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# Spectroscopic Observations of the Star Formation Regions in Nearby Galaxies† ⋆

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**Abstract** In recent years the number of worldwide 8∼10 m-class ground-based telescopes is continually increased, the 4 m-diameter or smaller telescopes have become the small and medium-sized telescopes. In order to obtain some noticeable scientific results by using these existing small and medium-sized telescopes, we have to consider very carefully what we can do, and what we can not. For this reason, the Time Allocation Committee of the 2.16 m telescope of the National Astronomical observatories of China (NAOC) has decided to support some key projects since 2013. The long-term project "Spectroscopic Observations of the Star Formation Regions in Nearby Galaxies" proposed by us is one of three key projects, it is supported by the committee with 30 dark/grey nights in each of three years.

The primary goal of this project is to make the spectroscopic observations of the star formation regions along the directions parallel and perpendicular to the main-axes of 20 nearby galaxies with the NAO 2.16 m telescope and the Hectospec multi-fiber spectrograph on the 6.5 m MMT (Multiple Mirror Telescope) via the Telescope Access Program (TAP). With the spectra of a large sample of

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star formation regions, combining with the exising multi-wavelength data from UV to IR, we can study the galaxy dust extinction, star formation rate, metal abundance, and the two-dimensional distributions of stellar population properties, as well as the relationships of the galaxy two-dimensional properties with the galaxy morphologies and environments. As the first paper of this project, we describe here the scientific objectives, sample selection, observation strategy, and present the preliminary result of the spectroscopic observation towards the galaxy NGC 2403.

**Key words:** ISM: dust, extinction—galaxies: emission lines—galaxies: kinematics and dynamics—galaxies: star formation

## 1. INTRODUCTION

In recent years, the large-sample spectroscopic survey, such as the Sloan Digital Sky Survey, and the multi-waveband deep-field survey observations of space telescopes and ground-based large telescopes have yielded revolutionary influences on the research of galaxies[1−4]. To compare the two aspects of rapid developments, the development in the research of galaxy formation and evolution by through the spatial-resolved spectroscopic observation, namely the spectral observation on different regions of a galaxy, seems to be relatively slow. The spatial-resolved spectroscopic data are very important for understanding the internal composition and kinematic characteristics of a galaxy, and therefore its formation, structure, and evolution. The IFU (Integral Field Unit) spectrograph is the most important tool for this kind of observations, in the past 5∼10 years, some systematic two-dimensional spectroscopic observations towards galaxies were successively made, but these observations are limited on the one side by the galaxy sample in which most member galaxies are elliptic galaxies (for example, the Spectroscopic Areal Unit for Research on Optical Nebulae, abbreviated as SAURON), on the other side by the relatively small field of view, as a result the observation is mainly focused on the galaxy's central region (for example, the PPAK IFS Nearby Galaxies Survey, PINGS in abbreviation)[5−6]. Because of the scientific significance of the spatial-resolved spectroscopic observation, the MaNGA (Mapping Nearby Galaxies at APO) project has become one of the three key projects after the third SDSS (SDSS-III), beginning from September 2014, and using the bounded optical fibre bundles, it will perform the two-dimensional spectroscopic observations on 10 000 nearby galaxies in order to study the galaxy formation history and dark matter distribution[1].

Considered the rapid development of the SDSS and other spectroscopic survey projects, the existence of many large-aperture telescopes in the world, as well as the rather small aperture of the telescopes and the lack of IFU terminals in China; at the same time, considered that the research based on the large-sample spectroscopic survey and deep-field survey has been relatively deepened, but the research based on the spatial-resolved spectroscopic observations is developed rather slowly[7−10], since 2008 we have performed the spectroscopic observations on the multiple star formation regions in a few nearby large galaxies with the

[1] http:www.sdss3.org/future/manga.php

2.16 m telescope of NAOC. But limited by the observational time, up to the end of 2012 we have finished only the observations of the multiple star formation regions in 4 nearby galaxies and their radial-direction spectra. In the workshop of Xinglong 2.16 m telescope and Gaomeigu 2.4 m telescope held on 9th∼10th July 2012, we proposed the project " Observations of the Star Formation Regions in Nearby Galaxies", and it was selected as one of six key projects of the 2.16 m telescope, finally, on 17th Oct. 2012, it was determined to be one of three key projects in the consultation about the key subjects of the 2.16 m telescope.

