

# The 2015A Report

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## The DIVING<sup>3D</sup> project: Deep IFS View of Nuclei of Galaxies

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### Executive Summary

This is the 2015A report of the LLP: DIVING<sup>3D</sup>- Deep IFS View of Nuclei of Galaxies . We will present the developments made in the period of 2014B.

First it should be noted that this LLP started formally in 2014A, but includes many objects from previous smaller projects. Therefore one should keep in mind that it has an “evolving strategy” of development.

We identified an additional problem in the data processing that did not allow the residuals of the spectral synthesis to have nearly Gaussian noise. After many months of research we found that this was caused by the telluric O2 band near 6200 Angstrom. This is easily corrected and the spectral synthesis, at least in the Halpha region is significantly better.

The ApJ Lett on NGC 3115 was published and 5 papers have been submitted, but only one is related to the LLP. The others are related to projects that were started before the beginning of the LLP, one year ago.

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 four appendices.

### Introduction

The DIVING<sup>3D</sup> 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 that we are using an 8m telescope (Palomar is a 5m telescope).

The study started formally one year ago; however it benefits from previous observations of many objects.

***An additional technical problem: telluric absorption***

We identified an additional problem in the spectral synthesis. The residuals did not appear nearly Gaussian, as expected in a good fitting procedure. After many months of research, we found that this problem was caused by the telluric absorption of O<sub>2</sub> at ~6200 Å. This had not been observed in previous works; we believe that it is detected now because of the larger signal/noise of our spectra (8 meter telescope). All the spectral synthesis will be made again in order to improve the reliability of our synthesis.

***Sub-samples***

Since the last report we have made small changes in the sub-samples definitions, according to the following table, where we show also the number of objects that have already been observed:

<b><i>Sub-sample</i></b>	<b><i>Obs</i></b>	<b><i>Unobs</i></b>	<b><i>Total</i></b>
1 – High-mass ( $\sigma > 200$ km/s) ETGs	32	0	32
2 – Low-mass ( $\sigma < 200$ km/s) ETGs	4	26	30
3 – Early type (Sa-Sb) spiral galaxies	4	32	36
4 – Milky Way twins	8	15	23
5 – Late type (Sc-Sd) spiral galaxies	10	39	49
<b><i>Total</i></b>	<b><i>58</i></b>	<b><i>112</i></b>	<b><i>170</i></b>

***Observational strategy and current (end of 2014B) degree of completion***

These sub-samples will be observed according to the following priority – the degree of completion is also shown:

<b><i>Priority</i></b>	<b><i>Completion</i></b>
1 – High –mass ETGs	100%
2 – Bright ( $B < 11.0$ ) Mini-DIVING <sup>3D</sup>	67%
3 – Low-mass ETGs	13%
4 – Milky Way twins	35%
5 – Early type spirals	11%
6 – Late type spirals	20%

Where the mini-DIVING<sup>3D</sup>: the bright ( $B < 11.0$ ) sub-sample is defined as follows:

43 galaxies with  $B < 11.0$ ,  $\delta < 0^\circ$  and  $|b| > 15^\circ$

<b><i>Sub-sample</i></b>	<b><i>Obs</i></b>	<b><i>Unobs</i></b>	<b><i>Total</i></b>
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1 – High-mass ( $\sigma > 200$ km/s) ETGs	8	0	8
2 – Low-mass ( $\sigma < 200$ km/s) ETGs	3	3	6
3 – Early type (Sa-Sb) spiral galaxies	4	4	8
4 – Milky Way twins	4	1	5
5 – Late type (Sc-Sd) spiral galaxies	10	6	16
<b>Total</b>	<b>29</b>	<b>14</b>	<b>43</b>

### ***Publications since the 2014B report***

Since the 2014B report, one paper was published:

Menezes, R. B., Steiner, J. E. & Ricci, T. V. 2014 Ap J Lett 796, L13  
*An off-centered active galactic nucleus in NGC 3115*

Since 2014B, the following papers were accepted for publication:

Related to DIVING 3D

Ricci, T. V., Steiner, J. E. & Menezes, R. B. Accepted for publication in MNRAS – Paper III  
*IFU spectroscopy of 10 early-type galactic nuclei - III. Properties of the circumnuclear gas emission*

