The 2014B Report
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The DIVING^{3D} project: Deep IFS View of Nuclei of Galaxies

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Executive Summary

This is the 2014B report of the LLP: DIVING^{3D}- Deep IFS View of Nuclei of Galaxies . We will present the developments made in the period April-September 2014.

Being concerned about the accuracy of our photometric calibrations, we have made observations of some of our sample galaxies with the SOAR Telescope, with very careful calibration procedures. We found a few errors in the Gemini standard treatment procedures and adopted new procedures.

We also studied the GMOS/IFU PSF and found that a Moffat profile is more adequate than a Gaussian profile.

We found that the galaxy NGC 3115 has an off-centered low luminosity Seyfert 1 galaxy. We appended the Letter that we have submitted for publication to the ApJ Letters. We have also listed all our papers published and submitted in 2014 or to be submitted for publication in the next months.

We provide a brief summary of the analysis of the sample of objects already observed, including the massive galaxy subsample, the late type galaxy sample and a small sample of Milky Way twins.

In addition we provide comments on the referee remarks.

Finally, we provide three appendices.

Introduction

The DIVING^{3D} Project (Deep IFS View of Nuclei of Galaxies) is a survey of 170 galaxies that satisfy the following criteria: B<12.0, $\delta<0^\circ$ and $|b|>15^\circ$ (11 galaxies classified as Sm/Im were excluded as they do not show any nucleus in the 2MASS images). 29 of these galaxies have already some type of nuclear activity reported in the NED (NASA Extragalactic Database).

This survey is distinct of the northern well known Palomar Survey (Ho et al, 1997). The main differences are that we have a better spatial resolution than Palomar Survey, the usage of 2D spectroscopy (they analyzed long slit spectra) and the fact the we are using an 8m telescope (Palomar is a 5m telescope).

Photometric Calibration

In order to check our photometric calibration errors, we observed 5 galaxies with the SOAR telescope and provided good photometric calibration. The Gemini standard observation provides only one photometric standard and it is usually observed on a different night from the target. This standard star spectrum is important to perform spectral rectification but it should be regarded with caution with calculating fluxes and luminosities.

We found two additional errors in the standard IRAF package for the Gemini Telescopes, particularly in the GFCUBE code. This program transforms the reduced and flux calibrated spectra from the fibers into a data cube. However, when performing this transformation, the code conserves the surface brightness along the spatial dimension instead of conserving the total flux. Both errors are associated with this procedure. One has to do with the way the fibers are packed and transformed in a rectangular data cube. This introduces a difference of 15% in the absolute flux measurements. The second error is much more dramatic and has to do with the re-pixelation. The two corrections together will be $\eta(S/0.2)^2$ where η=0.85 and S is the angular size of the spaxel in the data cube.

In any case, we believe that absolute fluxes should always be taken with caution and have formal errors of the order of 30%.

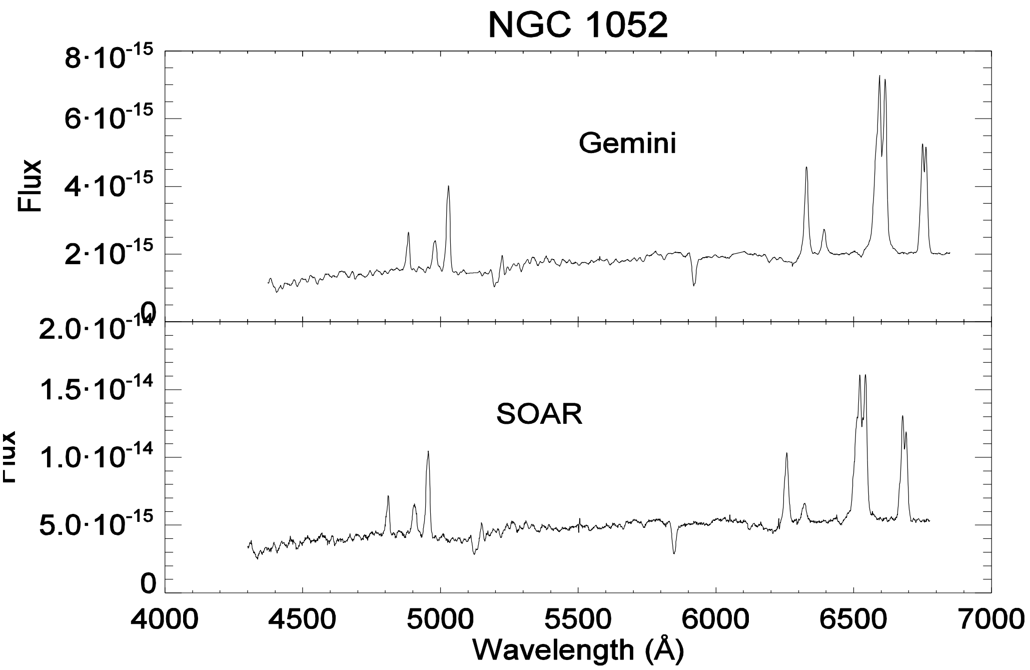

Figure 1. The spectra taken for the NGC 1052 galaxy with the Gemini and SOAR telescopes.

The Moffat profile PSF

One important step in of data processing has to do with deconvolution. In this process one has to assume a PSF (Point Spread Function). After a series of tests, we found that a Moffat profile is a better description of the GMOS PSF than a Gaussian profile. The Moffat profile is given by

$$PSF_{moffat} = A\left[1+\left(\frac{x^2}{\alpha^2}\right)\right]^{-\beta}$$

and

$$FWHM_{moffat} = \alpha\left(2\sqrt{2^{\frac{1}{\beta}}-1}\right)$$

where α and β are free parameters. However, our tests show that, for the GMOS data cubes, β=2.9. This means that FWHM = 1.039α. So, in fact, only one parameter has to be adjusted and it is basically the FWHM. When performing the deconvolution with this PSF, the resulting PSF becomes Gaussian.

