PROPUESTA CONICYT-Gemini

observing time request summary

Semester: 2011B

Observing Mode: queue

Instruments:
GMOS South

Gemini Reference:

Time Awarded:

Thesis:
no

Band 3 Acceptable:
No

Title: **Tracing gas flows in Active Galactic Nuclei down to the innermost few parsecs**

Principal Investigator: **Neil Nagar**
PI institution: Universidad de Concepcion, Departamento de Astronomia, Universidad de Concepcion, Barrio Universitario S/N,, Concepcion - Chile, Chile
PI status: PhD/Doctorate
PI phone/fax/e-mail: +56 (0)41 220 7171 / / nagar@astro-udec.cl
Co-Investigators: Thaisa Storchi-Bergmann: Universidade Federal do Rio Grande do Sul (UFRGS), thaisa@ufrgs.br
Allan Schnorr Muller: Universidade Federal do Rio Grande do Sul (UFRGS), allan.schnorr@ufrgs.br

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Partner Submission Details *(multiple entries for joint proposals)*

				NTAC			
Partner	**Partner Lead Scientist**	**Time Requested**	**Minimum Time Requested**	**Reference Number**	**Reco-mmended Time**	**Minimum Time Reco-mmended**	**Rank**
Chile	Nagar	7.0 hours	2.3 hours		0.0	0.0	
	Total Time	*7.0 hours*					

Abstract *(190 words)*

We propose GMOS IFU emission-line spectroscopy of the extended Halpha gas in the inner kiloparsec of nearby active galactic nuclei (AGN) hosts, selected for having dusty nuclear spirals, in order to test the hypothesis that these spirals trace the channels through which the nuclear supermassive black hole is being fed. This is a continuing study for which we have already data for 5 LINERs, 3 Seyfert 2 and 3 Seyfert 1 galaxies. The data we have already in hands show that the Halpha kinematics within the inner kiloparsec presents streaming motions towards the nucleus with speeds of the order of 50 km/s. This result suggests that dusty nuclear spirals do trace inflows, and we now aim at correlating the mass inflow rates with the strength (luminosity) of the nuclear activity, in order to characterize the black hole accretion and growth in a statistically significant sample of galaxies, spanning a range of nuclear power. We thus need to include in our sample a range of AGN luminosities and, towards this goal, we now propose to use Gemini/GMOS-IFU to map the gas kinematics in the nearby Seyfert

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galaxies NGC1386, NGC1566 and NGC7213.

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Science Justification *(1000 words)*

(Limit text to 1500 words with figures, captions and references on no more than two additional pages)

BACKGROUND: A long-standing problem in the study of the coeval evolution of galaxies and their black holes is understanding how mass is transferred from galactic scales down to nuclear scales to feed the supermassive black hole (hereafter SMBH). Many theoretical studies [1,2,3] and simulations have shown that non-axisymmetric potentials efficiently promote gas inflow towards the inner regions [4]. Recent observations have revealed that structures such as small-scale disks or nuclear bars and associated spiral arms are frequently observed in the inner kiloparsec of active galaxies [5,6,7]. The most common nuclear structures are dusty spirals, estimated to reside in more than half of active galaxies [8]. Further, a strong correlation between the presence of nuclear dust structures (filaments, spirals and disks) and accretion-related activity in galaxies has recently been reported [9]. This correlation between dust structures and accretion activity in galaxies along with the enhanced frequency of dusty spirals supports the hypothesis that nuclear spirals are a mechanism for fuelling the nuclear SMBH, transporting gas from kiloparsec scales down to a few tens of parsecs of the active nucleus [10,11,12,13,14,15,17]. This hypothesis has recently been confirmed by our group [16,18,19] in the cases of the LINER galaxies NGC1097 and NGC6951. Using GMOS-IFU spectroscopy we could kinematically map streaming motions of gas towards the nucleus approximately along dusty spiral arms, which are observed in HST images.

