Astrophysics in Spain, which includes the IAC

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Outline

- Spain
- The IAC
- The Observatories
- Selected projects
  - MAGIC
  - AMS
  - VSA
- The GTC and its instruments
- Astrophysics with the GTC

Astrophysics in Spain

- A fast growing discipline
- No Astronomy in Spain in the early 70's (some notable exceptions)
- Growth catalyzed by the international observatories:
  - La Palma, Tenerife, Calar Alto and later IRAM

Calar Alto

- Formerly German, now it is a 50 – 50 endeavour between Germany and Spain
- Telescope mainly devoted to long term projects (i.e. Alhambra)

Astronomy Institutions

- University Departments:
  - Barcelona (2), Granada, La Laguna, Madrid (3), Valencia, Santander, Santiago
- Large Institutes:
  - IAC (Includes La Laguna)
  - IAA
  - IECC
- Medium size institutes
  - IFCA (Santander)
  - LAEFF(Madrid)
  - CAB (Madrid)
  - OAN (Yebes)
- Small centers
  - U. Alicante, U. Oviedo, U. Zaragoza

Disciplines

- Mostly all branches of Astronomy
  - Solar Physics
  - Planetary Physics
  - Stellar Physics
  - Interstellar Medium
  - The Galaxy
  - External galaxies
  - Cosmology
- Both theory and observations
  - Biased towards the later

Activities in Space

- ESA projects
  - ISO
  - SOHO-Cluster
  - INTEGRAL
  - Rosetta
  - Planck
  - IMAX
  - ...
- Participating Institutes
  - IAA, IAC, IFCA, Valencia, U. Barcelona, etc

Demography

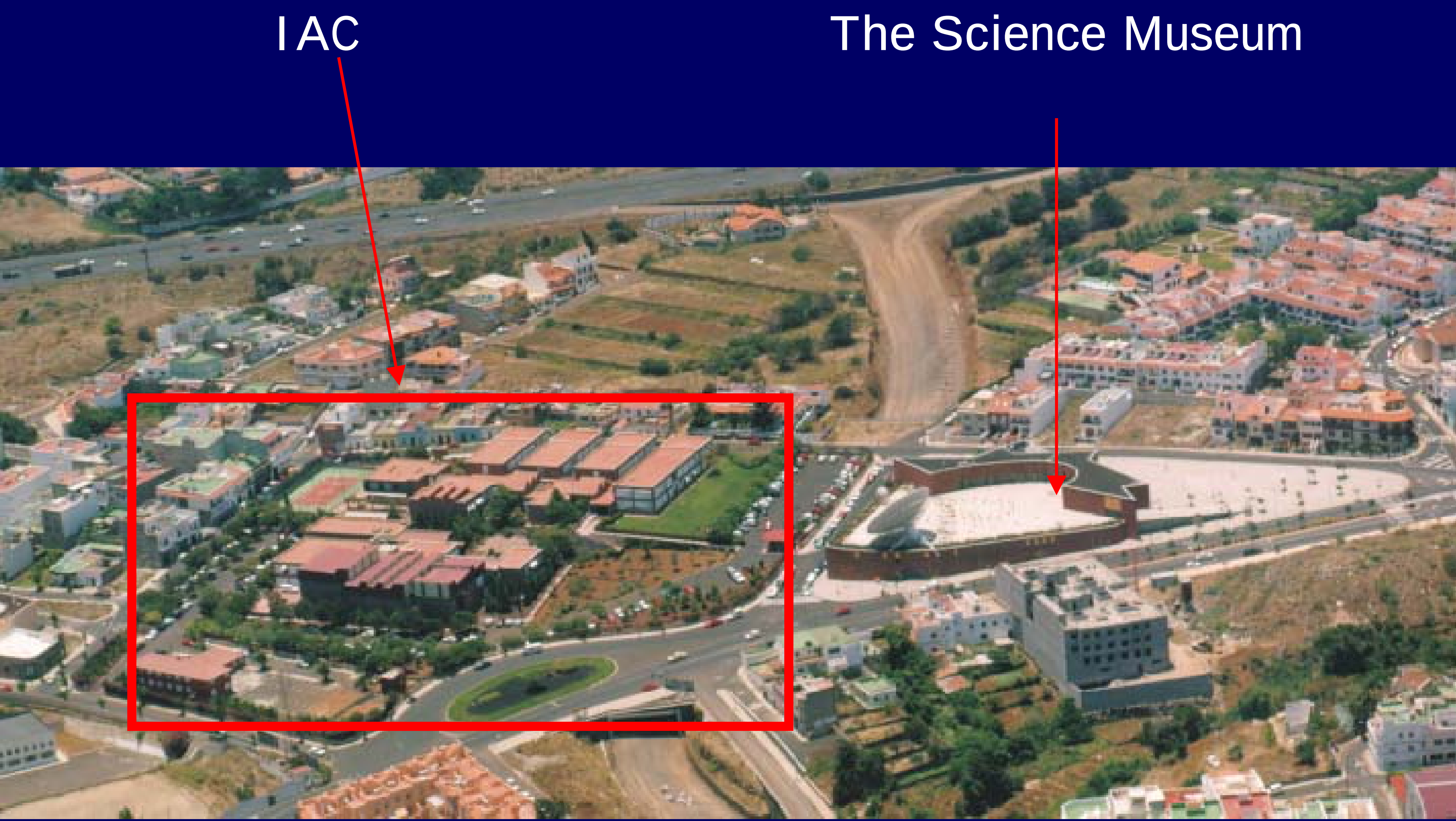
- About 400 active astronomers, not all with permanent positions
- Ratio of astronomers/inhabitant still a facto of 5 down from the average in Europe
- Great interest in joining the European Southern Observatory (ESO)
  - Discussion undergoing
  - Will provide access to the southern skies

Main Current Projects

The IAC

- The IAC is a joint institute. Participating institutions are:
  - The Spanish Central Government (Science Ministry
  - The Canarian Government
  - The Spanish Research Council (CSIC)
  - The University of La Laguna
- The IAC is in charge of the Graduate Programme and Undergraduate Astrophysics curriculum of the ULL
- Personnel
  - Some 45 Staff, 40 Postdocs & 40 Graduate Students
  - Plus about 60 Engineers and technicians
  - And about 60 Administrative staff (includes observatories personnel)

The Headquarters



Research Activities

- Research in most areas of Astronomy including:
  - Solar Physics
  - Low mass stars (brown dwarfs and extrasolar planets) & Massive stars, Cataclysmic variables, Collapsed objects,…
  - Interstellar medium (HII regions, PNs)
  - Galaxies (The Galaxy, Normal and Active galaxies, Starburst galaxies)
  - Cosmology
- Both theory and observational astronomy
- Both from ground and space
- Active instrumentation programme both for ground and space

The Observatories

- The IAC manages two international observatories
  - Teide, in Tenerife
  - ORM, in La Palma
- Teide: mostly Solar Physics
  - Also host the IAC-80, the TCS (1.5m), the OGS (ESA),
  - And the VSA
- The ORM host the larger night time telescopes, including the ING, the NOT, Galileo, Mercator, The Liverpool, MAGIC and soon the GTC
- But also some solar telescopes (Swedish, DOT)

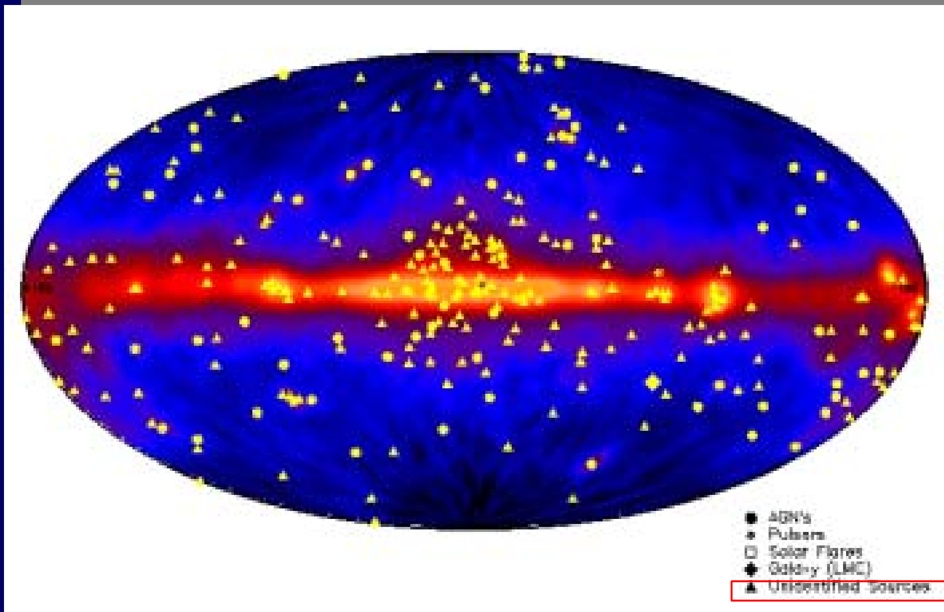
Teide Observatory

Obs. Del Roque de Los Muchachos (ORM)

MAGIC

- You are probably more familiar with MAGIC than many astronomers in Spain
- This is changing though

Looking for gamma rays from SNR with the right spectra



Wide field EGRET observations

- Satellite observations.
- Low resolution (PSF ~4 deg.)
- Energy range ~100 MeV – 10 GeV
- Many unidentified sources seen. Many of them positionally coincident or close to SNRs

MAGIC Cherenkov telescope

- New generation 17m Cherenkov telescope
- High resolution (compared with EGRET) ~3'
- Small FOV (~3.5 deg)
- Natural energy continuation to EGRET observations.