Involving data cubes but not containing data from DIVING 3D galaxies:

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

Menezes, R. B. & Steiner, J. E. ApJ accepted for publication.  
*The molecular H<sub>2</sub> emission and the stellar kinematics of the nuclear region of the Sombrero Galaxy.*

Ricci, T. V.; Steiner, J. E.; Giansante, L. A&A Accepted for publication  
*A hot bubble at the centre of M81*

May, D., Steiner, J. E., Ricci, T.V., Menezes, R.B, & Andrade, I.S. MNRAS, submitted.  
*Digging process in NGC 6951: the inclined molecular disk bumped by the outflow.* (This paper is still in discussion with the referee).

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 coming papers will be increasingly related to the DIVING3D project only.

### ***The sub-samples of DiVING3D: The status***

*The massive ( $\sigma > 200$  km/s) ETG galaxies*

The sub-sample of massive ETGs (Early Type Galaxies) comprises 32 galaxies. The observations have been completed by December 24, 2013. By March 2015, 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.

After identifying and solving a number of problems we have performed a second spectral synthesis and analysis of the gas cubes. The conclusion of the nuclear emission line properties will be published soon. For the stellar archeology, a last spectral synthesis run will be made by Cid Fernandes and Vale Asari.

#### *The low-mass ETGs*

One galaxy is processed: NGC 4546.

#### *The Sa-Sb subsample*

3 galaxies is processed: M104, NGC 1068 and NGC 4699.

#### *The Sbc sub-sample: the Milky Way twins*

Two galaxies have been analyzed: NGC 1566 and NGC 6744. Two papers are being elaborated. A third galaxy is also processed: NGC 1300.

#### *The Sc-Sd galaxy subsample*

The following galaxies have been observed, reduced and processed: NGC 253, NGC 5236, NGC 300, NGC 1313, NGC 3621, NGC 5643 and NGC 7424. Two of the galaxies will be subject of papers soon: NGC 3621 and NGC 1313.

We would like to call the attention to the fact that five of the galaxies scheduled to be observed in the semester 2014B were, actually, not observed: NGC 247, NGC 7793, NGC 2997, NGC 1232 and NGC 7090. We propose that these objects be observed in 2015B in observational time in addition to the 17 standard hours; otherwise the completion o DIVING3D will be delayed.

#### ***Comments to the referee remarks***

##### *Comentários e Sugestões:*

- *A sub-amostra de galáxias massivas (35 em total) já foi observada em 2014A (isso faz parte do report antigo). As observações da amostra de “late type spirals” deveria ser completada com a proposta atual (2015A) com as observações de 3 deste tipo de galáxias.*

As amostras foram ligeiramente re-definidas, sendo que a amostra de galáxias massivas agora compreende 32 ETGs (as 3 espirais massivas fazem parte das sub-amostras das espirais). Infelizmente, 5 das galáxias “late type” que estavam programadas para serem observadas em 2014B, não o foram por razões alheias à nossa vontade. Estamos solicitando o acréscimo dessas galáxias para serem observadas em 2015B.

- *Na avaliação do relatório anterior foram feitas as recomendações abaixo, e comento sobre elas após leitura do relatório:*

*o Recomendação 1- No próximo relatório o grupo deve apresentar uma análise quantitativa (síntese espectral) pelo menos da amostra de galáxias massivas, e uma análise, pelo menos preliminar, da amostra de galáxias Sc. Nota do relator: Esta solicitação foi atendida, embora nova análise deva ser feita pelo grupo após deconvolução por Moffat PSF.*

A síntese espectral foi feita para toda a amostra das ETGs massivas e para algumas das Sab-Sd. Encontramos problemas com relação as galáxias ETGs. O resíduo era muito maior do que o esperado. Após longa pesquisa (mais de um semestre de testes) encontramos o problema: trata-se da absorção da banda telúrica de O<sub>2</sub>, em ~6200 Angstroms. Isto não havia sido notado em trabalhos anteriores; acreditamos que isso tornou-se detectável agora por causa do grande sinal/ ruído das nossas observações (telescópio de 8 metros). De qualquer forma o problema foi detectado e agora iremos **refazer** todas as sínteses espectrais.