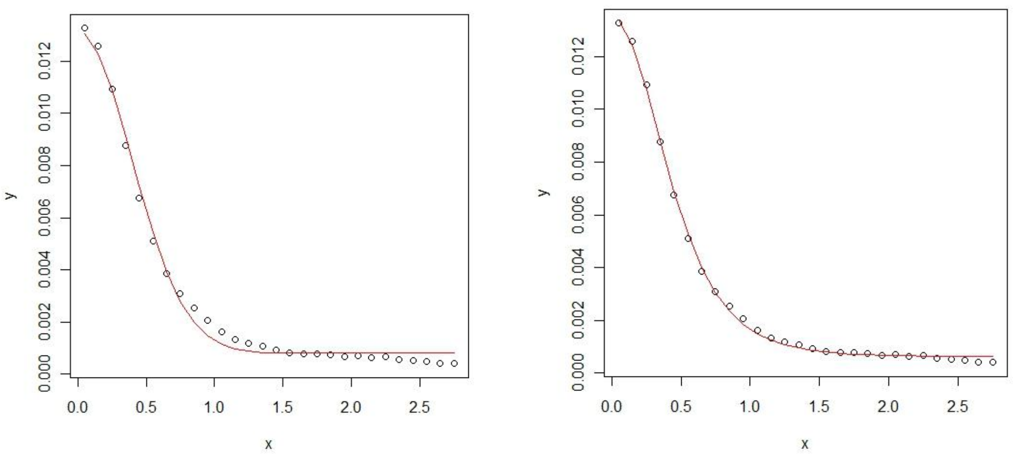

Figure 2. The observed PSF of the Hα wing of the galaxy NGC 1052, adjusted with a Gaussian (left) and a Moffat profile (right).

An off-centered Seyfert 1 nucleus in the galaxy NGC 3115.

One important result of the survey is the discovery that the galaxy NGC 3115 has an off-centered Seyfert 1 nucleus. This galaxy was used in the Palomar Survey as a template to subtract the stellar light from the galaxies. This means that a weak Sy 1 nucleus was subtracted! We have submitted a Letter to the ApJ and currently we are processing the referee report. As requested by the NTAC in response to the 2014A report, we are appending a copy of this paper, where all details are described (Menezes, R. B., Steiner, J. E. & Ricci, T. V. -*An off-centered active galactic nucleus in NGC3115* - Ap J Lett submitted in August 2014).

Publications in 2014

Since the 2014A report, three papers were published:

Ricci, T. V., Steiner, J. E. & Menezes, R. B. 2014a MNRAS 440, 2429 – Paper I
Integral field unit spectroscopy of 10 early-type galactic nuclei - I. Principal component analysis Tomography and nuclear activity

Ricci, T. V., Steiner, J. E. & Menezes, R. B. 2014b MNRAS 440, 2442 – Paper II
IFU spectroscopy of 10 early-type galactic nuclei - II. Nuclear emission line properties

Menezes, R. B., Steiner, J. E. & Ricci, T. V. 2014, MNRAS 438, 2597
A treatment procedure for Gemini North/NIFS data cubes: application to NGC 4151

The last paper is not directly related the the Survey but provides useful methodolocical experience for our effort.

Another paper is about to be submited:

Ricci, T. V., Steiner, J. E. & Menezes, R. B. to be submitted in October 2014 – Paper III
IFU spectroscopy of 10 early-type galactic nuclei - III. Properties of the circumnuclear gas emission

Three other papers (not directly related to the Survey) have been submitted (1) or will be submitted soon (2):

Menezes, R.B., da Silva, P., Ricci, T.V., Steiner, J. E. & May, D., MNRAS, submitted in August 2014
A treatment procedure for VLT/SINFONI data cubes: application to NGC 5643

Menezes, R. B. & Steiner, J. E. To be submitted to the ApJ in October 2014.
The molecular H2 emission and the stellar kinematics of the nuclear region of the Sombrero Galaxy.

May, D., Steiner, J. E., Ricci, T.V., Menezes, R.B, & Andrade, I.S. MNRAS to be submitted in October 2014.
Digging process in NGC 6951: the inclined molecular disk bumped by the outflow

We mention these papers as they have taken significant efforts from the group and are based on data taken previously to the start of the DIVING3D Survey.

The sub-sample of massive (σ>200 km/s) galaxies

As mentioned in the 2014A report, the sub-sample of massive galaxies comprises 35 galaxies. The observations have been completed by December 24, 2013. By March 2014, the following steps had been completed:

1- Data cube reduction: wavelength calibration; flux calibration; DAR (differential atmospheric refraction) correction.
2- Data cube processing: Fingerprint removal (using PCA Tomography); high spatial frequency noise filtering (using Butterworth filter); Richardson-Lucy deconvolution.

A preliminary analysis based on PCA Tomography only was presented in the previous report.

We have performed since than a first run of spectral synthesis (using the Starlight software). This first run was done on non-deconvolved data cube. The purpose is to improve the ability to define the PSF and have a first look to the presence/absence of emission lines and the presence of broad Hα emission. These two characteristics are listed in Table 1. We have assumed a very cautious criterion to define the presence of broad Hα. We can see this very clearly in 9 objects: 8 LINERS and one Sy1.

In Table 2 we compare our preliminary results with those of the high mass (σ>200 km/s) of the Palomar Survey. Two main results call our attention: We found that 11% of the galaxies do not show emission lines while in the Palomar Survey this rate was 24%. This obviously shows that our survey goes much deeper and, therefore, much care must be taken in the comparative analysis. We also found that our rate of detecting broad Hα is 23% while that of the Palomar Survey is 14% only.

We found that a much more careful analysis must be done as in many cases circumnuclear emission can be seen even if nuclear emission may be absent. This is a situation that was not reported in the Palomar survey as in that case only one spectrum per object was available.

After a deconvolution, done now with the Moffat PSF, the spectral synthesis of this sample will be redone and only then we will provide the first attempt of stellar archeology analysis. We believe that all possible cautions should be taken in our data processing before any serious attempt of a statistical analysis that could be published.

