Ten years of VLTI 2011

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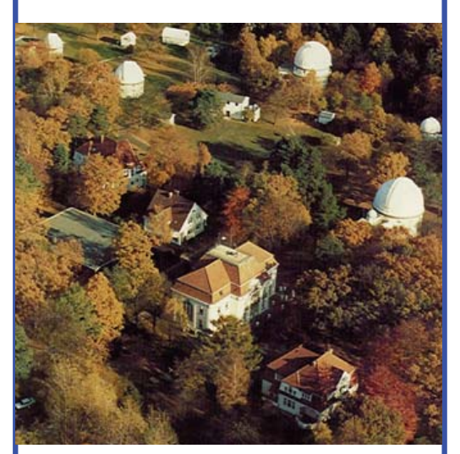

Spitzer and AKARI observations of obscured AGB and post-AGB stars

D. Engels[1], D. A. Garcia-Hernandez[2], P. García-Lario[3]

[1]Hamburger Sternwarte, Universität Hamburg, Germany, [2]Instituto de Astrofísica de Canarias, Tenerife, Spain, [3]European Space Astronomy Centre, ESA, Madrid, Spain

The AKARI and Spitzer satellites provided an unique opportunity to observe a variety of stars, which are considered as departing from the Asymptotic Giant Branch and have started their post-AGB evolution recently. Most of these stars are absent optically and are bright in the mid-IR wavelength range. Spectra of close to 200 objects have been obtained. For all of them the 1-160 μm spectral energy distribution has been constructed using in addition photometric data from various surveys. Typical examples of O-rich and C-rich sources are described in this poster.

Introduction

At the end of the stellar evolution on the Asymptotic Giant Branch (AGB) stars loose copious amounts of mass, which build up a circumstellar dust and gas shell hiding the star from optical view almost completely. Stars departing from the AGB and evolving towards the Planetary Nebula phase are therefore difficult to observe optically. It was found that a number of Proto-Planetary Nebulae show high velocity bipolar outflows which are connected to a fast, axially-symmetric wind, which is taking the place of the much slower, spherically-symmetric wind operating on the AGB. The physical mechanism responsible for the change of the spherically-symmetric to an axially-symmetric, or in some cases point-symmetric wind is strongly debated. Observations of masers in transition objects often reveal that this morphological change takes place at an early stage in the post-AGB phase, while the star is still obscured in the optical range (Zijlstra et al. 2001).
Non-variable OH/IR stars and IRAS selected infrared sources with extreme red colors are candidates for such hidden post-AGB stars. At mid-infrared wavelengths the emission emerges from the circumstellar envelopes (CSE) and their gas and dust composition has to be used to infer on the evolutionary state of the underlying star and the mass loss process (Engels et al. 2009). Many of these post-AGB star candidates will start to develop non-spherical symmetric morphologies as observed by Lagadec et al. (2011) in the mid-IR in a post-AGB sample, which is probably more advanced in its evolution.

AKARI and Spitzer observations

The AKARI observations were made with the Infrared Camera (IRC) (Onaka et al. 2007) and the spectroscopic observation mode AOT04. We obtained long and short exposed spectroscopic observations of dispersion elements NP (1.8-5.2 μm), SG1 (5.4-8.4 μm), SG2 (7.5-12.9 μm) and in some cases LG2 (17.5-25.7μm). For data reduction we used the IRC Spectroscopy Toolkit Version 20080528 (Ohyama et al. 2007) The Spitzer spectral data were taken with IRS under a General Observer program (#30258, PI, P. Garcia-Lario). Spitzer/IRS spectra were obtained by using the Short-High (SH: 9.9-19.6 μm; R~600) module. The Spitzer spectra were reduced with the help of SPICE and SMART.

