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Chemical abundances of Seyfert 2 AGNs – III. Reducing the oxygen abundance discrepancy

O. L. Dors[1⋆], R. Maiolino[2,3], M. V. Cardaci[4,5], G. F. Hägele[4,5], A. C. Krabbe[1], E. Pérez-Montero[6], M. Armah[1]

[1] *Universidade do Vale do Paraíba, Av. Shishima Hifumi, 2911, Cep 12244-000, São José dos Campos, SP, Brazil*
[2] *Cavendish Laboratory, University of Cambridge, 19 J. J. Thomson Ave., Cambridge CB3 0HE, UK*
[3] *Kavli Institute for Cosmology, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK*
[4] *Instituto de Astrofísica de La Plata (CONICET-UNLP), Argentina*
[5] *Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina*
[6] *Instituto de Astrofísica de Andalucía, Camino Bajo de Huétor s/n, Aptdo. 3004, E18080-Granada, Spain.*

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ABSTRACT

We investigate the discrepancy between oxygen abundance estimations for narrow-line regions (NLRs) of Active Galactic Nuclei (AGNs) type Seyfert 2 derived by using direct estimations of the electron temperature ($T_{\rm e}$-method) and those derived by using photoionization models. In view of this, observational emission-line ratios in the optical range ($3000 < \lambda(\text{Å}) < 7000$) of Seyfert 2 nuclei compiled from the literature were reproduced by detailed photoionization models built with the CLOUDY code. We find that the derived discrepancies are mainly due to the inappropriate use of the relations between temperatures of the low (t_2) and high (t_3) ionization gas zones derived for HII regions in AGN chemical abundance studies. Using a photoionization model grid, we derived a new expression for t_2 as a function of t_3 valid for Seyfert 2 nuclei. The use of this new expression in the AGN estimation of the O/H abundances based on $T_{\rm e}$-method produces O/H abundances slightly lower (about 0.2 dex) than those derived from detailed photoionization models. We also find that the new formalism for the $T_{\rm e}$-method reduces by about 0.4 dex the O/H discrepancies between the abundances obtained from strong emission-line calibrations and those derived from direct estimations.

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[1] Universidade do Vale do Paraíba, Av. Shishima Hifumi, 2911, Cep 12244-000, São José dos Campos, SP, Brazil
[2] Cavendish L ... HE, UK
[3] Kavli Institu ... 0HA, UK
[4] Instituto de ...
[5] Facultad de ... del Bosque s/n, 1900 La Plata, Argentina
[6] Instituto de ... ranada, Spain.

Accepted 2015 ...

... abundance estimations for narrow- ... Ns) type Seyfert 2 derived by using ... method) and those derived by us- ... ational emission-line ratios in the ... nuclei compiled from the literature ... s built with the CLOUDY code. We ... o the inappropriate use of the rela- ... h (t_3) ionization gas zones derived ... es. Using a photoionization model ... ion of t_3 valid for Seyfert 2 nuclei. ... tion of the O/H abundances based ... lower (about 0.2 dex) than those ... also find that the new formalism ... H discrepancies between the abun- ... ons and those derived from direct ... estimations.

Chemical Abundances in Active Galaxies

Sophia R. Flury[1⋆] and Edward C. Moran[2]
[1]Department of Astronomy, University of Massachusetts Amherst, Amherst, MA 01002, United States
[2]Department of Astronomy, Wesleyan University, Middletown, CT 06459, United States

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ABSTRACT
The Sloan Digital Sky Survey (SDSS) has proved to be a powerful resource for understanding the physical properties and chemical composition of star-forming galaxies in the local universe. The SDSS population of active galactic nuclei (AGN) remains as of yet less explored in this capacity. To extend the rigorous study of H II regions in the SDSS to AGN, we adapt methods for computing direct-method chemical abundances for application to the narrow-line regions (NLR) of AGN. By accounting for triply-ionized oxygen, we are able to more completely estimate the total oxygen abundance. We find a strong correlation between electron temperature and oxygen abundance due to collisional cooling by metals. Furthermore, we find that nitrogen and oxygen abundances in AGN are strongly correlated. From the metal-temperature relation and the coupling of nitrogen and oxygen abundances, we develop a new, empirically and physically motivated method for determining chemical abundances from the strong emission lines commonly employed in flux-ratio diagnostic diagrams (BPT diagrams). Our approach, which for AGN reduces to a single equation based on the BPT line ratios, consistently recovers direct-method abundances over a 1.5 dex range in oxygen abundance with an rms uncertainty of 0.18 dex. We have determined metallicities for thousands of AGN in the SDSS, and in the process have discovered an ionization-related discriminator for Seyfert and LINER galaxies.

