OBSERVING REQUEST
Telescope Access Program, China

Year: 2015 **Term:** Feb–Jul **Proposal type:** short-term

Spectroscopy of blue compact dwarf galaxies at intermediate redshift in the COSMOS deep field

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Abstract of Scientific Justification

There are two main goals of this proposal: exploring the mass-metallicity (MZ) relation at low mass and searching new extremely metal poor galaxies (XMPGs) outside local universe. A strong correlation between stellar mass and metallicity was found several decades ago. The physical origin of this relation is still under debate. A better description of MZ relation at low mass is important to discriminate different physical processes that govern the mass-metallicity relation and understand how galaxies evolves at early stage. Extremely metal poor galaxies are defined as galaxies with metallicity 12+log(OH) ≤ 7.65. Most XMPGs are gas-rich, blue compact dwarf galaxies and the most promising young galaxy candidates in local universe. A large sample of XMPGs are needed to assess the reality of the so-called 'metallicity floor'. However, XMPGs are very rare. To date, only $\sim$ 70 XMPGS are found with the majority in local universe $z < 0.1$. We selected a sample of 264 blue compact dwarf galaxies at $z < 0.7$ and propose to use the Hectospec on MMT telescope to perform a spectroscopic survey for them. With a sample ten times larger than previous works, we could expect that the intermediate-redshift MZ relation at low mass could be more strictly constrained. Based on the number density estimation in Ly et al. 2013, $\sim$ 20 galaxies with [O III]λ4363 detection and $\sim$ 4 XMPGs are expected in our spectroscopic survey. we estimate the exposure time by comparing to the similar survey conducted by Ly et al. 2013 using Hectospec on MMT. To conduct a spectroscopic survey $\sim$ 1 mag deeper than that in Ly et al. 2013, an exposure time of 4 hours is needed. We plan to split the 4 hour exposure time into four 60 minute exposures. Taken $\sim$ 15 minutes of overhead in each exposure into account, a total of 5 hour is required (half night).

Summary of observing runs requested for this project

Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Scheduling Optimal	Scheduling Acceptable	Sharing Poss.	Sharing Adv.
1	MMT	f/5	Hectospec	*		0.5	dark	Feb–Mar	Jan–Apr	yes	yes
or:											
1a										no	no

Scheduling constraints and unusable dates *(up to 4 lines)*: First half night observation is optimal in Jan–Feb and Second half night is optimal in Mar–Apr. Hectospec is available after January 20 due to cold temperatures.

no text past this line

A ⋆ appended to the proposal type indicates a continuation proposal; a ⋆ appended to the name of a proposer indicates the proposer is a (graduate) student; a proposer whose name is underlined is certified on the proposed telescope/instrument combination; if a ∗ appears within the PI or AO box in the observations summary table, the instrument is a PI instrument and/or Adaptive Optics are requested – signatures are required on the next page.

Target list (attach list if longer than 26 objects)

#	Object	RA	Dec	mag / color / type / redshift / comment / etc.
1	256	9:59:36.92	+2:30:54.8	z=0.32, $\mathrm{M_B}$=24.99, $\log(\mathrm{M_*}/\mathrm{M_\odot}) = 7.5$
2	251	10:00:54.48	+2:28:32.3	z=0.67, $\mathrm{M_B}$=24.99, $\log(\mathrm{M_*}/\mathrm{M_\odot}) = 8.9$
3	218	9:59:40.30	+2:8:1.6	z=0.47, $\mathrm{M_B}$=24.78, $\log(\mathrm{M_*}/\mathrm{M_\odot}) = 8.8$
4	263	10:00:15.58	+2:35:48.8	z=0.69, $\mathrm{M_B}$=24.71, $\log(\mathrm{M_*}/\mathrm{M_\odot}) = 9.0$

If this program uses a PI instrument, attach the approval email from the PI to this proposal.