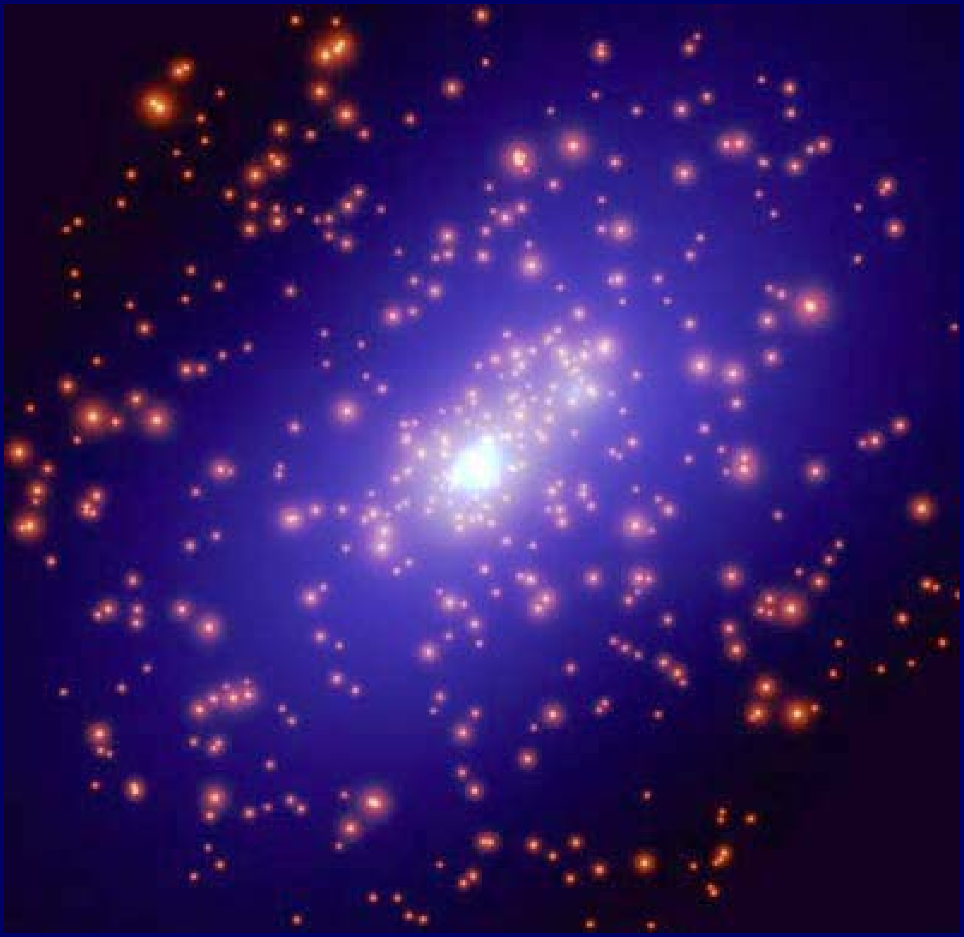
Study CR properties

- **Learn about source properties**
- **Identify MAGIC targets for searching for CR acceleration using EGRET and multiwavelength observations**

However, measuring high energy charged CR is a difficult task:

- Typically 1 particle per m^2 per second for E > 100GeV
- 99% are protons and alpha particles (He), so very good ID capabilities needed to discriminate other species
- Charged CR interact with atmosphere through both strong and electroweak interactions, so use preferably detectors at the top or above the atmosphere

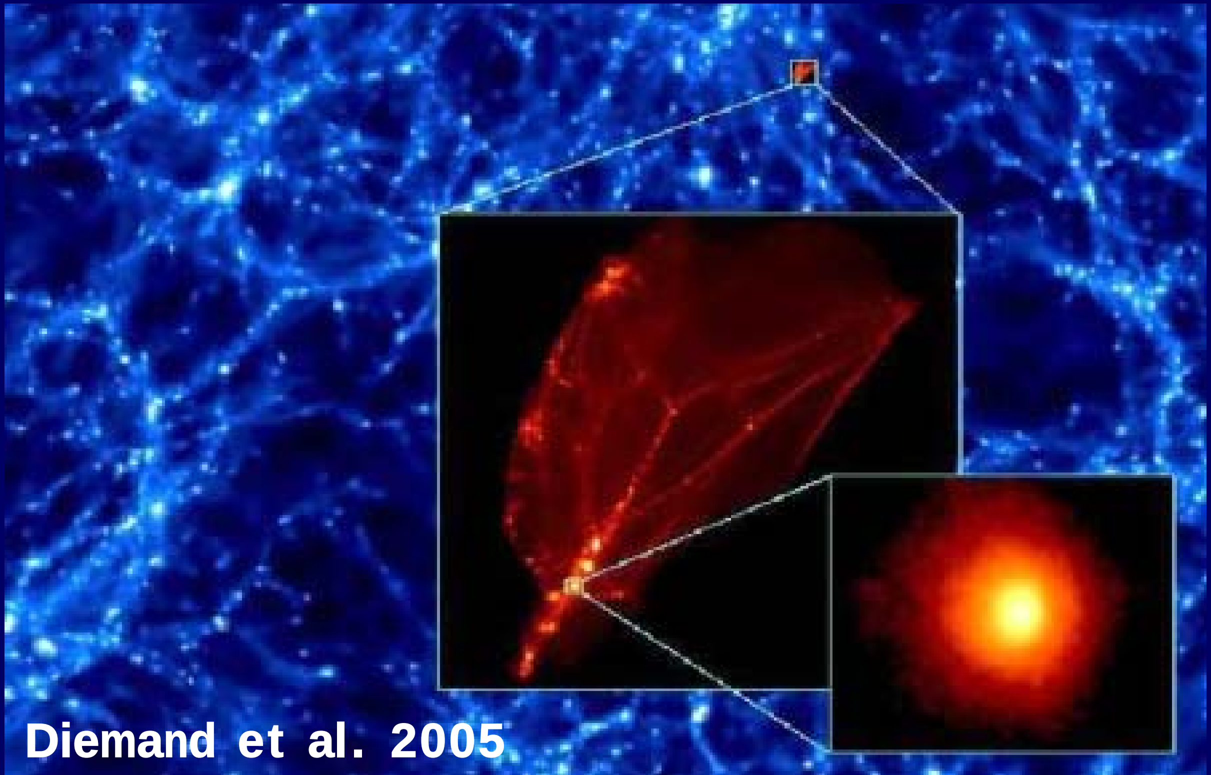
Dark Matter



- Galaxy rotation curves require Dark Matter haloes
- Galaxy cluster dynamics also require Dark Matter
- Likewise Structure formation scenarios require Dark Matter to govern mass assembly

Dark Matter searches with MAGIC

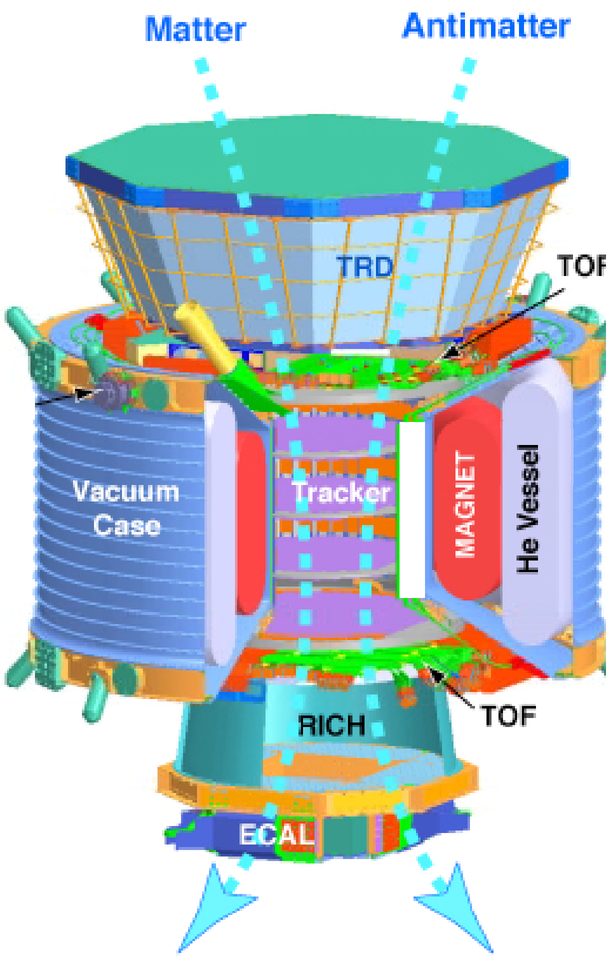
- Neutralino (χ) (39 GeV < m_χ < 1.5 TeV) is a SUSY WIMP
- Neutralino annihilation products could be detected with MAGIC
- Possible targets:
  - Galactic Center
  - Earth size (10-6 $M_\odot$) dark matter haloes in the vicinity of the Solar System

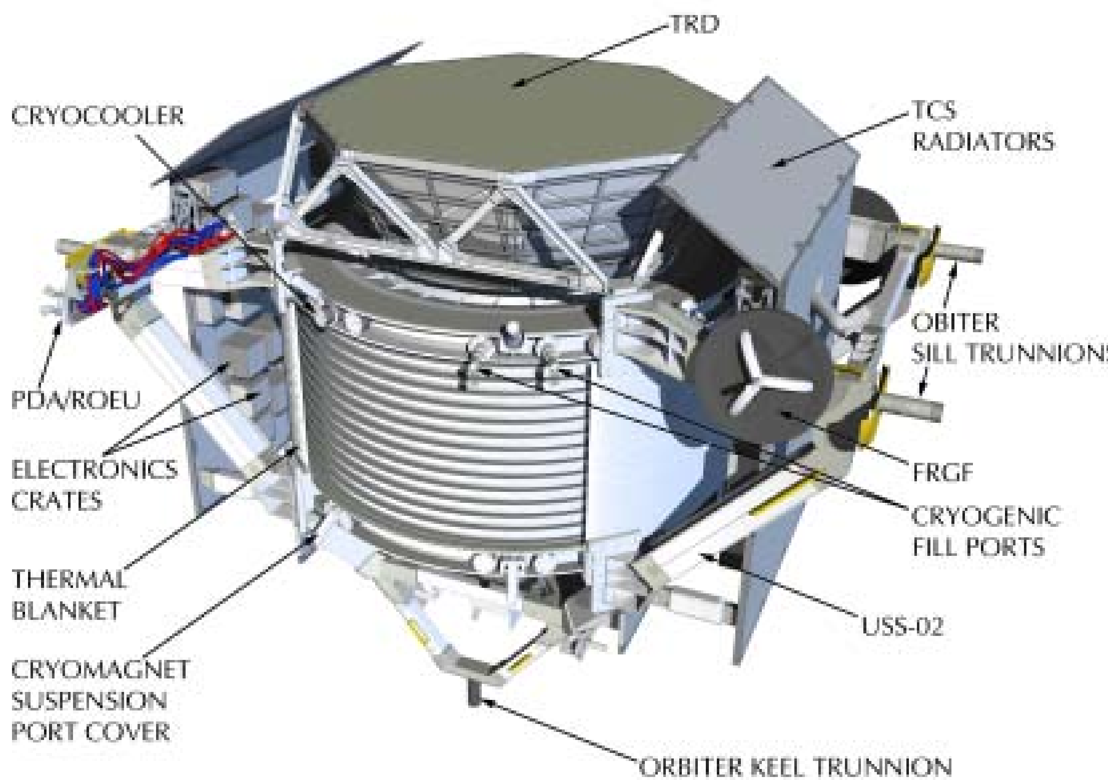


AMS on board the ISS

AMS: A TeV Magnetic Spectrometer in Space (3m x 3m x 3m, 7t)

