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Kyoto 3D-spectrographs: Multimode Area Spectrographs

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1. Instrument

1.1. Kyoto 3D-I

The first generation instrument, Kyoto 3D-I, an area spectrograph in optical region is in commission at the 188cm telescope of the Okayama Astrophysical Observatory (Ohtani et al. 1994, 1998). This instrument is equipped with four modes of area spectroscopic method, i.e., filter imager, long slit for slit scan, imaging Fabry-Perot interferometer, and integral field spectrograph (IFS) (Figure 1). Selection of a particular mode is made by moving the slide table to insert an appropriate focal unit (filter, slit, or aperture plate with enlarger) and switching the ray path with a movable folding mirror. The filter imager and the long slit modes are quite usual ones, and, therefore, these are not described here.

Two Fabry-Perot etalons of Queensgate Instruments are available; one is a tunable narrow band filter and the other is for measurement of velocity filed. The etalon parameters are given in Table 1. The observing field of view is 4.6' square. The etalon temperature is stabilized within ± 0.5C$^\circ$ to suppress drifts of the transmitting wavelength within one tenth of the width of the Airy profile.

IFS is of the TIGER (Bacon et al. 1995) type, but has a dual-channel enlarging optics before the microlens array; one channel acquiring a target area of an extended object and the other an 'uncontaminated' sky apart from the object by 3.7', simultaneously. A 1".3 square field is subtended by a single lenslet of the microlens array, of which 7 x 11 and 7 x 2 lenslets are allocated to the target and the sky, respectively. Thus, ninety one spectra in total can be obtained within the wavelength range of 4000 to 7000 Å.

1.2. Kyoto 3D-II

The second generation instrument, Kyoto 3D-II, similar to the first but with much higher performances than it is under development. This spectrograph is

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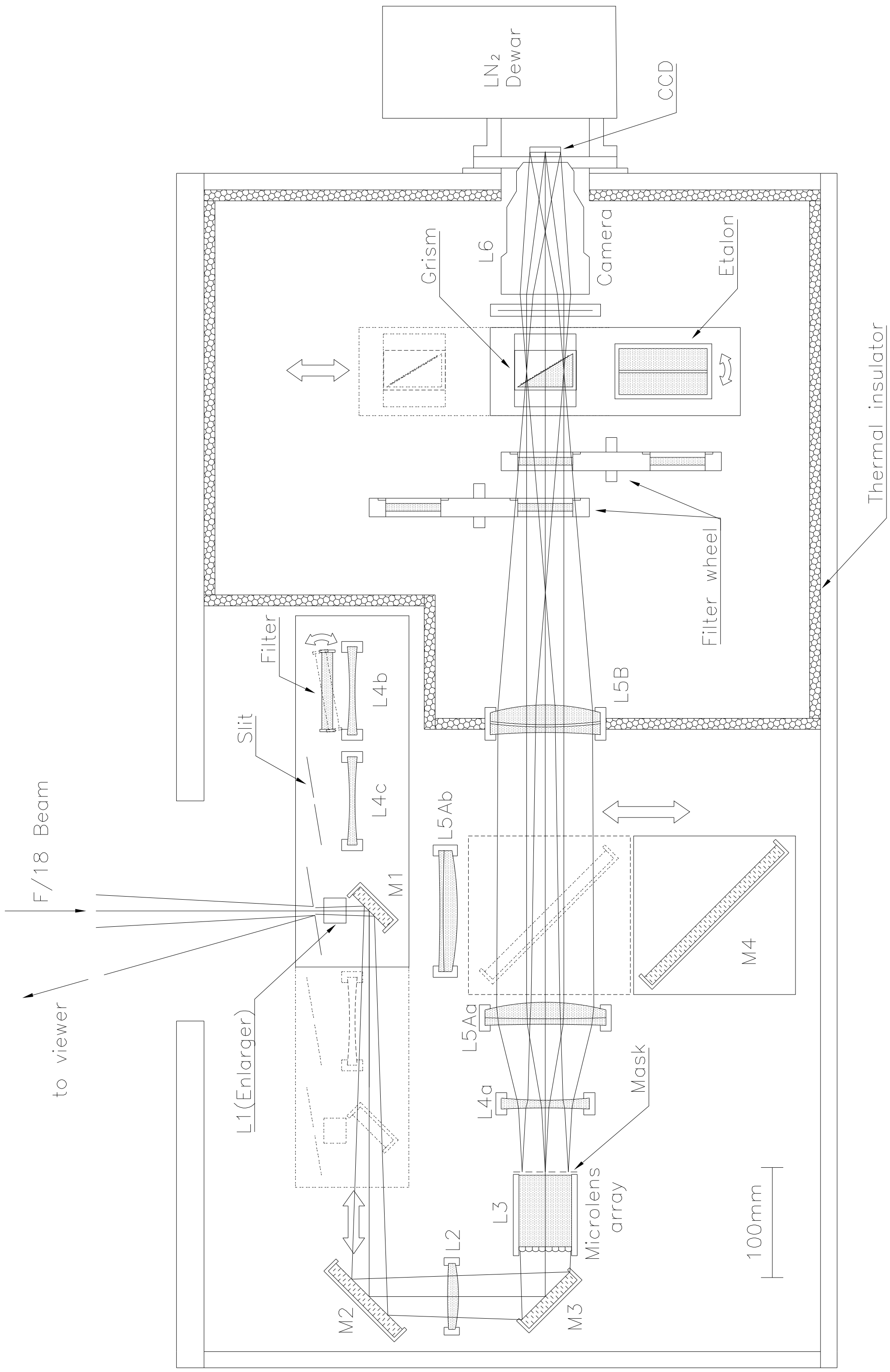

