Photoionization models of the CALIFA HII regions

I. Hybrid models

ArXiv: 1606.01146

C. Morisset[1,10], G. Delgado-Inglada[1], S. F. Sánchez[1], L. Galbany[2,3], R. García-Benito[4], B. Husemann[5], R. A. Marino[6,7], D. Mast[4], M. M. Roth[8], and CALIFA collaboration[9]

[1] Instituto de Astronomía, Universidad Nacional Autonoma de Mexico, Apdo. Postal 70264, 04510, Mexico D.F., Mexico
[2] Millennium Institute of Astrophysics, Chile
[3] Departamento de Astronomía, Universidad de Chile, Camino El Observatorio 1515, Las Condes, Santiago, Chile
[4] Instituto de Astrofísica de Andalucía (CSIC), Glorieta de la Astronomía s/n, Aptdo. 3004, E18080-Granada, Spain
[5] European Southern Observatory (ESO), Karl-Schwarzschild-Str.2, D-85748 Garching b. München, Germany
[6] Department of Physics, Institute for Astronomy, ETH Zürich, CH-8093 Zürich, Switzerland
[7] Departamento Astrofísica, Universidad Complutense de Madrid, Avda.Ciudad Universitaria s/n 28040 - Madrid, Spain
[8] Leibniz Institut für Astrophysik, An der Sternwarte 16, 14482 - Potsdam, Germany
[9] http://califa.caha.es/
[10] e-mail: chris.morisset@gmail.com
ORCID 0000-0001-5801-6724

Received 04 2016; accepted 06 2016

ABSTRACT

Photoionization models of H II regions require as input a description of the ionizing SED (Spectral Energy Distribution) and of the gas distribution, in terms of ionization parameter U and chemical abundances (e.g. O/H and N/O). A strong degeneracy exists between the hardness of the SED and U, which in turn leads to high uncertainties in the determination of the other parameters, including abundances. One way to resolve the degeneracy is to fix one of the parameters using additional information.

For each of the ~ 20,000 sources of the CALIFA H II regions catalog, a grid of photoionization models is computed assuming the ionizing SED being described by the underlying stellar population obtained from spectral synthesis modeling. The ionizing SED is then defined as the sum of various stellar bursts of different ages and metallicities. This solves the degeneracy between the shape of the ionizing SED and U. The nebular metallicity (associated to O/H) is defined using the classical strong line method O3N2 (which gives to our models the status of "hybrids"). The remaining free parameters are the abundance ratio N/O and the ionization parameter U, which are determined by looking for the model fitting [N II]/Hα and [O III]/Hβ. The models are also selected to fit [O II]/Hβ. This process leads to a set of ~ 3,200 models that reproduce simultaneously the three observations.

We find that the regions associated to young stellar bursts (i.e., ionized by OB stars) suffer leaking of the ionizing photons, the proportion of escaping photons having a median of 80%. The set of photoionization models satisfactorily reproduces the electron temperature derived from the [O III]λ4363/5007 line ratio. We determine new relations between the nebular parameters, like the ionization parameter U and the [O II]/[O III] or [S II]/[S III] line ratios. A new relation between N/O and O/H is obtained, mostly compatible with previous empirical determinations (and not with previous results obtained using photoionization models). A new relation between U and O/H is also determined.

All the models are publicly available on the Mexican Million Models database 3MdB.

