Convocatorias 2016
Proyectos EXCELENCIA y Proyectos RETOS
Dirección General de Investigación Científica y Técnica
Subdirección General de Proyectos de Investigación

Parte A: RESUMEN DE LA PROPUESTA/SUMMARY OF THE PROPOSAL

A.1. DATOS DEL PROYECTO COORDINADO

INVESTIGADOR/ES COORDINADOR/ES

INVESTIGADOR COORDINADOR PRINCIPAL 1 (Nombre y apellidos)**:**

Angeles I. Díaz Beltrán

INVESTIGADOR COORDINADOR PRINCIPAL 2 (Nombre y apellidos)**:**

Yago Ascasibar Sequeiros

TÍTULO GENERAL DEL PROYECTO COORDINADO:

Estallidos de formación estelar y evolución de galaxias

ACRÓNIMO DEL PROYECTO COORDINADO: ESTALLIDOS 6.0

RESUMEN DEL PROYECTO COORDINADO:

Los estallidos de formación estelar (Starbursts o SB) juegan un papel fundamental en la evolución de las galaxies y, por lo tanto, en la historia de formación estelar (FE) del Universo, en la producción de metales, y en los procesos de retroalimentación que acoplan las galaxias con la red cósmica en la que viven. Las primeras estrellas y galaxias se desarrollaron en condiciones físicas extremas, de forma que el fenómeno SB necesariamente constituye in ingrediente fundamental de nuestra comprensión del Universo. Los SBs aparecen por todas partes, desde las regiones HII gigantes de las galaxias espirales hasta los brotes masivos típicos de los objetos a alto 'redshift'. Nuestro proyecto tiene como meta la realización del estudio completo de la física de la regiones masivas del universo local, con objeto de entender el funcionamiento de las galaxias más lejanas y de los SBs más extremos. Representa la continuación natural de ESTALLIDOS 5.0, en donde nos planteamos las preguntas que han surgido de la evolución del campo y también algunas que quedaron sin responder. Combinaremos estudios observacionales (usando telescopios terrestres y espaciales) con nuestros modelos teóricos. Entre las instalaciones que usaremos destacan los nuevos instrumentos de GTC, EMIR y MEGARA, en los que el equipo investigador participa tanto en su desarrollo como en la explotación científica. EMIR y MEGARA entrarán en funcionamiento durante el periodo que cubre este proyecto.

Hemos estructurado nuestra investigación de los próximos tres años alrededor de cinco objetivos que llamamos:

1) La interacción entre la FS masiva y el medio interestelar.
2) El gas en la formación de las galaxias disco.
3) El papel del entorno en la FS masiva y la evolución de galaxias.
4) Formación estelar extrema en el Universo.
5) Participación en la construcción de nueva instrumentación y en su verificación científica.

Los principales resultados que esperamos del proyecto son: i) obtener una mejor comprensión de la evolución química de las galaxias usando datos de IFUs y modelos bi-

dimensionales, ii) entender el papel que en la formación de galaxias juegan el gas molecular y los fotones energéticos de fondo, iii) desarrollar una técnica para hacer imagen del gas de la red cósmica que alimenta la formación estelar en galaxias, iv) caracterizar las propiedades químicas y dinámicas del gas que cae sobre las galaxias, v) descifrar las distintas formas en las que el entorno afecta a la formación estelar a lo largo de la vida del Universo, prestando especial atención al disparo de la FE en las galaxias con menos metales, vi) explicar como SB masivos son capaces de evolucionar en modo de 'positive feedback', para poder entender los SB extremos presentes en el Universo primitivo, vii) estudiar la FS en galaxias Ly-alpha y Ly-break, viii) averiguar si existen candidatos a ser estrellas de población III en galaxias extremadamente pobres en metales, locales y a alto 'redshift', ix) desarrollar las técnicas necesarias que permitan un uso eficiente de EMIR y MEGARA. Lideraremos casos científicos en los que se usan estos instrumentos, tanto durante la fase de verificación como en su explotación posterior.

PALABRAS CLAVE DEL PROYECTO COORDINADO: evolución de galaxias, formación estelar, medio interestelar, estrellas masivas, enriquecimiento químico, espirales,baja

TITLE OF THE COORDINATED PROJECT: Starbursts and galaxy evolution

ACRONYM OF THE COORDINATED PROJECT: ESTALLIDOS 6.0

SUMMARY OF THE COORDINATED PROJECT:

Starsbursts play a key role in the cosmic evolution of galaxies, and so, in the star formation (SF) history of the universe, the production of metals, and the feedback coupling galaxies with the cosmic web. Extreme SF conditions prevail early on during the formation of the first stars and galaxies, therefore, the starburst phenomenon constitutes a fundamental ingredient of our understanding of the Universe. Starbursts are observed throughout, from the giant HII regions in nearby spirals, to the massive clumps typical of high redshift objects. This project is aimed at carrying out a comprehensive study of the physics of local massive SF regions in order to enlarge our understanding of the most distant galaxies and most extreme starbursts. It represents the natural continuation of ESTALLIDOS 5.0, addressing the new questions that have emerged from the evolution of the field as well as questions that remain open. We will combine observational studies (using ground based and space-borne spectrophotometry) along with our self-consistent theoretical models. Among the observational facilities, the team is directly involved in the development and scientific exploitation of the GTC instruments EMIR and MEGARA, which will become operational during the timespan of the project.

We have structured our research for the next three years around five main objectives:

1) The interplay between massive SF and the interstellar medium within galaxies.
2) Understanding the formation of disk galaxies.
3) The rôle of the environment on the massive SF and evolution of galaxies.
4) Extreme starbursting in the Universe.
5) Participation in the science verification and building of new instrumentation.

The main results expected from this project include: i) constraining the chemical evolution of galaxies using a combination of integral-field spectroscopy and fully bi-dimensional models, ii) understanding the role of molecular gas and high-energy background photons on the formation of galaxies, iii) developing a technique to image the cosmic web gas that feeds the starbursts, iv) characterizing the chemical and dynamical properties of the gas that is falling into the galaxies, v) deciphering the different ways in which the environment can affect the

SF in star-forming galaxies along cosmic time; paying especial attention to the triggering of violent SF bursts in the lowest metallicity galaxies. vi) explaining how very massive and compact starbursts may evolve in the so-called positive feedback mode, accounting for extreme starbursts in local galaxy analogs to the objects present in the primeval universe. vii) understanding the SF in Lya and Ly-break galaxies, viii) constraining the existence of candidate stars analog to PopIII in extremely metal poor galaxies, both in the local universe and at high redshift, ix) developing the knowhow needed for an effective use of EMIR and MEGARA. We aim at getting the most from these new instruments by leading science cases during the verification phase and later on.

KEY WORDS OF THE COORDINATED PROJECT: galaxies evolution, star formation, interstellar medium, massive stars, chemical enrichment, spiral and low mass galaxies

A.2. DATOS DE LOS SUBPROYECTOS

SUBPROYECTO 1:	**nodo UAM**
INVESTIGADOR PRINCIPAL 1:	Ángeles Isabel Díaz Beltrán
INVESTIGADOR PRINCIPAL 2:	Yago Ascasibar Sequeiros
TÍTULO:	Estallidos de formación estelar y evolución de galaxias

SUBPROYECTO 2:	**nodo CIEMAT**
INVESTIGADOR PRINCIPAL 1:	Mercedes Mollá Lorente
TÍTULO:	Estallidos de formación estelar y evolución de galaxias

SUBPROYECTO 3:	**nodo IAA**
INVESTIGADOR PRINCIPAL 1:	José Manuel Vílchez Medina
INVESTIGADOR PRINCIPAL 2:	Enrique Pérez Montero
TÍTULO:	Estallidos de formación estelar y evolución de galaxias

SUBPROYECTO 4:	**nodo IAC**
INVESTIGADOR PRINCIPAL 1:	Casiana Muñoz Tuñón
INVESTIGADOR PRINCIPAL 2:	Jorge Sánchez Almeida
TÍTULO:	Estallidos de formación estelar y evolución de galaxias

Parte B: INFORMACIÓN ESPECÍFICA DEL EQUIPO

B.1. RELACIÓN DE LAS PERSONAS NO DOCTORES QUE COMPONEN EL EQUIPO DE TRABAJO (se recuerda que los doctores del equipo de trabajo y los componentes del equipo de investigación no se solicitan aquí porque deberán incluirse en la aplicación informática de solicitud). Repita la siguiente secuencia tantas veces como precise para cada uno de los subproyectos.

1. Nombre y apellidos: Sheilla Wekesa
   Titulación: graduado
   Tipo de contrato: en formación en entidad extranjera (Universidad de Nairobi)
   Duración del contrato: becario predoctoral de universidad 3 años
   Subproyecto al que pertenece (nombre y apellidos del investigador principal): Mercedes Mollá Lorente

2. Nombre y apellidos: Salvador Duarte Puertas
   Titulación: licenciado
   Tipo de contrato: en formación (FPI)
   Duración del contrato: temporal
   Subproyecto al que pertenece (nombre y apellidos del investigador principal): José Manuel Vílchez Medina

3. Nombre y apellidos: Alejandro Lumbreras Calle
   Titulación: licenciado
   Tipo de contrato: en formación (FPI)
   Duración del contrato: temporal
   Subproyecto al que pertenece (nombre y apellidos del investigador principal): IAC-Casiana Muñoz-Tuñón & Jorge Sánchez Almeida

4. Nombre y apellidos: Amanda del Olmo
   Titulación: licenciado
   Tipo de contrato: en formación – Astrofísico Residente-IAC
   Duración del contrato: temporal
   Subproyecto al que pertenece (nombre y apellidos del investigador principal): IAC-Casiana Muñoz-Tuñón & Jorge Sánchez Almeida

5. Nombre y apellidos: Pablo Arrabal Haro
   Titulación: licenciado
   Tipo de contrato: en formación (FPI-Severo Ochoa)
   Duración del contrato: temporal
   Subproyecto al que pertenece (nombre y apellidos del investigador principal): IAC-Casiana Muñoz-Tuñón & Jorge Sánchez Almeida

B.2. FINANCIACIÓN PÚBLICA Y PRIVADA (PROYECTOS Y/O CONTRATOS DE I+D+I) DEL EQUIPO DE INVESTIGACIÓN (repita la secuencia tantas veces como se precise en cada uno de los subproyectos participantes hasta un máximo de 5 proyectos y/o contratos por cada subproyecto)

SUBPROYECTO 1: UAM

1. Miembros del equipo de investigación que participan: AID, YA
   Referencia del proyecto: FP7-PEOPLE-2013-IRSES-612701
   Título: "*Study of Emission-Line Galaxies with Integral-Field Spectroscopy (SELGIFS)"*
   Investigador principal (nombre y apellidos): Ángeles I. Díaz
   Entidad financiadora: REA (EU)
   Duración (fecha inicio - fecha fin): 01/10/2013 - 30/09/2017
   Financiación recibida (en euros): 237.300 €
   Relación con el proyecto que se presenta: muy relacionado
   Estado del proyecto o contrato: concedido

2. Miembros del equipo de investigación que participan: AID, YA, MSL, ME, PRP, MAA
   Referencia del proyecto: AYA2013-47742-C4-3-P
   Título: *"El papel de los estallidos de formación estelar en la formación y evolución de galaxias: Estallidos 5"*
   Investigadores principales (nombres y apellidos): Ángeles I. Díaz, Yago Ascasibar
   Entidad financiadora: MINECO
   Duración (fecha inicio - fecha fin): 01/01/2014 - 31/12/2016
   Financiación recibida (en euros): 158.510 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido

3. Miembros del equipo de investigación que participan: YA
   Referencia del proyecto: PPP-Spain-57050803
   Título: "*The chemical and dynamical structure of disk galaxies"*
   Investigadores principales (nombres y apellidos): Yago Ascasibar, Cecilia Scannapieco
   Entidad financiadora: DAAD (Germany)
   Duración (fecha inicio - fecha fin): 01/01/2014 - 31/12/2015
   Financiación recibida (en euros): 13.528 €
   Relación con el proyecto que se presenta: muy relacionado
   Estado del proyecto o contrato: concedido y finalizado

4. Miembros del equipo de investigación que participan: AID, YA, MSL, ME, PRP, MAA
   Referencia del proyecto: AYA2010-21887-C04-03
   Título: "*Starbursts and their imprint in the cosmic evolution of galaxies"*
   Investigador principal (nombre y apellidos): Ángeles I. Díaz
   Entidad financiadora: MICINN
   Duración (fecha inicio - fecha fin): 01/01/2011 - 12/12/2013
   Financiación recibida (en euros): 231.110 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