We have also used GMOS-IFU to map the gas kinematics in the nuclear region of another LINER galaxy: M81[20]. In this case, instead of using models of circular rotation to isolate streaming motions from the orbital motions in the galaxy potential, we used the stellar velocity field. The results are shown in Fig.1. Also, in order to further investigate additional kinematic components in the emitting gas, we have applied the technique of principal component analysis (PCA) [21] to the datacube. Relevant results are illustrated in Fig.2, which shows the "eigen-spectra" PC3 and PC4 in the bottom panels, and the corresponding tomograms in the top panels. These eigen-spectra and tomograms reveal two kinematic components: (1) a compact rotating disk (PC3), with radius of ~20 pc; (2) a compact outflow (PC4) perpendicular to the disk, whose presence is supported by previous radio data showing a compact jet

GOALS OF THE PRESENT PROPOSAL: apply the techniques we have recently developed and described above to: (1) obtain the stellar kinematics from the fitting of the stellar absorption bands using the pPXF method [22]; (2) map the inflows around nearby AGN, as well as possible outflows, using models of circular rotation and the stellar kinematics as references for rotation in the galaxy gravitational field; (3) look for the association of inflows with nuclear spirals and outflows with radio components; (4) constrain physical parameters of the inflows and outflows such as the mass flow rate, geometry and gas density; (5) correlate these parameters with other properties of the galaxies and their active nuclei, such as the nuclear accretion rate, molecular gas content and host galaxy morphology.

SAMPLE: This is a continuing study for which we have already data for 5 LINERs, 3 Seyfert 2 and 3 Seyfert 1 galaxies. The data we have already in hands show that the Halpha kinematics within the inner kiloparsec presents streaming motions towards the nucleus (see Fig. 1), suggesting that dusty nuclear spirals do trace inflows. We now aim at correlating the mass inflow rates with the strength (luminosity) of the nuclear activity, in order to characterize the black hole accretion and growth in a statistically significant sample of galaxies, spanning a range of nuclear power. In order to "fill the gaps" we have in nuclear power, we now propose to use Gemini/GMOS-IFU to map the gas kinematics in the nearby Seyfert galaxies NGC1386(Sy2), NGC1566(Sy1) and NGC7213(Sy1). With these galaxies we will complete a sample covering a range of nuclear power and activity types, comprising 5 LINERs, 4 Seyfert 2 and 4 Seyfert 1 galaxies. Preliminary results we have obtained for the galaxies NGC1358, NGC1667 and NGC2110 are shown in Fig.3, namely nuclear spiral structures in Halpha.

Althought there is publically availiable GMOS-IFU data of NGC1566 in the archive, the Halpha and [NII]6585A lines, both crucial to our analysis, are not measurable in this data, as they are affected by the gap between the CCDs. It is then necessary for us to observe this galaxy again.

REFERENCES: [1] Shlosman, I., Begelman, M. C., Frank, J. 1990, Nature, 345, 679. [2] Emsellem, E., Goudfrooij, P., Ferruit, P. 2003, MNRAS, 345, 1297. [3] Knapen, J. H. 2005, ApSS, 295, 85. [4] Englmaier, P., Shlosman, I. 2004, ApJ, 617, L115. [5] Erwin, P., Sparke, L. S. 1999, ASPC, 182, 243. [6] Pogge, R. W., Martini, P. 2002, ApJ, 569, 624. [7] Laine, S. et al. 2003, AJ, 126, 2717. [8] Martini, P., Regan, M. W., Mulchaey, J. S., Pogge, R. W. 2003, ApJ, 589, 77. [9] Simoes Lopes R. D., Storchi-Bergmann T., de Fatima Saraiva M., Martini P., 2007, ApJ, 655, 718. [10] Knapen, J. H. et al. 2000, ApJ, 528, 219. [11] Emsellem, E., et al. 2001, A&A, 368, 52. [12] Maciejewski, W., Teuben, P. J., Sparke, L. S., Stone, J. M. 2002, MNRAS, 329, 502. [13] Marconi A., Axon D.J. et al. 2003, ApJ, 586, 868. [14] Crenshaw, D. M., Kraemer, S. B., Gabel, J. R. 2003, AJ, 126, 1690. [15] Fathi K. et al. 2005, MNRAS, 364, 773. [16] Fathi K., Storchi-Bergmann, T., Riffel, R. A., Winge, C., Axon, D. J., Robinson, A., Capetti, A. & Marconi, A. 2006, ApJ, 641, L25. [17] Maciejewski, W. 2004, MNRAS, 354, 892. [18] Storchi-Bergmann et al. 2007, ApJ, 670,959 [19] Riffel R. A., Storchi-Bergmann T., Winge C., McGregor P. J., Beck T., Schmitt H., 2008, MNRAS, 385, 1129. [20] Schnorr Muller, Allan; Storchi-Bergmann, Thaisa; Riffel, Rogemar A.; Ferrari, Fabricio; Steiner, J. E.; Axon, David J.; Robinson, Andrew 2011, MNRAS, In Press, Availiable at arXiv:1012.3015. [21] Steiner J. E., Menezes R. B., Ricci T. V., Oliveira A. S., 2009, MNRAS, 395, 64. [22] Cappellari & Emsellem, 2007, PASP, 431, 465.

