

Physics with IACTS

VHE Gamma rays and Stellar Intensity Interferometry

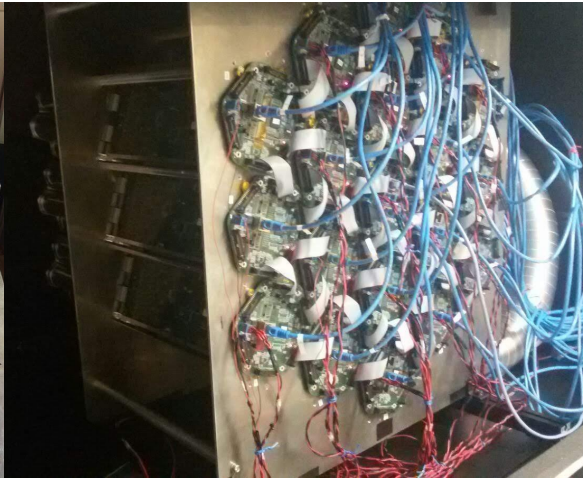
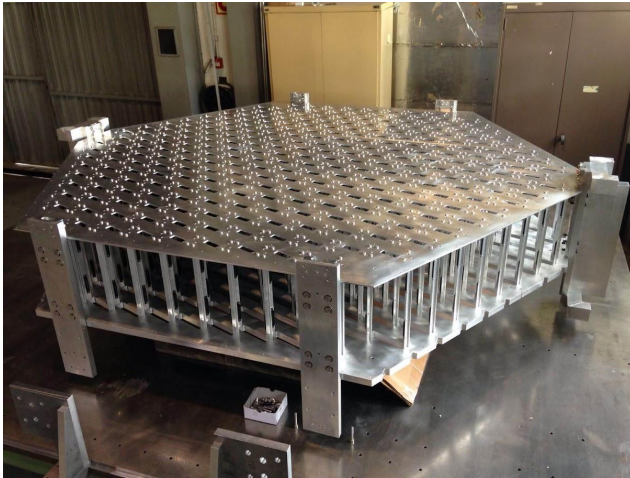


Historical context

The line was created in 2008, as CTA project was gaining momentum and Spain aimed to play a key role, using MAGIC as a platform to acquire experience.

Our hardware knowledge and bottom-up approach to the instrument, put us in a privileged position to open a new observation mode:

Stellar Intensity interferometry with IACTs (MAGIC and CTA-LST)

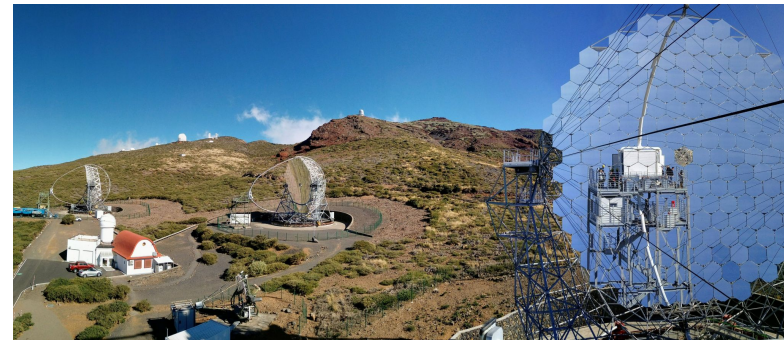
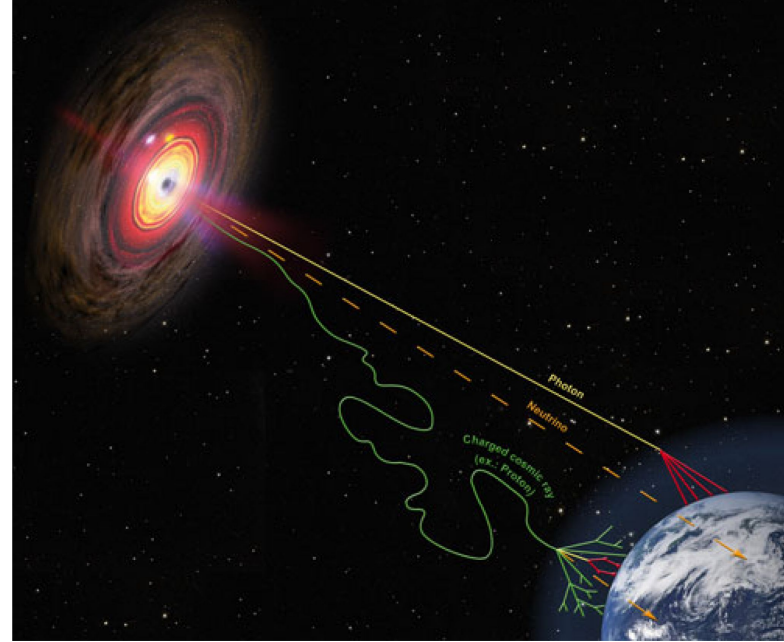


Scientific goals of the line

Employing VHE cosmic gamma rays as messengers

Understanding the Origin and Role of
Relativistic Cosmic Particles
Probing Extreme Environments
Exploring Frontiers in Physics

