Studying Physical Conditions in Star Forming Regions Using Cloudy

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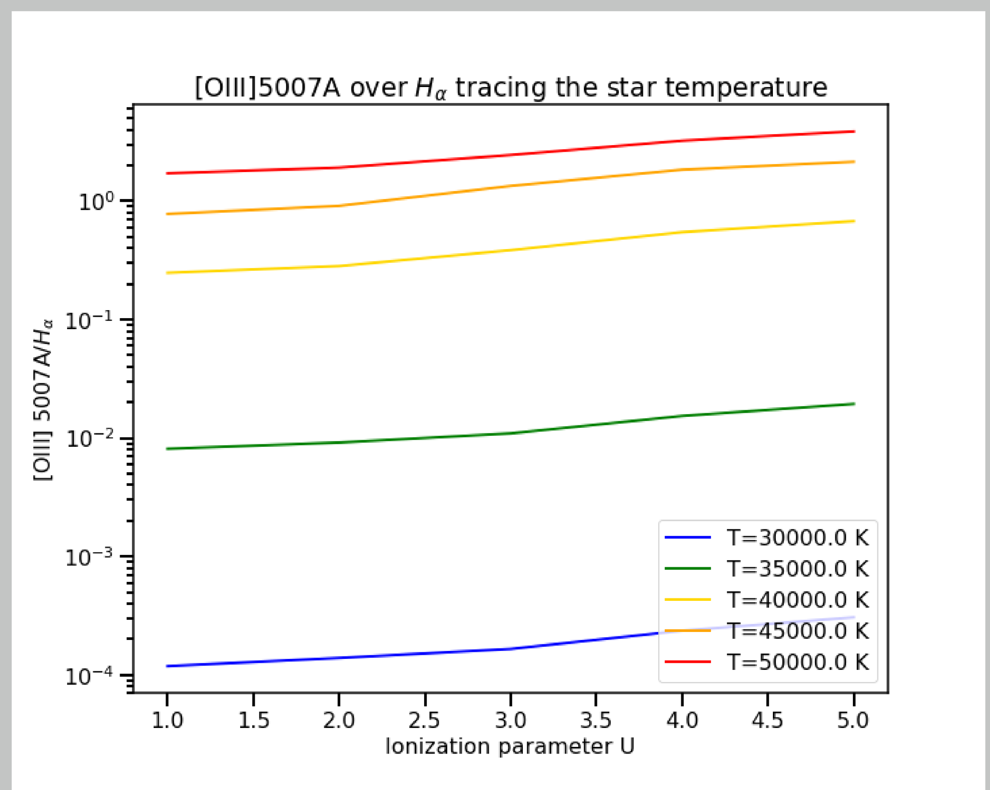
SynRGy

