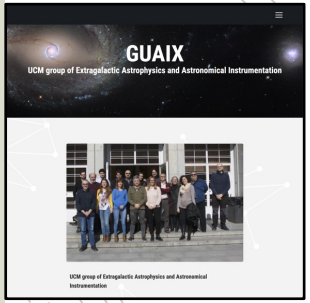
UCM group of Extragalactic Astrophysics and Astronomical Instrumentation

Activities

JESÚS GALLEGO

https://guaix.ucm.es/





IPARCOS

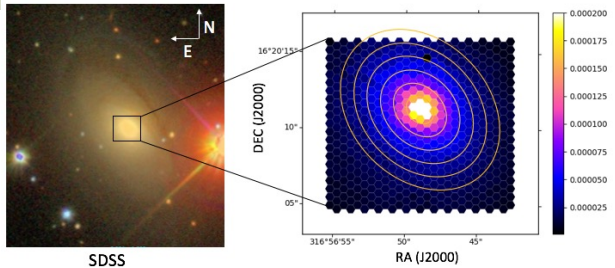
Index

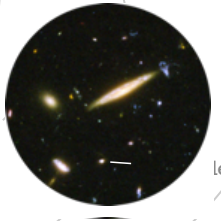
- GUAIX group
- Local Galaxies Science
- Distant Galaxies Science
- Formation and evolution of galaxies through N-body simulations
- Instrumental projects
- Dark-skies and light-pollution awareness initiatives

IPARCOS

GUAIX group

- 24 researchers UCM staff, postdocs, predocs, PM
- Major observational and modeling efforts in the field of Galaxy formation and evolution
- Major instrumental initiatives for astronomy
  - LICA laboratory, as UCM-CAI unit
  - Astronomical instrumentation
- Dark-skies and light-pollution awareness initiatives





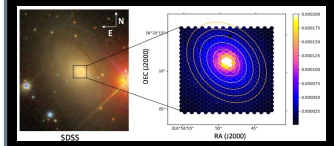


IPARCOS

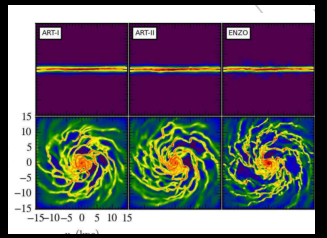
GUAIX group

People

Local Galaxies Science	Distant Galaxies Science	Formation and evolution of galaxies: N-body simulations	Dark Skies
A. Gil de Paz Á. Castillo-Morales Patricia Sánchez C. Catalán B.T. Dullo J. Gorgas M. Lara-López E. Bellocchi	J. Gallego N. Cardiel M. Lara-López S. Pascual C. Cabello Ángela García	Mariángeles Gómez-Flechoso S. Roca-Fábrega Begoña García-L.	J. Zamorano Alex Sánchez J. Gallego S. Pascual N. Cardiel









GUAIX group

Local galaxies Science

IPARCOS

MEGADES

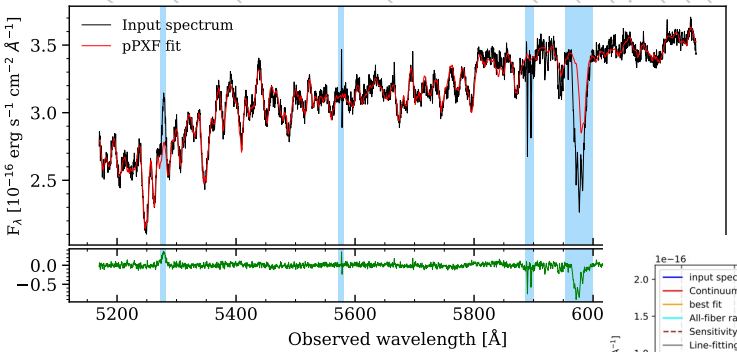
MEGARA Legacy Survey

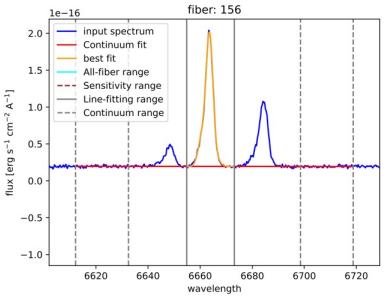
Chamorro-Cazorla et al. 2022

MEGARA Data:
- ✓ FoV 12.5 x 11.3 arcsec^2
- ✓ R = 6000 (~50 km s^{-1})
- ✓ Spectral coverage 4350 – 7288 Å
- ✓ Spatial resolution 0.62 arcsec

Sample (43 galaxies):
- ✓ Subsample from S4G with (30 galaxies):
  - Distance < 40 Mpc
  - Galactic latitude |b| > 30°
  - Declination Dec(J2000) > –20°
  - Apparent magnitude $m_{B,corr}$ < 15.5 mag
  - Apparent diameter 2.5'<D25<4'
  - Inclination 40° < i < 70°
- ✓ Subsample from CALIFA (13 galaxies) with $EW_{ISM-NaD}$ > 2 Å

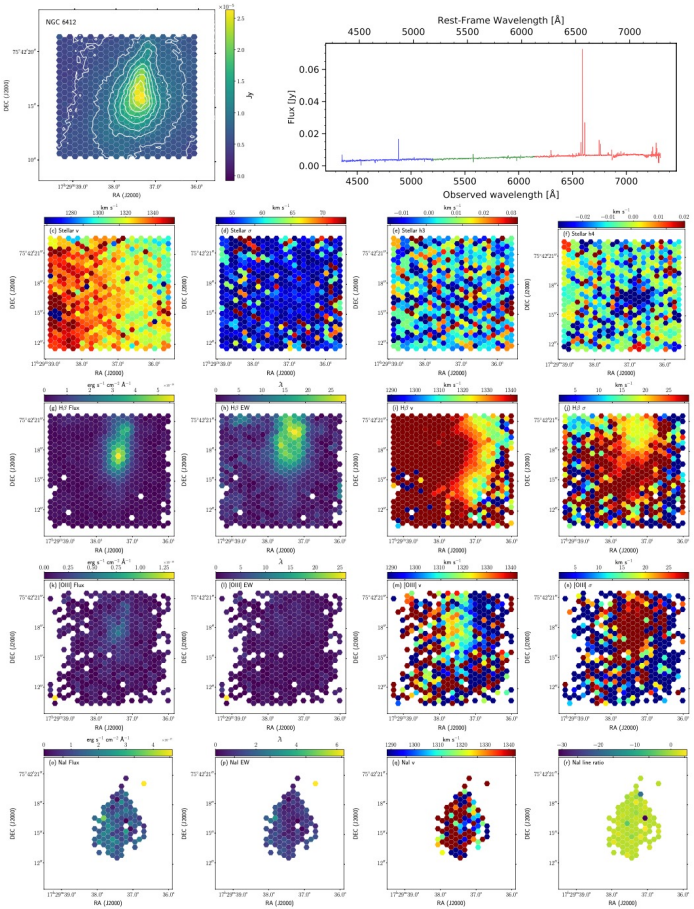
Chamorro-Cazorla et al. 2022 (in prep.) includes:
- ✓ Reduced data realease
- ✓ Analysis of stellar kinematic properties derived with pPXF
- ✓ Emission and absorption lines information: H_β, [OIII], NaI, H_α, NII (6584), [SII].

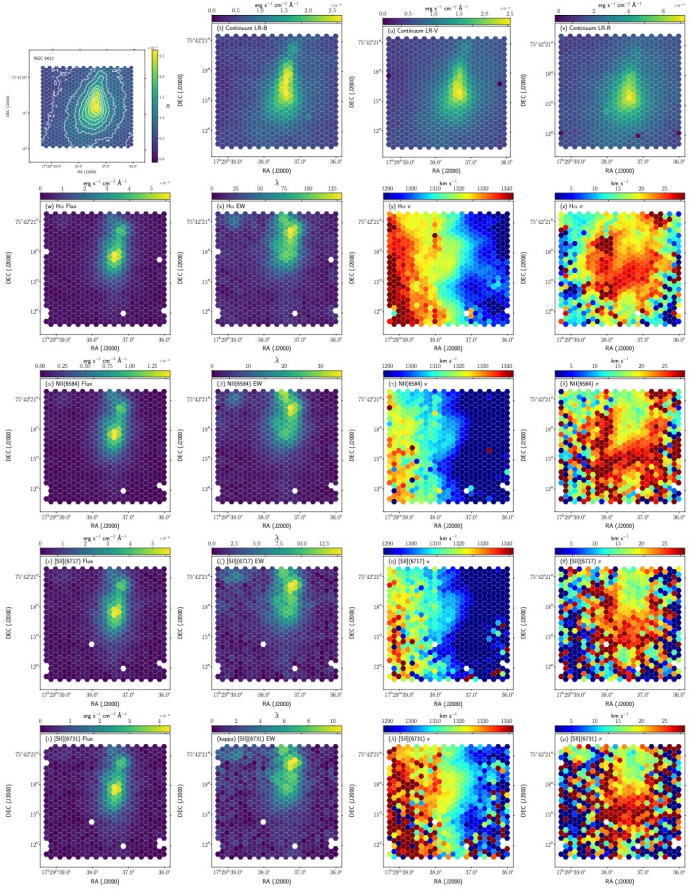




Mario Chamorro-Cazorla
Armando Gil de Paz
África Castillo-Morales

MEGADES





g. .62. NGC 6412 card

Mario Chamorro-Cazorla
Armando Gil de Paz
África Castillo-Morales

Chamorro-Cazorla et al. 2022

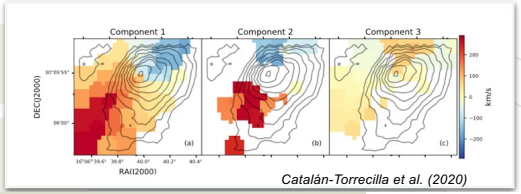
Spatially resolved analysis of nearby galaxies

