Ionization Correction Factors in Planetary Nebulae

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ABSTRACT

We derive new Ionization Correction Factors (ICFs) for planetary nebulae using around 2300 photoionization models that cover a wide range of physical parameters. We also compute analytical formulae to estimate the errors bars associated with the ICFs. This should be useful for empirical abundances studies since errors in ICFs are usually not considered when estimating errors in element abundances. We discuss here our results for N and Ar, the whole analysis will be presented in Delgado-Inglada et al. 2013, in prep.

1. MOTIVATION

Most of the Ionization Correction Factors (ICFs) adopted in the literature have been derived from a small sample of photoionization models that cover a narrow range of observed parameters.

We calculate new ICFs and recipes for their associated uncertainties. We test our ICFs on a large sample of observed PNe and compare the results with the ones obtained with previous ICFs.

2. THE MODELS

We compute a grid of radiation- and matter-bounded models using Cloudy (Ferland et al. 2013). The models cover a wide range of physical parameters: 25000 K $\leq$ Teff $\leq$ 240000 K, 200 $L_\odot \leq L_* \leq$ 30000 $L_\odot$, 30 $cm^{-3} \leq n_H \leq$ 300000 cm^{-3}, and 3×10^{15} cm $\leq R_{in} \leq 3\times10^{18}$ cm.

We apply different criteria to exclude unrealistic (or unobservable) models. For example, those with very low surface brightness or located outside typical stellar tracks (see Figure 1). The final grid of blackbody models with constant density and solar metallicity consists of around 2300 models.

3. THE OBSERVATIONAL SAMPLE

Our sample of observed PNe consists of around 300 PNe from our galaxy and from the Magellanic Clouds. The spectra were taken from the literature because they have the necessary lines to calculate physical conditions and ionic abundances. All the quantities were calculated with the python tool PYNEB (Luridiana et al. 2012).

4. DISCUSSION

Our ICFs are derived from complete spherical models and they are not be adequate for small aperture observations of outer regions in PNe.

Figure 2 shows N and Ar ionic fractions as a function of $O^{++}/(O^{+}+O^{++})$. Panel (a): For N we suggest to use two formulae (solid lines) depending on the observed value of I(He II)/I(Hβ). The red vertical lines marks the region of validity of the formulae. The ICF from Kingsburgh & Barlow (1994) underestimates N/O values in PNe with low Teff central stars and overestimates them in PNe with high Teff central stars (dashed line). Panel (b): As for Ar we suggest a simple correction scheme: Ar/O = $Ar^{++}/(O^{+}+O^{++})$ (solid line). We integrate the correction for other argon ions inside the error bars.

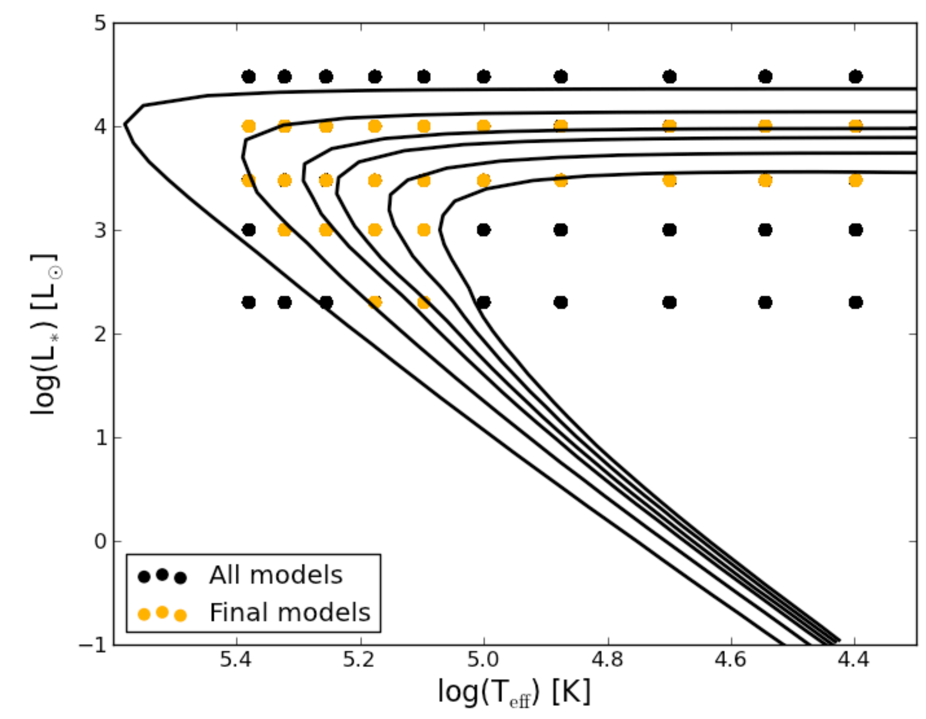

Figure 1. Hertzsprung-Russel diagram for our models with constant density and solar metallicity. The orange circles are those that satisfied our selection criteria. The H-burning tracks from Vassiliadis and Woods (1994) are overplotted.