5. Miembros del equipo de investigación que participan: AID, YA, MSL, ME, PRP, MAA
   Referencia del proyecto: AYA2007-67965-C03-01
   Título: "*Estallidos de formación estelar (3ª Fase)"*
   Investigador principal (nombre y apellidos): Ángeles I. Díaz
   Entidad financiadora: MEC
   Duración (fecha inicio - fecha fin): 01/01/2008 - 31/12/2010
   Financiación recibida (en euros): 326.337 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

SUBPROYECTO 2: CIEMAT

1. Miembros del equipo de investigación que participan: MM, NL, MSS, MS
   Referencia del proyecto: AYA2013-47742-C4-4P
   Título: *"El papel de los estallidos de formación estelar en la formación y evolución de galaxias: Estallidos 5"*
   Investigador principal (nombre y apellidos): Mercedes Mollá
   Entidad financiadora: MINECO
   Duración (fecha inicio - fecha fin): 01/01/2014 - 31/12/2016
   Financiación recibida (en euros): 72.600 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido

2. Miembros del equipo de investigación que participan: MM, NL, MSS, MS
   Referencia del proyecto: AYA2010-21887-C04-02
   Título: "*Starbursts and their imprint in the cosmic evolution of galaxies"*
   Investigador principal (nombre y apellidos): Mercedes Mollá
   Entidad financiadora: MICINN
   Duración (fecha inicio - fecha fin): 01/01/2011 - 31/12/2013
   Financiación recibida (en euros): 50.820 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

3. Miembros del equipo de investigación que participan: MM
   Referencia del proyecto: CAM S2009/ESP-1496
   Título: " *Astrofísica y desarrollos tecnológicos en la Comunidad de Madrid"*
   Investigador principal (nombre y apellidos): José Miguel Mas Hesse
   Entidad financiadora: Consejería de Educación, Comunidad de Madrid
   Duración (fecha inicio - fecha fin): 01/01/2010 – 31/12/2013
   Financiación recibida (en euros): 883.660 €
   Relación con el proyecto que se presenta: algo relacionado
   Estado del proyecto o contrato: concedido y finalizado

4. Miembros del equipo de investigación que participan: MM
   Referencia del proyecto: MDM-2015-0509
   Título: "*Ciemat Física de Partículas, Unidad de excelencia María de Maeztu"*
   Investigador principal (nombre y apellidos): Nicanor Colino
   Entidad financiadora: MINECO
   Duración (fecha inicio - fecha fin): 01/01/2016 - 31/12/2019
   Financiación recibida (en euros): 2.000.000 €
   Relación con el proyecto que se presenta: algo relacionado
   Estado del proyecto o contrato: concedido

5. Miembros del equipo de investigación que participan: MM
   Referencia del proyecto: CSD 2006-00070
   Título: "*Primera Ciencia con GTC: La astronomía española en vanguardia de la astronomía europea"*
   Investigador principal (nombre y apellidos): José M. Rodríguez Espinosa
   Entidad financiadora: MEC, Consolider-Ingenio 2010
   Duración (fecha inicio - fecha fin): 01/01/2006 - 31/12/2012
   Financiación recibida (en euros): 5.500.000 €
   Relación con el proyecto que se presenta: algo relacionado
   Estado del proyecto o contrato: concedido

SUBPROYECTO 3: IAA

1. Miembros del equipo de investigación que participan: JVM, EPM, JIP
   Referencia del proyecto: AYA2013-47742-C4-1P
   Título: *"El papel de los estallidos de formación estelar en la formación y evolución de galaxias: Estallidos 5"*
   Investigador principal (nombre y apellidos): José M. Vílchez Medina
   Enrique Pérez Montero
   Entidad financiadora: MINECO
   Duración (fecha inicio - fecha fin): 01/01/2013 - 31/12/2016
   Financiación recibida (en euros): 158.510 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido

2. Miembros del equipo de investigación que participan: JVM, EPM, JIP
   Referencia del proyecto: AYA2010-21887-C04-0
   Título: "*Starbursts and their imprint in the cosmic evolution of galaxies"*
   Investigador principal (nombre y apellidos): José M. Vílchez
   Entidad financiadora: MICINN
   Duración (fecha inicio - fecha fin): 01/01/2011 - 31/12/2013
   Financiación recibida (en euros): 277.816 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

3. Miembros del equipo de investigación que participan: JVM, JIP
   Referencia del proyecto: AYA2007-67965-C03-02
   Título: "*Estallidos de formación estelar (3ª Fase)"*
   Investigador principal (nombre y apellidos): José M. Vilchez
   Entidad financiadora: MEC
   Duración (fecha inicio - fecha fin): 01/01/2008 - 31/12/2010
   Financiación recibida (en euros): 185.130 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

4. Miembros del equipo de investigación que participan: JIP, JVM
   Referencia del proyecto: FQM7058
   Título: "*Proyecto de excelencia Historia de formación estelar y evolución de galaxias en entornos de diferente densidad"*
   Investigador principal (nombre y apellidos): Jorge Iglesias Páramo
   Entidad financiadora: Junta de Andalucía
   Duración (fecha inicio - fecha fin): 01/02/2012 - 31/12/2015
   Financiación recibida (en euros): 304.000 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

5. Miembros del equipo de investigación que participan: JIP
   Referencia del proyecto: P07-FQM2864
   Título: "*Proyecto de excelencia Ciencias del Espacio desde el Observatorio de Sierra Nevada"*
   Investigador principal (nombre y apellidos): Jorge Iglesias Páramo
   Entidad financiadora: Junta de Andalucía
   Duración (fecha inicio - fecha fin): 01/02/2008 - 31/12/2010
   Financiación recibida (en euros): 265.193,16 €
   Relación con el proyecto que se presenta: algo relacionado
   Estado del proyecto o contrato: concedido y finalizado

SUBPROYECTO 4: IAC

1. Miembros del equipo de investigación que participan: CMT
   Referencia del proyecto: AYA2015-71542-REDT
   Título: "*Red española de estudios sobre la contaminación lumínica"*
   Investigador principal (nombre y apellidos): Jesús Gallego Maestro
   Entidad financiadora: MINECO
   Duración (fecha inicio - fecha fin): 01/01/2016 - 21/12/2018
   Financiación recibida (en euros): 30.000 €
   Relación con el proyecto que se presenta: sin relación
   Estado del proyecto o contrato: concedido

2. Miembros del equipo de investigación que participan: CMT + Estallidos-IAC
   Referencia del proyecto: AYA2013-47742-C4-3-P
   Título: *"El papel de los estallidos de formación estelar en la formación y evolución de galaxias: Estallidos 5"*
   Investigador principal (nombre y apellidos): Casiana Muñoz Tuñón, Jorge Sánchez Almeida
   Entidad financiadora: MINECO
   Duración (fecha inicio - fecha fin): 01/01/2013 - 31/12/2016
   Financiación recibida (en euros): 131.000 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido

3. Miembros del equipo de investigación que participan: CMT + Estallidos-IAC
   Referencia del proyecto: AYA2010-21887-C04-04
   Título: "*Starbursts and their imprint in the cosmic evolution of galaxies"*
   Investigador principal (nombre y apellidos): Casiana Muñoz Tuñón
   Entidad financiadora: MICINN
   Duración (fecha inicio - fecha fin): 01/01/2011 a 31/12/2013
   Financiación recibida (en euros): 291.610 €
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

4. Miembros del equipo de investigación que participan: CMT + Estallidos-IAC
   Referencia del proyecto: AYA2007-67965-C03-01
   Título: "*Estallidos de formación estelar (3ª Fase)"*
   Investigador principal (nombre y apellidos): Casiana Muñoz Tuñón
   Entidad financiadora: MEC
   Duración (fecha inicio - fecha fin): 01/01/2008 - 31/12/2010
   Financiación recibida (en euros): 326.337€
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido y finalizado

5. Miembros del equipo de investigación que participan: CMT
   Referencia del proyecto: PIEF-GA-2012-327934,
   Título: "*Feeding and hiding AGN"*
   Investigador principal (nombre y apellidos): Cristina Ramos Almeida
   Entidad financiadora: REA (EU)
   Duración (fecha inicio - fecha fin): 01/01/2014 - 31/12/2015
   Financiación recibida (en euros): 166.336,2€
   Relación con el proyecto que se presenta: muy relacionado
   Estado del proyecto o contrato: concedido y finalizado

Parte C: DOCUMENTO CIENTÍFICO. Máximo 25 páginas.

C.1. JUSTIFICACIÓN DE LA COORDINACIÓN

Star formation is at the basis of galaxy evolution, and is ever present in the history of the Universe, from the highest redshift emitters to our own Galaxy. However the study of the star formation process is complex and requires expertise covering different areas, both observational and theoretical, to provide the comprehensive approach we propose. The ESTALLIDOS collaboration includes experts in observational astrophysics, numerical simulations and theoretical modelling, and bases its strength in an effective coordination of their members in four different teams whose objectives are intertwined. The added value of this coordination is clear: it is directly related to the synergistic research performed as a result of the combination of the expertise and specialization of the scientists from the four nodes.

Our working scheme has been optimized over the years to improve the coordination efficiency. We have designed this proposal guided by three main aims: i) major challenging scientific goals; ii) productive interaction among project members and objectives; iii) efficient and high impact dissemination of results.

For the research activity in this project, we seek that the entire ESTALLIDOS team be involved in the five main objectives (each one responsibility of two senior specialists) although the dedication of the different team members to each objective is different according to their expertise (see sections C.2.4).

The coordination scheme and management of this project involves:
1.- Coordination Team (CT), The core of the coordination of the project are PIs and Co-PIs and seniors responsible for Objectives. Members (in alphabetic order by first names): Ángeles I. Díaz Beltrán, Casiana Muñoz Tuñón, Enrique Pérez Montero, Jorge Iglesias Páramo, Jorge Sánchez Almeida, J. Miguel Mas Hesse, José M. Vílchez Medina, José Miguel Rodríguez Espinosa, Mercedes Mollá Lorente and Yago Ascasíbar Sequeiros.
Note: *J. Miguel Mas Hesse and Jose Miguel Rodriguez Espinosa are active members in ESTALLIDOS since its beginning- They are part of our team even if they can not be members formally for bureaucratic reasons.*

2.- Management and coordination meetings, to facilitate the monitoring of the day by day operation of the collaboration. These meetings can be held by teleconference among the PIs of the different subproject nodes. Then operating strategies will be followed up and tuned when required. All CT members are invited to participate. From our previous experience we estimate that a frequency of 4/year is enough for taking decisions as needed. We believe that the video/telecon format is appropriate, saving travel time and unnecessary expenses.

3.-Review Meetings (1/year). The CT members will meet every year (presential/telecon) to supervise the correct scientific progress of the project and the foreseen achievements of each objective; the leaders of each objective, and the members of the CT, will attend these meetings. Whenever possible, each review meeting will follow a management meeting in order to optimize time.

4.-Science Meetings: ESTALLIDOS Workshops and Specific Seminars. As part of the coordination of the project, an initial workshop (first year) and a final one will be organized. One of these meetings will be an international conference (International Symposia level). In addition, specific seminars (typically 20 participants) driven by the project objectives will be organized. In the previous edition of this project we organized two international conferences, three workshops and three specific seminars in the previous five years. Some examples are:
Miraflores-2015 ; SF-feedback-2015 ; Estallidos-2015 ; Metals-3D ;
ESTALLIDOS@EMIR2015

C.2. PROPUESTA CIENTÍFICA

1. Antecedentes y estado actual de los conocimientos científico-técnicos

ESTALLIDOS started formally as a coordinated team to study the formation and evolution of massive stars in starbursts in the Plan Nacional I+D back in 2001, continuing the activities of the GEFE (Grupo de Estudios de Formación Estelar) group. The ESTALLIDOS team is in an ideal position to identify and make progress on the most challenging topics related to massive star formation in galaxies thanks to the expertise we have gained along more than 15 years of working in collaboration. We benefit from the advantage of being a large but well coordinated team, sharing deep expertise on the different techniques of multi-wavelength studies, observational methods and theoretical modelling.

Our projects, in their nature, are mid-term projects and thus every edition is usually structured in two periods of 3 yr. The present proposal is thus a natural continuation of the previous one: ESTALLIDOS 5, during which we plan to approach some of the issues that, due to different reasons, could not ben attacked yet, conclude some of the still open questions and incorporate some new ones that have appeared and become relevant during the last three years and that constitute the natural evolution of an active research as the one we conduct. Our original four objectives from ESTALLIDOS 5 remain and a new one has been added relating to the developing and exploitation of new instrumentation. The 5 main objectives of the present proposal are then:

1) The interplay between massive SF and the interstellar medium within galaxies.
2) Understanding the formation of disk galaxies.
3) The role of the environment on the massive SF and evolution of galaxies.
4) Extreme starbursts in the Universe.
5) Participation in the science verification and building of new instrumentation,

Bellow we review our recent work in these five objectives.