Figure 1. Layout of the Kyoto 3D-I

Table 1. Parameters of Fabry-Perot etalons

Etalon	Gap (μm)	Wavelength Region (Å)	Finess at 6328Å	Resolution R at Hα	Remark
No.1	3-8	4000-7000	25	250-600	Tunable Filter
No.2	55 ± 3	4000-7000	40	6800	Velocity Field

intended to be mounted on a 2-meter telescope under construction at Haleakala by Tokyo University and also on the SUBARU.

The optics of the new spectrograph is designed to have excellent image quality and high transmission from 3600 to 9000 Å; about 40 percent even at 3600 Åis expected with a multilayer AR coat. An EEV thinned 2K x 2K CCD with an AR coat is used. Image scales of the Fabry-Perot imaging modes are 0.3" and 0.06" per pixel for the 2 meter telescope and the SUBARU, respectively.

In the IFS mode, a crossed-cylindrical microlens array of quartz manufactured by LIMO is used. The array format is 37 x 37. The pitch corresponds to 0.4" at the 2 meter telescope and to 0.07" at the SUBARU. The latter is optimized for the case when adaptive optics becomes available.

This instrument will be completed in a year. The readers should refer to Sugai et al. (1998) for more details of this spectrograph.

2. Astronomical Results with Kyoto 3D-I

2.1. Observations with the 188cm telescope

Indication of Accelerated Gas Outflow from the Nucleus of NGC4151 A Fabry-Perot interferometric observation at [OIII] 5007 Åline was made to obtain velocity field around the nucleus of NGC4151. Line-splitting increases with distance in NE and SW from the nucleus, and suddenly diminishes at 3" in the both directions. This may be due to existence of accelerated gas outflows from the nucleus along the inner surfaces of the bipolar radiation cone embedded in the the galactic disk (Ohtani et al.,1997).