And constraining stellar fundamental properties
with Cherenkov Telescopes



Scientific goals of the line

Employing VHE cosmic gamma rays as messengers

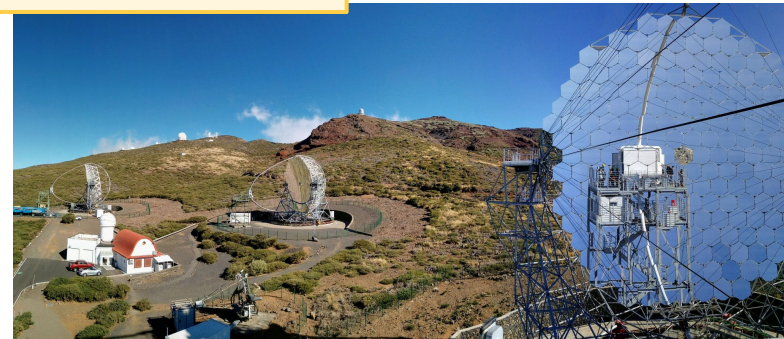
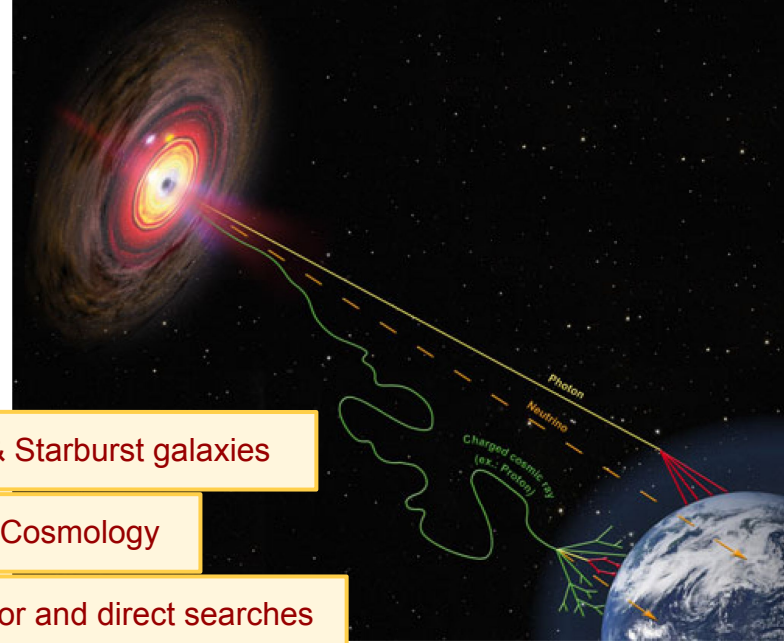
Understanding the Origin and Role of
Relativistic Cosmic Particles
Probing Extreme Environments
Exploring Frontiers in Physics