1. Interplay between massive SF and the interstellar medium within galaxies

The ESTALLIDOS collaboration is an internationally-recognized leader in the study of chemical abundances in galaxies (e.g. Víchez et al. 1988; Víchez & Esteban 1996; Vílchez & Iglesias-Páramo 1998; Díaz & Pérez-Montero 2000; Pérez-Montero & Díaz 2003, 2005; Pérez-Montero & Contini 2009; Díaz et al. 2007; Haegele et al. 2010; Pérez-Montero et al. 2013, 2016). The integral-field spectroscopy (IFS) and multi-object spectrographs now provide data on local scales, for the ionized gas phase of the ISM as well as the underlying stellar population. Our expertise, combined with our galaxy evolutionary models (Mollá & Díaz 2005; Mollá et al. 2009; Gavilán et al. 2005, 2006, 2013), allows a physically meaningful interpretation of the IFS data, such as CALIFA (Sánchez et al. 2012), where several of our team's members are involved. For chemical evolution models, the best combination of IMF and stellar yields used as inputs was constrained (Mollá et al. 2015), and a new grid of models with varying infall rates and SF efficiencies will allow characterizing spiral galaxies (Mollá et al., 2016). In this kind of models diffuse neutral gas and molecular clouds play a crucial role. A simple model based on the formation and destruction of hydrogen molecules (Gnedin & Kravtsov 2011; Krumholz et al. 2008, 2009, 2013) was done (Romero B.Sc. thesis, UAM 2014) and these prescriptions will be now included in our codes. A comparison with compiled observational data (Pinto B.Sc. thesis, UAM 2014) shows that the relation between metallicity and stellar fraction also occurs on kpc scales (Ascasíbar et al. 2015). The existence of local scaling relations between stellar mass surface density and gas-phase oxygen abundance (Sánchez et al. 2014) and star formation rate (Cano-Díaz et al. 2016; González-Delgado et al. 2016) hints that the SF regulation seems be dominated by local processes. Through the relation between two proxies of SF on different timescales – as the (u-r) color and EW(Hα) - Casado et al. (2015) identify an ageing sequence, consistent with a gradual conversion of gas into stars, as the main mode of SF for isolated galaxies, with a quenching sequence, signature of a recent drop in SF, only in dense environments. IFS data confirms these results, but suggests a more complex picture on resolved scales (Casado et

al., in prep). For what refers to the impact of the enrichment of galaxies on their observed properties, we have studied the relation between Supernovae (SNe) luminosities and the metallicity of their host galaxies. This is work by M.E. Moreno-Raya for his PhD thesis, and it is considered finished (the thesis will be defended in July 2016). This work has produced 6 articles (Moreno-Raya 2016a,2016b,2016c, Galbany et al. 2016, Vallely et al. 2015 and Smartt et al. 2015) and two press releases. The Astrophysical Journal Letters has considered a highlight our results presented in Moreno-Raya et al. 2016a.

2. Understanding the formation of disk galaxies

Gas accretion from the cosmic web is thought to be controlling the star formation in disk galaxies, so that the net gas accretion rate balances the star-formation rate (e.g., Filantor & Dave 2008; Schaye et al. 2010; Fraternali & Tomassetti 2012). The process is expected to be particularly efficient at redshifts between 2 and 3, but it never shuts off, continuing at the present time in the local universe (e.g., Dekel et al. 2013). The gas infall is central to our understanding of how galaxies form, but its importance is as clear from theory as obscure from observations (see Sanchez Almeida et al. 2014, and references therein). Our team has already provided evidence for the process being at work, in the form of young metal-poor starbursts in otherwise old normal-metallicity disk galaxies (Sanchez Almeida et al., 2013, 2015). We have also analyzed the gas infall necessary to form disks with the observed properties (Mollá et al. 2016).

3. The rôle of the environment on massive SF and evolution of galaxies

The role of the environment on the evolution of galaxies has been largely discussed in the literature since the 80s (e.g. Dressler et al. 1980, Postman & Geller 1984). Different processes, acting on different components of the galaxies, have revealed to be at the basis of this differential evolution: e.g. ram pressure stripping removes the neutral gas reservoir of the disks (e.g.Gunn & Gott 1972); harassment reduces the size of the disks as galaxies enter in high density ambients (e.g. Moore 1996); and starvation exhausts the tenuous hot gaseous haloes of galaxies (e.g. Larson et al. 1980).The overall observational effect is that, as the local density of galaxies increases, the fractions of spiral and star forming galaxies decrease and the metallicity of the galaxies increases, and this happens both at low (e.g. Rines et al. 2005; Lewis et al. 2002; Ellison et al. 2009; Casado et al. 2015) and high redshift (e.g. Kulas et al. 2013, Shimakawa et al. 2015). However, the relative predominance of each of the effects mentioned above is not yet fully established (Hernández-Fernández et al 2012), and some works report other different trends (e.g. Elbaz et al. 2007, Valentino et al. 2014). In addition, theoretical studies show that the neutral gas in spiral galaxies is redistributed during close encounters of galaxies or in the presence of a dense intergalactic gas (e.g. di Matteo et al 2008; Bekki 2009). In many cases this reservoir of neutral gas is expelled out of the main body of the parent galaxy, producing effects that alter the normal evolution of galaxies. Moreover, the interaction of pairs of field galaxies (of any mass), also modifies their morphology and star formation activity (di Matteo et al. 2007). Thus, the results of galaxy-galaxy interactions which may include morphological transformation (mergers), strong starbursts and/or galaxy formation (tidal dwarf galaxies) have to be considered (Iglesias-Páramo et al 2012). Regarding star formation and the chemical evolution of galaxies in clusters, previous works from our group in the local Universe have shown that cluster galaxies show larger abundances of oxygen than field galaxies, but also that the difference depends on the stellar mass of the galaxies, being larger for more massive galaxies (see Petropoulou et al. 2011, 2012; and recent references to this work by Genel, 2106; Cortese et al 2016).

4. Extreme starbursts in the Universe

In today's cosmology, the study of the star formation negative feedback is recognized as one of the central issues regarding galaxy formation (Dekel and Silk 1986; Friaça and Terlevich 1998; Scannapieco et al. 2002; Ferreras et al. 2002). The current models of galaxy formation are only able to match the observations by including the negative feedback produced by AGNs and SNe (Governato et al. 2010). Massive stars, which produce photons and

mechanical energy, are able to drive super galactic winds (SGW). These SGWs can remove the material from the galaxy and, together with the ionization, inhibit further SF (Heckman et al. 1990; Tenorio-Tagle & Muñoz-Tuñón, 1997, 1998). However, our more recent results based on hydrodynamical simulations of massive and compact star forming regions (Tenorio-Tagle et al, 2005, 2007; Wunsch et al 2008; Tenorio-Tagle et al 2010; Silich et al. 2007, 2010; Tenorio-Tagle et al 2013) have demonstrated how, in some cases, this feedback may result positive, thus implying that little or none of the returned matter will be ejected out of the system. Large stellar densities may lead to strong radiative cooling causing the matter reinserted by massive stars inside the inner zones of the cluster to remain gravitationally bound.

Careful determinations of abundance distributions over galaxies at the early stages of their evolution could provide important pieces of information about their formation processes since gas accretion or gas ejection episodes will leave an imprint on these abundance distributions. However, several important caveats exist: (a) the assumption that the ionization of the gas in inner regions of galaxies is due *only* to star formation processes; (b) that the star formation modes dominating at high redshifts are similar to those encountered in the local universe. Regarding the first, it is nowadays generally accepted that some connection exists between star formation and activity in galactic nuclei, and young stars appear as one component of the unified model of AGN giving rise to the blue featureless continuum which is observed in Seyfert 2 galaxies where the broad line region is obscured. But regarding the second, that is that the star formation modes dominating at high redshifts are similar to those encountered in the local universe, this might not be the case. Large and massive clumps of star formation have been detected in more than half of the resolved $z>1$ galaxies in the Hubble UDF (see Elmegreen et al. 2005). These star-forming entities are in galaxies at all distances covered by the ACS ($0.07<z<5$). They have sizes of about 2 kpc, estimated ages of ~10 Myr and masses often larger than 10^8 Msun. They are so luminous that they dominate the appearance of their host galaxies. Massive clumps like these are found in galaxies with a variety of morphologies, from somewhat normal ellipticals, spirals, and irregulars, to types not observed locally, including chain galaxies and their face-on counterparts, clump-cluster galaxies (see Elmegreen et al. 2005). Interestingly enough the star-forming entities, which seem to constitute the star formation mode in galaxies at high redshifts, resemble the well -known circumnuclear star-forming regions, a common mode of star formation found close to galactic nuclei.

On a different matter, one of the clearest examples of extreme star-forming galaxies are possibly the strong nebular HeII emiters. This emission constitutes a clear evidence for the presence of very high-energy photons (with energy over 54.4 eV) in these galaxies. Strong emission from HeII is arguably one of the most important footprints of massive Population III stars, the very first hot metal-free stars, that should be accessible today at high-z (e.g. Schaerer 2003; Cassata et al. 2013; Sobral et al. 2015). These stars -which as of today only exist in the theory-, are believed to have contributed significantly to the reionization of the Universe playing a central role in the chemical history of the cosmos. Metal-poor starbursts tend to show larger nebular HeII emission compared to those with higher metallicities (e.g., Guseva et al. 2000), and so the metal-poor sensitivity of the HeII lines is a primary motivation to develop diagnostics for distant unevolved starbursts. However, when moving to the low redshift universe, we find that the main mechanism powering nebular HeII4686 emission in star-forming regions still remains difficult to understand in particular for metal-poor galaxies (e.g. Kehrig et al. 2011; 2016; Shirazi & Brinchmann, 2012). In our previous project edition, Kehrig et al. (2015), based on PMAS data, have reported the total HeII-ionizing photon flux [Q(HeII)obs] in IZw18, likely the most metal-poor galaxy known in the local Universe. Our data, combined with stellar model predictions, indicate that conventional HeII-ionizing sources (WRs, shocks, X-ray binaries) are not sufficient to explain the total ionization budget derived for this galaxy (e.g., Meynet & Maeder, 2005; Crowther & Hadfield 2006; Leitherer et al. 2014). In order to explain the ionization budget we find that only the models for rotating $Z=0$ metal-free stars (Yoon, Dierks, & Langer 2012) can reproduce our data. This suggests, for the first time, that peculiar, very hot nearly metal-free ionizing stars (called here PopIII-star siblings) might hold the key to the HeII-ionization in IZw18. This result goes in line with recent simulations which predict the late formation of analogues to Pop III-stars (siblings) at

moderate redshifts, due to a local and slow metal enrichment process, leaving plenty of pristine gas to exist and thus allowing for a composite stellar population: PopIII-star siblings plus chemically more evolved stars (e.g. Tornatore et al. 2007; Xu et al. 2016).

5. Participation in science verification and construction of new instrumentation

The primary goal of ESTALLIDOS is to deliver high quality research on massive bursts of star formation and their impact on galaxy evolution. To achieve this goal, a final transversal and fundamental objective of this project has been to remain deeply committed to the development and scientific verification of new instrumentation. ESTALLIDOS was part of the core group of the CONSOLIDER project "1st Science with GTC", and its members have contributed at different levels to the scientific verification and exploitation of GTC. Given the well known observational and technological experience of this collaboration -- including support astronomers and operations specialists in spectroscopy and deep imaging --, we have been invited into the science verification and commissioning teams of new instruments and to form part of the construction consortia of some future ones. In fact we have already participated in some projects listed below:

(1) EMIR for GTC. ESTALLIDOS- through the IAC - is member of EMIR consortium team. ESTALLIDOS has organized (Febr. 2016) a specific workshop at the IAC in preparation of EMIR commissioning and a team of 15 scientists has been formed to proceed with it. In addition, our IAC node has funded a one-year postdoc (2015) developing the ETC calculator of EMIR.

(2) MEGARA for GTC. ESTALLIDOS -through the IAA node- form part of the construction consortium for this IFU-MOS instrument.

(3) SITELLE at CFHT. We have been invited to join the team for the scientific exploitation and science verification of this new Fourier Transform Spectrograph at the Canada-France-Hawai telescope.

2. Hipótesis de partida y objetivos generales

Our project has a basic premise: the comprehensive study of the physics of local massive SF regions allows for the understanding of the most distant galaxies and most extreme starbursts. Our team, ESTALLIDOS, has demonstrated wide expertise in this field combining the observational studies of starbursts (using ground based spectrophotometry together with space-borne observations) along with the construction of self-consistent theoretical models of, e.g., photoionization, stellar evolutionary synthesis, chemical evolution, as well as hydrodynamics and ISM feedback.

