SCIENCE WITH THE E-ELT IN THE NORTHERN HEMISPHERE

(ABRIDGED*)

A WORKSHOP ORGANIZED BY THE
RED DE INFRAESTRUCTURAS ASTRONOMICAS

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PREPARED BY:

A. HERRERO DAVÓ
S. ARRIBAS MOCOROA
X. BARCONS JAUREGUI
C. MARTINEZ ROGER
J. CEPA NOGUÉ
C. GALLART GALLART
R. REBOLO LÓPEZ

*The unabridged document can be found in
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CONTENTS

Interest of the Spanish Community in the E-ELT

The European Extremely Large Telescope (E-ELT) is a remarkable european project aimed at the construction of what will be the world's largest optical-infrared telescope. The European Organisation for Astronomical Research in the Southern Hemisphere (ESO) is leading the project, on behalf of its 14 member states, including Spain. It is expected that the E-ELT will have a diameter of 42m and its primary mirror will be composed of more than 1000 segments. The combination of its photon collecting power with the expected spatial resolution (diffraction limited in the J-band) will open new prospects for Astronomy, in Europe and all around the world.

This document contains the conclusions of the workshop held in Madrid (April 16-17th, 2009, organized by the Spanish Astronomical Network of Astronomical Infrastructures - RIA) with the topic "Science with the E-ELT in the Northern Hemisphere". Previous documents describing the scientific motivation of ELT include, among others, the report by the Science Working Group (I.M. Hook & M. Franx (eds), 2006), the OPTICON Science Case for the European Extremely Large Telescope (I.M. Hook (ed.), 2005) or the ASTRONET Science Vision document (P.T. de Zeeuw & F.J. Molster (eds), 2007). Links to these and other documents (including the present one in its full version) can be found in the web page of the Red de Infraestructuras Astronómicas:
http://www.riastronomia.es/opencms/opencms/Workshops/R_20090323.html

The workshop was organized in response to the interest of the Spanish astronomical community in the construction of the E-ELT. The Spanish astronomical community was well represented at the workshop by over 60 scientists from virtually all astronomical research centres and University departments in Spain. The community stated enthusiastically and very clearly the strongest scientific interest and support to the construction of the EELT. This was backed by intense scientific discussions around already noted and new science cases for the E-ELT. As a second, independent goal, the Spanish community is interested in promoting the Observatorio del Roque de los Muchachos as a possible and competitive location for the E-ELT.

In order to properly address both of the above issues, the workshop attempted to specify scientific cases that could be carried out preferentially from the Northern Hemisphere as a complement (not competition!) to the cases that can be addressed preferentialy from the Southern Hemisphere. Because of the ESO tradition and long previous work in the Southern Hemisphere, we feel that the science cases considered until now by the ESO community could be biased towards the south. We expect to contribute to balance this bias and show that both hemispheres offer plenty of interesting science cases and previous preparatory work that merit the strong impulse that will represent a telescope like the E-ELT.

The scientific cases presented here are therefore focussed on the Northern Hemisphere, but not in an exclusive way; in fact a good fraction of them are hemisphere uncritical. The sites being currently considered for the E-ELT share an appreciable fraction of the sky and most scientific cases can be equally carried out from both hemispheres (yet your pet object will be located in one of them). While there are unique astronomical targets in both hemispheres, supporting facilities, synergies and preparatory surveys can also be found in both, and first-level Science (the ultimate goal of the E-ELT) can be carried out independently of the final site.

We hope that the cases presented during the workshop and contained in this document will contribute to better define and emphasize the top Science that will be possible with the E-ELT.

Session 1: Stars and Planets

This session included half a dozen presentations that covered exoplanet detection in nearby stars and in the young stellar clusters Hyades and Pleiades, exo-Earth follow-up characterization of transiting planets with emphasis in detection of bio-markers and also studies of low-mass stars in nearby star forming regions. We also discussed E-ELT research on our own Solar System with focus on the largest trans-neptunian objects known as well as studies of nearby stars with proto-planetary disks. While general science cases can be addressed from both hemispheres, the favourable conditions of the Pleiades and Hyades clusters and the selected field of view of the Kepler satellite turn the Northern Hemisphere more suitable for certain topics.

1.1 Exoplanets

At least 7% of solar-type stars host giant planets at separations of less than 5 AU. This discovery has opened a new domain for research. High precision radial velocity measurements of stars and microlensing techniques provide increasing evidence that planets with terrestrial mass and radius may also be abundant (Mayor et al. 2009). The diversity of the properties (orbital distances, eccentricities and projected mass distributions) of known giant exoplanets has already challenged traditional theories of planet formation: do these planets form via gravitational instabilities in protoplanetary disks or via accretion of planetesimals? what are the planetary environments around other stars? how typical is our Solar System? are there other Earths? how important is evolution for habitability? Characterisation via direct imaging and low-resolution spectroscopy of exoplanets in various evolutionary stages will be key to answer these questions. Direct detection will make feasible the determination of masses, radii, atmospheric temperatures and chemical compositions both for giant and terrestrial planets at different times of evolution. This will offer unique information to understand how planets form and evolve.

Extremely large telescopes will enable the direct study of planetary systems during formation in proto-planetary discs for many nearby very young stars. ELT observations of giant planets in young stellar clusters and star forming regions will trace their evolution as a function of age. An ELT will also be capable of detecting reflected light from mature giant planets (Jupiter to Neptune-like) orbiting at separations smaller than 1 AU around hundreds of stars. It will explore and characterise other solar systems including possible terrestrial planets around nearby stars (d< 10 pc). Detection of Earth-like planets in extra-solar systems will lead to the search for bio-markers (e.g. water in the near infrared and oxygen bands in the optical far red) via low resolution spectroscopy.

1.3.1 Terrestrial planets in habitable zones "Exo-Earths".

The Sun is ~10^{10} times brighter than the Earth´s reflected light at visible and near-IR wavelengths. Provided the glare from the parent star is drastically suppressed, the E-ELT will be able to detect reflected light of nearby exoplanets, even those as small as Earth at similar physical separation than Earth from the Sun. This telescope equipped with Adaptive Optics (AO) and suitable choronagraphic systems will be able to separate the reflected light from a habitable planet from the central diffraction peak of a solar type star within 10 pc. Indeed, the E-ELT will explore a vast range of exoplanet systems covering planets outside and inside the so-called “Habitable Zone” (HZ), the range of separations to the star where water will be liquid and could favour the emergence of life as we know in our planet. Both hemispheres provide suitable targets comparable in number and characteristics to perform this fundamental research.

1.3.2 Spectroscopic signatures of life: biomarkers

The detection of terrestrial planets producing eclipses of their parent stars will provide an unique opportunity to investigate exo-Earth atmospheres and the presence of life beyond the Solar System. In Pallé et al. 2009 we can see many absorption features that characterize the Earth atmosphere and will be actively searched in exo-Earths. In march 2009, the Kepler NASA´s mission was launched with the aim to detect eclipses of exo-Earths around solar-type stars. This mission will monitor more than 100000 stars in the Northern Hemisphere for this purpose and it is widely recognized for its great potential to discover Earth analogues. A detailed spectroscopic follow-up investigation is mandatory. The E-ELT can play a key role in the spectroscopic search for biomarkers in the spectra of these planets. Among them we can remark the ``B'' absorption complex of oxygen at 760 nm in the far-red optical wavelength range. Significant amounts of free oxygen in the atmosphere of an exoplanet would be a strong indicator of the presence of photosynthetic biochemistry, i.e. of life.

