European Organisation for Astronomical Research in the Southern Hemisphere

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

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APPLICATION FOR OBSERVING TIME — PERIOD: **80A**

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted

1. Title — Category: **B–2**

The Chemo-Dynamical Structure of Galaxies

2. Abstract

We propose a multi-object spectrosopic survey of the resolved stellar populations in a range of nearby galaxies out to the distance of Virgo, sampling the entire galaxy, from inner to outer regions. This will allow us to probe the total mass of all galaxies very accuratly and also to accurately determine the chemical evolution history of all components of nearby galaxies (ie., disk, bulge & halo), including a kinematic deconvolution of all these components and a comparison of their detailed properties over a range of galaxy type and environment. We will obtain a more accurate picture of the dark matter properties of a range of different galaxy types, the effects of tidal perturbation and the ubiquity of metallicity distribution functions.

3.

Run	Period	Instrument	Time	Month	Moon	Seeing	Sky Trans.	Obs.Mode
A	79	FORS2	20h	any	d	$\leq 0.4''$	PHO	v
B	79	FORS2	66h	any	d	$\leq 0.4''$	PHO	v

4. Number of nights/hours — Telescope(s) — Amount of time

a) already awarded to this project:

b) still required to complete this project:

5. Special remarks:

6. Principal Investigator: Eline Tolstoy (RUG, NL, etolstoy@astro.rug.nl)

CoI(s): Giuseppina Battaglia (ESO, ESO)

7. Is this proposal linked to a PhD thesis preparation? State role of PhD student in this project

8. Description of the proposed programme

A) Scientific Rationale:

One of the main unsolved questions in astronomy is how galaxies form and evolve. In 1936 Edwin Hubble presented his tuning fork diagram classifying the different types of galaxy to be found in the Universe. This was the first attempt to find a pattern in the properties of different systems and thus search for a common evolutionary link. Elliptical galaxies appear to be shaped predominantly by a single component composed of old stars, while spiral galaxies have several components with a range of stellar ages, gas disks, dust and stellar bars. This 'Hubble tuning fork' diagram survives until today as the standard manner of presenting the morphologies of galaxies, with the addition of small dwarf spheroidal and irregular type galaxies. Fitting all these galaxy types into a common evolutionary scenario still remains to be achieved. According to the most widely accepted current structure formation scenario (the Cold Dark Matter, or CDM paradigm), all galaxies are built up from smaller pieces, the fundamental building blocks of galactic evolution, coalescing through time starting in the early universe (at high red-shift) to form the galaxies we see today. The present day systems we see around therefore provide a unique insight into the galactic assembly process and the chemo-dynamical evolution of the galaxy distribution.

The directly observable components of any galaxy are gas, dust and stars, and there is an intimate link between them. Stars form from gas, and synthesise elements in their interiors and the stars that explode at death disperse these elements into the gas from which dust and subsequent generations of stars are formed. All galaxies are thus the integrated products of all the star formation during their entire lifetimes, and the chemical elements in the stellar populations of different ages provide the most detailed evidence for this past star formation. Because low mass stars can have lifetimes comparable to the age of the Universe, the low mass tail of the ancient star formation that occurred at the formation epoch of a galaxy remains visible today and provides unique clues to the earliest physical process in the Universe. Stars of all ages provide an accurate and detailed probe of changing galaxy properties. By observing large numbers of individual stars we can measure how the rate of star formation and chemical composition of a galaxy has varied from its formation to the present and thus how galaxies were built up over time. To unravel this formative epoch detailed spatial, kinematic and chemical surveys of resolved stellar populations are required; providing a unified picture between local near-field cosmology, predictions from high red-shift surveys and theoretical simulations of galaxy formation and evolution.

Until now the sensitivity and resolution limitations have meant that detailed studies have only been possible within the Local Group and specifically around our own Galaxy. This means that only small dwarf type galaxies have had their ancient stellar populations accurately probed; massive galaxies still await this careful scrutiny. The Local Group contains only two massive galaxies (spiral systems M31 and the Milky Way) and around 40 smaller, mostly dwarf, galaxies. This is hardly representative of the range of galaxy types, and our Local Group is not necessarily representative of the high-density regions of the Universe where most galaxies live. Careful studies of dwarf galaxies have already shown inconsistencies between observations and the standard CDM picture and these need to be extended to larger galaxies to make an accurate comparison with the properties of small galaxies.

To make significant progress we need to study large numbers of resolved stars in a range of galaxy types and this requires us to look beyond the halo of the Milky Way.

