REM:		Prop. #:

CHILEAN NATIONAL TAC

Proposal for observations **Category: Optical/IR+Radio**

Semester 2010-A **Deadline: 19 October 2010** **Submit pdf or ps file to cntac@das.uchile.cl.**

1. Title

Constraining the epoch of the build-up of the red-sequence through IFU spectroscopy of AGN galaxies

2. Abstract

The major aim of the present proposal is to observe bright galaxies in their transition towards the Red Sequence as a result of AGN quenching feedback on to circum-nuclear star forming regions at late and intermediate epoch. The need for energy input from AGN to suppress star formation in early-type galaxies is demanded both by observational evidence and by cosmological simulations of galaxy evolution.

We selected a sample of 10 type-II AGNs and red galaxies at $0.3 < z < 0.5$ from the zCOSMOS survey catalogues, for which optical/nUV photometry is already available. We plan to perform spatially resolved spectroscopy for galaxies hosting a type-II AGN and for red galaxies not showing any significant sign of present activity, in order to track down the epoch at which AGN activity would turn the galaxy red and dead. We aim at estimating SFR in the AGN host galaxy by means of Integral Field Spectroscopy (IFU), mainly from Hα and [OII] λ3727 lines.

3a. Number of requested nights, or hours, on each telescope/radiotelescope (see also #15)

AURA

Blanco	SOAR	1.5m	1.3m	1.0m	0.9m	Prompt	Curtis-Schmidt	WHAM
								N/A

LCO

Baade	Clay	du Pont	Swope
3n			

3b. Instrument(s) requested

IMACS

National Telescopes

Warsaw	Danish	Euler	REM	TAROT	ESO-Schmidt	MiniTAO
	N/A					

Radio

ASTE	NANTEN	QUIET	ACT
N/A	N/A		

4. Principal investigator

Status (A,S,V): A

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5. Co-investigators (names and institutions)

◁ Roberto Muñoz (U. Valparaiso, Chile)
◁ Nicola Napolitano (INAF Naples, Italy)
◁ Giovanni Covone (U. Federico II Naples, Italy)
Andres Meza (U. A. Bello, Chile)
Vincenzo Antonuccio-Delogu (INAF Catania, Italy)
Crescenzo Tortora (ITP Zurich, Switzerland)
Mario Radovich (INAF Naples, Italy)
◁ Maurilio Pannella (NRAO Socorro, NM, USA)
Maurizio Paolillo (U. Federico II Naples, Italy)

6a. Preferred months

first choice: Apr/May second choice: Feb/Mar

6b. Other scheduling constraints (use also box 16)

7. Moonlight constraints

No restriction [X]

Max. # of days from new moon [ ]

8a. Past and future of this project

i) Time already awarded to this project:

ii) Time required to complete this project:

8b. Long-term status request* [ ]

**Refer to the CNTAC policy for long-term programs.*

9. Service observing

Desirable [ ] Impossible [ ]

10a. If this proposal is part of a MSc or PhD thesis project, write here the name of the student, the thesis title, and briefly describe the importance of the requested observations to achieve the goals of the thesis.

10b. Describe how the proposed observations complement data from non-CNTAC facilities. For each of the latter, indicate the nature of the observations (yours or those of others), and describe the importance of the observations proposed here in the context of the entire program.

11a. CNTAC observing time in the last 2 years

Proposal code	Proposal title			
Dates	**Telescope**	**Awarded time**	**Loss (%)**	**Reason(s)**

11b. Brief description of the status of this (these) project(s), including publications based on these observations.