Key words: ISM: abundances – galaxies: abundances – galaxies: active

1 INTRODUCTION

Spurred by revolutionary ideas about the nature of gaseous nebulae (e.g., Strömgren 1939), Menzel applied then-new ideas about quantum mechanics to emission-line phenomena to develop a working theory of nebular astrophysics, often in collaboration with Baker and Aller. This enabled the first empirical estimates of physical properties like electron temperature (Menzel & Aller 1941) and ionic abundances like O^{+2}/H (Menzel et al. 1941) in gaseous nebulae. Seyfert, their contemporary, reported the discovery of a new class of emission-line objects in 1943 that later came to be known as active galactic nuclei (AGN). While Menzel's the-

and other Local Group galaxies; and (ii) AGN nebulae have a more complex ionization structure (e.g., Osterbrock & Ferland 2006, henceforth OF06). Sixteen years passed between the development of a method for the direct estimation of chemical abundances in the Orion Nebula (Aller & Liller 1959) and the first investigation of metallicity in an AGN (Osterbrock & Miller 1975). While Koski (1978) and Shuder & Osterbrock (1981) analyzed the physical properties of the gas in Seyfert nebulae, and Storchi-Bergmann & Pastoriza (1990) established the range of metallicities for a sample of AGN using photoionization models, it was not until Cruz-Gonzalez et al. (1991) that direct-method abundances (i.e., abundances determined using the electron temperature and

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463 из SDSS для проверки

Моделируют AGN в CLOUDY для разных параметров O/H; N/H; S/H, ne; R_in

Object
IZw 92
NGC 3393
Mrk 3
Mrk 573
Mrk 78
Mrk 34
Mrk 1
3c433
Mrk 270
3c452
Mrk 198
Mrk 6
ESO 138 G1
NGC 3081
NGC 3281
NGC 4388
NGC 5135
NGC 5728
IC 5063
IC 5135
Mrk 744
NGC 5506
Akn 347
UM 16
Mrk 533
Mrk 612