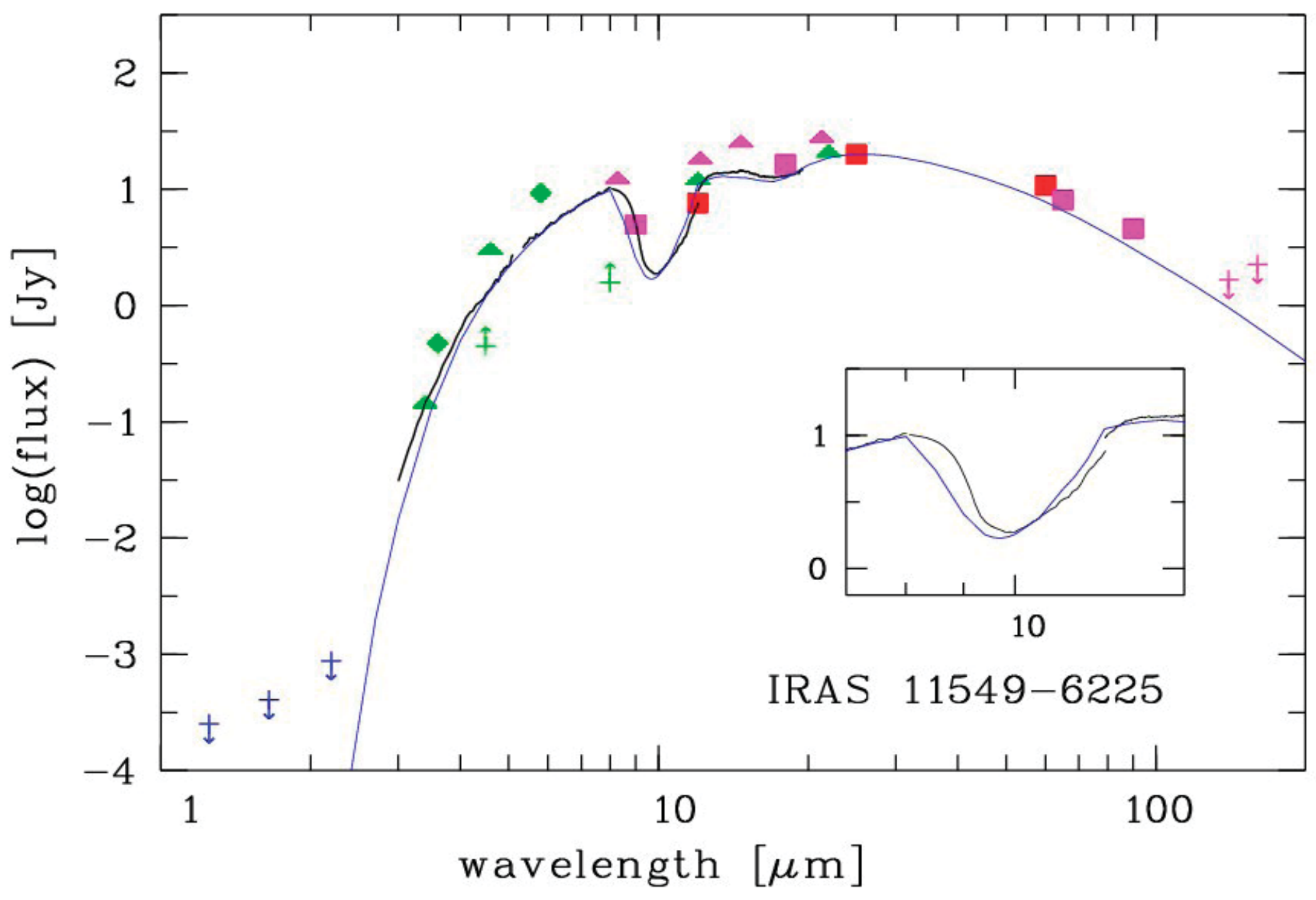

Fig. 1: IRAS 11549-6225. Classification: OH/IR star on the AGB. Photometry: 2MASS, DENIS (blue), GLIMPSE, WISE (green), IRAS (red), MSX and AKARI (magenta). Spectra: AKARI (5-12 μm), Spitzer (>12 μm). Model: DUSTY. The optical depth of the O-rich model is τ = 16. Although the fit is in general satisfactory, details (see the inset covering the 10 μm region) cannot be reproduced in detail.