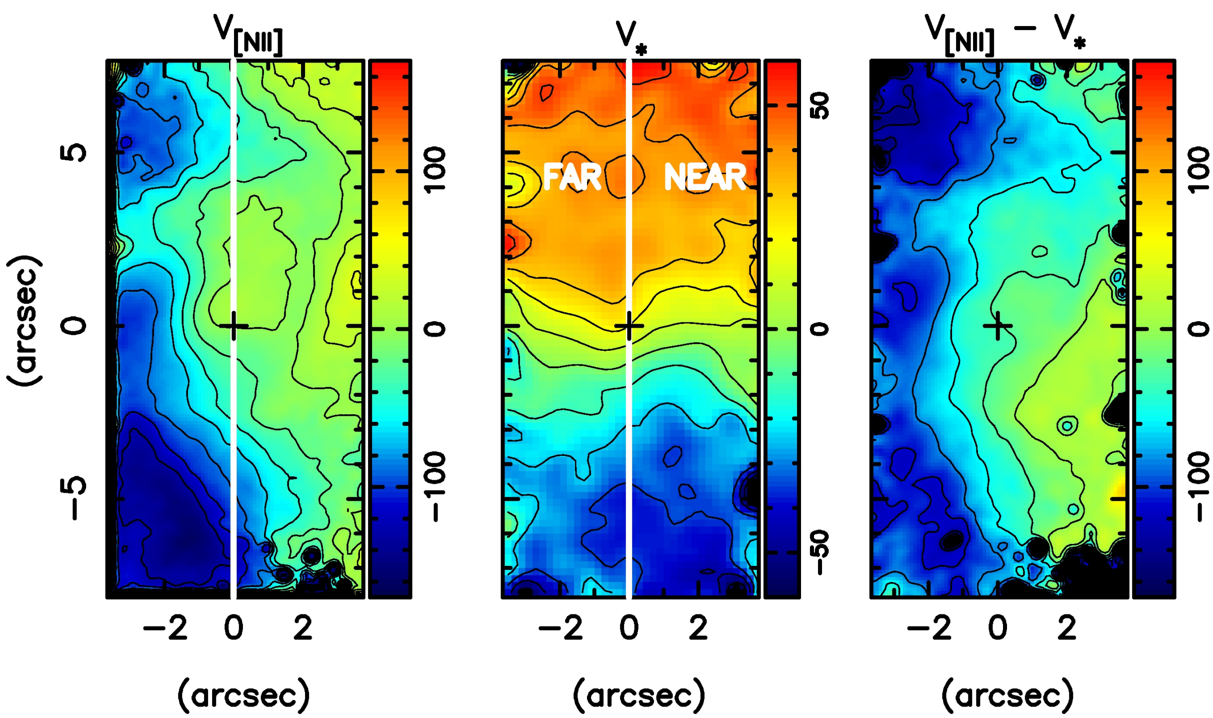


Figure 1 : Fig. 1: Results for M81: From left to right: gaseous velocity field, stellar velocity field and the residual between gaseous and stellar velocity field. The straight white line indicates the position of the line of nodes. Gemini Observatory Tracing gas flows in Active Galactic Nuclei down to the innermost few parsecs Page 4