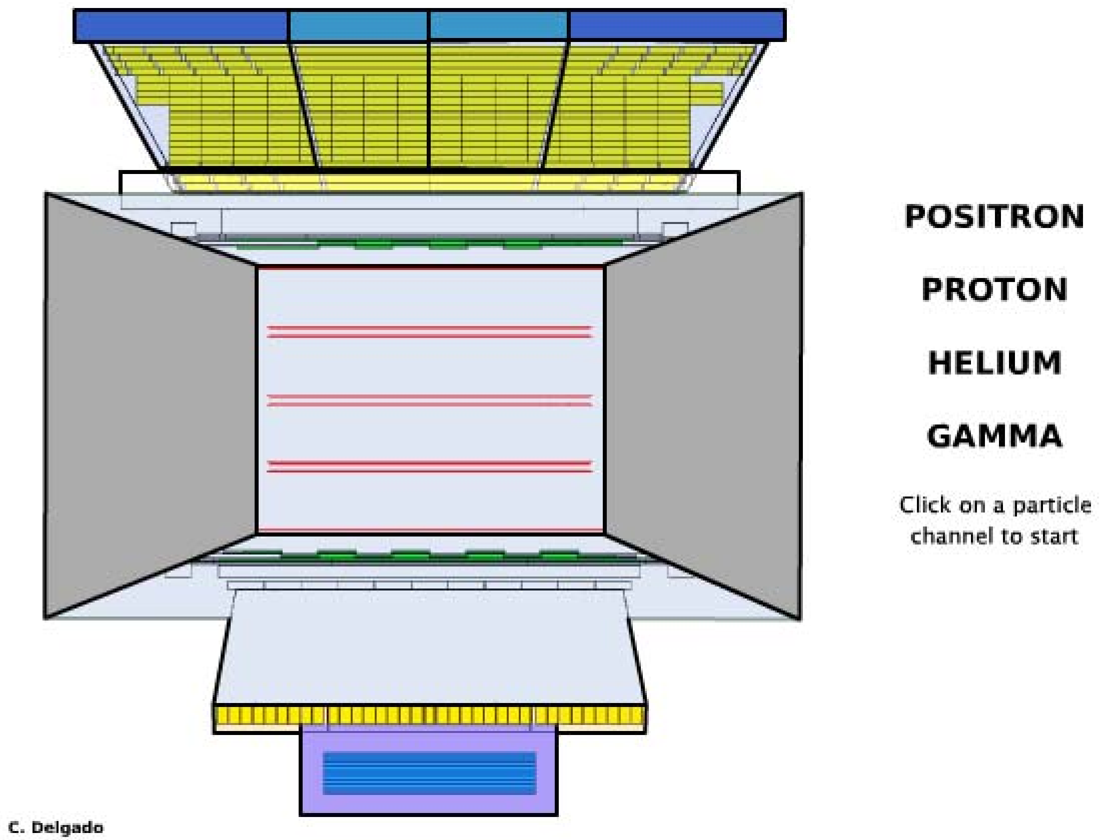
The AMS detector has been under construction for 10 years.
Final ESA thermal vacuum test of the entire detector in 2006.





y03K193_13a TeV US

AMS-02 functional layout



IAC implication in AMS-02

- **Gamma ray astronomy**
  - Perform observations both with MAGIC and other optical and IR telescopes to interpret the results
  - Develop analysis tools and new analysis methods for MAGIC.
- **CR composition and spectra**
  - Develop analysis tools and reconstruction methods for AMS detectors
  - Perform Monte Carlo simulations of detector response
  - Study propagation simulations and implement them as inputs to AMS simulations
  - Perform analysis of actual data from AMS

VSA

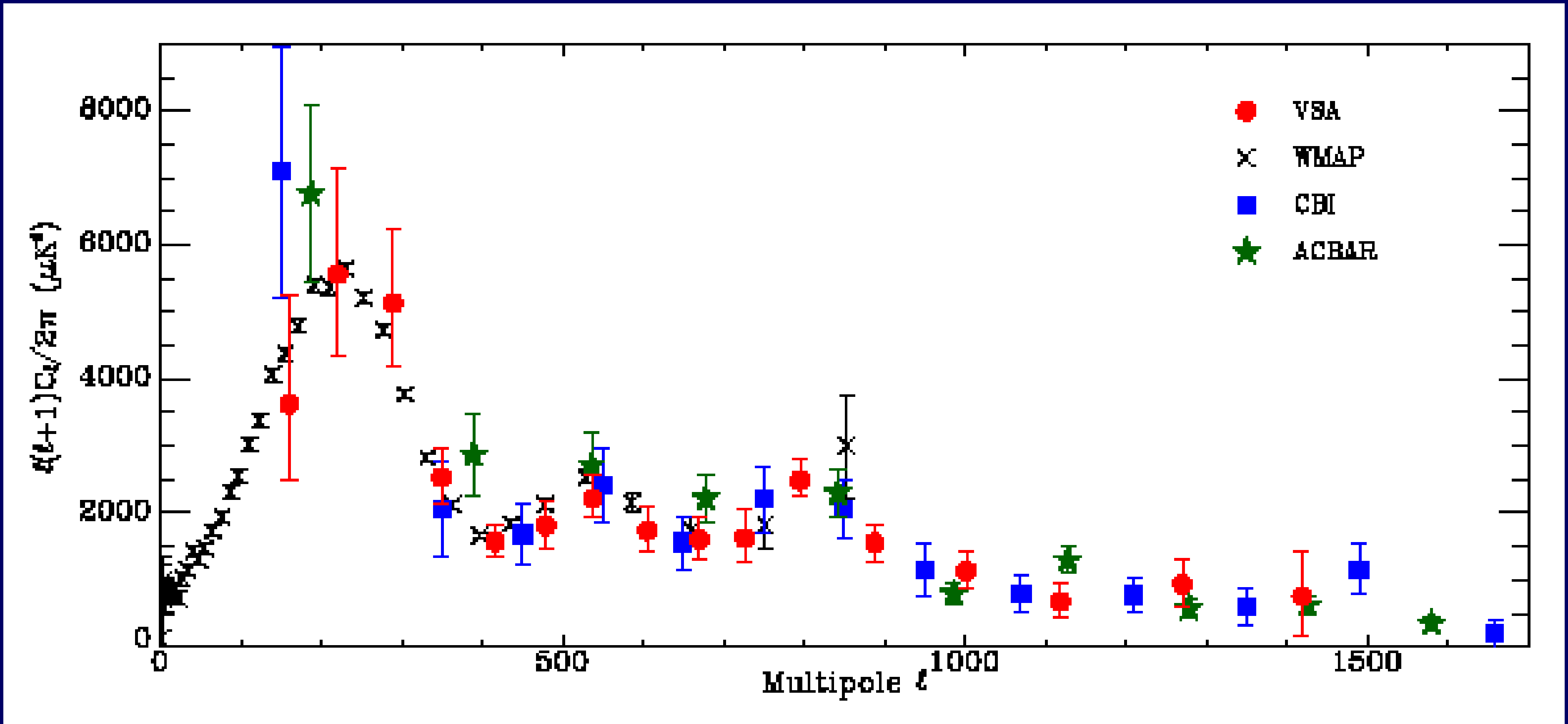
- Long standing collaboration with Jodrell bank and Cambridge
- Started with the Tenerife experiment
  - Detected CMB anisotropies at the same time as COBE
- VSA built to increase the angular resolution

VSA

VSA Results

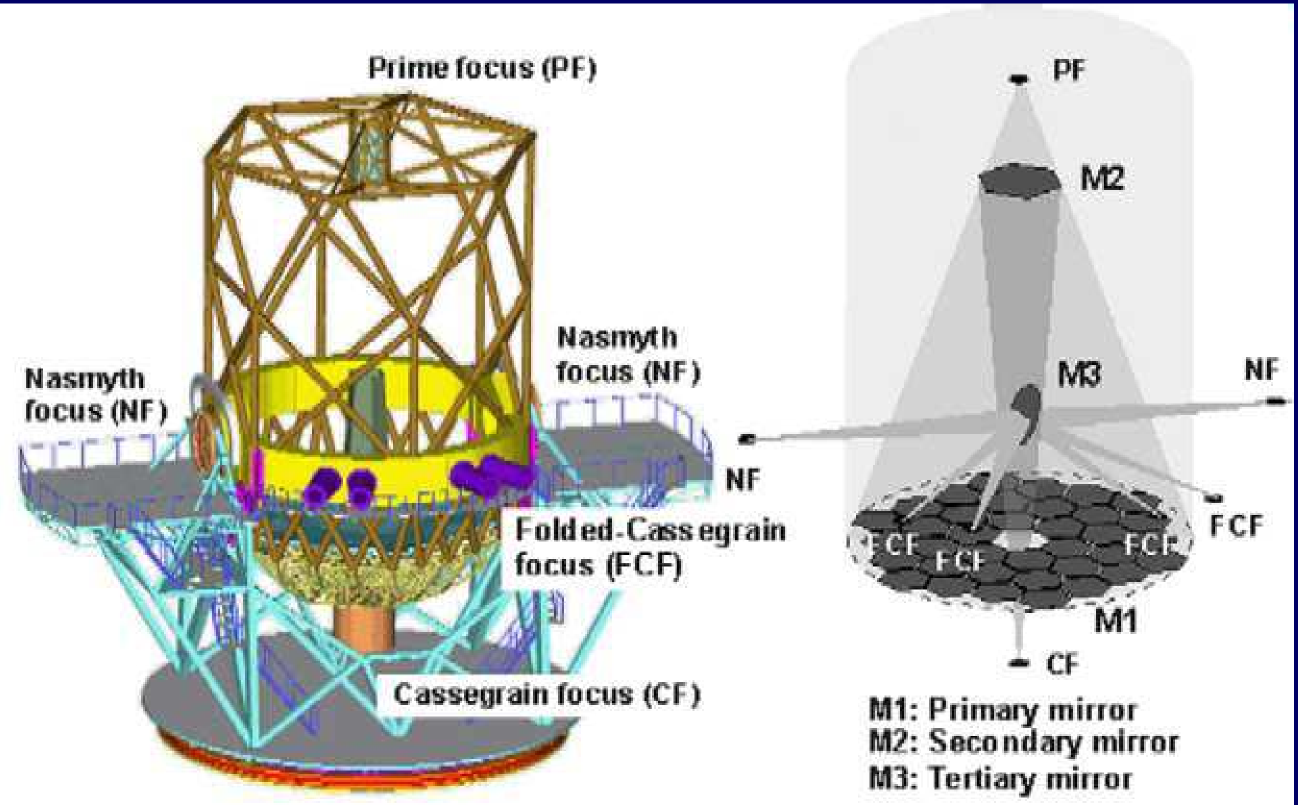
- In broad agreement with WMAP, but the new VSA data allow tighter parameter constraints
- Slight differences in the 3rd acoustic peak and in the overall scaling
  - Has implications for cosmological models
- Better *l* coverage than WMAP, i.e. better angular resolution
- Obtain a negative ($n_{run} = -0.069 \pm 0.032$) running index for the density fluctuation power spectrum
  - Reduces the amount of power at small scales and hence the amount of structure at early times
- Constrain the fraction of dark matter in the form of neutrinos ($f_\nu < 0.087$), which implies $m_\nu < 0.32$eV (for all ν masses equal)

VSA results



VSA will be reconfigured with larger horns and longer baselines, allowing to increase the multipole range up to about l=3000