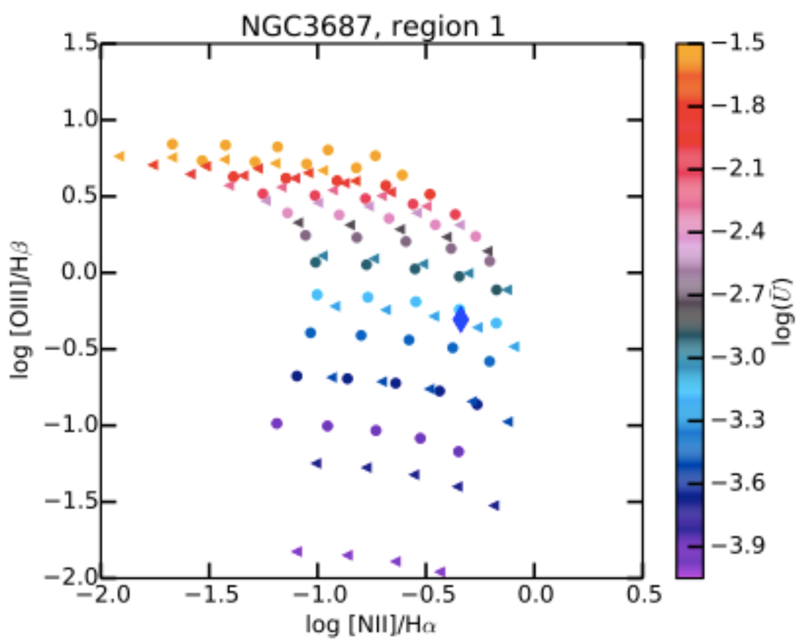


Fig. 1. Illustration of the modeled BPT diagram [O III]/Hβ vs. [N II]/Hα used to interpolate the values of log($\bar{U}$) and N/O for the region 1 of NGC3687. The blue diamond corresponds to the observed values in this [O III]/Hβ vs. [N II]/Hα diagram. The circles and triangles correspond to the values of the models obtained with the morphological factor fr set to 0.03 (filled sphere) and to 3.0 (thin shell) respectively. The colors correspond to the values of log($\bar{U}$) while the different values of N/O lead to models from left to right for increasing N/O.

- Выборка CALIFA ~20 000 областей ионизованного газа
- Металличность газа 12+log(O/H) определяется из наблюдательных данных методом O3N2 (Marino et al. 2013)
- Свойства звездного населения (возраст, металличность) определяется из анализа наблюдаемого спектра с помощью FIT3D
- Определенные параметры используются для генерации SED в результате взвешенного суммирования индивидуальных моделей POPSTAR (Molla et al. 2009) и IMF – Salpeter (1955). Хотя использование IMF Chabrier (2003) на результаты сильно не влияет.
- Полученные SED, металличность, обилие элементов (кроме азота) в соответствие с Asplund et al. (2009) – на вход CLOUDY, включив пыль и рассмотрев несколько вариантов геометрии области
- Свободные параметры модели – N/H (N/O), и ионизационный параметр U.

