様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

平成　２９　年　　６　月　　６　日現在

機関番号：１２６０１
研究種目：若手研究(B)
研究期間：2015～2016
課題番号：１５Ｋ１７６００

研究課題名（和文）Systematic study of the stellar initial mass function and its variation

研究課題名（英文）Systematic study of the stellar initial mass function and its variation

研究代表者
ＭＯＲＥ　Ｓｕｒｈｕｄ（MORE, Surhud）

東京大学・カブリ数物連携宇宙研究機構・特任助教

研究者番号：００６４６０４４

交付決定額（研究期間全体）：（直接経費）　　3,000,000円

研究成果の概要（和文）：本研究の目的は、弱重力レンズとスタックした銀河の分光スペクトルの測定を組み合わせ、初期の星質量関数を制限する手法を開発することである。銀河の重力レンズ効果の測定を用いることにより、SDSS-BOSS銀河の星質量の上限を得ることができ、これにより異なる初期質量関数の理論モデルを区別できる可能性がある。BOSS銀河の星質量を正確に測定するには、すばるHSCデータにおいて銀河が密集した領域の重力レンズ効果を測定する必要がある。このため、異なる銀河の重なりを区別するための指標を定義し、HSCパイプラインに実装した。また、この研究の一部としてHSCデータの重力レンズ解析のためのソフトウェアも開発した。

研究成果の概要（英文）：The purpose of this project was to develop methods to put constraints on the initial mass function of stars using weak gravitational lensing and stacking of stellar spectra. High signal-to-noise ratio stacked spectra of SDSS-BOSS galaxies as a function of different BOSS galaxy properties have been obtained and the theoretical analysis of these stacked spectra is ongoing. We were able to infer limits on the stellar mass of BOSS galaxies using the weak gravitational lensing signal from the CFHTLS survey which could distinguish between theoretical estimates based on different initial mass functions. Measurement of the stellar masses of BOSS galaxies will require the measurement of the weak lensing signal in crowded regions in the Hyper Suprime-Cam (HSC) survey. We have developed and implemented a blendedness parameter to identify blended objects. As part of this project, we have also developed a weak lensing pipeline for the analysis of Hyper Suprime-Cam data.

研究分野：天文学

キーワード：Stellar IMF constraints　HSC weak lensing

１．研究開始当初の背景

The stellar initial mass function (IMF hereafter) of galaxies describes the probability distribution of the mass of stars at the time of their birth, $¥xi(M)¥propto M^{-x}$. The IMF is an important ingredient for observational astrophysics, in the determinations of stellar masses, star formation histories and metallicities of galaxies. The IMF controls the relative abundance of the low to high mass stars. It is the most fundamental constraint on theories concerning star formation. The IMF is commonly determined from stellar counts in the solar neighborhood. Salpeter (1955) inferred x=2.3 at the high mass end while broken power laws have been suggested by Kroupa et al. 2001 and Chabrier et al. 2003 at the low mass end. Observationally, the low mass end is very difficult to constrain. Most observational studies proceed under the simple but rather unjustified assumption that the IMF is universal. Theoretically, the IMF may be dictated by the local turbulence in gas near sites of star formation. The subsequent fragmentation results in the observed mass spectrum of stars. Averaged overlarge scales such as a galaxy, these local factors could result in a universal IMF. However, there have been several recent indications that IMF may be non-universal, and could either evolve with time or depend on different galaxy properties (van Dokkum & Conroy 2010, Dutton et al. 2010, Smith et al. 2013, Spineillo et al. 2012). However some of these results in the literature have been conflicting due to the different methodologies used even though the same galaxies were analyzed.

２．研究の目的

The purpose of the research was to systematically study and constrain the initial mass function of stars using SDSS BOSS galaxies as a function of different galaxy properties, based on stacked spectra of galaxies. The secondmethod mentioned was to use weak gravitational lensing signal in order to measure absolute stellar masses of SDSS BOSS galaxies. The stellar mass-to-light ratio is sensitive to the initial stellar mass function.