Results and model calculations

For all sources spectral energy distributions (SED) between 1 and up to 160 micron are constructed using photometry from several point source catalogs created from 2MASS, DENIS (ground-based surveys) and several space-based surveys: GLIMPSE, WISE, MSX, IRAS and AKARI. The observed AKARI and Spitzer spectra are added. For the stars considered here the SED is completely dominated by dust emission from the CSE. The resulting SEDs were modelled using DUSTY, a code to model radiation transfer in dusty environments (Ivezic & Elitzur 1995). We fixed the temperature of the central star (T_{eff} = 2500 K), the condensation temperature of the dust (T_{dust} = 1000 K), and the grain size distribution. The parameters varied were the composition of the dust (silicates or carbon-rich) and the optical depth of the CSE, as they have the dominant influence on the resulting spectral shapes.

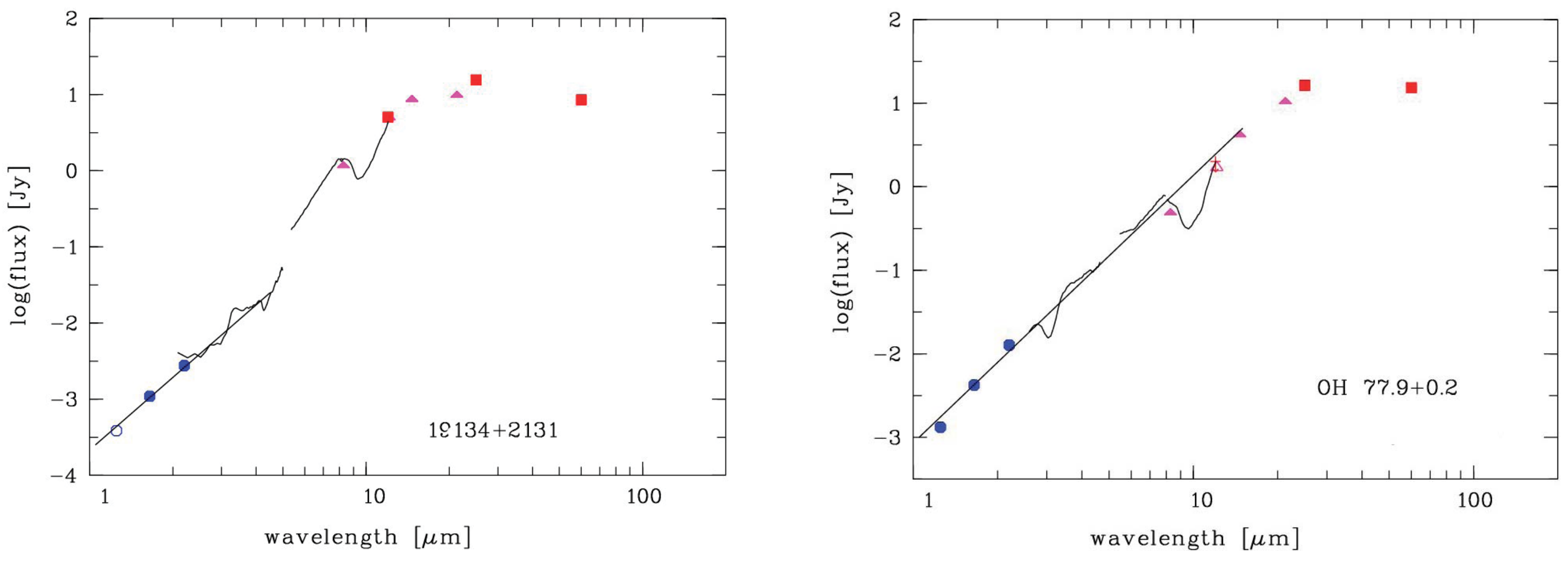

Fig. 2: IRAS 19134+2131 and OH 77.9+0.2, Classification: O-rich post-AGB stars. The sources for photometry and spectra are as in Fig. 1. Spectra: AKARI. The almost linear increase of the SED in a log-log plot is a signature of emission from bipolar lobes.

