

## **2nd Report: Brazilian Large Gemini Program LP002**

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### **AGNIFS: NIFS survey of feeding and feedback processes in nearby Active Galaxies**

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#### **Summary of the project:**

We have been awarded 82.5 hours (spread over 6 semesters: 2015A-2017B) to complete NIFS+ALTAIR observations in the J and K bands of the inner few hundred parsecs of a distance limited sample of 26 nearby Seyfert galaxies drawn from the Swift-BAT 60-month catalogue and selected to have 14-195 keV luminosities larger than  $10^{41.5}$  erg/s, redshifts  $z < 0.015$  and being accessible to NIFS ( $-30^\circ < \delta < 73^\circ$ ). Our goal is to map the ionized and hot molecular gas distributions and kinematics, as well as the stellar population and kinematics in order to answer the following questions: (i) How much mass is available for accretion, what mechanisms bring gas to the environs of the SMBH and what are the mass inflow rates? (ii) How do outflows interact with the interstellar medium, what are the mass outflow rates and kinetic power? Can the outflows strip the ISM away from around the BH? (iii) What is the role of star formation in the process? Can we find signatures of recent star formation in the vicinity of the AGN -- a signature of co-evolution of the bulge and SMBH?

#### **Observations already obtained**

In order to complete the observations of the sample of 26 nearby Seyfert galaxies, we need to observe 16 galaxies in the J and K bands plus one galaxy, NGC2110, only in the J band. We have estimated 5 hours exposure per galaxy, thus need 82.5 hours for the completion of the observations. The first semester of observations was 2015A, the last is expected to be 2017B.

#### **2015A: received only 50% of the approved observations**

The project was awarded 20 hours: 15 hours in Band 1 under the project **GN-2015-Q-3** and 5 hours in Band 2 under project **GN-2015A-Q35**. We received only 10 hours of data instead of the awarded 20:

**GN-2015-Q-3:** Only two galaxies were observed (10 hours of the 15 asked):

NGC3516: recently observed in the J and K bands in May and June 2015. The data is already reduced, and the analysis has just begun.

NGC5506 was also observed in the J and K bands in June 2015. The data is already reduced, and the analysis just began.

We were also awarded 5 hs to observe NGC4388 in J and K bands but these observations were not done: we received only 2 frames with exposures of 400s in the K-band, instead of the 10 exposures in each band. These observations are useless and we will need to re-observe this galaxy

**GN-2015-Q-35:** We did not receive any data (0 hours of the 5 asked)

We were awarded 5 hours in Band 2 to observe the galaxy NGC4939 but received no data.

**Summary of semester 2015A: We received only 10hs from the 20hs awarded. We need these observations and will request them in the next observing runs.**

**2015B: not observed yet**

We were awarded 2.5hs to observe the J-band of NGC2110, 10 hours to observe J and K bands of Mrk9 and NGC788, and 2.5hs to observe only the K-band of NGC3081. The observations were not done yet.

**Next semester: 2016A**

We propose to observe, besides three new galaxies (NGC3227, NGC4235, NGC4935), NGC4388, for which we have been awarded time but have not received any data. NGC4935 was supposed to be observed in 2015A (GN-2015-Q-35), thus, we will need more time in the forthcoming semesters to compensate for the observations not done of this one galaxy.

**Current status of the observations**

We are keeping an Excel table with the list of the BAT-AGN sample objects and data obtained so far to control our progress. Below you can find the table with the list of objects to be observed during the LLP. We exclude objects observed previously as part of other proposals (as listed in Table 1 of the original proposal).

