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Ionizing Photon Production Efficiency of Star-Forming Galaxies at $z = 3.8 - 5.0$: Implications for Cosmic Reionization

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35-166357

Abstract

We present observational estimates of the ionizing photon production efficiency $\xi_{\rm ion}$ of star-forming galaxies at $z = 3.8 - 5.0$, addressing two questions of the cosmic reionization, ionizing sources and the cosmic reionization history. Our sample consists of 52 Lyman break galaxies in the UD-SXDS and UD-COSMOS fields with the spectroscopic redshift confirmation. We estimate the ionizing photon production efficiency based on the Hα luminosity of the galaxy. There is no Hα spectroscopy data available beyond $z \sim 3$. However, for galaxies at $z = 3.8 - 5.0$, the Hα emission line is redshifted to the passband of *Spitzer*/Infrared Array Camera (IRAC) 3.6μm. This redshift is closest to the reionization epoch whose galaxies' Hα emission can be estimated with the IRAC bands. We measure Hα fluxes based on the excess of the *Spitzer*/IRAC 3.6μm magnitude to the continuum level provided by the spectral energy distribution fitting. We calculate the ionizing photon production rate with Hα fluxes, and estimate an average value of $\xi_{\rm ion}$ with an escape fraction $f_{\rm esc}$ to be $\log \xi_{\rm ion}(1 - f_{\rm esc})$ [erg Hz^{-1}] $= 25.40 \pm 0.02$, about 0.1 dex higher than those obtained by Bouwens et al. (2016). We think that the difference is caused by the possibility of contamination in the Bouwens et al. (2016) sample. Using the ionization equation at the epoch of reionization with our $\xi_{\rm ion}$ measurements, we find that the ionized hydrogen fraction increases rapidly from $z \sim 7$ to $z \sim 6$. Our results also suggest that $f_{\rm esc} = 13 - 18\%$ is needed, if star-forming galaxies are the major sources of cosmic reionization.

Line-depth ratios as indicators of stellar parameters in near-infrared high-resolution spectra

35-166358

JIAN MINGJIE

Abstract

Determining stellar parameters is an essential step in stellar astronomy. Depth ratios of carefully selected line pairs are sensitive to stellar effective temperature ($T_{\rm eff}$), and relations established between the line-depth ratio (LDR) and $T_{\rm eff}$ allow one to determine $T_{\rm eff}$ precisely. Many previous studies used optical spectra to derive LDR–$T_{\rm eff}$ relations. They have been established for dwarfs, giants and supergiants, and a precision of a few tens of Kelvin can be easily achieved by using many relations altogether. However, LDRs may also depend on other stellar parameters such as metallicity, abundance ratios and gravity. Such dependencies would limit the accuracy of the LDR method unless they are properly taken into account. We investigate those effects on the LDRs in the infrared range (YJH-bands). The LDR–$T_{\rm eff}$ relations in these bands have been found recently, but the dependencies on stellar parameters remain to be investigated.

In this thesis, we make use of large datasets of high-resolution near-infrared spectra: H-band spectra of $\sim$ 12,000 stars publicly released by the APOGEE project and YJ-band spectra of $\sim$ 160 stars which we obtained with the WINERED spectrograph. The metallicity and/or gravity of these stars have been obtained by previous works, and they allow us to study the effects of these parameters on the LDRs.

We clearly detected the effects of metallicity and abundance ratios with the H-band APOGEE dataset; $T_{\rm eff}$ corresponding to a given LDR depends on the metallicity, 100–1000 K dex^{-1}, and the dependency on the abundance ratios also exists (100–1300 K dex^{-1}) when the LDR involves absorption lines of different elements. For the 11 line pairs in the H-band we investigated, the LDR–$T_{\rm eff}$ relations with abundance-related terms added have scatters as small as 40–105 K within the range of $3625 < T_{\rm eff} < 5000$

K and $-0.7 < [Fe/H] < +0.4$ dex. By comparing the observed spectra with synthetic ones, we found that saturation of the absorption lines can at least partly explain the metallicity effect.

The metallicity effect was also found in the YJ-band WINERED dataset, and it can also be explained by line saturation. In the YJ-band, 81 LDR–$T_{\rm eff}$ relations are known, much more than in H-band. Some of them cover wide ranges of LDR value from below 1 to over 1. We found that the metallicity effect tends to give shifts in the opposite directions; the LDR increases with increasing metallicity (or with increasing degree of saturation) when the LDR is smaller than 1, but it decreases when it is larger than 1. This trend was found in both observed and synthetic spectra.

The gravity effect on the LDRs was also detected with the YJ-band dataset. Many of the LDR relations for dwarfs show systemic offsets toward the upper side compared to those of giants/supergiants. Roughly half of the relations show such offsets. We propose that the gravity effect can be understood by considering that different elements with different ionization states have different sensitivities to the electron pressure in the stellar atmosphere which changes with the surface gravity.