AMS & Starburst galaxies

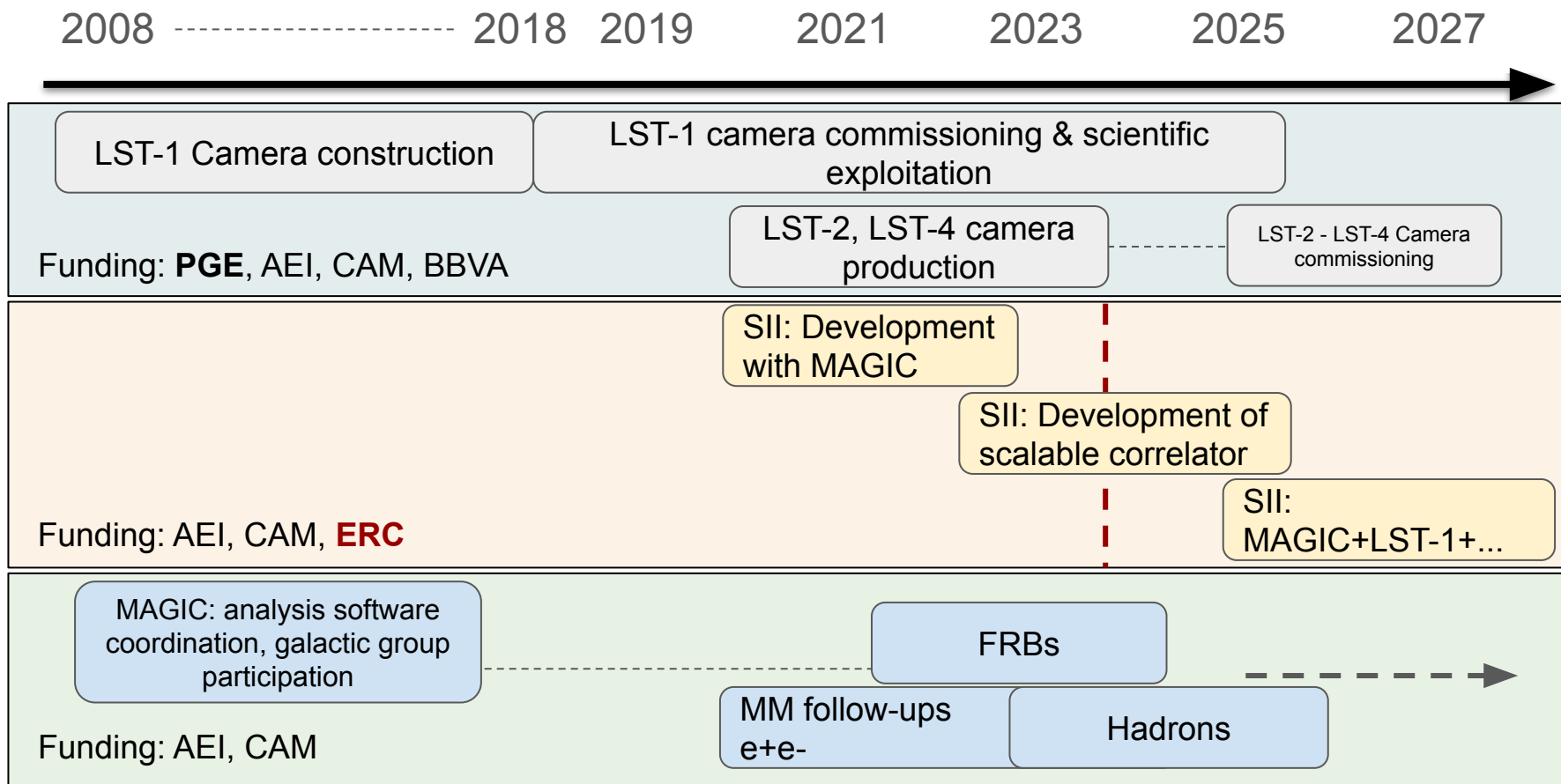
Cosmology

Accelerator and direct searches

And constraining stellar fundamental properties
with Cherenkov Telescopes



Timeline



Time

200

MicroStars

Extreme time and angular resolution in the optical with Cherenkov telescopes



Tarek Hassan Collado

2023

2025

2027



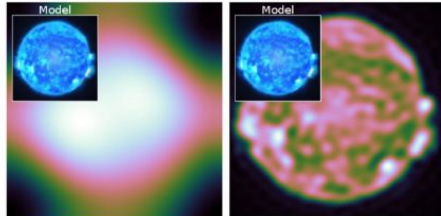
Angular resolution

Time resolution

1 | Imaging stars and their surroundings

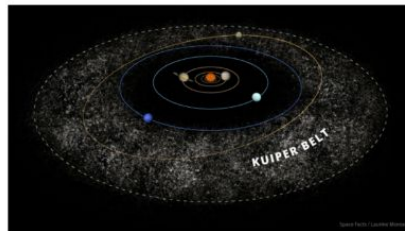
2 | Unraveling the collisional history of the Solar System

Simulated star of ~ 1 mas diameter



Now

MicroStars



Fundir

ent

SII: Development of scalable correlator

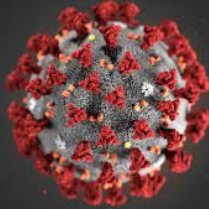
SII: MAGIC+LST-1+...

Timeline

2008 ----- 2018 2019 2021 2023 2025 2027

LST-1 Camera construction

Funding: **PGE**, AEI, CAM, BBVA

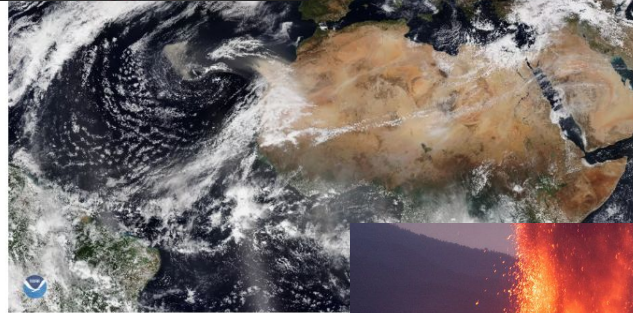


Commissioning & scientific exploitation

LST-2, LST-4 camera

LST-2 - LST-4 Camera commissioning

Funding: AEI, CAM, **ERC**



The NOAA-20 satellite captured this image of a large dust storm over the African continent on March 23, 2020

Development of correlator

LST-1

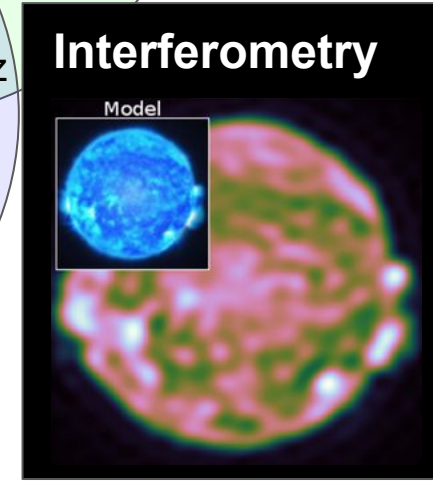
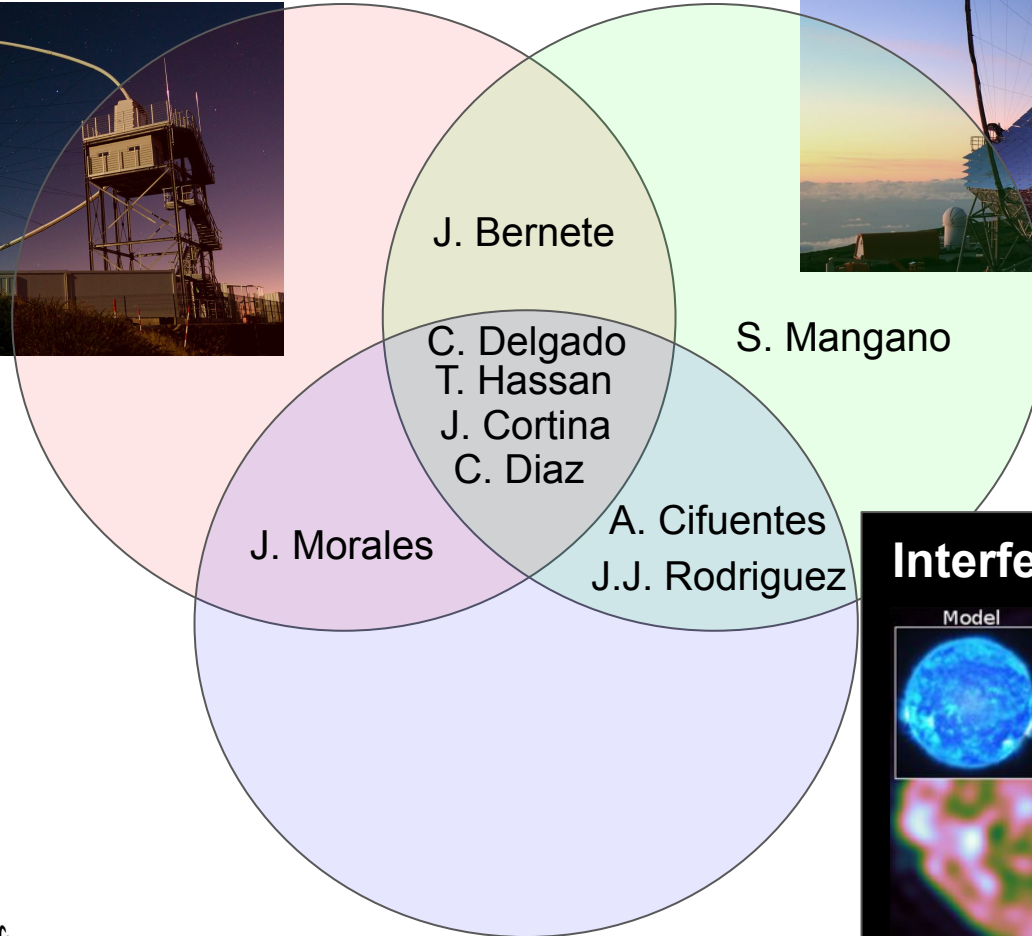
MAGIC: analysis software coordination, galactic group participation