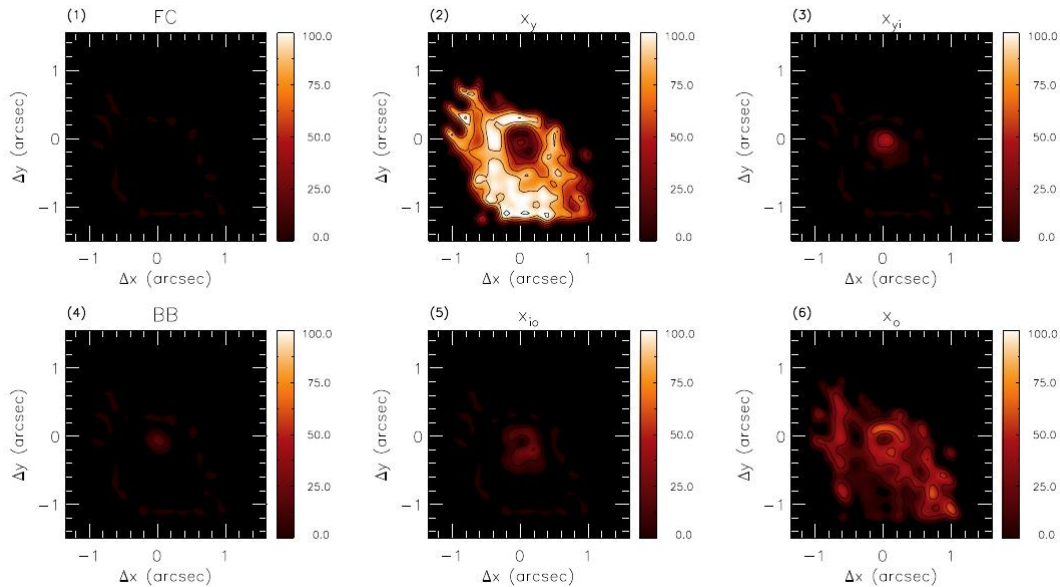
Galaxy	Activity	Semester	Status
NGC788	Sy2	15B	Current semester. Still not observed
NGC1125	Sy2	16B	
NGC1194	Sy1	16B	
NGC2110	Sy2	15B*	J band: Current semester. Still not observed. K-band observed in a previous proposal and published (Diniz+2015)
Mrk9	Sy1	15B	Current semester. Still not observed
NGC2992	Sy2	16B	
NGC3035	Sy1	17B	
NGC3081	Sy2	15B	K band to be obtained in the current semester. Still not observed. <b>J-band still needs to be obtained.</b>
NGC3227	Sy1.5	16A	
NGC3393	Sy2	17A	
NGC3516	Sy1.5	15A	Observed in May and July: Data reduction completed and analysis starting.
NGC3786	Sy1.8	17A	
NGC4235	Sy1	16A	
NGC4388	Sy2	15A	<b>Only 2 K-band exposures were obtained and none in the J-band. Observations are useless and this galaxy needs to be re-observed in both bands. We have asked to observe it in 2016A.</b>
NGC4939	Sy1	16A	<b>Approved for 2015A (GN-2015-Q-35), but no data was obtained. Needs to be re-scheduled. We have asked to be observed in 2016A.</b>
NGC5506	Sy1.9	15A	Observed between May and July: Data reduction complete and analysis starting.
NGC5728	Sy2	17A	

## Work being done and main results:

Dr Rogemar Riffel already reduced the data of the two galaxies observed last semester. As pointed out above, we received data only for half of the galaxies (2 instead of 4) approved for the semester. He has recently finished a paper (see below the list of publications) on NGC5929 that reveals an equatorial outflow (perpendicular to the radio jet) observed in all emission lines, e.g. [FeII], H2 and Pa $\beta$ . He has presented these results also in the IAU Symposium 309.