- Embora o trabalho tenha uma importante componente na análise dos resultados com a amostra completa, publicação de resultados intermediários é encorajada. Existe a previsão de um artigo sobre a descoberta de um AGN off-centered. Recomendamos fortemente a submissão deste artigo até a preparação do próximo relatório e solicitamos um plano de publicações para este projeto. Nota do relator: Este item foi atendido e artigo foi aceito para publicação.

1 - O artigo mencionado tem a seguinte referência:

Menezes, R. B., Steiner, J. E. & Ricci, T. V. 2014 Ap J Lett 796, L13

*An off-centered active galactic nucleus in NGC 3115*

2 – Estamos atentos para as publicações intermediárias relacionadas a objetos individuais ou a grupos menores de objetos. Neste sentido estamos preparando vários artigos sobre objetos individuais:

2a - Ricci, T. V., Steiner, J. E. & Menezes, R. B.: *IFU spectroscopy of 10 early-type galactic nuclei - IV. Properties of stellar kinematics.*

2b – NGC 1566 (Sab) – Descoberta de região HII a 1" do AGN e quantificação do contínuo não estelar por novo método.

2c – NGC 6744 (Sab): a detecção de um sistema binário de AGNs, separados de 1".

2d – A descoberta de mais um candidato a buraco negro for a do centro: desta vez a 2", sendo um candidato muito promissor para "Recoiling Black Hole", causado pela emissão de ondas gravitacionais no processo de fusão de dois buracos negros menores.

2e – A descoberta de vários objetos de tipo 1 em galáxias sem emissão previamente detectadas.

2f – NGC 1313 – A descoberta de uma estrela tipo Eta Carinae a 1" do núcleo.

Vários outros objetos estão programados para serem assunto de papers a serem escritos. No entanto não teremos condições de encaminhar tudo isso em apenas um semestre.

- Na Figura 1, chamou a atenção dos membros do comitê o offset em comprimento de onda entre os espectros de Gemini e SOAR para NGC1052.

A figura está errada e pedimos desculpas pelo descuido.

- Alertamos à equipe que dados para os seguintes alvos existem no arquivo GSA; mesmo que a configuração instrumental seja diferente, poderia ser proveitoso integrar eles na análise da equipe:

o NGC 5102

o NGC 5068

Estamos atentos para essas observações bem como de outros objetos. No caso de NGC 5102, os dados não cobrem a região de grande interesse em Halfa. No caso de NGC 5068, as observações foram feitas com o GMOS, porém não no modo IFU. Sempre que possível iremos também analisar dados públicos de objetos de interesse, cobrindo não apenas o óptico.

- O formato do relatório encaminhado pelo grupo está bom e deve ser mantido. O comitê gostaria que os próximos relatórios incluam uma descrição do papel de cada um dos Co-Is. Em particular, gostaríamos que a equipe identifique se alguns aspectos do programa representam o trabalho de tese dos alunos envolvidos.

Os co-Is tem as seguintes funções:

1. Roberto Menezes: redução, processamento e análise dos objetos que constam do projeto de pós-doutorado dele (amostra de ETGs e Sc-Sc).
2. Tiago Ricci: redução e processamento e análise dos objetos que constam do projeto de pós-doutorado dele (amostra completa de ETGs massivas).

3. Roberto Cid Fernandes e Natália do Vale: Nova síntese espectral e responsabilidade pelas publicações relacionadas à arqueologia estelar.
4. Paula Coelho: análise dos dados e modelos espectrais referentes a alfa-enhancement.

Quanto a trabalhos de dissertações e teses, estamos com os seguintes alunos:

1. Inaiara Andrade, doutorado (IAG/USP; orientador Joao Steiner): Estudo da região central de galáxias S0 ativas e inativas.
2. Patrícia Silva, mestrado (IAG/USP; orientador Joao Steiner): Estudo dos núcleos de galáxias gêmeas da Via Láctea.
3. Maiara S. Carvalho, doutorado (UFSC; orientador Cid Fernandes) – Arqueologia estelar da mini-amostra estatisticamente completa de galáxias com  $B < 11.0$  do hemisfério sul.

