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Late stages of stellar evolution with Planck: a feasibility study

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Abstract. We present a feasibility study of the last phases of the stellar evolution that from the Asymptotic Giant Branch (AGB) lead to the formation of Planetary Nebulae (PNs) with the Planck mission. We selected samples of AGB, Post-AGB and PNs, for a total of 1700 objects, with strong infrared fluxes in the IRAS bands. The flux density has been extrapolated to the Planck frequencies. For PNs also the radio free-free emission has been considerated in the flux estimation. A list of evolved Galactic sources that Planck can detect has been produced, showing that this mission, even if devised for the study of the cosmic microwave background, can provide important clues for the study of the last phases of the stellar life.

Key words. Stars: AGB and post-AGB – planetary nebulae: general – cosmic microwave background – Radio continuum: ISM.

1. Introduction

The Planck mission [1], originally devised for cosmological studies, may in principle have a large impact on stellar studies because it will cover a very important observational band.

For various classes of stellar objects continuum observations at millimetric and submillimetric wavelengths would be very fruitful, because they provide essential clues to understand the physics of these stars and constitute a powerful addition to current studies, which are carried out mostly at centimetric wavelengths.

However, the high level of Galactic confusion together with the intrisic low flux density make the detection of such kinds of source quite challenging.

2. From AGB to PNs

When a low or intermediate mass star is approcing the end of its evolution, it goes through a period of heavy massloss known as Asymptotic Giant Branch (AGB phase). The ejected envelopes are partially condensed in dust grains and completely obscure the central star. Immediately after the AGB phase, the massloss stops and the central object may become optically visible as the dust disperse (Proto Planetary PPNs phase). Once it reaches a temperature of 20,000-30,000 K, the central star starts to ionize the AGB shell and a Planetary Nebula (PNs phase) will form.

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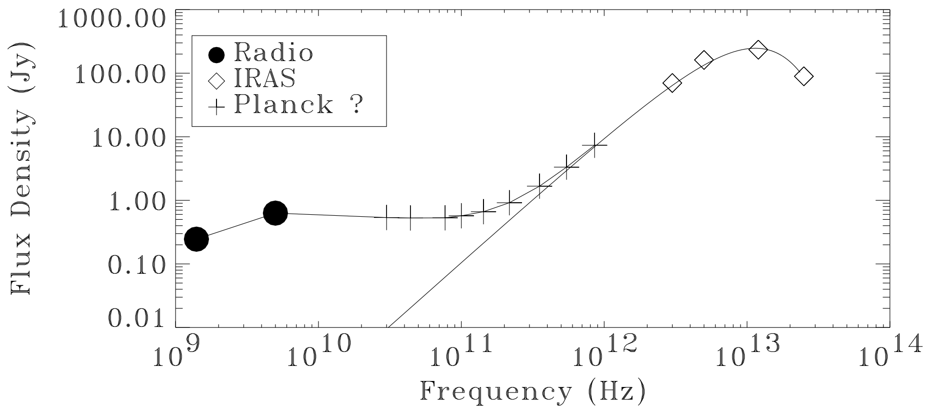

Fig. 1. An example of the extrapolation procedure for the evaluation of the flux density at the PLANCK bands starting from the IRAS measurements (with a BB curve) and the radio flux density (free-free spectrum).

PLANCK observations of these evolved Galactic objects would provide important clues for the study the physical properties of their dusty envelopes and thus clarify these still quite unclear phases of stellar evolution.

3. Samples selection

In order to study the detectability of such sources in the PLANCK bands we selected our samples from more recent and complete compilations, namely:

- Post-AGB: Garcia-Lario et al. (1997); cross correlation between IRAS PSC and SAO (Oudmaijer et al. 1992);
- PNs: Cross correlation between NVSS and Galactic catalog (Condon & Kaplan 1998);
- AGB: Nyman et al. (1992);

for a total of about 1,700 objects. All the selected candidates have strong signatures in the infrared (IR excess), millimetric and submillimetric emission measured in small samples (up to few Jy). PNs have also free-free contribution (up few Jy). Finally, several targets are located at high Galactic latitude.

To evaluate the chance to detect them with a given S/N, their intrinsic emission should be compared to the PLANCK nominal sensitivity and the microwave sky confusion noise.

4. Predicted fluxes at PLANCK frequencies

All the selected candidates are IRAS sources. Moreover, for the PNs sample, which also present a free-free contribution due to ionization of part of circumstellar envelopes, a radio measurement is available from the NVSS.