B) Immediate Objective:

The Virgo cluster is the real prize for studying Elliptical galaxies. Virgo at an average distance of 17 Mpc, with over 2000 member galaxies of all morphological types, is the nearest large cluster of galaxies. But the main aim of this proposal is to a study a wide range of galaxy types, including spiral galaxies (e.g., NGC253, NGC300, M81) in nearby galaxy groups, such as Sculptor (in the south) or M81 (in the north) both around 2 Mpc distance. We also propose to look in more detail at galaxies in and on the edge of the Local Group, such as M31, M33 and and more distant dwarf irregular galaxies. We also include starburst galaxies NGC1569 and NGC1705 (at 2.2Mpc) and faint low surface brightness galaxies such as DD0154 (at $\sim$ 4 Mpc). This survey would also include the closest Elliptical galaxies (Centaurus A, 3.5Mpc away and NGC3379, 10Mpc) if at all possible and also dwarf elliptical galaxies, such as M32 and the large samples found in nearby galaxy groups (e.g., sample of De Rijcke et al. 2005, A&A, 438, 491).

Thus, the objective of this proposal is to understand the formation and evolution of galaxies in a range of environments using direct measurements of the chemo-dynamical properties of resolved stars as probes of the evolutionary history of these galaxies and their different components as well as their current dynamical state and thus their dark matter masses and distributions.

The most basic requirement is spectra in the CaT spectral region (8500-9000Å) of at least 1000 stars per galaxy at R$\sim$6000. Ideally each separate component of the galaxies (e.g., halo, disk, bulge) should have similarly large sample. It is also desireable to have complementary observations at high resolution (R$\sim$20000) in each system of at least 100 stars per galaxy, or component of the larger systems. This would ideally cover at least the wavelength range from 480-680nm. This would thus mimic the capabilities of the current FLAMES/GIRAFFE instrumental setup on the VLT.

8. Description of the proposed programme (continued)

Elliptical galaxies require the highest spatial resolution and sensitivity. But, as with all galaxies - they have dense central region and a diffuse halo. This gives some degree of flexibility where we can make our spectroscopic selections.
Spiral galaxies are the most easily available targets for this type of study, but they have slightly different technical requirements, as there are quite a few examples closer than Virgo they have slightly lower demands on both sensitivity and spatial resolution. However, partly because they are closer by they are typically larger on the sky (in our sample). They also contain (typically) a sparser stellar density in their outskirts - meaning that spatial resolution can be compromised for increased field of view.

C) Telescope Justification: We need the ELT because of the spatial resolution AND the faintness of the spectroscopic targets. We would ideally like to take spectra over a field of view of around 2 arcmin, or greater. It is unlikely that diffraction limited performace is required, although in the most distant targets, in Virgo, crowding of the targets is likely to be a problem if the PSF is too large.

D) Observing Mode Justification (visitor or service): visitor mode is preferred as we just love to sit in tin boxes and would like to see the Eiffeltower on its side.

E) Strategy for Data Reduction and Analysis: We still need to work out the detailed technical requirements.
Basically need imaging of the targets (with accurate colours and magnitudes), enabling a selection of RGB stars to be made.
NGC4660 - A Virgo Elliptical
This is the most challenging case. At a distance modulus $(m - M)_0 \sim 31.2$. This means that the tip of the RGB is at I∼27.2, K∼25. The central surface brightness of this galaxy is given as I(0)= $\mu_0 = 16$ mag/arcsec^2 (in B, Gavazzi et 2005 A&A 430, 411), with a half-light radius r_e = 8.6arcsec and I(R_e) = 14.7 mag/arcsec^2 in H [H-K = 0.25mag, typically]; r_e = 15.3arcsec and I(R_e) = 19.6 mag/arcsec^2 in B; from Goldmine:
`http://goldmine.mib.infn.it/search-by-name.html`
(Gavazzi et al. 2004 A&A, 417, 499). The major axis of this galaxy is 1.9 arcmin; minor axis 1.24 arcmin. The total extent (∼4 disk scale lengths, 25mag/arcsec^2) is 140 arcsec ($2 \times r_{ext}$). I estimate, at r_e we will have more than 5000 stars per arcsec^2 at the Horizontal branch magnitude (average star to star separation of 15mas), and in the centre, r_0, around 1 million stars per arcsec^2 (average star to star separation of 1mas), also at the Horizontal Branch. This means that the positioning of the field depends strongly upon the achievable resolution, and the depth of the photometry.
There are 2MASS images (in J,H,K), these can be obtained from web (via NED)
There are HST images (ACS), from Andres Jordan (g, z sloan filters).
M83 - the nearest face-on spiral galaxy
At a distance modulus $(m - M)_0 \sim 28.3$. This means that the tip of the RGB is at I∼24.3 K∼22; the HB at I∼28, K∼28; the oldest MSTO at I∼32, K∼32(?).
The surface brightness is variable, depending where observations are made. The major axis of this galaxy is 13 arcmin; minor axis 11 arcmin.
There are 2MASS images (in J,H,K), you can also find them via NED.
There are HST images (ACS + NICMOS, apparently quite deep).