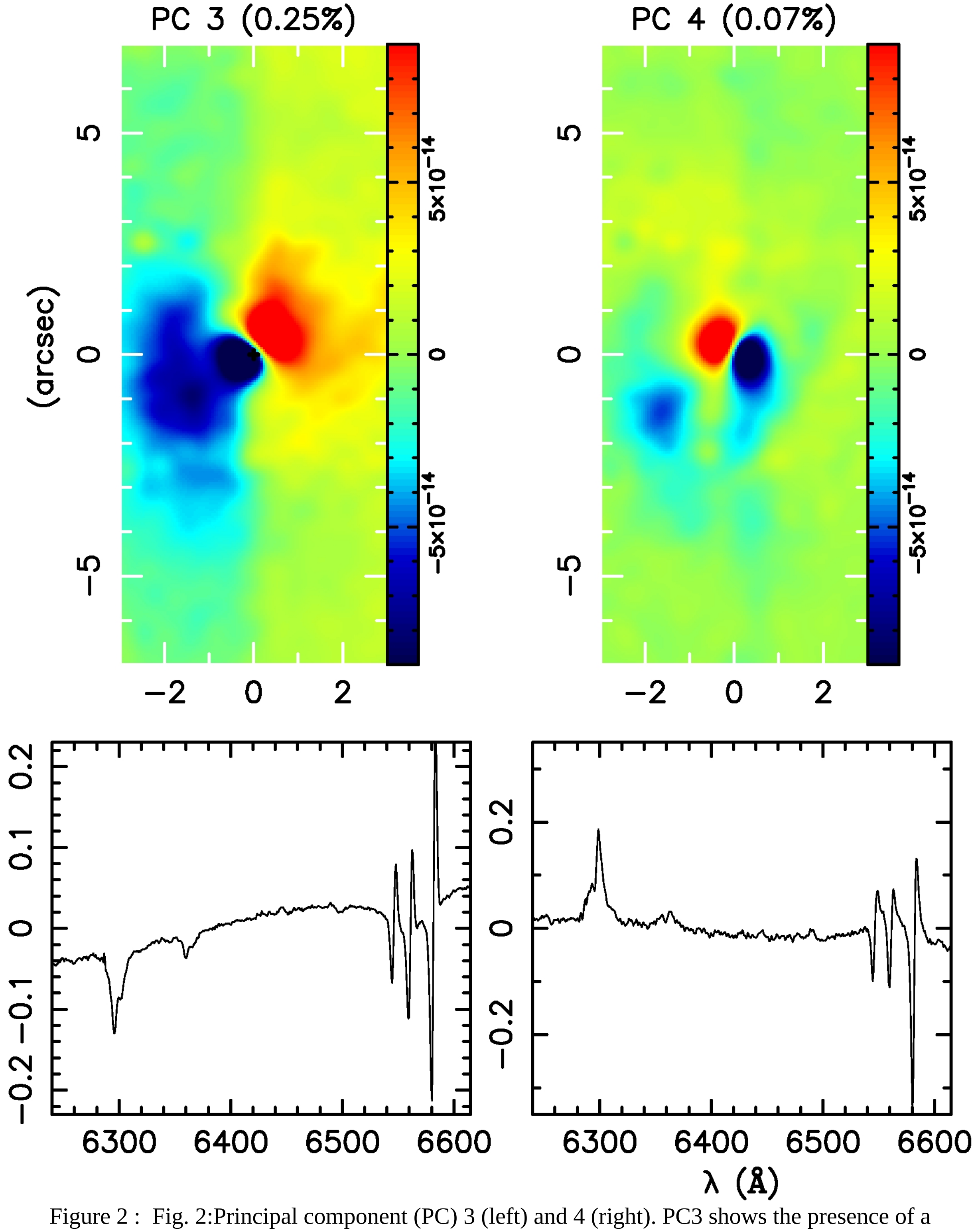


Figure 2 : Fig. 2:Principal component (PC) 3 (left) and 4 (right). PC3 shows the presence of a compact rotating disk in the central region of the galaxy and PC4 shows an outflow perpendicular to the disk. Gemini Observatory Tracing gas flows in Active Galactic Nuclei down to the innermost few parsecs Page 5