Possible Shock Interaction between the Molecular Ring and the Radio Lobe in NGC1068 A map of [SII]/ Hα intensity ratio was obtained from monochromatic images obtained with the tunable filter. Distribution of relative intensity of [SII]/Hα is anticorrelated with that of [OIII]/ Hα which has the biconical shape along NE-SW axis. In addition, an arc feature is recognized in the [SII]/Hα map between the molecular (or starburst) ring and the head of the SW radio lobe. From the shape and [SII] enhancement, this feature seems due to shock interaction between them. (Ishigaki et al., 1998)

Emission Line Imaging of LINERs A survey program of line imaging of LINER galaxies is in progress. In nuclear regions of some objects, there have been detected extended emission line regions whose shape of Balmer line image is different from that of forbidden line images. This may be indication of existence of anisotropy of nonthermal ionizing radiation from the nucleus such as seen in Seyferts. An example, NGC4457, is presented in Figure 2.

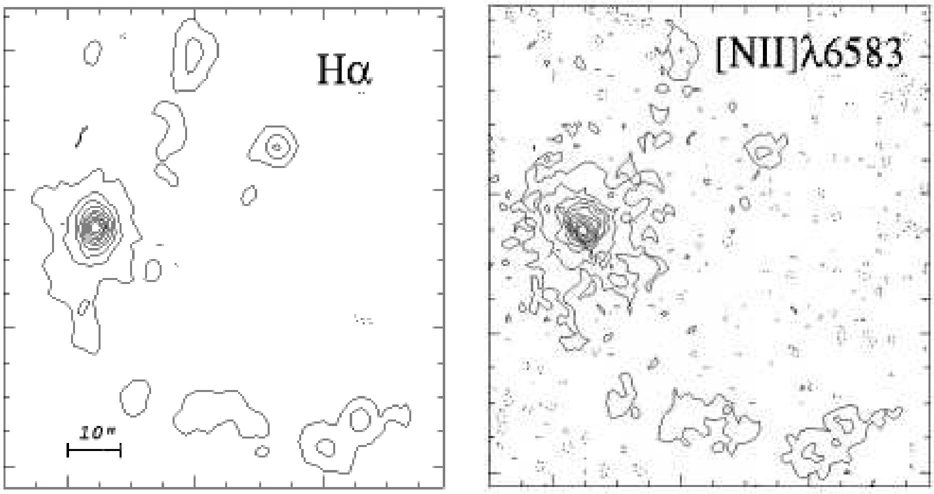

Figure 2. Emission line images of the LINER galaxy NGC4457

IR Luminous Interacting System with AGN Extensive 3D spectroscopic observations with imaging Fabry-Perot and slit scan were carried out for the IR luminous interacting systems Mrk266 and NGC7592.

For the former, gases in the largest tidal tail extending to the north have been found to be ionized by a power law continuum which is probably originated from the Seyfert nucleus of the SW galaxy of the system. The nucleus is inferred to be one of the most powerful Seyfert nuclei.

For the latter object, one component has been found to be a disk galaxy with active starbursts. In the other component, a Seyfert 2 galaxy, has been detected a biconical ionizing radiation cone and a starburst ring surrounding the nucleus.

Details of these studies are presented elsewhere in the present conference (Ishigaki et al. 1999, and Hattori et al. 1999).

Velocity Field of the Bipolar Planetary Nebula Hb4 An integral field spectrogram of the bipolar planetary nebula Hb4 was obtained. The velocity field was analyzed(Figure 3). The northern part and the southern part of the main body around the central star are approaching to and receding from us, respectively, while the northern jet and the southern one are receding and approaching, respectively. This suggests that the main body is an expanding disk along whose axis the bipolar jet was ejected.

2.2. Super-Wide-Filed Observation

A telephoto lens of focal length 300mm can be attached to the spectrograph in stead of the telescope. The spectrograph with the lens is mounted on the tube of a 60 cm telescope. Then, a very wide panoramic 3D-spectral view is obtained. The observing parameters in this case are tabulated in Table 2.