9. Justification of requested observing time and lunar phase

Lunar Phase Justification: We can probably live with grey time, but sensitivity is likely to be an issue, so more distant sources need dark.

Time Justification: (including seeing overhead) Using the ELT- Experimental ETC (Version 2.5WG) assuming that Laser tomography Adaptive Optics is available, 10mas pixels for an average star (e.g., K0) we can obtain spectra of point sources down to a magnitude of I=27 (S/N=10) in approximately 40 hours of integration at R=5000 in dark time, and assuming LTAO (because this gives the shortest exposure time). This means that we can obtain CaT spectroscopy for galaxies out to a distance of Virgo. For M83 this limit will be about 3 hours for stars on the tip of the RGB, although ideally one want to look at stars down to a magnitude or two below TRGB, which leads to integration times of around 20hours. with the currently available ETC numbers. It is a bit difficult to explore too much with the ETC - because I can't play around with the resolution & pixel size too much - so the exposure times are extremely uncertain - there is flexibility in the resolution & pixel scale.
The high resolution observations are likely to be much more expensive in observing time - the ETC gives unrealistically bad predictions from what I can see - as usual in the optical.
I have selected LTAO only because it gives the shortest exposure times. the most photons on the detector is the prefered option.

Calibration Request: Special Calibration - Observations of globular cluster calibrators

10. Report on the use of ESO facilities during the last 2 years

Report on the use of the ESO facilities during the last 2 years (4 observing periods). Describe the status of the data obtained and the scientific output generated.

11. Applicant's publications related to the subject of this application during the last 2 years

12. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	name	RA	DEC	time(hrs)	mag	DM	ang diam(')	note
A	*M83	13 37 00	-29 51 57	10x2hrs	28.9, 28.8	28.3	12	Nearest face on MW-type spiral
B	*NGC3379 (M105)	10 47 50	+12 34 54	5 fields	30.9, 30.8	30.3	5	second closest giant early type galaxy
A	NGC4660	12 44 32	+11 11 26	5 fields	31.8, 31.7	31.2	2	Virgo Elliptical
B	M87 (NGC4486)	12 30 49	+12 23 28	10x2hrs	31.8, 31.7	31.2	11	central elliptical in Virgo
B	M59 (NGC4621)	12 42 02	+11 38 49	5x2hrs	31.8, 31.7	31.2	8	Typical Virgo Giant Elliptical
B	M 32 (NGC221)	00 42 42	+40 51 55	5 fields	29, 28.3	24.5	9	Local Group dwarf elliptical
B	*CenA (NGC5128)	13 25 28	-43 01 08.8	10x2hrs	30.5, 29.8	26	30	Closest giant early type galaxy
B	NGC4486B	12 30 32	+12 29 26	2hrs	31.8, 31.7	31.2	0.5	Virgo compact dwarf elliptical
B	Sombrero (M104)	12 39 59	-11 37 23	5x2hrs	30.3, 30.2	29.7	9	Nearest Sa galaxy
B	*NGC300	00 54 54	-37 41 04	10x2hrs	30.3, 30.1	26.3	22	Sculptor Spiral galaxy
B	M100 (NGC4321)	12 22 55	+15 49 21	5x2hrs	31.6, 31.5	31	8	Virgo Spiral Galaxy
B	*NGC 891	02 22 33	+42 20 57	5x2hrs	30.6, 30.5	30	15	Edge-on Milky Way twin
B	IC5052	20 52 01	-69 11 36	3x2hrs	29.4, 29.3	28.8	6	Edge-on galaxy
B	*M 31	00 42 44	+41 16 09	20x2hrs	28.9, 28.2	24.4	200	Local Group Spiral Galaxy
B	M 33	01 33 51	+30 39 36	10x2hrs	29.1, 28.4	24.6	70	Local Group small spiral galaxy
B	*ngc1569	04 30 49	+64 50 53	?				Nearby BCD galaxy
B	*ngc1705	04 54 13.5	-53 21 40	?				Nearby BCD galaxy
B	ddo154	12 54 05	+27 08 59	?				Nearby LSB/BCD galaxy
B	ngc253	00 47 33	-25 17 18	?				Nearby (Scl) spiral galaxy
B	M81	09 55 33	+69 03 55	?				Nearby spiral galaxy
B	*Sculptor Group	00 23 38	-38 00 01	?				Nearby group of galaxies

Target Notes: The targets in run A and the main ones for this exercise; the targets in run B give a more general impression of the types of (large) galaxy we might like to observe with an ELT with the same requirements as run A.
Number of points per field listed with time, I, K mags listed. Angular diameter is the total size of the entire galaxy not always necessary to observe the entire galaxy.

12b. ESO Archive - Are the data requested by this proposal in the ESO Archive (http://archive.eso.org)? If yes, explain why the need for new data.

13. Scheduling requirements

14. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
79	FORS2	A	IMG	VIJHK
79	FORS2	B	IMG	VIJHK