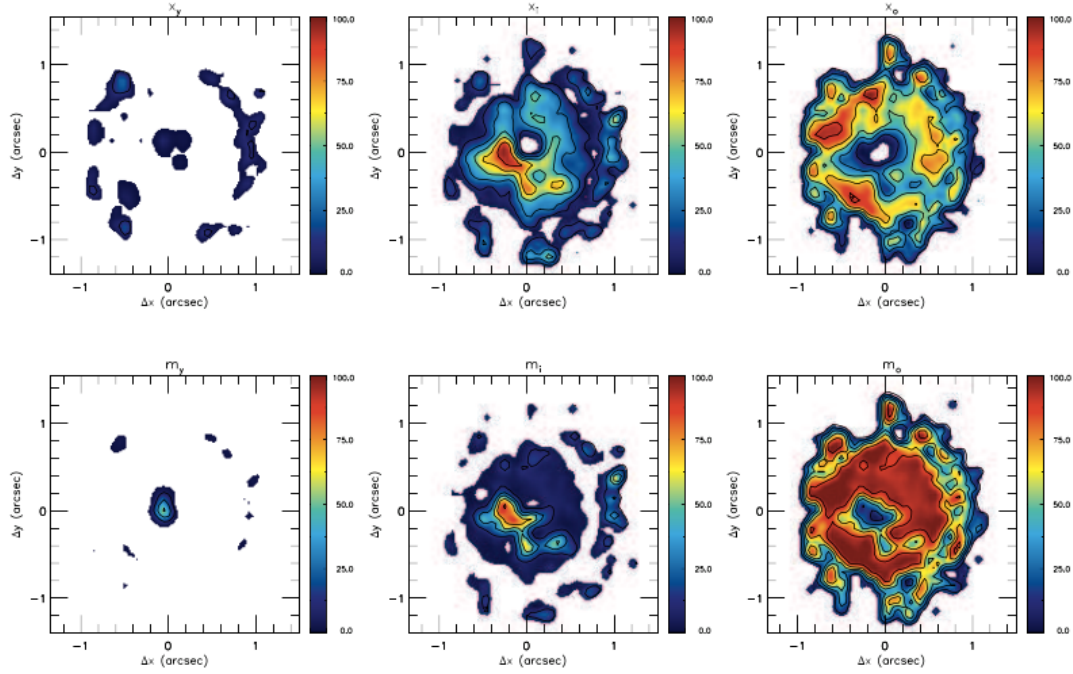
Dr. Rogemar Riffel is advising the student Marlon Diniz who has recently published the results of the observations of the galaxy NGC2110 in the K band (see list of publications bellow). These observations show signatures of molecular gas inflow along nuclear spiral arms plus a compact outflow. Marlon just presented his PhD qualifying exam, in which he presented some preliminary results on the stellar population analysis for some galaxies of our sample. He is also in charge of the stellar population synthesis of the galaxies observed in 2015A.

Preliminary results of on the stellar population of the inner region of NGC5899, showing young stars in the vicinity of the active nucleus are shown in the Figure below:



Dr. Thaisa Storchi Bergmann is advising the student Astor Schönnell João Jr., who is finishing a paper on the analysis of J and K-band observations of the Seyfert 1 galaxy NGC5548. The main results of this study are: (1) the observation of an outflow in Pa $\beta$ , besides rotation in the plane, while the molecular gas is in rotation in the plane. The mass outflow rate is  $\sim 5 M_{\text{sun}}/\text{yr}$ , while the total mass of ionized gas is  $\sim 2 \times 10^6 M_{\text{sun}}$ , but the molecular gas mass

(including cold gas) is estimated to be up to 100 times larger. (2) He has also performed spectral synthesis of the spectra, finding both young and intermediate age stars in the inner 500 pc (see figure below). Astor is also in charge of the analysis of the gas distribution excitation and kinematics of the galaxies observed in 2015A. Dr. Storchi Bergmann has been presenting results for the combined sample so far observed in a number of conferences, the most recent one being the IAU General Assembly meeting, in August 2015.



**Figure 10.** Spatial distributions of the per cent contribution of each SPC to the flux at  $\lambda = 2.12\mu\text{m}$  ( $x_j$ ) and to the mass ( $m_j$ ), where  $j$  represents the age of the SPC: young ( $t \leq 50$  Myr); intermediate ( $50 \text{ Myr} < t \leq 2 \text{ Gyr}$ ) and old ( $2 \text{ Gyr} < t \leq 15 \text{ Gyr}$ ).

A new collaborator to our team is Dr. Luis Colina, who has been visiting under the PVE opportunity of the "Science without Borders" program. He has collected all data we had from previous observations to construct spatially resolved near-infrared diagnostic diagrams, improving the statistics in the definition of the regions occupied by Seyfert, LINER and Starburst activity, as shown in the figure below. A paper (see list of publications) has been recently published with these results.