３．研究の方法

Stacked stellar spectra

The BOSS survey spectrograph is sensitive between the wavelength range 0.360$¥mu$ and 1.040$¥mu$. A number of spectral features that arise in the atmospheres of dwarf stars exist in this wavelength range. Although many of these features will be difficult to detect in individual galaxies, they can manifest themselves in stacked spectra of BOSS galaxies. These stacked spectra will then be fit using stellar population synthesis sy nthesis models, which will give us an idea of the IMF and its systematic variation with galaxy velocity dispersion. Although such studies have been done with earlier SDSS-I SDSS I and II data, they have been limited to a limited spectral range than what BOSS provides in the infrared.

Weak gravitational lensing

Weak gravitational lensing signal can be measured in the very inner regions around BOSS galaxies. On large scales, the signal can put constraints on the halo masses these galaxies reside in, while the small scale signal can directly probe the stellar mass-to-light light ratio of these galaxies (which depends crucially upon the IMF). Since gravitational lensing is a relatively clean probe of the mass distribution, this method can contrast our results for the expected stellar mass given the IMF constraints obtained from the spectral analysis.

However, performing weak lensing measurements on small scales is challenging.

Measurements of shapes in crowded regions can be hampered by blending of isophotes, especially for high quality data such as the one that will be obtained from the Hyper Suprime-Cam survey. The goal was to develop methods to aid the weak lensing efforts in the HSC in order to be able to measure weak lensing signal around BOSS galaxies.

４．研究成果

Major outcome of the research

- Its positioning and impact in domestic and overseas trends
- Future prospects

We have obtained high signal-to-noise stacked SDSS BOSS galaxy spectra by binning SDSS galaxies on velocity dispersion. These measurements can give detailed insights into the stellar properties of the SDSS galaxies. The theoretical analysis of the stacked spectra are ongoing but are complicated by the fact that the interpretation of stacked spectra is that indicators in the optical wavelengths in order to constrain the initial stellar mass function may not be optimal. We have instead performed the backup project of obtaining weak lensing constraints around SDSS BOSS galaxies using the CFHTLS data. We have measured the weak lensing signal on small scales. The models suggest upper limits on the stellar mass of BOSS galaxies at a redshift of 0.55, which is the highest redshift where such a study has been performed so far. These upper limits constrain the various estimates of the stellar masses provided in the BOSS collaboration. These weak lensing measurements were also combined with clustering measurements to obtain constraints on cosmological parameters such as the matter density and the amplitude of density fluctuations in the Universe.

I have also been part of an effort to measure the weak lensing masses of blue starforming galaxies, and red and dead elliptical galaxies in SDSS. These measurements are precursors to what can be done with the Hyper Suprime-Cam survey. This has paved the way to combine these weak lensing measurements with the various galaxy scaling relations in order to obtain constraints on the stellar IMF.

During this project I have developed and implemented the blendedness parameter in the HSC software pipeline. This parameter quantifies the amount by which neighbouring objects are blended. This metric is a basic sanity test for the photometry and size measurement estimates in crowded regions. I have also developed a HS pipeline which provides automated measurements of the weak lensing signal around galaxy or galaxy cluster samples. These have been used to compute weak lensing signals with mock catalogs in order to obtain covariance matrices. These covariance matrices inform the signal-to-noise expected from HSC data and these have been used to set requirements on various shear catalog calibrations. The first year HSC catalogs are becoming available now. So these tools are expected to be heavily used in the future.

Lastly, but most importantly, while investigating systematics in weak gravitational lensing during the course of this project, we have stumbled upon the detection of assembly bias on galaxy cluster scales and the edges of galaxy clusters in observations. Although these are not directly related to this the main goal of this project, these observational developments have stoked the interest of the scientific community, to look into possible systematics of the weak lensing signal as well as optical cluster finding systematics. This side project has become topic of a parallel investigation supported by a grant innovative research area (cosmic acceleration research PI: Hitoshi Murayama).