Massive Starbursts are ubiquitous processes in the Universe, which can be observed extending from large HII regions in nearby galaxies to the very distant primeval galaxies, discovered in large numbers in the last decade and lighting short time after reionization. Massive stars evolve fast, lose a significant fraction of their gas during their evolution, and end their lives in supernova explosions that return recycled material back to the interstellar medium (ISM), thus causing its chemical enrichment. Thus, the impact of starbursts on the evolution of galaxies and thereof on the cosmic evolution of the Universe is unquestionable. Research in massive Star Formation (SF) in galaxies has experienced a tremendous development in recent years mainly thanks to the great progress made by space telescopes (HST, Spitzer, Herschel, GALEX, Chandra, XMM...) complemented with results obtained from the last generation of large optical-infrared telescopes and from radio and (sub)millimetre telescopes that have culminated with the advent of ALMA.

In what follows we list the main objectives of the proposed research:

1. Interplay between massive SF and the interstellar medium within galaxies
Our main objective is to investigate the mechanism(s) that regulate SF in galaxies. We assume that measurements of relevant quantities can be obtained from observations at

different wavelengths, and that, once these data are combined and compared with theoretical predictions, we will be able to disentangle the rôle of local and global processes shaping galaxy evolution. In order to achieve this goal we will (1) gain insight from optical integral-field spectroscopy (IFS) surveys; (2) study the rôle of molecular clouds and diffuse gas; (3) take into account the contribution of the high-energy processes through the associated X-ray and gamma-ray emission.

2. Understanding the formation of disk galaxies

The galaxies, as we observe them, represent big and complex systems that evolve through interaction with the circumgalactic and intergalactic medium, and with other galaxies. Dark matter and baryons are accreted continuously, and feedback processes return to the intergalactic medium an important fraction of the debris from stellar evolution. The importance of the various physical processes depends strongly on the total mass of the galaxy, and the environment they live in. This paradigm emerges from the cosmological numerical simulations of galaxy formation which self-consistently treat the physics of baryons (e.g., Ceverino et al. 2010; Vogelsberger et al. 2014; Schaye et al. 2015). However, the fundamental rôle that the simulations assign to the interaction with the (either nearby or distant) environment is far from having been tested observationally. The work proposed here is expected to provide additional observational constraints to the point that the global picture could be upheld or discarded. Building up on our expertise, we will search for gas accretion driving star formation in a number of different but complementary ways: (1) imaging the gas before it arrives to the disks, i.e., in the circumgalactic and intergalactic medium; (2) modelling the chemical properties of disk galaxies; (3) characterizing chemical and dynamical inhomogeneities in disk galaxies; and (4) using realistic cosmological numerical simulations to disclose the observational signatures to be expected from the accretion process. The completion of these tasks will completely renew our observational view of the formation of disks through gas accretion.

3. The rôle of the environment on massive SF and evolution of galaxies

The rôle of the environment on the evolution of galaxies has been discussed above. Given that this objective requires a detailed view of the internal structure of galaxies, we will restrict our study to the local Universe, where we will use our database of Hα images of cluster galaxies in the local Universe that has been already exploited for studies of global properties of galaxies in dense environments (PhD thesis of D. Reverte). We propose (1) to perform a detailed study of the distribution of the Hα emission in the disks of spiral galaxies belonging to nearby clusters, since this distribution mimics that of the star formation activity. By comparing our results with the observables predicted by models of galaxies in dense environments we will shed light on the relative importance of the environmental processes at different local densities; and (2) to trace the evolution with redshift of the effects of galaxy density on the evolution of galaxies which will shed light on the relative importance of the environment of galaxies throughout the life of the Universe. We are particularly interested in the evolution of metallicity with redshift in cluster galaxies. We propose to extend the study of clusters of galaxies in the local universe to clusters at higher redshifts, and likely to proto-clusters, thus mapping a sequence of redshifts that will include clusters of galaxies at different stages of evolution. We aim at establishing an observationally-based link with the epoch of the Universe when star formation and chemical evolution started to be affected by the environment, a much needed result.

4. Extreme starbursts in the Universe

With respect to the extreme starbursts, we will continue our studies about positive feedback. It predicts that several stellar generations with different metallicities may form inside the star cluster volume and, as a result, star formation would be extremely efficient. One possible case in which the different stellar generations seems to form from the processed mass within the still forming cluster volume is the case of the globular clusters (see Tenorio- Tagle, et al., 2015, 2016). This result will be explored by searching for Extreme Starbursts, in which the SF, size, mass, or metallicity of the star forming clumps are beyond average. We have already compiled a catalogue of starbursts in COSMOS and characterized the starbursts clumps and their host galaxy. GOODS-N is also accessible and, from our tailored made procedures, we are now able to select all the starbursts in both surveys up to z=1. This new

sample – together with other previously compiled by ESTALLIDOS - will allow the analysis of both the starburst clumps and their host galaxy in the broad picture of the models of the formation and evolution of galaxies. At still larger redshifts, SF is mostly seen in Lyman Break Galaxies (LBG) and Lyman-alpha Emitters (LAE). Their specific features and full characterization is extremely important to get a more global picture. The feedback mechanisms leading the starbursts will be studied as crucial for the cosmological models and for identifying which disc galaxies seem to be in the process of assembly at all redshifts-even in our local universe.

Regarding the nature of star formation modes, we will continue with our study of the connection between cincumnuclear SF and nuclear activity in galaxies paying special attention to the high energy emission of both components, star forming regions (e.g. binary stars and WR population, supernova remnants) and high energy emission coming from the AGN to the X-ray and gamma-ray spectrum.

Regarding the study of nebular HeII emiters, using a methodology similar to Kehrig et al. (2015), we will dicuss the origin of HeII4686A nebular lines in a large sample of nearby metal-poor starbursts to gain insight into the ionizing sources of the distant universe. Before interpreting high-z HeII emitters, it is crucial first to understand the formation of the HeII lines at low-z.

5. Participation in science verification and construction of new instrumentation
ESTALLIDOS aims at keeping closely integrated with the development of the new instrumentation. We do believe this activity is essential for the project providing us with an advanced position for the future scientific exploitation of these new facilities. In fact we have already participated in some projects as follows. (1) EMIR for GTC: we have been invited to participate in the science verification phase of EMIR and we already form part of the EMIR consortium. We have also been invited to apply to the EMIR guaranteed time and representative science cases of this project are underway; (2) MEGARA for GTC: we will provide the software to avoid collisions among the fibers positioners and we have developed user interfaces for the preparation of observations and data analysis, within the control software group with the UCM; (3) SITELLE at CFHT: we have been invited to join the team for the early scientific exploitation and science verification of this new Fourier Transform Spectrograph at the Canada-France-Hawaii telescope. Fresh panoramic (over 10´x 10´) full wavelength spectroscopic images with excellent seeing of nearby galaxies are in our hands and will be the basis of the main work of a new postdoc requested and, eventually, of potential Ph.D. students later. ESTALLIDOS is presently involved (at different levels) in several challenging future instruments as: (i) WEAVE for WHT: (ii) ATHENA mission and notably (iii) MOSAIC the MOS project for E-ELT.

3. Objetivos específicos

As in previous editions of this collaboration projects members from all the nodes will work in all the objectives. Therefore we will detail our specific objectives in the context of each of the main ones described above.

1. Interplay between massive SF and the interstellar medium within galaxies.

1.1 *Insight from optical IFS surveys*. Develop 2D codes that include non-axisymmetric components (e.g. bulge, bar and spiral arms). Reconstruct the recent SF and chemical evolution on kpc scales, and investigate the relations between ageing and quenching, stellar and gas mass, density, morphology, environment, and kinematics.

1.2 *The rôle of molecular clouds and diffuse gas*. Include the formation and destruction of molecular gas in our models and simulations, and compare their results with observational measurements.

1.3 *The high-energy component*. Include in our models the different contributions of hot gas, star forming regions (e.g. binary stars and WR population), and supernova remnants to the

X-ray and gamma-ray spectrum, confronting the predictions with observations and constrain different feedback mechanisms.

2. Understanding the formation of galaxy disks

2.1.- *Imaging the gas in the circum-galactic and intergalactic medium.* We aim at imaging the cosmic web in Hα around local galaxies, as well as to finding it as CaII H&K absorption features on the spectra of background sources. None of these approaches have been tried before, so, our proposal should be regarded as an effort to develop the tools needed to diagnose gas inflows and outflows around local galaxies. We will explore the surroundings of extremely metal poor (XMP) galaxies (described in item 2.3), as they are going through a gas accretion event at present, so their environment is expected to be particularly gas rich.

2.2.- *Modelling the chemo-photometric properties of disk galaxies.* Local massive spirals show negative abundance gradients, with the metallicity decreasing inside out. This metallicity pattern is related to the infall of gas forming the disks. We will use our chemical evolution models (e.g. Mollá & Díaz 2005, 2015, 2016) to predict the evolution of the radial gradients in galaxies of different morphological types and dynamical masses, and to compare them with observations to constrain the infall rate law. These predictions will be compared with existing data at various redshifts on the radial distributions of elemental abundances in disks. In addition we will try and model the fundamental metallicity relationship (Mannucci et al. 2010) to infer the typical gas inflow rates, mass loading factors, and clumpiness of the accreted gas (e.g., Peng and Maiolino, 2014).

2.3.- *Characterization of chemical and dynamical inhomogeneities in disk galaxies*. We will use 2D (IFU) spectroscopy to confirm our findings of existing inhomogeneities associated with the star-forming regions in disk galaxies (see 1.2) and to look for kinematical inhomogeneities that could support the external cause of the triggering of the star formation. Moreover, the dynamical studies are expected to assess rotation, and to what extent the disks are turbulent and pressure supported. These chemo-dynamical studies will also be carried out in Green Peas and other galaxies actively forming stars, known to have kinematically distinct but spatially overlapping gas components (Amorín et al. 2012; James et al. 2013). The chemical analysis of the different dynamical components will allow us to distinguish the metal-poor gas falling from the IGM from ejecta of SNe explosions. Polar-ring galaxies will be subject to chemo-dynamical analysis too.

2.4.-*Observational signatures to be expected from the accretion process*. The new generation of numerical simulations of galaxies in a cosmological context produces extremely realistic model galaxies (e.g., Schaye et al. 2015). We will use the EAGLE numerical simulations to identify chemical and dynamical inhomogeneities in the ISM of these galaxias, and to trace back in time their origin as individual accretion events. This would allow us to address several fundamental questions like: did the gas come from the galaxy gaseous halo, or was it accreted directly from the cosmic web? What is the time-lag between a gas accretion event and the starbursts that it triggers? Is accretion continuous or clumpy? Is it isotropic or along well defined streams? What can we learn from the cosmic web properties by studying metallicity inhomogeneities in XMPs?

3. Rôle of the environment on massive SF and evolution of galaxies

3.1.- *The spatial distribution of star-formation in cluster galaxies of the local Universe.* We will develop a method to automatically extract quantitative parameters describing the spatial distribution of the Hα emission in galaxies. We will also perform a quantitative study of the parameters describing the spatial distribution of the Hα emission in cluster galaxies, compared to that of a sample of field galaxies with similar properties. Finally, we will discriminate, with the aid of theoretical models, which physical mechanisms are (mostly) responsible for the observed properties of the distribution of the Hα emission in cluster galaxies, taking into account the global properties of the clusters and the position of galaxies with respect to the center of the clusters.

3.2.- *Star formation and chemical evolution in galaxy clusters: an overview along the history of the Universe.* We will select a sample of clusters covering a large redshift range, to be observed with different telescopes/instruments (PMAS@Calar Alto, MEGARA@GTC, EMIR@GTC). We will also study the evolution of the total SFR of cluster galaxies with redshift to confirm or discard a possible reversal of the star formation – density relation (e.g. Elbaz et al. 2007). Finally, we will make a detailed study of the metallicities of cluster galaxies at different redshifts to explore the link between star formation activity and metallicity evolution and the effect of the intergalactic medium on the balance between ambient pressure and gas outflows in cluster galaxies.

4. Extreme starbursts in the Universe

4.1.- The identification and characterization of starburst galaxies at different z in GOODs-N surveys. This - together with the analysis of each target by means of deep images from CANDELS -will allow to find the physical parameters of the bursts and their host galaxies.

4.2.- Select and study the bursts and host galaxy of the so called Green Peas and eXtreme Metal Poor (XMP) objects. Analyse the results in the global context of starburst galaxies. Confirm or discard the disk nature of their hosts.

4.3.- Determine the feedback of the clump sample in the starbursts galaxies with the use of our theoretical photometric and spectroscopic diagnosis diagrams. Establish their statistical importance and resulting mechanical energy output. Discuss the results in a broad cosmological context. Explore the possibilities to take these results into account in the EAGLE simulations.

4.4**-** We will make use of the updated stellar population models described in 1.3 to quantify the different contributions to both star forming regions and the AGN to the X-ray and gamma-ray spectrum, confronting the predictions with observations and computing the energy balance in as much as possible.