1.3.3 Evolution and characterization of planetary systems

RV searches and more recently direct imaging techniques have provided detection of planetary systems. A large fraction of stars appear to host these systems where migration of giant planets appears as a potential explanation for the observed distributions of separations. Evolution of the orbits seem to be essential to the planetary formation process. It would be important to investigate the presence of planetary systems in samples of stars of well known ages to characterise this evolution. Most exoplanet discoveries have been performed in field stars where it is difficult if not impossible to know an accurate age. Star clusters may allow a significant step in our understanding of the processes of formation of planetary systems. In the Northern Hemisphere we are fortunate to have access to the Hyades cluster the nearest stellar cluster (d ~ 45 pc) with an age of order 600 Myr and the Pleiades cluster at 140 pc and with an age of 120 Myr. Both provide with unique samples of hundreds of solar type stars where E-ELT can conduct a dedicated search for planetary systems using RV and imaging techniques. These two clusters have been benchmark laboratories for stellar studies for decades and will constitute also an essential reference in our understanding on the evolution of planetary systems.

In addition, these clusters are exceptional also to investigate the presence of extremely faint free-floating planetary-mass objects which are known to exist in much younger (a few Myr old) stellar systems. E-ELT will enable us to compare these objects with gaseous planets orbiting stars over a wide range of ages and circumstances. We will determine the evolution of their physical properties (effective temperature, gravity and chemical composition).

1.4 Our Solar System

The E-ELT's extremely high angular resolution and powerful spectroscopic capabilities will represent a major step in the study of the most distant and faintest components of the Solar System. It will image solar system´s planetary satellites with extraordinary resolution and multiwavelength surface coverage. For the few hundred largest asteroids complete surface maps with spatial resolutions of several km will be obtained providing topography and geological information. Main-belt objects will be sufficiently resolved to determine rotational periods, sizes, shapes, axis orientations and approximate surface distribution of geological components. Major advances will occur in the determination of sizes, masses and densities for binary objects in the Kuiper belt as well as in the understanding of their thermal properties.

The largest Trans-neptunian objects (TNOs) will be resolved. Long-term monitoring of these TNOS will allow the study of surface evolution. Spatially resolved spectroscopy will be possible at spectral resolutions comparable or higher than the best spectra currently available for Pluto. This will identify surface ices and their physical states (mixture ratios, etc) and allow an accurate determination of temperatures as well as detailed studies of albedo features and the correlation with specific materials. The brightest TNOs are located at the Northern Hemisphere.

1.5 Stars and discs

Stars and planets form within dark molecular clouds. However, despite many years of study, little is understood about the internal structure of these clouds and consequently the initial conditions that give rise to star and planet formation. The star formation process begins with the growth of condensations in molecular clouds. When the density of a condensation reaches some critical value the collapse begins and a protostar forms frequently surrounded by an accretion disk. As time progresses the inflowing material falls preferentially onto the disk. Finally, the disk may be dispersed or partially coagulate into planets. The E-ELT can spatially resolve the inflow and accretion regions and determine essential parameters (density, temperature and dynamics) to constrain physical models. The planet formation process pose many questions which require high spatial and spectral resolution: What fraction of the disks are forming planets? At what stage in the accretion process are planets formed? How long do they take to form? What determines their masses? What density, temperature and kinematic structure characterise those disks in which planets form?

Orion is one of the nearest and richer birthplaces for stars and therefore particularly suitable to address these questions with E-ELT. Being equatorial it can be observed equally well from both hemispheres. The much closer (d~200 pc) Perseus molecular complex in the Northern Hemisphere is also an outstanding region offering an extraordinary research potential. Many field nearby stars (d < 40 pc) with disks offer the best opportunity to follow the details of planet formation. Excellent targets are available with similar numbers and characteristics in both hemispheres.

Session 2: The Local Universe

This session included 11 presentations, which could lead to one or more science cases for the Design Science Reference Plan (DSRP) each. From the titles of the presentations alone it can be concluded that three objects unique to the Northern Hemisphere are of particular interest to the Spanish astronomical community, namely the two Local Group spiral galaxies M31 and M33, and the Coma Cluster. In other cases, candidate objects could be found in both hemispheres, although even in such cases key preferred objects were located at positive declinations.

2.1. The Local Group spirals

The Local Group spiral galaxies M31 and M33, located at a distance of 770 and 850 Kpc respectively, are near enough to offer the unique possibility of studying with great accuracy several aspects directly related to key questions of galaxy formation and evolution. The following were discussed:

i) Reaching the oldest main sequence turnoffs in the color-magnitude diagram (CMD) of a stellar system allows us to retrieve, accurately and unambiguously, its star formation history (SFH) (in the case of a composite population) or its age (in the case of a simple population). Obtaining information of resolved stellar populations in the nearby Universe, out to the distance of the Virgo Cluster, with the aim of reconstructing the formation and evolution histories of a representative sample of galaxies is one of the main science drivers of the E-ELT. However, in the case of the most distant (and possibly most interesting) target, the Virgo Cluster, only shallow CMDs reaching the brightest RGB stars would be possible even with the E-ELT. This would really offer very limited information, possibly no more conclusive than the information that can be currently obtained with integrated spectroscopy.

In this context, the possibility of retrieving very accurate, **spatially resolved SFHs and globular cluster ages**, through CMDs reaching the oldest main sequence turnoffs for the two Local Group spiral galaxies (a "normal" one, M31, and a small one, M33) would provide invaluable information on the formation and evolution mechanisms of one of the most common types of galaxies in the Universe, containing (in contrast with dwarf galaxies) a considerable amount of the Universe's baryonic mass.

ii) Recently, **young massive Galactic clusters** have been found or identified. Studying the properties and distributions of these massive clusters in the Local Group spirals (Milky Way, M31, M33) will allow us to constrain the role of the local conditions in the formation and evolution of massive stars and clusters: the presence or absence of a central supermassive black hole, a bar or an interaction region between the bar and the spiral arms. However, these clusters have typical radii of 1 pc, which at the distance of M31 and M33 represents angular sizes of only 0.25 arcsec. To carry out photometry and spectroscopy of individual stars we need NIR diffraction-limited images and R= 4000 NIR spectra with high spatial resolution IFUs assisted by MOAO in a telescope of 40m. With near- diffraction limited images in the J band we obtain about 2500 resolution elements over the area of a cluster like Westerlund 1, the most massive Galactic cluster with a radius of 1.0 parsec.

iii) Very high resolution imaging (at the diffraction limit of the telescope in the near-infrared) of the inner regions (R<10 pc) of M31, M32 and M33 will make possible to explore the vicinity (down to 2 light months) of three **supermassive black-holes** of very different mass. Using line-of-sight velocities of individual bright stars and stellar proper motions (with a time baseline of 15 years) in these regions it is possible: a) to estimate the mass of these SMBHs with an accuracy of 30%, b) to explore whether there is anisotropy or counter-rotation in the innermost stellar dynamics and if that correlates with the mass of the SMBH, c) to probe whether the stellar population properties around SMBH vary with the mass of the black-hole. This information is key to understand which feedback mechanism is behind the tight relation found between the host galaxy bulge mass and its SMBH mass.

2.2. The Coma cluster

Galaxy clusters and super clusters are the most massive structures observed in the Universe. One of the key goals of modern cosmology is to understand how these structures are formed and how galaxies evolved inside galaxy clusters. The most massive and evolved galaxy cluster in the nearby Universe is the Coma cluster. This cluster is the ideal laboratory in order to bring some light to key questions of galaxy formation theories. The following projects related with the Coma cluster were discussed in this panel:

i) The standard paradigm for structure formation claims that galaxies grow by mergers and accretion of smaller subsystems. Fossil records of these events are expected to be found in the outermost regions of galaxies, as different mechanisms for galaxy assembly (e.g., major mergers with and without gas, minor mergers, dissipative collapse, etc) are believed to leave a different imprint in the dynamic and metallicity gradient of the galaxies. Although studies of the outermost regions of galaxies are very rare in the literature because they have very faint surface-brightness, thanks to its proximity thousands of individual Planetary Nebulae (PNe) can be resolved with 40m class telescopes like the E-ELT across the extended halos of the galaxies in Coma, in order to determine the **formation history of galaxies** in high density environments.

