari20_olx1mg2_td3_nd316_u3_400000
Spectrum: 392331
Average error: 21.3633%

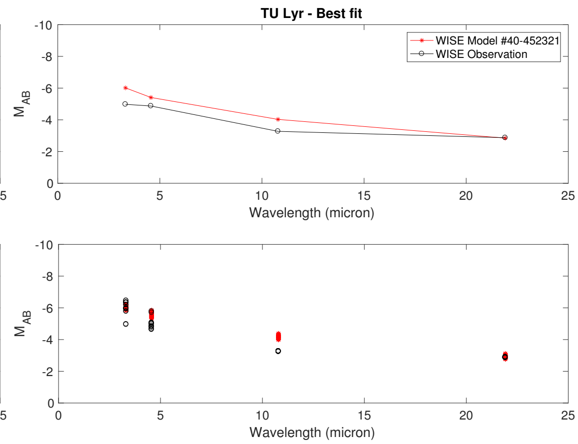


(d) **Object:** AH Dra
Model: l50t29m10r1_bari20_olx1mg2_td3_nd316_u3_400000
Spectrum: 392641
Average error: 14.4853%

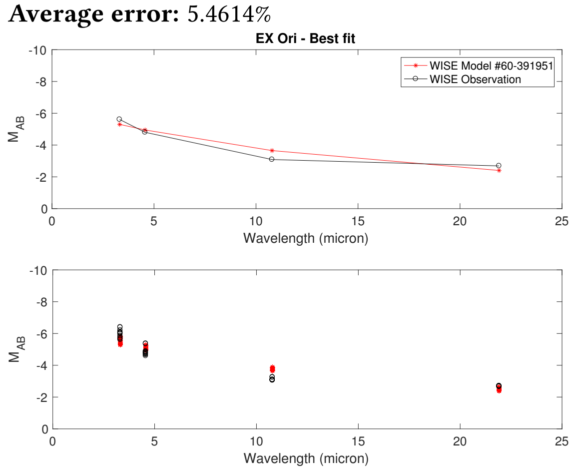
Figure 1: Best fit and model info for object 1 – 4



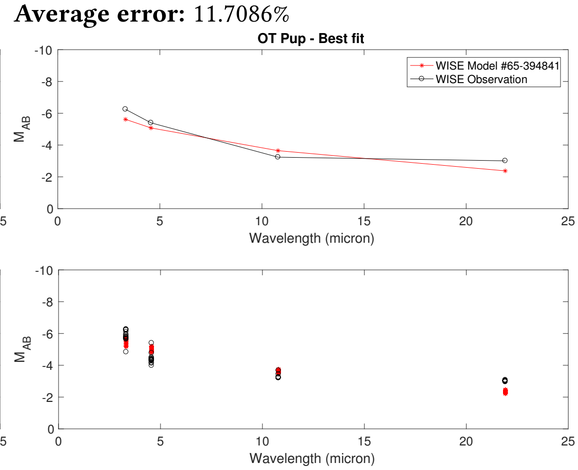
(a) **Object:** SY Lyr
Model: l70t28m10r2_bari20_olx1mg2_td3_nd16_u4_460000
Spectrum: 451701
Average error: 5.4614%



(b) **Object:** TU Lyr
Model: l10t31m10r1_bari20_olx1mg2_td3_nd315_u2_460000
Spectrum: 452321
Average error: 11.7086%



(c) **Object:** EX Ori
Model: l50t28m10r1_bari20_olx1mg2_td3_nd15_u4_400000
Spectrum: 391951
Average error: 9.0431%



(d) **Object:** OT Pup
Model: l50t29m10r1_bari20_olx1mg2_td3_nd15_u4_400000
Spectrum: 394841
Average error: 13.8534%

Figure 2: Best fit and model info for object 5 – 8

B Filter systems

B.1 NIRCam

Filter	F070W	F090W	F115W	F150W	F200W	F277W	F356W	F444W
λ_{eff}	0.70	0.90	1.15	1.50	2.00	2.77	3.56	4.44

Table 2: NIRCam filters used and the corresponding λ_{eff} (NASA/STScI, 2016a)

B.2 MIRI

Filter	F560W	F770W	F1000W	F1130W	F1280W	F1500W	F1800W	F2100W
λ_{eff}	5.60	7.70	10.00	11.30	12.80	15.00	18.00	21.00

Table 3: MIRI filters used and the corresponding λ_{eff} (NASA/STScI, 2016b)

B.3 WISE

Filter	W1	W2	W3	W4
λ_{eff}	3.3157	4.5645	10.7868	21.9150

Table 4: WISE filters used and the corresponding λ_{eff} (Spanish Virtual Observatory, 2012)

B.4 Generic

Filter	UX	BX	B	V	R	I	J	J2m
λ_{eff}	0.366	0.438	0.438	0.545	0.641	0.798	1.220	1.235

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Filter	H	H2m	Ks2m	K	L	Lp	M	Mp
λ_{eff}	1.630	1.662	2.159	2.19	3.45	3.80	4.75	4.80

Table 5: Generic filters (filters ending in 2m is from 2MASS(Spanish Virtual Observatory, 2012)) used in Eriksson, K. *et al.* (2014) and the corresponding λ_{eff}

C WISE objects

Number	Object Name	Distance	T_{bb}	$\dot{M}$
1	BC And	450	2510	2.0
2	CE And	740	2720	5
3	SV Aqr	470	2180	3
4	AH Dra	340	2680	0.8
5	SY Lyr	640	2410	6
6	TU Lyr	420	2470	3
7	EX Ori	470	2490	0.8
8	OT Pup	500	2630	5

Table 6: List of objects from Olofsson, H. *et al.* (2002) that could be used with data from the AllWISE Multiepoch Photometry Database. Distances are given in pc. T_{bb} is the stellar blackbody temperature given in kelvin. The value in $\dot{\mathrm{M}}$ is the observed mass loss given in $M_{\odot} \times 10^{-7}$ yr^{-1}.