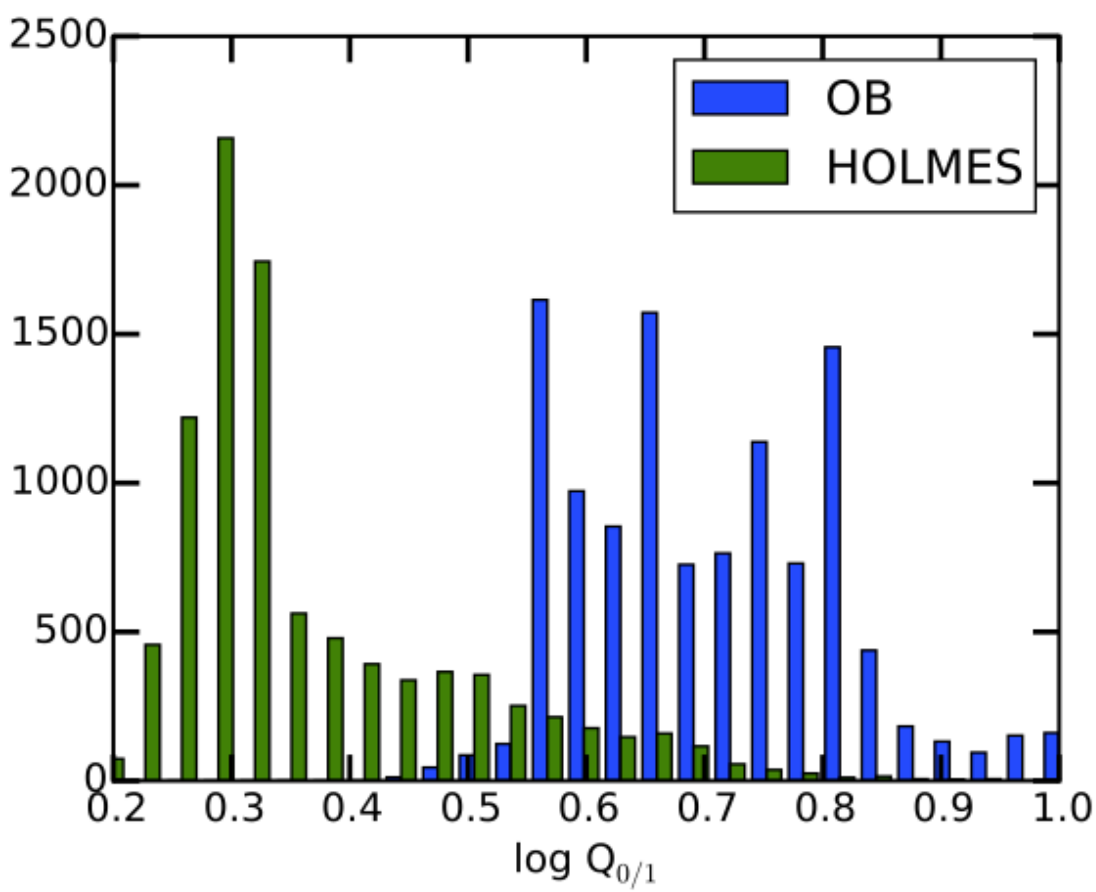
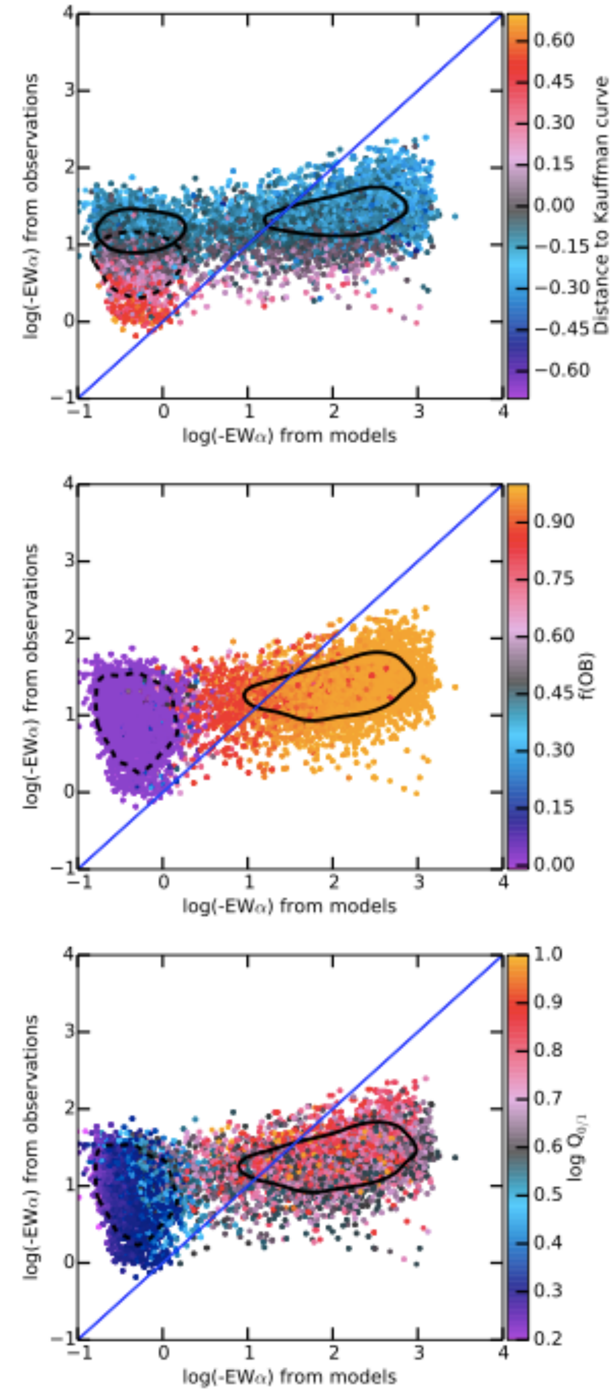


Fig. 2. Histogram of $Q_{0/1} = Q(H^0)/Q(He^0)$ for the OB and HOLMES dominated spectra.