At the center of this cluster we find the nearest pair of massive **cD galaxies**. These two galaxies are ideally suited to test predictions of hierarchical structure formation theories by measuring the physical properties of their extended halos, that we can trace by detecting a large amount of PNe with the E-ELT. This dataset will give us the possibility of observing substructures that can be compared with predictions from cosmological simulations, determining mass models of these galaxies and deriving O and Ne abundances at different projected radii. These observations will provide crucial observational constrains for the understanding of the **mass assembly** in galaxy clusters and can only be carried out with 40m class telescopes.

ii) **Globular clusters** (GCs) are known to be fossils of the major star-forming episodes in the Universe. Therefore, they provide essential clues to constrain the role that the different **galaxy formation and evolution** scenarios have had in their host galaxies. In addition, extragalactic GCs are ideal systems to trace the **baryonic and dark matter content** of galaxies over a wide range in mass, as they can be studied in a wide variety of galaxy types and can reach large galactocentric distances (>10 Reff). Therefore, GCs may provide additional information on galactic kinematics aside from the one derived from galactic stellar light and/or PNe.

Typical spectroscopic studies of GCs in 8-10m telescopes are limited to objects with V < 22.5. Since GCs follow a universal log-normal luminosity function that peaks at M_V ~ -7.4 (V ~ 24 at the distance of Virgo), only the brightest objects in nearby galaxies have been reasonably observed so far. All these galaxies are either in the field or in low-density galaxy groups/clusters, such as Virgo and Fornax. However, we still lack of spectroscopic studies of GCs in **high-density environments** where, according to recent theories of galaxy formation, galaxies formed earlier and in shorter time-scales.

With a multiobject optical facility at E-ELT, typical spectroscopic studies of GC systems can be extended out to galaxies in Coma, the richest galaxy cluster in the local universe. As such, it constitutes a unique window to study the stellar populations of GCs which formed in very dense and dynamically relaxed (older) environments, as well as to test the recent scenarios of GC formation.

iii) Given their mere dominance in galaxy clusters and their importance as potential building blocks of giant ellipticals, the understanding of the nature and origin of **dwarf galaxies** is key in drawing a complete picture of galaxy formation and evolution. Integral-field spectroscopy of these low surface brightness objects on the E-ELT will provide high-spatial resolution maps of the stellar kinematics, absorption line strengths and ionized gas properties for a sample of dwarf galaxies in the Coma Cluster. These observations, and in particular the two-dimensional perspective they provide, will allow us to study the presence of kinematic substructures, the internal variation of metallicity and age, and the connection of the stellar (and gas) kinematics with the local metal enrichment in these galaxies. The results, combined with dynamical models, will allow us to recover the internal stellar population and mass distributions in dwarf galaxies, and hence also to investigate their location in the Fundamental Plane of giant ellipticals.

2.3. Thick disk formation

The disk (thin disk) is the defining feature of spiral galaxies. Most spirals have a second *thicker* disk component which appears to be a discrete component distinct from the thin disk. This thick disk formed early in the formation of the galaxy. Since the stars in the thick disk spend most of their time far from the galactic plane, their dynamics represents a relic of the early galaxy and an excellent laboratory to study galaxy assembling.

Mainly two possibilities are considered today regarding thick disk formation, namely: i) thick disks form from the heating of the thin disk at early epochs; ii) they form from early accretion of satellites. Information on galaxy disk formation, and in particular, information helping us to discern the dominant mechanism in the building up of the galaxy disk, can be obtained from the detailed study, on a resolved star basis, of edge-on disk galaxies, through chemical and dynamical tagging to identify groups of stars that might have formed together. NGC 891 (ra=02h dec=+42º, a Milky Way twin) and NGC 5907 (ra=15h dec=+56º) are, at a distance of 10 Mpc, the closest examples of edge-on spiral galaxies.

2.4. AGB stars in Local Group galaxies

Asymptotic Giant Branch stars (AGB) constitute a late phase of low and intermediate-mass stars. They account for the cosmic origin of roughly half of all elements heavier than Fe (e.g. Herwig 2005, ARA&A 43, 435) and are the main source of long-term gas return and dust input into the interstellar medium (ISM). Basically, carbon and heavy (s-process) elements such as Rb, Zr, Sr, Ba, La, etc. are produced during the thermal pulsing phase at the end of the AGB. According to our current understanding, low-mass AGB stars (< 4 solar mass) can turn C-rich and s-process rich, but higher mass AGB stars remain O-rich as a consequence of the "Hot Bottom Burning" activation. Also, high mass AGB stars form different elements and isotopes than lower mass AGB stars and Supernovae. This general scenario is strongly modulated by metallicity as predicted by current theoretical models. Thus, AGB stars constitute excellent laboratories to test stellar evolution and nucleosynthesis theories.

Present facilities only permit observations in our Galaxy (at solar metallicity) and of the brightest stars in the nearest galaxies, where we find a wider range of metallicities and distances are known. In addition, thanks to the Spitzer Space Telescope, an important number of AGB stars are being identified in low-metallicity Local Group Galaxies. The large collecting area of the E-ELT will permit us to do high-resolution (R>40,000) spectroscopic observations in the optical and near-infrared ranges (from 400 to 2500 nm) in AGB stars in Local Group Galaxies. These observations will be crucial in order to understand the relationship between AGB stellar nucleosynthesis and other stellar parameters like metallicity, luminosity, stellar mass, etc. with an unprecedented detail.

This will undoubtedly be of interest not only to many different areas in astrophysics (such as stellar evolution and the overall nucleosynthesis of heavy elements in galaxies, etc.), but also to other disciplines, such as the chemical composition of meteorites in the Solar System.

2.5. ULXs in the Local Universe

Ultraluminous X-ray Sources (ULXs) are extragalactic X-ray point sources with X-ray luminosities in the range $L_X \sim 10^{39}$-10^{41} ergs/s, well in excess of the Eddington limit for a stellar-mass black holes (BH). They have been discovered over the last decade (by XMM and Chandra) and tend to be found in galaxies with a high star-formation rate. The nature of their compact accretors is one of the big open questions in current astrophysics. Proposed scenarios are super-Eddington and beamed collimated accretion onto stellar-mass BHs (King et al. 2001, ApJ 552, L109) or accretion onto intermediate-mass BHs (IMBH) of 10^2-10^4 $M_\odot$ (King & Dehnen 2005, MNRAS 357, 275). IMBHs might be remnants of massive stellar collapse in the early universe and the missing link in the formation of supermassive BHs in galactic nuclei. Deriving dynamical masses of the brightest ULXs is the *only* way to settle the debate as to the nature of the compact object and the possible existence of IMBHs.

There are over 200 ULXs currently known (Liu & Mirabel 2005, A&A 429, 1125) but only a handful of optical counterparts have been identified. Optical colours and spectra are consistent with OB stars and furthermore, orbital X-ray modulation has been detected, giving support to an X-ray binary scenario. Since ULXs tend to be located in star-forming regions they are usually contaminated by nebulosity and nearby young stars. Therefore, good seeing conditions ~ 0.6" are required to resolve the counterparts in crowded fields whereas high spectral resolution (R>5000) is essential to extract accurate radial velocities from the photospheric absorptions of the OB star and derive unbiased dynamical information. Using model atmospheres and observed properties of the OB star to derive its radius and luminosity, together with the Roche lobe geometry and orbital solution, will constrain the mass of the BH. This observing strategy has been applied with GEMINI to M33 X-1, a B=19 high mass X-ray binary with a 16 $M_\odot$ BH (Orosz et al. 2007, Nature 449, 872). The E-ELT will enable us to extend this analysis ~3.5 mag fainter and target the brightest ULXs: Holmberg II (B=21.4) and NGC 5204 (B=21.9), both at high positive declinations.