The Rosette Nebula: Shock Interaction with a Supernova Remnant Line images of [SII] and Hα were obtained with the tunable filter. [SII]/Hα intensity ratio

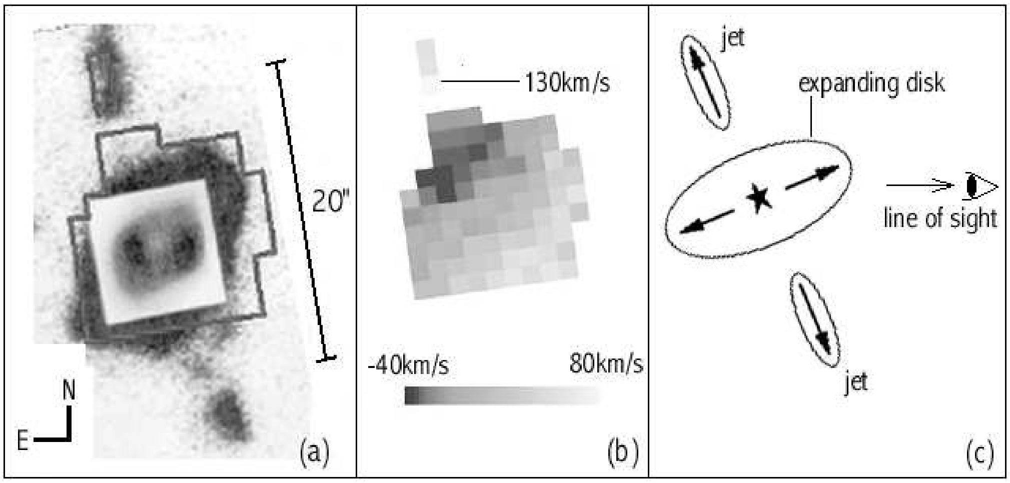

Figure 3. Bipolar planetary nebula Hb 4. (a) Hα image (Schwarz et al.,1992),(b)and (c) Hα velocity field

Table 2. Super-Wide-Field

Mode	F.O.V.	Spatial resolution
F-P	7 x 7 degree	1.0 arc min
IFS	18 x 28 arc min	2.5 arc min

is large in three parts of the peripheral regions of the Rosette. In the two among the three, the SE and the NW parts, molecular clouds are detected and, therefore, these parts are partially ionized regions like the Orion Bright Bar. In the other, the NE part, neither CO nor HI radio line is detected. The Monoceros Loop, a ring of faint filamentary nebulosities seen between the Cone Nebula and the Rosette apparently contacts here with the latter. From these, the [SII] enhancement in the NE part is interpreted as the result of shock excitation due to collision with the Loop. This also implies that the Loop is the remnant of a supernova exploded in the Monoceros star forming complex.

Global Ionizaion Structure of the Orion Nebula 3D spectrum for the whole of the Orion Nebula was obtained in the IFS mode and maps of various line ratios were made. From these, radial variations of the line intensity ratios can be traced up to the periphery of the Nebula, i.e., nearly to the surface of the Strömgren sphere. So far, no observation of such a large scale was performed. Distribution of [NII]/Hα ratio is presented in Figure 4 where a general tendency of increase of the ratio near the periphery is seen. This is consistent with results of theoretical model calculations. Farther study will be useful to examine details of the UV spectral energy distributions of the exciting stars.

References

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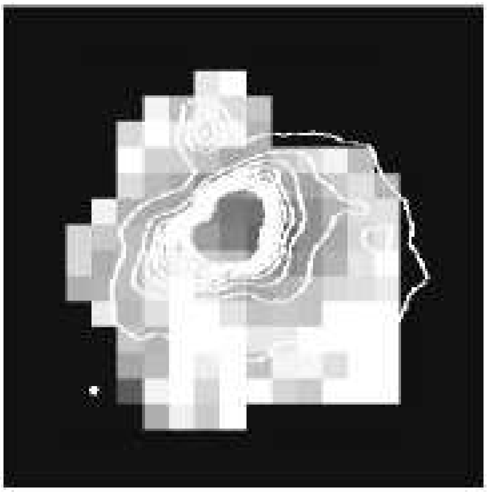

Figure 4. Distribution of [NII]/Hα ratio for the whole area of the Orion Nebula.The denser the gray scale, the ratio is the smaller

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