## **Appendix A. Relevant publications**

### ***A1 - Publications by our group involving objects from the DIVING<sup>3D</sup> 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*

Ricci, T. V.; Steiner, J. E.; Menezes, R. B. 2015 MNRAS 447, 1504  
*Erratum: 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 796, L13  
*An off-centered active galactic nucleus in NGC 3115*

### ***A2 - 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 H $\alpha$  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*

Ricci, T. V.; Steiner, J. E.; Giansante, L. 2015 accepted for publication in A&A  
*A hot bubble at the centre of M81*

### ***A3 - Other publications based on IFU data cubes (not related to the DIVING<sup>3D</sup> 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., accepted for publication in MNRAS

*A treatment procedure for VLT/SINFONI data cubes: application to NGC 5643*

Menezes, R. B. & Steiner, J. E. accepted for publication in ApJ.

*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).
- Fingerprint removed
- High frequency spatial noise remove with Butterworth filter

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

- 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 6 data releases, after observations, reduction, data processing and preliminary analysis and quality control of the each of the following samples:

<b><i>Priority</i></b>	<b><i>Completion (Feb 2015)</i></b>
1 – High –mass ETGs	100%
2 – Bright ( $B < 11.0$ ) Mini-DIVING <sup>3D</sup>	67%
3 – Low-mass ETGs	13%
4 – Milky Way twins	35%
5 – Early type spirals	11%
6 – Late type spirals	20%

The first sample has been completed in terms of observations, data reduction and processing. The data release was initially promised be made by March, 1, 2015. However, given the many technical problems we encountered, the scientific output was delayed. We therefore ask the NTAC to authorized the release by October 2015, before the Advanced School on Astrophysics (to be held in November, 2015) on the theme “Integral field spectroscopy and spectral synthesis”. This was theme was motivated by the two LLPs approved by the Brazilian NTAC. The data of the first release (a complete sample of massive ETGs) are already in the site and can be accessed, under request, by the NTAC, for inspection:

- 1 - Please access the site [diving3d.iag.usp.br](http://diving3d.iag.usp.br) to see the list with the names of the galaxies.
- 2 – Sent an e-mail to [diving3d@iag.usp.br](mailto:diving3d@iag.usp.br) and specify the requested archives. Note that for each galaxy there are two datacubes: one with and one without deconvolution.
- 3 – The requested archives will be placed in the site, available to the user under a login and password provided by the administrator.

### ***Appendix C: the galaxies of each subsample and their status***

#### **1 - The sub-sample of high-mass ( $\sigma > 200$ km/s) ETGs**

*1a - Sub-sample definition and basic properties – 32 objects*

<i>Name</i>	<i>Sem./ Red.</i>	<i>Type NED</i>	<i>B mag</i>	<i>d Mpc</i>	<i>gr/clust</i>	<i>AddObs</i>
<b><i>Ellipticals</i></b>						
NGC 1549	13B/R	E0-1	10.76	16	Dor gr	
NGC 1399	08B/T	cD	10.79	18	Forn cl	SINFONI; ACS/WFPC2
NGC 3923	13A/T	E4-5	10.91	21		ACS
NGC 1407	13B/R	E0	10.93	23	Erid cl	ACS
NGC 3585	13A/T	E6	10.93	18		ACS/WFPC2
IC 1459	08B/T	E3-4	10.96	27		WFPC2
NGC 1404	08B/T	E1	11.04	19	Forn cl	ACS/WFPC2
NGC 720	13B/T	E5	11.15	24		
NGC 1395	13B/R	E2	11.18	21		
NGC 584	13B/T	E4	11.2	20		WFPC2
NGC 7507	13B/T	E0	11.43	22		
NGC 3557	13A/T	E3	11.46	37		WFPC2
NGC 1052	13B/T	E4	11.53	19		NIFS; ACS/WFPC2
IC 4296	13A/T	E	11.58	51	Gr(30)	ACS/WFPC2
NGC 4696	13A/T	cD	11.59	38	Cen cl	ACS/WFPC2
NGC 3962	13A/T	E1	11.66	31		
NGC 5018	13A/T	E3?	11.71	38		WFPC2
NGC 2974	13A/T	E4	11.78	25		WFPC2
NGC 6868	13A/T	E2	11.83	32		
NGC 4105	13A/T	E3	11.88	28		
NGC 5044	13A/T	E0	11.92	35		WFPC2
NGC 3904	13A/T	E2-3?	11.95	25		
NGC 1700	13B/T	E4	11.96	41		WFPC2
<b><i>S0s</i></b>						
NGC 1316	13B/R	SAB0 <sup>0</sup> (s)	9.6 E4?	20	Forn A	SINFONI; ACS/WFPC2
NGC 3115	13A/R	S0 <sup>^</sup> -	9.98	10.2		ACS/WFPC2
NGC 1380	08B/T	SA0	11.1	19	Forn cl	ACS/WFPC2
NGC 1574	13B/T	SA0 <sup>^</sup> -(s)?	11.19	19	Dor gr	WFPC2
NGC 2784	13A/T	SA0 <sup>0</sup> (s)?	11.21	8.5		WFPC2
NGC 1332	13B/T	S0 <sup>^</sup> -?(s)	11.24	20	Erid cl	SINFONI; WFPC2
NGC 5101	13A/T	(R)SB0/a(rs)	11.58	27		
NGC 2217	13B/T	(R)SB0+(rs)	11.59	19		
NGC 7049	13A/T	SA0 <sup>0</sup> (s)	11.64	28		ACS