Session 3: Galaxies and Cosmology

7 contributions were presented in this session. The general scientific cases are insensitive to the hemisphere because of the large-scale isotropy of the far Universe and the existence of cosmological fields of interest both in the Northern and Southern Hemispheres, as can be seen in the Table below (courtesy of P. Pérez González, Universidad Complutense de Madrid).

Campo	ORM , Maruecos			Chile, Argentina		
FIR	*Hrs / noche*	*Noches útiles*	*Seeing*	*Hrs / noche*	*Noches útiles*	*Seeing*
Lockman	10h Feb	67% (7h)	0,87"	0h	-	-
GOODS-N	10h Mar	70% (7h)	0,87"	0h	-	-
EGS	8h Abr	74% (6h)	0,73"	0h	-	-
SXDS	6h Nov	60% (4h)	0,92"	8h Nov	85% (7h)	1,0"
GOODS-S	<3h	-	-	8h Nov	85% (7h)	1,0"
COSMOS	7h Feb	67% (5h)	0,87"	7hFeb	85% (6h)	0,9"

Table 1- This table shows the observing time, weather, and seeing statistics for the 6 deepest multi-wavelength cosmological surveys fields in the sky as a function of the possible locations of E-ELT in the Northern and in the Southern Hemispheres. The first column for each location gives the maximum number of hours during which the field is observable (corresponding to an elevation larger than 30 degrees) and the month when this occurs. The second column corrects the previous figures for the typical observing time lost due to weather and the duration of the night in each month and location. The third column gives the typical seeing of the ORM (Varela & Jiménez, private communication, from DIMM campaigns 1995-2006) and Paranal (http://www.eso.org/gen-fac/pubs/astclim/papers/mess2000/update.html) in each month. Green colours: favourable conditions for observation; red colours: observations are not possible; light yellow: intermediate conditions (only a few hours are usable each night or the seeing is the highest of the year).

3.1. The enrichment of the intergalactic medium

In the Local Universe, the fraction of barions locked into the different phases (gas, stars, etc) is quite clearly established, and it is very different from the distribution of metals, that are mostly locked into stellar remnants. However, 10 Gyr ago (z = 2.5) the metal distribution was completely different. A large fraction of the metals produced at this redshift should be present into the intergalactic medium (IGM), and were believed to be mostly ejected from low mass galaxies. However, recent observations do not support this idea. Extremely large telescopes are required for measuring the metals in the IGM at redshifts larger than 3 (from 3.8 up to 6) via Lyα forest on the spectra of QSO.

3.2. Gamma Ray Bursts versus Supernovae

Gamma ray bursts (GRBs) are intense but short-lived extragalactic emissions of gamma rays. From a phenomenological point of view, they can be classified as long (>2s) or short (<2s) bursts. Till now, up to 150 GRBs with redshifts ranging from local up to 6.3 have been detected.

Long GRBs are believed to be produced by the last stages of massive stars, and 2 weeks after the gamma glow, a Supernovae (SN) of type Ib/c (or Hypernova) is detected. This is interpreted through the called "Collapsar" model, due to the collapse of a massive star through an accretion disc around a rotating black hole. In this model, GRBs should happen in low metallicity environments with respect to pure SN.

The ideal target for testing the Collapsar model is NGC2770, a spiral galaxy that can be best observed from the North hemisphere and that is called the "Supenovae Factory" since three SNe have been observed in the last years, one of them associated to a GRB. NGC2770, that has a low metallicity, has the advantage of being a quite nearby galaxy, allowing observations with good spatial resolution.

3.3. Characterizing galaxy assembly at z = 2-4 with E-ELT

A full zoo of galaxies has already been detected in the redshift domain between z=2 and z=4, but most of them are still pending of a comprehensive classification and characterization. This is the cosmic time interval where the most massive galaxies wereformed, the size of spheroid galaxies grew by factors larger than 5, and where the density of QSOs seems to reach a peak. Therefore, the study of galaxies in this redshift interval will provide important clues for galaxy formation and evolution. Current photometric and (more pronouncedly) spectroscopic surveys carried out with 8-10m class telescopes are biased towards UV/optically bright sources (e.g., Lyman break galaxies). However, a large amount of the z=2-4 galaxy population is very faint in the optical and brighter in the near-infrared, which also probes the most useful spectral features in the rest-frame optical. Consequently, to obtain reliable redshifts, star formation rates, morphologies, 2D stellar populations, dynamical masses, and chemical compositions for this kind of galaxies it is necessary to have a large collecting area and observing capabilities in the near-infrared, the two main characteristics of E-ELT. It is also worth noticing that most of the deepest multi-wavelength cosmological fields in the sky are best observed from the Northern Hemisphere (see Table 1), and E-ELT will have to rely on the wealth of ancillary data obtained at other wavelengths by current and future ground-based and space facilities.

3.4. The star formation history of the most metal poor galaxies. A case of near-field cosmology.

In the hierarchical picture of galaxy formation, large galaxies arise through the assembly of smaller aggregates. Extremely metal-deficient dwarf galaxies are the closest examples one could find of the elementary primordial units from which galaxies assembled. Their study can be (and has been) used in numerous cosmological studies, from the determination of primordial abundances (big bang nucleosynthesis and/or Pop III stars), to understanding star formation in pristine gas. Obviously, these targets are too faint to be available at high redshift, and they have to be studied locally. The record braking low metallicity dwarfs represent a sub-class among the Blue Compact Dwarfs (BCDs), and there are only a handful of them available. It would be extremely important to determine the star formation history of a (fairly) complete set of these low metallicity BCDs. Although these systems are presently undergoing a major starburst which makes it easy detecting their interstellar medium, studying the properties of the faint underlying galaxy requires 50-m class telescopes.

E-ELT synergy with other facilities and hemisphere sensitivity

The E-ELT will represent the most important step forward within the future astronomical infrastructures by itself, and therefore the E-ELT alone has to be the first priority when taking decisions about its design, instrumentation or location. Nevertheless, it will benefit from previous works (like present day 8-10m telescopes) and complementarity with other observing facilities. Therefore possible synergies of the E-ELT with present or future facilities and surveys (ground based or space borne) are important and were considered during the meeting as something that may increase the scientific outcome of the telescope. The presence of these facilities or the availability of previous observations in one or the other hemisphere may imply a difference among them.

However, synergies among different facilities are not easy to foresee. A clear example of the difficulties arising is given by the ESO-ESA agreement on the ESO-XMM programme which grants VLT and XMM Newton observations from either ESO or ESA. The programme has a ceiling of only 400 kiloseconds per year each side, but it really never saturates. A few general points have to be emphasized when we try to study the possible synergies between two facilities.
a) If two facilities cover different wavelengths, then the possible synergy will depend on the Spectral Energy Distribution (SED) of the considered objects and facility sensitivity.
b) Two facilities located at different latitudes may still share an appreciable fraction of the sky.
c) We shall always distinguish between the case posed by a specific target and the general science case.
d) Large facilities are not survey facilities and cannot be used as finders for other large facilities.

Let us briefly illustrate these cases, for example using ALMA. ALMA has an angular resolution similar to the E-ELT (when operating in Adaptive Optics mode) and covers a different wavelength range, resulting in clear complementarity. It is probably the facility most commonly considered for synergies with the E-ELT. Recognizing the interest of this synergy, point (a) indicates that it will be interesting to observe the same object with both facilities only if the SED is adequate for observation with both of them. For sources with strong SED slopes (ie, much brighter at submillimeter wavelengths than at optical-near-IR or *vice versa*) one of the facilities may be blind.

The possible ALMA-EELT synergy is frequently used as an argument to conclude that the E-ELT should be located at approximately the same latitude as ALMA. Point (b) however indicates that the situation is more flexible. With the E-ELT in a northern latitude like the ORM, the E-ELT and ALMA will still share an appreciable fraction of the sky. If we restrict ourselves to observations at airmasses below 1.5 the ORM and Chajnantor still share 50º of declination on the sky (declinations from -22 to +27). If we observe at airmasses lower than 2 the common sky will cover 70º (from declination +37 to -32). For most object distributions in the sky, this will allow a large overlap. Figure 1 illustrates this point for all known class 0 protostars.