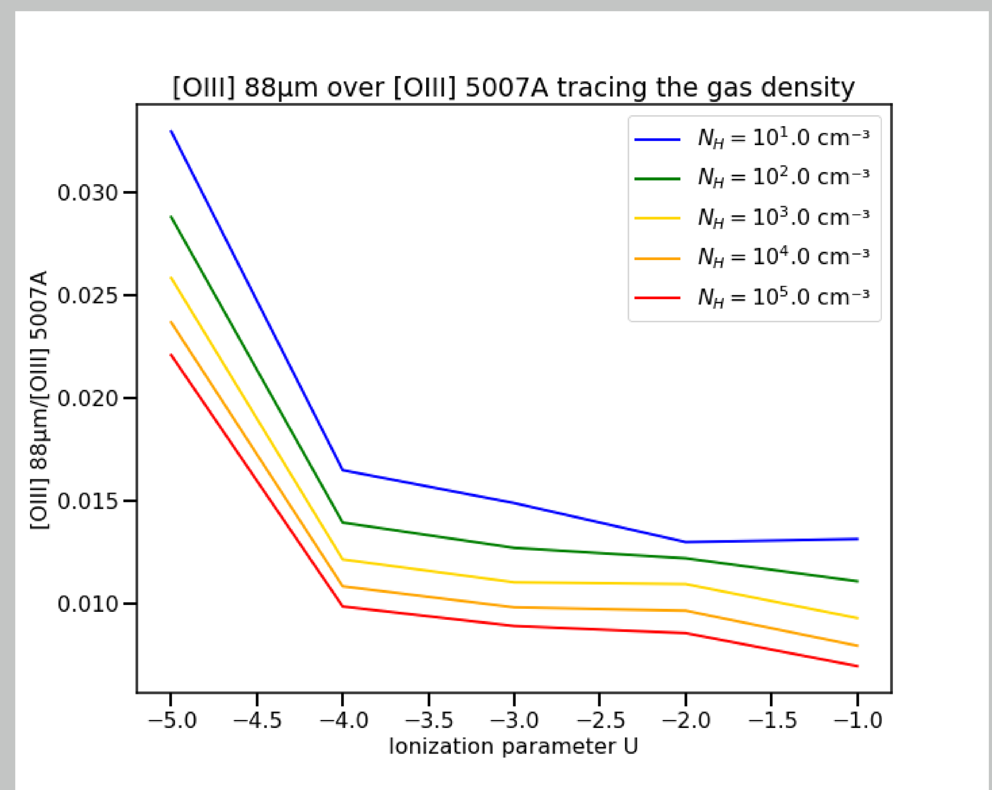
Introduction

Emission lines from ions, atoms and molecules are widely used in astrophysics to probe the physical conditions in the interstellar medium (ISM). But different spectral line and line ratios behave differently in different environments, therefore they can not be treated in the same fashion. So we investigated few lines and line ratios associated with specific parameters in star forming region (SFR). In order to do that, we used Cloudy photoionization model (Ferland et al. 2017 [1] and references therein) which allow us to control and vary a number of parameters to simulate the physical conditions in the nebula.

Line ratios and ionization parameters

We first attemp to see the the ionization parameters (U) dependences of line ratios for different density structures of the nebula (N_H) and the temperatures of central star (O-type star with a blackbody spectrum; Osterbrock & Feyland 2006 [2]). To do this we used two line ratios as described in V. Lebouteiller et al. (2012) [3]. The results are shown in the following figures.





From the above figures it is clear that these line ratios are good tracers for the density and the star temperature if the ionization parameter is known. However, the metallicity could play an important role, and change the behaviors of those lines.

Summary, acknowledgement and references

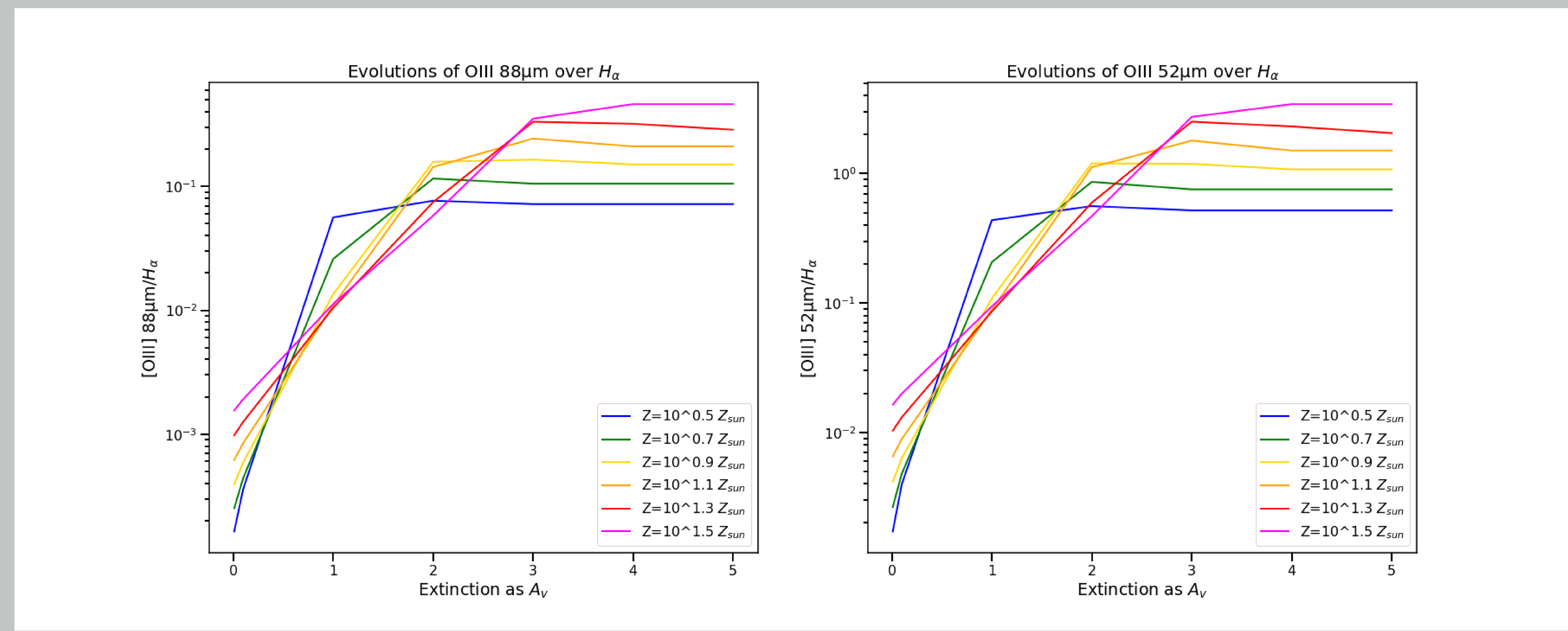
We have here investigated a few line ratios and their dependences on ionizing parameters, extinction for different star temperatures, density structures and metallicities. We also tried to see how the intensity of the spectral line depends on the magnetic field strength. It should be noted that these results are very preliminary. The dependences of line ratios on the metallicity/extinction and intensities of lines against magnetic field should be investigated for more lines and line ratios before reaching any final conclusion.