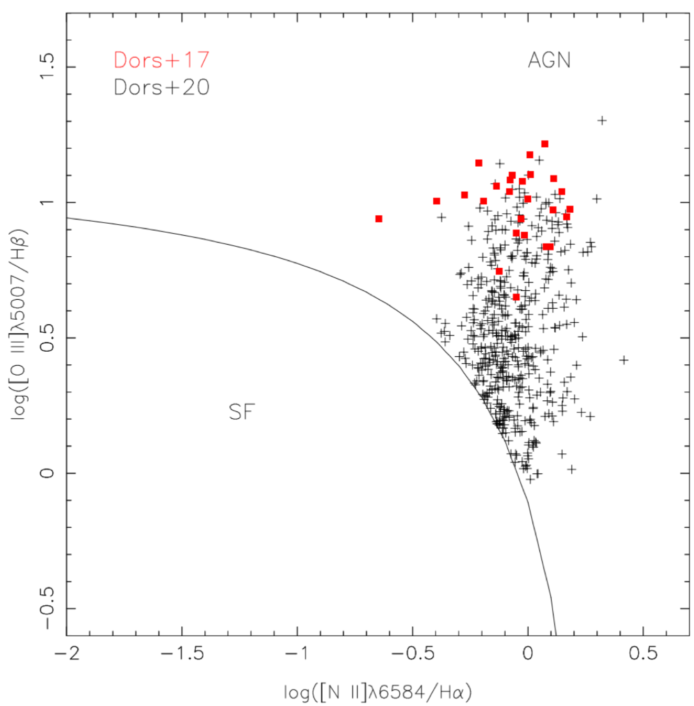
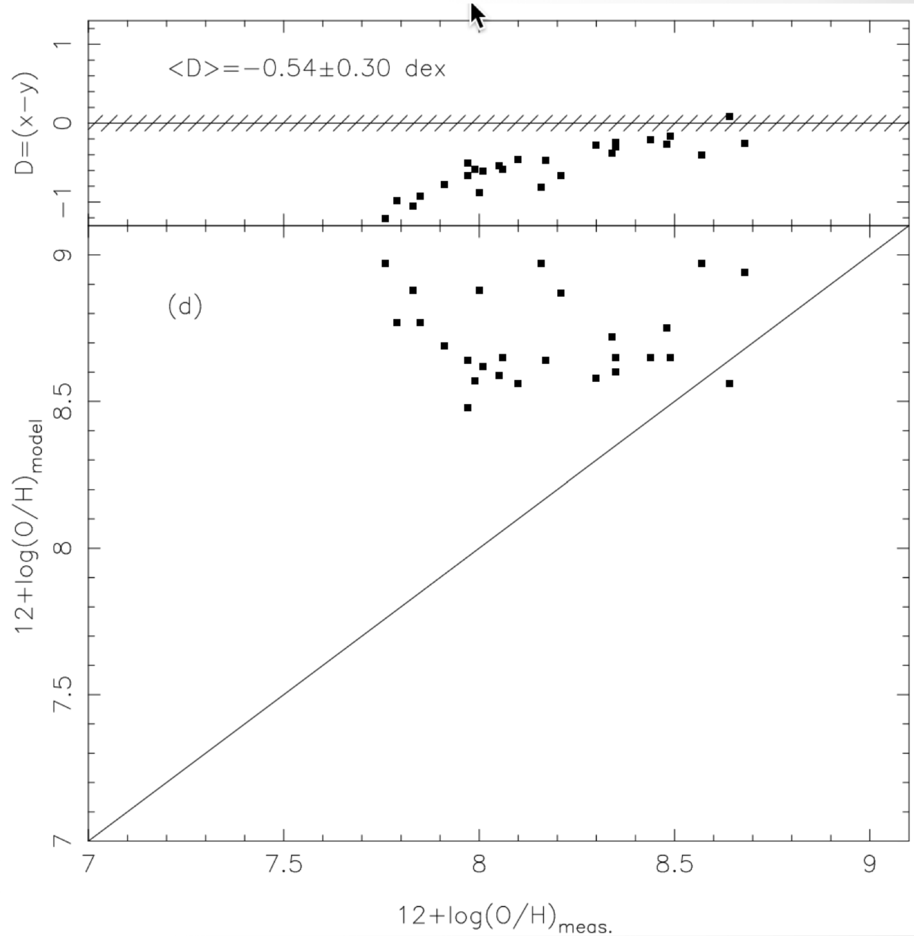
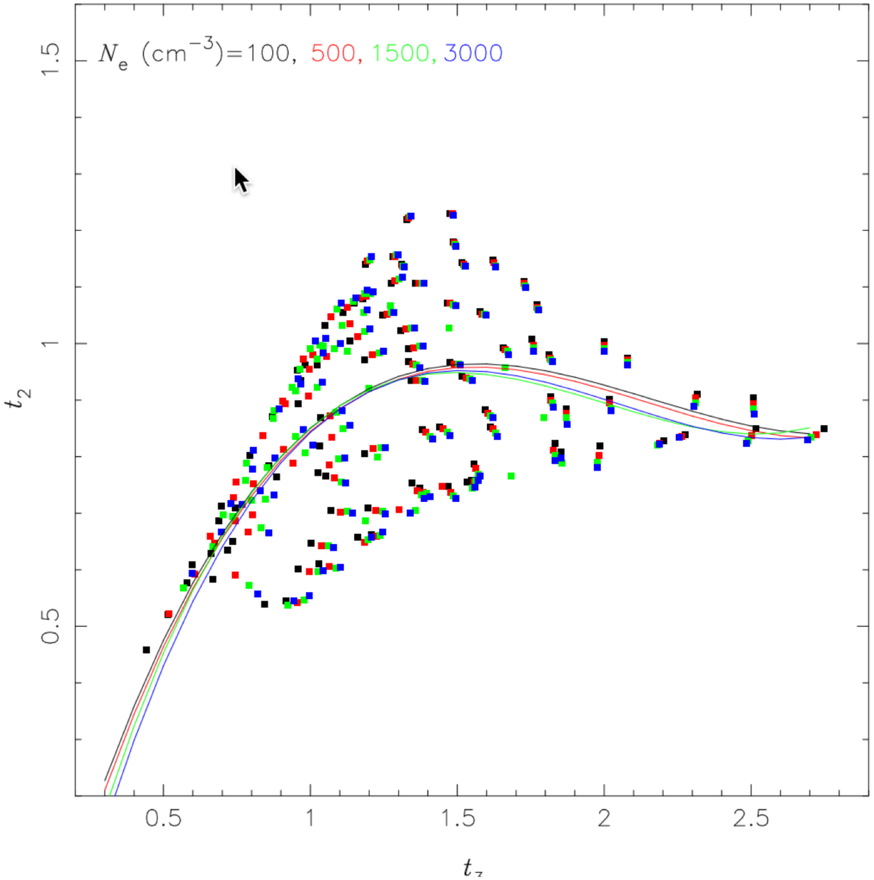