Figure 1 can also be used to illustrate point (c). If we are interested in a particular object in the Figure, it may be observable or not both with ALMA and the E-ELT located in a northern latitude. However, if we are interested in the science of Class 0 objects, it is clear that there are enough overlapping cases. Of course, a given object is always a particular case. For example, assume we are interested in studying irregular metal-poor dwarf galaxies. There are examples in both hemispheres. But if we are interested in observing the Magellanic Clouds, this can only be done from the South. By the contrary, if we are interested in large spiral galaxies, there are again examples in both hemispheres. But if we want to observe M31, this can only be done from the North.

Point (d) finally emphasizes the issue that only a few selected targets, chosen by its particular interest (and not necessarily known a priori) will be observed with both facilities. It will be difficult to construct a complex science project on the basis of the synergy between two large facilities.

Therefore, the ALMA-EELT synergy will depend on the particular conditions of the science case considered. As general rule, the same will be true for any other facility.

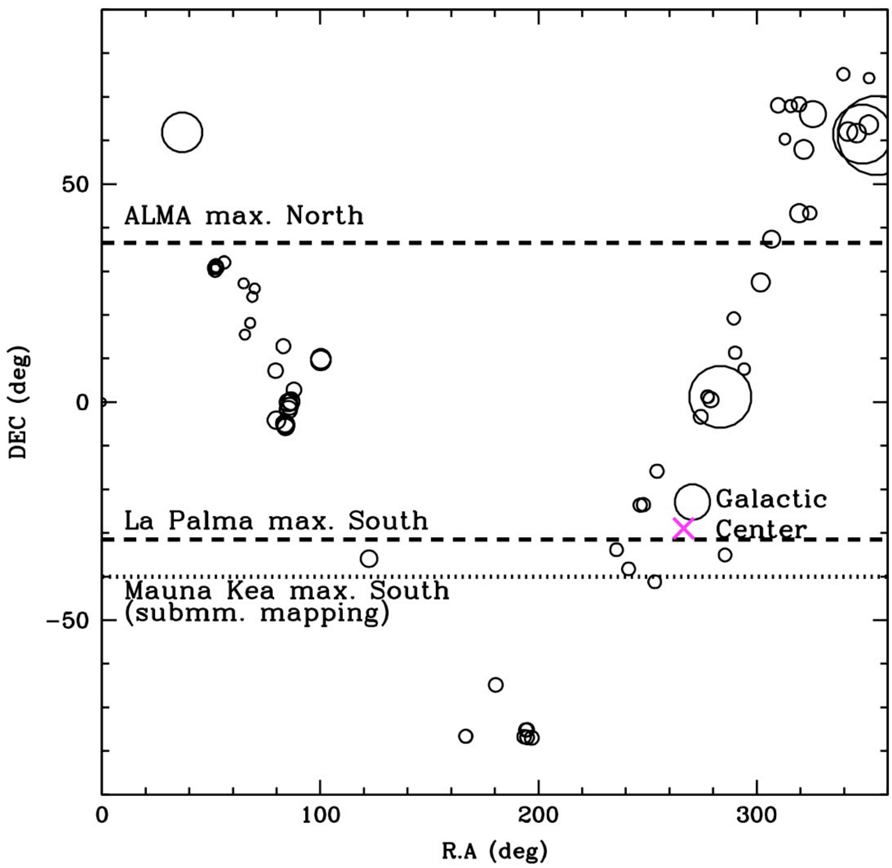

Figure 1. The distribution of known Class 0 objects on the sky, with approximated maximum ranges for ALMA (towards the North) and telescopes in La Palma and Hawaii (towards the South). Circles areas are proportional to the source distance. Lines correspond to air masses equal 2.0. (Courtesy of D. Barrado Navascués, Centro de Astrobiología).

Other facilities offer as well the possibility of a synergy with the E-ELT. In the radio domain, SKA in the South, or EVN, e-EVN (and VLA, e-VLBI) in the North offer also excellent possibilities, even reaching (expectedly) better sensitivity and angular resolution than ALMA, this time at cm wavelengths.

Smaller facilities on the other hand can collect a large number of objects, from which the most interesting ones can be then observed by the E-ELT. The 30-m IRAM telescope and the planned Northern Extended mm Array in Plateau de Bure, the 40-m Yebes antenna or the Giant Millimeter Telescope in Mexico (all in the North) offer excellent possibilities for the E-ELT in this context, complementing the wavelength range towards mm wavelengths while single dish observations can provide flux calibration for interferometric observations.

One of the most interesting synergy possibilities is that offered by dedicated survey facilities, as it will be the case of VISTA (Paranal). In the Northern Hemisphere we may cite SCUBA-2 at the JCMT, UKIDSS from the UKIRT and Pan-Starrs, all in Hawaii. While VISTA and UKIDSS use NIR observations and Pan-Starrs observes in the optical, SCUBA-2 is a particularly interesting possibility because it covers the sub-mm range. All these surveys are providing or will provide enough interesting targets for the E-ELT.

Cosmological surveys and fields are available in both hemispheres, including several equatorial ones, although some of them are accessible only from the North (e.g., the Lockman Hole, the Groth Strip or the GOODS-N) or from the South (e.g., the GOODS-S field, and the Ultra Deep Field within GOODS-S). Nevertheless, the E-ELT will benefit from most of this previous work, whatever location is chosen.

In the era of the E-ELT, present 8-10 m-class telescopes may play an important role as auxiliary facilities. Europe is in an excellent situation here, as it has access (either global or by individual countries with which agreements may be possible) to VLT and Gemini-S in the South, and GTC, Gemini-N and LBT in the North. We would also like to mention here the wide-field camera SuprimeCam at the Subaru (Hawaii) and the Large Synoptic Telescope (Cerro Pachón) that will provide the possibility of large surveys with 8-m class telescopes.

Space-based facilities are usually not linked to any hemisphere, although sometimes, like in the case of the Kepler satellite, the target field is limited to one of them (in the case of Kepler, a northern field). Apart from present and new satellites like Spitzer and Herschel, the largest interest will be in the satellites that will probably operate during the time of E-ELT. Gaia will map the Galaxy with unprecedent accuracy and the World Space Observatory will provide a UV complement to the E-ELT. Finally the JWST and the ELT are expected to complement each other in a similar way as the HST and the 8-10 m-class telescopes have been doing for more than 15 years. The ultra-sensitive NIR and mid-IR JWST instruments will discover objects requiring detailed high angular resolution follow-up observations with ELT. Other observing capabilities of ELT and JWST (e.g. R, spectral coverage, PSF stability, etc) will also be highly complementary.

We conclude that many facilities, at many different wavelengths and spectral or spatial resolutions and located in both hemispheres will be an excellent complement for the E-ELT. Which one of them offers the best possibilities depends on the particular science case. The same can be said for the selection of a given hemisphere. Although our individual pet object may be only accessible from one of them, **general science cases can be equally addressed from both hemispheres.**

Annex I.- List of talks presented during the metting

Session 1: Stars and Planets

R. Rebolo: Introduction

M.R. Zapatero Osorio: Early evolution of exoplanetary systems

E. Pallé: Exoplanet characterization during transits

V.J. Béjar and R. Rebolo: Evolution of the mass-luminosity relationship for BDs and superJupiters

D. Barrado Navascués: Star formation at low-masses

J. Licandro: Characterization of Trans-Neptunian objects

L. Labadie: Exoplanetary Disks

Session 2: The Local Universe

A. Herrero: Young Massive Star Clusters in M31 and M33.

A. García: AGB stars in Local Group galaxies.

C. Gallart and A. Marín-Franch: Formation and evolution of galaxy disks, bulges, and stellar cluster systems: detailed and unambiguous information for M31 and M33.