Catalán-Torrecilla et al

MEGARA@GTC: kinematics & galactic outflows

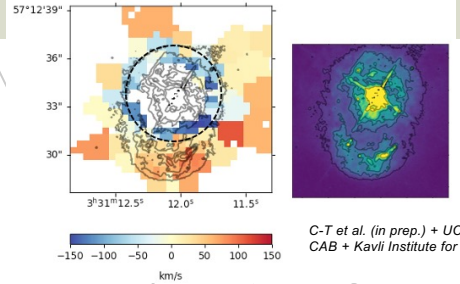
- **The power of high-resolution data (R ~ 18000) to understand complex ionized gas kinematics**





Three kinematically distinct gaseous components: gas in a thin disk (i=75°) + gas with a higher inclination (i=83°) in a position coincident with the dust lane structure

- **The regulation of star formation in the central regions of galaxies via galactic outflows**

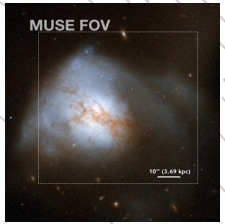


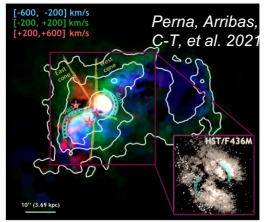
Detection of positive feedback processes

C-T et al. (in prep.) + UCM + CAB + Kavli Institute for Cosmology

MUSE@VLT: stellar populations in ULIRGs

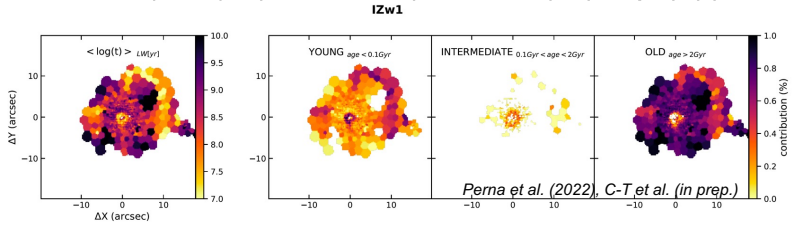
- **MUSE view of Arp220: the nearest and prototypical ULIRG galaxy**





Disturbed kpc-scale disc in the innermost nuclear regions + highly perturbed multi-pase (neutral & ionised) gas along the minor axis of the disc

- **Physics of ULIRGs with MUSE and ALMA: The PUMA project III. Star formation histories and evolution**



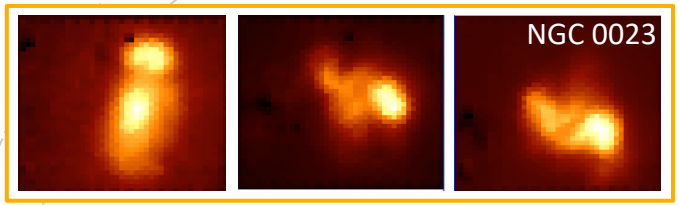
The age of the young stellar populations is consistent with the episode of the major burst of SF associated with the galaxy merger event

Kinematic analysis of a local sample of galaxies observed with MEGARA IFU/GTC

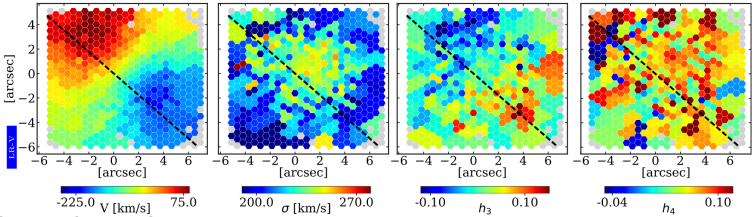
E. Bellocchi
& A. Gil de Paz, C. Catalán,
M. Chamorro, A. Castillo, S. Pascual

2-D kinematic characterization of a local sample of galaxies with different ionization types at high spatial resolution (R=6.000). We Will be able:

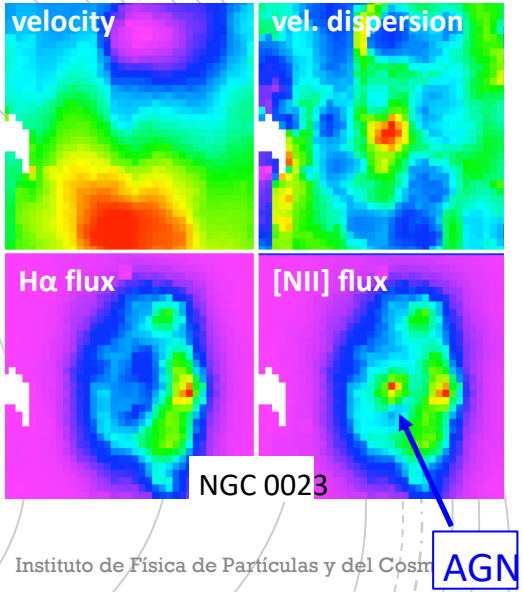
1) To study the **ionized (Halpha, [NII], [SII] …) and neutral gas phases (NaID)** of the systemic & outflow components
2) To derive physical properties of the outflow (size, mass outflow rate …)



3) To derive the kinematics of the stellar emisión (i.e. v, sigma, h3, h4)

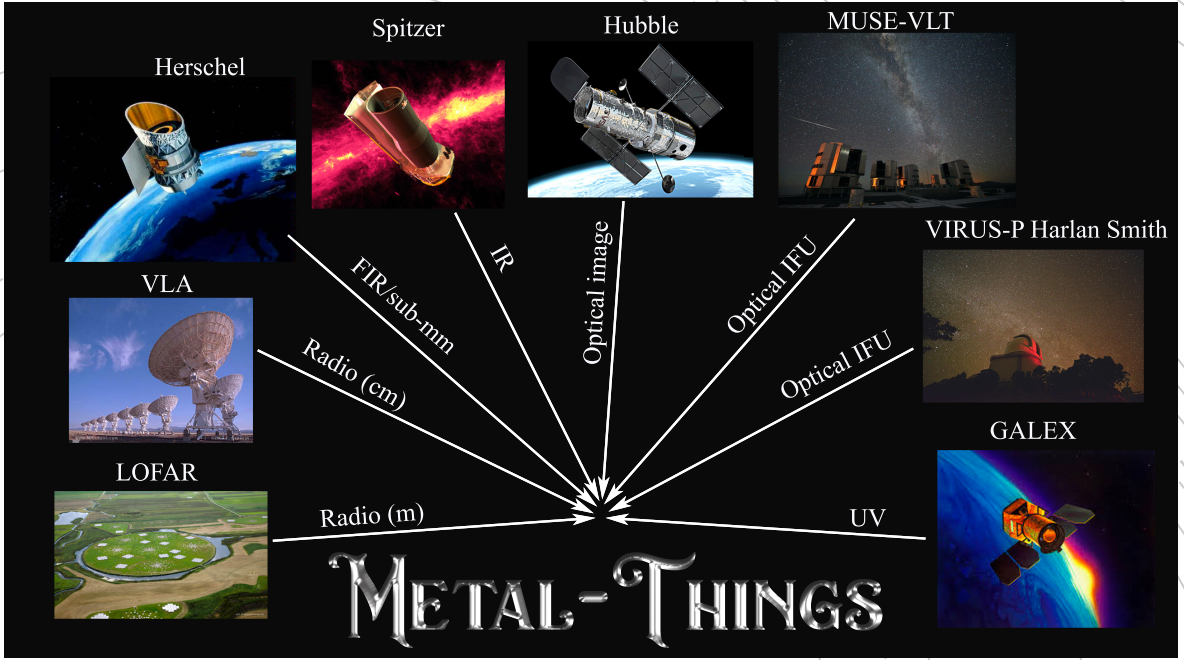


4) To compute dynamical masses, to study ionization mechanisms, etc



The Metal-THINGS survey

M. Lara-López
et al



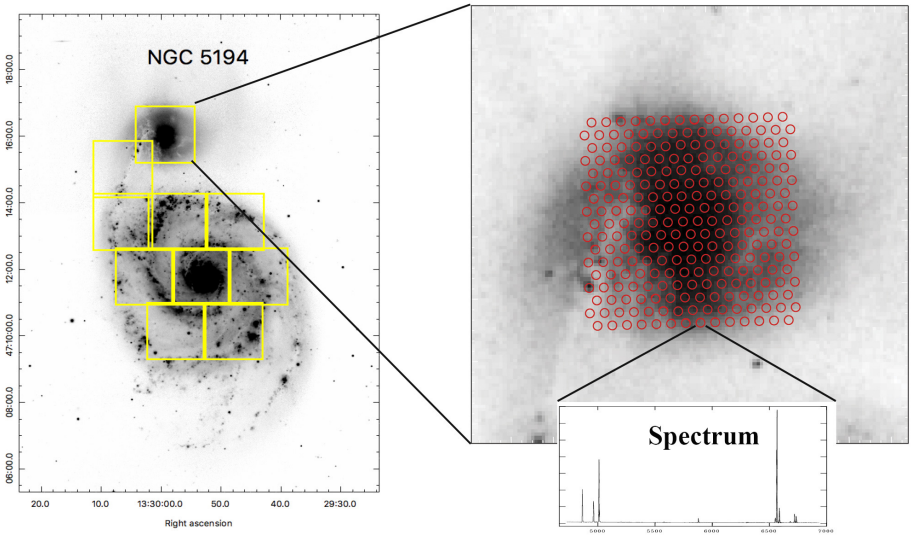
-Unique panchromatic set of resolved properties of galaxies