## 2 - The sub-sample of low-mass ( $\sigma < 200$ km/s) ETGs

### 2a - Sub-sample definition and basic properties – 30 objects

Name	Sem/ Red	Type NED	B mag	d Mpc	group/clust
<i>Ellipticals</i>					
NGC 4697	14A/R/ok	E6	10.11	12.3	
NGC 1344		E5	11.28	18.7	Erid cl
NGC 5061		E0	11.35	25.6	15A
NGC 7144		E0	11.79	25.5	
NGC 0596		cD pec?	11.88	21.5	
NGC 1427		cD	11.94	19.4	Erid cl
IC 5328		E4	11.95	34.7	
<i>S0s</i>					
NGC 5128	/R	S0 pec	7.89	3.7	Cen A 15A SINFONI
NGC 1291	14B/I/ok	(R)SB0/a(s)	9.42	8.6	
NGC 1553	14B/R/ok	SA0 <sup>0</sup> (r)	10.42	15.1	Dor gr
NGC 5102	/R	SA0 <sup>+</sup> -	10.64	18.8	15A SINFONI?
NGC 4753	/I	I0	10.85	16.9	15A
NGC 0936	/R	SB0 <sup>+</sup> +(rs)	11.19	20.7	
NGC 4546	08A/T	SB0 <sup>+</sup> -(s)?	11.3	18.1	WFPC2
NGC 1326	/I	(R)SB0 <sup>+</sup> +(r)	11.34	17.0	
NGC 6684	/I	(R')SB0 <sup>0</sup> (s)	11.34	12.4	15A
NGC 1302		(R)SB0/a(r)	11.38	20	
IC 5267		SA0/a(s)	11.39	26.1	15A
NGC 4856		SB0/a(s)	11.4	21.1	15A
NGC 4958		SB0(r)? e-o	11.48	18.5	
NGC 1543		(R)SB0 <sup>0</sup> (s)	11.49	17.2	Dor gr
NGC 1201		SA0 <sup>0</sup> (r)?	11.56	20.4	
NGC 1537		SAB0 <sup>+</sup> - pec?	11.62	18.5	
NGC 1527		SAB0 <sup>+</sup> -(r)?	11.7	16.6	
NGC 1411		SA0 <sup>+</sup> -(r)?	11.7	15.5	
NGC 4691		(R)SB0/a(s) p	11.7	22.5	15A
NGC 1533		SB0 <sup>+</sup> -	11.71	18.4	Dor gr
NGC 4984		(R)SAB0 <sup>+</sup> +(rs)	11.71	21.3	
NGC 1387		SAB0 <sup>+</sup> -(s)	11.83	17.2	Erid cl
NGC 1947		S0 <sup>+</sup> - pec	11.86	16.3	

