The Astronomical Journal, 135:1291–1300, 2008 April doi:10.1088/0004-6256/135/4/1291

A RE-EXAMINATION OF OBSERVED AND PREDICTED STELLAR IONIZING FLUXES IN THE LARGE MAGELLANIC CLOUD

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Received 2007 August 31; accepted 2008 January 21; published 2008 March 6

ABSTRACT

We use Hα luminosities of H II regions in the Large Magellanic Cloud to test the latest generation of hot-star atmosphere models. These newer models predict softer spectral energy distributions, and imply that less ionizing radiation escapes from classical H II regions than found in our previous study. Our analysis is based on a sample of 14 objects that have comprehensive inventories of spectroscopic classifications for the ionizing stars, and we also present a larger sample of 39 objects for which stellar properties are more roughly estimated from broadband photometry. Although the latter sample offers crude constraints, the results are fully consistent with, and support those from, the former sample. We find that the latest stellar atmosphere models predict that only 20–30% of H II regions are density bounded. This is consistent with the shell-like and filamentary morphology seen in those candidates. With these results, the total photon budget may not provide enough Lyman continuum radiation to account for the diffuse, warm ionized medium.

Key words: galaxies: ISM – H II regions – ISM: general – Magellanic Clouds – stars: atmospheres – stars: early-type

1. INTRODUCTION

The ionizing radiation from massive stars is a feedback mechanism of vital importance to a wide variety of astrophysical processes, including star formation, galaxy evolution, and cosmic re-ionization. Yet, on a quantitative level, the ionizing photon emission rates are still relatively uncertain, as a function of specific stellar parameters. Models of these complex, non-LTE stellar atmospheres have improved dramatically during the last two decades, but empirical tests of these models remain few. Photoionized nebulae offer a classical test of stellar atmosphere models (e.g., Morton 1969) by offering an essentially direct measure of the Lyman continuum photon emission rates from the parent star. Oey & Kennicutt (1997; hereafter OK97) compared observed and predicted H II region luminosities for 14 OB associations in the Large Magellanic Cloud (LMC), and Hunter & Massey (1990) compared observed and predicted ionization rates for 30 Galactic H II regions, based on Hα and/or radio continuum observations. One complication for empirical tests is the variation in properties of individual stars. Thus, tests carried out for larger samples offer a broader evaluation of the models. For example, Hoopes & Walterbos (2000) used *HST* FUV–optical photometry of OB stars in M33 to derive predicted ionizing luminosities for H II regions and the field population. The goals of this current study are twofold: to evaluate more recent stellar atmosphere models and their predictions for stellar Lyman continuum emission rates; and to increase the sample of objects for which this comparison between observations and predictions has been made.

The results directly affect our understanding of the diffuse, warm ionized medium (WIM), a ubiquitous component of the interstellar medium in star-forming galaxies. What is the role of massive field stars in ionizing the WIM, relative to massive stars in OB associations? The WIM tends to have brighter emission near H II regions (Hoopes et al. 1996; Ferguson et al. 1996), suggesting that leakage of ionizing photons from nebulae may be an important contributor. Our global study of an external galaxy's H II regions is an important step toward understanding the fate of ionizing photons.

Earlier, we found that for some H II regions, the Hα luminosity predicted from the observed stellar content is higher than the observed Hα luminosity (OK97). This implies that those H II regions are density bounded and that ionizing radiation escapes from them. An inhomogeneous medium complicates matters because if we consider that the medium may have pockets of low-density gas, the distance over which ionization and recombination rates balance will vary. One can see that where regions of low-density gas exist, there will be pockets where the photons can travel further and ionize hydrogen beyond the classical Strömgren radius, or possibly escape from the local region altogether.

The concept of leaky H II regions has helped reconcile our models of H II regions, stellar atmospheres, and the WIM. However, the percentage of H II regions that may be leaky is not well determined. In their study of 14 H II regions in the LMC, OK97 found the ratio of the observed-to-predicted Hα luminosity to be <0.70 for six of them. Hoopes & Walterbos (2000) noted that the two regions in OK97 that were leaking the most photons both had a ring-like morphology, prompting an exploration of the relation between H II region morphology and the leakiness. Hoopes and Walterbos classified the H II regions in M33 as either compact (center-brightened and discrete) or diffuse (filamentary or ring-like), but their results did not reveal a strong trend with morphology.

2. IONIZATION RATES FROM DIFFERENT MODELS

There are still significant variations in the predictions for Lyman continuum emission rates among different sets of model stellar atmospheres. Figure 1 shows the H-ionizing photon emission rate Q^0 as a function of stellar spectral type. The heavy and light lines denote dwarfs and supergiants, respectively. We compare predictions by Martins et al. (2005; hereafter MSH), Smith et al. (2002; hereafter SNC), Schaerer & de Koter (1997; hereafter SdK), Vacca et al. (1996; hereafter VGS),