The Sbc-Sd galaxy subsample

More objects of this sample were observed in the last semester and by December 31 we will have analyzed all the observed objects and present the results in the next report.

The twins of the Milky Way

We have started to analyze a particular group of galaxies: the twins of the Milky Way, that is, galaxies of the morphological type SBbc (or SABbc). There are 4 galaxies in this sample:

NGC 134	SAB(s)bc
NGC 613	SB(rs)bc
NGC 1566	SAB(rs)bc Sy 1
NGC 6744	SAB(rs)bc

The Seyfert 1 galaxy NGC 1566 has already been fully reduced. The Hα image is shown in Fig 3 and the stellar archeology, in Fig 4.

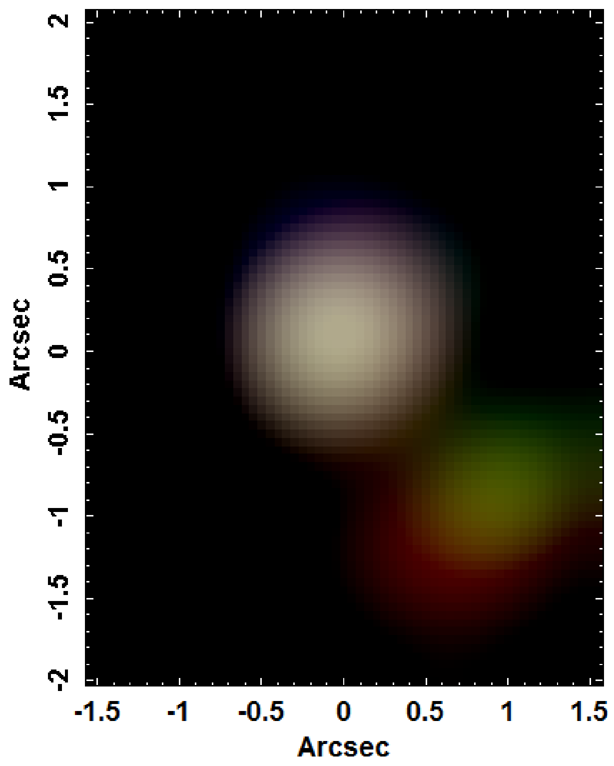

Figure 3. NGC 1566 – Hα. This image shows the nucleus and a redshifted emission spot at ~1" from the nucleus.

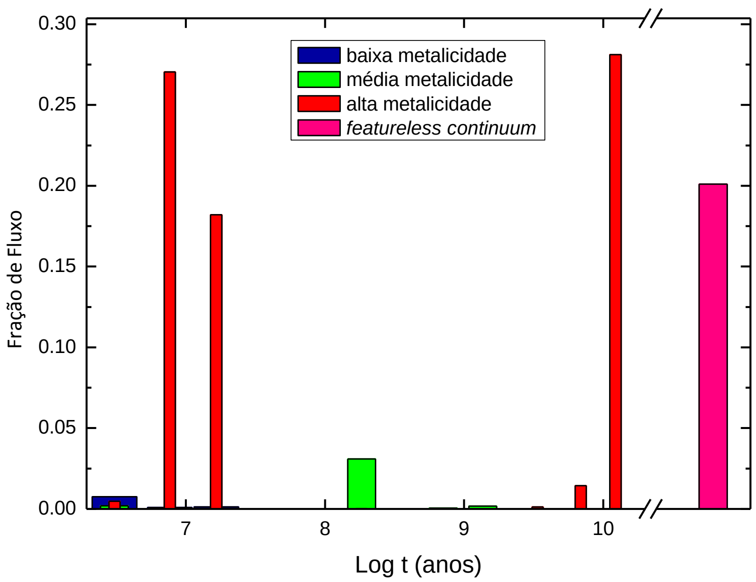

Figure 4. The history of star formation of NGC 1566. The featureless continuum corresponds to about 20% of the optical intensity.

Table 1
The DIVING^{3D} project
The sub-sample of massive (σ>200 km/s) galaxies

Preliminary result: PCA and Starlight

Name	AGN PCA	AGN Strlght	CNE PCA	Stl.disk PCA	Dust PCA	Comment
Ellipticals						
IC 1459	Lb FC	Lb	cne	FR	Dust lane (HST)	
IC 4296	Lb?	L2	cne IC	SR	Dust lane (HST)	
NGC 584	Lb?	L2	cne	FR		
NGC 720	Lw		cne	SR		
NGC 1052	Lb FC	Lb	cne IC	FR		
NGC 1395	L2	L2	cne	FR		
NGC 1399	-	Lw	-	SR		
NGC 1404	-	Lw	-	SR	Dust spot (HST-Ev2)	
NGC 1407	NE	NE	-	SR		unusual shape
NGC 1549	Lw	Lw?	-	FR		
NGC 1700	Lw		cne?	FR	nD+G(Ev2)	
NGC 2974	???		cne IC?	FR	Obsc AGN?	
NGC 3557	Lb	Lb	cne	FR	Dust disk(GMOS)	
NGC 3585	Lw		-	FR	nD+G(Ev2)	
NGC 3904	NE		-	FR	nD+G(Ev2)	
NGC 3923	NE		-	SR		Stellar shells
NGC 3962	Ln?		cne IC	SR		
NGC 4105	L2		cne IC	FR	nD+G(Ev3)	
NGC 4696	Lb	L2	cne	SR		Rdshftd peak Halfa/NII/SII
NGC 5018	Lcn		IC?	FR	nD+G(Ev2)	
NGC 5044	Lb	Lb:	cne	FR?		
NGC 6868	L2?	L2?	cne IC	SR	Obsc. AGN	
NGC 7507	NE		-	SR	nD+G(Ev2)	
S0s						
NGC 1316	L2/S2	S2/L2	cne IC	FR?	dust lane(HST)	
NGC 1332	Ln?		cne?	FR	dust lane(GMOS?)	
NGC 1380	Ln	L2	cne	FR	dust disk (HST) nD+G(Ev2)	
NGC 1574	L		cne IC?	FR	nD+G?	
NGC 2217	S1.8 FC	S1.8	cne IC	FR		
NGC 2784	Lwb?	L2		FR		
NGC 3115	-	Lb		FR	nD+G(Ev2)	Off-centered AGN
NGC 5101	Ln		cne	FR		
NGC 7049	Lb	Lb	cne	FR	dust ring (HST)	
Spirals						
NGC 1300	Lb?	L2	cne	FR	nD+G(Ev2)	
NGC 4594	Lb FC	Lb	cne	FR	nD+G?(Ev2)	M104 Sombr
NGC 4699	Lb	Lb	cne	FR		