Funding: AEI, CAM

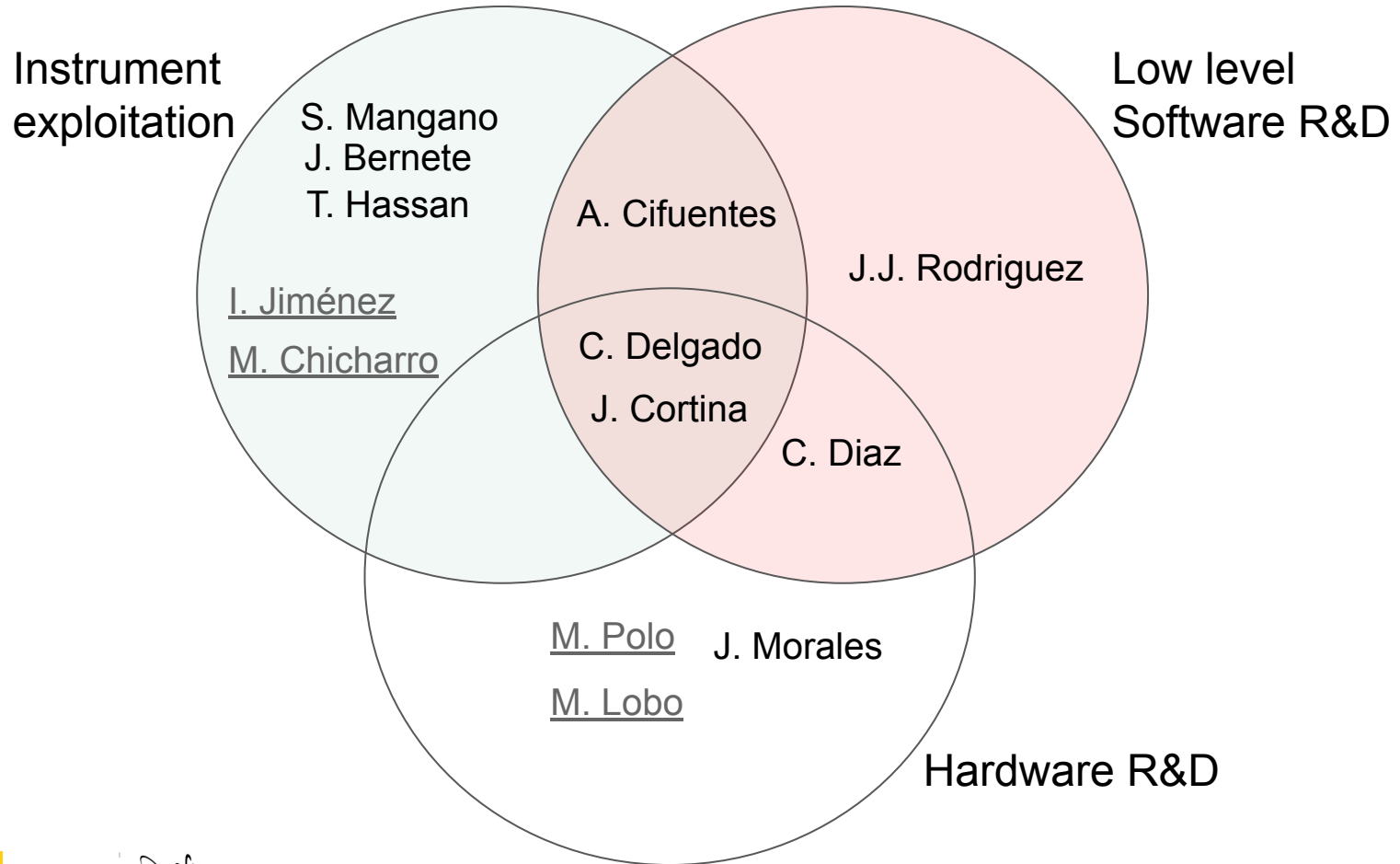
MM follow-up



Structure of the line: projects



Structure of the line: activities (with former members)



On going & future activities: CTA (CTA-N)

Funded via AEI, PGE and CAM: ~500 k€/year from 2020 to 2023

- Increment to 750k€ from mid 2023.