I. Trujillo: The inner 10 pc of M31 and M33: what drives the formation of supermassive black-holes?

C. del Burgo: Study of black holes in the Local Universe

I. Negueruela and J. Casares: ULX in the Local Universe

I. Pérez: Galaxy disk reconstruction from kinematics and stellar populations of edge-on galaxies using the E-ELT

P. Sánchez Blázquez: Abundances determinations in the outskirts of galaxies

A. López Aguerri: Abundances and kinematics through PNe in Coma

J. Cenarro: Kinematics and Stellar Populations of Globular Cluster Systems in Coma

J. Falcón: Dwarf Espheroidals in Coma

Session 3: Galaxies and Cosmology

J. Beckman: Intergalactic Medium

J. Gorosabel: The SNe factory

I. Pérez Fournon: Multiwavelength Extragalactic Surveys

P. Pérez González: High redshift galaxies

J. Cepa: Lyman-α emitters

J. Sánchez Almeida: Galaxies formation and Large-scale structure

N. Benítez: Physics of the Accelerating Universe

Special Session: Sinergies with the E-ELT

M.A. Pérez Torres: Sinergies between the E-ELT and radio interferometric facilities

D. Barrado Navascués: Star Formation at low masses: E-ELT, ALMA and other facilities

J. Gallego: Synergies of the E-ELT at high redshift

J. Cepa: OSIRIS-ALMA and E-ELT synergies

J. Torra: Synergies between E-ELT and Gaia

S. Arribas: E-ELT and JWST complementarity

Annex II: Proposals submitted to the Design Reference Science Plan

What follows are the abstracts of proposals submitted to the DRSP at the time of closing the present document. Other proposals are expected to be submitted before the corresponding deadline.

The architecture of planetary systems - including Earth-mass planets in the habitable zones - with age
P.I.: M.R. Zapatero Osorio
Instituto de Astrofísica de Canarias
E-mail: mosorio@iac.es

CoIs: R. Rebolo (IAC), E. Pallé (IAC), V. J. S. Béjar (IAC), C. Eiroa (UAM), J. A. Caballero (UCM), D. Barrado y Navascués (LAEFF-CAB), I. Ribas (IEEC-CSIC)

Abstract: Planets orbiting stars are common and hundreds of them are already known around an heterogeneous sample of field, mature stars of different metallicities and poorly-constrained ages. Here, we propose to investigate the architecture of planetary systems with parental stellar mass in the range 0.3-1 Msol and planets of 1 Earth-mass up to super-Jupiters by exploring the surroundings, including the habitable zones of many targets, of 400 fully-proved star members of the Pleiades (125 Myr) and Hyades (625 Myr) open clusters. Characterizing planets around cluster stars will provide unique constraints on the planet-mass dependence on stellar size for stars of constant age and metallicity that share a common birth and early dynamical evolution. Additionally, our results will be compared with the properties of the older "field" planetary systems to provide an evolutionary picture of the planet orbits as a function of the planet and star masses in the wide age interval 100 Myr to several Gyr.

Characterizing the atmospheres of transiting rocky planets within the habitable zone of M stars
P.I.: E. Pallé
Instituto de Astrofísica de Canarias
E-mail: epalle@iac.es

Cols: I. Ribas (IEEC_CSIC), M.R Zapatero-Osorio (IAC), R. Rebolo (IAC), G. Tinetti (UCL), F. Selsis (U. Bordeaux), D. Barrado y Navascués (LAEFF-CAB), S. Udry (O. Geneve), A. García-Muñoz (IAC)

Abstract: We propose the follow-up observations and atmospheric characterization of previously known transiting rocky planets around M-stars. Visible and near-infrared medium-to-high resolution spectra of the in transit and out of transit star+planet system will be observed, and from their ratio measurements, the transmission spectrum of the planetary atmosphere will be obtained. Our recent characterization of the Earth's transmission spectrum has shown that most of the major atmospheric constituents present strong absorption features. These include the important atmospheric bio-markers water, oxygen and methane (as seen in combination). Our simulations using the empirical Earth's transmission spectrum, and the observed stellar spectra for a variety of stellar types, indicate that the E-ELT is capable of retrieving the transmission spectrum of an Earth-like planet around an M-star. This will require to co-add observations during several transits to a total of 25 hours of in transit data, plus another 25 hours of out of transit data

Taxonomy of the formation of Low Mass Objects: from the Local Bubble to the Perseus Arm

P.I.: D. Barrado y Navascués
LAEX-CAB Centro de Astrobiología, INTA-CSIC
E-mail: barrado@laeff.inta.es

Cols: I. de Gregorio (LAEX-CAB)

Abstract: One of the most important astrophysical phenomena which is needing a comprehensive explanation is star formation, specially in the low-mass range, down to substellar masses, specially in an environment as different as the Perseus Arm, located beyond 2 kpc, when compared with the Local Bubble. This E-ELT proposal deals with this issue and several specific questions: i) evolution of Young Stellar Objects, specially for Very Low Luminosity Objects, and those having also very low mass. ii) Protoplanetary disk properties (accretion, ices and grains) and evolution. iii) Multiplicity in very low-mass, very young objects. Observations done at different wavelengths and taken with different techniques would provide (together with the data in the literature) an uniform database, a requirement for accurate classification of Young Stellar Objects. Spectral features available such as H(alpha),

Br(gamma), CaII IRT (stellar classification, accretion and age indicators) in the optical, and on the other hand PAH, ices and silicates from the disk in the mid-IR will allow to link stellar and disk evolution. Multiplicity and disk morphology in young, embedded objects will be tackled with mid-IR imaging. Here we propose to create a platform of observational data, complemented with theoretical interpretation, on which a sound paradigm for the stellar and brown dwarf formation and early evolution can be built.

Multiplicity of very low luminosity objects
P.I.: D. Barrado y Navascués
LAEX-CAB Centro de Astrobiología, INTA-CSIC
E-mail: barrado@laeff.inta.es

CoIs: N. Huélamo (LAEX-CAB), E. Pantin (LAIM, CEA, France)

Abstract: One of the most important astrophysical phenomena which is needing a comprehensive explanation is star formation, specially in the very low-mass range, down to substellar masses. This proposal deals multiplicity in solar-type stars and low-mass objects, very young objects, which are embbeded and present very strong extinctions at optical and even at near-infrared wavelenghths. The multiplicity of the youngest stellar and substellar objects is directly linked to their formation process, and therefore represents one of the most critical parameters to constrain theories of star formation. Therefore, we propose to systematically study a sample of Class 0/I and II objects in nearby star forming regions.

TNO, icy relics of the early Solar System
P.I.: J. Licandro
Instituto de Astrofísica de Canarias
E-mail: jlicandr@iac.es

CoIs: A. Alvarez Candal (OPM), A. Fitzsimmons (Queen Mary College)

Abstract: Trans-neptunian objects (TNOs) are icy bodies, relics of the early stage of the Solar System and their study is of great cosmogonical interest as they have the most pristine materials that can be found in any Solar System object. The aim of this proposal is to significantly improve our knowledge of their surface composition and the resurfacing

processed that affect them. We plan to obtain high S/N spectroscopy in the 500-2500nm range of a large series of selected TNOs of a wide range of sizes, and spectroscopy in the 3000-5000nm spectral region of the largest members of the population.