Notes: nD = nuclear dust +G=plus neutral gas; FR = Fast rotator; SR = Slow rotator; cne = circum-nuclear emission lines; IC= Ionization Cone; FC = featureless continuum; RG = Radio-galaxy; NE = no emission; L=LINER; Lw = weak LINER; Lb = LINER with broad Halfa.

Notes: Galaxies IC 1459, NGC 1052 and NGC 4594 (Sombrero) are Lb LINERs and NGC 2217 is a Sy galaxy with evidence of featureless continuum (FC), on the basis of the Fe I profile in Ev2.

Table 2
Preliminary comparison with the Palomar Survey for massive galaxies (σ>200 km/s)

Type	Palomar Survey		DIVING3D	
	Nr	%	Nr	%
L1.9	10	14%	8	23%
S1.5	2	3%	1	3%
NE	17	24%	4	11%
S2	4	6%	1	3%
H	3	4%	0	0%
L2+T2	34	48%	21	60%
Total	71	100%	35	100%

Comments to the referee remarks

1. The spatial resolution is quite distinct in the Palomar and in the DIVING3D. Of course, we are not repeating the Palomar survey in the South. This is a new survey, but a comparison with the results in the PS should be done. And, indeed, much care must be taken as shown above.

2. A fraction of the galaxies in our sample have been observed with the HST. We have already a parallel project of analyzing all the images obtained with the HST. This is the goal of the IC project of Fernanda Huller do Nascimento.

3. Our reduction procedures and software are available

   http://www.astro.iag.usp.br/~pcatomography

Appendix A. Relevant publications

A- Publications by our group involving objects from the DIVING^{3D} Project, observed with the Gemini telescopes GMOS IFU:

Menezes, R. B. 2012 - PhD Thesis – Universidade de São Paulo

Ricci, T, V 2013 - PhD Thesis -Universidade de São Paulo

Menezes, R. B., Steiner, J. E., Ricci, T. V. 2013 Ap J 765, L40
Collimation and Scattering of the Active Galactic Nucleus Emission in the Sombrero Galaxy

Ricci, T. V., Steiner, J. E. & Menezes, R. B. 2014a MNRAS 440, 2429 – Paper I
Integral field unit spectroscopy of 10 early-type galactic nuclei - I. Principal component analysis Tomography and nuclear activity

Ricci, T. V., Steiner, J. E. & Menezes, R. B. 2014b MNRAS 440, 2442 – Paper II
IFU spectroscopy of 10 early-type galactic nuclei - II. Nuclear emission line properties

Menezes, R. B., Steiner, J. E. & Ricci, T. V. 2014 Ap J Lett submitted in August 2014
An off-centered active galactic nucleus in NGC 3115

Ricci, T. V., Steiner, J. E. & Menezes, R. B. to be submitted in October 2014 – Paper III
IFU spectroscopy of 10 early-type galactic nuclei - III. Properties of the circumnuclear gas emission

B- Publications involving observations with the Gemini telescopes IFUs that are related to the project in terms of methodology

Steiner, J. E., Menezes, R. B., Ricci, T. V. & Oliveira, A. S. 2009, MNRAS, 395, 64
PCA Tomography: how to extract information from data cubes

Steiner, J. E., Menezes, R. B., Ricci, T. V. & Oliveira, A. S. 2009, MNRAS 396, 788
Mapping low- and high-density clouds in astrophysical nebulae by imaging forbidden line emission

Ricci, T. V., Steiner, J. E. & Menezes, R. B. 2011, ApJ, 734, L10
NGC 7097: The Active Galactic Nucleus and its Mirror, Revealed by Principal Component Analysis Tomography

Menezes, R. B., Steiner, J. E. & Ricci, T. V. 2013 Ap J 762, L29
Discovery of an Halpha Emitting Disk around the Supermassive Black Hole of M31

Menezes, R. B., Steiner, J. E. & Ricci, T. V. 2014, MNRAS 438, 2597
A treatment procedure for Gemini North/NIFS data cubes: application to NGC 4151

May, D., Steiner, J. E., Ricci, T.V., Menezes, R.B, & Andrade, I.S. MNRAS to be submitted in October 2014.
Digging process in NGC 6951: the inclined molecular disk bumped by the outflow

C- Other publications based on IFU data cubes (not related to the DIVING3D Survey)

Oliveira, A. S.; Steiner, J. E.; Ricci, T. V.; Menezes, R. B.; Borges, B. W. 2010 A&A 517, L5

Optical identification of the transient supersoft X-ray source RX J0527.8-6954, in the LMC

Steiner, J. E.; Menezes, R. B.; Amorim, Daniel 2013, MNRAS 431, 2789
Identification of a high-velocity compact nebular filament 2.2 arcsec south of the Galactic Centre

Menezes, R.B., da Silva, P., Ricci, T.V., Steiner, J. E. & May, D., MNRAS, submitted in August 2014
A treatment procedure for VLT/SINFONI data cubes: application to NGC 5643

Menezes, R. B. & Steiner, J. E. To be submitted to the ApJ in October 2014.
The molecular H2 emission and the stellar kinematics of the nuclear region of the Sombrero Galaxy.

Appendix B:

The Legacy strategy

Our commitment is to deliver the data to the Brazilian Astronomical Community. The idea is to give access to our community not only to the raw data (available after 1 year anyway) but also the reduced and the processed data. For this reason we will deliver two datacubes for each galaxy:

A – One data-cube with all spectra:

- Calibrated in wavelength
- Calibrated in flux
- Corrected for the differential atmospheric refraction (DAR).