The SEDs of **obscured variable OH/IR stars** peak in the wavelength range 5-30 micron and show a strong 10 μm and a weaker 18 μm absorption feature. These SEDs can be modeled in detail using cold dust opacity functions of amorphous silicates (Suh & Kim 2002). The results for IRAS 11549-6225 are shown in Fig. 1. The DUSTY model contains 86% amorphous silicates and 14% amorphous carbon. It is however questionable if the shell contains amorphous carbon in reality. Possibly the opacity function for the silicates is inadequate.

For several **O-rich post-AGB stars** with silicate absorption features we had indications for their post-AGB nature beforehand. Either due to the presence of bipolar high-velocity outflows traced by H_2O masers or due to the presence of a near-infrared excess. Infrared imaging (f.e. Gledhill et al. 2011) show that the emission at λ<10 μm comes from bipolar lobes, and is scattered light from warm dust which is hidden from direct view by optically thick material in front of it (a torus?). The SED of such sources increases almost linearly in a log-log plot. Only at λ>20 μm emission from the remnant AGB shell start to dominate. As examples the SEDs of IRAS 19134+2131 and OH 77.9+0.2 are shown in Fig. 2. Besides the presence of the 10 μm absorption feature due to silicates, the spectrum of OH 77.9+0.2 shows a strong absorption feature at 3.1 μm due to H_2O ice.