In our previous work we addressed the more general issue of galaxy formation and evolution by means of cosmological and hydrodynamical simulations (see Romeo+ 2006), aiming at modelling in a self-consistent way the chemical enrichment of the inter-galactic medium (IGM) in reply to the stellar feedback (galactic winds). One of the main results was to reproduce the evolution of observable properties such as the colour-magnitude (CM) relation since redshift $z = 2$. In Romeo+ (2008) we found that the building of the Red Sequence (RS) in clusters and groups is mostly driven by the specific star formation rate (SSFR): galaxies move to the RS as they get aged over times and eventually set upon a "dead sequence" once they have stopped their bulk star formation activity.
Recent results from some co-investigators (Muñoz+, in preparation) confirm the occurrence of a clear separation between RS and a blue cloud already at $z = 1$. Fig. 2 shows the colour-magnitude diagram (CMD) in Js and Ks band for the composite sample at that redshift, made up of 15 clusters discovered in the Red-Sequence Cluster Survey (RCS-1), for which deep imaging was followed up with VLT/ISAAC instrument.
A shutdown mechanism could then explain the early $(z > 1)$ buildup of the bright end of the galaxy RS, through the quenching of star formation and the subsequent entry in to the "red and dead" phase, followed by a long lasting passive reddening (see Bell+ 2004, Cattaneo+ 2008). The transition phase towards the dead sequence occurs at an epoch that depends on the environment density, ranging from z =1 to 0.5 (see Romeo+ 2008). This can be a likely result of AGN re-activation, occurring for some massive systems even at $z < 0.2$ (see Tortora+ 2009). Such a mechanism might lead to overcome a drawback common to most known hydrodynamical simulations, where AGN feedback is not properly assumed, that is the outcome of a too blue brightest central galaxy (BCG), as a result of an accelerate late stellar birth-rate.
The link between star formation rate and AGN activity upon the galaxy displacement across the local CMD was already highlighted by other co-investigators (Sorrentino, Radovich & Rifatto, 2006), who had extracted galaxies from the Fourth Data Release (DR4) of the Sloan Digital Sky Survey (SDSS), in the redshift range $0.05 < z < 0.1$ and with $M_R < 19$. Emission-line ratios and/or widths were used to separate AGNs from star-forming galaxies. Fig. 3 (left) shows how the CM bimodality is clearly associated with star-forming activity, while (right panel) the *U-R* colour distribution appears to exhibit also a third peak in corrispondence of AGN active galaxies (the so-called *green valley*), when such a classification is considered.
Recently, some of us (Antonuccio & Silk 2008, Tortora et al. 2009) have studied the impact of relativistic jets fed by an AGN on the quenching of star formation in clouds closer to the galaxy centre. In particular, a strong suppression of possible cooling flows and hence of late star formation at the centre of BCGs has been found to occur during the active phase of AGN jets during their propagation.

11c. Other publications in the course of the past 3 years on the topic of this proposal (including article titles).

Antonuccio-Delogu, V. & Silk, J., 2008, MNRAS 389, 1750 *Active galactic nuclei jet-induced feedback in galaxies - I. Suppression of star formation*

Muñoz R.P., Barrientos L.F., Koester B.P., Gilbank D.G., Gladders M.D. & Yee H.K.C., 2009 in preparation, *The growth of the Red Sequence in clusters since z=1*

Romeo, A.D., Napolitano, N.R., Covone, G., et al., 2008, MNRAS 389, 13 *The evolution of the galaxy red sequence in simulated clusters and groups*

Sorrentino G., Radovich M. & Rifatto A., 2006, A&A 451, 809, *The environment of active galaxies in the SDSS-DR4*

Tortora C., Antonuccio-Delogu V., Kaviraj S., et al., 2009, MNRAS 396, 61 *AGN jet-induced feedback in galaxies - II. Galaxy colours from a multicloud simulation*