B – One additional cube will be available to the community with the additional data processing:

- Fingerprint removed
- High frequency spatial noise remove with Butterworth filter
- Richardson-Lucy deconvolution

The data will be located in the projects' site ("DIVING3D" in CLOUD-USP) and can be accessed by any Brazilian scientist or student with a password provided under request. The password must be strictly personal and the data cannot be transferred to non Brazilian astronomers.

We plan to deliver 4 data releases, after observations, preliminary analysis and quality control of the first 25%, 50%, 75% and 100% of the data acquired. The first data release will be made by March, 1, 2015.

The sample definition and subsample observing strategy

We are adopting the following strategy of defining subsamples of galaxies:

Subsample	Number of galaxies	Observed	Proposed for 2014B	Proposed for 2015A
Massive galaxies – σ>200 km/s	35	35	0	0
Late type galaxies (Sbc – Sd) with B <11.2	27	13	11	3
Bright galaxies (B < 11.2)	57	30	15	7
ETG (E+S0) with σ<200 km/s and B≥11.2	23	1	0	3
Remaining galaxies	71	0	0	6

Appendix C: The original proposal

Abstract

Galactic nuclei are special regions of galaxies, hosting supermassive black holes and stellar populations that record important aspects of the history of the galaxy formation and evolution. In this proposal we aim to perform a survey of nuclei of a complete sample with deep 3D spectroscopy, with a combination of unprecedented spatial resolution and signal-to noise.

We expect to achieve 4 scientific goals: a-***Nuclear emission line properties.*** Detect and study the statistical, geometric and physical properties of Low Luminosity AGN: "dwarf" Seyferts and LINERs as well as starburst nuclei. We propose to carry out the deepest demographic study of supermassive black holes and their local environment yet performed. b-***Circum-nuclear emission line properties.*** Determine the nature and ionization mechanism as well as the kinematics of the line emitting gas in the ~100 pc scale circum-nuclear region. c-***Stellar kinematical properties*** of all nuclei. Mass-to-light ratios will be derived on dynamical basis and compared to those of spectral synthesis and stellar velocity dispersion in order to study the importance of dark matter and the IMF. d-***Stellar populations archeology.*** Study the chemical composition and history of star formation using state-of the-art methods and stellar population models.

The Science Case

Galaxies have been known as entities containing hundreds of billions of stars - islands in the universe - for about 90 years. Their nuclei certainly preserve important information about their origin and evolution. For these reasons it is important to study them, both at the individual level and on a statistical basis. Besides the stellar emission, many galactic nuclei present emission lines that are not originated by stars. They are frequently called Active Galactic Nuclei (AGNs). The luminosity function of AGN is such that they can be studied at large distances. Curiously the most abundant objects are of low luminosity (LLAGN) and not so well studied although abundantly populating the galaxies in the local universe. The LLAGN (as all AGNs) can be classified as type 1 (with broad permitted emission lines) or type 2, without broad emission lines. The presence of a broad component is considered a conclusive proof that the object contains a supermassive black hole.

Most of the massive galaxies host an active nucleus [1], the majority of them presenting low ionization emission lines and hence classified as LINERs (Low Ionization Nuclear Emission Regions [2]). The nuclear emission in LINERs has been proposed to be similar to that of Seyfert galaxies, but in an environment with lower ionization parameter [3, 4]; this idea was confirmed by the discovery of broad Hα emission in a significant fraction of the LINERs as well as the detection of optical non-thermal continuum, high ionization forbidden lines and in X-Rays. Such characteristics are usually associated with a black hole. But it was also found that this low ionization emission can be quite extended in early type galaxies [5], far beyond the ionization produced by a low luminosity central source. The source of this ionization was proposed to be a population of post-AGB stars [6]. In the last two decades significant evidence of nuclear activity has been detected in LINER galaxies [1] but also the evidence of extended post-AGB ionized emission has grown [7-10]. Approximately two thirds of E-Sb galaxies exhibit local weak nuclear activity incompatible with normal stellar processes; in contrast, only about 15% of the Sc-Sm galaxies are known to have AGN activity [1]. Late type galaxies are generally of low mass, gas rich, with strong star formation, bulgeless or associated with pseudo-bulges. These galaxies are frequently characterized as having a central cluster [11, 12]. The nature of these clusters is still poorly understood and they are even considered as failed black holes [13]. It is now well accepted that AGN, Seyfert galaxies as well as most LINERs, are associated with supermassive black holes (BH), with masses ranging from 10^6 -10^10 M☼. It is also well established that there is a strong correlation between BH mass and host galaxy properties [14-16], which has generated great interest in studying the connections between BH growth and galaxy formation/evolution. As a direct manifestation of accretion and growth, BHs have been considered as essential components of structure formation [17-19]. An effective way of studying galaxies and their nuclei is by performing surveys of large samples. With such surveys, new and interesting objects have been found and, if the samples are selected by rigorous criteria, statistical properties can be derived. In this proposal we aim to study a complete sample of galaxies in the southern hemisphere with high (unprecedented) spatial resolution and high signal/noise.