4.5.- Search for targets at high z or Lyα emitters. Identify and characterize of Lyα sources.
SF Feedback of the Star Forming clumps in LAE galaxies at low z- HST data.

4.6.- To develop observing proposals for EMIR (for targets in points 4.2 and 4.5), MEGARA (targets in points 4.1 and 4.2) and WEAVE (targets in point 4.1).

4.7- Investigate the nature of nebular HeII emission in a sample of extreme metal-poor star-forming galaxies: observe candidate hosts of analogues to PopIII star siblings. Total HeII ionizing photon budget of most metal-poor galaxies will be derived and discussed on the basis of the predictions of state of the art stellar models and conventional HeII ionizing sources as proposed in Kehrig et al. (2015).

5. Participation in science verification and construction of new instrumentation

5.1.- *EMIR for GTC.* Implementation of observing proposals of ESTALLIDOS science (distant galaxies; z-evolution of clusters galaxies; Lyman targets) that will be carried out in the science verification phase of EMIR. Participation, by invitation, to submit applications to the EMIR guaranteed time (in coordination with WP 3.2 & WP 4.5).

5.2.- *MEGARA for GTC.* ESTALLIDOS -through the IAA node- form part of the construction consortium for this IFU-MOS instrument; we belong to the control team of his consortium, and will provide S/W for fibre positioners. We will provide user interfaces for preparation and analysis, as part of the control group in collaboration with the UCM.

5.3.- *SITELLE at CFHT.* Build a robust data reduction package and provide extensive data reduction and analysis -over 10´x 10´- of panoramic full wavelength spectroscopic images, (with excellent seeing), of a selected set of extended disks of nearby galaxies (the IAA node belongs to the team for 1st science exploitation and science verification).

5.4.- *Other commitments of ESTALLIDOS for future instruments:* (i) WEAVE for WHT: contributing as active members of two science groups of the Science Team: “galaxies” and “clusters of galaxies” (all nodes); (ii) mission ATHENA: provide preparatory work with our own galaxy simulations (UAM node); (iii) preparatory work within the control system S/W for MOSAIC for E-ELT (after Phase A, the IAA node in collaboration with the UCM, contributing to the consortium).

4. Metodología

1. The interplay between massive SF and the Interstellar medium within galaxies
Leaders: MM (CIEMAT) and AID (UAM)

WP1.1.- *Insight from optical IFS surveys*
We will develop a new generation of 2D chemical evolution models, extending the successful bi-parametric grid of 1D models for galaxy disks by Mollá & Díaz (2005) by considering a bi-dimensional density distribution including a parametric spiral wave (Junqueira et al. 2013) as model input (WP1.1a1). At a later stage, we will try and include the spiral arm equation in the evolution code. A large grid of chemical models for spiral galaxies in 2D, with varying spiral pattern speed, perturbation amplitude, and scale lengths, will be computed and made publicly available through a dedicated web interface (WP1.1a2). The development of these models will be the subject of SW's PhD thesis, co-supervised by MM and DSW, from U. Nairobi (Kenya).
We will also characterize recent SF on local scales, using proxies such as EW(Hα) and broadband colours (WP1.1b1), as well as full reconstructions of the SF history based on spectral population synthesis modelling (WP1.1b2). In both cases, signatures of ageing and quenching processes will be investigated as a function of global observables (stellar and gas mass, morphology, environment, interactions) as well as the presence of AGN (WP1.1b3). These tasks will be led by the experienced (postdoctoral) researcher ER-UAM.

WP1.2.-*The role of molecular clouds and diffuse gas*
This will be the subject of FPI-UAM1's PhD thesis, co-supervised by YA and MM. Rather than considering the formation timescale of molecular clouds as a free parameter, we will attempt to model the condensation of hydrogen molecules onto dust grains and their photodissociation by UV photons following Draine & Bertoldi (1996). Instantaneous SF will be proportional to molecular gas mass (Leroy et al. 2008), and chemical evolution may proceed according to our previous treatment. This scheme will be compared with other prescriptions in the literature using Milky Way data (WP1.2a1), and more elaborate modelling -- including turbulence, cosmic rays and magnetic fields – will be attempted at a later stage (WP1.2a2). In addition to these analytical models, we will implement the corresponding equations into the cosmological simulation code Gadget (WP1.2a3) in collaboration with Dr. C. Scannapieco (AIP, Germany). In this moment we are also working in the calibration of the different molecular gas formation prescriptions within our chemical evolution code comparing with the Milky Way radial distributions. In order to constrain the models and study the dependence of local gas flows and SF on mass and metallicity (WP1.2b2), we will combine optical IFS and radio observations of a set of blue compact dwarfs (WP1.2b1) with literature data on larger and more metal-rich systems. YA and ALS plan to apply for external funding in order to co-supervise a PhD thesis on this topic under the recent agreement between the UAM and U. Macquarie (Sydney, Australia).

WP1.3.- *The high-energy component*
WP 1.3.1: Update our evolutionary synthesis code for simple stellar populations (Mollá et al. 2009), which already computes the expected numbers of massive stars of different types, supernovae, and compact remnants. High spectral resolution, binary stars, rotation, and metal-dependent mass loss, potentially affecting the formation and evolution of WR stars (e.g. Meynet & Maeder 2005, Vanbeveren et al. 2007; Eldridge et al. 2008) will also be included, as well as the effect of a finite (low) number of stars, significantly improving upon current models (as shown by e.g. Bruzual 2014). These tasks could constitute an outstanding Ph.D. project for FPI-CIEMAT1, to be co-supervised by MM and YA.

WP 1.3.2: By adding the high-energy component (photons and cosmic rays) to our evolutionary synthesis PopStar code, we will be able to predict the full spectral energy distribution of a given galaxy, from gamma rays to the radio band, as a function of the local physical conditions (most notably, gas density and intensity of the radiation and magnetic fields), which will help to discriminate different SF feedback mechanism adding the high spectral resolution. It implies to include the phenomenological treatment of high-energy photons in our current evolutionary synthesis models, making a complete census of such astrophysical sources within the Milky Way and including this information in the Popstar code. These tasks could constitute the Ph.D. Project for FPI-CIEMAT2, also in close collaboration with the UAM node.
WP 1.3.3: Use the public GALPROP code to relate the cosmic-ray spectra with the non-thermal component of the emission of starburst galaxies. This will be the work for ER-CIEMAT, and it can´t be accomplished without the required manpower.

2.- Understanding the formation of disk galaxies.
Leaders: JSA (IAC) and EPM (IAA)

WP2.1.- *Imaging the gas in the circumgalactic and intergalactic medium.*
Due to various physical processes, like release of gravitational energy (Furlanetto et al. 2003, Goerth et al. 2010) or re-emission of UV photons from nearby sources (Cantaluto et al. 2014, Elmegreen et al. 2014), the gas of the cosmic web is expected to emit in the HI lines. It has been observed at redshift around two in Lyα (e.g., Cantaluto et al. 2014), and the same processes will produce Hα as well. The expected signals are very uncertain but, in any case, they will be weak, of the order of 10^{-19} – 10^{-17}erg/sec/cm^2/arsec^2. The observation of these faint signals is difficult but feasible. The main problem is to overcome the emission of the sky, which is at least two orders of magnitudes brighter than the expected signals. First, the sky has to be subtracted, and second, the photon noise must be small enough to be neglected, since it cannot be removed. The sky subtraction requires a precise flatfielding using the observations (e.g., Fluri & Trujillo, 2016) and the fact that we observe an emission line allows us to remove the sky by subtracting a narrow band image from a quasi-simultaneous broad-band image. Using a GTC medium band filter (150A FWHM), the noise created by the sky reaches a level comparable with the expected signal after integrating for several hours; therefore, the use of large telescopes is mandatory to carry out the imaging. Moreover, GTC is a realistic option since 5% of the nights per semester are photometric with very poor seeing (< 2 arcsec), a time which could be used for our project running as a filler program. (5% of 100 nights represent 40 hours per semester.) In order to proof the viability of the approach, we have already observed a target for 10 hours using GTC, a data set that we are in the process of reduction at present. Going to space is another option to avoid the sky emission, and thus, we requested and got time to observe one of the targets (Elmegreen et al. 2014). These observations are in the process of analysis at present, and they will also be pursued if successful. The use of IFUs for the same purpose will also be discussed in WP2.3.

WP2.2.- *Modeling the chemo-photometric properties of disk galaxies.*
The radial distribution of elements like O, N, C, S, or Ne, is obtained from HII regions and also from PNe (Maciel & Koppen 1994; Maciel et al. 2005; 2006). Both measurements combined provide the time evolution, since HII regions yield the present time distribution while PNe sample the abundance of the ISM several billions years ago. Thus, Maciel et al. (2005, 2006, 2007) suggest that the radial abundance gradients tend to steepen in the past, flattening with time as predicted in Mollá et al. (1997), Marcon-Uchida et al. (2010), and Fu et al. (2009). This is in agreement with several works (e.g., Magrini et al. 2007; Kudritzki et al. 2012), but disagrees with others finding gradients steepening with time (Stanghellini et al 2006; Stanghellini & Haywood 2010) or remaining unchanged (Magrini et al 2009a,b, Bresolin 2011). We will calculate grids of chemical evolution models with different prescriptions for the gas infall rate and for the star formation law, to see which one of these possibilities is closer to the observations and, therefore, which is the most probable scenario for isolated galaxies. This is a task for one ER-CIEMAT.

WP2.3.- *Searching for chemical and dynamical inhomogeneities in disk galaxies.*

In order to detect local inhomogeneities, we need spatially resolved spectra of the targets. So far, we have used long-slit spectra (Amorín et al. 2012, Sánchez Almeida et al. 2015), but we plan to use IFUs to get 2D maps of galaxy properties. We will use archival data for exploring inhomogeneities in massive galaxies (CALIFA; Sánchez et al. 2012), and MUSE (Bacon et al. 2010) and the new GTC IFU, MEGARA (Gil de Paz et al. 2014) and the recent SITELLE panoramic full wavelength spectra, to analyse our targets. These new data are at the basis of the work of the new IAA PhD, and form part of the work to be carry out by one of the new postdocs ER-IAA2. The determination of the metallicities will be carried out using the direct method whenever possible, or the variant developed by Perez-Montero (2014). In order to verify that the inhomogeneities are produced by mixing with metal poor gas, we will measure the abundances of at least two elements: N and O. Dynamical properties will be computed using emission line widths and centers (e.g., Sánchez Almeida et al. 2013), and multicomponent decompositions will be carried out when required (e.g., Amorin et al. 2010, del Olmo et al. 2016). Having enough spectral resolution is critical in this respect. As far as the targets is concerned, we have compiled catalogues with all the known XMPs (Morales Luis et al. 2011; Filho et al. 2013, Sanchez Almeida et al. 2016), which include a few hundred sources. For the chemo-dynamic studies of SB galaxies in zCOSMOS (redshift < 0.7), for which we have MEGARA granted time, we will use targets selected in Amorin et al. (2015).

The IFU data can also be used to image the cosmic web, as proposed in objective 2.1. It has many advantages with respect to the color filter approach, since it allows minimizing the contamination produced by the sky (e.g., Vera et al. 2016). The sky emission to be subtracted is obtained automatically and with a minimal contamination. The drawback of the IFU approach is the small FOV compared to the expected spread out emission. For this reason, IFUs are not our first option to search for cosmic web signals, however, we will search for them around the targets studied with IFUs for inhomogeneities.

WP2.4.- *Observational signatures to be expected from the accretion process.*
One of the few numerical simulations of galaxy formation with the baryon physics explicitly included is the EAGLE numerical simulation (Schaye et al. 2015; Crane et al. 2015). We have already a scientific project approved within the EAGLE consortium ('Search and characterization of metallicity inhomogeneities in primitive disks') to characterize the properties of the starbursts in model galaxies, including the kinematics and the presence of metallicity inhomogeneities. The numerical simulations are already available. Software tools will be developed to identify the clumps and to trace back in time their extragalactic origin.