Under the support of the key project of the 2.16 m telescope, by use of the Cassegrain focus spectrograph (OMR) of the 2.16 m telescope, including the planning puncher and other instruments, and by applying for the observational time of the American 6.5 m MMT telescope via the Telescope Access Program, we plan to observe the multiple star formation regions in 20 nearby large galaxies, and the spectra along the directions parallel and perpendicular to the main-axes of these galaxies (50 spectra for each galaxy, equivalent to the observed result of IFU, but not so dense in spatial distribution, however these spectra may cover a wider range than IFU), and hope to obtain a noticeable and scientifically-significant sample of the spectra of star formation regions in nearby galaxies. At the same time, because that the emission lines in the spectra of galactic star formation regions are very strong, and easy to be observed and identified, so this project especially suits the practical situations of the 2.16 m telescope, namely the relative small aperture, the rather bright sky background, and relatively large seeing of the site. With the spectroscopic data of galaxy's different regions obtained from the 2.16 m telescope and the MMT telescope, in combination with the existing u-band data of the South Galactic Cap U-band Sky Survey (SCUSS), the color data of the BATC survey[11], and the UV data of the Galaxy Evolution Explorer (GALEX)[12], as well as the Spitzer and Herschel infrared data[13−14], we can conduct the research in the aspects of the galaxy star formation rate, metal abundance, dust extinction, and the two-dimensional distributions of stellar population properties, and the research on the relationships of the two-dimensional characteristics of galaxies with their morphologies and environments. In this paper, Sec.2 describes the selection of the galaxy sample, Sec.3 presents the observation strategy of the sample galaxies and the up-to-date progress of the observation, Sec.4 describes the important scientific significance, Sec.5 gives some preliminary results of the observation on the nearby galaxy NGC 2403, finally, Sec.6 is the summary of this paper.

## 2. THE SELECTION OF GALAXY SAMPLE

Nearby galaxies are the ideal objects to study the galaxy formation, structure, and evolution, and to provide plenty of observational constraints for the galaxy formation and evolution theories. These galaxies are relatively close to us, the spectra in different regions of these galaxies can be observed by telescopes, combining with the image data and the stellar population synthesis method, we can study the dust extinction, stellar population age, metal abundance, and star formation rate in star formation regions, and the important characteristic quantities of a galaxy, such as the gradients of its physical properties, and the internal dust distribution, so as to study further the early formation and chemical evolution of a galaxy for understanding the galaxy formation and evolution history[15−17]. Because of the importance of the research of nearby galaxies, now there are many space and ground-based telescopes dedicated to the multi-wavelength observations on them. For example, with the Spitzer infrared telescope, SINGS (Spitzer Infrared Nearby Galaxies Survey) observed the infrared images of 75 nearby galaxies, and the infrared spectra of a part of regions[13]. With the GALEX ultraviolet satellite, the NGS (Nearby Galaxy Survey) project of GALEX observed the ultraviolet images of 1 034 nearby galaxies[12]. Using the VLA (Very Large Array) telescope, THINGS (The HI Nearby Galaxy Survey) observed the radio images of 34 nearby galaxies[18]. And KINGFISH (Key Insights on Nearby Galaxies: a Far-infrared Survey with Herchel) planed to observe the far-infrared images and spectra of 61 nearby galaxies with the Herschel telescope[14].

The multi-waveband data are very important for studying the characteristics of galaxies, hence in the selection of sample galaxies, we hope that the multi-waveband data available now can be utilized as possible. In the optical waveband we have obtained the color data from the BATC survey observations, the UV and infrared data can be collected from the public databases. (1) Considered that in the infrared waveband there are now the observed data of Spitzer, WISE (Wide-field Infrared Survey Explorer), and Heschel satellites, in the UV waveband there are mainly the data of GALEX, hence the first criterion of our sample selection is the availability of the near-UV and far-UV data of GALEX, namely, taking the NGS of GALEX as the mother sample. (2) In order to study the two-dimensional distributions of galaxy's physical properties, as well as the radial gradient and kinematic characteristics, we hope to select some relatively large galaxies, so the second criterion of sample selection is that the major axis of the B-band 25 mag·arcsec$^{-2}$ contour should be 2A$> 7'$, and the minor axis should be 2B$> 5'$. (3) The latitude of the Xinglong station is about 40.0°, for the effective observations, the declinations of galaxies should be in the range of $0° < Dec.(2000) < 70°$. Using these criterions, we finally select the sample including 20 nearby galaxies.