Previous surveys of galaxies and their nuclei in the local universe have been done in the past and that are relevant to the present proposal. PALOMAR: The most popular survey of galactic nuclei[1, 20]. This work has generated a significant number of papers (see [1, 35] for recent reviews) with a large number of citations. This survey is based on single spectra taken with a 2”x4” slit on the Palomar 5 m telescope taken for every galaxy brighter than B=12.5 in the Revised Shapley-Ames Catalog of Bright Galaxies. A total of 486 galaxies satisfy this criterion in the northern hemisphere (delta>0). Important and influential as it was (and still is), the Palomar Survey offers no information on the spatial distribution of the light emitting/absorbing sources. That requires Integral Field Units (IFUs). With the coming of age of IFUs, survey studies are bringing additional capabilities of better studying not only the nucleus itself but also its environment. Some relevant IFU-based surveys are: SAURON – A sample of 327 galaxies were observed with the 4.2 m Herschel telescope [21]. In the low resolution mode the pixel size was 0.94”x0.94” with a spectral resolution of 3.6 A. The spectral coverage did not include the Hα+[N II] as well as the [O I] and [SII] lines, very important to study the AGN. The sample included galaxies with Mb<-18 and $-6^\circ<\delta<64^\circ$. ATLAS 3D - This survey [22] is an extension of SAURON, but for early type galaxies only. It, again, does not include the spectral coverage of important emission lines. CALIFA - This survey uses the 3.5 m telescope of Calar Alto to observe ~600 galaxies [23]. The main goal is to observe the whole galaxy in the FOV. For this reason the spatial resolution was degraded to ~3” and is not optimized to study the nucleus. Other surveys such as MANGA and SAMI are being planned with IFUs to observe large samples at higher redshifts *a la* Sloan Survey.

The GSGN will obviously benefit from both the scientific insight and the analysis tools developed for these previous and ongoing IFU surveys. Yet, it will explore a spatial scale **not resolved** by these surveys. While CALIFA (as SAURON and ATLAS 3D) reveals the spatial arrangement of phenomena which are all mixed up in Palomar and SDSS data, GSGN will map physics which is blurred in the data cubes of those surveys. For instance, the GSGN FoV spans just ~ a couple of spatial resolution elements of CALIFA! GSGN will thus map physical processes in the nuclear and circum-nuclear scales (100 pc) to a degree of detail (**20** pc resolution) which is completely **out of reach of other surveys**. No other IFU survey is aiming at this sweet spot region of galaxies, where high stellar and gaseous densities, high metallicities, presence of (active or dormant) supermassive black holes and other extreme conditions drive a variety phenomena seen nowhere else in galaxies: scattering cones, obscuring torus, the NLR, BLR, inflows and outflows, nuclear clusters, inner gaseous and stellar disks, etc.

The exquisite spatial resolution of GSGN will allow us to investigate the connection between AGN and its surrounding stellar population to an unprecedented level of spatial detail, shedding new light on long standing puzzles. For instance, while type 2 Seyferts show a clear tendency to host recent star-formation [38-41], it is unclear whether this also happens in type 1 Seyferts. The unadorned unified model implies that type 1s should also exhibit such young stars, but it may also be that, over time, the mechanical and radiative action of star formation and the AGN dissipates the obscuring torus, clearing the view towards the nucleus and making a type 2 evolve to a type 1. Studying this issue requires disentangling the different spectral components, which is best achieved through IFU of the inner ~ 100 pc.

The statistics of LLAGN is limited by the sensitivity of the detection techniques. We believe that, with the techniques developed by our group (30, 32, 36, 37, 50-52; see Figs 1 and 2), we are able to detect AGN at significant lower luminosity limits than the current level of detection such as in the Palomar Survey. We base this belief on two facts: We are concluding a mini-survey of massive galactic nuclei, comprising an unbiased sample of 36 southern galaxies. Our preliminary statistics indicate that we found two times more objects with broad Hα then anticipated from the Palomar survey. This is probably due to the fact that we have much better spatial resolution. A second and perhaps more important argument comes from the Log N x Log S analysis of AGN present in Sc-Sd galaxies. There is a very strong tendency of such objects to appear in the nearest galaxies only. In X-rays a larger proportion than expected has been detected but X-rays are poised by binaries and the statistics are not all that reliable [24]. More reliable is the detection of [Ne V] at 14 and 24 micron (MIR) [25] that suggests that the presence of AGN could be possibly 4 times higher that determined at optical wavelengths.

LINERs also pose interesting questions. If star formation and AGN are indeed interconnected (possibly with a time-delay due to AGN feedback quenching star formation [47], then the fact that LINERs reside among old stars poses a puzzle. Maybe the once young and luminous stars present in an earlier Seyfert phase dim to a level where they can no longer be detected in contrast to the much brighter bulge population, especially when observed through large apertures. Again, the spatial resolution of GSGN, coupled to our sophisticated analysis techniques, will help identifying stellar population variations. Based on SDSS data, it was proposed [9] that LINERs containing true AGN show some residual level of recent star formation in the last Gyr, while those LINERs where stars are all old are not truly AGN, but retired galaxies [7], where the ionizing photon budget is dominated not by an AGN but hot post-AGB stars and white dwarfs. With the much greater sensitivity to AGN signatures of the GSGN will help disentangling true from fake AGN.