3.- <u>The Rôle of the environment on massive SF and evolution of galaxies</u>
Leaders: JIP (IAA) and JVM (IAA)

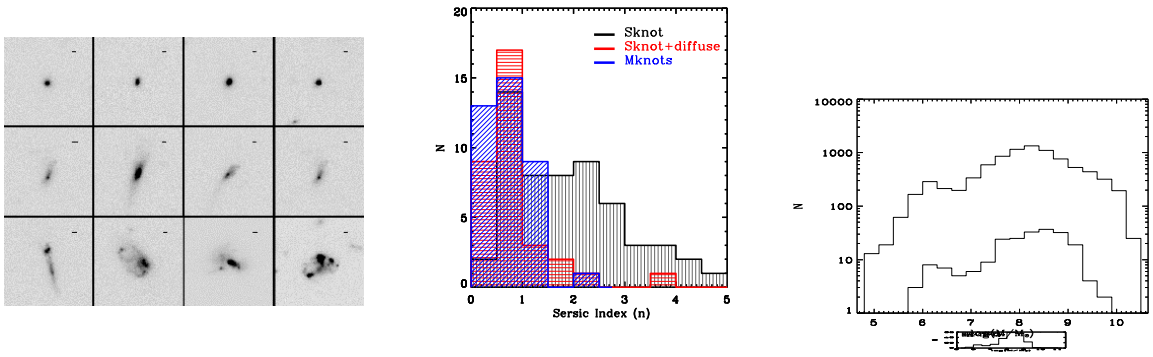
WP3.1.- *The spatial distribution of star-formation in cluster galaxies of the local Universe*
WP3.1.1: First we will select the sample of galaxies to be studied from our database of cluster galaxies observed in Hα. Catalogues of galaxies from this database are already built from previous work. The selection will be based on morphology and stellar mass limit.
WP3.2.2: Next, we (JIP, JVM, SDP, DRP, JHF, JAC) will compile a control sample composed by field galaxies of the local Universe from previous works in the literature (e.g. James et al. 2008) to be compared to our cluster galaxy sample.
WP3.1.3: Once we have our two samples of galaxies we will develop an automated method to characterize the distribution of the Hα emission of the cluster galaxies. For this, we will estimate quantitative parameters like concentration and asymmetry of the emission, and eventually the Gini indices. This method will produce a list of parameters describing the distribution of the Hα emission in both the cluster and field galaxy samples.
W3.1.4: With these results, we will classify the cluster and field galaxies according to the morphological parameters obtained from the Hα emission, and compare them. In order to test the role of the environment on the Hα morphology of cluster galaxies, both the global properties of the cluster (total mass, pressure of the intergalactic medium) and the position of the galaxies within the cluster will be evaluated.
W3.1.5: Finally, to interpret our results in terms of the dominant physical mechanisms acting on the galaxy clusters, we will compare our results to the predictions of theoretical models of

galaxies entering dense environments (e.g. Kronberger et al. 2008, Bekki 2009), and galaxy-galaxy interactions (e.g. di Matteo et al. 2008).

WP3.2.- *Star formation and chemical evolution in galaxy clusters: an overview along the history of the Universe.*
WP3.2.1: A sample of clusters at different redshifts will be selected, covering up to the limit imposed by EMIR @ GTC to get the Hα+[NII] emission lines.
WP3.2.2: We will design observing proposals for EMIR @ GTC for the distant clusters of our sample. By properly combining different setups, we will be able to observe, for the distant clusters, the Hα+[NII] lines as well as the Hβ+[OIII] lines.
WP3.2.3: We will also prepare observing proposals for MEGARA @ GTC, to observe the local Universe clusters of our sample.
WP3.2.4: Once the clusters have been observed, the data will be reduced and prepared for interpretation using the pipelines provided for each of the instruments.
WP3.2.5: The analysis of the spectra obtained both from MEGARA and EMIR will provide two important parameters: the star formation rate (SFR) and the metallicity of the cluster galaxies. The SFR will be estimated from the Hα luminosity, corrected for extinction via the Hα/Hβ ratio. Also, the EW(Hα) will provide information on the intensity of the star formation activity. The metallicity of individual galaxies will be estimated, we will use empirical parameters like O3N2 (log([NII]/Hα)-log([OIII]/Hβ)), or N2 (log([NII]/Hα)), as well as semi-empirical and model based determinations.
WP3.2.6: Finally, we will perform a detailed analysis of the evolution of the SFR and metallicity with redshift. Special attention will be paid to the correlation of these two parameters with the position of the galaxies in the clusters and the global properties of these latter ones. A comparison of the results of the observations with the most relevant models (Davé et al. 2011, 2012) will be carried out.
These WPs, and very especially the new data from EMIR and MEGARA at GTC, constitute the basis of the work to be carried out by the postdoc ER-IAA1 requested by IAA node.

4) Extreme starbursts in the Universe
Leaders: CMT (IAC) and MMH (CAB)

WP4.1 *The identification and characterization of starburst galaxies at different z in GOODs-N surveys*.
Previous studies have shown than starbursts in COSMOS up to z=1 are clumpy and the mass of the more massive clumps scale to that of their host galaxy. We have also classified the starburst clumps as: Single knot (Sknot), Sknot and diffuse light (Sknot+diff) and Multiple knots (Mknot) (Fig 1).



(a) (b) (c)

Fig.1 . a) Examples of the three classes identified in the starbursts. b) The distribution of the parameters for the hosts. c) Mass distribution of starbursts galaxies in COSMOS up to z=0.5.

The search was made using the SUBARU filters and was part of Hinojosa Goñi PhD work (Hinojosa Goñi et al. 2016a). Panel a) shows examples of the three classes identified as starbursts. An important conclusion is that all classes but the Sknot galaxies are disks (Hinojosa Goñi etal, 2016b) (see panel b). The Sknot class may be a transition one with characteristic similar to that of the LSB galaxies and Green Peas. Panel c) shows the mass

distribution of starbursts galaxies in COSMOS up to z=0.5. The plot includes also that of the quiescent. Note that both distributions are remarkably similar what puts into evidence that starbursts are just transient fases. The mass peaks at about 10^8 Msun (see panel c). Based on the prediction of recent numerical simulations, we suggested that most of the clumps have been produced by violent disk instabilities. In this scenario, large and massive clumps at the galaxy centers are the end-product of the coalescence of surviving smaller clumps from the outskirts. A similar procedure will be implemented in GOODs – using also results from SHARDS (Pérez-González et al. 2014) to identify objects with emission lines up to z=1. CANDELs will be used to identify the star forming knots, classify the galaxies according to their starburst morphology and parameterize the host.

WP4.2.- *Select and study the bursts and host galaxy of the so called Green Peas and Xtreme Metal Poor (XMP) objects.*
We will extend the study of the targets using high spectral resolution (HSR) data. We already have a large sample observed at the INT including more than 30 galaxies which also have been identified as XMPs (Morales Luis et al, 2011). With this data we will be able to further confirm their disk nature by means of the rotation curve pattern, as we did in Sánchez Almeida et al. (2013).

WP4.3.- *Determine the feedback of the clump sample in the starbursts galaxies with the use of our theoretical photometric and spectroscopic diagnosis diagrams.*
The details of the emission line pattern of the starburst clumps will be annalysed to define their feedback following the spectroscopic and photometric diagnosis plots from our models (Tenorio-Tagle et al 2010, 2013). Our theoretical models provide the parameters to be used to define the feedback of the SB clumps.

WP4.4- *Massive circumnuclear clumps and AGNs.*
Circumnuclear massive regions, many of them a few hundred pc in size, seem to be made of several HII regions showing integrated Hα luminosities, which overlap with those of HII galaxies (typically higher than 10^{39} erg s^{-1}) and seem to be ionized by luminous compact stellar clusters whose sizes, as measured from high spatial resolution Hubble Space Telescope (HST) images, are seen to be of only a few pc. These regions are young (age< 10^7 yr), massive (M_{dyn} up to $2x10^8$ Msun) and in the UV-B wavebands, they contribute substantially to the emission of the entire nuclear region, even in the presence of an active nucleus (e.g. Colina et al. 2002).
The best strategy to study the complex star forming regions in galaxies is the use of Integral Field Spectroscopy. While CNSFR in nearby galaxies can be studied with current IFUS like VIMOS at the ESO VLT or GMOS at GEMINI telescope, for intermediate redshift galaxies the best instrument to do accomplish this work is MUSE (Multi Unit Spectroscopic Explorer) a new instrument for the VLT expected in the next years. MUSE is the new Integral Field Unit spectrograph for the VLT. With a field of view 1 arcmin x1 arcmin it would be the more powerful and large IFU device available in a large telescope. We will use this incredible instrument to carry out spatially resolved spectroscopy of galaxies at intermediate redshifts, z approx. 1.0 within the wavelength range from 4650 Å to 9300 Å. Our experience with other IFUs tells us that this will provide a very deep search for emission line objects e.g. in the discs of spirals and star-forming dwarf galaxies at earlier epochs.
The availability of a partial Adaptive Optics system in MUSE, will enhance efficiency, providing unique access to the inside of compact star forming complexes, and their young super star clusters responsible of ionisation, living in bursting star forming galaxies at z around 1. For $0.5 < z < 1$, the MUSE pixel size of 0.2 arctic projects in a physical size of approx 1.6 kpc (concordance cosmology). This scale will allow to export our technique for derivation of chemical abundances and the physical parameters to this redshift window with a guarantee of success. Therefore, galaxy variations of gas chemical composition, stellar populations ages and metallicities, and extinction, among other properties, can be explored with this instrument at VLT. Of course, all these parameters will be combined with the study of the stellar and gas kinematics. For the redshift range of $0.25 < z < 0.9$, all oxygen lines [OII] 3727, [OIII] 4959, 5007 and Hβ are reached within the MUSE spectral range allowing our detailed science case to be developed for intermediate redshift. According to MUSE ETC specifications, for typical present-day L* galaxies spatial information can be derived from

emission lines with fluxes larger than 10^{-17} erg s^{-1} cm^{-2}, which is enough for the purposes of this study.

WP 4.5 *Search for targets at high z or Lyα emitters*.
The Lyα galaxies study will be two-folded: we will search for targets at higher z – the Lyα emitters sample – and we will study galaxies from LARS (Östlin 2009) at lower z. LARS aim was to quantify the dependence of the Lyα escape fraction on the host galaxy, improving the calibration of this tracer. In ESTALLIDOS we will analyse the data – accessible to us – aiming at determining the feedback of the different knots in the galaxies. For that we will use the photometric and spectroscopic data, already available, and our diagnostic models. This is part of the PhD work of Alejandro Lumbreras.
For the Lyα emitters we are currently undertaking a search in the SHARDS survey, where we have found ~90 LAEs /LBGs (PhD work of Pablo Arrabal Haro). Preliminary results are exciting. We have spotted a Lyα excess, close to a LAE galaxy at z=3.5. The HST ACS camera does not see this excess emission, though the HST/ACS image does indeed show the companion galaxy, even if the ACS image is much deeper than the SHARDS narrow band image. If it is a new starburst it could be the second case of recurring star formation in high-z galaxies, the first being the one found in our group (Rodriguez Espinosa et al. 2014). If it is pristine gas falling onto the companion galaxy this would be the first known case at high-z, where it should be commonplace (Sánchez-Almeida et al. 2014). If, finally, it were an outflow we should see the velocity-displaced Lyα line with respect to the Lyman break seen in the companion galaxy.
Besides the detailed study of particular targets we will be able to do a statistical study of Lyman α sources in SHARDs (Pérez-González et al. 2013) catalogue up to z=5. For this we count on the close collaboration with Pablo Pérez González (Shards, PI)

WP 4.6 *Development of observing proposals for EMIR, MEGARA and WEAVE.*
The complete sample of nearly 1000 galaxies in our catalogue in COSMOS up to z=1 is ideal for observations with WEAVE. Although no long slit is available we will place the fibbers on the precise location of the knots already known from our previous work. Moreover and after the photometric analysis already carried out we can define the extreme cases that will be those observed with high priority.

WP4.7 *Investigate the nature of nebular HeII emission in a sample of extreme metal-poor star-forming galaxies.*
A preliminary sample for extreme HeII emitters in the local universe is prepared with a complete search for HeII emitters in SDSS latest releases. First, a BPT selection of star-forming objects will be done, imposing also narrow lined emission to avoid WR and/or AGN contamination; then, a careful inspection of the underlying stellar population subtraction will be addressed. This is a procedure that needs to be optimized, given that the HeII4686A line flux is not large, by comparing and cross-correlating the Portsmouth and MPA SDSS databases of spectral emission line fluxes. The HeII4686A line does not appear detected as such with a workable measured flux in MPA based SDSS tables. Once this preliminary list is done (about 300 candidates are to be selected from our previous tests) we can start the analysis of the excitation and physical properties of the objects. Then we will elaborate a framework for the highest HeII emitters in the most metal-poor galaxies, selected via their O/H abundance derived making use of [OIII] 4363 A line flux for electron temperature derivation.

Finally, a reduced list of high quality local and distant HeII emitters will be selected from the above and also from our own previous observations, plus the literature (e.g. Tornatore et al. 2007; Xu et al. 2016; see refs. in sect 1 above) as well as from data from the most recent (e.g. VLT) and ongoing surveys to be made public soon. IZw18-like galaxies (including it as the prototype, Kehrig et al 2016 in press) will be observed using MEGARA during guaranteed time (IAA). Following Kehrig et al. (2015) the spatial extension of the HeII emission zone will be mapped and the corresponding quantitative ionization budget analysis will be carried out for each object.

5.- Science verification and construction of new instrumentation
Leaders: JVM (IAA), CMT (IAC)

To achieve this transversal objective of ESTALLIDOS we are deeply committed to this fundamental WP5. i.e. giving support to the development and scientific verification of the new instrumentation, as detailed below.