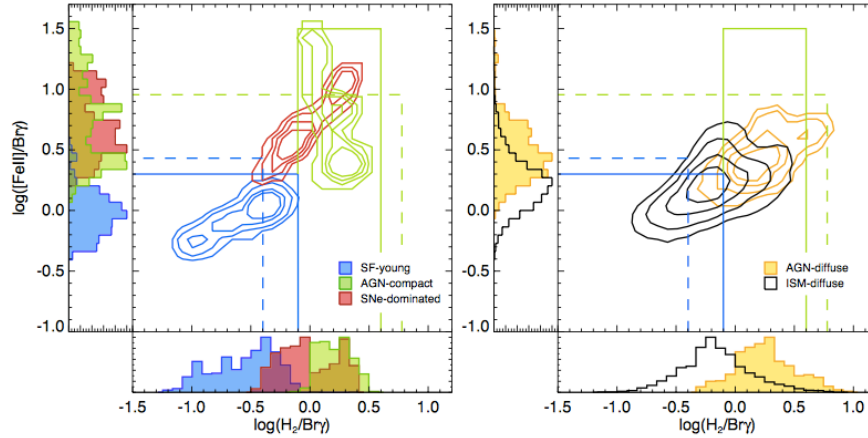
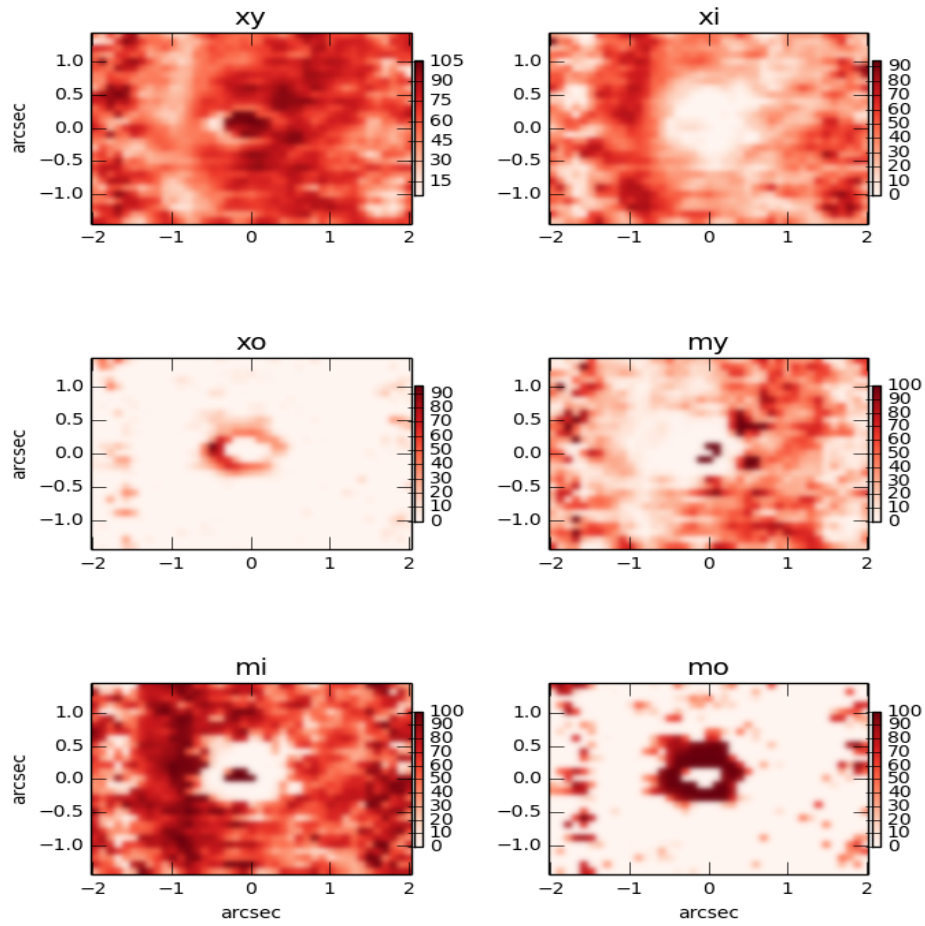


Fig. 5: Distribution of the line ratios in the  $\log(\text{FeII}1.64\mu\text{m}/\text{Br}\gamma) - \log(\text{H}_22.12\mu\text{m}/\text{Br}\gamma)$  plane for the various types of regions identified in the three prototypes (IC4687, NGC 7130, and NGC 5135). Left panel: compact high surface brightness young star-forming clumps (blue), aged, SNe-dominated clumps (red), compact nuclear AGN (green). Right panel: diffuse AGN (yellow), and general diffuse medium (white). The blue and green lines indicate the new upper limits for the young star-forming regions and Seyferts as derived from our spatially resolved two-dimensional spectroscopy on the high surface brightness compact regions. For comparison, the two broken lines represent the upper limits of the line ratios for the starbursts and Seyferts previously identified by Riffel and coworkers (Riffel et al. 2013a) based on 1D spectroscopy. Contours contain 25%, 50%, 75%, and 90% of the points for each class.