Our proposal: The Gemini Survey of Galactic Nuclei (GSGN). We propose a survey of galactic nuclei in the southern hemisphere inspired on the Palomar Survey. This will be, in fact the first such a survey of galaxies in the local universe done in the southern hemisphere. But it is not meant to replicate the Palomar Survey. First it is designed to go much deeper (although for a smaller sample): It will use an 8 m telescope (instead of 5 m) with updated detector technology. More importantly, it will be made with 3D spectroscopy instead of a single slit. It will have a spatial resolution limited by seeing instead of a single spectrum with 4”x2”. In fact this survey will have the highest spatial resolution of any survey of galaxies done or in progress. The scientific goals of our survey are: ***a-Nuclear emission line properties.*** Detect and study the statistical, geometric and physical properties of Low Luminosity AGN (LLAGN): “dwarf” Seyferts and LINERs as well as starburst nuclei. We propose to carry out the deepest demographic study of supermassive black holes and their local environment yet performed. ***b-Circumnuclear emission line properties.*** We expect to determine the nature and ionization mechanism of the line emitting gas in the circum-nuclear region with a ~100 pc scale. We have found that in a few cases one can see the light of the AGN being reflected by the ionization cones [31, 36, 50, 51]. This is an additional demonstration of the existence of a central black hole. It also demonstrates the application of the unified model to LLAGN. These findings were made with the use of PCA tomography [30] and many more such configurations could be found in the survey [31]. Gaseous kinematics may also provide important information about the black hole mass and the geometry of the emitting region [52]. ***c-Stellar kinematical properties***. This will allow to determine the mass of the black hole for the nearest massive galaxies as well as to recover important parameters as the existence of stellar discs and their angular momentum. We will determine the stellar parameters related to kinematics (Gauss-Hermite moments [26]). With those, it is possible to measure the angular momentum related parameter λ_R [28]. This is the parameter that defines, in combination with the eccentricity, slow and fast rotators. We intend to relate λR to other parameters such as galaxy morphology, galaxy stellar luminosity, AGN properties, galaxy environment (groups, clusters etc). For this purpose, we will use the Jeans [29] and the Schwarzschild methods. We will also determine the mass to light (M/L) ratio whenever it is possible and correlate this with other parameters such as velocity dispersion [27] or IMF [28]. ***d-Stellar population archeology.*** Techniques to dissect the fossil record of star formation and chemical histories encoded in galaxy spectra have matured tremendously over the past decade. Both index-based and full spectral fitting methods have been perfected and used to explore the avalanche of data from surveys like the SDSS [32, 41-43], advancing our understanding of the global (spatially integrated) SFH of galaxies of different types. Stellar population models also developed significantly over the last years, making possible to estimate the time scale of the star formation history via the measurement of alpha-enhancements in integrated spectra [48, 49]. These stellar archeology techniques recently started to be applied to IFU-based surveys like ATLAS^{3D} and CALIFA [44, 45], producing SFH maps with ~ kpc scale resolution. Elaborated pipelines have been devoted to explore the highly informative manifold resulting from combination of the spatial information with the age/chemical abundances/extinction record [46].

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Experimental Design

The **SAMPLE**: From a Log N-Log S type of argument one can show that the Revised Shapley-Ames Catalog of Bright Galaxies [33] is nearly complete to B=12.4. At B=12.5 the degree of incompleteness starts to be significant. It is also clear that the sample is complete to $|b|>15^\circ$. For the sample to be feasible in the LLP program we have chosen all galaxies with B<12.0, $\delta<0^\circ$ and $|b|>15^\circ$. This sample has a total of 181 galaxies. From them, 11 are Sm/Im in which one cannot identify a nucleus in the 2MASS images. The total number of our sample is therefore 170 galaxies. A sub-sample of 36 massive galaxies (σ>200 km/s) have already been allocated time in 2013. In addition, 7 galaxies have already been observed in other programs (NGC 253-300-908-1068-1313-1566-7424). Why a sample limited to B=12.0 and not to any other limit? In surveys like this, the larger the sample, more accurate the conclusions. With the limit of B=12.0 our uncertainties will be of ~7.4%. With a limit of B=12.5 the accuracy would increase to 5.2% but it would cost twice as much telescope time, and would not be feasible within the limits of our LLP program. **The STRATEGY:** The remaining 127 galaxies demand about 135 hours of observations, considering that on average each galaxy needs 1.06 hs of telescope in order to achieve S/N ~10 per fiber. We propose to complete the GSGN survey in 8 semesters, requiring about 17 hours per semester (see Table 1 and technical description). We will use a strategy of prioritizing 5 sub-samples of galaxies: a- The massive galaxy (MG), with σ>200 km/s. This comprises a total of 36 galaxies. b- Early type (ETG) – galaxies of morphologies E+S0. c- All LTG (late type galaxies) with B<11.5. We will call this the Sc sub-sample. d -All LTG to B=12.0. e - All other galaxies.

The GSGN is LEGACY project. As in the standard Gemini procedure, all data will be available to international access as soon as the proprietary period is over. More than that, we will offer all our reduced and processed data cubes to the Brazilian community, by request, 6 months after each of the subsample processing has been completed. For each galaxy the fully reduced and processed data cube will be available. This means that we will have 170 data cubes with 4800 spectra each. The total of 700 thousand fully processed spectra will be made available to the Brazilian community. The GSGN team comprises experts in all areas related to this field, from stellar libraries and evolutionary tracks (major ingredients in the analysis of stellar populations) to spectral fitting, emission lines, sophisticated data reduction and analysis tools, as well as the organization and distribution of data and value added products in public databases. After the reduction, a data treatment will be applied with the following routines, all developed and validated by our group [36]: DAR correction; Butterworth filtering of spatial and spectral high frequency noises; removal of instrumental fingerprints; R-L deconvolution. The data will be analyzed with the following techniques: PCA Tomography [30, 31]; determination of the stellar Gauss-Hermite moments with the pPXF procedure [26]; stellar spectral synthesis [32] and archeology; analysis of the residual emission lines, after the stellar continuum subtraction with traditional diagnostic diagrams [19]. In addition we will also test a new method to detect AGN, associated with high and low density clouds [37].

The proponent´s responsibilities: **Joao Steiner** (coordination); **Roberto Cid Fernandes** (Methods of spectral synthesis; stellar archeology); **Paula Coelho** (study and definition of stellar template basis; stellar archeology); **Natalia Vale Asari** (analysis of objects with faint emission lines/retired galaxies; dust diagnostics; emission line modeling); **Roberto B. Menezes, Tiago V. Ricci and Daniel May** (Interaction with the Gemini Observatory; data reduction; data processing: DAR correction, fingerprint removal, Butterworth filtering, deconvolution, PCA Tomography; starlight spectral synthesis; emission line analysis); analysis and modeling of stellar kinematics; **André Luiz de Amorim** (Database; analysis tools).

Please note that for 2014A we are submitting two related projects, with a total of 17 hs (Table 1). The accompanying project of Sc galaxies (Menezes et al) is being re-submitted as it has already been initiated. Even if our LLP project is not approved, it makes sense to be continued.