HOLMES = HOt Low Mass Evolved Stars

log(O/H) < -3.5 => log(age/yr) < 6.8 для OB, > 8.25 для HOLMES
log(O/H) > -3.5 => log(age/yr) < 6.7 для OB, > 7.9 для HOLMES

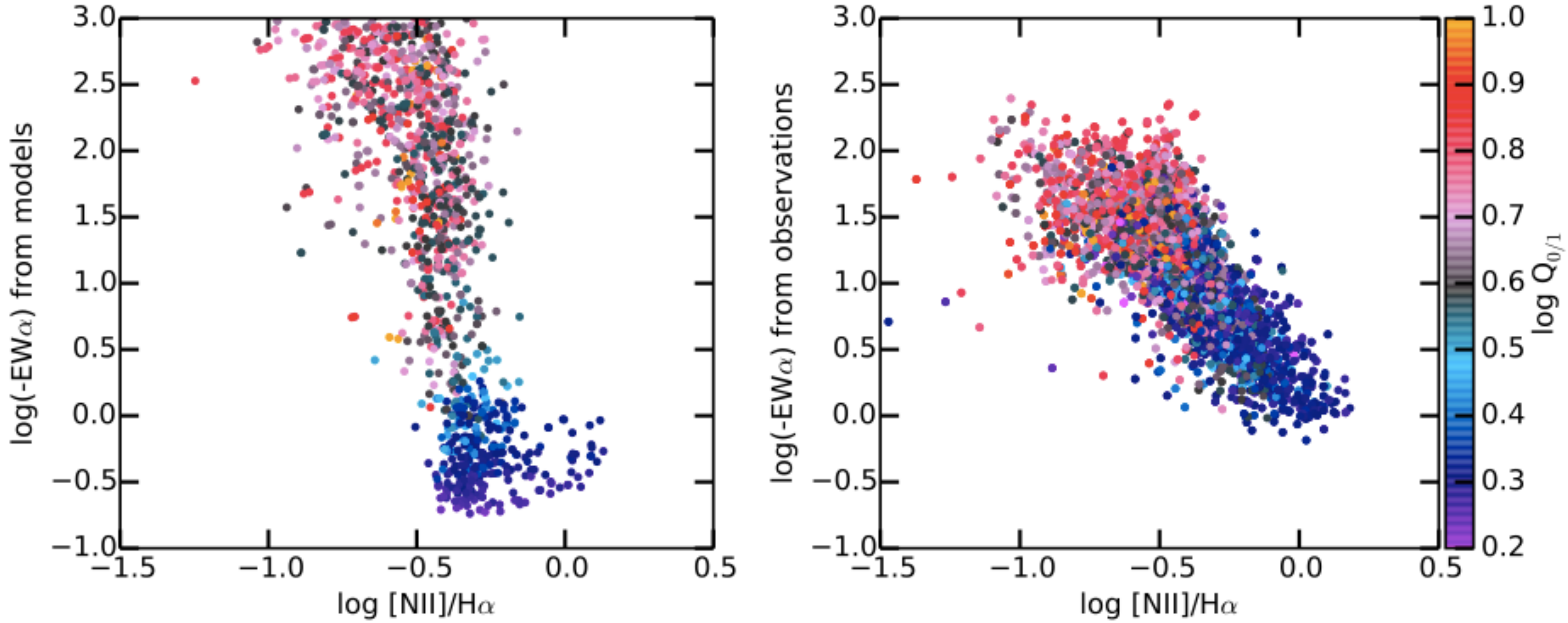


Fig. 9. WHAN diagrams: values of EW_α from the models (left panel) and from the observations (right panel) as a function of [N II]/Hα. The color code represents the proportion of OB stars.