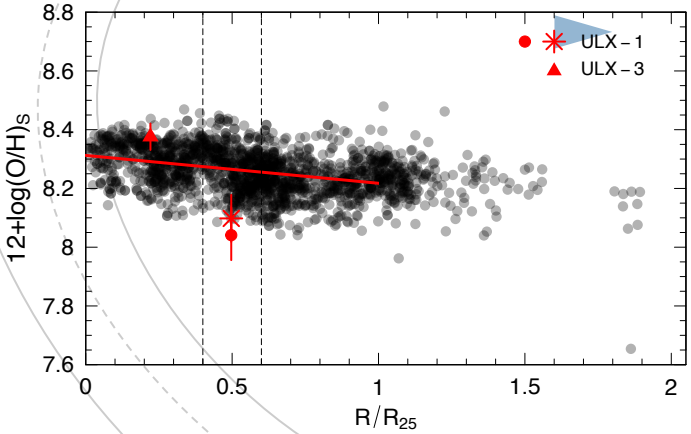
-Observing 34 nearby galaxies (THINGS survey) with IFU spectoscopy
VIRUS-P (2.7m Harlan Smith Telescope, McDonald Observatory, Texas)
MUSE (8.2m VLT Telescope, ESO, Chile)

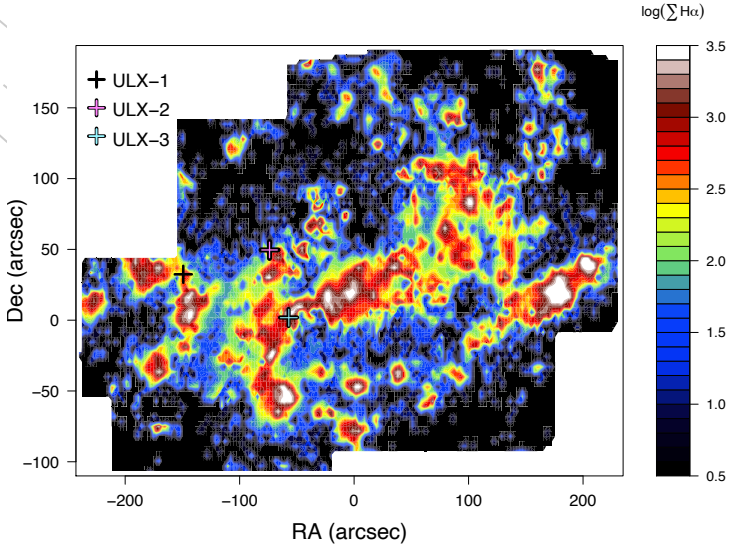
Lara-López et al (2021)

Science:

-Identification of the main drivers in the evolution of galaxies
-Metallicity, SFR, ionization and dust gradients
-Kennicutt-Schmidt law
-Star Formation efficiencies, gas consumption
-Supernova Remnants, Ultra Luminous X-rays sorces (ULXs)
-Biproducts: Calibrations (gas mass, dust, metallicities)







GUAIX group

Distant Galaxies Science

Expectations for the analysis of SFHs in 2D with HST+JWST data

García-Argumánez et al. 2022
(to be submitted)

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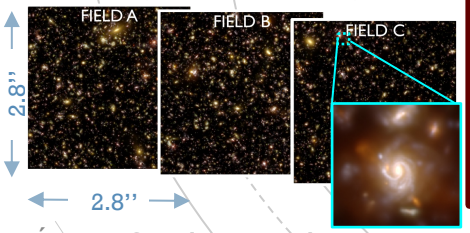
AIM

Our aim is to infer when the early stages of the stellar mass assembly took place in local very massive galaxies by analyzing the 2D Star Formation Histories (SFHs) of their progenitor galaxies at $1 < z < 4$.

SAMPLE

We select simulated massive ($M* > 10^{10}$ $M_\odot$) galaxies included in the Illustris-1 synthetic deep survey images that lie at $1 < z < 4$, and which will evolve to a very massive ($M* > 10^{11}$ $M_\odot$) descendant at z=0.

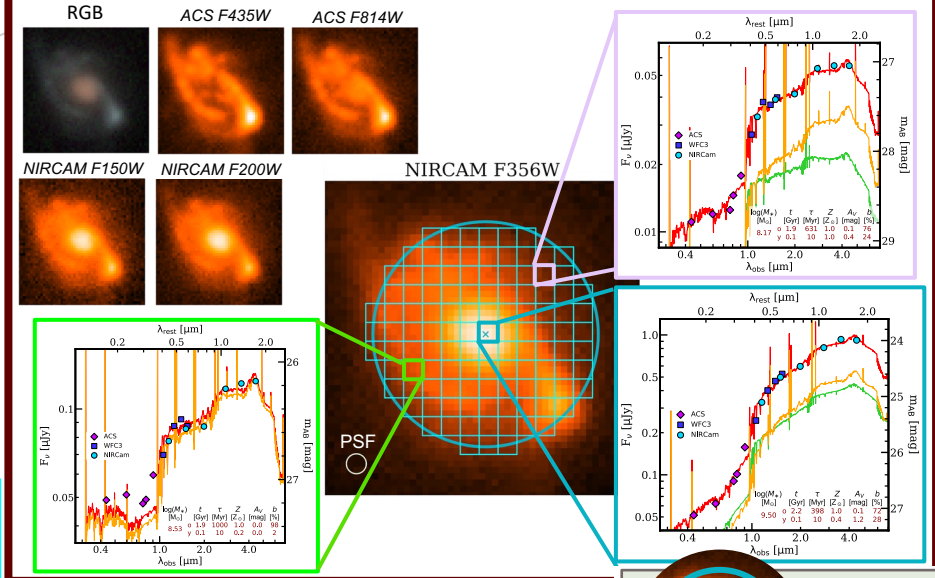
Illustris-1 synthetic deep survey images



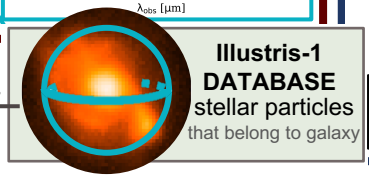
Ángela García-Argumánez
Pablo G. Pérez-González
Armando Gil de Paz

STELLAR POPULATION SYNTHESIS IN 2D

We build Spectral Energy Distributions (SEDs) in 2D for each galaxy using 15 broad-band UV-to-NIR HST+JWST filters. We apply stellar population synthesis (SPS) on these 2D SEDs to derive the galaxy SFH. This galaxy SFH is compared with the ground-truth SFH built from the simulated particles belonging to the galaxy.



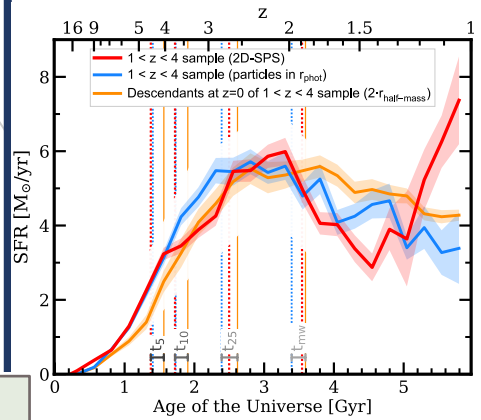
Photometry-derived galaxy SFH vs. Ground-truth galaxy SFH



Illustris-1 DATABASE stellar particles that belong to galaxy

RESULTS

To characterize the earliest phases in the formation of massive galaxies, we calculate the **mass-fraction formation times** t_5, t_{10}, t_{25}, and t_{mw}, from the median SFH of the sample built from the 2D SED fits. This typical SFH is compared with the median ground-truth SFH given by the simulated particles in the sample and with the median ground-truth SFH for the descendants of this sample at z=0 (all descendants with $M* > 10^{11}$ $M_\odot$).



We recover t_5, t_{10}, t_{25}, and t_{mw} with a precision lower than 4% for all cases.