The GTC in a few numbers

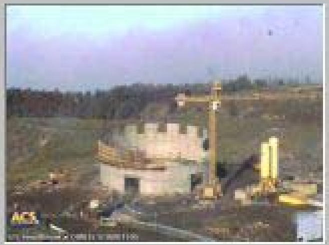


- **10.4 m segmented mirror telescope**
- **36 individually controlled segments (M1)**
- **Chopping lightweighted secondary mirror (M2)**
- **Steerable tertiary mirror (M3)**
- **8 focal stations**
- **20 arcmin FOV at Nasmyth focus (8 arcmin unvignetted)**

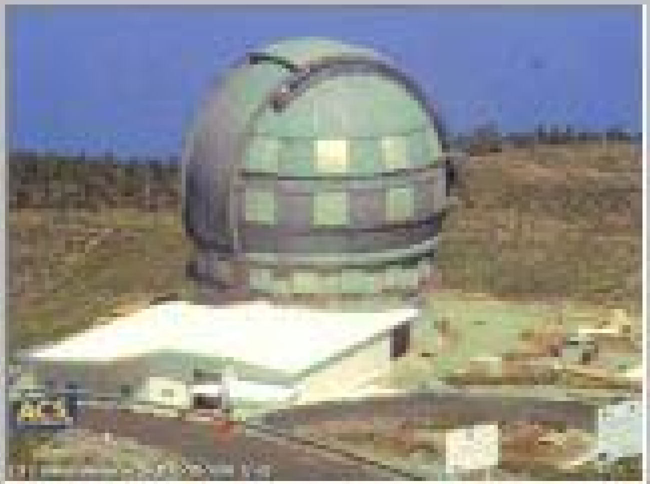
GTC: The Civil work

Roque de los Muchachos, La Palma, Canary Islands

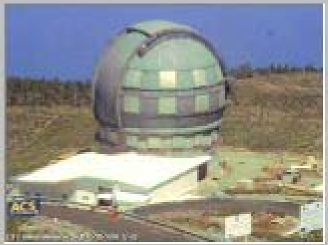