Table 1 gives the basic parameters of the sample galaxies. In which, the first column gives the names of galaxies, the second and third columns present the coordinates of galaxies, the values of Right Ascension (h:m:s) and Declination (d:m:s) are taken from the NED (NASA/IPAC Extragalactic Database). Columns 4∼6 give respectively the major axis and minor axis of the B-band illuminance contour of the galaxy at 25 mag·arcsec$^{-2}$, and the azimuthal angle of the galaxy's main axis, which are taken from the Third Reference Catalogue of Bright Galaxies (RC3). The 7th column gives the morphologies of galaxies in RC3, from this table we can find that our sample galaxies are all spiral galaxies, in conjunction with the data of IFU observations of SAURON elliptic galaxies, we can study the relationship between the galaxy two-dimensional characteristics and the galaxy morphologies. The 8th column indicates whether there are observed data in the UV, infrared, and $H_\alpha$ wavebands, $G$ means that there are observed data of the GALEX satellite, $S$ means that there are observed data of the Spitzer satellite, $H$ means that there are far-infrared data observed by the Herschel satellite, $H_\alpha$ means that there are $H_\alpha$-band data, and $X$ means that there are no observed data of the Herschel satellite.

**Table 1 Sample galaxies and their properties**

| Galaxy name | RA.(J2000) | Dec.(J2000) | $2A/(')$ | $2B/(')$ | PA/(°) | Morphology | Image |
|---|---|---|---|---|---|---|---|
| IC 1613 | 1:04:47.8 | +02:07:04.0 | 16.2 | 14.5 | 50 | IB(s)m | G,S,X,H$\alpha$ |
| NGC 0598(M 33) | 1:33:50.9 | +30:39:35.8 | 70.8 | 41.7 | 23 | SA(s)cd | G,S,X,H$\alpha$ |
| NGC 0628 | 1:36:41.8 | +15:47:00.5 | 10.5 | 9.5 | 25 | SA(s)c | G,S,H,H$\alpha$ |
| NGC 0925 | 2:27:16.9 | +33:34:45.0 | 10.5 | 5.9 | 102 | SAB(s)d | G,S,H,H$\alpha$ |
| NGC 2403 | 7:36:51.4 | +65:36:09.2 | 21.9 | 12.3 | 127 | SAB(s)cd | G,S,X,H$\alpha$ |
| NGC 2903 | 9:32:10.1 | +21:30:03.0 | 12.6 | 6.0 | 17 | SB(s)d | G,S,X,H$\alpha$ |
| NGC 3031(M 81) | 9:55:33.2 | +69:03:55.1 | 26.9 | 14.1 | 157 | SA(s)ab | G,S,H,H$\alpha$ |
| IC 2574 | 10:28:23.5 | +68:24:43.7 | 13.2 | 5.4 | 50 | SAB(s)m | G,S,H,H$\alpha$ |
| NGC 3344 | 10:43:31.2 | +24:55:20.0 | 7.1 | 6.5 | 0 | SAB(r)bc | G,S,X,H$\alpha$ |
| NGC 3368(M 96) | 10:46:45.7 | +11:49:11.8 | 7.6 | 5.2 | 5 | SAB(rs)ab | G,S,X,H$\alpha$ |
| NGC 3486 | 11:00:24.0 | +28:58:29.3 | 7.1 | 5.2 | 80 | SAB(r)c | G,S,X,H$\alpha$ |
| NGC 4236 | 12:16:42.1 | +69:27:45.3 | 21.9 | 7.2 | 162 | SB(s)dm | G,S,H,H$\alpha$ |
| NGC 4258(M 106) | 12:18:57.5 | +47:18:14.2 | 18.6 | 7.2 | 150 | SAB(s)bc | G,S,X,H$\alpha$ |
| NGC 4321 | 12:22:54.9 | +15:49:20.6 | 7.4 | 6.3 | 30 | SAB(s)bc | G,S,H,H$\alpha$ |
| NGC 4395 | 12:25:48.9 | +33:32:48.3 | 13.2 | 11.0 | 147 | SA(s)m | G,S,H,H$\alpha$ |
| NGC 4736 | 12:50:53.1 | +41:07:13.6 | 11.2 | 9.1 | 105 | SA(r)ab | G,S,H,H$\alpha$ |
| NGC 4826(M 64) | 12:56:43.8 | +21:40:51.9 | 10.0 | 5.4 | 115 | SA(rs)ab | G,S,H,H$\alpha$ |
| NGC 5055 | 13:15:49.3 | +42:01:45.4 | 12.6 | 7.2 | 105 | SA(rs)bc | G,S,H,H$\alpha$ |
| NGC 5194(M 51) | 13:29:52.7 | +47:11:42.6 | 11.2 | 6.9 | 163 | SA(s)bc | G,S,H,H$\alpha$ |
| NGC 5457(M 101) | 14:03:12.6 | +54:20:56.7 | 28.8 | 26.9 | 90 | SAB(rs)cd | G,S,H,H$\alpha$ |