IPARCOS

GUAIX

Distant Galaxies Science:

Exploiting the capabilities of the GTC instrumentation to detect distant galaxies



10.4m GTC telescope

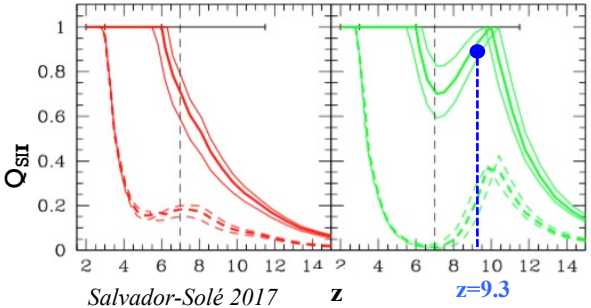
Cristina Cabello
Nicolás Cardiel & Jesús Gallego

Science with CIRCE@GTC

Searching for Lyman-α Emitters (LAEs) at z ~ 9

Reionization of the Universe

Single scenario — Double scenario

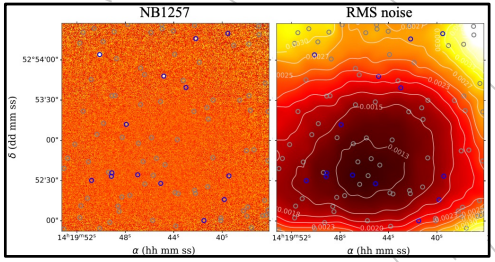


Salvador-Solé 2017

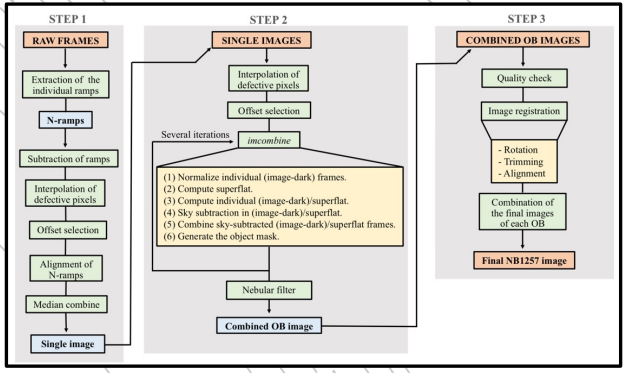
CIRCE@GTC + Narrow-band filter

FoV: 3.4' x 3.4'
Plate scale: 0.1"/px

λ_c = 1257 nm
FWHM = 11 nm

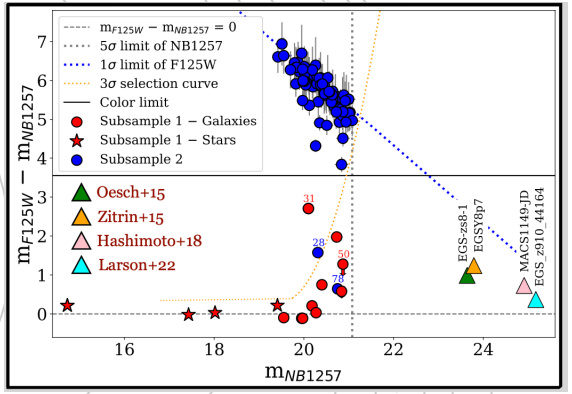


Cabello et al. 2022



The Lyα narrow-band survey at the highest redshift to date!

- We developed a data reduction procedure that was especially optimized to minimize instrumental effects. Python codes are publicly available on https://github.com/criscabe/
  - Final near-IR narrow-band image of 18.3 h of exposure time.
  - Identification of 10 galaxies in the range z = [0.34 – 1.53]
  - No z ~ 9 LAE candidates were found.
  - Both wide and deep observations are needed to study the first galaxies.



Cristina Cabello
Jesús Gallego
Nicolás Cardiel

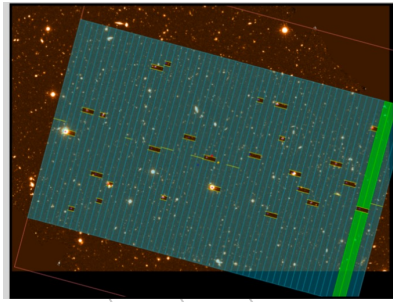
Science with EMIR@GTC

Studying star-forming galaxies at 0.8 < z < 1.7

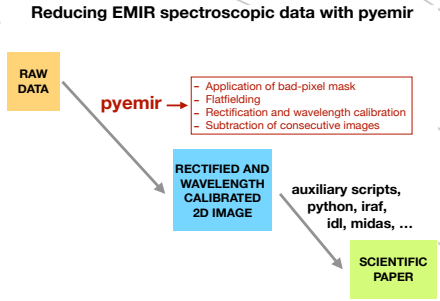
GOYA

The survey to explore the high-redshift Universe using the EMIR MOS mode

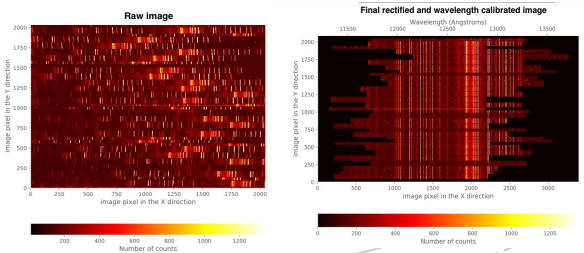
- First galaxies
- HII galaxies
- Massive quiescent galaxies
- **Low-mass star-forming galaxies**



Data reduction with PyEmir

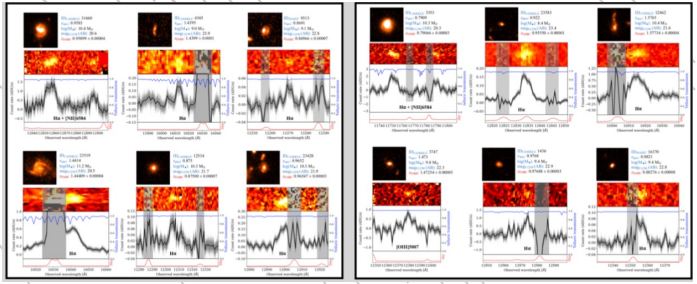


The EMIR data reduction pipeline, **PyEmir**, based on Python, was developed in order to facilitate the automatic reduction of EMIR data taken in both imaging and spectroscopy mode. (Cardiel+19, Pascual +19)



GOYA early results

Hα + [NII]6584 emission from z ~ 1 galaxies



- The current detector exhibits an effective sensitivity lower than expected.
- GOYA GTO awaits the arrival of the new HAWAII-2RG detector (September 2022)



Cristina Cabello
Nicolás Cardiel
Jesús Gallego

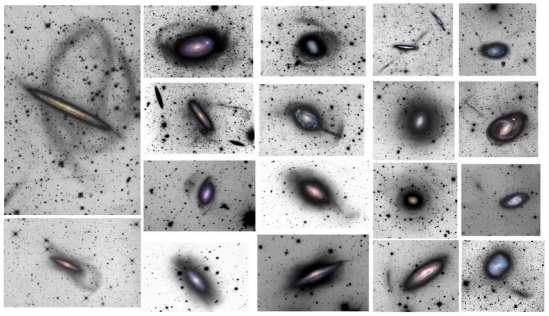
Formation and evolution of galaxies through N-body simulations

Unveiling the Dark Matter nature

M.Á. Gómez-Flechoso,
S. Roca, J. Gallego

PROBLEMS:

1) Missing satellites problem

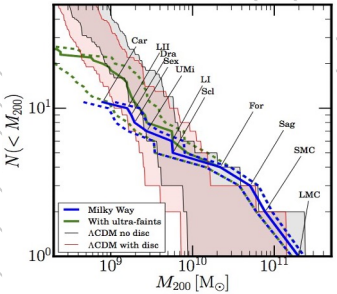


Martínez-Delgado et al (2010)

Read & Erkal 2019



LCDM simulation



2) Low number of stellar streams in the galaxy halos (~15%)



Lovell et al 2014

Predictions are highly dependent on the DM model

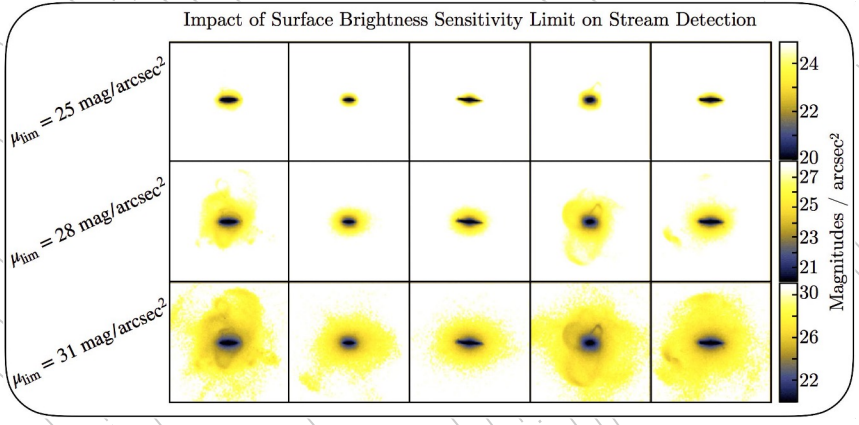
Unveiling the Dark Matter nature

M.Á. Gómez-Flechoso,
S. Roca, J. Gallego

IPARCOS

Low surface brightness observations are needed

Ground-based observations only reach
29 mag/arcsec² (limited by the atmosphere)