1999



2000



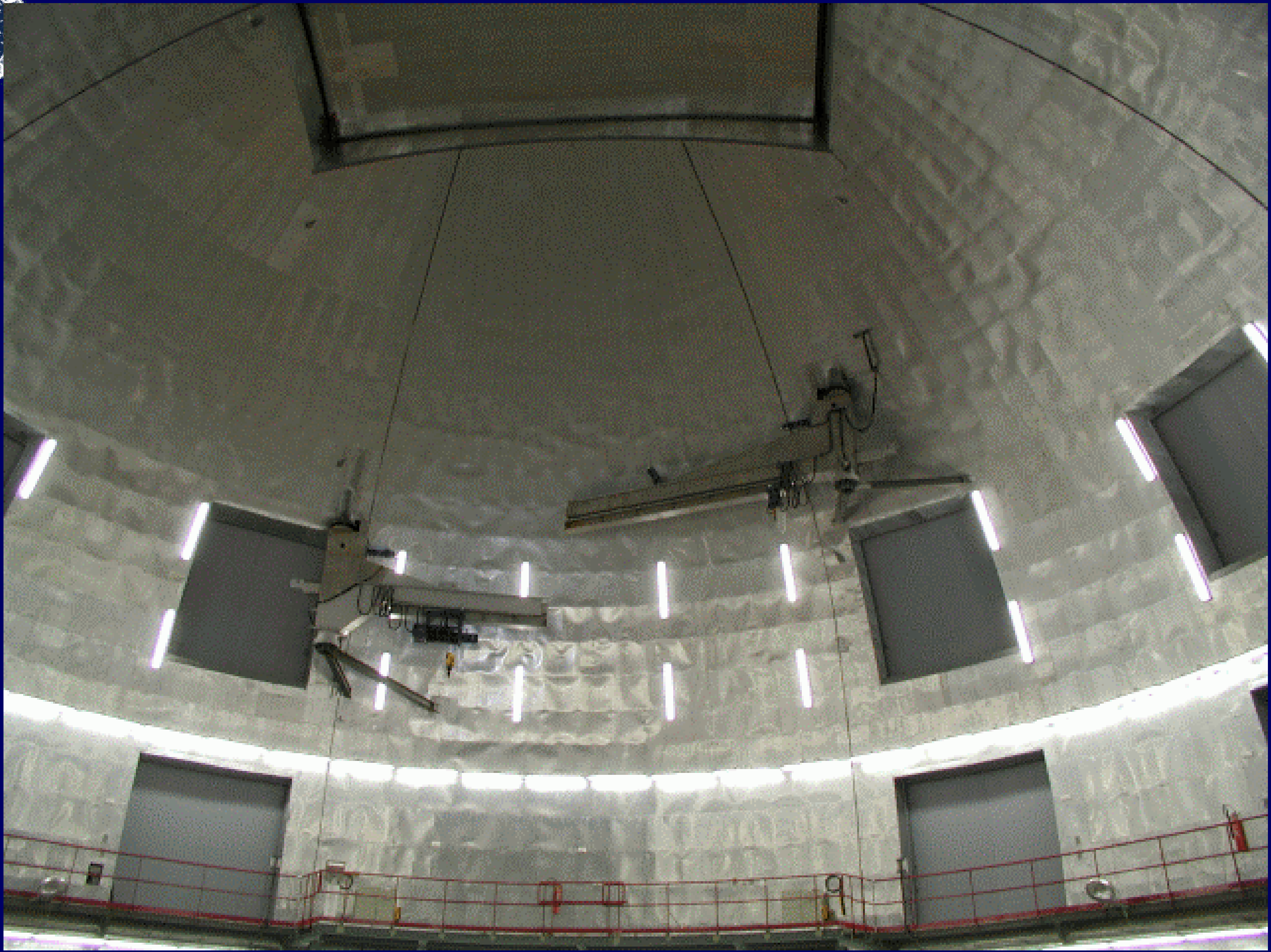
2001



May 2002

Web page of Project Office

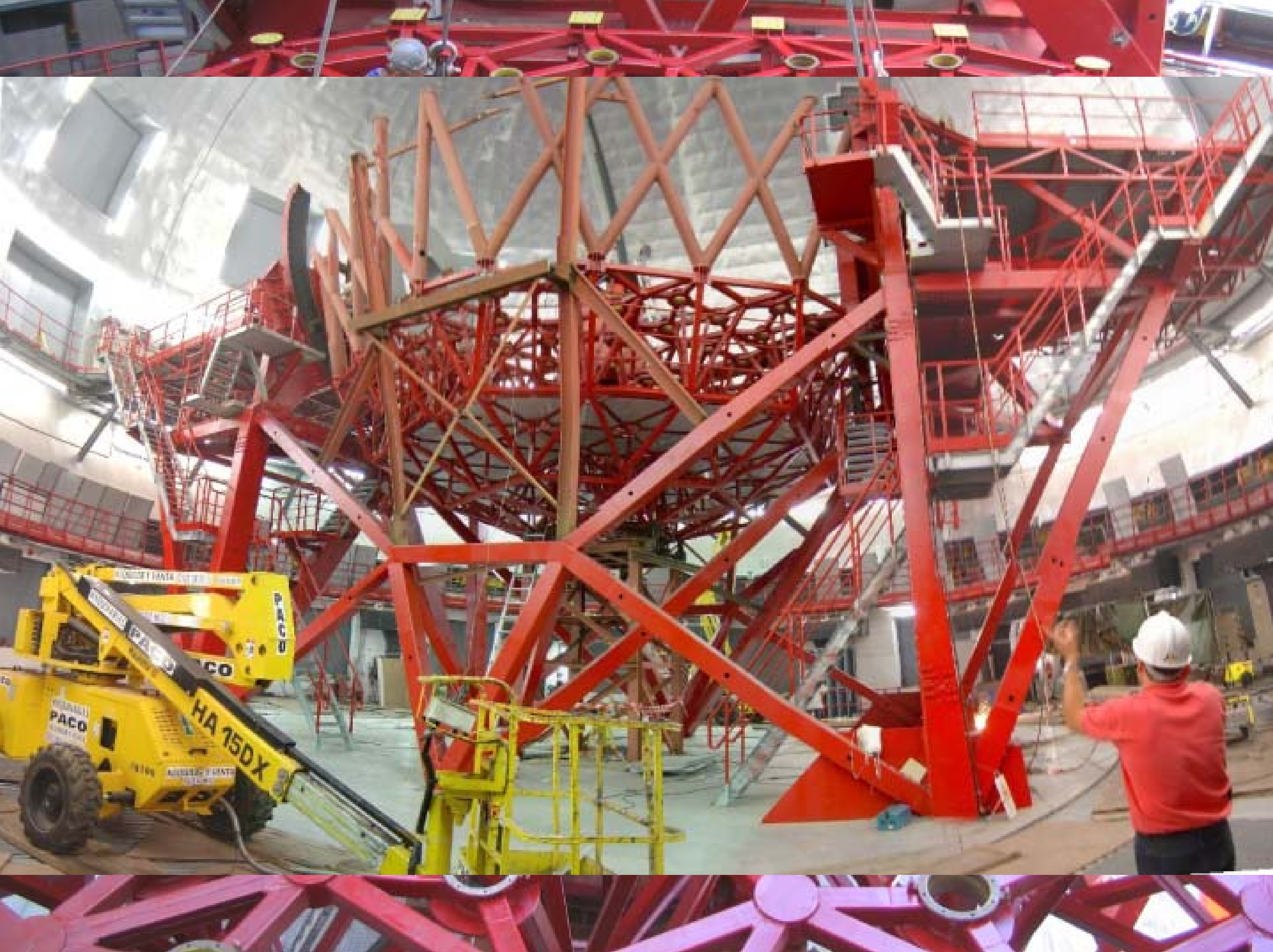
http://www.gtc.iac.es

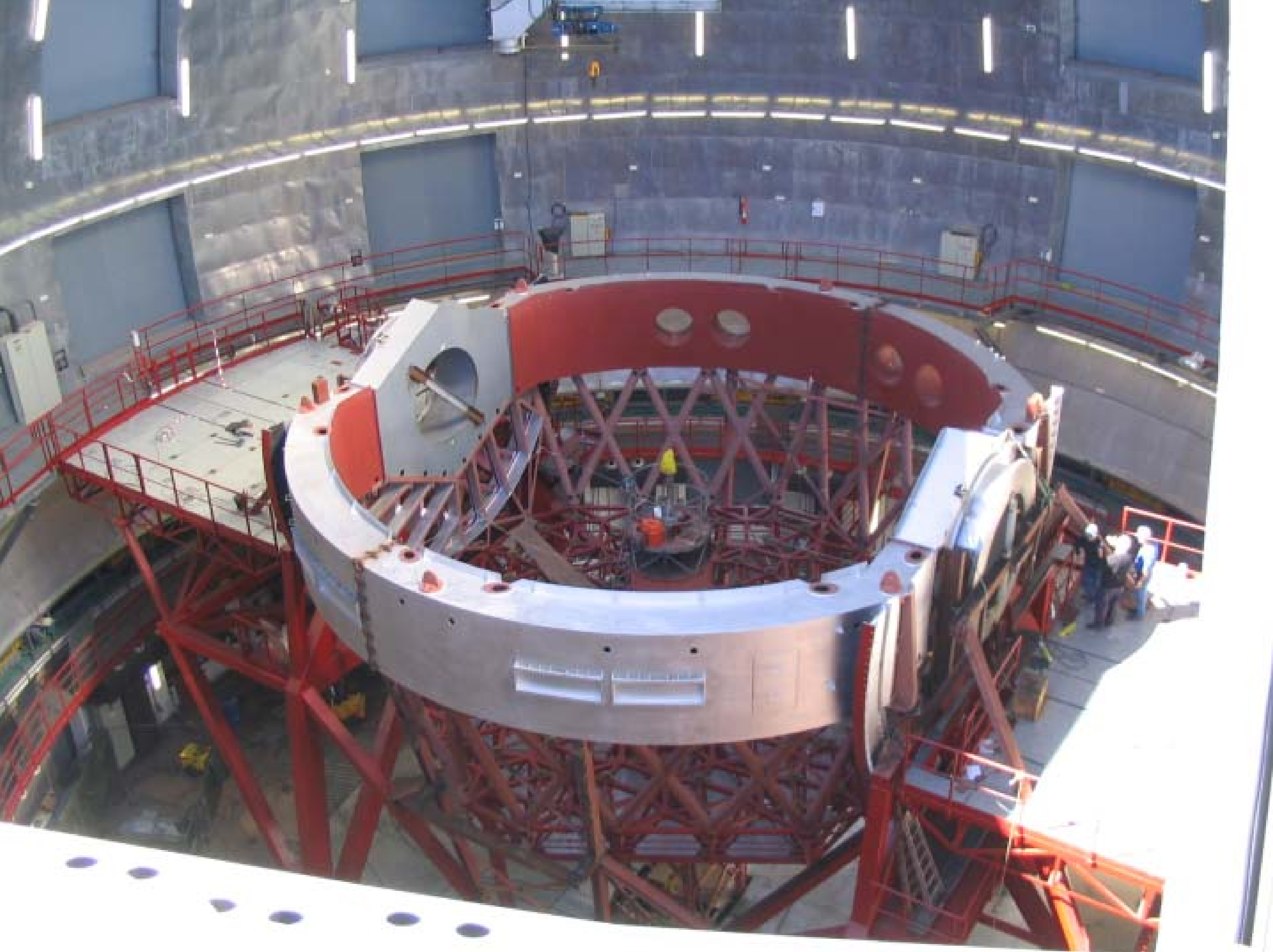


Telescope mechanics

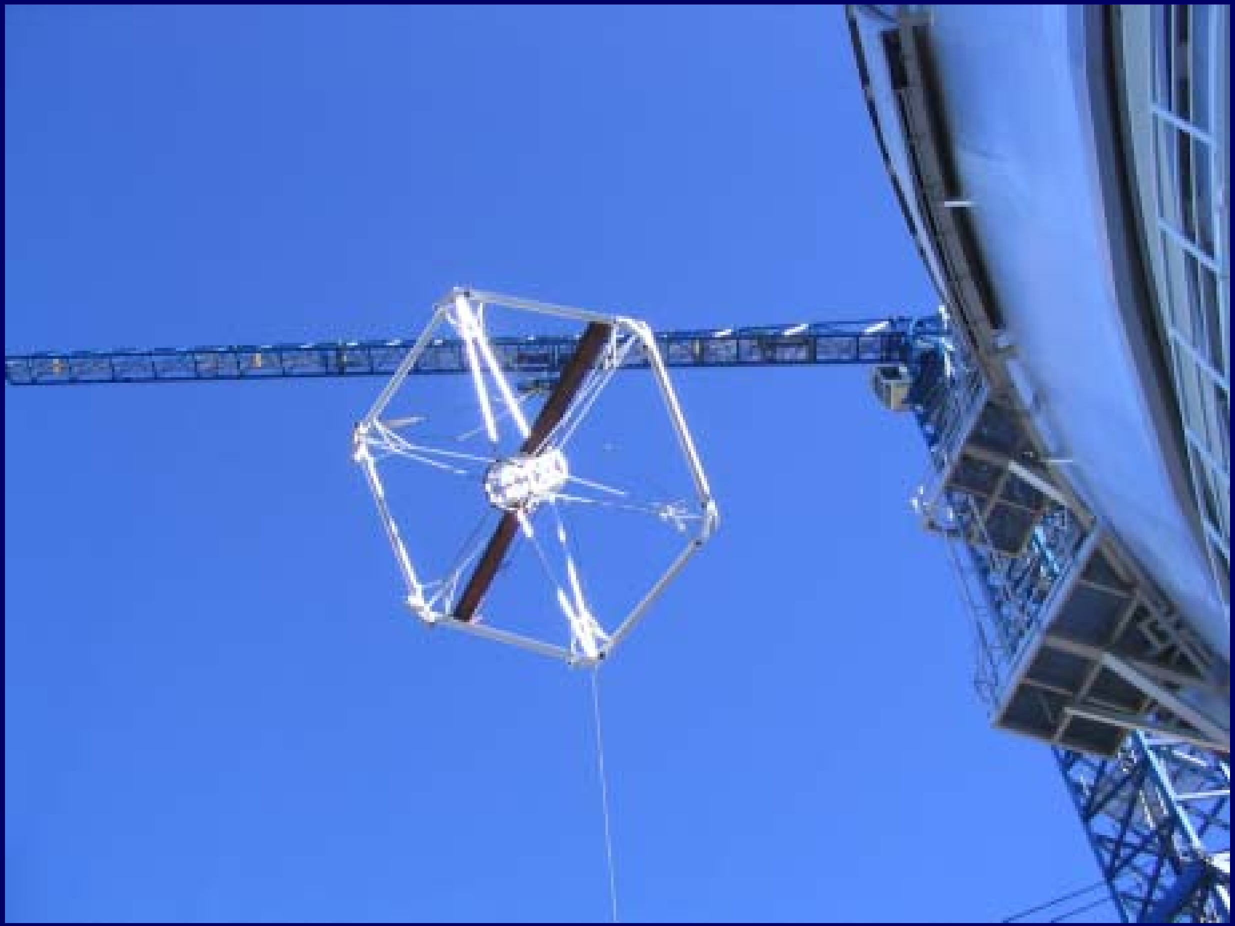
Telescope currently being mounted at the observatory.

- Structure ready by the summer
- Tests will follow
- The Telescope ready for taking up the optics (September 2005)
- First light before the end of the year