Graduate students *(provide the following information for **each** student named as PI or CoI on the cover page.)*

Student's Name	Advisor's Name	Thesis
Jianhui Lian	Xu Kong	yes
Ning Hu	Xu Kong	yes
Chengyun Ye	Xu Kong	yes

Scientific Justification *Please include overall significance to astronomy and significance within the proposal's discipline. Limit text to one page, with a maximum of two additional pages for figures, captions, and references.*

There are two main goals of this proposal. The first one is to explore the inter-mediate redshift mass-metallicity (MZ) relation at low mass end. The second one is to search new extremely metal poor galaxies (XMPGs) outside the local universe.

Mass-metallicity relation at low mass: Metallicity is a key parameter to probe the galaxy formation and evolution. Metal enrichment process of a galaxy is driven by star formation and regulated by gas outflows from supernova and inflows from cosmic accretion. A correlation between galaxy masses and gas metallicities was found in the 1970s (Lequeux et al. 1979). Subsequently, Tremonti et al. (2004) confirmed this relation at $z \sim 0.1$ by using $\sim$ 50000 SDSS galaxies. The mass metallicity relation is an important probe to the balance between gaseous inflows, outflows and star formation. One possible explanation of the MZ relation is the supernova-driven winds, which could remove the metal-enriched gas from galaxies and are more effective in low mass galaxies with shallow gravitational potential. It is also suggested by many works that outflows are prevalent in low mass galaxies (Izotov et al. 2006; Martin et al. 2012). However, the properties of these gaseous flows are poorly constrained and the physical driver of MZ relation is still under debate. A better understanding of MZ relation at low mass are important to fully understand the MZ relation and how galaxies evolves at early stage. There are many works that studied the local MZ relation (or luminosity-metallicity relation) of low mass galaxies (Lee et al 2006; Zhao et al. 2010 ; Berg et al. 2012). However, outside the local universe, the MZ relation at stellar mass below $10^9\mathrm{M}_\odot$ has not been extensively explored. Recently, Henry et al. (2013) firstly derived the low-mass, intermediate-redshift MZ relation with 26 emission-line galaxies reaching mass $10^8\mathrm{M}_\odot$ at $z \sim 0.6 - 0.7$. They found the metallicity is typical lower than that at $z \sim 0.1$ by about 0.12 dex at a fixed mass.

Extremely metal poor galaxies: Metal poor galaxies are ideal laboratory to study star formation and gas enrichment in a nearly pristine interstellar medium. Extremely metal poor galaxies are defined as galaxies with metallicity 12+log(OH) ≤ 7.65 (Knizev et al. 2003; Kakazu et al. 2007). Most XMPGs are gas-rich, blue compact dwarf galaxies with spectra dominated by emission lines and mass $\sim 10^8\mathrm{M}_\odot$ (Brown et al. 2008). The XMPGs are the most promising young galaxy candidates and possibly the pristine units from which galaxies formed. A metal floor of XMPGs seems to exist, which means that even the most metal deficient galaxies formed from pre-enriched matter (Kunth & Ö stin 2000; Izotov et al. 2012). A large sample of XMPGs are needed to assess the reality of such a metallicity floor. However, XMPGs are very rare. Efforts have been made to search for XMPGs in the local universe (Brown et al. 2008; Izotov et al. 2012), and at higher redshift (Hu et al. 2009; Ly et al. 2013). Hu et al. (2009) conducted spectroscopic observation with Keck for a narrow band (NB) selected emission line galaxy (ELG) sample at $z \sim 0.4 - 0.85$. 28 galaxies are detected in the [O III]λ4363 line where the metallicity can be determined by using the direct T_e method, and 5 galaxies have 12+log(OH) ≤ 7.65. Recently, Ly et al. (2013) found 20 galaxies with the [O III]λ4363 line detected at $\geq 3\sigma$ in a spectroscopic survey of $\sim$ 900 NB selected ELGs in the Subaru Deep Field. Four galaxies in their sample are XMPGs. To date, only $\sim$ 70 XMPGS are found with the majority in local universe $z < 0.1$.