Evolution of the mass-luminosity relationship for brown dwarfs and superJupiters
P.I.: V.J.S. Béjar
Instituto de Astrofísica de Canarias
E-mail: vbejar@iac.es

Cols: R. Rebolo (IAC), M. R. Zapatero Osorio (IAC), D. Barrado y Navascués (LAEX-CAB)

Abstract: To date, more than 300 planets have been found orbiting other stars different from the Sun. The study of the transits of a few of them have allowed us to derive their physical properties, but a full characterization of extrasolar planets will require the direct detection of their light. We propose to perform a search for brown dwarf and superjupiters (1-10MJup) around Solar type and very low-mass stars in nearby young stellar associations and clusters (<1Gyr, <150pc), like Taurus, Scorpius, Pleiades and Hyades. Using near-infrared and high-contrast (10-3 - 10-5) instruments, like EPICS and HARMONY on the E-ELT, we will be able to detect and characterize the physical properties of superjupiters around stars at separations of a few AU, corresponding to angular separations larger than 30-100 mas. Given the relatively short periods of a few years, the dynamical characterization of their orbits will allow us to determine their masses and derive the dependence of their mass-luminosity relations with age. All these observations will be fundamental to understand the formation and evolution of giant planets and planetary systems. In this sense, the Pleiades and Hyades clusters are unique to address these questions.

The inner 10 pc of M31, M32 and M33: what drives the formation of supermassive blackholes?
P.I.: I. Trujillo
Instituto de Astrofisica de Canarias
E-mail: trujillo@iac.es

Cols: C. Gallart (IAC), J. Casares (IAC), A. Herrero (IAC), M. Balcells (IAC)

Abstract: We propose to take very high resolution imaging of the inner regions (<10 pc) of M31, M32 and M33. Working at the diffraction limit of the telescope in the near-infrared, we will be in position to explore the vicinity (down to 2 light months) of three (very different in mass) supermassive blackholes. Together with line-of-sight velocities of individual bright stars in these regions we plan to obtain (using a time baseline of 15 years) stellar proper motions. These studies will allow us: a) to estimate the mass of these SMBHs with an accuracy of 30%, b) to explore whether there is anisotropy or counterrotation in the innermost stellar dynamics and if that correlates with the mass of the SMBH, c) to probe whether the stellar population properties around SMBH vary with the mass of the blackhole. This information will be key to understand which feedback mechanism is behind the tight relation found between the host galaxy bulge mass and its SMBH mass.

Young Massive Star Clusters in M31 and M33

P.I.: A. Herrero
Instituto de Astrofísica de Canarias
E-mail: ahd@iac.es

Cols: F. Najarro (CAB), I. Negueruela (UA), D.J. Lennon (STScI), F. Comerón (ESO), J. Puls (USM), B. Davies (U. Leeds), D. Figer (RIT), M.A. Urbaneja (IfA), J. Maíz Apellániz (IAA), A. Marín Franch (IAC), M. García (IAC

Abstract: In the last decade, massive Galactic clusters have been found or indentified near the center of the Milky Way or in regions close to the bar-spiral arm interaction region. Their distribution suggests some link with the structure of our Galaxy and triggering star formation mechanisms. Our project aims at multiplying the number of resolved young massive clusters studied in spiral galaxies by a factor of ~20. Studying the properties and distributions of these clusters in the Local Group spirals (Milky Way, M31, M33) will allow us to constrain the role of the local conditions in the formation and evolution of massive stars and clusters: (a) the mass and type of the spiral galaxy; (b) the presence or absence of a central supermassive black hole, a bar or an interaction region between the bar and the spiral arms; and (c) the galactic metallicity. But these clusters have typical radii of 1 pc, which at the distance of M31 and M33 represents angular sizes of only 0.25 arcsec.

To carry out photometry and spectroscopy of individual stars we need NIR diffraction-limited images and multi-IFU spectroscopy at high spatial resolution in a telescope of ~40m.

The formation and evolution of disk galaxies: detailed information for M31 and M33
P.I.: C. Gallart
Instituto de Astrofísica de Canarias
Email: carme@iac.es

CoIs: J.A.L. Aguerri (IAC), A. Aparicio(IAC), M. Balcells (IAC), R. Carrera (O. A. Bologna), A. Ferguson (ROE), A. Marín Franch (IAC), I. Pérez (U. Granada), M. Rejkuba (ESO), P. Sánchez Blázquez (IAC), A. Sarajedini (U. Florida), I. Trujillo (IAC)

Abstract: We propose a detailed study of the nearest spiral galaxies, M31 and M33, through deep photometry and high-resolution spectroscopy. In particular: i) color-magnitude diagrams reaching the oldest main-sequence turnoffs in the disks of these galaxies, and in a significant number of globular clusters would allow us to retrieve accurate star formation histories and ages, respectively, and ii) high resolution spectroscopy of RGB stars would provide abundances and stellar kinematics. Such a detailed study, capable of providing definitive answers on key questions about disk galaxy formation and evolution, is only possible for these two spirals, which are signifficantly closer than any other spiral galaxy.

AGB stars in Local Group Galaxies
P.I.: A. García Hernández
Instituto de Astrofísica de Canarias
Email: agarcia@iac.es

CoIs: A. Manchado (IAC), C. Abia (U. Granada), B. Plez (GRAAL), M. Lugaro (U. Utrecht-CSPA), A.I. Karakas (RSAA), M. van Raai (U. Utrecht), I. Domínguez (U. Granada), F. D'Antona (INAF), P. García-Lario (ESA), O. Straniero (INAF), S. Cristallo (INAF), D.L. Lambert (U. Texas)

Abstract: We propose to obtain high-resolution (R > 40000) optical and near-infrared spectra of Asymptotic Giant Branch (AGB) stars in Local Group Galaxies. The main objective of this project is to determine their s-process element and CNO isotopic abundances, and to investigate the dependence with other stellar parameters such as luminosity, stellar mass and metallicity with an unprecedent detail. These observations will improve our understanding of the nucleosynthesis processes ocurring within AGB stars as a function of metallicity and stellar mass, imposing important observational constraints on current AGB nucleosynthesis models. These results will be of great interest to many different areas in astrophysics.

Dwarf Galaxies in the Coma Cluster: probing the faint end of the luminosity function in dense environments.

P.I.: J. Falcón Barroso
Instituto de Astrofísica de Canarias
E-mail: jfalcon@iac.es

Cols: Mina Koleva (IAC), A. Bosseli (LAM), S. De Riejke (U. Gent), J. Gorgas (UCM), R. Guzmán (U. Florida), R.F. Peletier (Kapteyn AI), Ph. Prugniel (CRAL), A. Vazdekis (IAC)

Abstract: We propose to use integral-field (multi-object) spectroscopy on E-ELT to obtain high-spatial resolution maps of the stellar kinematics, absorption line strengths and ionized gas properties for a complete sample of dwarf galaxies in the Coma Cluster, drawn from the HST/ACS Coma Treasury Survey. These observations, and in particular the two-dimensional perspective they provide, will allow us to study the presence of kinematic substructures, the internal variation of metallicity and age, and the connection of the stellar (and gas) kinematics with the local metal enrichment in these galaxies. The results, combined with dynamical models, will allow us to recover the internal stellar population and mass distributions in dwarf galaxies, and hence also to investigate their location in the Fundamental Plane of giant ellipticals. This will help us understand the nature and origin of dwarfs, which, given their mere dominance in clusters as well as their importance as potential building blocks of giant ellipticals, is key in drawing a complete picture of galaxy formation and evolution.

A Spectroscopic Survey of Globular Clusters in Coma: Early Galaxy Formation and Dark Matter Content

P.I.: A. J. Cenarro
Instituto de Astrofísica de Canarias
E-mail: cenarro@iac.es

Cols: D. Carter (Liverpool JMU), R.M. Sharples (U. Durham), A. Vazdekis (IAC), M. Balcells (IAC), R. Guzmán (U. Florida)

Abstract: Spectroscopy of globular clusters (GCs) around external galaxies provides invaluable information on the main episodes of star formation in the Universe, as well as on the distribution of dark matter at large galactocentric distances. Unfortunately, there is a lack of spectroscopic studies of GCs in truly high-density environments where, according to detailed stellar population analysis and recent theories of galaxy formation, massive galaxies could form ~2 Gyr earlier. This proposal outlines how ELT/OPTIMOS would provide, for the first time, spectra for thousands of Coma GCs, thereby constraining the epoch of GC/galaxy formation and the baryonic and dark matter distribution throughout the cluster.