Management of LST project: Co-Pi and camera engineering coordination

Participation in operation & maintenance of LST1; managing of Spanish funds for maintenance and operation of LSTs

Camera mechanics, environmental system, and trigger distribution

- Commissioning of LST-1 to LST-4 and scientific exploitation
- Redesign of MST shutter, and follow up of LST-South project

Commissioning of LSTs cameras

- LST cameras engineering coordination
- LST camera software managing developer

Analysis

- Dark matter with SMC (M. Bernardos Phd. Thesis, 2020)
- Event type tagging (2021 -)
- Preparation of LST 1-4 analysis

R&D for future upgrade cameras (2023 -)



On going & future activities: Stellar Intensity Interferometry

Funded via AIE, ERC & CAM: 500k€/year since 2023

Coordination of activities in MAGIC and LST (since ~2021)

- Definition of targets
- Scheduling of observations

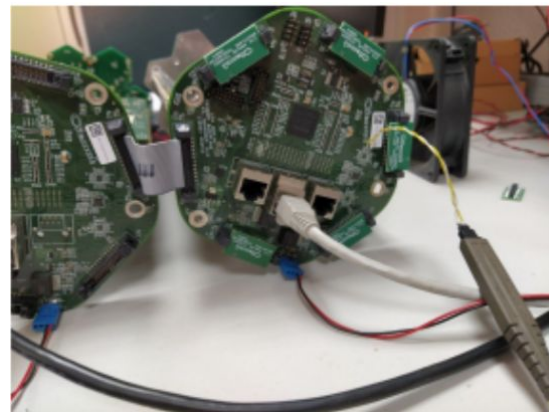
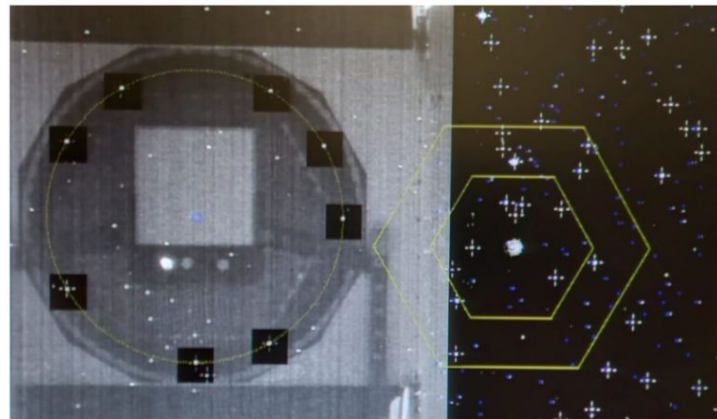
Development of

- Optics & mechanics for MAGIC and LST
- Electronics for LST
- Design and construction of scalable realtime correlator
- Control & DAQ software

Deployment and maintenance of correlators hardware

Analysis

- Coordination of activities
- Development of main analysis pipeline
- Lead of main analysis



On going & future activities: MAGIC

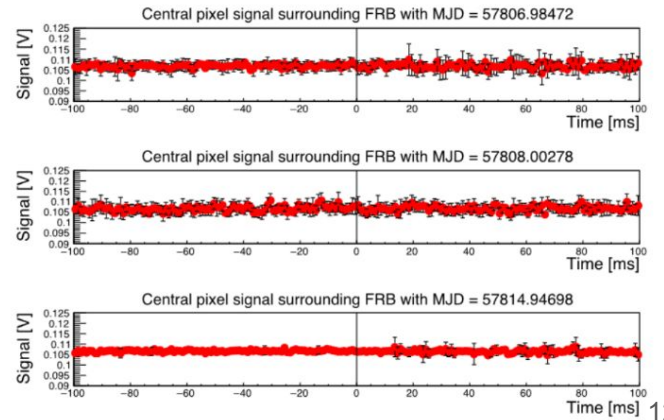
Funded via AEI: ~ 40k€/year

On site IT administration and maintenance of central control software

Convenorship of Galactic Working Group

Proposal leadership and analysis

- Observation of FRBs in optical and VHE
- (I. Jimenez Phd. Thesis 2023)
- Follow-up of multi-messenger alerts
- Optical observation of occultations
- Leptons flux measurement
- Hadron flux reconstruction



(Selected) Running collaborations

- MAGIC & LST Collaborations & CTA Consortium
- **Instrument R&D:**
 - Participation in M2Tech project (HORIZON-INFRA-2024-TECH-01-01) with CNRS, INFN, U. of Geneva, UB, and others
 - CIEMAT Division of Scientific instrumentation and Technology Department (LST camera & SII)
 - University of Geneva & MPI for SII
- **Analysis:**
 - IAC (hadrons analysis)
 - University of Geneva (hadrons analysis)
- **IAC for LST-2 to LST-4 cameras acceptance**
- **Knowledge transfer**
 - Arquimea: redesign of MST shutter for knowledge transfer
 - Bari University: LST-South camera mechanics
 - INFN: LST-South camera trigger distribution and L1 level (with Technology department)
- **CTA Spain Management & coordination.**