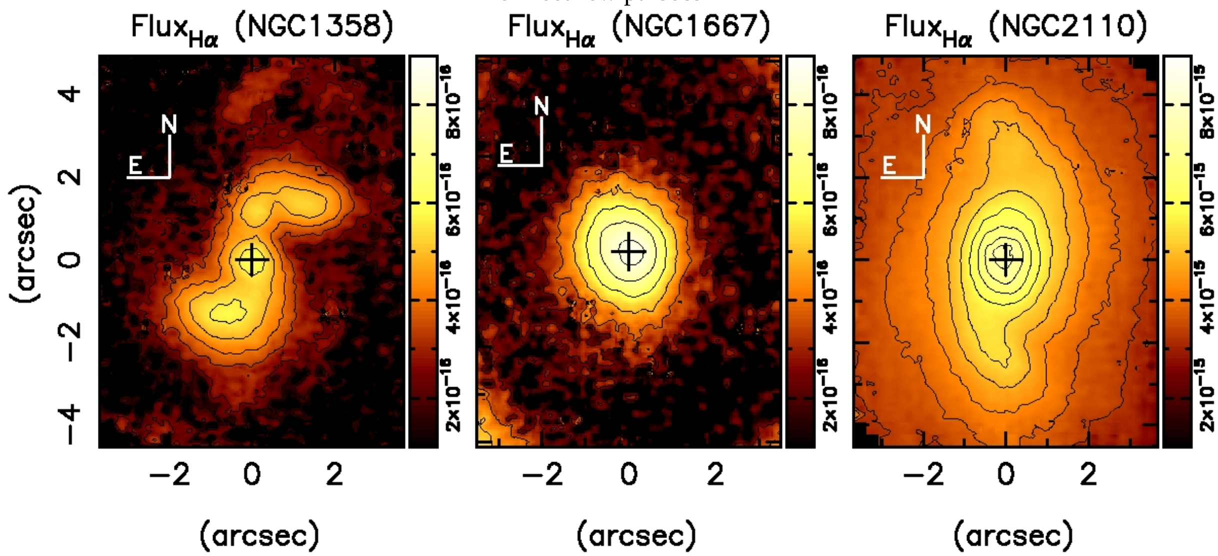


Figure 3 : Fig. 3: Halpha flux for NGC1358, NGC1667 and NGC2110. Strong nuclear spiral structures are seen in both NGC1358 and NGC2110.

Technical Justification *(764 words)*

(Limit text to 1000 words)

DESCRIPTION OF OBSERVATIONS: In order to reach our scientific goals we propose to obtain the 2D gas and stellar kinematics within the inner kiloparsec of the galaxies NGC1386, NGC1566 and NGC7213 at sub-arcsecond spatial resolution. We propose to do that by measuring the emission-line profiles (wavelengths, fluxes, widths) of a few of the brightest emission lines of the spectra, namely Halpha, [NII]6548,84 and [SII]6717,31, as well as the stellar absorption features present in the covered wavelength interval (see below). The streaming gas motions towards the center will appear (if present) only after the subtraction of the rotation component. The rotation component will be derived via modelling (as done for NGC1097) or, if the gaseous velocity field is too disturbed to be modelled (as is the case of M81) then the rotation component will be obtained from the stellar kinematics. We will then estimate the mass inflow rate which will be compared with the nuclear accretion rate (to feed the SMBH). With a sample covering a range of activity types, we will be able to test if the streaming velocities and mass inflow rates are related to the type and strength of the nuclear activity. Besides obtaining the gas kinematics we will be able to derive the gas excitation through the [NII]/Halpha ratio and gas density through the ratio of the two [SII] lines. We will also apply the PCA technique to the data as an alternate method of mapping inflows and outflows. This technique was succesfully applied to the M81 datacube and it has allowed us to unveil faint components which seem to map the inflows and also outflows at the smallest scales around the SMBH.