In summary, we clearly detected and characterized the metallicity and gravity effects on the LDRs in the infrared range. The detection of these effects is for the first time in the infrared, and the characterization is more comprehensive and clear compared to previous works on the LDRs in the optical. Our results also indicate that the LDRs have the potential to determine stellar parameters other than $T_{\rm eff}$.

Physics of Non-thermal Emission from the Binary Neutron Star Merger GW170817

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35-166359

Abstract

A long lasting non-thermal afterglow has been observed to follow the binary neutron star merger event GW170817. The observed properties of the non-thermal spectrum are consistent with synchrotron radiation from a population of non-thermal electrons accelerated in the shock driven by outflow from the merger. The previous afterglow modelings frequently relied on a simplified assumption that all electrons in the shock are accelerated as a non-thermal population, and the minimum electron Lorentz factor γ_m is solely controlled by the fractional shock energy given to non-thermal electrons. However, in reality only a small fraction would be accelerated and the majority of electrons should remain as a thermal population, as normally observed in supernova remnant.

In this thesis, we model the non-thermal afterglow of GW170817 with a more natural model of electron energy distribution, in the sense that the fraction of accelerated electrons f is allowed as a new degree of freedom, while γ_m is another parameter corresponding to the degree of proton-electron equilibrium. In the context of structured jet and radially-stratified spherical outflow, we perform Markov-Chain Monte-Carlo analysis to obtain the posterior distribution of model parameters. Interestingly, a new solution is found with radio flux in the regime of low frequency synchrotron tail ($\nu < \nu_m$) in the early phase, in contrast to previous fits that found the entire spectrum above ν_m. Implications of this new result for physics of the outflow and ambient medium are discussed.

Abstract

Fluctuating Cosmic Magnetic Field, Non-Maxwellian distribution, and Impact on Big-Bang Nucleosynthesis
宇宙磁場揺らぎに起因する粒子の非マクスウェル分布とビッグバン元素合成への影響

by Yudong LUO
35-166360

Big Bang Nucleosynthesis (BBN) agrees well with the observational abundances of light elements D, ^{3}He, ^{4}He and ^{7}Li in the early universe except for ^{7}Li.
In order to resolve this problem, a non-Maxwellian distribution, Tsallis distribution for single particle is introduced into BBN epoch. The distribution function of the relative velocity in the framework of Tsallis is derived, we show that the distribution function of the relative velocity is different from the Tsallis distribution. We also used in calculations of thermonuclear reaction rates and derive revised nuclear reaction rates. Utilizing the revised rates, more accurate results of big bang nucleosynthesis are obtained for the Tsallis statistics. We find that it is possible to reduce the primordial ^{7}Li abundance by increase the parameter q in Tsallis statistics, by using observational constraints of D/H, we find a q value region in which it is impossible to realize a ^{7}Li abundance at the level of metal-poor stars without violating other elemental observations.
Although the physical interpretation of q in BBN is not discussed here, the deviation of Maxwellian distribution motivated us to consider the temperature fluctuation which can be triggered by the large scale Primordial Magnetic Field (PMF). We investigate the effect on the abundances of these elements from the presence of a stochastic PMF whose strength is spatially inhomogeneous. We assume a uniform total energy density and a large-scale stochastic PMF with a power law (PL) correlation function and a gaussian distribution of field strength. In this case, domains of different temperatures exist in the BBN epoch due to variations in the local PMF. We show that in such case, the effective distribution function of particle velocities averaged over domains of different temperatures deviates from the Maxwellian distribution. This deviation is related to the scale invariant (SI) strength of the PMF energy density ρ_{Bc} and the fluctuation parameter σ_B. We perform BBN network calculations taking into account the PMF strength distribution, and deduce the element abundances as functions of baryon-to-photon ratio η, ρ_{Bc}, and σ_B. We find that the fluctuation of the PMF reduces the ^{7}Be production and enhances D production. We analyze the averaged thermonuclear reaction rates compared with those of a single temperature, and find that the charged-particle reaction rates are very different. Finally, we constrain the parameters ρ_{Bc} and σ_B. for our fluctuating PMF model from observed abundances of ^{4}He and D. In this model, the ^{7}Li abundance is significantly reduced. We also discuss the possibility that the baryon-to-photon ratio decreased after the BBN epoch. In this case, we find that if the η value during BBN was larger than the present-day value, all produced light elements are consistent with observational data. In this project, for the first time, we connect non-Maxwellian distribution with physical processes during primordial nucleosynthesis epoch.[1]

[1] In this thesis, chapter 2 is based on Motohiko Kusakabe, Toshitaka Kajino, Grant J Mathews and Yudong Luo (2018), chapter 3 is based on Luo et al. (2018)