Formation and Evolution of the two giant ellipticals of the Coma Cluster

P.I.: J. Alfonso López Aguerri
Instituto de Astrofísica de Canarias
E-mail: jalfonso@iac.es

Cols: P. Sánchez Blázquez (IAC)

Abstract: Under the LCDM paradigm, giant elliptical galaxies in the center of clusters are believed to be the end-products of the violent star formation and merger events that took place in the central regions of clusters. Some of these galaxies (cD) show an faint stellar halo that could have formed as the result of stellar accretion during the cluster mass assembly. These extended halos are extremely faint and can not be observed by standard techniques. Nevertheless they can be investigated by detecting some tracers such as PNe. The closest central galaxies in clusters are those in the Coma cluster, being ideal targets for 40-m telescopes.

Extragalactic black holes: are ULXs intermediate mass black holes?

P.I.: Jorge Casares
Instituto de Astrofísica de Canarias
E-mail: jcv@iac.es

Cols: I. Negueruela (UA), F. Vilardell (UA), A. Herrero (IAC), T. Shahbaz (IAC)

Abstract: The nature of ULXs in nearby galaxies is highly controversial: are they the long-sought intermediate mass black holes or a new state of stellar-mass black hole X-ray binary? Only radial velocity studies can unambiguously solve this puzzle, and we have chosen the brightest ULXs (B<22) in NGC 5204 and Holmberg II. We propose long-slit spectroscopy with ELT to obtain the first radial velocity curve of two ULX companion stars and probe whether they contain ~100-1000 Msun black holes or not. Excellent ground seeing conditions (<0.6") and intermediate spectral resolution (R~5000) are requested to avoid crowding and contamination by background nebular lines.

The star formation history of the most metal poor galaxies. A case of near-field cosmology.

P.I.: J. Sanchez Almeida
Instituto de Astrofisica de Canarias
E-mail: jos@iac.es

Co-Is: J.A.L. Aguerri (IAC), C. Muñoz-Tuñón (IAC), J. Vilchez (IAA), R. Sanchez-Janssen (IAC), R. Amorín (IAC)

Abstract: In the hierarchical picture of galaxy formation, large galaxies arise through the assembly of smaller aggregates. Extremely metal-deficient dwarf galaxies are the closest examples one could find of the elementary primordial units from which galaxies assembled. Their study can be (and has been) used in numerous cosmological studies, from the determination of primordial abundances (big bang nucleosynthesis and/or Pop III stars), to understanding star formation in pristine gas. Obviously, these targets are too faint to be available at high redshift, and they have to be studied locally. The record braking low metallicity dwarfs represent a sub-class among the Blue Compact Dwarfs (BCDs), and there are only a handful of them available. These systems are presently

undergoing a major starburst which makes it easy detecting their interstellar medium. However, studying the properties of the faint underlying galaxy requires 50-m class telescopes. We propose determining the star formation history of a (fairly) complete set of these low metallicity BCDs.

The impact of the host galaxy environment to trigger SNe and GRBs: probing the SN factory NGC2770.

P.I.: Gorosabel J.
Instituto de Astrofísica de Andalucía (CSIC)
E-mail: jgu@iaa.es

Co-Is: Castro-Tirado A.J. (IAA-CSIC), M. Jelinek (IAA/CSIC), P. Kubanek (IAA/CSIC), S. Guziy (IAA/CSIC), A. de Ugarte Postigo (ESO), on behalf of a large collaboration

Abstract: The recent discovery of X-ray bursts in a few SNe (called X-ray flashes, XRFs), reveals a soft transition between standard SNe and cannonical GRBs. NGC2770 is the closet GRB host galaxy to date. There, appart from an XRF, 3 standard SNe have occurred in the last nine years. We propose to observe the field of NGC2770 and its satellite galaxy NGC2770B in order to study the enviromental effect to trigger SNe and GRBs.

The evolution of metallicity in the intergalactic medium from high redshift.

P.I.: John Beckman
Instituto de Astrofísica de Canarias
E-mail: jeb@iac.es

Abstract: The distribution of metals in the universe at high z is a basic clue to its evolution.This proposal is to study the "smoking gun", direct detection of escaping gas from galaxies. This will be detected using redshifted MgII in absorption, which is a useful direct metallicity indicator. A study equivalent to DEEP2 (1000 objects) can be conducted out to z = 3 in 30 hours with the E-ELT, and out to z = 5 a study of 100 galaxies implies a similar observing period. We outline the latter here.

Detailed characterization of the galaxies with the most intense star formation at z=1-4

P.I.: P.G. Pérez González
Universidad Complutense de Madrid
Email: pgperez@astrax.fis.ucm.es

CoIs: G. Barro (UCM), I. Pérez-Fournon (IAC), J. Gallego (UCM), J. Cepa (IAC), I. Trujillo (IAC), A. Alonso-Herrero (IEM-CSIC), N. Scoville (Caltech), C. Conselice (U. Nottingham)

Abstract: We propose to obtain 1-D and 2-D/AO (resolution lower than 50 mas) NIR spectroscopy for a representative sample of 500-1000 IR-bright galaxies at z=1-4 selected with the Spitzer, Herschel, SCUBA-2, and/or ALMA deepest surveys, all of them being extremely faint at optical (R>25) and NIR (K>22) wavelengths. These galaxies are known to dominate the SFR density of the Universe at z>1, and be an important phase in the early formation of the most massive galaxies in the downsizing scenario. Our main goal is obtaining robust estimations of parameters such as the stellar and dynamical mass, kinematics, SFR, metallicity, ages of the stellar populations, etc.. in a galaxy-by-galaxy basis. Exploiting the synergies with JWST and ALMA to also characterize the dust and gas properties, this project will be a giant step forward on our understanding of the formation of galaxies in a key epoch of galaxy evolution.

Luminuous and Ultraluminous Galaxies up to z=3

P.I.: Santiago Arribas
Instituto de Estructura de la Materia
E-mail: arribas@damir.csic.es

CoIs: Luis Colina (IEM/CSIC)

Abstract: We propose to study the internal physical and dynamical structure of a representative sample of about 60 Luminous and Ultraluminous Infrared Galaxies ((U)LIRGs) up to a redshift of 3. Local (U)LIRGs are ideal astrophysical laboratories to study the processes governing the formation and evolution of galaxies (interactions/mergers, star and AGN formation, enrichment of IGM, etc) . In addition their contribution to the total SFR density increases steadily from z~0 up to

z~3, forming at least half of the newly born stars by z~1.5. The spectral range, angular resolution, sensitivity, and IFS capability of HARMONI makes it ideal for this program.

The cosmic history of Super-Massive Black Hole growth

P.I.: Xavier Barcons
Instituto de Física de Cantabria (CSIC-UC)
E-mail: barcons@ifca.unican.es

Cols: J. Aird (Kyoto U), W.N. Brandt (PSU), F.J. Carrera (IFCA), A. Comastri (INAF-Bologna), A. Fernández-Soto (IFCA), K. Nandra (IC), A. Ruiz (INAF-Brera), Y. Ueda (Kyoto U)

Abstract: The evolution of galaxies needs the study of both their stellar component and of the growth of the super-massive black holes (SMBH) in their centre. During their accreting phases, SMBH show up as luminous AGN and regulate both star formation and further growth by accretion. Mapping the co-evolution of stars and SMBH in galaxies at redshifts z~6-10 is key to understand galaxy evolution, and a goal of many large facilities in the next decade. Here we propose to use the E-ELT and IXO in conjunction to unveil young growing SMBH in the form of mini-QSOs in that critical redshift range.