	DUNES	ARRAKIHS
Collaboration	USA+Spain (+Switzerland+Sweden)	Spain+Switzerland+Sweden (+Austria+UK+USA)
Sample	100 galaxies/200 degrees²	Complete nearby MW galaxies sample
Telescope	2x0.17m, f/10	4x0.17m, f/10
Filters	EUCLID VIS + J bands	LSST g + EUCLID VIS + Y + J bands
SB	~31 mag/arcsec²	~32 mag/arcsec²
Lifespan	3 years	5 years
Starting in	2025	2030
Budget	20M$	130M€
Platform	Microsat (<100kg)	Minisat (<250kg)

Two scientific space mission has been submitted

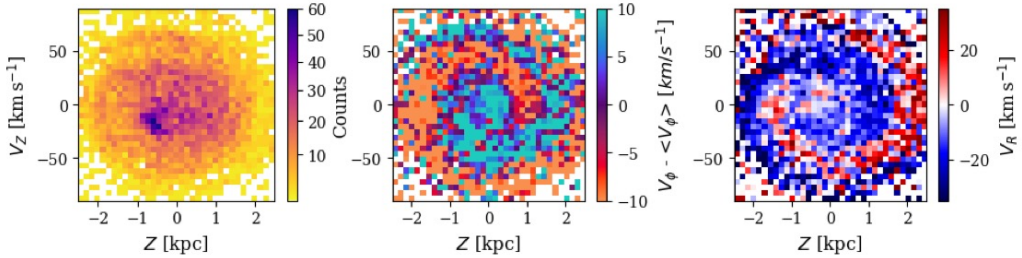
DUNES (Dark matter Unveiled with a New Explorer SmallSat) @ NASA

ARRAKIHS (Analysis of Resolved Remnants of Accreted galaxies as a Key Instrument for Halo Surveys) @ ESA

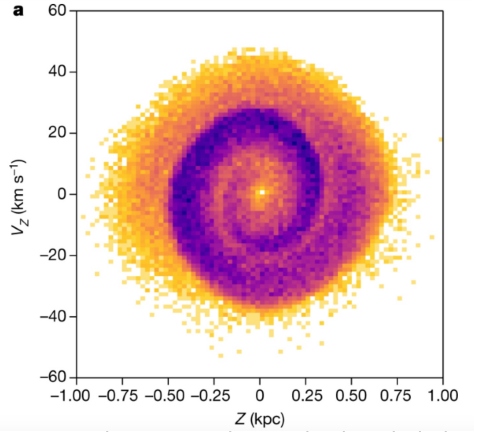
A perturbed Milky Way disk

Ph.D. by García-Conde, Roca-Fàbrega, Antoja, Ramos, Valenzuela, Gómez-Flechoso

- Phase space spirals and ridges in cosmological simulations to understand Gaia satellite observations



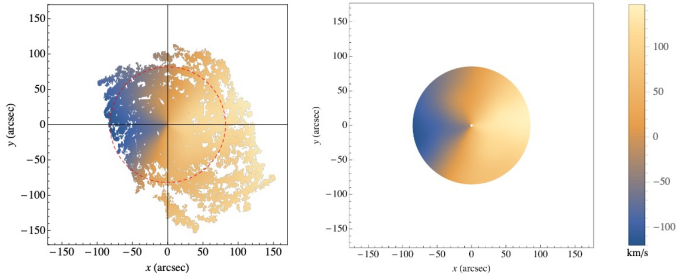
Results from the GARROTXA cosmological simulation (Roca-Fàbrega et al. 2016)
Presented in García-Conde et al. 2022



Gaia data
presented in Antoja et al. 2018

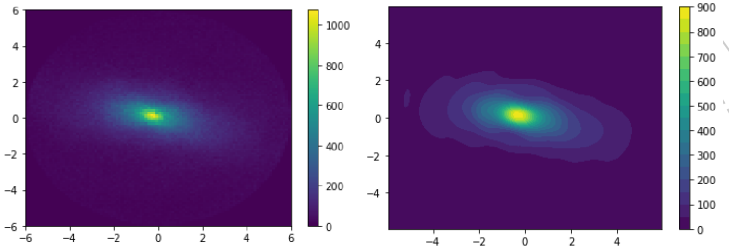
The nature of spiral arms and bars

- CO and stellar kinematics analyzed using Fourier decomposition (Ph.D. by Díaz-Fernández, Sánchez-Blázquez, Roca-Fàbrega)



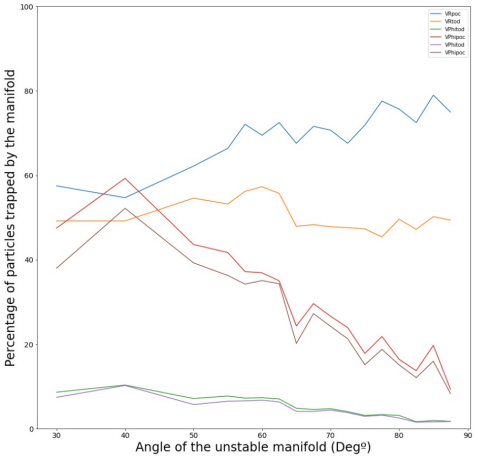
Observed and recovered CO kinematic maps for the NGC4253

- Structure of bars in simulations and observations using 3-D Bessel coefficients (TFM by Matey, Amaya, Costantin, Roca-Fàbrega)



Real density distribution of a simulated galactic bar (left), and the recovered density distribution by using 3-D Bessel functions (right)

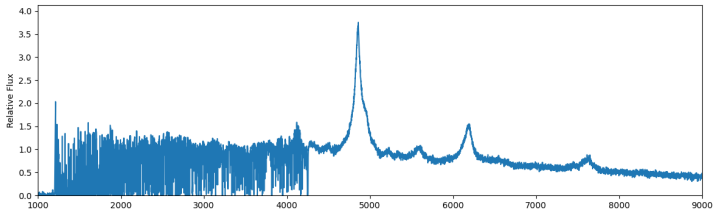
Invariant manifolds in simulations (Ph.D. by Padura-Feito, Roca-Fàbrega, Romero-Gómez, Gil de Paz)



Fraction of particles trapped by spiral arm-like invariant manifolds as a function of distance to the L2 saddle point.

Circumgalactic medium: gas, streams and satellites

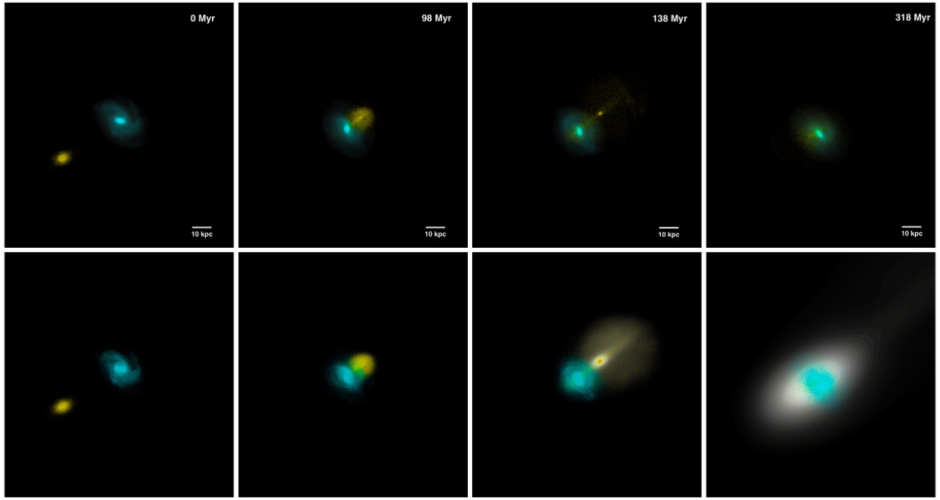
- Study of sBLA (strong Blended Ly-a) systems as function of impact parameter and CGM(CircumGalactic Medium) density (TFM by Alunda, Roca-Fàbrega, Pérez-Ràfols)



Espectro sintético obtenido de una simulación cosmológica usando la herramienta YT-TRIDENT

- AGORA-CGM: Variations in the CGM properties when using different numerical codes (Ph.D. by Strawn, Roca-Fàbrega, Primack)

- Detection and modelling of stellar streams in external galaxies (lead by Martínez-Delgado, Gómez-Flechoso, Roca-Fàbrega)
  - DUNES, and ARRAKHIS space missions (lead by Guzmán, Gómez-Flechoso)