Dr. Rogério Riffel is advising the PhD students Natacha Z. Dametto and Luis Gabriel Dahmer Hahn, who just joined the team. Natacha is testing all available optical to Near Infrared Evolutionary Simple Stellar Populations models, using KOSMOS+GNIRS long-slit spectroscopy. These tests are of fundamental importance to interpret our BAT-AGN sample results, since there is a debate in the literature on the possible bias that different models (by including or not the effect of TP-AGB stars) may introduce in the stellar population synthesis results (e.g. excess of young to intermediate age stellar populations or a dominant old population, see for example Riffel et al. 2015, MNRAS, 450,3069). In addition these tests will help us to compare what is expected for the NIR stellar populations with what is observed in the optical, since the same apertures have been used for optical and NIR spectra. The only difference should thus be related with the light of the stars we are probing. These results will help us to better understand/interpret the 3D stellar populations maps derived for the BAT-AGN sample. So far, we got preliminary stellar populations maps for NGC 4303 and NGC 4151 (see figure below), using data obtained in previous runs. The main results for NGC4151 is a dominant young stellar population in the inner region of this galaxy arranged in an approximate ring-like structure (radius  $\sim 150\text{pc}$ ). The presence of such a young component is in agreement with what has been reported in the literature (see Davies et al. 2009, for example). Also non-thermal contributions at the nucleus are clearly detected (hot dust and AGN featureless continuum, not shown in the Figure ).

# SinteseM05NGC4151.dat



## **Recent Publications (2015):**

During the year 2015, we have published the following papers using data from the galaxies of the BAT-AGN sample that have been already observed in previous runs:

Diniz, Marlon R.; Riffel, Rogemar A.; Storchi-Bergmann, Thaisa; Winge, Claudia, 2015, MNRAS, 453, 1727: Feeding versus feedback in AGN from near-infrared IFU observations XI: NGC 2110

Riffel, Rogemar A.; Storchi-Bergmann, Thaisa; Riffel, Rogério 2015, MNRAS, 451, 3587: Feeding versus feedback in active galactic nuclei from near-infrared integral field spectroscopy - X. NGC 5929

Storchi Bergmann, Thaisa, IAU General Assembly, Meeting #29, #2286157: Active Galactic Nuclei in 3D: feeding and feedback processes

Colina, Luis; Piqueras López, Javier; Arribas, Santiago; Riffel, Rogério; Riffel, Rogemar A.; Rodríguez-Ardila, Alberto; Pastoriza, Miriani; Storchi-Bergmann, Thaisa; Alonso-Herrero, Almudena; Sales, Dinalva 2015, A&A, 578, 48: Understanding the two-dimensional ionization structure in luminous infrared galaxies. A near-IR integral field spectroscopy perspective

Riffel, Rogemar A.; Storchi-Bergmann, Thaisa; Riffel, Rogério, 2015, IAU Symp. 309, 339: Near-IR Integral Field Spectroscopy of the central region of NGC 5929

Riffel, R.; Pastoriza, M. G.; Rodríguez-Ardila, A.; Dametto, N. Z.; Ruschel-Dutra, D.; Riffel, R. A.; Storchi-Bergmann, T.; Martins, L. P.; Mason, R.; Ho, L. C., 2015, ASPC, 497, 459: Models Constraints from Observations of Active Galaxies

Alf Drehmer, Daniel; Storchi-Bergmann, Thaisa; Ferrari, Fabricio; Cappellari, Michele; Riffel, Rogemar A. 2015, MNRAS, 450, 128: The benchmark black hole in NGC 4258: dynamical models from high-resolution two-dimensional stellar kinematics