PACO
HA 15DX

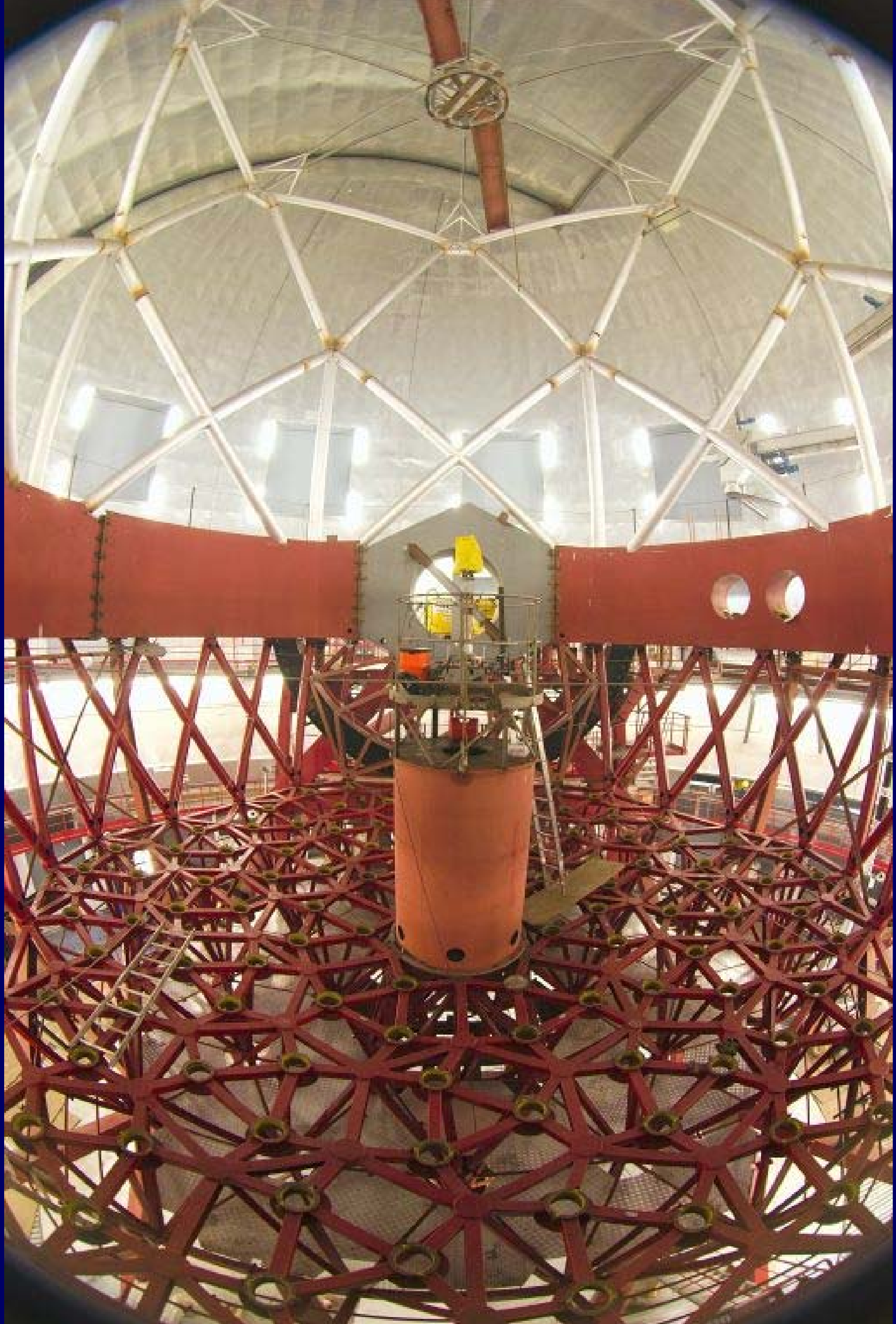


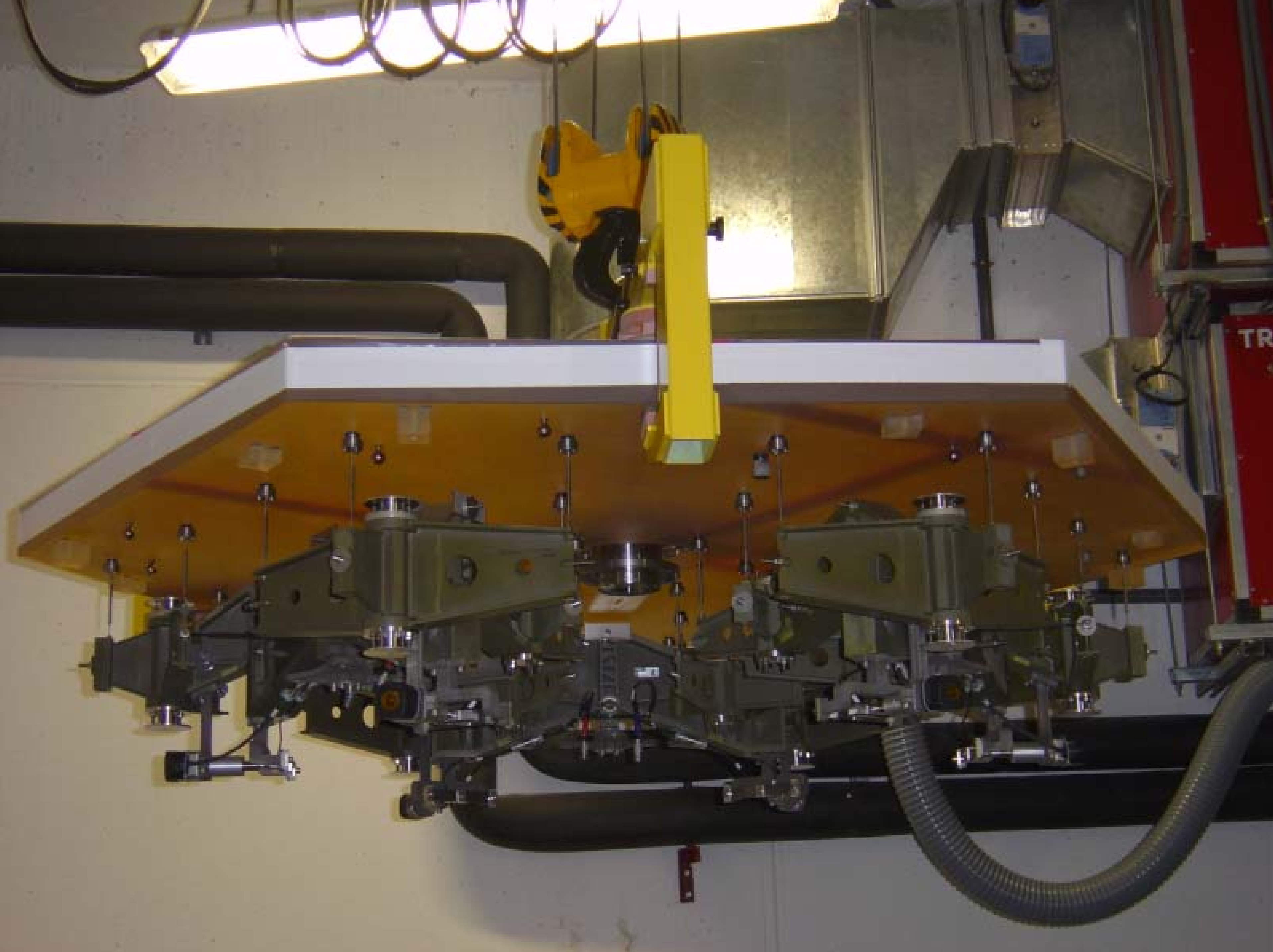
Telescopio



Secondary mirror spider mounted on January 5th

Main structure in place





REOSC SAGEM

A013_11HF_S

Date : 26/03/04

Time : 14:13:30

Wavefront

L = 1000.00 nm

R = 936.36 nm

Resol. : 400x400

Scale Lin. :

-94.870 nm to

95.103 nm

102580 points

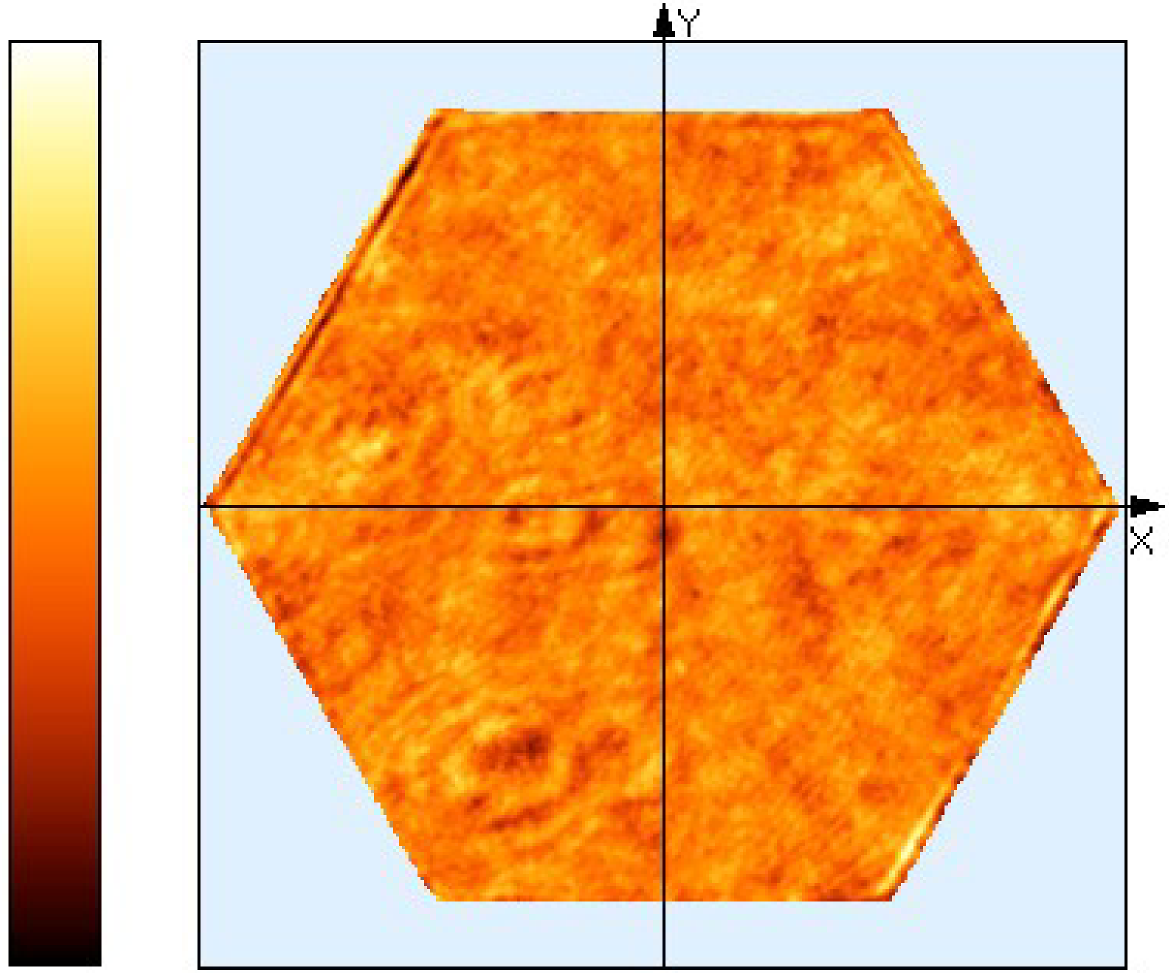
Min = -94.870 nm

Max = 95.103 nm

Avg = 0.000 nm

P-V = 189.973 nm

RMS = 14.275 nm



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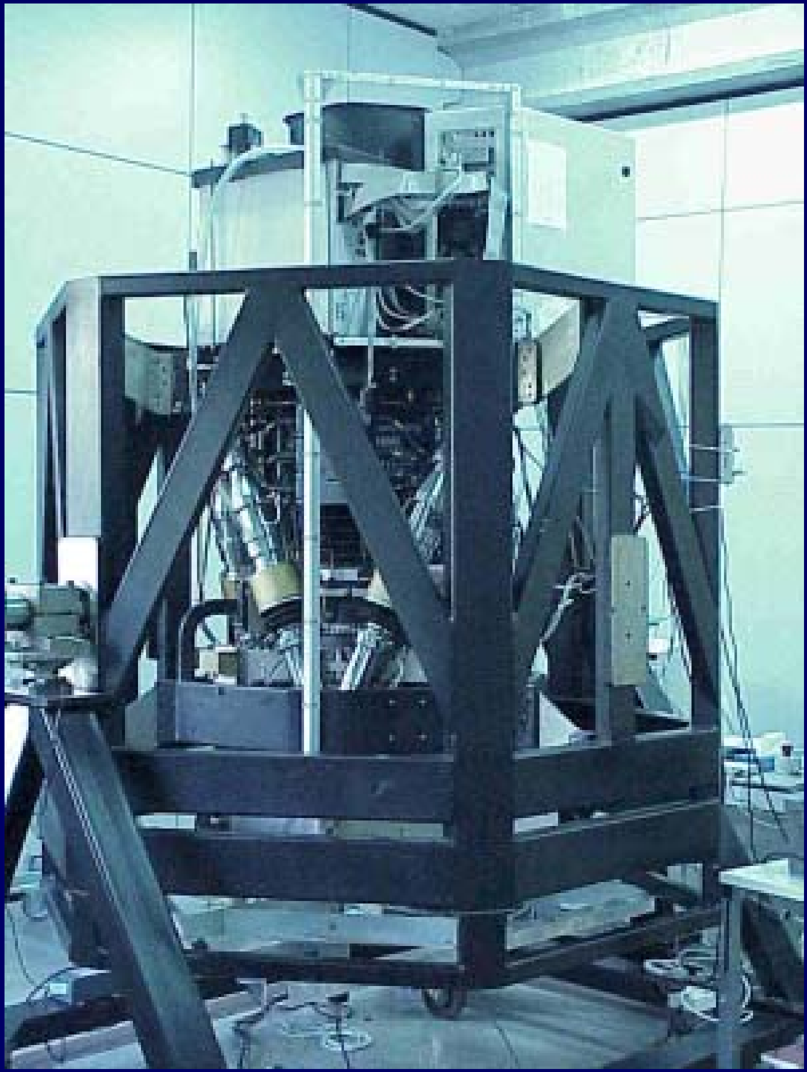
X = 0.4276 Y = 0.6364 R = 0.7667 Z = 6.4771 nm