## 3. SPECTROSCOPIC OBSERVATION OF GALAXIES

In this section we describe how the 2.16 m telescope of NAOC and the 6.5 m MMT telescope are used to observe the multiple star formation regions in nearby galaxies, and the spectra along the radial directions of these galaxies.

### 3.1 The Observations Made on the 2.16 m Telescope

Our sample includes totally 20 nearby galaxies. From 2008 to the end of 2012, we have basically performed the observations of 4 galaxies, and for the two large galaxies M101 and M33 we have made observations with the 6.5 m MMT telescope (see below), thus there are still 14 galaxies remained to observe with the 2.16 m telescope. The instrument to be used is the OMR Cassegrain spectrograph installed on the telescope, during observations the grating of 300 line/mm is selected, the corresponding spectral resolution is 4.8 Å/pixel. The slit width adopts 2.5”, and the central wavelength is 5 500 Å.

For each galaxy, we will observe the spectra along the directions parallel and perpendicular to its main axis in the best weather condition, since that in the spectra along these directions, strong emission lines may appear, and that the good weather will help us to obtain the continuum and absorption-line spectra with high signal/noise ratios in the extended regions of these galaxies. For the every galaxy, the slit should be placed on each of its major-axis and minor-axis once, and placed along the directions parallel to the major-axis and minor-axis, but deviated from the central position, for two times each. Besides, along each direction the sky background should be observed once, which is used to subtract the background sky light from the galaxy spectra. For the galactic star formation regions, because that strong emission lines exist in their spectra, the observations are relatively easy, the requirement on the weather condition can be slightly relaxed. In order to improve the observing efficiency, in each observing night, the slit position should be adjusted repeatedly to make sure that the slit covers as many star formation regions as possible. Before and after the observation of the objective source, the spectra of the calibration lamp are taken for the accurate wavelength calibration. And in each observing night, the spectra of standard stars as many as possible are taken for the accurate flux calibration of spectra.

As an example, Fig.1 displays the $H_\alpha$ images of two nearby galaxies, the positions of the brightest 100 star formation regions in each galaxy (circles), and the slit positions during the spectroscopic observations. The yellow dashed-line square in the lower-left of the left panel shows the size of the field of view of the telescope OMR, the slit length is 4'. The green and blue solid lines indicate the slit positions parallel and perpendicular to the main-axis of the galaxy, the red lines indicate the slit positions where the spectroscopic observation of star formation regions has been performed, and the blue-and-green lines indicate the slit positions remained to observe. The blue and green dashed lines apart from the galaxy represent the two of slit positions for the sky background observation, most of them are failed to display in the figure because of their over large distances from the galaxy.