UNIVERSITÉ
DE GENÈVE



Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

ARQUIMEA



Universidad de Jaén



CSIC
Spanish Council of Research



Institut de Física d'Altes Energies

13

Highlights from second half of 2023

First detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1

ATel #16381; **Juan Cortina (CIEMAT)** for the CTAO LST collaboration
on 15 Dec 2023; 14:31 UT

Credential Certification: **Juan Cortina (Juan.Cortina@ciemat.es)**

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, AGN, Blazar, Quasar

Post

First ever detection of OP 313 above 130 GeV

10th quasar detected at VHE

Most distant active galactic nuclei (AGN) ever detected by a
Cherenkov telescope

LST prototype's performance is exceptional, even in commissioning
phase.

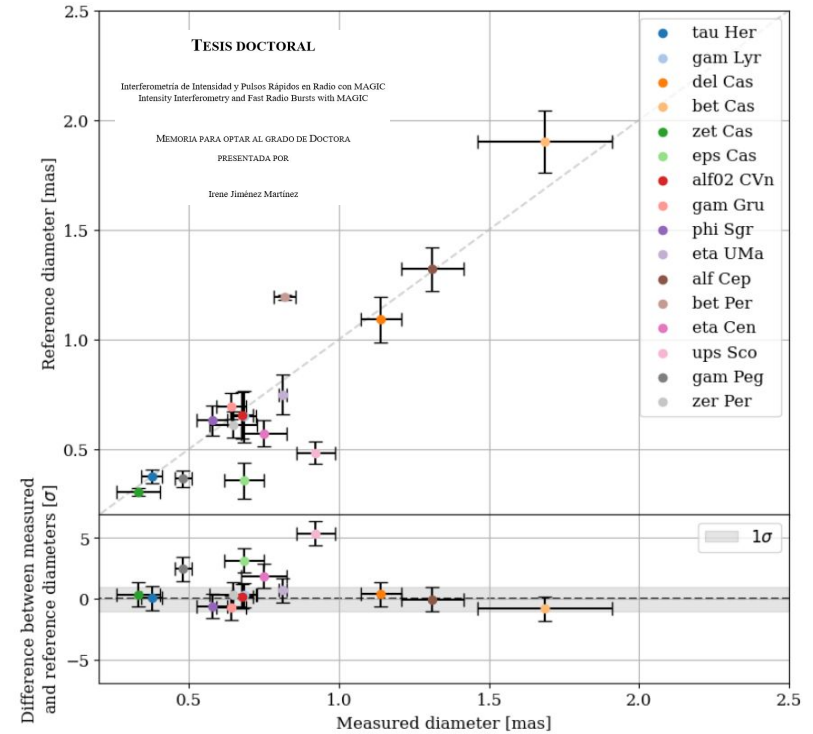
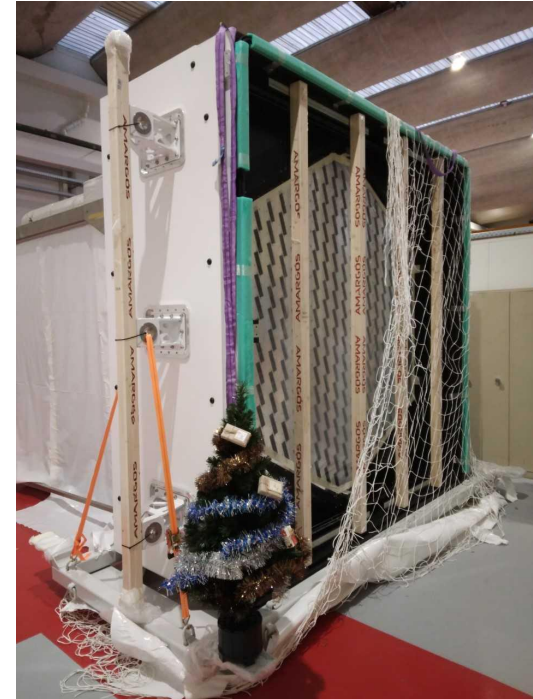


Figure 8.2: Comparison between modeled and measured angular diameters for stars without a direct angular diameter measurement in our optical band.

Knowledge transfer milestones in 2023

Delivery of first MST camera structures produced by Arquimea, thanks to know-how transfer from CIEMAT.



And camera mechanics for LST-South tender also won by Arquimea

Scientific & technical challenges

- LST

- Finalization of commissioning of LST-1: reaching >95% operation efficiency (~2024)
- Start planning of camera upgrade (~2024)
- Installation of LST-2 to LST-4 cameras and commission them (~2025)
- Exploitation of LST-1 to LST-4 until CTAO acceptance (>2025)
- Preparation of acceptance of LST by CTAO (> 2026)

- SII:

- Add LST-1 to MAGIC correlator (~2024)
- Develop correlated noise mitigation to enhanced sensibility at low baseline (~2024)
- Develop and commissioning scalable correlator (~2025)