12. Description of the programme (1 page of text + up to 2 pages for references, tables and figures.)

A) Scientific rationale Recent studies about the star formation histories in early type galaxies (ETGs) derived from the analysis of spectral line indices and abundance ratios, reveal a strong correlation between the mean stellar ages and galactic stellar masses of ETGs (e.g. Thomas +2005, Nelan +2005, Jimenez +2005). This correlation implies that massive ETGs formed their stellar populations earlier and more rapidly than least massive ones, and it is consistent with the *downsizing* scenario first noted by Cowie et al (1996).
The physical processes responsible for the quenching of star formation in ETGs is still unclear, but may be related to AGN feedback, which has been invoked to provide a correct counterbalance of cooling and non-gravitational heating in the IGM dynamics (see Bower+ 2006, Croton+ 2006). Such feedback arises when energy is transferred from the AGN to the ISM of the host galaxy, heating the residual gas and eventually expelling it out of the spheroid. Daddi+ (2007) inferred that AGN feedback will more efficiently switch star formation off in most massive galaxies hosting a Compton-thick AGN activity.
The currently advocated AGN mechanisms are the quasar mode (Springel+ 2005), occurring during major gas-rich mergers at high z, and the radio mode (Schawinski+ 2009) which occurs at lower z. The former generates galactic outflows resulting in a truncation of star formation on short timescales; in the the latter, instead, a small fraction of the accreted hot gas is injected by the AGN in to the ISM over an extended period, keeping the host galaxy quiescent. In this way, the role of AGN appears to play a primary role all over the host galaxy's life, across different epochs and mechanisms: at $z > 2$ a powerful quasar engine is required to rapidly halt star formation, whereas at low z the residual star formig activity is suppressed by low-luminosity AGNs over a periodic timescale corresponding to an AGN duty-cycle (0.5 Gyrs; e.g. Shabala+ 2008).
Furthermore, the understanding of the nature and timescales of the AGN activity is a crucial information within the galaxy formation theories: the presence of a non-stellar feedback is required in order to prevent galaxies with minor star forming episodes at low z from being driven away from the RS. This holds even more for high mass systems (of the order of BCGs down to $M_V^{BCG} + 2$) remained with large molecular gas reservoir since $z < 0.5$, which has to be destroyed to account for their passive evolution on to the RS.
There is increasing observational evidence for the need of energy input from AGN to suppress star formation in ETGs at late epochs, since star-forming ETGs are found to inhabit the blue cloud of the CMD, while ETGs with AGN activity are located considerably closer to the RS (Schawinski+ 2007).
More recently, Tortora et al. (2009) have shown that most galaxies experience a quenching effect stopping residual star formation in the last Gyr of their history, demonstrating that AGN feedback affects the colours of the host galaxy making it move along the RS. In this framework, nuclear activity may be the effective driver of the final building-up of the RS.

B) Scientific aim The major aim of the present proposal is to investigate the effects on star formation and hence RS building by AGN activity in a sample of galaxies at intermediate redshift. We have chosen our targets from the second data release (DR2) of zCOSMOS survey (Lilly et al. 2007). We selected a sample of 10 type-II AGN and red galaxies with i_{775}-band (F814W) magnitudes brighter than $i_{775} = 20.6$, corresponding to $I = 19.5$, and in the redshift range $0.3 < z < 0.5$. Photometry in the u, r, i_{775} bands is already available for this catalogue. We plan to perform spectroscopy for galaxies which host a type-II AGN and for red galaxies as a non active control sample.
A reliable estimate of the SFR is needed to this purpose: in particular, Integral Field Spectroscopy (IFU) provides a unique tool to map the star forming activity in the AGN host galaxy. The usual emission line ratios (Veilleux & Osterbrock 1987: [NII] λ6583/H_α, [SII] λ6716,6731/H_α, [OIII] λ5007/H_β) will be used to discriminate between thermal and non-thermal ionization. The SFR will then be estimated from the H_α and [OII] λ3727 lines.
In order to single out the effect of AGN feedback on the stellar populations of the host galaxy, we need that the observed spectrum not be dominated by AGN non-thermal emission. IFU spatial resolution will be around 1.2 kpc at $z = 0.4$, sufficient for separating AGN spectrum from that of star forming region out of the galactic core. We have used composite spectra, shown in Fig. 1, to estimate the exposure times for different S/N.
At a median redshift $z \approx 0.4$ the linear scale is $\approx 5.34 kpc/arcsec$ (in ΛCDM cosmology), thus enabling to resolve the central kiloparsec of the targets, when using fibers having a diameter 0.2". In such a way one will be able to reach a resolution equivalent to half R_{eff}, necessary to search for gradients in age or metallicity, which can be evidences of recent ($z < 1$, see Naab+ 2006) dry merging activity.
For these systems MgI B triplet λ5170 Å, Fe lines λ5270, 5335 Å, [OIII] λ5007 Å, Hβ λ4861 Å are spectral features suitable for line strength measurement and galaxy kinematics, to possibly measure their degree of quiescence. In addition, 2D spectroscopy will be used to map the kinematics of the gas in the regions around the AGN, allowing to establish the velocity field. SED fitting will be used to constrain the properties of stellar populations (age, metallicity and stellar mass).
Lick/IDS indeces can be derived from Hβ, MgI B triplet, Fe lines. Line strength can be converted in the standard Lick system (Worthey & Ottaviani 1997) in order to measure their indeces. From the latters, we can also estimate the $\frac{\alpha}{Fe}$ ratio, a further indicator of stellar populations. Moreover, the UV/visible photometry will be exploited to check the results of line-strength measurements and to extend the wavelength baseline covered by spectra.
We will then use our models (Romeo+ 2008, Antonuccio-Delogu & Silk 2008, Tortora+ 2009), to compare with data from the simulations over a wider redshift range. In this way the processes responsible for the evolution of the RS features will be enlightened along with constraining the assembly of the stellar component of massive early type galaxies.