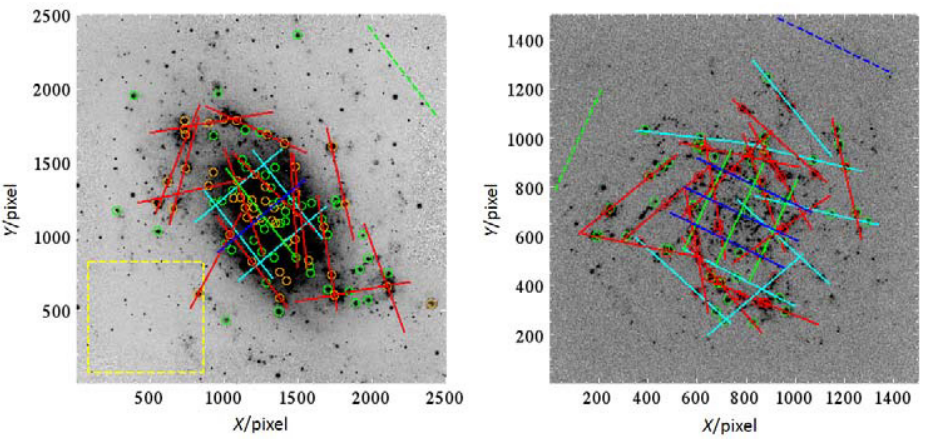


Fig. 1 The $H_\alpha$-band images of two nearby galaxies and the slit positions during the spectroscopic observations. The slit length and width are 4' and 2.5", respectively. Left: NGC 2403, Right: NGC 628. The circles show the positions of bright star formation regions.

### 3.2 The Observations Made on the MMT Telescope

In our nearby galaxy sample, the galaxies M101 (28.8'×26.9') and M33 (70.8'×41.7') are large galaxies, however the size of the field of view of the OMR spectrograph of the 2.16 m telescope is only about 4' (as shown by the yellow dashed-line square in Fig.1), to observe the two large galaxies with the 2.16 m telescope of small field of view will need a very long observational time. To overcome this difficulty, by through the TAP program, we have applied for the time to observe the spectra of the star formation regions in these two galaxies with the Hectospec multi-fiber spectrograph of the 6.5 m MMT telescope[19]. The Hectospec multi-fiber spectrograph possesses 300 fibers, it can observe simultaneously the spectra of 300 objects. The diameter of its field of view is about 1°, very suitable for observing the spectra from the different regions of a galaxy as large as M33 or M101. In the observation the grating of 270 line/mm is used, the corresponding spectral resolution is 5 Å/pixel, and the wavelength range is 3650∼9200 Å.

We have applied for and obtained the observational times 2012A and 2013A, and have finished the spectroscopic observation on the star formation regions and other regions of the galaxy M101. Besides, we have applied for and obtained the observational time MMT 2013B, and planed to finish the spectroscopic observation of the star formation regions and other regions of the galaxy M33 in the end of 2013.

## 4. SCIENTIFIC SIGNIFICANCE

Nearby galaxies are rather close to us, we can obtain their high-resolution images to analyze in detail the galaxy characteristics, as a reference for studying the high-redshift galaxies with unresolvable internal structures. At present, the multi-waveband study of nearby galaxies has become a hot point, many telescopes in the world give priority to the observation of nearby galaxies, and the observed data in the UV, infrared, and radio wavebands have been available already.

Using the 2.16 m telescope of NAOC and the 6.5 m MMT telescope in the USA, we will realize the spectroscopic observations on the star formation regions and other different regions in 20 nearby large galaxies, with these spectroscopic data, in combination with the available multi-waveband image data, we can analyze the dust extinction in the galactic star formation regions, the distributions of stellar population, metal abundance, and other properties, as well as the relationships of theses distributions with the galaxy morphology and galaxy environment. In addition, with the spectra of star formation regions and the multi-band image data, we can study the galaxy dust extinction, the calibrations of star formation rate and metal abundance, etc. In this section we list only a part of feasible research subjects.