WP5.1.- For *EMIR@GTC* (led by the IAC node) we will keep organizing the activities of the Commissioning Team of 15 astronomers and the preparation and submission of proposals for early science with EMIR Guaranteed Time (2017).

WP5.2.- For *MEGARA@GTC* (led by the IAA node) we will keep participating in the instrument construction consortium and attend to the weekly Telecons of the Consortium and the technical meetings of the Control system group (two/year typically) and annual meetings. We will also participate in the astronomers' team for science verification at GTC (2017-18; the GTC contact astronomer, DRP, is a member of the IAA node team). And finally, we will continue the technical work: S/W packages provided by the IAA node (two IAA engineers involved), including preparation of the documentation for final delivery (2017).

WP5.3.- For *SITELLE@CFHT* (led by the IAA node) we will work with first science data of common proposals with Univ. Laval (Quebec). We will also Implement the data reduction of panoramic images adapting our methodology, used in CALIFA project, to recover and extract spectra of the diffuse emission. (iv) Other instruments (all nodes UAM+CIEMAT+IAC+IAA). For MOSAIC (E-ELT) we will attend the consortium telecons (one/month) and the corresponding annual meetings of the collaboration. We will also contribute to the science team and to related scientific documentation. On this new MOS (expected for 2024) we are involved together with the UCM in the consortium (IAA node), contributing after phase A is completed.

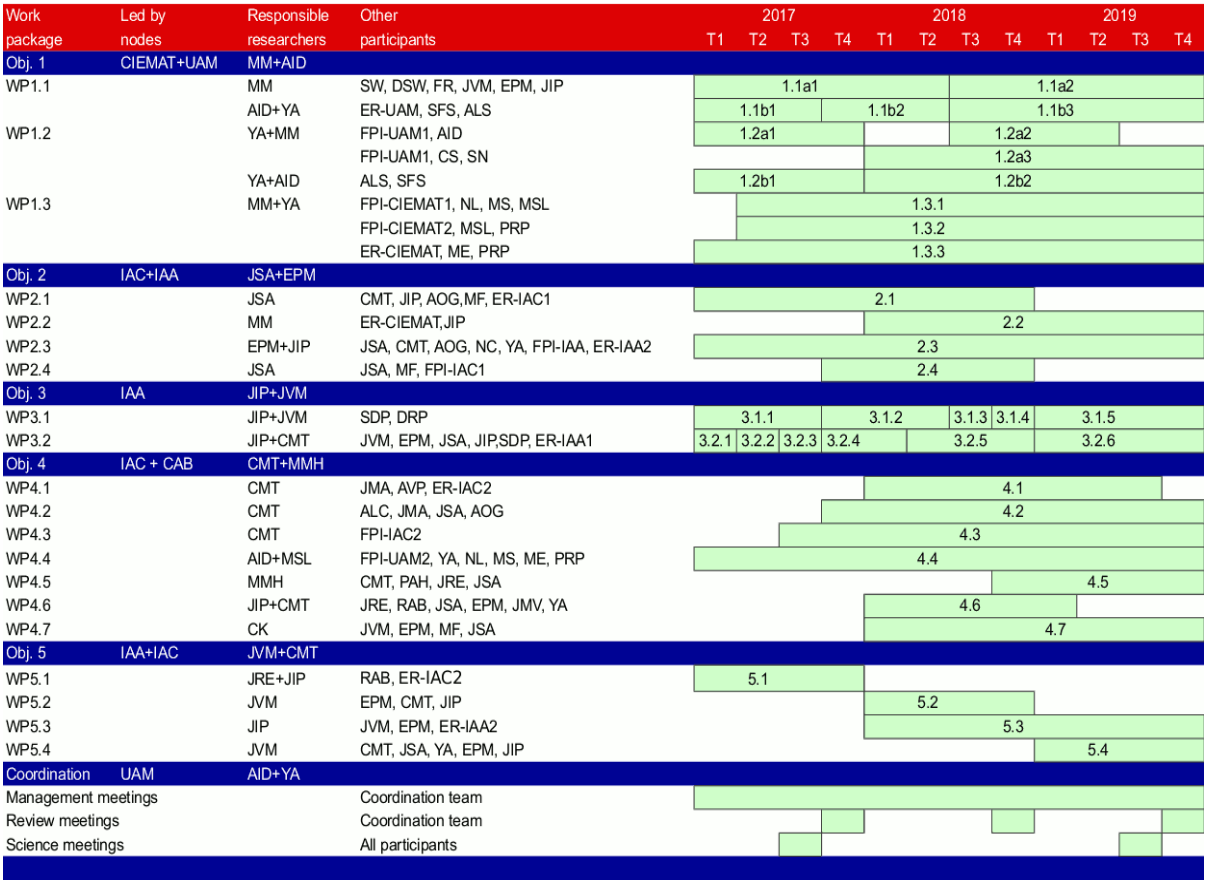
WP5.4.- *Other instrumental commitments* of ESTALLIDOS include: WEAVE for WHT where we belong to the Science Team (members of two science groups: galaxies and clusters of galaxies); the mission ATHENA (preparation of galaxy simulations for Science Working Group SWG2.3), and most notably MOSAIC for E-ELT (IAA node responsibility: we will keep attending all consortium meetings and telecons, and the IAA, in collaboration with the UCM group, will be contributing within the consortium construction once Phase A is over).

5. Medios materiales, infraestructuras y equipamientos singulares

All the nodes can make use of the facilities that each institution makes available to them, including computing facilities, access to the different data bases and archival data and supercomputer facilities (UAM: Centro de Computación Científica). All the researchers at the different nodes can apply for observing time at the different national ICTS on a competitive basis as well as to ESA and ESO time and other infrastructures in open access regime. All the nodes possess the necessary software to reduce and analyse the secured data.

6. Cronograma

A succinct timeline of the proposed work packages is provided below, including information about the tentative schedule of the main coordination tasks:



7. Contratación de personal

Subproject UAM (A.I. Díaz & Y. Ascasíbar) requests one postdoctoral contract to play a leading role in task WP1.1b, involving the analysis of IFS observations, their interpretation in terms of population synthesis models, and a systematic study of the relation with global galaxy properties, such as mass, morphology, and environment, as well as locally-measured quantities such as surface density, metallicity, or the presence of an AGN. Aside from the necessary technical knowledge, this work requires a large degree of thought and interpretation in order to be successfully accomplished, and it is certainly most appropriate for an experienced researcher (ER-UAM) in close collaboration with the PIs. The amount of work involved is substantial, and it would be difficult to carry it out without the requested contract. On the other hand, it also provides excellent training opportunities, and the ER will be encouraged to co-supervise any available graduate or (most likely) undergraduate students towards the completion of their M.Sc. and B.Sc. projects.
This coordinated project involves a large number of researchers and collaborators of different international institutions and proposes to carry out a variety of activities: conference organization, specific workshops design, dissemination of results, outreach activities etc. Therefore, in order to have an efficient planning, development and monitoring it requires a scientist in charge of these functions. He/she would also be in charge of the maintenance and update of the project WEB page that would help to improve communication between members and increase the visibility of the project. We then propose the part time (20h) contract of a Science graduate.

Subproject CIEMAT (M. Mollá) is requesting for two post-doctoral contracts (ER) to do some of the tasks already described, in particular T1.3c and T2.2. In the first case the ER will work with the GALPROP code to update the information about MW included there and also to modify it, including data of other star-forming galaxies in order to relate the resulting gamma diffuse maps with the non-thermal emission of starburt galaxies. This is hard task which implies the well known of a (quasi)-public code with a large number of sub-packages, good

knowledge of the metal enrichment, gas distributions, supernova behaviour and also a good management of the transport equation applied to the cosmic rays and of the HE phenomena. This task will be done in close coordination with the UAM subproject. The second one refers to the adequate extraction of information of grid of chemical evolution models and the comparison of results for a set of different masses and morphological type theoretical galaxies with observational data and other cosmological hydrodynamic simulations. Therefore it is also would need the construction of a good catalogue of all type of data: abundances, stellar populations, infall rates, gas and stellar densities, SFR, colors, etc, which is now feasible but hardly due to the large number of IFU projects with available data. This will need the coordination with members of the IAA and UAM. In both cases it is necessary to claim that CIEMAT group is small and, even if we account for with the other nodes researches and other foreign institutions doctors, we need more people to better address the assigned tasks.

Subproject IAA (JVM & EPM) requests two postdoctoral (ER) contracts:
A) One ER-IAA1 to carry out the tasks related to objective WP3.2. This objective includes the study of the evolution of the star formation rate (SFR) and metallicity of a sample of galaxies in clusters, selected along different epochs of the Universe, using different instruments, most notably MEGARA and EMIR @ GTC. The necessity of incorporating an ER postdoc here is crucial since most of the tasks related to this objective only can be performed by an experienced researcher in the field. The profile required for this contract should include:
i) experience in the field of galaxy evolution, in particular, in the derivation of parameters like SFR and metallicity of galaxies, accounting for the population of the young massive stars and gas in galaxies;
ii) experience in the physics of and properties of galaxies located in dense environments, like groups or clusters of galaxies, and expertise with the study of the effects of interactions on galaxy evolution (galaxy-galaxy interactions, mergers, tidal dwarf galaxies, etc…);
iii) must hold experience in observational Astronomy, mainly optical and NIR spectroscopy, since these skills will be absolutely necessary during all phases of this objective (preparing observing proposals, data reduction and handling, data analysis, etc...); and
iv) experience with theoretical models, since the observational results should be compared to the most relevant models of chemical evolution of galaxies in dense environments. As it can be seen, this set of tasks, which are explained in more detail in the Methodology section of this document, represents in itself a selfconsistent project that deserves complete dedication of one experienced person. For this reason we ask for funding for a postdoctoral (ER level) contract in order to coordinate and lead this objective within the IAA group. We have estimated that the duration of this objective, to reach a satisfactory and advanced stage, is in agreement with the three (3) years duration of the postdoctoral contract requested.

B) IAA node asks for one ER (ER-IAA2) to work on WP2.3 in close coordination with the WP 5.3. This researcher will be in charge o the development of an automated method to detect and measure the spectrum of the diffuse gas in star forming and disk galaxies from bi-dimensional spectroscopy (PMAS, SITELLE). This is a complicated task since the diffuse ionized gas (DIG) is a very tenuous component that has not been studied in detail outside of the Milky Way because of its low surface brightness. Our participation in SITELLE @ CFHT (see methodology WP5.3; led by IAA node) offers a precious and timely opportunity to work with the first science data of panoramic (10´x10´) spectroscopy of nearby galaxies, in collaboration with Univ. Laval (Quebec). We will implement the data reduction of panoramic images adapting our methodology, used in our previous ESTALLIDOS edition for the CALIFA project, to recover and extract the spectra of the diffuse emission. We need to adapt and develop a complete and robust method to detect and measure this component for these panoramic field spectra. We estimate that (from our experience in CALIFA) the full code for extracting the spectra of the DIG, derive their main properties and performing the full spectral analysis of the regions in the panoramic spectroscopy data will take 3-years to this experienced researcher. He/she will apply his/her method to the complete databases of extended CALIFA and SITELLE (already available observed) galaxy targets. This researcher must hold a PhD in Astronomy with high experience in programing and familiar with the physics of the ionized gas in star forming regions. He/she will be an expert dealing with bi-

dimensional spectroscopy data and have demonstrated skills in programming with IDL, or Python.

Subproject IAC

The subproject IAC Tenerife node requests two postdoctoral (ER) contracts (two years each). One of them associated with the tasks of objective 2 and the other with objective 4. Task 2.1 requires of processing images to reach unprecedented depth, and we will need external assistance for it. We are in the quest for a new method to characterize the gas of the cosmic web. If the effort turns out to be successful, the postdoc will end up with a knowhow fundamental for the advance of the discipline, and so, with unique skills to support his/her future scientific career. In addition to this task, the postdoc is needed to participate as team members in all the activities of the project at the IAC.

Tasks 4.1-4.5 include the development of specific tools for the search of targets at longer wavelengths to extend the study to z larger than 1. Our positive feedback models are also to be extensively tested both by observations in the mm wavelength (warm dust) and tailored for massive clumps of kpc sizes. These are the duties and skills of the postdoc proposed. Besides, both postdocs for objectives 2 and 4 will participate as team members in all the activities of the project at the IAC.