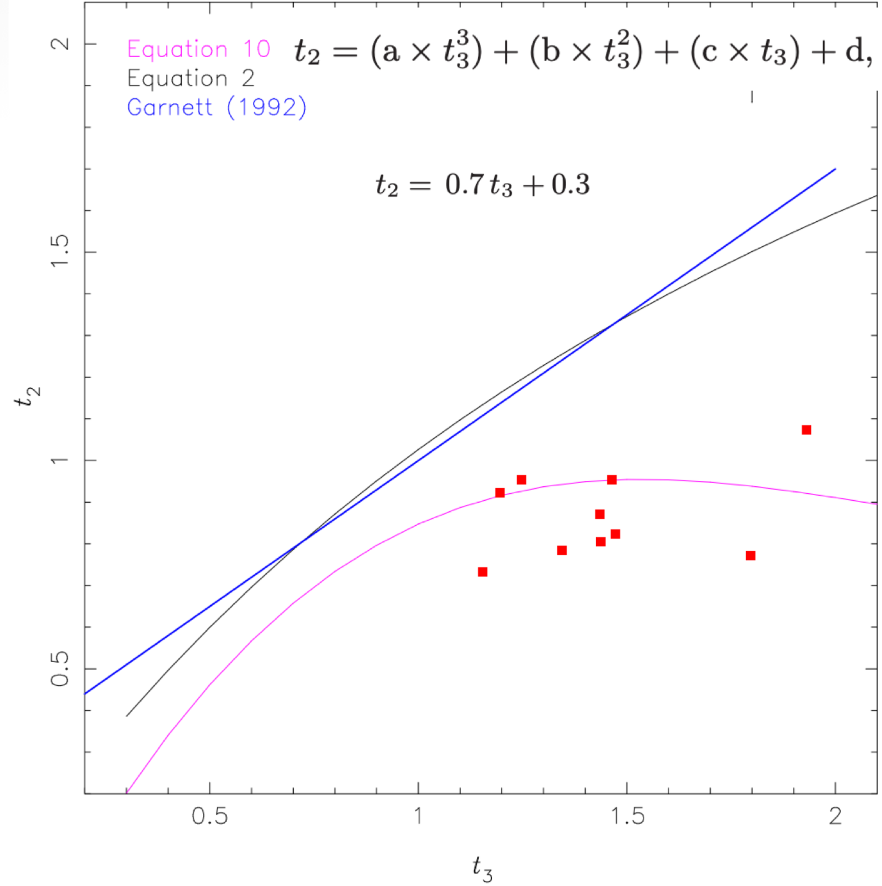
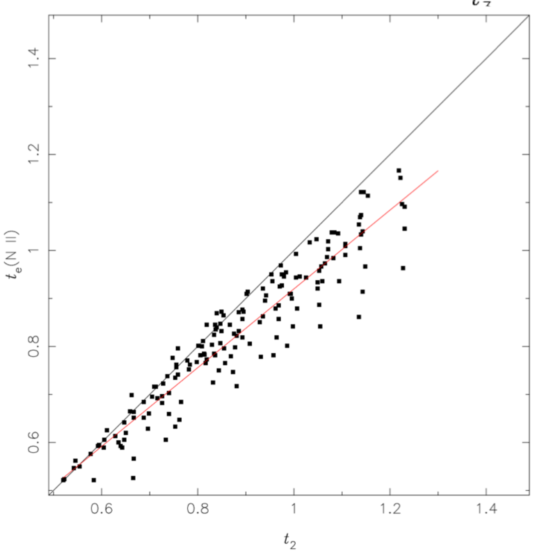