### 4.1 Physical Origin of the Dispersion of the IRX-$\beta$ Relation

A large amount of dust exists in the interior of a galaxy, the absorption and scattering of dust on the star light become increasingly serious as the wavelength decreases, it makes many of observed characteristics of galaxies changed[20]. Especially for the star-burst galaxies and high-redshift galaxies of violent star formation activity, in these galaxies the radiation of young stellar objects mainly concentrates in the UV band, and here the influence of interstellar extinction is especially serious. How to calculate correctly the dust extinction in the interior of a galaxy is extremely important for understanding the observed galaxy characteristics, and for studying the galaxy physical properties from these observed characteristics[21−22].

The Balmer decrement (i.e., the $H_\alpha/H_\beta$ spectral flux ratio), and the ratio of total infrared luminosity (TIR) and ultraviolet luminosity (UV) (denoted as IRX = TIR/UV) are commonly used for calculating the dust extinction in the interior of an emission line galaxy. But with the increase of redshift, the $H_\alpha$ line will shift to the near-infrared band, and the infrared radiation will shift to sub-millimeter or even longer wavelengths, making the observation become more difficult. So these two approaches suit only the calculation of dust extinction for the galaxies with rather low redshifts[23]. Since the IRX-value of a star-burst galaxy and its UV spectral slope $\beta$ (equivalent to the UV color FUV-NUV) are strongly correlated, in recent years the UV spectral slope $\beta$ is considered to be a good replacement of IRX for calculating the internal dust extinction of a galaxy. Especially for the high-redshift galaxies, their UV radiation will be shifted to the optical waveband, using the photometric data at the optical waveband, we can obtain the UV $\beta$-value to calculate the galaxy's internal extinction, and hereby to study the other physical properties of the high-redshift galaxy[24]. Along with the release of the GALEX UV data and Spitzer infrared data, many authors have made the study of the IRX-$\beta$ relation, and found that in the IRX-$\beta$ diagram the distribution of normal galaxies exhibits a very large dispersion, now, about the origin of this dispersion exist still many arguments[16−17,21,23].

Compared with the whole galaxy, the star formation regions in the galaxy are more simple in the aspects of star formation history, dust type, and geometrical distribution. At the same time, the emission lines in the spectra of star formation regions are quite strong, and easy to be measured accurately. Considered this two factors, we intend to study the distributions of the galaxies and star formation regions in the IRX-$\beta$ diagram, as well as the physical origin of the dispersed distribution, by using the images and spectroscopic data of star formation regions in nearby galaxies. These sample galaxies have rich ultraviolet, optical, and infrared observational data, the IR luminosity and UV luminosity data can be used to measure the IRX-values of the different star formation regions. The GALEX far-UV and near-UV images can be used to measure the color, namely the UV spectral slope $\beta$, for the different star formation regions. Using these data, we can obtain the distribution of the different star formation regions in one and the same galaxy on the IRX-$\beta$ diagram. The spectra of star formation regions contain numerous emission lines and absorption lines, we can calculate the galaxy's internal extinction by using the $H_\alpha/H_\beta$ flux ratio, calculate the stellar population age by the 4000 Å sudden change of the continuum, study the population age and star formation history by the absorption lines, etc. With these data, we can investigate the different methods for the calculation of galaxy's internal extinction, including the Balmer decrement, IR luminosity-UV luminosity ratio (IRX), UV color ($\beta$), etc., and from the differences of the results to study the accurate formula for calculating the galaxy's internal extinction. At the same time, with the spectroscopic data in combination with models, we can study the possible physical origins of the dispersion of the distribution of the galaxies and star formation regions on the IRX-$\beta$ diagram, for example, the differences in the star formation history, dust type, extinction law, the geometrical distribution of dust, and so on.

### 4.2 Other Possible Research Subjects

The calibration of star formation rate: star formation rate (SFR) is an important physical quantity of a galaxy to characterize the activeness of star formation in the galaxy. In recent years the various new sky survey projects have provided the multi-band (from X-ray to radio) and large-sample observational data. With these data, by the comparison and analysis of different SFR indicators in the same galaxy sample, we can understand their differences, advantages, and limitations. The different SFR indicators are generally applied to the different redshift ranges, hence to study the different SFR indicators is of important significance for the study of the star formation history of the universe. At present, using the UV or optical emission line, infrared or X-ray luminosity, and composite indicators, the results given by the different researchers exhibit large differences[25]. Compared with the physical and environmental differences of different galaxies, the differences of the different star formation regions in the same galaxy are smaller. With our observed spectra of galactic star formation regions, we can systematically study and calibrate these different SFR indicators.