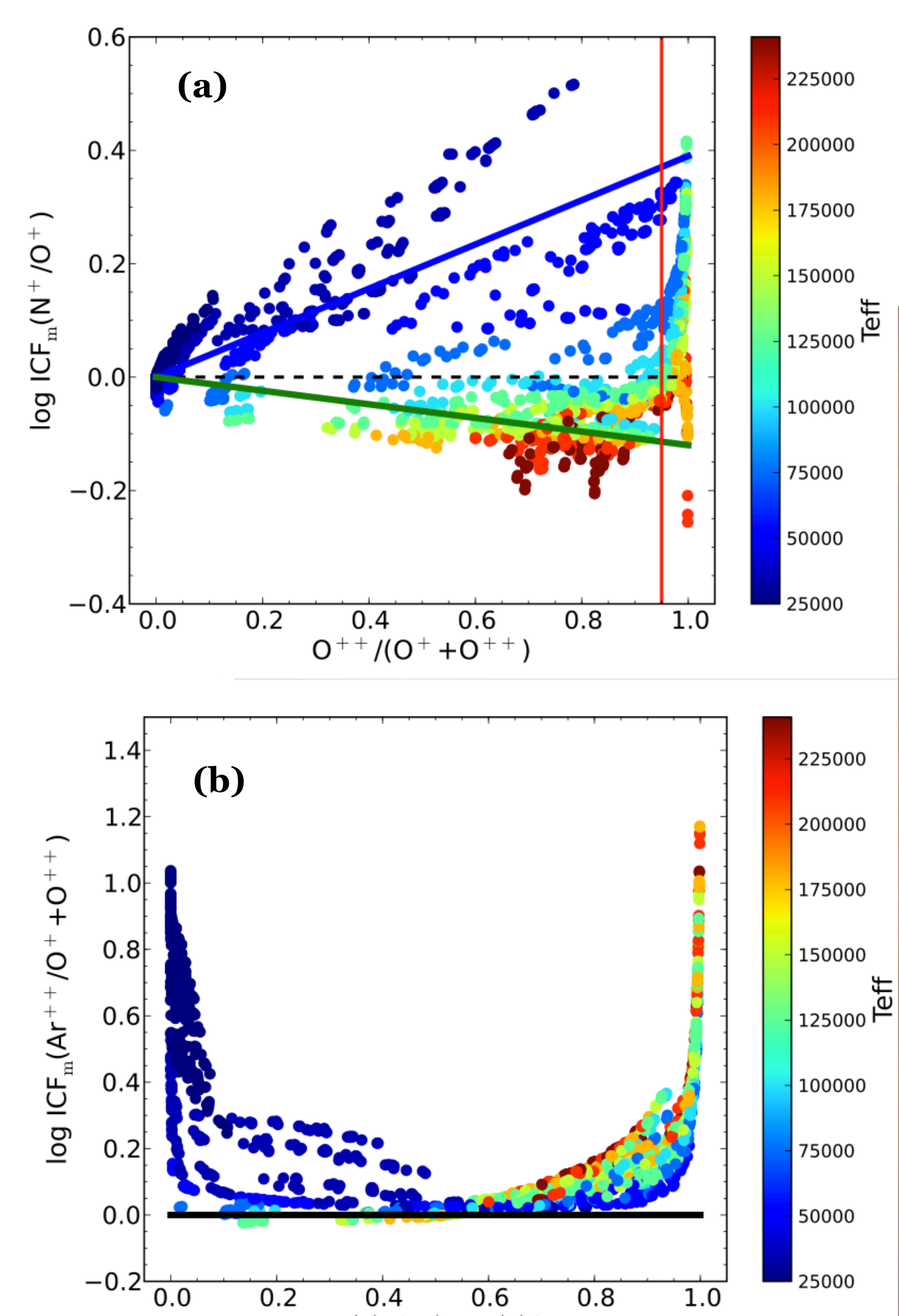

Figure 2. Ionic fractions of nitrogen and argon of our photoionization models as a function of $O^{++}/(O^{+}+O^{++})$.