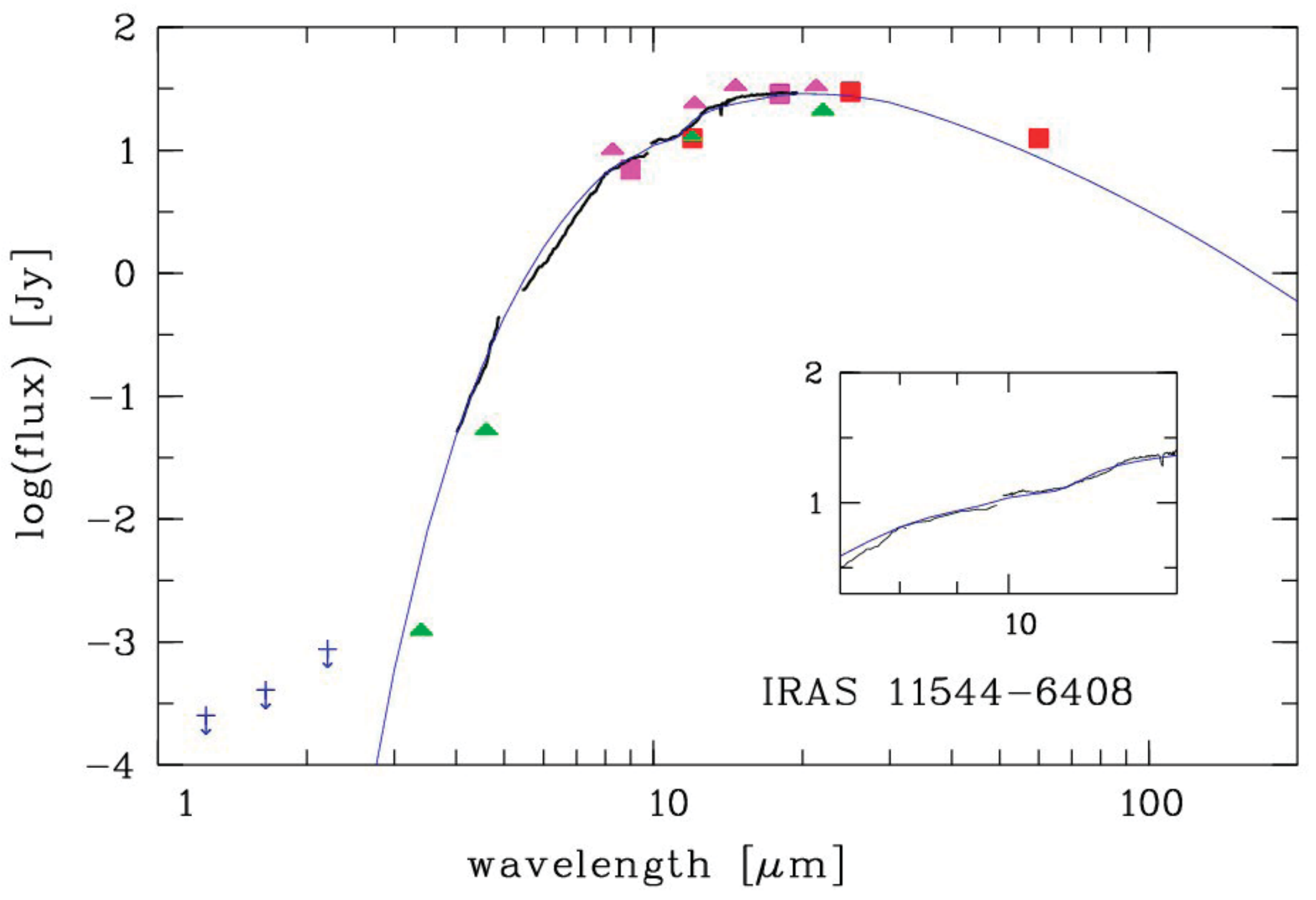

Fig. 3: IRAS 11544-6408. Classification: Extreme carbon star possibly still on the AGB. The sources for photometry and spectra are as in Fig. 1. The optical depth of the C-rich DUSTY model is τ = 6. A contribution of amorphous silicates is required to model the depression around 10 μm. It is quite possible that the silicates belong to the interstellar medium.

The **extreme carbon stars** are rarer than OH/IR stars and harder to classify because of the lack of prominent dust features and radio maser emission. C-rich sources usually have almost featureless spectra (e.g. typical of carbonaceous grains) with a weak 9-12 μm depression (which might be attributed to small amounts of SiC or amorphous silicates). A telltale signature of the C-rich dust is the presence of an absorption line of acetylene (C_2H_2) at 13.7 μm, which was found in several Spitzer spectra. The results for IRAS 11544-6408 are shown in Fig. 3. The DUSTY model contains 86% amorphous carbon, 7% amorphous silicates and 7% SiC.