To explore the low- and intermediate-redshift MZ relation at low mass, we selected a sample of 264 blue compact dwarf galaxies at photometric redshift lower than 0.7 in the COSMOS deep field (Skelton et al. 2014; Muzzin et al. 2013). The redshift of the sample ranges from 0.08 to 0.70 with 75 galaxies in $z < 0.3$. Our dwarf galaxy sample is about 10 times larger than previous works and reaches mass as low as $10^7\mathrm{M}_\odot$. We propose to use the Hectospec on MMT telescope to perform a spectroscopic survey for this dwarf galaxy sample. With a much larger sample, we could expect that the intermediate-redshift MZ relation at low mass could be more strictly constrained. The number density of [O III]λ4363 detected galaxies, based on Ly et al. (2013) estimation, are $6 * 10^{-4}\mathrm{Mpc}^{-3}$ at $z \sim 0.3 - 0,65$, which corresponds to a surface density of one per 13 acrmin^2. About one fifth of these galaxies are expected to be XMPGs. We selected our sample in a image cut of COSMOS deep field with area of $\sim 600\ \mathrm{arcmin}^2$. Therefore, $\sim$ 40 galaxies with [O III]λ4363 detection and $\sim$ 8 XMPGs are expected in our spectroscopic survey. It can be expected that the sample of XMPGs outside the local universe will be notably increased.

References

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Experimental Design & Technical Description *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? Justify sample size, instrument choice, signal-to-noise, exposure times, and lunar phase. Also briefly explain plans for data reduction, and what expertise or effort each team member will contribute to the project.* (***up to one page***)

Hectospec is a moderate-resolution, multi-object optical spectrograph on MMT telescope. There are 300 fibers available with a core diameter of $1.5''$. The spectral coverage of Hectospec ranges from 3650 Å to 9200 Å, which covers most of the optical emission lines. With a large field of view of $\sim$ one square degree, Hectospec is very suitable to be used to conduct spectroscopic survey in deep fields.

To explore the low mass, intermediate-redshift MZ relation and find new XMPGs, we selected a sample of 264 blue compact dwarfs galaxies at $z < 0.7$ in 3D-HST COSMOS deep field. This sample is selected based on three major criteria: 1) dwarf, stellar mass $\mathrm{M}_* < 10^9\mathrm{M}_\odot$; 2) blue, $\mathrm{U-B} < 0.37$ and $\mathrm{B-V} < 0.67$; 3) compact, $\mu_{\mathrm{B,peak}} < 22\ \mathrm{mag\ arcsec^{-2}}$, where $\mu_{\mathrm{B,peak}}$ is the peak surface brightness at optical B band (Gil De Paz et al. 2003). We impose a cutoff of redshift at 0.7 because the [O III]$\lambda\lambda$4959, 5007 doublet of galaxies at $z > 0.7$ are redshifted to wavelength longer than 8500 Å where the sky lines could heavily contaminate the emission lines. There are 700 galaxies selected by these criteria and only galaxies brighter than 25 mag in B band are included to constitute the final sample. The brightness criteria makes sure that all the objects are detectable with exposure time of 4 hours. The adjacent fibers of Hectospec should be separated with a distance larger than $22''$. Objects which have a object nearer than $22''$ and are fainter than the neighbor are excluded. We have inspected the image of each object to ensure that all galaxies have compact morphology.

Exposure time: Since we have no clue about the strength of emission lines, especially the [O III]λ4363 line, we estimate the exposure time by comparing to the similar survey conducted by Ly et al. (2013) using Hectospec on MMT. Ly et al. (2013) found 20 galaxies at $z \sim 0.3 - 0.65$ with [O III]λ4363 detection. The exposure time of 14 galaxies observed by the Hectospec on MMT are 80 minutes for 5 galaxies, 120 minutes for 7 galaxies and 240 minutes for 2 galaxies. The other 6 galaxies with [O III]λ4363 detection were observed by the DEIMOS on Keck with exposure time of 2–3 hours. There are two XMPGs found by MMT and Keck, respectively. The metal-poor galaxies observed by MMT in Ly et al. (2013) are brighter than 24.4 mag in the optical B band, with a median of 23.1 mag. The median magnitude of our dwarf galaxy sample at B band is 24.5 mag. To conduct a spectroscopic survey $\sim$ 1 mag deeper than that in Ly et al. (2013) using Hectospec on MMT, an exposure time of 4 hours is needed. We plan to split the 4 hour exposure time into four 60 minute exposures. Taken $\sim$ 15 minutes of overhead in each exposure into account, a total of 5 hour is required (half night). To detect the weak emission line of [O III]λ 4363, low level of noises from sky background is necessary. Therefore, we request half dark night to perform the spectroscopic survey.