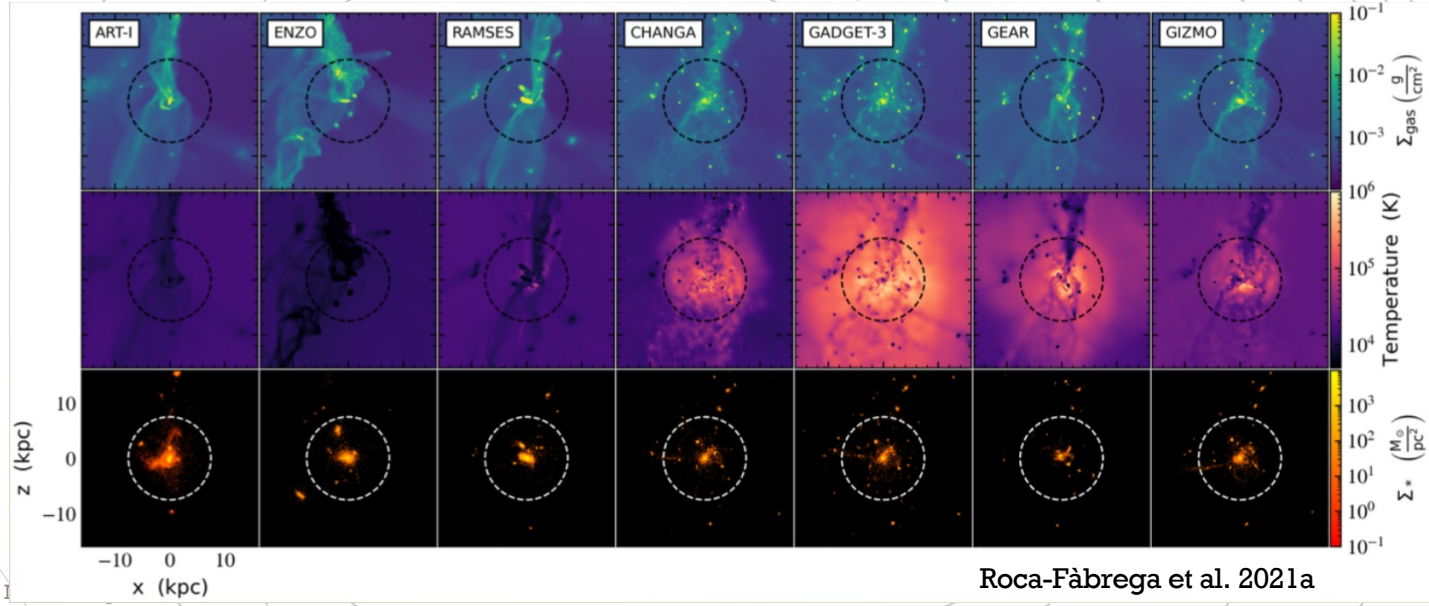
N-body model to study the formation of a tidal ring galaxy
Martínez-Delgado et al. in prep.

Codes comparison: The AGORA project

Roca-Fàbrega + 20 international

Simulations of a Milky Way-size galaxy formation and evolution using the 8 most used numerical codes in the community

5 Follow-up projects including the analysis of the circumgalactic medium, AGN activation, and clumps formation at high-z.



Roca-Fàbrega et al. 2021a

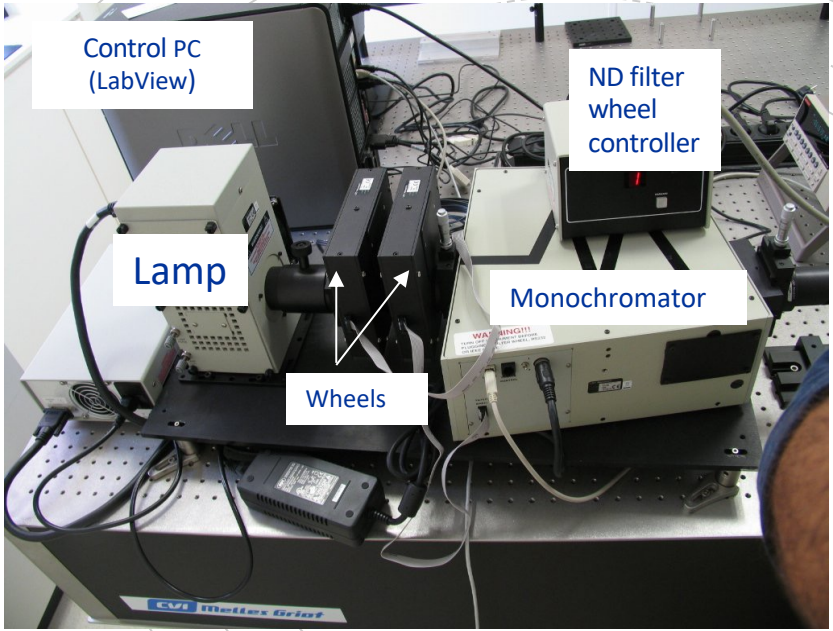
Instrumental Projects

LICA: Laboratorio de Instrumentación Científica Avanzada

IPARCOS

UCM-CAI unit





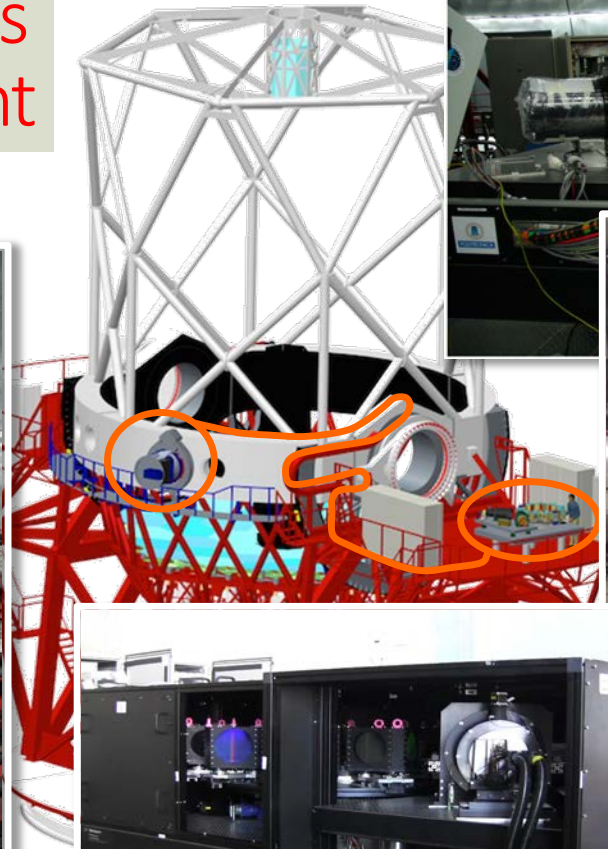


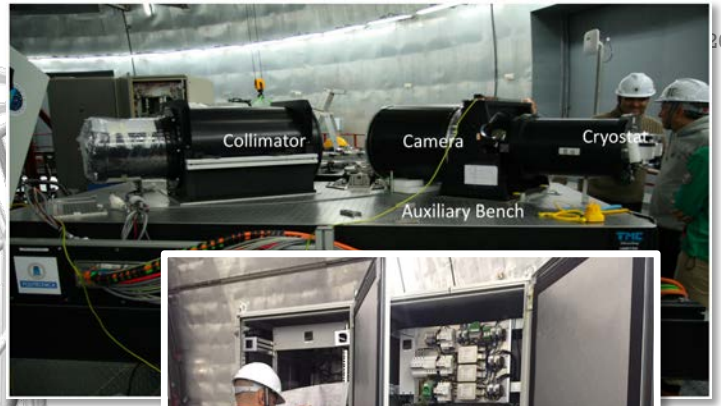
MEGARA, GTC's new instrument

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Multi Espectrógrafo en GTC de Alta Resolución para Astronomía