Technical justification

All of the observations will be performed with the GMOS-IFU in the single slit mode. The early-type galaxies will be observed using the B600 grating, in a central wavelength of 5620 Å. Such configuration provides a spectral coverage from 4250 Å to 7000 Å and a spectral resolution of 3.3 Å at 5620 Å. We require this spectral coverage in order to detect emission lines like Hβ, [O III] λ4959; 5007, [O I] λ6300, [N II] λ6548; 6584, Hα and [S II] λ6716; 6731, which are considerably important for our purposes. We propose to obtain three observations, of 10 min integration each, of each one of the early-type galaxies. The late-type galaxies will be observed using the R831 grating, in a central wavelength of 5850 Å. Such configuration provides a spectral coverage from 4800 Å to 6890 Å and a spectral resolution of about 1.3 Å at 5850 Å. We require a higher spectral resolution in the observations of the late-type galaxies because many of them show significantly low values of the stellar velocity dispersions; therefore, a high spectral resolution is required in order to measure this kinematical parameter. We propose to obtain three observations, of 15 min integration each, of each one of the late-type galaxies.

Using the GMOS ITC for our faintest early-type galaxy (NGC 1700), whose source is an elliptical galaxy with 16.71 Bmag/arcsec^2 on the central region. The medium signal to noise is about 26 in this case. On the other hand, using the GMOS Integration Time Calculator for our faintest late type galaxy (NGC 5584), we concluded that it is possible to obtain a median S/N of about 10, except at wavelengths corresponding to the main emission lines, where the S/N is considerably higher. The surface brightness (an input parameter for the ITC) was calculated by taking the flux of the central region of NGC 1042 corresponding to the field of view of the IFU (17.5 square arcsec) as being equal to, approximately, 9% of the total flux of the galaxy. This flux fraction was estimated using an HST image of this galaxy. Our previous experiences revealed that our methods of analysis require a minimum S/N of about 10 in order to provide reliable information.

We propose to obtain an arc lamp observation for each target. Considering, for the early-type galaxies, a 18 min telescope setup time per target plus a 1.5 min exposure corresponding to the observation of the arc lamp image plus 76 s per exposure to cover the readout time, we estimate that, for each early-type galaxy, it is necessary an integration time of 18 min + 3*(10) min + 3*76 s + 1.5 min + 76 s = 54.57 min = 0.91 hr. On the other hand, considering, for the late-type galaxies, a 18 min telescope setup time per target plus a 5 min exposure corresponding to the observation of the arc lamp image plus 76 s per exposure to cover the readout time, we estimate that, for each late-type galaxy, it is necessary an integration time of 18 min + 3*(15) min + 3*76 s + 5 min + 76 s = 73.07 min = 1.22 hr.

Since our sample comprises 62 early-type galaxies and 58 late-type galaxies, we require a total of 62*0.91 hr + 58*1.22 hr = 127.18 hr to complete the program. We require the following observing conditions: Sky Background = 80%, Cloud Cover = 70%, Image Quality = 70% and Water Vapor = Any. Under these conditions, which correspond to 39.2% of all observing nights, no target in the 2014 A semester has a probability of finding guiding stars lower than 33%. Since we do not require specific position angles for the observations, the probabilities of finding guiding stars lower than 100% obtained with the Phase I Tool will probably not represent problems for the observations.

Table 1: The requested time, per semester

	MG	Sc (B<11.5)	GSGN
2013A	*14.1hs*	*2.5 hr*	
2013B	*12.3hs*	*3.9 hs*	
2014A		10.4 hs	6.6 hs
2014B			17 hs
2015A-2017B			17 hs/semester

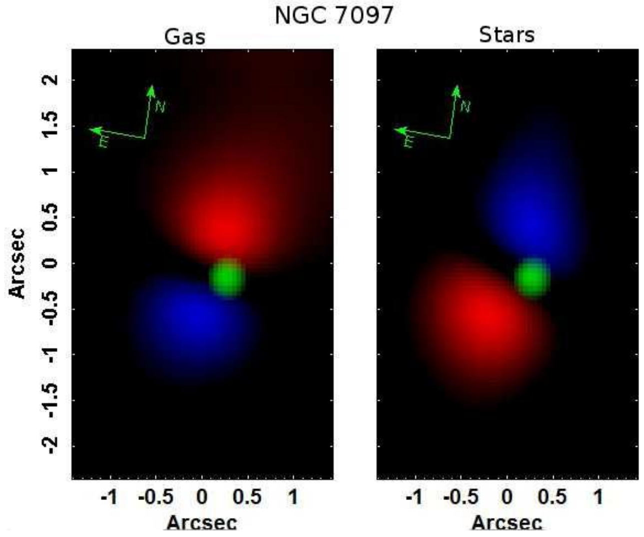

Figure 1 – Tomograms (se [30, 51] for definitions]of NGC 7097 representing the counter rotating gaseous and stellar disks (blue and red) as well as the AGN (green).

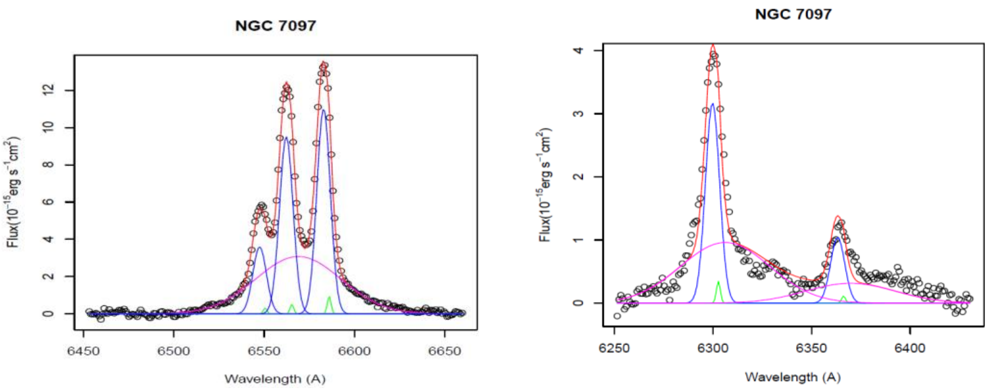

Figure 2. Left: Gaussian decomposition of the Hα */[N II] lines, showing the broad and narrow components. Right: The same for the [O I] lines showing again the broad (surprising!) and narrow components.*