References

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Worthey G. & Ottaviani D.L., 1997, ApJS 111, 377

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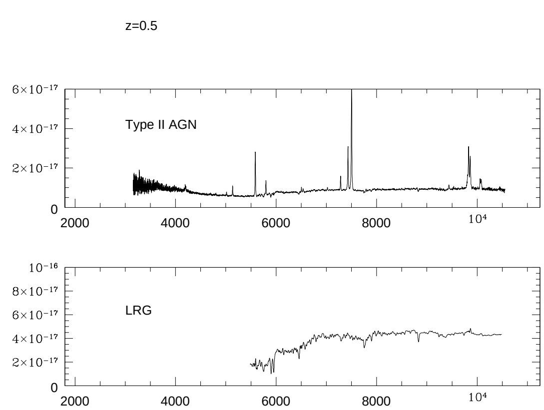


Figure 1: Composite spectrum of a Type-II AGN (Zakamska +, 2003) and of a "Red galaxy" (Eisenstein +, 2001) at z=0.5, in the observer frame.

Figure 2: Background-subtracted CMD for the combined sample of RCS-1 cluster at $z = 1$ (Muñoz et al., in preparation). The best-fit CM was subtracted to leave a RS of zero slope and colour. The upper and lower solid lines show the detected RS and blue cloud, respectively. The vertical dashed lines show the magnitude limits defined by De Lucia et al. (2007). The slanted solid line shows the 90% completeness limit for the deepest cluster image used to build the CMD.

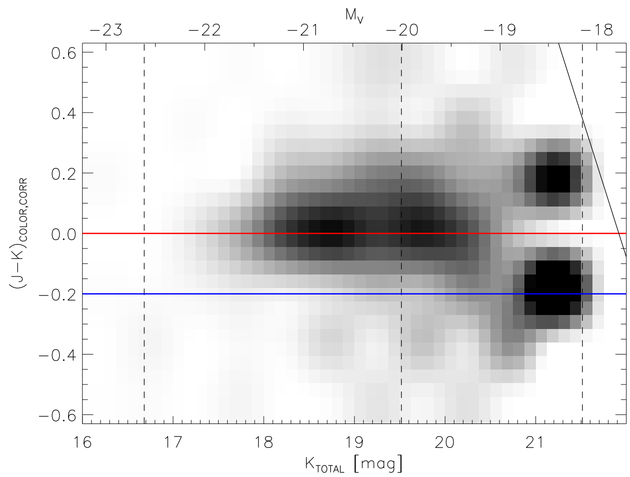
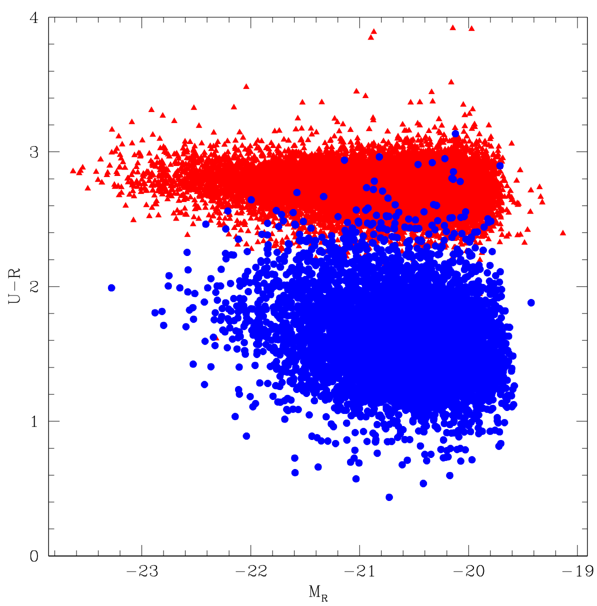
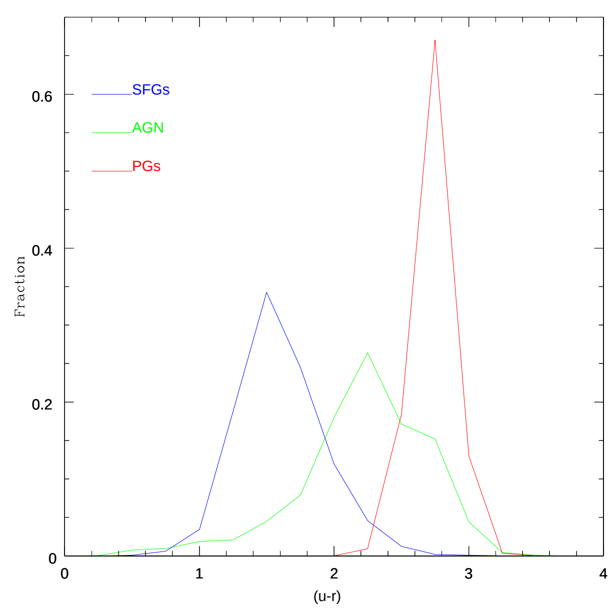