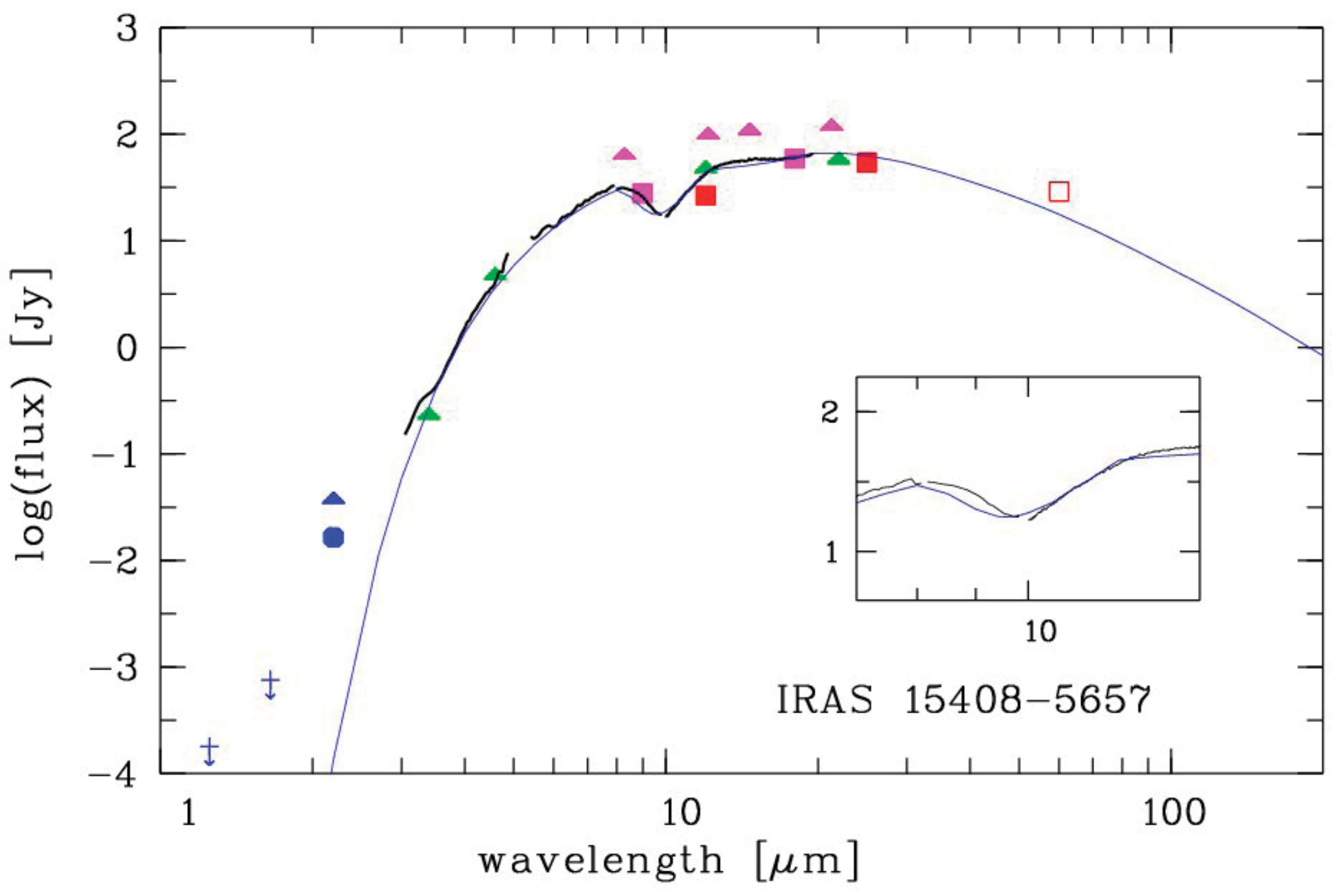

Fig. 4: IRAS 15408-5657. Classification: Extreme carbon star. The 10 μm silicate absorption may originate from an outer O-rich dust shell around the star or from O-rich dust in dense clouds of the interstellar medium. The optical depth of the DUSTY model with mixed chemistry is τ = 8.

C-rich post-AGB stars are not easy to distinguish. One hint is a low IRAS variability index, because post-AGB stars should have stopped pulsating. One candidate is IRAS 15408-5657 (Figure 4). At first glance it would not be classified as C-rich, because of the presence of the 10 μm silicate feauture. However, the silicate absorption feature is too weak for its red continuum. The model SED requires a mixture of carbon and silicate dust in almost equal parts to obtain the appropriate strength of the silicate band. It is unlikely that both dust species spatially coexist, because the underabundant atomic species (C or O) should be locked in CO, and would not be available for dust formation. Thus, the mixed chemistry may indicate the presence of two shells, an inner shell with C-rich dust and an outer one with O-rich dust. Alternatively the SED can be modelled by pure amorphous carbon, seen through a screen with silicate rich material.

Conclusions

The AKARI and Spitzer observations of ``hidden'' AGB and post-AGB stars reveal a large variety of spectra. While the SEDs of stars, considered to be still on the AGB, can be modeled by spherically symmetric dust shells, the SEDs of post-AGB stars are more complex. During both phases the dominant chemistry (O- or C-rich) can be determined, but there is also evidence that during the post-AGB phase cases of mixed chemistry occur. Due to the short evolutionary time scales and the break of spherical symmetry, Mid-IR imaging (Vizir, MIDI) will be an essential requirement to characterize the evolutionary phase for the individual objects during the fast transition from AGB to post-AGB evolution.

References

Engels D., Garcia-Lario P., Bunzel, F., et al., 2009, in ``AKARI, a light to illuminate the misty Universe'', Eds I. Yamamura, Tokio 2009, ASPC 418, 159
Gledhill T.M., Forde K.P., Lowe K.T.E., Smith M.D., 2011, MNRAS 411, 1453
Ivezic Z., Elitzur M., 1995, ApJ, 445, 415,
Lagadec E., Verhoelst T., Mekarnia D., et al., 2011, MNRAS 417, 32
Ohyama Y., Onaka T., Matsuhara H., et al. 2007, PASJ 59, 411
Onaka T., Matsuhara H., Wada T., et al. 2007, PASJ 59, 401
Suh K., Kim H.-Y., 2002, A&A, 391, 665
Zijlstra et al. 2001, MNRAS 322, 280