We propose to use the GMOS IFU with grating R400 in combination with the r(630nm) filter in order to cover the wavelength range 560-700nm, which includes the above emission lines and a suitable number of stellar absorption features to allow the derivation of the stellar kinematics. For an effective output slit width for the IFU=0.31", the spectral resolution will be: R=3523, which is adequate for our purposes, according to the results we have obtained in our previous studies. We propose to observe in two slit mode, which will allow an angular coverage of 5"x7". At the typical distance of the targets, in order to cover a large enough field to map the kinematics we propose to observe two adjacent IFU fields with 1 arcseconds of overlap, covering 9 arcsec along the major axis and 7 arcseconds along the minor axis. The surface brightness in the continuum for the three galaxies is approximately 1 x 10^{-16} erg s^{-1} cm^{-2} A^{-1} arcsec^{-2}. Using the ITC, we obtain an integration time of 45 min to obtain S/N ratios of about 8 in the continuum. The total exposure time (for two fields) will then be 90 min on-source plus 25min overheads = 115min per galaxy. We intend to flux calibrate the data, in order to derive the mass flow rate towards the center, thus we need to observe one standard star. Time required for the standard star (25min) is mainly overhead. We propose three observations of the standard, considering the possibility that all three galaxies are observed at different nights. The total time will thus be: 3 x 115 + 3 x 25 = 420 min=7 hr. The minimum time requested is 2.3 h for the observation of only one galaxy and standard.

THE NEED FOR GEMINI AND GMOS IFU: We need the large aperture of Gemini to reach faint emission levels and obtain an adequate spatial coverage of the gas emission. The 2D coverage of the GMOS IFU is essential to adequately constrain the velocity field, at the necessary spatial resolution. Without the spatial resolution provided by the GMOS-IFU we would not have been able to kinematically map the streaming motions in narrow spiral arms as we successfully did for NGC1097 and NGC6951 [16,18].

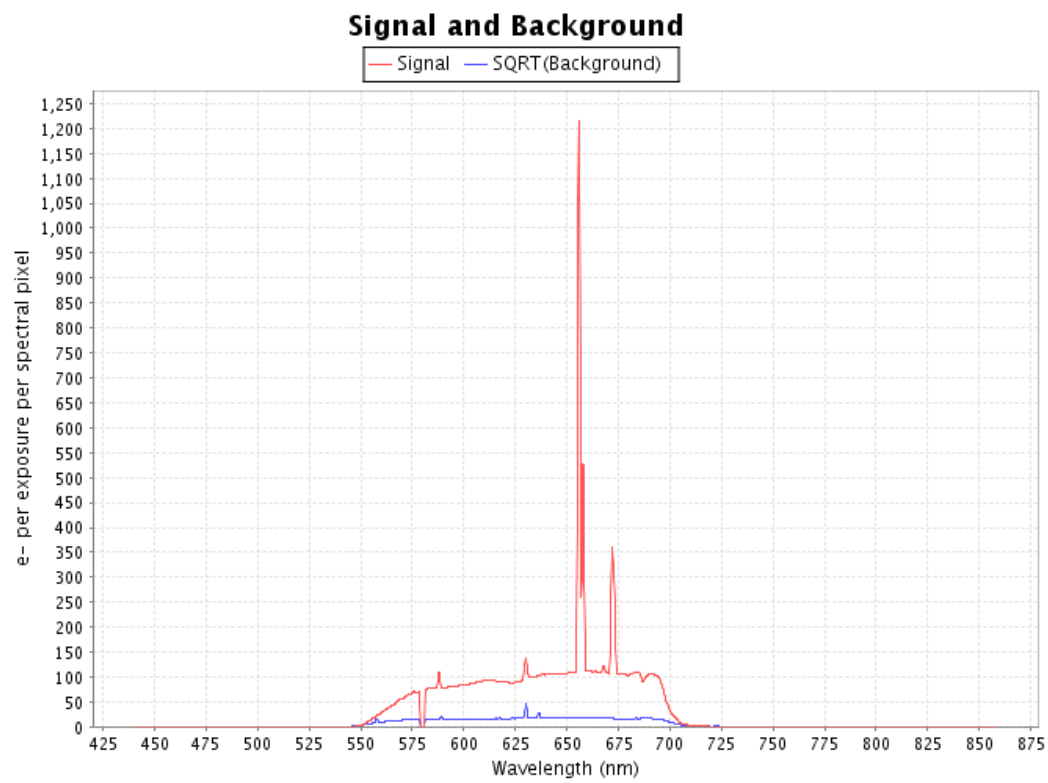
MEASUREMENTS TO BE MADE FROM THE DATA: We will measure the emission-line fluxes (Halpha, [NII] and [SII]), central wavelengths and line widths in order to map the gaseous distribution, excitation, density and, most important, the gas kinematics. We will also obtain the stellar kinematics from the fitting of the stellar absorption bands using the pPXF method [22]. The two-dimensional measurements will allows us to appropriately deal with the non-circular kinematic components and constrain the circumnuclear disk geometry. We will use the technique successfully used by Fathi et al. [16] and Storchi-Bergmann et al. [18] as well as those we have used for M81 [20] to quantify the non-circular motions and to separate them from the circular velocity.