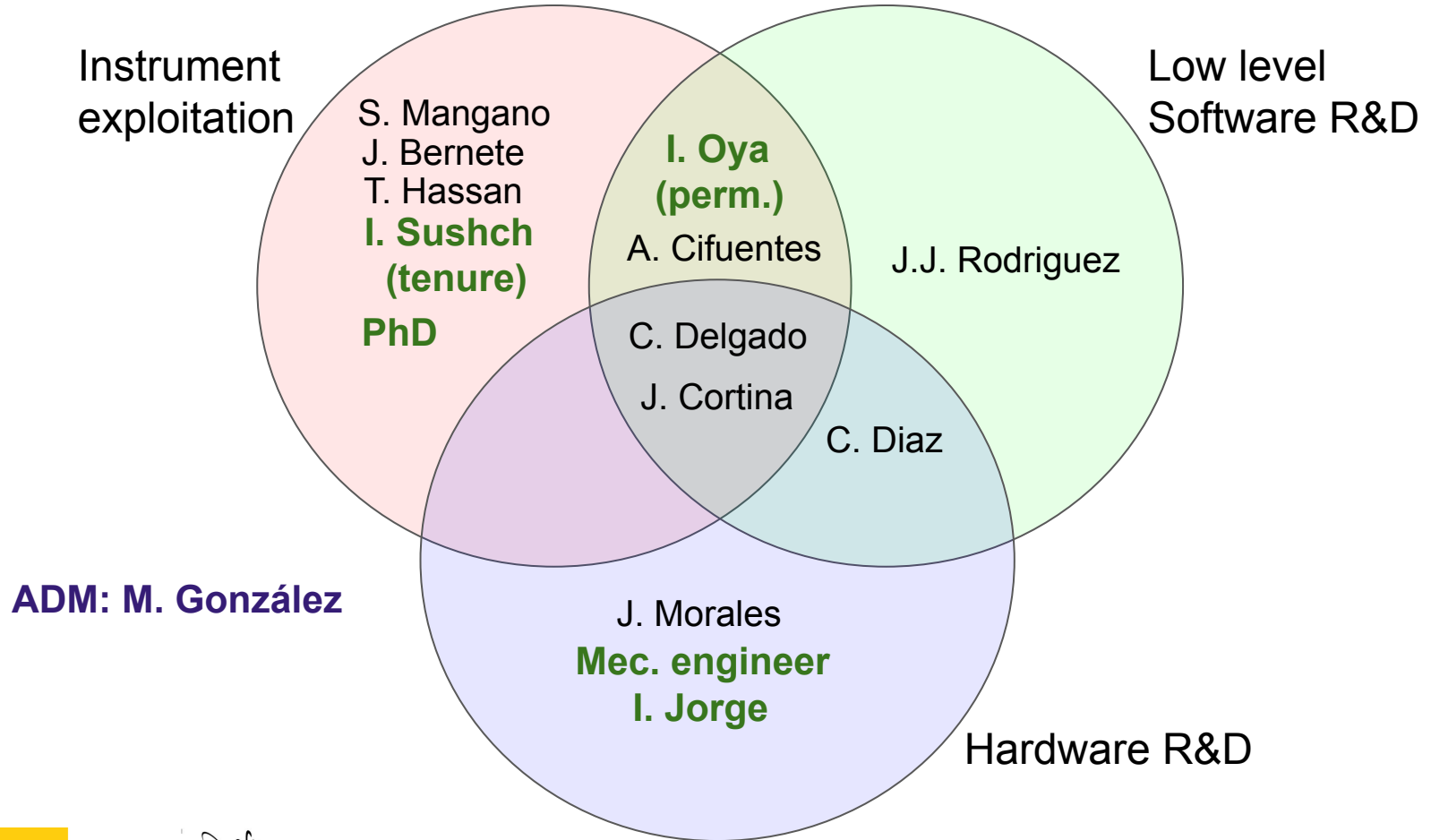


Management Challenges

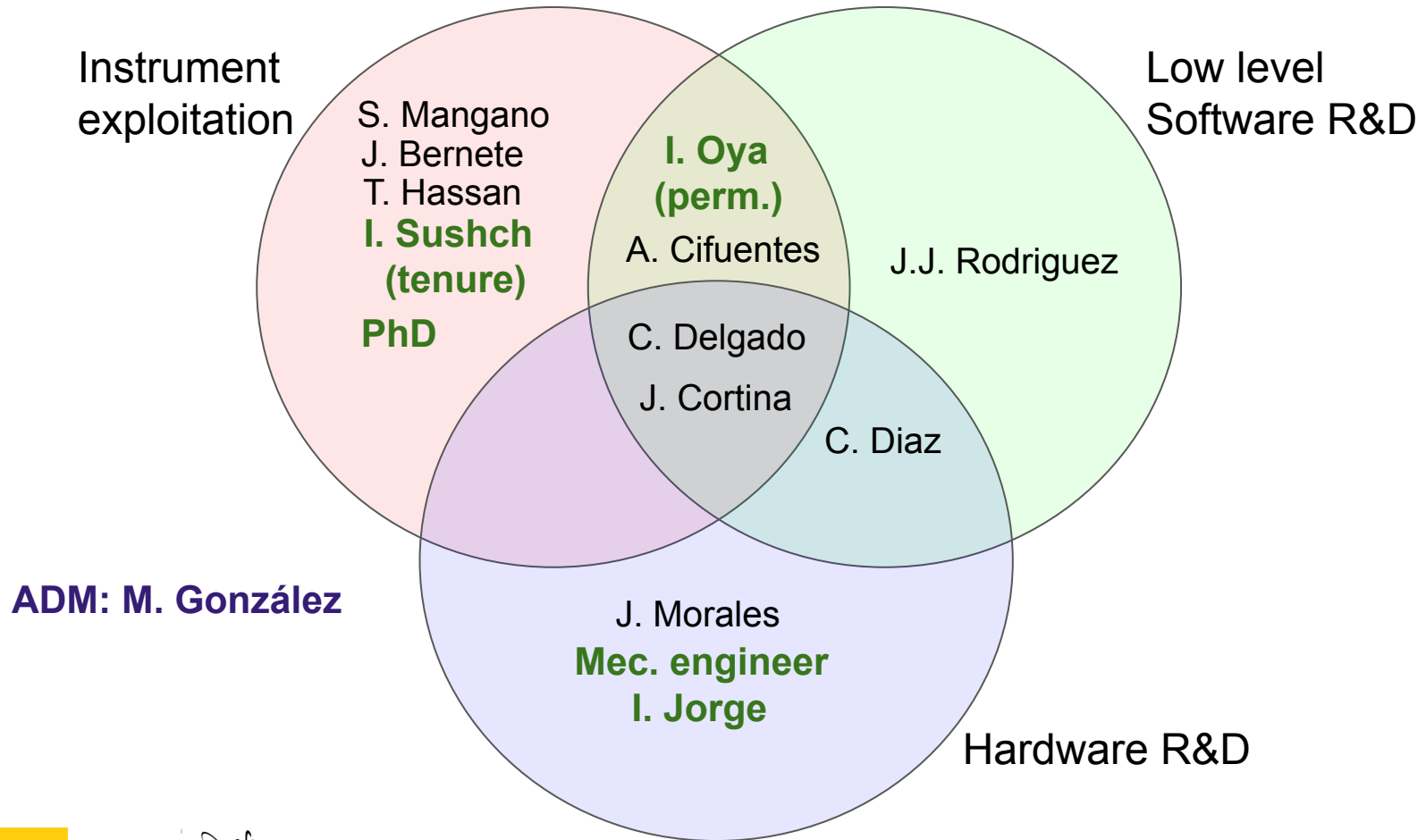
- Transition to professional maintenance and operation support in LST
 - The increase of funds to cover the operations and maintenance costs of LST-1 to LST-4 is being addressed by CIEMAT and IAC together with the Ministry
 - It is not clear yet how to manage the additional administrative load to manage the funds

- Need to find a new balance between R&D and purely scientific activities:
 - Installation & commissioning of LST-2 to LST-4 requires to find out additional technical personnel in a relatively short time scale
 - In medium term scale we have to focus in scientific exploitation of LST and SII
 - Support of LST-South construction and commissioning, and R&D in future cameras for LST upgrade in ~15 years time scale has to be kept in the agenda.

We already started: **incoming** members



We already started: **incoming** members

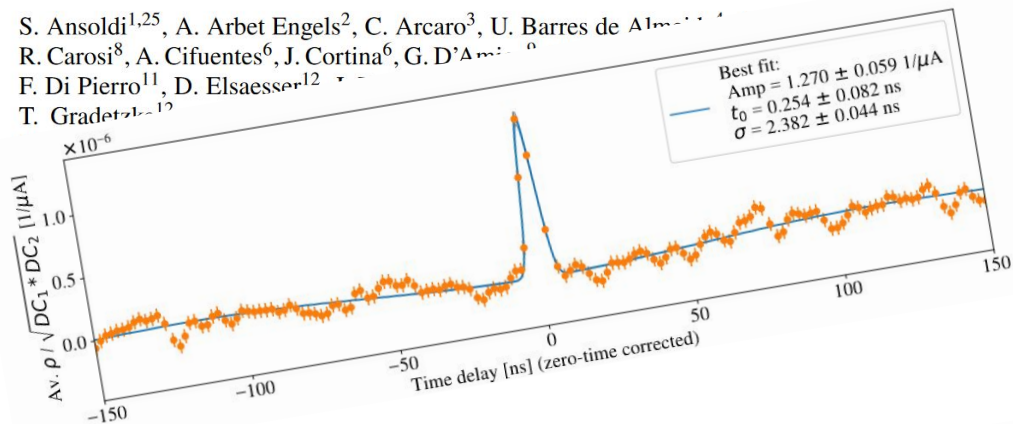


The End

Coming in few months scale

Performance of the MAGIC Stellar Intensity Interferometer