## 3 - The sub-sample of early spiral galaxies (Sa-Sb)

### 3a - Sub-sample definition and basic properties – 36 objects

Name	Type NED	B(T) mag	d (Mpc) Mpc	
M 104	/R	SA(s)a e-on	9.28	10.4
NGC 1068	/R	(R)SA(rs)b	9.55	13.5
NGC 1097	/Thai	SB(s)b	10.16	20.0
NGC 1365	14B/ok	SB(s)b	10.21	17.9
NGC 4699	13A/T	SAB(rs)b	10.44	24.7
NGC 1398	/	(R')SB(r)a	10.6	21.0
NGC 1433	/	(R')SB(r)ab	10.68	10.0
NGC 1808	/	(R)SAB(s)a	10.7	11.5
				NIFS; ACS/WFPC2
				NIFS; SINFONI
				Forn cl
				Erid cl

NGC 1672	/	SB(s)b	11.03	14.5	Dor gr	
NGC 7213	/Thai	SA(s)a?	11.18	22		15A
NGC 7410	/	SB(s)a	11.3	20.1		15A
NGC 1617	/	SB(s)a	11.37	13.4	Dor gr	
NGC 1512	/	SB(r)a	11.38	12.3		
NGC 1350	/	(R')SB(r)ab	11.4	20.9	Erid cl	
NGC 7552	/	(R')SB(s)ab	11.4	17.1		
NGC 7582	/T	(R')SB(s)ab	11.46	20.6		SINFONI?
NGC 1371	/	SAB(rs)a	11.5	23.2	Erid cl	
NGC 1532	/	SB(s)b pec e-on	11.53	17.0	Forn cl	
NGC 7606	/	SA(s)b	11.55	31.5		
NGC 7727	/	SAB(s)a pec	11.55	23.3		
NGC 1425	/	SA(s)b	11.6	21.3	Forn cl	
NGC 1964	/	SAB(s)b	11.6	21.4		
NGC 0210	/	SAB(s)b	11.65	21.0		
NGC 4593	/	(R)SB(rs)b	11.72	33.9		
NGC 5792	/	SB(rs)b	11.72	24.4		
NGC 0150	/	SB(rs)b?	11.75	21.0		
NGC 7496	/	SB(s)b	11.78	15.0		
NGC 0986	/	SB(rs)ab	11.8	17.1		
NGC 7723	/	SB(r)b	11.85	27.4		
NGC 0779	/	SAB(r)b	11.86	17.7		
NGC 3223	/	SA(s)b	11.88	33.4		
NGC 4818	/	SAB(rs)ab pec?	11.89	20.0		
NGC 4941	/	(R)SAB(r)ab?	11.9	18.2		
NGC 4995	/	SAB(rs)b	11.9	28.9		
NGC 4902	/	SB(r)b	11.9	39.2		
NGC 6753	/	(R)SA(r)b	11.93			

#### 4 - The sub-sample of Milky Way twins (Sbc)

4a - Sub-sample definition and basic properties – 23 objects

Name	Sem Red	Type NED	B(T) mag	d Mpc	Gr/cl	
NGC 6744	14A/P	SAB(r)bc	9.24	9.5		
NGC 1566	13B/P	SAB(s)bc	10.21	12.2	Dor gr	WFPC2
NGC 613	14B/P	SB(rs)bc	10.75	25.1		
NGC 1792	14B/ok	SA(rs)bc	10.85	13.2		
NGC 134		SAB(s)bc	10.96	18.9		14B Not obs
NGC 157	14B/P	SAB(rs)bc	11.04	19.5		
NGC 4030	14A/ok	SA(s)bc	11.07	24.5		
NGC 5247		SA(s)bc	11.1	22.2		15A
NGC 1300	13B/T	SB(rs)bc	11.1	18.0	Erid cl	ACS/WFPC2
NGC 2442	14A/ok	SB(s)bc pec	11.16	17.1		
NGC 2207		SAB(rs)bc pec	11.35	26.5		WFPC2
NGC 5054		SA(s)bc	11.51	19.8		15A
NGC 4939		SA(s)bc	11.56	39		15A
NGC 7205		SA(s)bc	11.57	19.4		
NGC 1255		SAB(rs)bc	11.6	21.5		
NGC 3887		SB(r)bc	11.6	19.3		
NGC 7314		SAB(rs)bc	11.65	18.5		
NGC 7083		SA(s)bc	11.8	33.3		

NGC 0289	SB(rs)bc	11.81	22.8
NGC 4981	SAB(r)bc	11.83	24.7
NGC 1515	SAB(s)bc	11.93	16.9
NGC 1421	SAB(rs)bc?	11.95	26.4
NGC 5530	SA(rs)bc	11.98	14.