We would like to thank NARIT, to have hosted this workshop, Gary Ferland, Christophe Morisset and Peter Van Hoof, for their wonderful lectures, and all the participants for making atmosphere of the workshop pleasant.

[1] G.J. Ferland et al. 2017, RMxAA, 52, 385
[2] D.E. Osterblock & G.J. Ferland 2006, AGN3, University Science Books
[3] V. Lebouteiller et al. 2012, A&A, 548, 91
[4] T.H. Troland et al. 2016, ApJ, 825, 2

Scaling in extinction and metallicity

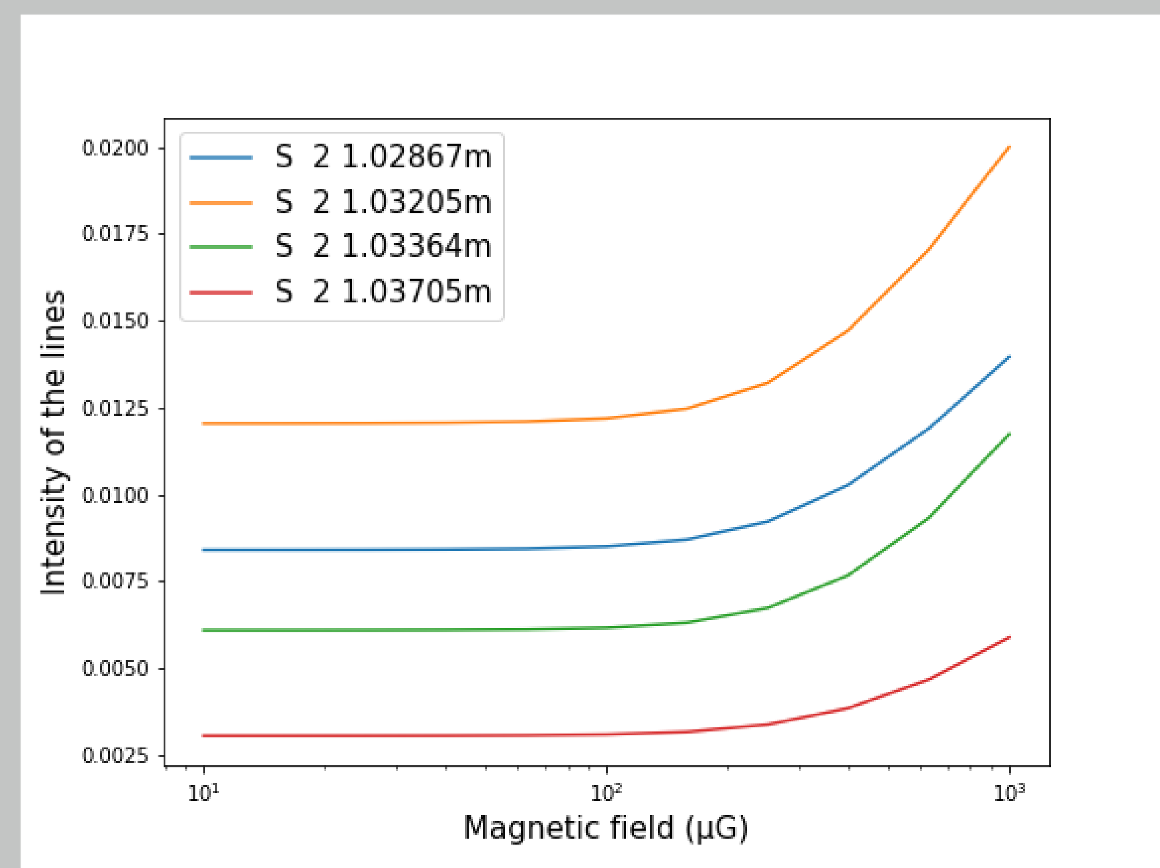
Star forming regions in the Galaxy and other galaxies may have very different metallicity than that in the solar neighborhood, affecting the extinction of several lines and that of the nebula. Our aim here was to investigate how intensities of infrared and optical lines depend on extinction for different metallicity.



These figures show that the infrared OIII lines with H_α can trace the metallicity at high extinction. However, infrared over optical OIII lines (not shown here) can not trace the extinction, because the optical lines are too sensitive to the gas temperature, which is linked to the extinction. The only difference between the two infrared lines is the strength of the lines (10 times stronger for [OIII] 52 μm). The very different behavior with the metallicity is also a problem with these ratios.

Role of the magnetic field

The magnetic field in the ISM is often traced by molecular lines, so we intended to see what is the role of magnetic field over the intensity of emission lines. Here we selected SII quadruplet in the near-infrared to study the effect of the magnetic field on its emission.



From the above figures we can see that the lines under 1 mG are not affected significantlyty. Magnetic field has been detected as high as 350 μG (T.H. Troland et al. 2016 [4]), but it is very rare and a higher value is improbable in star forming regions. However, it is possible that other lines may be more affected.