S. Ansoldi^{1,25}, A. Arbet Engels², C. Arcaro³, U. Barres de Almeida⁴,
R. Carosi⁸, A. Cifuentes⁶, J. Cortina⁶, G. D'Amico⁵,
F. Di Pierro¹¹, D. Elsaesser¹²,
T. Graczyk¹³



Performance of the joint LST-1 and MAGIC observations evaluated with Crab Nebula observations

Astronomy & Astrophysics manuscript no. output
December 4, 2023

A detailed study of the Very-High-Energy Crab Pulsar emission with the LST-1 telescope

©ESO 2023

Who we are in the Unit as of today

Scientific Personnel

Seniors: J. Cortina, C. Delgado, S. Mangano

Postdocs: T. Hassan (promoting to senior soon)

Students: J. Bernete, A. Cifuentes

Technical Personnel

Senior mechanical Engineering: C. Diaz

Senior IT engineering: J.J. Rodriguez

Technical Personnel

Technician: J. Morales

New personnel starting by end 2023 or 2024

Scientific Personnel

Seniors: **I. Oya** (estabilizacion)

Postdocs: **I. Susch** (CAM's talent attraction)

Student: FPI on process

Technical Personnel

Mechanical Engineering: ERC on process

Electronics engineering: **I. Jorge** (ERC)

Administration

M. Gonzalez (ERC)