Secondary mirror

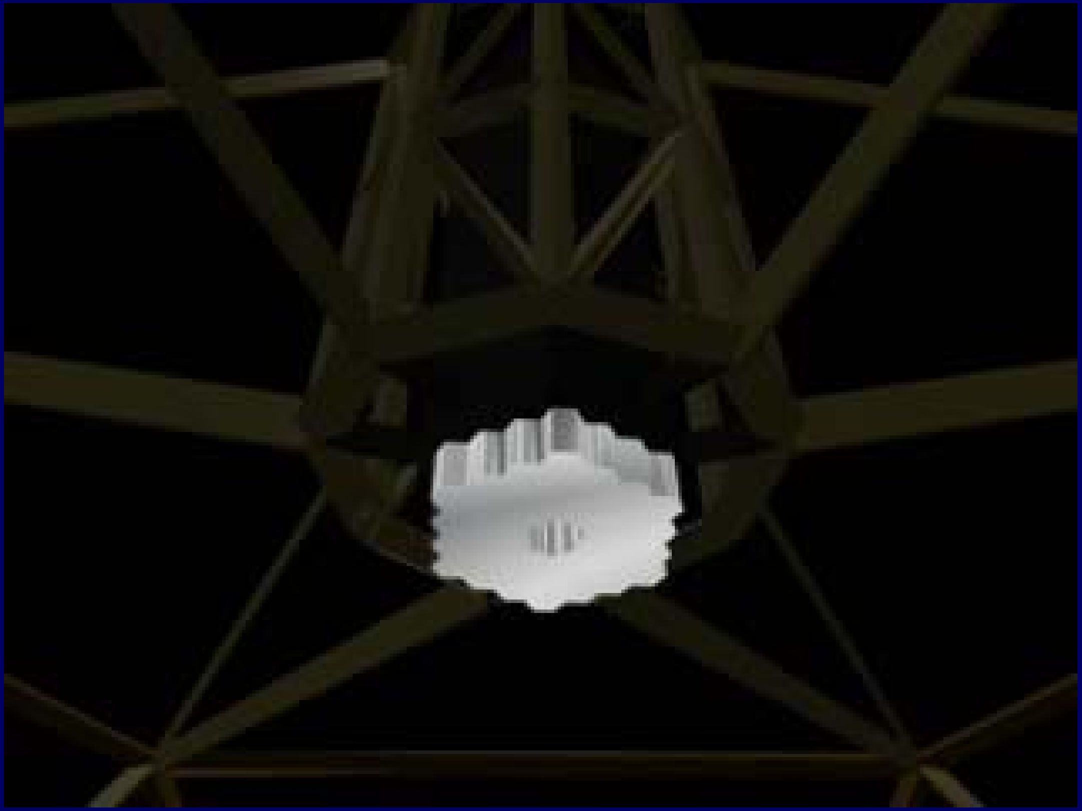
M2 Polishing being finished

M2 drive system fabricated

Delivery expected in short



M2 versatility



- X-Y translation for alignment
- Z translation for focusing
- Fast two axes oscillation for correcting image motion
- Two axes rotation for IR sky subtraction

Segmentos en la sala de almacenaje

GTC Status

- Next milestone: FIRST LIGHT
  - Before the end of the year!!!
- Detailed integration and commissioning plan already drafted

- Start of science observations: End 2006!!!
- However,
  - This winter is being terrible. No work in February
  - Some problems with the dome have slowed down the introduction of large pieces through the slit

A specially severe winter!

Scientific Instruments

- The telescope is just a flux collector
- Scientific capabilities mostly determined by the type of instruments attached to the Tel. Foci
- Instruments are changed periodically and evolve with technology to keep the facility at the forefront of research
- This imposes a big load on the community to provide state of the art instruments.

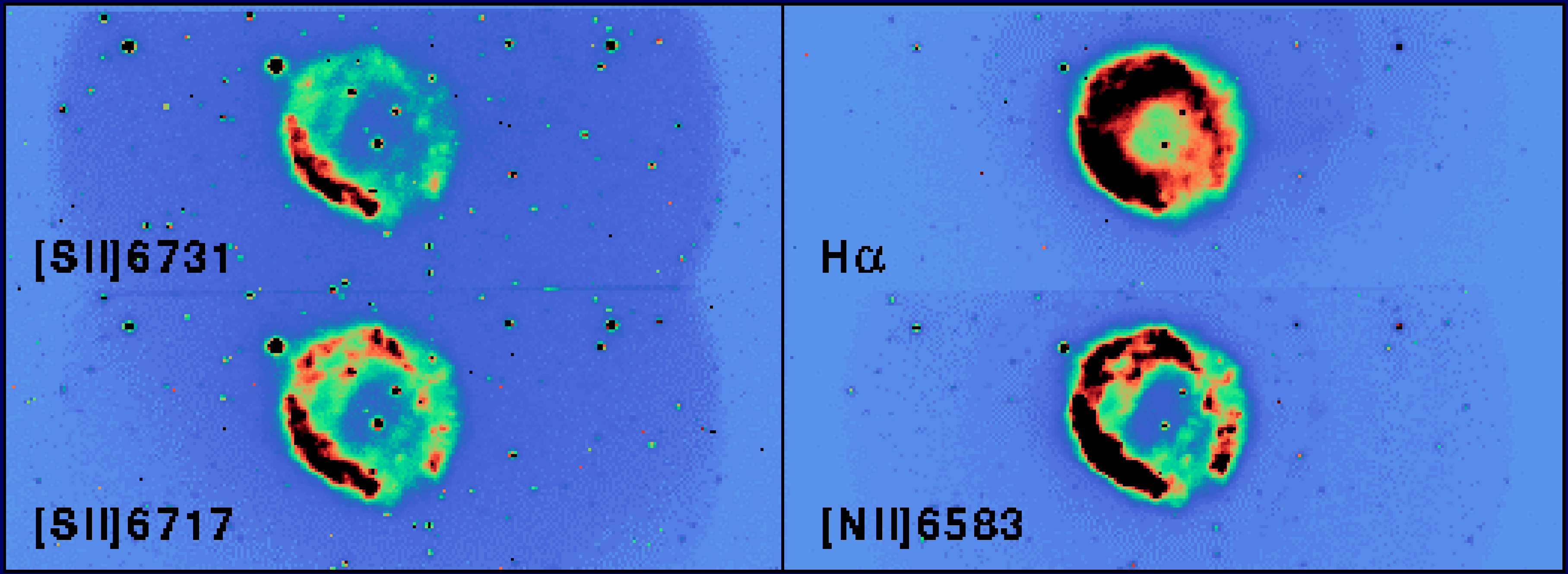
Key features of the first GTC instruments

- First Generation Science Instruments
  - OSIRIS: Tuneable filter imaging
  - ELMER: High throughput optical imager/spectrograph
  - CANARICAM: Coronagraphy and Polarimetry in the thermal IR
- Second Generation Science Instruments
  - EMIR: Wide field Multi-Object K band spectroscopy
  - FRIDA: Adaptive Optics Integral Field Unit imager/spectrometer
  - Intermediate resolution spectrometer (TBD)

OSIRIS

- Developed by:
  - IAC, IAA, IFCA, LAEFF/INTA (Spain); AAO (Aus); IA–UNAM (Mex); Utexas (USA); NRO (Japan)
- Wavelength range: 0.36 - 1.0 μ
  - 4Kx4K Marconi (15 μ/pixel) array
- Field of view: 8.5' x 8.5' with a pixel size of 0.12 arcsec
  - Design driven by the use of Tuneable filters
- Spectral Resolution: from 300 to 2500 with grisms. Considering VPHs for R ~5000
- Observing modes:
  - Imaging with tuneable filters and charge shuffling
  - Long-slit and Multi-slit spectroscopy

Line imaging with TFs

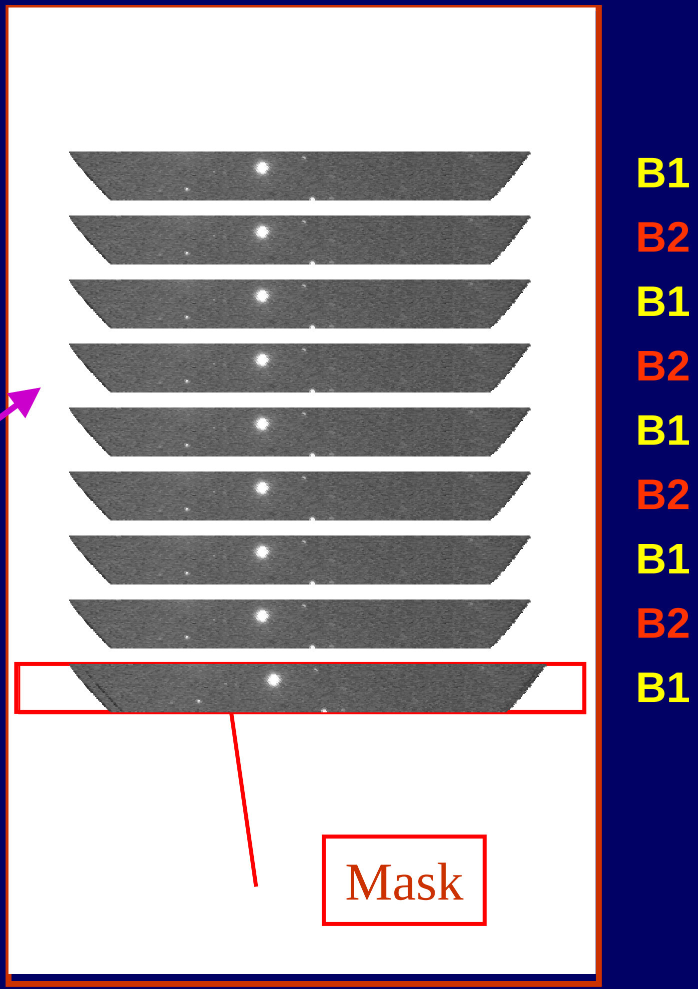


Line ratios can be obtained under non photometric conditions

Time Series

TF can be used for time series using the charge shuffling technique with duty cycles of under 1 sec.