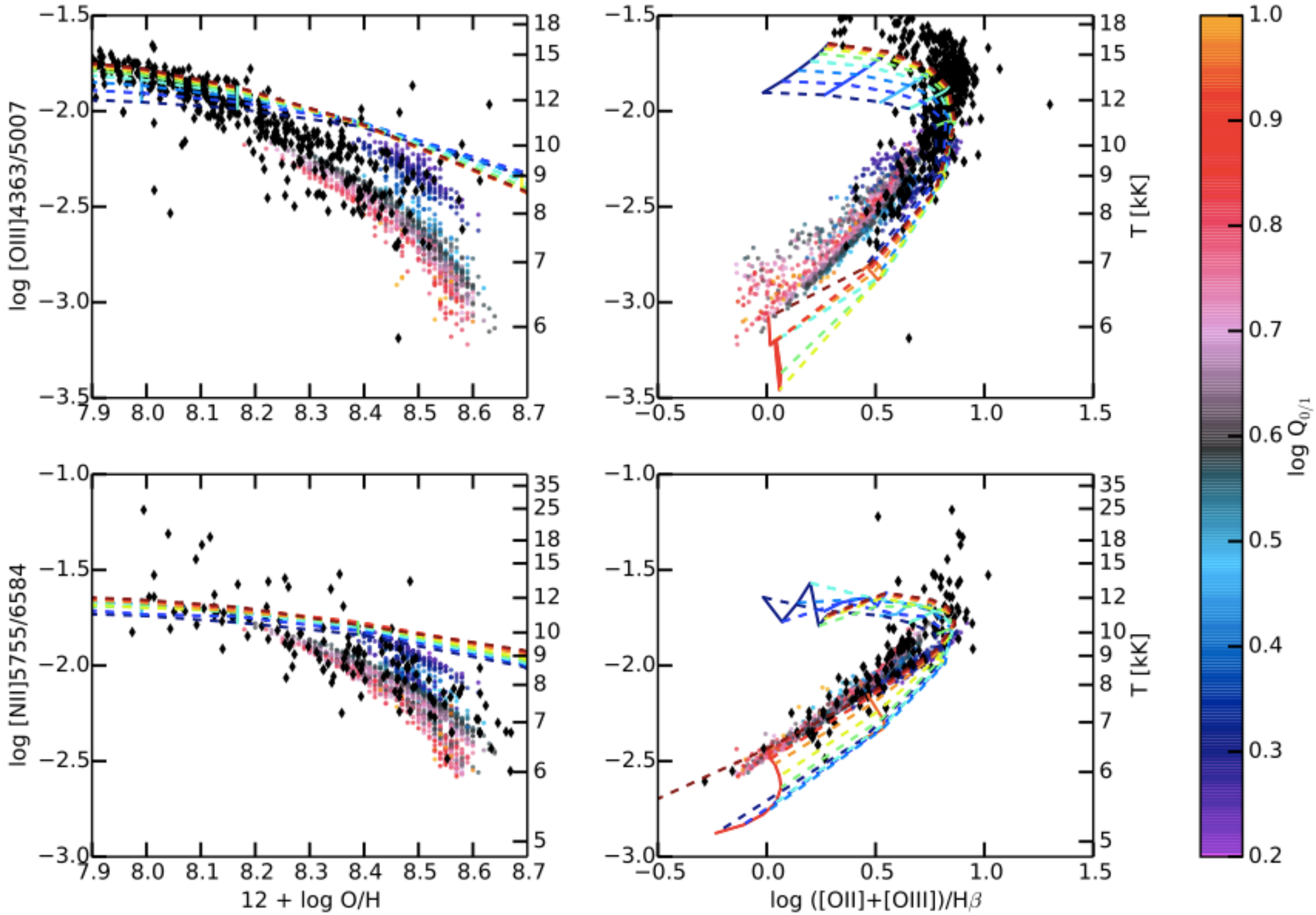