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ACRONYMS:

- AGN: Active Galactic Nuclei
- CALIFA: Calar Alto Legacy Integral Field Area Survey
- GTC: Gran Telescopio Canarias
- ER: Experienced researcher (Postdoc)
- FOV: Filed of view
- FWHM: Full width at half maximum
- HST: Hubble Space Telescope
- IFU: Integral Field Units
- IGM: Inter galactic medium
- MEGARA: Multi-Espectrógrafo en GTC de Alta Resolución para Astronomía
- MWG Milky Way Galaxy
- MUSE: Multi Unit Spectroscopic Explorer
- PNe: Planetary nebulae
- QSO: Quasi Stellar Object
- XMP: Extremely metal poor galaxies

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C.3. IMPACTO ESPERADO DE LOS RESULTADOS

The four nodes (IAC-IAA-UAM-CIEMAT) of ESTALLIDOS will keep a commitment to disseminate the main results arising from the scientific activities of its members. And this dissemination will follow the main guidelines of this diffusion plan.

We will focus on the diffusion or our results among the members of the scientific community. All our scientific findings will be published, as it was done in our previous projects, in top impact journals (e.g. MNRAS, A&A, ApJ, AJ, etc), where the visibility of the scientific results is high among the members of the international scientific community. Also, the members of ESTALLIDOS will attend the most straightforward scientific meetings and workshops to present our results, whenever possible in the form of review or invited contributions.

In addition to this, we know of the importance of becoming a world-leading group in our research area. For this we plan to participate at the highest level in the organization of international collaborations and networks, and to become members of advisory panels of institutes, journals, facilities (telescopes/instruments), etc. An international conference organized (mostly) by ESTALLIDOS members will be proposed for the last year of the duration of the project.

We do consider that the transmission of the results of our research must be shared with the society at all the possible levels. The main tool we will use for this task is our web page (http://estallidos.iac.es/estallidos/). This page already contains a section devoted to our outreach activities. We will add new sections to attract new visitors demanding answers to satisfy their curiosity. For that we plan to open a new section “Ask a question, get an answer”, where people interested on astronomy will have the possibility to submit their questions which will be answered by professional astronomers from the ESTALLIDOS team, and both the questions and answers will be public for all the interested people visiting our web site.

We will organize public outreach seminars. One seminar will be given each time we meet for a workshop of the collaboration. As before, press releases will be done along the project duration when our results are of the special relevance.

An activity that we have already started is to do informal meetings in schools, to share part of our time with primary or secondary school children and to communicate not only our astronomical knowledge, but also practical issues related to a researcher’s career, like academic options, choice of a degree or how to become a professional astronomer. All the nodes of the ESTALLIDOS will contribute to the dissemination of the results via their implication in the open house sessions that all the institutions will organize yearly.

The results of simulations, observations, new codes, etc. will be publicly available by means of adequate interfaces, such as the Virtual Observatory or by means, the webpages of the corresponding journals or other resources created “ad-hoc”.

In summary, ESTALLIDOS and its members have been always characterized by their compromise with a continuous transfer of both skills and knowledge to the new members of the group, later identified by their work within the project, and to the rest of the community by means of their implication in new astronomical collaborations in new facilities and scientific projects and the immediate publication and transfer of the acquired results and the methodologies.

C.4. CAPACIDAD FORMATIVA DEL EQUIPO SOLICITANTE

Subproject UAM

In order to carry out the proposed research, the UAM node requests two FPI contracts to work on WPs 1.1 and 4.3, eventually leading to Ph.D. theses to be defended at the UAM. The Astrophysics group at the UAM provides an excellent environment, encouraging collaboration between researchers of different fields and nationalities, and former students have been fully integrated in large international collaborations and profited from different research exchange programmes to visit foreign institutions. In the context of the present project, FPI-UAM1, whose Ph.D. thesis will be co-supervised by YA and MM, will acquire a strong theoretical background, both analytic (e.g. turbulence, atomic and molecular physics) and numeric (cosmological hydrodynamic simulations), as well as an understanding of the observational data needed to provide a meaningful interpretation of the results. The work of FPI-UAM2, leading to a Ph.D. thesis supervised by AID and MSL, will focus WP4.3 on the connection between circumnuclear SF and activity in galaxies, updating the stellar population models described in 1.3 to quantify the different contributions to both star forming regions and the AGN to the X-ray and gamma-ray spectrum, confronting the predictions with observations and computing the energy balance in as much as possible.

Both PIs of the UAM node have significant experience in training students and early-stage researchers. In addition to 5 M.Sc. theses and 7 B.Sc. theses, YA has co-supervised 1 Ph.D. thesis, and another will be submitted around June 2016. AID has supervised 14 Ph.D. students over her career, as well as 18 M.Sc. theses, often in collaboration with other members of the research team, both at the UAM node as well as CIEMAT. Over the past 10 years, the following Ph.D. thesis have been successfully defended. We provide the date, title, name of the student and supervisor(s), as well as the current position of the student:

06/2006 *On the nature of Luminous Compact Blue Galaxies (LCBGs)*
Carlos de Hoyos Fernández de Córdova (AID & Rafael Guzmán, UFL, USA)
Associate Proffessor at U. Carlos III (Madrid)

09/2008 *A comparative study of star formation processes in different environments*
Guillermo F. Hägele (AID & ET)
Lecturer Universidad de La Plata (Argentina)

05/2009 *Evolución de galaxias enanas aisladas*
Marta Gavilán Bouzas (AID & MM)
External collaborator at the UAM

05/2009 *Emission-Line Star-forming Dwarf Galaxies: Self-consistent Evolutionary Models*
Mariluz Martín Manjón (AID & MM)
Consultant at Digital Strategy (Banco Bilbao Vizcaya Argentaria)

08/2009 *A Spatially Resolved Study of Ionized Regions in Galaxies at Different Scales*
Rubén García Benito (AID)
Postdoctoral researcher at IAA (Granada)

09/2010 *Gas altamente ionizado en galaxias seyfert 1: interpretación de sus marcas en espectros de rayos X de alta resolución*
Mónica Cardaci (AID, MSL)
Lecturer Universidad de La Plata (Argentina)

08/2013 *Astrophysical signatures of dark matter*
Maneenate Wechakama (YA & Volker Müller, U. Potsdam, Germany)
U. Kasetstat (Thailand)

09/2015 *Submillimetric study of nearby galaxies*
Ilhuiyolitzin Villicaña Pedraza (Jesús Martín Pintado, CAB-CSIC & AID)
Searching for a postdoc position

07/2016 *A new perspective on the evolution of galaxies: from global to local scales*
Javier Casado (YA, AID)

09/2016 *A differential study of the massive star formation process in circumnuclear and outer disk regions of nearby spiral galaxies*
Marina Rodríguez Baras (AID)

Subproject CIEMAT

The CIEMAT requests one predoctoral contract in order to work on task T1.3a, related with the high-energy spectra and processes that we want incorporate to our PopStar evolutionary synthesis code. In particular, the inclusion of binary stars, WR stars, and X-ray spectra will form part of a new PhD Project, co-supervised by MM and YA. Furthermore, the student will have the possibility to work partially at ESAC, where some members of the research team will contribute with their expertise in X-ray astronomy to his/her training, providing substantial added value to the project and enhancing its competitiveness (in both training and scientific terms) by including this transversal vision. In the last 10 years, 3 Ph.D. theses have been finished, 2 of them in collaboration with the UAM node:

05/2009 *Evolución de galaxias enanas aisladas*
Marta Gavilán Bouzas (AID & MM)
External collaborator, UAM

05/2009 *Emission-Line Star-forming Dwarf Galaxies: Self-consistent Evolutionary Models*
Mariluz Martín Manjón (AID & MM)
Consultant at Digital Strategy (Banco Bilbao Vizcaya Argentaria)

07/2016 *Study of the relation between the SN Ia luminosity with host galaxy metallicity*
Manuel Emilio Moreno Raya (MM & ALS)
Postdoctoral researcher at Ciemat

Subproject IAA

The IAA group is prepared to form one new FPI Ph.D. student, to study the most active star formation in metal-poor galaxies, including WR and PopIII siblings, using existing IFU data (PMAS/PPAK, MUSE) as well as new GTC data from the science verification and guaranteed time within the framework of the IAA participation in the construction of MEGARA.

The IAA has ideal conditions for the formation of new PhD students: it offers an international research atmosphere together with the traditional close links between the IAA and the University of Granada. The PhD Thesis listed below have been completed and defended “Cum Laude” by former members of the group at the University of Granada, plus one at the observatory of Rio de Janeiro (BR). All the tools and S/W necessary for reduction and analysis of astronomical observations (optical, IR and radio) are made available. The easy access to the telescopes of the observatories at Calar Alto and, especially, at Sierra Nevada (30 mins) also offers fantastic training tools for new astronomers – its optical/IR telescopes together with the nearby 30m IRAM instrument, allow our students a close contact with complementary wavelength ranges-, in addition to the IAA own student’s training program which include advanced software programming and technology.

The group in Granada has 3 senior researchers working at the IAA with proven experience in the formation of students at various academic levels. JMV started this experience teaching at the graduate student level on observational techniques and chemical abundances of galaxies at the IAC./Dpto.de Astrofisica (ULL); he has supervised 10 PhD theses, plus one PhD ongoing, and several master theses and DEAs. He is also a member of the “Comisión Académica” of the new PhD program "Physics and Astronomy", and a former fellow of the Fisymat program, at the Univ. de Granada and he is one of the lecturers of the new Physics Master program. JIP has supervised three theses (one co-supervised). In addition, JIP has been responsible for several graduate students final research works at the Granada and La Laguna Universities and he is a professor at the Master. EPM has co-supervised one PhD Thesis that has been defended at the University of Granada and two master theses at the ViU Universidad Internacional de Valencia. During the last 10 years five PhD Thesis have been completed in our group, and one is presently ongoing:

2007 *Spectroscopy of Low Metallicity HII Galaxies*
Carolina Kehrig
Postdoctoral researcher at U. Michigan (USA)
Alexander von Humboldt fellow at the AIP (Germany)
Postdoctoral researcher at IAA

2008 *Star formation in nearby clusters of galaxies: a deep Halpha sample*
D. Reverte Payá
Permanent staff astronomer of the GTC telescope and current MEGARA contact
2011 *Galaxy Evolution in Clusters of Galaxies with Databases of GALEX & SDSS*
J. Hernández Fernández
Postdoctoral researcher at IA of U. Sao Paulo (Brazil)
2012 *SF in nearby clusters of galaxies: spectroscopic properties and metal enrichment*
Vasiliki Petropoulou (Dr. Europeus).
Postdoctoral researcher at the Osservatorio Astronomico di Brera, Milano, (Italy)
2013 *Estructura de ionización y composición química de nebulosas galácticas*
Alba Fernandez Martín
Postdoctoral researcher at the IRYA of UNAM, Morelia (Mexico)
(ongoing) *Star formation and chemical evolution of galaxies in different environments*
Salvador Duarte Puertas

Subproject IAC

The Group at the IAC has several senior researchers with proven capability to form new students within the PhD Astrophysics Programme, sponsored by the Spanish Ministry of Education through an Excellence Mention. As leaders of objectives 2 and 4 of Estallidos 6 and actives in the science cases in Objective 5 we propose two Thesis research projects. One of them will be focused on the analysis of existing numerical simulations to determine the observables that reveal the existence of gas accretion events going on in model galaxies. This characterization is a natural intermediate step to interpret galaxias observations. It offers a unique opportunity for the student to become engaged with the team that developed the EAGLE numerical simulations which, includes names as J. Schaye and C. Frenk.

A second Thesis will deal with the star formation feedback from observations and application of our numerical models. For Estallidos 6 we plan this student to participate in the observations with the new instruments, MEGARA and EMIR @ GTC for specific samples of Estallidos already in the Science cases of the instruments. Moreover the catalogue of targets in COSMOS is proposed to be observed with WEAVE. The targets are particularly suitable for the HSR mode of the instrument. All these targets and observations will be the base for the Ph.D. work that will be two-folded, observational and theoretical. No need to emphasize the ample expertise the student will gain in participating from the very beginning in such a recent and challenging instrumentation. Note also that some of our collaborators in foreign institutions were before Ph.D. students within the Estallidos project and are presently affiliated to prestigious institutions with postdoctoral positions. The working team at the IAC is fully involved in the science that we propose and eager to actively participate in the training of the requested students. List of Ph.D. Theses defended at the University of la Laguna during the last 10 years, supervised by members of the team (all of them awarded with cum laude):

10/2008 *Modelado de la galaxia anfitriona de las BCDs (Blue Compact Dwarfs)*
Ricardo Amorín Barbieri
07/2009 *Morfología y formación estelar en Galaxias en Cúmulos cercanos*
Ruben Sánchez Janssen
07/2009 *Impacto de la formación estelar en galaxias compactas azules*
Ismael Martínez Delgado
11/2013 *Search and characterization of Galaxies with the lowest metallicity*
A.B. Morales
05/2015 *Observational properties of fossil galaxy systems from the FOGO project*
Stefano Zarattini
03/2016 *Search and characterization of starbursts in the survey of COSMOS*
R. Hinojosa Goñi