Gemini Integration Time Calculator GMOS version 4.0

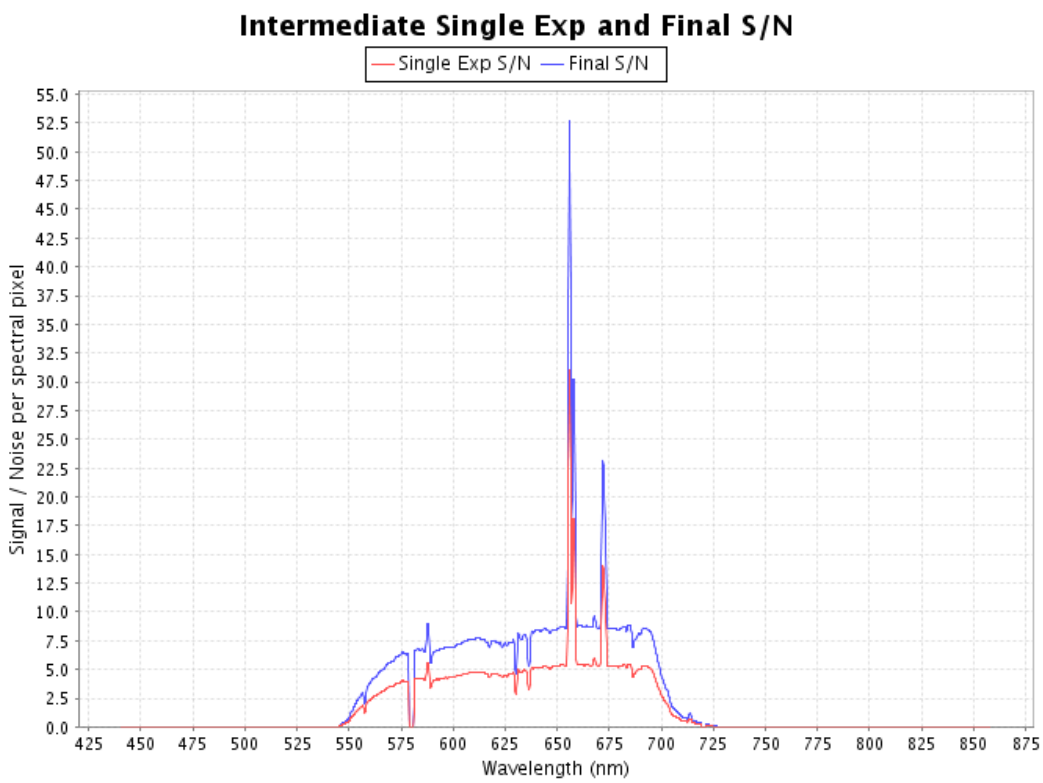
Click here for help with the results page.
Read noise: 4.1
derived image size(FWHM) for a point source = 0.99arcsec

Sky subtraction aperture = 5.0 times the software aperture.

Requested total integration time = 2700.00 secs, of which 2700.00 secs is on source.



Click here for ASCII signal spectrum.
Click here for ASCII background spectrum.



Click here for Single Exposure S/N ASCII data.
Click here for Final S/N ASCII data.