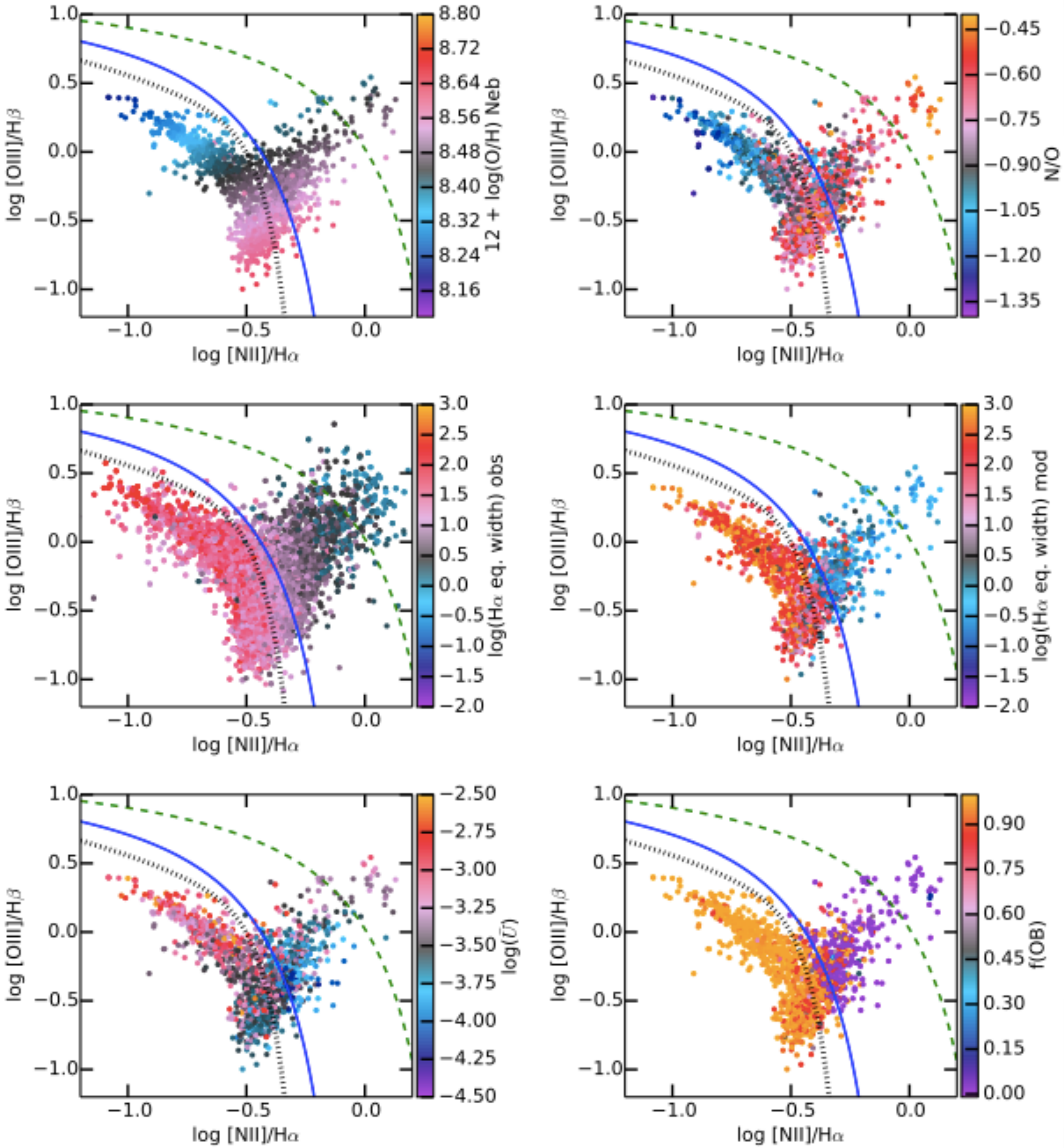