## 5 - The sub-sample of late type galaxies (Sc-Sd)

5a - Sub-sample definition and basic properties- 49 objects

Name	Sem Red	Type Ned	B(T) mag	d Mpc	Gr/cl	
NGC 253	13B/R	SAB(s)c	8.13	3.1		Phoenix; ACS/WFPC2
N5236/M83	14A/R	SAB(s)c	8.51	7.0		ACS/WFPC2
NGC 300	13B/R	SA(s)d	8.7	2.0		ACS/WFPC2
NGC 1313	12B/R	SB(s)d	9.37	3.9		
NGC 247		SAB(s)d	9.51	3.6		14B Not obs NIFS(2008)
NGC 7793		SA(s)d	9.65	4.2		14B Not obs
NGC 3621	14A/R	SA(s)d	10.03	6.8		GNIRS(Mason); ACS/WFPC2
NGC 2997		SAB(rs)c	10.32	10.8		14B Not obs ACS/WFPC2
NGC 1232		SAB(rs)c	10.5	18.7	Erid cl	14B Not obs 15A
NGC 5068		SAB(rs)cd	10.53	6.1		15A WFPC2
NGC 908	14B/ok	SA(s)c	10.87	17.6		
NGC 5643	14A/R	SAB(rs)c	10.89	16.9		WFPC2
NGC 1187	14B/ok	SB(r)c	10.93	18.8		
NGC 2835		SB(rs)c	10.95	10.8		15A
NGC 1559	13B/ok	SB(s)cd	10.97	15.7		WFPC2
NGC 7424	13A/R	SAB(rs)cd	10.99	11.5		WFPC2
NGC 7090		SBc? e-on	11.1	8.4		14B Not obs ACS/WFPC2
NGC 1084		SA(s)c	11.25	21.2		
IC 5332		SA(s)d	11.25	8.4		15A WFPC2
NGC 1448		SAcd? e-on	11.3	17.4		ACS
NGC 578		SAB(rs)c	11.48	21.8		
NGC 1042		SAB(rs)cd	11.49	9.4		WFPC2
NGC 1637		SAB(rs)c	11.52	10.7		
IC 5201		SB(rs)cd	11.54	14.4		
NGC 4731		SB(s)cd	11.55	19.7		15A
NGC 3511	SA(s)c	11.56	14.3			15A
NGC 1087		SAB(rs)c	11.56	17.5		
NGC 4666		SABc?	11.56	18.2		15A
NGC 7713		SB(r)d?	11.65	10.3		
NGC 1385		SB(s)cd	11.65	14.9	Erid cl	
NGC 3672		SA(s)c	11.66	27.1		
NGC 4487		SAB(rs)cd	11.66	20.0		
NGC 7184		SB(r)c	11.67	33.6		
NGC 4781		SB(rs)d	11.69	16.1		
NGC 1744		SB(s)d	11.7	10.8		
NGC 4775		SA(s)d	11.74	26.6		
NGC 1249		SB(s)cd	11.8	15.8		
NGC 1493		SB(r)cd	11.82	11.3		
NGC 2090		SA(rs)c	11.85	12.8		
NGC 5170		SA(s)c? e-on	11.88	27.3		
NGC 5556		SAB(rs)d	11.88	18.7		
NGC 5334		SB(rs)c?	11.9	32.6		
IC 5273		SB(rs)cd?	11.9	16.6		
NGC 6118		SA(s)cd	11.91	23.4		
NGC 4504		SA(s)cd	11.92	21.8		
NGC 5584		SAB(rs)cd	11.95	26.7		
NGC 685		SAB(r)c	11.97	15.2		
NGC 5161		SA(s)c?	11.98	24.3		
NGC 3513		SB(rs)c	11.99	13.1		