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計　８件）

① More, S., H. Miyatake, M. Takada, and 10 more co-authors, Detection of the Splashback Radius and Halo Assembly Bias of Massive Galaxy Clusters, The Astrophysical Journal, (2016), 825, 39, refereed, doi://10.3847/0004-637X/825/1/39

② Mandelbaum, R., W. Wang, Y. Zu, S. White, B. Henriques, and S. More, Strong bimodality in the host halo mass of central galaxies from galaxy-galaxy lensing, Monthly Notices of the Royal Astronomical Society, (2016), 457, pages 3200-3218, refereed, doi://10.1093/mnras/stw188

③ Miyatake, H., S. More, M. Takada, and 3 more co-authors, Evidence of Halo Assembly Bias in Massive Clusters, Physical Review Letters, (2016), 116, 041301, refereed doi://10.1103/PhysRevLett.116.041301

④ Hoshino, H., A. Leauthaud, C. Lackner, C. Hikage, E. Rozo, E. Rykoff, R. Mandelbaum, S. More, A. More, S. Saito, and B. Vulcani, Luminous red galaxies in clusters: central occupation, spatial distributions and miscentring, Monthly Notices of the Royal Astronomical Society, (2015), 452, pages 998-1013, refereed doi://10.1093/mnras/stv1271

⑤ More, S., B. Diemer, and A. V. Kravtsov, The Splashback Radius as

a Physical Halo Boundary and the Growth of Halo Mass, The Astrophysical Journal, (2015), 810, 36, refereed doi://10.1088/0004-637X/810/1/36

⑥ More, S., H. Miyatake, R. Mandelbaum, and 4 more coauthors, The Weak Lensing Signal and the Clustering of BOSS Galaxies. II. Astrophysical and Cosmological Constraints, The Astrophysical Journal, (2015), 806, 2, refereed, doi://10.1088/0004-637X/806/1/2

⑦ Miyatake, H., S. More, R. Mandelbaum, and 6 more coauthors, The Weak Lensing Signal and the Clustering of BOSS Galaxies. I. Measurements, The Astrophysical Journal, (2015), 806, 1, refereed , doi://10.1088/0004-637X/806/1/1

⑧ Kobayashi, M. I. N., A. Leauthaud, S. More, and 4 more coauthors, Can we use weak lensing to measure total mass profiles of galaxies on 20 kpc scales?, Monthly Notices of the Royal Astronomical Society, (2015), 449, pages 2128-2143, refereed, doi://10.1093/mnras/stv424

〔学会発表〕（計　2 件）

① Surhud More, Detection of the Splashback radius and assembly bias of clusters, The Galaxy-Halo connection, 16 March, 2016, Snowbird, Utah (USA)
② Surhud More, Structure and large scale distribution of dark matter halos: Overview and new horizons, Dark side of the Universe,15 December 2015, YITP, Kyoto

〔図書〕（計　0 件）

〔産業財産権〕

○出願状況（計　0 件）

名称：
発明者：
権利者：
種類：
番号：
出願年月日：
国内外の別：

○取得状況（計　0 件）

名称：
発明者：
権利者：
種類：
番号：
取得年月日：
国内外の別：

〔その他〕

The detection of the assembly bias result was reported widely in the news media and was a subject of a press release by IPMU.
The cosmological results from the BOSS CFHTLS weak lensing were featured in IPMU News.
All the publications resulting from the grant were made available on the publicly accessible websitewww.arxiv.org.

6．研究組織

(1)研究代表者
モレ　スルド（MORE, Surhud）
東京大学・カブリ数物連携宇宙研究機構・特任助教
研究者番号：00646044

(2)研究分担者
なし

研究者番号：

(3)連携研究者
なし

研究者番号：

(4)研究協力者
なし