Figure 3: *Left:* *U-R* CMD for galaxies at $z < 0.1$ from SDSS-DR4 survey, separated in passive (red triangles) and star-forming (blue circles): see Sorrentino et al. (2006). *Right:* Colour distribution of star-forming (blue), AGN active (green) and passive (red) galaxies.





13. List of targets (note that the absence of a proper object list and information will weaken your proposal).

Name	α	δ	Epoch	Mag.	Additional Information
zCOSMOS 818578	150.105	1.98114	J2000	i=18.81	AGN II, z=0.3726
zCOSMOS 818170	150.18	2.11033	J2000	i=18.79	AGN II, z=0.3597
zCOSMOS 830695	150.308	2.43006	J2000	i=20.26	AGN II, z=0.3738
zCOSMOS 833842	149.701	2.40258	J2000	i=20.61	AGN II, z=0.3738
zCOSMOS 835771	150.683	2.57462	J2000	i=18.91	AGN II, z=0.3738
zCOSMOS 818848	150.047	2.10814	J2000	i=20.31	z=0.4798
zCOSMOS 813133	149.862	1.89481	J2000	i=18.95	z=0.4445
zCOSMOS 818082	150.198	1.98622	J2000	i=18.76	z=0.4368
zCOSMOS 816998	150.418	2.08515	J2000	i=19.99	z=0.4248
zCOSMOS 806758	149.864	1.77638	J2000	i=19.72	z=0.4266

14. Observational strategy and justification of requested time (please take into account overheads).

We propose to use the IMAC Integral Field Unit in order to be able to separate the spectral signal of the AGN host galaxy from the signal of the central AGN itself. This cannot be reliably accomplished by means of traditional longslit spectroscopy.

We based the estimate for the requested telescope time on our previous experience in similar observations with the VIMOS Integral Field Unit (Covone et al. 2006), and rescaling to the IMACS-IFU efficiency (Schmoll et al. 2004).

We converted our i_{775}-band magnitudes to Cousin I-band magnitude by adopting $I_{AB} - i_{775} = -1.21$, so that our faintest target has surface brightness $\mu_{\rm I} = 19.5$. In order to reach a S/N=10-15 on the continuum per 1 pixel along the dispersion direction in the fibers of the galaxy outer regions and a final S/N>20 after collapsing 3-4 fiber per spatial resolution element (which is suitable for 2D kinematics), we need 6000s per target. With this exposure time we expect much higher S/N in the central fiber where the AGN signatures are expected. This will allow us to perform reliable SED-fitting of the galaxy spectra and to measure accurate star-formation rates from the available emission lines (Hα and [OII]).

We assumed the following typical sky conditions: seeing 1 arcsec, seven days from the new moon, and airmass not lower than 1.3. Therefore, in order to complete the observations of our selected sample of 10 targets, we request a total of 20 hours (including a 20% overheads); this amounts to 3 full nights. Observations of each target will be performed by splitting and dithering the individual exposures.

No strong constraint is posed on the presence of the Moon, as we will observe in the red part of the optical spectrum.

All the magnitudes in this proposal are in the AB magnitude system.

15a. Optical/IR telescopes: requested instrument(s) setup

15b. Radio

Telescope	LST interval	Obs. periods	Total # of hours	Type	Lines	Rec/Spec (bandwidth)

16. Scheduling constraints, special requirements and other remarks

17. Backup program (if proposal needs outstanding weather)