The calibration of metal abundance: the existing methods to calculate the metal abundance are the electron temperature method and various strong-line methods (including R23, N2, O3N2, etc. more than 10 methods), the results given by these methods differ greatly[26]. However, the metal abundance is an important physical quantity for the research of galaxy evolution, we intend to study the differences of the results given by the different methods, and to calibrate the results obtained from the different metal abundance calculation methods, by using the simple spectra of the star-formation regions with strong emission lines.

The study of galaxy two-dimensional characteristics: by comparing the two-dimensional characteristics of our galaxy sample (mainly the late-type galaxies) with the result of SAURON (mainly the elliptic galaxies and lensing galaxies), we may study the relationships among the galaxy two-dimensional characteristics, stellar motions, and galaxy morphologies, to improve our knowledge about the galaxy formation and evolution[5].

## 5. PRELIMINARY RESULT—THE GALAXY NGC 2403

NGC 2403 is an Sc-type spiral galaxy in the galaxy group M81 at a distance of $d \approx 3.13$ Mpc from us. Its B-band iso-luminance radius is $r \approx 10.9' = 9.89$ kpc[27,28]. Since many properties of NGC 2403 are similar with those of M33 and NGC 300, it is an ideal object for studying the formation of late-type spiral galaxies. In recent years, many telescopes in the world have made the imaging observations on it at the radio, infrared, near-infrared, optical, ultraviolet, and X-ray wavebands. Relative to the rich image data, its spectroscopic data are less. The latest spectroscopic observation was made by Fraternali et al.[29], they made the long-slit spectroscopic observation on the 6 different positions of NGC 2403, and studied the kinematics of gas in the galaxy. The spectrum of the largest star formation region in NGC 2403 was observed by Garnett et al.[30], with a 2.5 m Newtonian telescope they obtained the spectroscopic data of totally 12 star formation regions of NGC 2403, and studied the gradient of elemental abundance in this galaxy.

In order to obtain a larger sample of star formation region spectra, in the period of 2008∼2010, with the OMR spectrograph of the NAO 2.16 telescope, we observed the narrow-slit spectra at the 18 different positions within NGC 2403. By adjusting the slit direction, each slit position covered multiple star formation regions, thus the spectra of totally 80 star formation regions were obtained. The IRAF software was used for the spectral processing, including the background subtraction, flat-field correction, wavelength/flux calibration, Galactic extinction correction, etc. Figs.2(a)∼(c) show the spectra of three star formation regions. Fig.2(d) displays the distribution of the star formation regions on the BPT diagram. From this figure we can find that most star formation regions are distributed under the demarcation line of strong star formation given by Kauffmann et al.[1], only a small number of star formation regions are distributed in the transition region between the star-formation and AGN demarcation lines. The circle, square, and triangle in Fig.2(d) correspond to the star formation regions of Fig.2(a), Fig.2(b), and Fig.2(c), respectively.