## *Appendix D: 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  $\sim 100$  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 H $\alpha$  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  $10^6$  -  $10^{10}$   $M_{\odot}$ . 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  $2'' \times 4''$  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  $0.94'' \times 0.94''$  with a spectral resolution of 3.6 Å. The spectral coverage did not include the  $H\alpha$ + $[N II]$  as well as the  $[O I]$  and  $[S II]$  lines, very important to study the AGN. The sample included galaxies with  $M_b < -18$  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  $\sim 600$  galaxies [23]. The main goal is to observe the whole galaxy in the FOV. For this reason the spatial resolution was degraded to  $\sim 3''$  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  $\sim$  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  $\sim 100$  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  $H\alpha$  than

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 than 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  $\lambda R$  [28]. This is the parameter that defines, in combination with the eccentricity, slow and fast rotators. We intend to relate  $\lambda R$  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<sup>3D</sup> and CALIFA [44, 45], producing SFH maps with  $\sim$  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 ( $\sigma>200$  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  $\sim 7.4\%$ . 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  $\sim 10$  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  $\sigma>200$  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 H $\beta$ , [O III]  $\lambda$ 4959; 5007, [O I]  $\lambda$ 6300, [N II]  $\lambda$ 6548; 6584, H $\alpha$  and [S II]  $\lambda$ 6716; 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<sup>2</sup> 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

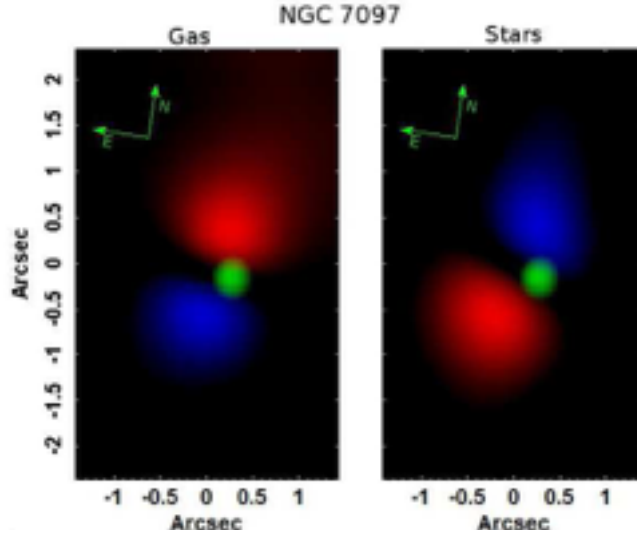


Figure 1 – Tomograms (see [30, 51] for definitions) of NGC 7097 representing the counter rotating gaseous and stellar disks (blue and red) as well as the AGN (green).

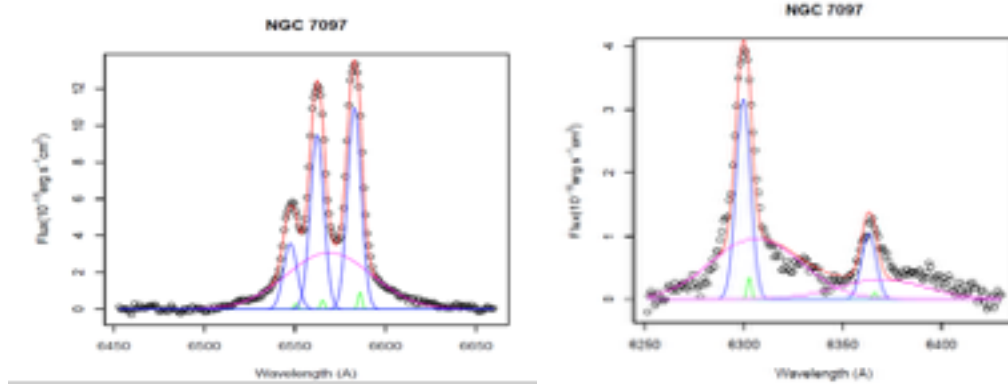


Figure 2. Left: Gaussian decomposition of the  $H\alpha$  /  $[N II]$  lines, showing the broad and narrow components. Right: The same for the  $[O I]$  lines showing again the broad (surprising!) and narrow components.