Figure 3 shows a comparison of N/O and Ar/O values obtained from our ICF and from the one suggested by Kingsburgh & Barlow (1994) for the sample of PNe. The error bars in the plots only consider the errors related to the ICF. The maximum differences are up to 0.4 dex for N and up to 0.6 dex for Ar.

Figure 4 displays the values of N/O and Ar/O obtained from our ICFs as a function of the degree of ionization. We distinguish the PNe with the highest quality spectra and the ones where the abundance ratios are uncertain. We see that there is no obvious trend with the degree of ionization, as expected if the ICFs are appropriate.

The whole analysis will be presented in Delgado.-Inglada et al. in prep.

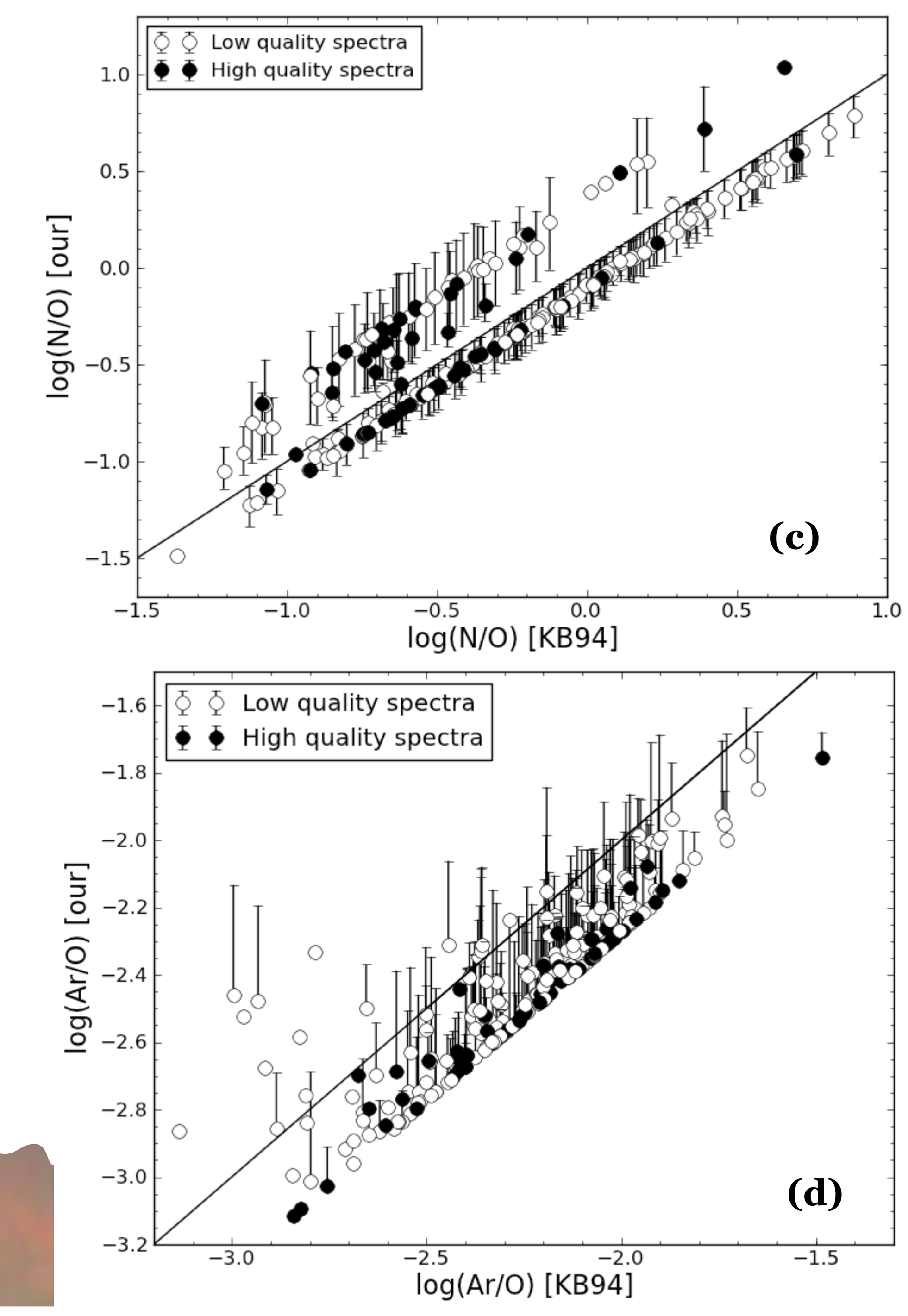

Figure 3. Comparison between N/O (c) and Ar/O (d) values computed from teo ICFs.