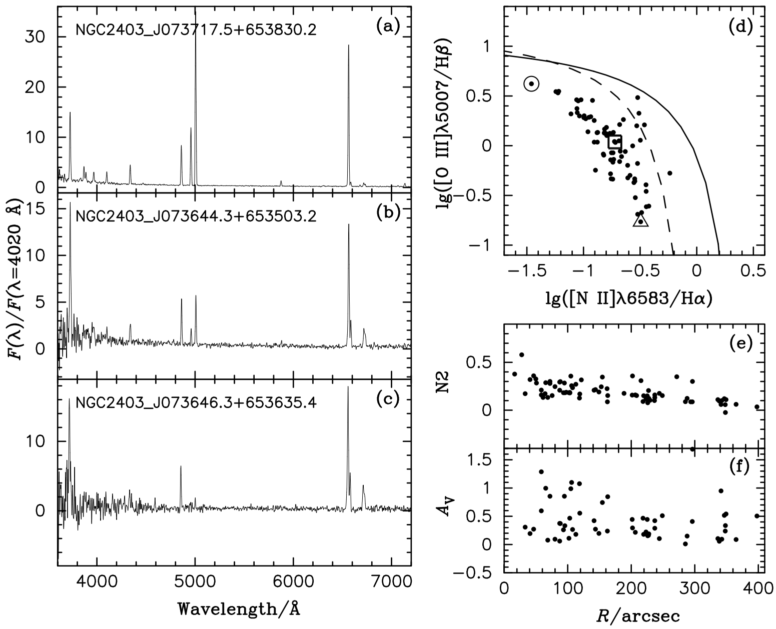


Fig. 2 The example spectra of three star formation regions in NGC 2403 (a,b,c), the BPT diagram (d), and the radial distributions of $N2 = F([N_{II}]\lambda6583)/F(H_\alpha)$ (e), and dust extinction (f) of 80 star formation regions in NGC 2403. The circle, square, and triangle in Fig.2(d) denote the three examples in Fig.2(a), Fig.2(b), and Fig.2(c), respectively. The solid and dashed lines in Fig.2(d) are used to demarcate the pure star formation regions (lower left) and the region of AGNs (upper right).

Fig.2(e) shows the radial distribution of $N2 = F([N_{II}]\lambda6583)/F(H_\alpha)$ for the spectra of star formation regions. Now, there are multiple methods to calculate the galaxy metal abundance, including the electron temperature method and the R23, N2, O3N2 etc. more than 10 empirical strong-line methods. Compared with the other methods, the N2 method has the following advantages: it is easy to observe (the two spectral lines are strong enough), with a smaller effect of dust extinction (the wavelengths of the two lines are close to each other), and without the double-value problem. From Fig.2(e) we can find that the star formation regions around the center of the galaxy have a higher N2-value, namely a higher metal abundance, and the outer star formation regions have a lower N2-value, namely a lower metal abundance. By observing the spectra of the star formation regions in different regions of the galaxy, and by using the emission lines in the spectra, we find that a radial gradient of metal abundance exists in NGC 2403.

Since the $H_\alpha$ and $H_\beta$ lines in the spectra of galaxies and their line emission regions are quite strong, the Balmer decrement is generally used to calculate the internal extinctions of emission-line galaxies. Fig.2(f) shows the distribution of the extinction values of different star formation regions obtained from the calculation of Balmer decrement as a function of the radial distance from the center of NGC 2403. The dispersion of the extinction $A_v$-values is rather large in the galaxy's central region, generally greater than that of the $A_v$-values of outer star formation regions. The extinction value exhibits a trend to decrease outward from the center, but it is not so evident as the decrease of metal abundance shown in Fig.2(e).

## 6. SUMMARY

This paper has described the scientific objectives, the criterions of sample selection, the observation strategy, and preliminary result of the project "Spectroscopic Observation of the Star Formation Regions in Nearby Galaxies"—one of three key projects of the 2.16 m telescope of NAOC. With the observational time of 30 dark/grey nights in each of 3 years, and the observational time of the 6.5 m MMT telescope applied via the TAP program, this project will perform the spectroscopic observations on the multiple star formation regions parallel and perpendicular to the main-axes of 20 nearby large galaxies, in order to obtain the spectral sample of multiple star formation regions in different types of nearby galaxies. With these spectroscopic data, in combination with the existing multi-waveband data, we can make studies in the aspects of dust extinction, star formation rate, metal abundance, and the two-dimensional distributions of stellar population properties, etc., to deepen the overall understanding of the physical process of galaxy formation and evolution.

As an example, in Sec.5 of this paper we have described the observation on the galaxy NGC 2403, and the preliminary result. With the 2.16 m telescope of NAOC, we have observed the spectra of 80 star formation regions in NGC 2403 (previously, the largest spectral sample of star formation regions in this galaxy consists of 12 star formation regions). With these spectral data we have studied the radial distributions of metal abundance and dust extinction in the galaxy, the result indicates that an evident gradient of metal abundance exists in NGC 2403, namely, high metal abundances are distributed in the central region, low metal abundances in the outer region. The radial distribution of dust extinction exists also the similar trend to decrease outward from the center, but it is not so significant as the gradient of metal abundance.

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