Input Parameters:
Instrument: GMOS-S

Source spatial profile, brightness, and spectral distribution:
The Source is a 1.0E-16 ergs_fd_wavelength_per_sq_arcsec spiral-galaxy at R.

Instrument configuration:
Optical Components:

- Filter: r_G0303
- Fixed Optics
- IFU Transmission
- Grating Optics: R400_G5305
- Detector - GMOS South CCDs
- Focal Plane Mask: ifu

Central Wavelength: 650.0 nm
Spatial Binning: 4

Spectral Binning: 4
Pixel Size in Spatial Direction: 0.288arcsec
Pixel Size in Spectral Direction: 0.2692nm
IFU is selected,with a single IFU element at 0.0arcsecs.

Telescope configuration:
- silver mirror coating.
- side looking port.
- wavefront sensor: oiwfs

Observing Conditions:
- Image Quality: 70.00%
- Sky Transparency (cloud cover): 70.00%
- Sky transparency (water vapour): 100.00%
- Sky background: 80.00%

Frequency of occurrence of these conditions: 39.19%

Calculation and analysis methods:
- mode: spectroscopy
- Calculation of S/N ratio with 3 exposures of 900.00 secs, and 100.00 % of them were on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 5.00 times the target apeture.

Output:
- Spectra autoscaled.

Figure 1 : Integration Time Calculator results

Band 3 Information

This proposal cannot be scheduled in Band 3.

Observation Details

Observation	RA	Dec	Brightness	Total Time *(including overheads)*
NGC1386	03:36:46.2	-35:59:57.0	V=12.09	115.0 minutes
109-008358(wfs)	3:37:14.179	-35:57:31.11	11.080 UCmag,10.127 Jmag,9.800 Kmag	separation 6.16
Observing conditions:		resources:		
NGC1566	04:20:0.4	-54:56:16.0	V=10.33	115.0 minutes
071-009425(wfs)	4:19:49.577	-54:51:03.44	12.322 UCmag,11.030 Jmag,10.693 Kmag	separation 5.44
Observing conditions:		resources:		
NGC7213	22:09:16.3	-47:10:0.0	V=11.01	115.0 minutes
086-422954(wfs)	22:09:45.89	-47:13:15.61	10.744 UCmag,9.891 Jmag,9.608 Kmag	separation 5.99
Observing conditions:		resources:		
LTT 2415	05:56:24.3	-27:51:28.8	V=12.21	25.0 minutes
125-019963(wfs)	5:56:01.812	-27:47:14.87	12.492 UCmag,10.895 Jmag,10.323 Kmag	separation 6.53
Observing conditions:		resources:		
LTT 2415	05:56:24.3	-27:51:28.8	V=12.21	25.0 minutes
125-019963(wfs)	5:56:01.812	-27:47:14.87	12.492 UCmag,10.895 Jmag,10.323 Kmag	separation 6.53
Observing conditions:		resources:		
LTT 2415	05:56:24.3	-27:51:28.8	V=12.21	25.0 minutes
125-019963(wfs)	5:56:01.812	-27:47:14.87	12.492 UCmag,10.895 Jmag,10.323 Kmag	separation 6.53
Observing conditions:		resources:		

Observing Conditions

Name	Image Quality	Sky Background	Water Vapor	Cloud Cover
Medium	70 %	80 %	Any	70 %

Resources

- Gemini South
  - GMOS South
    - Focal Plane Unit
      - IFU w/ 2 slits
    - Disperser
      - R400_G5325
    - Filter
      - r_G0326

Scheduling Information

Scheduling constraints and non-usable dates

- (impossible):
- (optimal):
- (synchronous):

Additional Information

Keyword Category: extraGalactic
Keywords: Active galaxies
Dynamics
Emission lines
Galaxy bulges
Galaxy centers
Intergalactic medium
Seyfert galaxies
Survey

Allocations:

Reference	Time	% Useful	Status of previous data
GS-2010B-Q-19	6.6 hours	100%	Observed on 26-28 January 2011 (i.e. 2 months ago). Data has been processed (see Fig.3 of this proposal) and is currently being analyzed in detail. Publication in process.