Data plan: The data will be reduced following standard procedures with the IRAF Hectospec Reduction Software. We have obtained three half night observation time of MMT from 2012A to 2014A semester with Hectospec. N. Hu has lots of experience in reducing observation data from Hectospec on MMT. J. Lian is a graduate student who will accompany X. Kong for the observing and will be trained in observing and data reduction.

TAP Usage and Context *The TAC needs to understand the scope of this project — (1) How many total TAP nights are you requesting this semester, including any CFHT time from a linked proposal, and if more time will be necessary in future semesters, how many nights will you need to complete the project (best guess)?; (2) If a substantial amount of observing for this project comes from non-TAP telescopes, tell us about that observing, and how the TAP part fits in; (3) If you are collaborating with people who have access to other telescopes, especially if you are part of a large collaboration, tell us who is leading the project, and how TAP time and your participation fit in. 4) Please explain the ways in which this program would help fulfill the goals of the Telescope Access Program. (**up to one page**)*

We are requesting half night from TAP on the MMT 6.5m telescope in 2015A. This will be sufficient to complete this project. There is currently no time from non-TAP telescopes allocated to this project.This program will increase the expertise of Chinese astronomers in multi-object spectroscopy survey, and will train three students in observing, data reduction and analysis.

Therefore, our program will build a observer community and a user community for the future project, it will fulfill the goals of the Telescope Access Program completely.

ALL allocations of telescope time through TAP

We have got three half bright nights at MMT and three dark/grey nights at P200 from 2012A to 2014B. Now 2012A, 2013B and 2014A have finished for observation, but 2014B will be observed in Jan. 13, 2015. All allocations telescope time for the projects from our group on facilities available through TAP during the past 2 years are:

2012A 0.5 night (bright), MMT/Hectospec, Xu Kong: “Spectroscopy of HII Regions in Nearby Galaxies”

2012B 0.5 night (bright), MMT/Hectospec, Xu Kong: Completing Spectroscopy of HII Regions in Nearby Galaxies (2012A-03)

2013B 0.5 night (bright), MMT/Hectospec, Xu Kong: “Spectroscopic Observations of the Star Formation Regions in Nearby Galaxies”

2014A 1 night (dark), P200/SWIFT, Xu Kong: Integral Field Spectroscopy of Dusty Lyman Break Analogs

2014B 2 night (grey), P200/SWIFT, Xu Kong: Integral field spectroscopy of local blue compact dwarf galaxies

Publications that were based on data obtained at TAP facilities

1. Lin, Lin; Zou, Hu; Kong, Xu; Lin, Xuanbin; Mao, Yewei; Cheng, Fuzhen; Jiang, Zhaoji; Zhou, Xu, “Gradients of Stellar Population Properties and Evolution Clues in a Nearby Galaxy M101”, The Astrophysical Journal, 2013, Volume 769, 127

2. Kong, Xu; Lin, Lin; Li, Jin-rong; Zhou, Xu; Zou, Hu; Li, Hong-yu; Cheng, Fu-zhen; Du, Wei; Fan, Zhou; Mao, Ye-wei; Wang, Jing; Zhu, Yi-nan; Zhou, Zhi-min, “Spectroscopic Observations of the Star Formation Regions in Nearby Galaxies”, Chinese Astronomy and Astrophysics, 2014, 55, 29

3. Kong, Xu; Lin, Lin; Zou, Hu; Lin, Xuanbin; Mao, Yewei; Cheng, Fuzhen; Jiang, Zhaoji; Zhou, Xu, “Abundance analysis of M101 Based on the spectrum of HII regions”, The Astrophysical Journal, 2014, in preparation

4. Lian, Jianhui; Kong Xu; Li, Jin-rong; Hu, Ning; Ye, Chengyun, “A merger of two dispersion-dominated galaxies”, The Astrophysical Journal, 2014, in preparation