Fig. 5. Electron temperature diagnostic line ratios as a function of O/H (left panels) and ([O III]λ5007 + [O II]λ3727)/Hβ (right panels) for our models (colored circles). From top to bottom, the diagnostics are [O III]λ4363/λ5007 and [N II]λ5755/λ6584. Black diamonds represent the T_e-based sample of H II regions used by Marino et al. (2013). The dashed-color lines correspond to the grid of models computed by (Dopita et al. 2013). The color bar is following $Q_{0/1}$, the softness of the ionizing radiation.



log [OIII]/Hβ
log [NII]/Hα
1.0
0.5
0.0
−0.5
−1.0
12 + log(O/H) Neb
8.80
8.72
8.64
8.56
8.48
8.40
8.32
8.24
8.16
N/O
−0.45
−0.60
−0.75
−0.90
−1.05
−1.20
−1.35
log(Hα eq. width) obs
log(Hα eq. width) mod
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
log($\bar{U}$)
−2.50
−2.75
−3.00
−3.25
−3.50
−3.75
−4.00
−4.25
−4.50
f(OB)
0.90
0.75
0.60
0.45
0.30
0.15
0.00

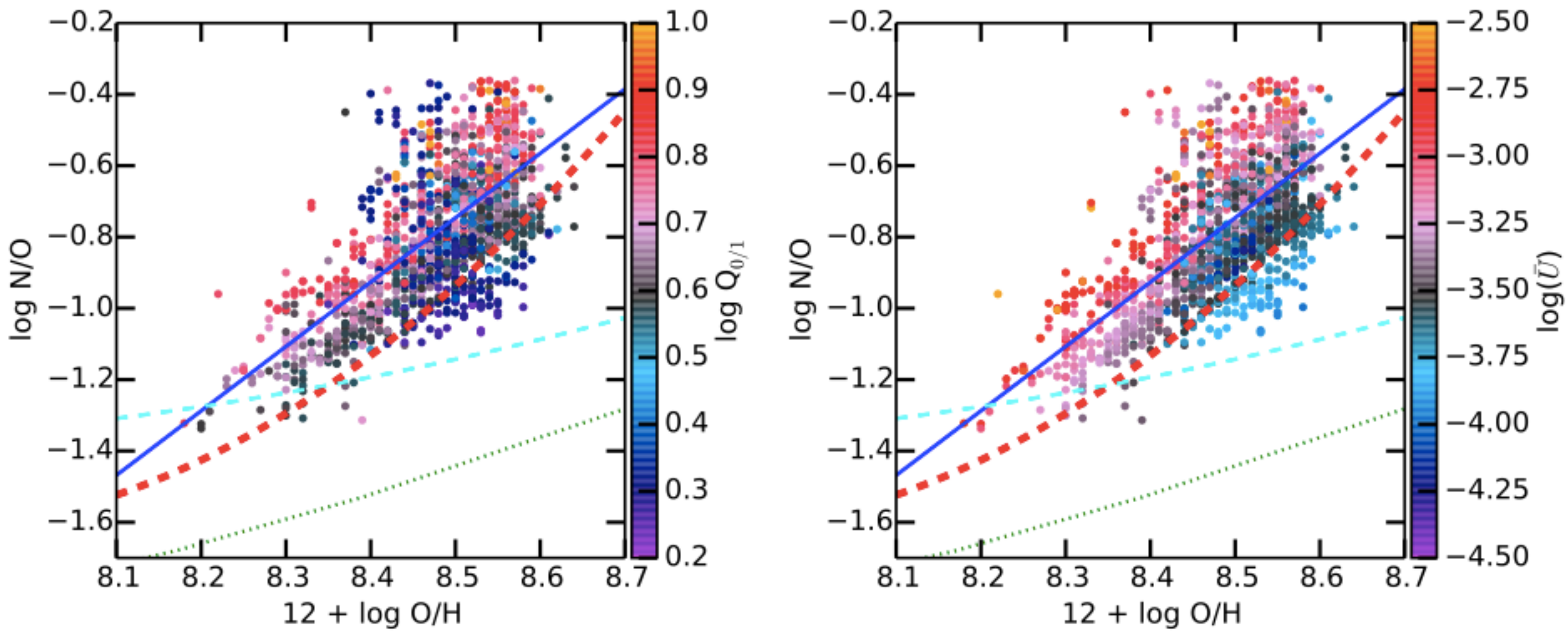


Fig. 12. N/O vs. O/H. Left panel: the color is coding the hardness of the ionizing radiation $Q_{0/1}$. Right panel: the color is coding the value of log($\bar{U}$). The blue line is the fit of the $Q_{0/1} > 0.55$ regions (gray/red/orange points), see text for the corresponding values. The red dashed line corresponds to the fit by Pilyugin et al. (2012), the cyan dashed line to Vila Costas & Edmunds (1993)
, and the green doted line to the fit by Dopita et al. (2013).

- Представлена модель областей HII, построенная по большой выборке CALIFA.
- Модели прекрасно согласуются с металличностью, определенной Te-методом. Хотя, температура получается слегка заниженной.
- Смоделированная эквивалентная ширина EW(Halpha) плохо согласуется с наблюдаемой. Авторы говорят об высокой (до 80%) доле утечки квантов из классических областей звездообразования и необходимости других источников ионизации (или несовершенстве моделей postAGB) – в области «ионизации старыми звездами»

- Все модели доступны для скачивания в базе данных 3MdB

https://sites.google. com/site/mexicanmillionmodels