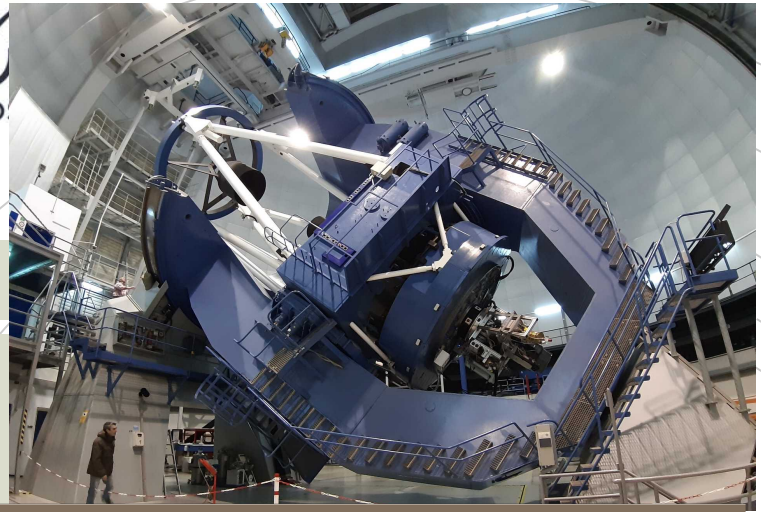




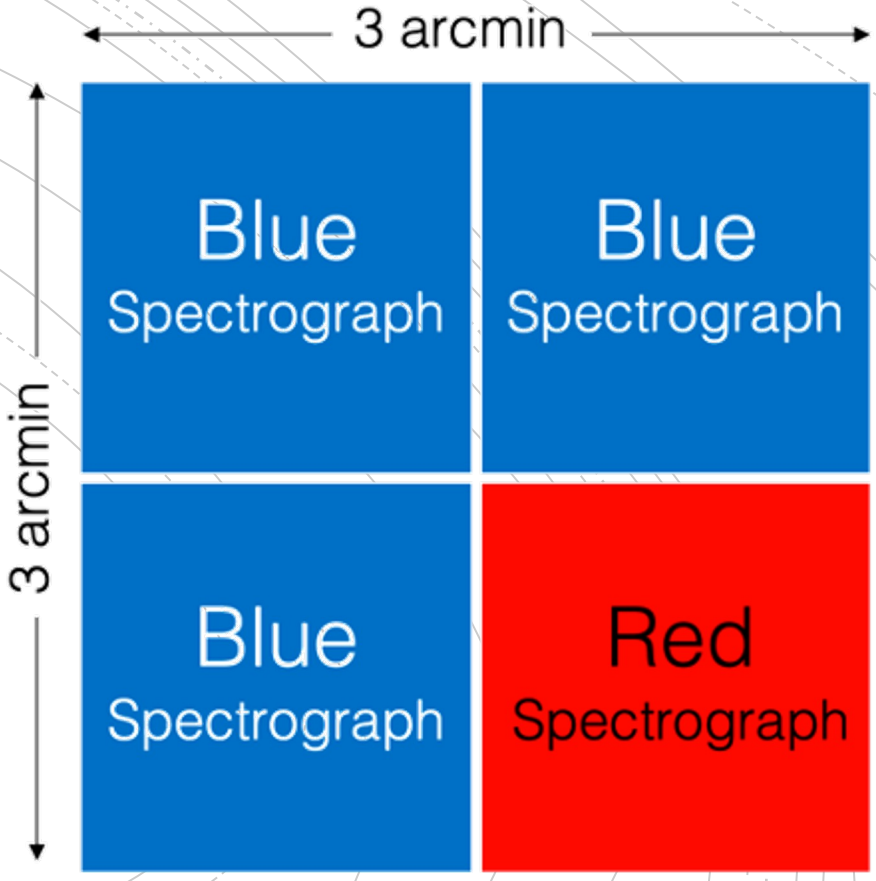
Armando Gil de Paz & MEGARA Consortium & team, including the UCM-ISCAR group

Instituto de Física de Partículas y del Cosmos

TARSIS: THE INSTRUMENT



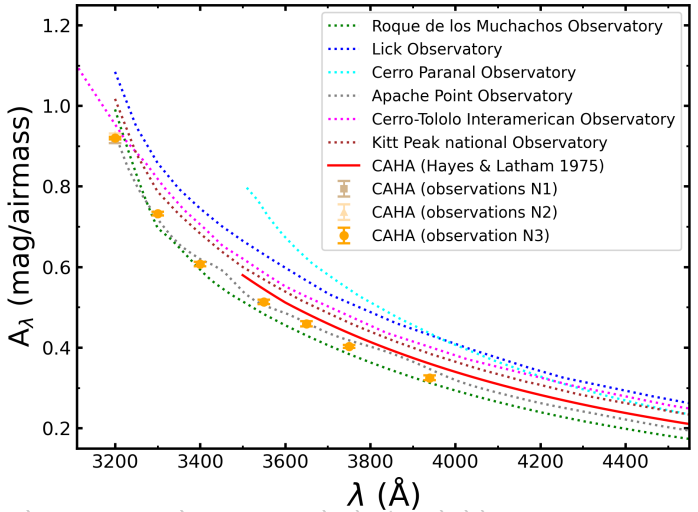
Parameter	Specification
Efficiency	>20% (Blue), ~30% (Red)
Field-of-View (FoV)	9 arcmin^2 (3/4 Blue; 1/4 Red)
Spectral range	320-520 nm & 510-810 nm & 590-730 nm (HR)
Spaxel size	2 x 2 arcsec^2
Resolution element	3.6 pix
Spectral resolution	R≥800-1000 & R≥800-1000 & R=1500-2500



CATARSIS observing goals

- The scientific goals of CATARSIS require reaching galaxies with continuum magnitudes $\mathbf{m_{AB,r}}$**~21**, and limiting line fluxes **(1-2)x10^{-17} erg s^{-1} cm^{-2}**.

- The required exposure time per pointing is **28800s (8h) for the Blue range**, and **9600s (2h40m) the Red**.



- To achieve these requirements, **observations will be carried out during clear dark (or with low Moon illumination) nights** (although not necessarily photometric).

- We require **AIRMASS to be lower than 1.22**, to limit the extinction at the blue end and to fulfill our detection limits (**see CAHA UV extinction curve above**).

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TARSIS Press Release:

Navegar identificado | Buscar en la web

UNIVERSIDAD COMPLUTENSE MADRID

Universidades Españolas con UCRANIA

UCM | Estudiar | Investigar | Internacional | Vida universitaria

Portada / Portada UCM / [...] / Mayo 2022

La Complutense y el IAA-CSIC, a la vanguardia de la Astronomía con TARSIS, el nuevo instrumento para el telescopio de 3,5m de Calar Alto

La Complutense y el IAA-CSIC, a la vanguardia de la Astronomía con TARSIS, el nuevo instrumento para el telescopio de 3,5m de Calar Alto

NOTA DE PRENSA

- Se trata de un espectrógrafo de campo integral que tiene características únicas, en particular su capacidad para detectar luz en el ultravioleta cercano y su campo de visión sin precedentes, junto con un ambicioso estudio de observación de cúmulos de galaxias (CATARSIS) adaptado específicamente a él.
- El diseño de TARSIS basado en cuatro brazos (tres optimizados en azul, uno en rojo) permitirá observaciones en un dominio casi inexplorado desde la Tierra, detectando objetos hasta miles de millones de veces más débiles que las estrellas más tenues visibles a simple vista en un lugar completamente oscuro.

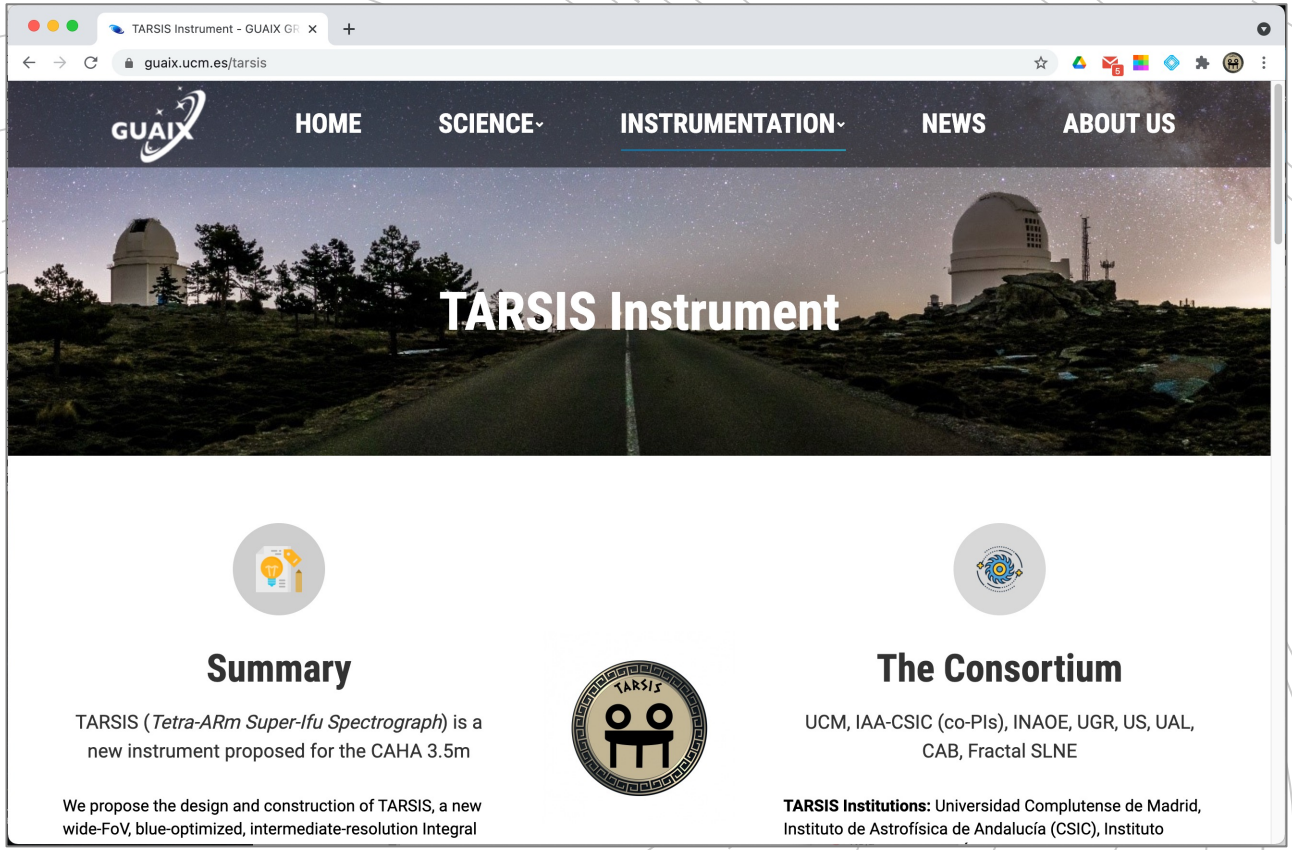
Diario de Almería — ALMERÍA

Granada

Calar Alto incorporará el instrumento 'Tarsis' con

Webpage:

https://tarsis.caha.es/

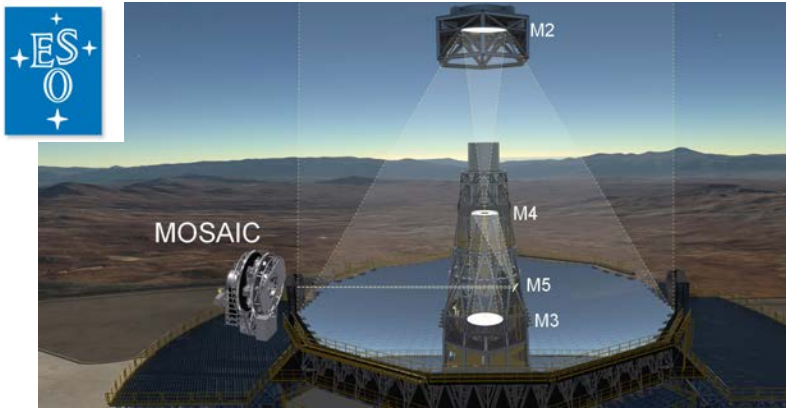


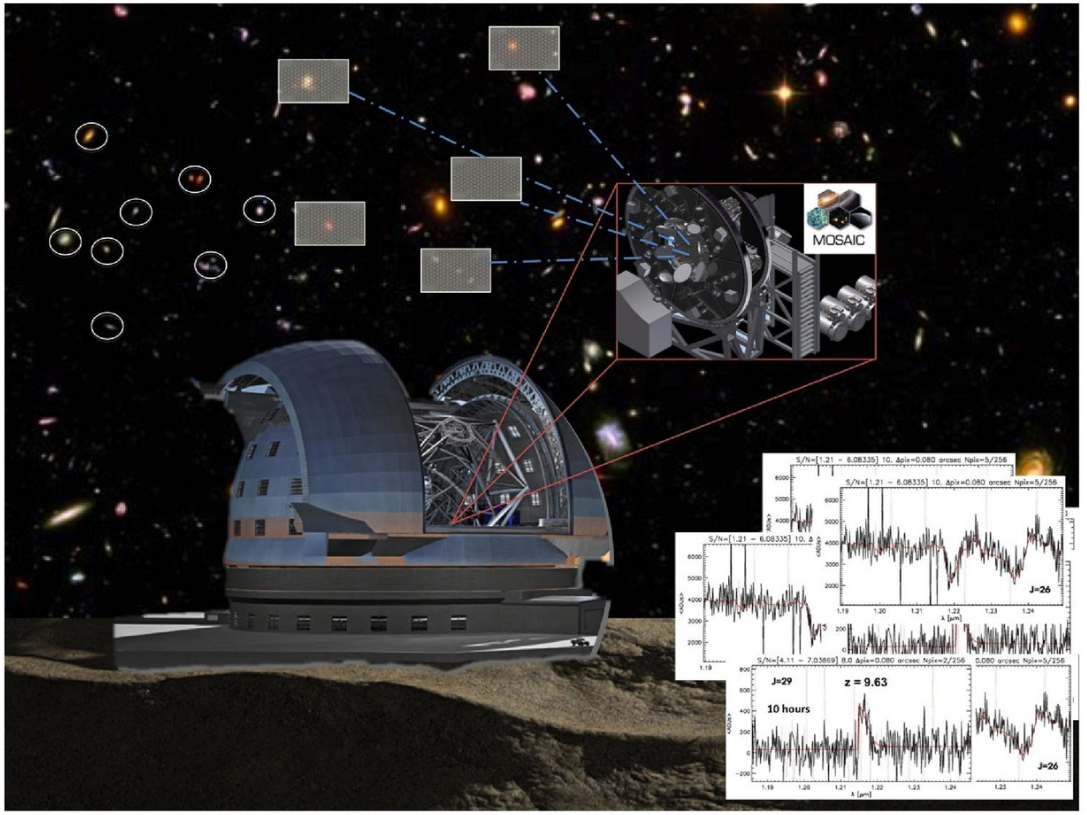
https://guaix.ucm.es/tarsis

MOSAIC: MOS for the ELT

- 39m European ELT, Chile, 2025
- Adaptive optics (80 mas)
- Multiobject (80x), 30 arcmin^2 FoV

- Optical, Near-IR J, H
- J=28 mag_{lim}
- 2031, 8x7x13m





Jesús Gallego, África Castillo-Morales, Armando Gil de Paz +

Instrument Contributors

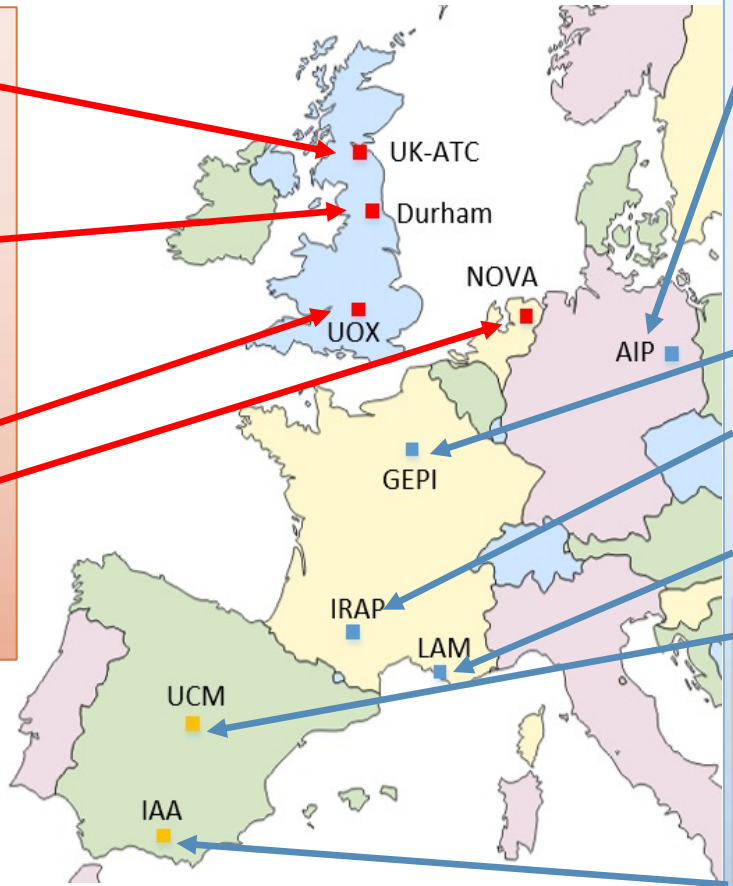
UK-ATC : 5 spectros NIR with Teledyne H4RG (4k x 4k)

Durham : AO, fast & slow + Core structure (rotators)

UOX : positioners

NOVA : 5 spectros VIS with E2V CCD231-C6 (6k x 6 k)

Opto-mechanical design & fabrication



AIP : fibers (passive)

GEPI : Management, science software (obs. prep. + pipeline)

IRAP: control/command (HW & SW)

LAM : AIT

UCM : **CALIB unit IRMechanisms**

IAA : **NIR motion control**

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Other ground-based optical/near-IR instruments

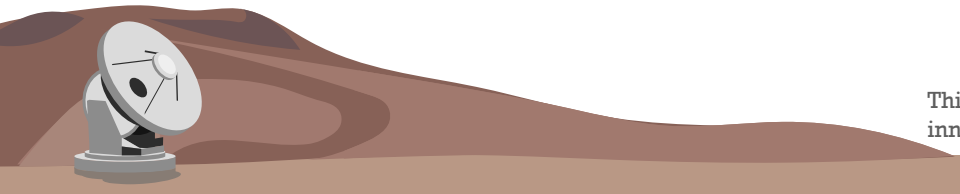
- **EMIR:** Near-infrared instrument by IAC-CSIC of 10.4m GTC.
  At UCM: **Data Reduction Pipeline**.
- FRIDA: AO-assisted near-infrared spectrograph for GTC.
  At UCM: Data Reduction Pipeline.
- SCORPIO: New instrument for Gemini Telescope (2021-22).
  At UCM: Laboratory integration @ LICA in collaboration with SwRI (TX, USA) and Fractal SLNE.
- MIRADAS: Mid-resolution near-IR spectrograph for GTC.
  At UCM: Data Reduction Pipeline.

Participation in AtLAST

Francisco Montenegro-Montes et al

Atacama Large Aperture Submillimetre Telescope

- Next generation 50m-class single-dish telescope, operating at sub-mm wavelengths
- Design study funded by EU (2021-2024)
- Large FoV and sensitivity. Great potential for surveys down to sensitivities just below the confusion limit (Cosmology, Galaxy evolution & Galactic science)
- Strong emphasis on sustainability (green energy)
- Consortium led by The University of Oslo
- F. Montenegro-Montes contributing to WP-4 (Telescope Operations) with emphasis on the data management plan.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 951815

Dark-skies and light-pollution awareness initiatives

IPARCOS

The evolution of Madrid illumination from the sky



Jaime Zamorano, Jesús Gallego, Carlos Tapia

Instituto de Física de Partículas y del Cosmos



Jaime Zamorano
Alex Sánchez, J. Gallego

Horizon 2020
European Union funding
for research and innovation

STARS4ALL

Instituto de Física de Partículas y del Cosmos

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GUAIX group

Other contributions

- Today 15:50 Maritza Lara
  “Identifying the main drivers in the evolution of galaxies”
- Friday 09:30 Alejandro Sánchez de Miguel
  “Nocturnal remote sensing: a bridge between astrophysics and the interdisciplinary world”
- Friday 09:45 Armando Gil de Paz
  “TARSIS, the new IPARCOS-led instrument for the Calar Alto 3.5m telescope”
- Friday 10:30 Francisco Montenegro
  “From Science Operations to instrument and survey management: exploring ML/AI techniques”