Figure 1. [OIII]λ5007/Hβ versus [NII]λ6584/Hα diagnostic diagram for the objects in our samples (see Sect. 2). Each sample is represented with a different colour as indicated. Solid line, taken from Kewley et al. (2001), separates SF-like objects from AGN-like objects.



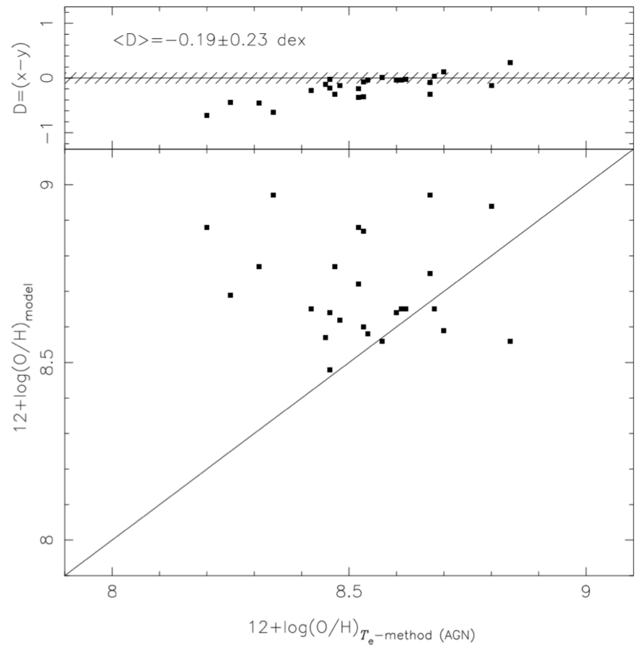


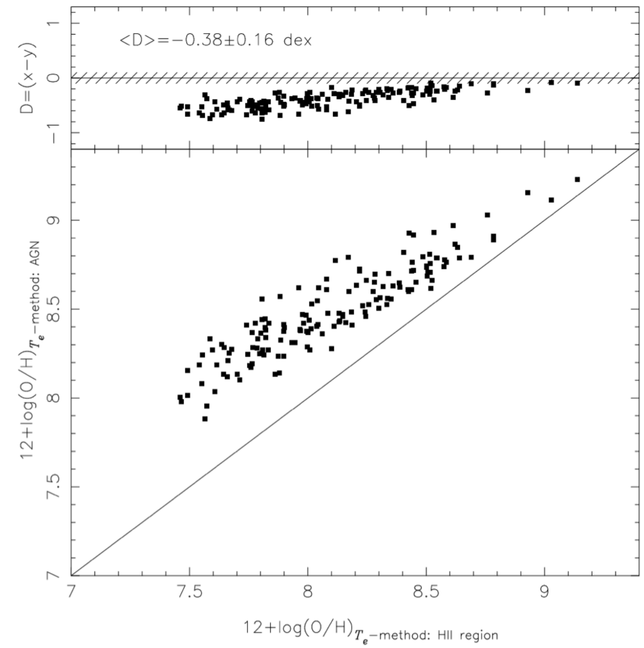


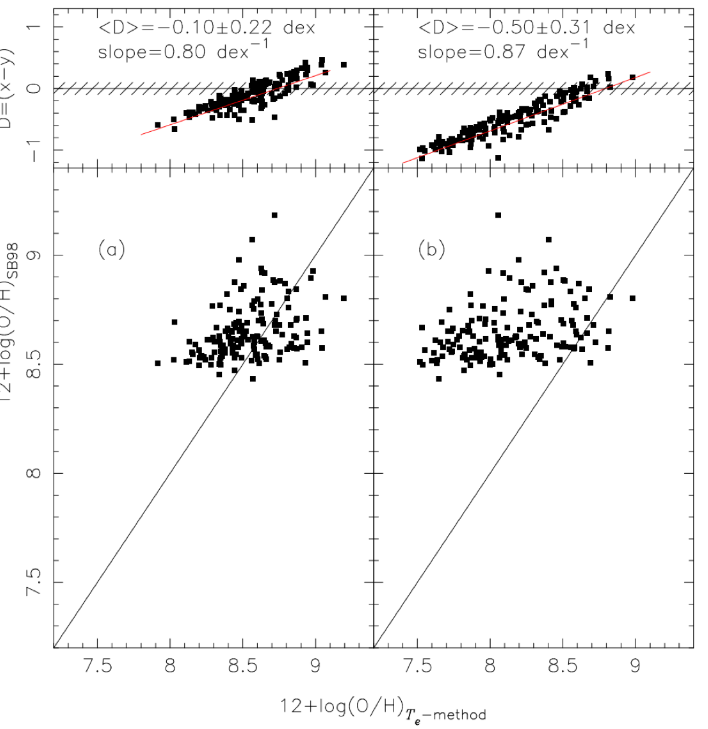


Эмпирическая закономерность t3 vs t2, калиброванная по HII, не работает для AGN

$$t_2 = 0.82 \times t_e(\mathrm{N\ II}) + 0.1.$$







Согласие между модельными и Te методом для AGN существенно улучшилось, но не идеально.