In order to estimate the intrinsic flux density we fitted the IRAS measurement with a blackbody curve and extrapolated the dust contribution to the PLANCK frequencies. For the PNs sample we summed to the dust contribution the free-free radio emission obtained from the NVSS measurement, extrapolated to the PLANCK frequencies assuming an optically thin Nebula (note that the last hypothesis may be not valid and the estimate should be considered as a lower limit!).

In the analysis the following sources of noise have been considered:

- The nominal instrumental PLANCK sensitivity per resolution element ($\sigma_{\rm ins}$)
- Galactic ($\sigma_{\rm Gal}$) and extragalactic ($\sigma_{\rm Ex.sou}$) foregrounds confusion noise (Toffolatti et al. 1998)
- CMB confusion noise ($\sigma_{\rm CMB}$) (Bennett et al. 2003)

The relevant global sensitivity for point source detection/observation is tipically as-

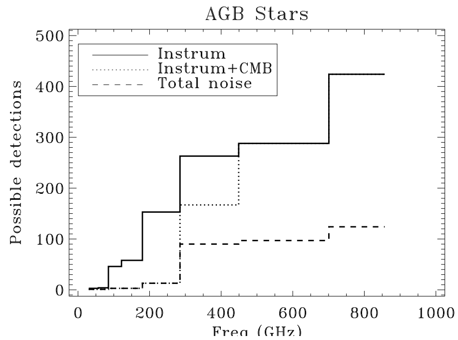

Fig. 2. Histogram showing the number of AGB stars that can be detected by Planck; only instrumental r.m.s., instrumental r.m.s. and CMB fluctuations, and total noise are considered.

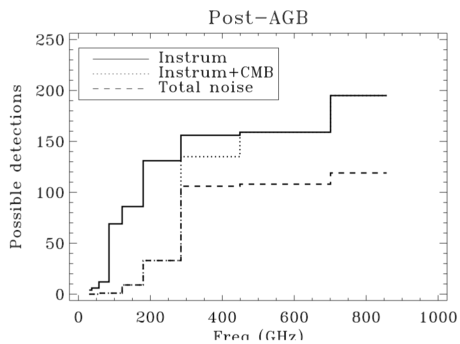

Fig. 3. As Fig. 2 for Post-AGB stars.

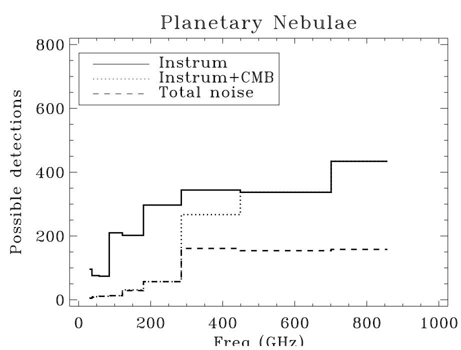

Fig. 4. As Fig. 2 and 3 for Planetary Nebulae.

sumed to be the sum in quadrature of all the sources of confusion noise.

In Table 1 we report the relevant parameters at the various frequencies, ν, of the two Planck instruments, LFI and HFI.

Table 1. Planck sensitivity and estimates of the microwave sky confusion noise.

ν (GHz)	FWHM (arcmin)	$\sigma_{\rm ins}$ (mJy)	$\sigma_{\rm CMB}$ (mJy)	$\sigma_{\rm Gal}$ (mJy)	$\sigma_{\rm Ex.sou}$ (mJy)
30	33.6	13.4	245	100	60
44	22.9	20.5	238	45	45
70	14.4	28.0	221	15	30
100	10.7	8.7	192	7	20
143	8.0	11.5	149	6	15
217	5.5	11.5	82.6	5	8-15
353	5.0	19.4	19.1	18	20-35
545	5.0	38.0	1.5	62	45-80
857	5.0	43.0	0.016	120	100-180

Results for such an analysis are summarized in Fig. 2, 3, and 4. Here the number of sources observable with a $3\,\sigma$ S/N (or better) are indicated. Each plot refers to different classes of object; different lines are relative to contribution of different noise source.

5. Conclusions

Even if in the framework of our conservative analysis we foresee that a significative number of evolved Galactic sources (AGB, post-AGB and PNs) can be studied at millimetric wavelengths with Planck.

Future work to better estimate the confusion noise sources and the source intrinsic flux will include: accurate estimates of the Galactic confusion noise at various Galactic latitudes, around source positions, from WMAP and extrapolated IR surveys; dedicated radio and millimetric observations aimed to better evaluate the SEDs of these objects.

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