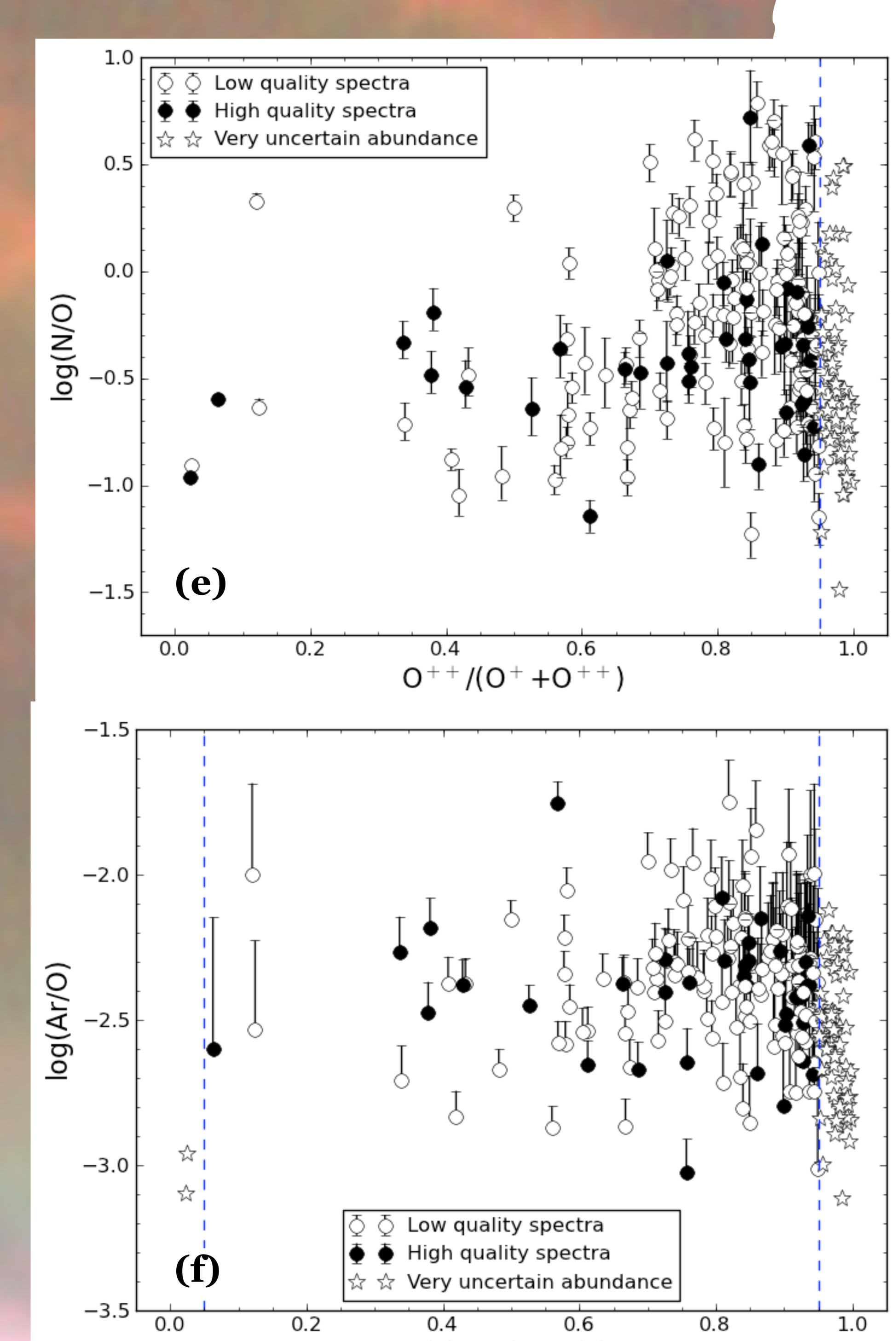

Figure 4. Values of N/O (e) and Ar/O (f) computed from our ICFs as a function of the degree of ionization for all the PNe sample. The filled circles represent the PNe with the best quality spectra and the stars represent PNe where the adopted ICF (and thus the abundance) is uncertain.

REFERENCES

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Kingsburgh & Barlow 1994, MNRAS, 271, 257

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Vassiliadis & Wood 1994, APJS, 92, 125