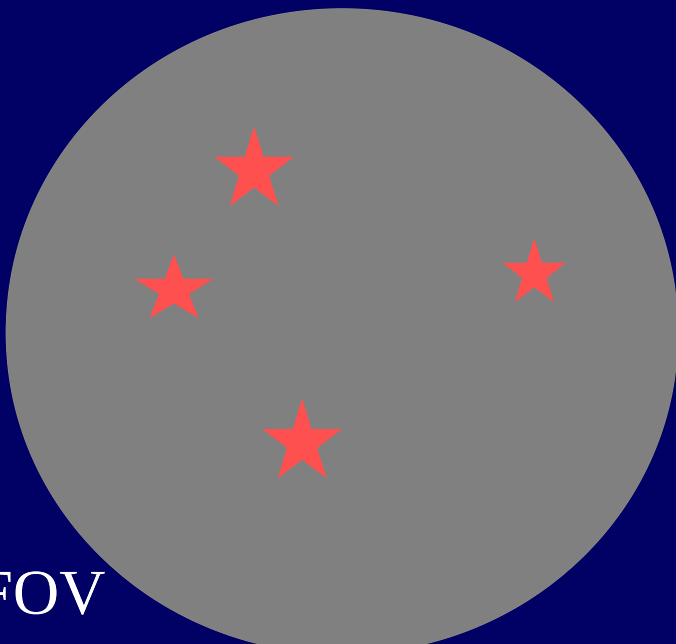
OSIRIS Field of Vision: 8.5’



Microshuffle

A focal plane mask selects the targets

Charge is shuffled between exposures at different wavelengths

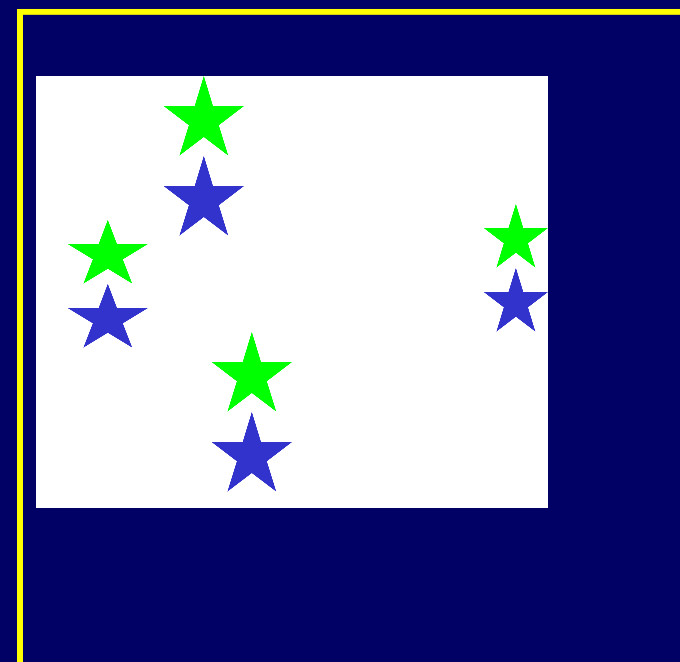


FOV

Exposing..

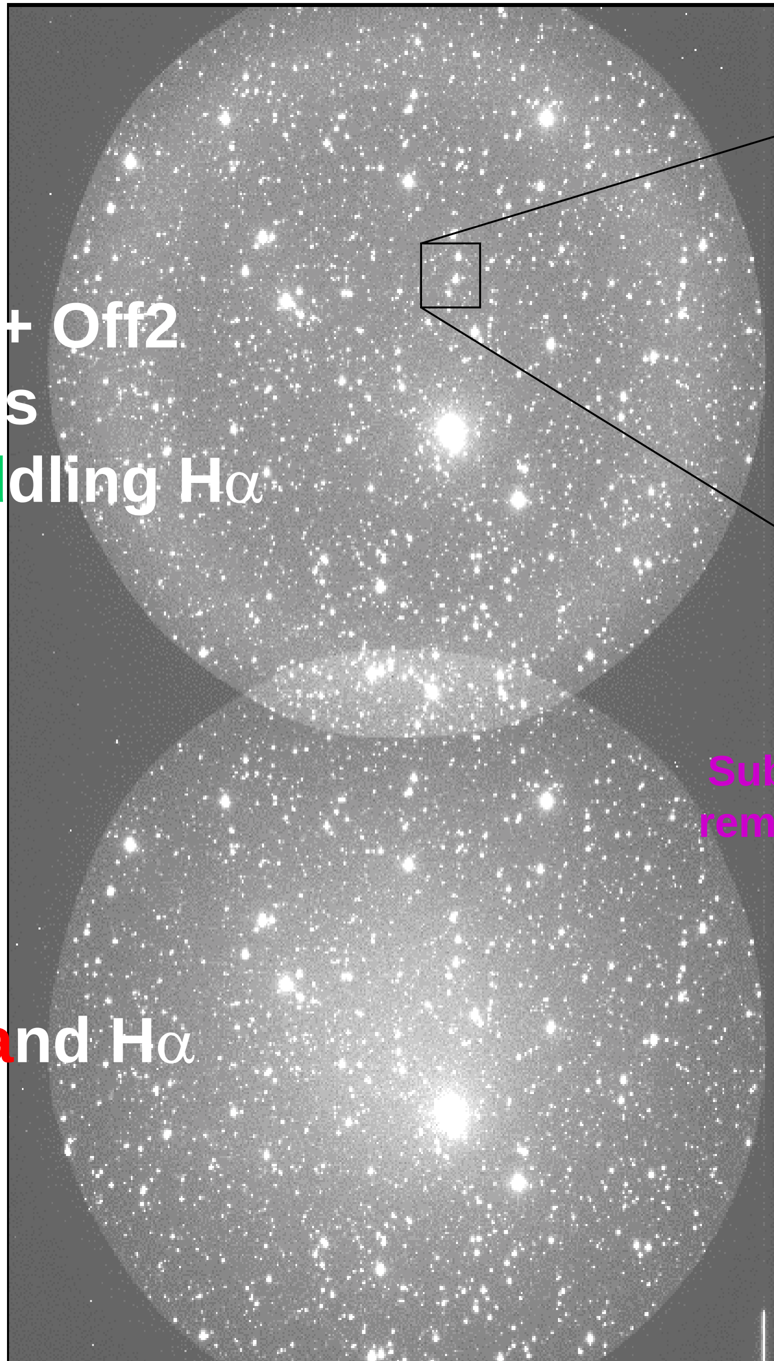
and so on...

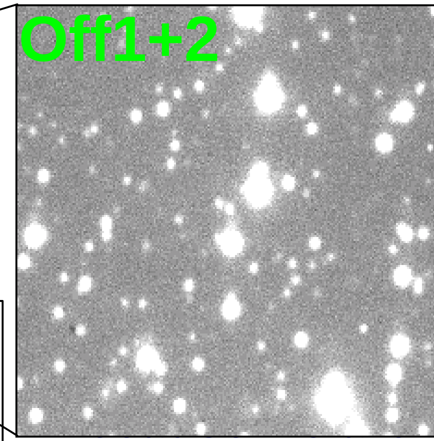
CCD

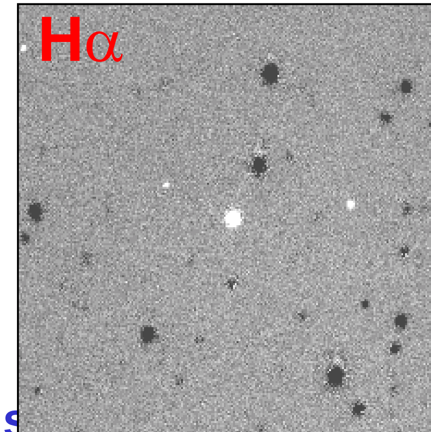


Differential imaging allows perfect sky & continuum subtraction or ratio maps even in non-photometric conditions

Hα Emitter





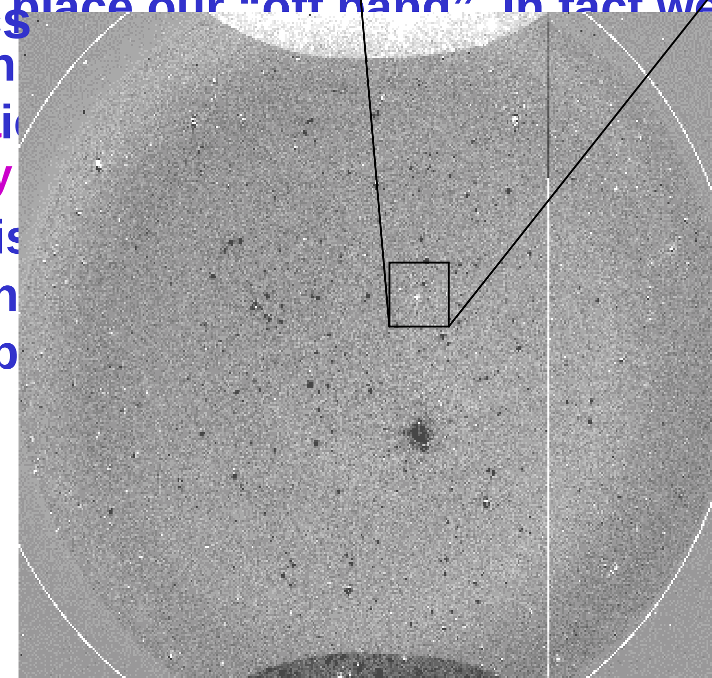


Same seeing, same pixels, same optics

filter we can choose exactly where we place our "off band". In fact we can

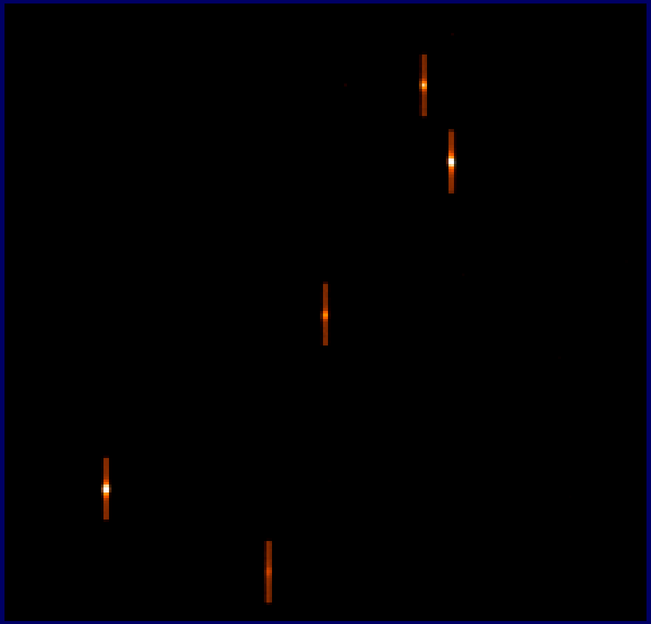
Subtract & remove sky

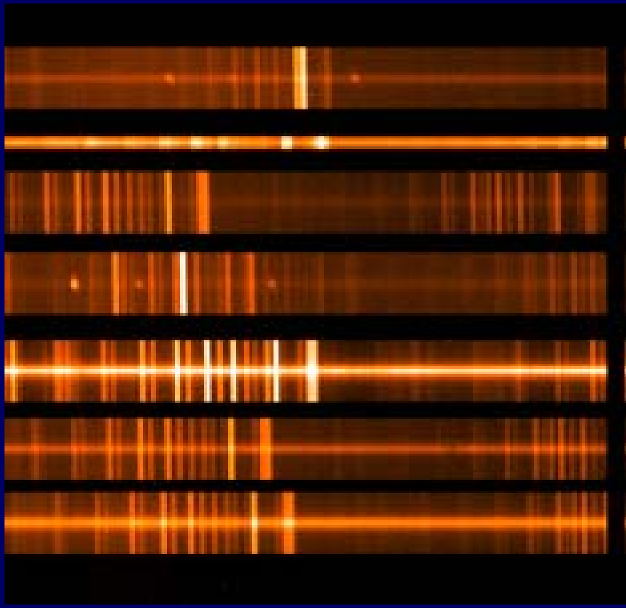
This con sub



Hα Image

Multi Object spectroscopy





OSIRIS: OTELO

- OTELO is the main program of the OSIRIS team
- It should be one of the deepest emission line survey to date
- Will provide a representative sample of the population of emission line emitters from z = 0.24 through 6.7

Science with OSIRIS

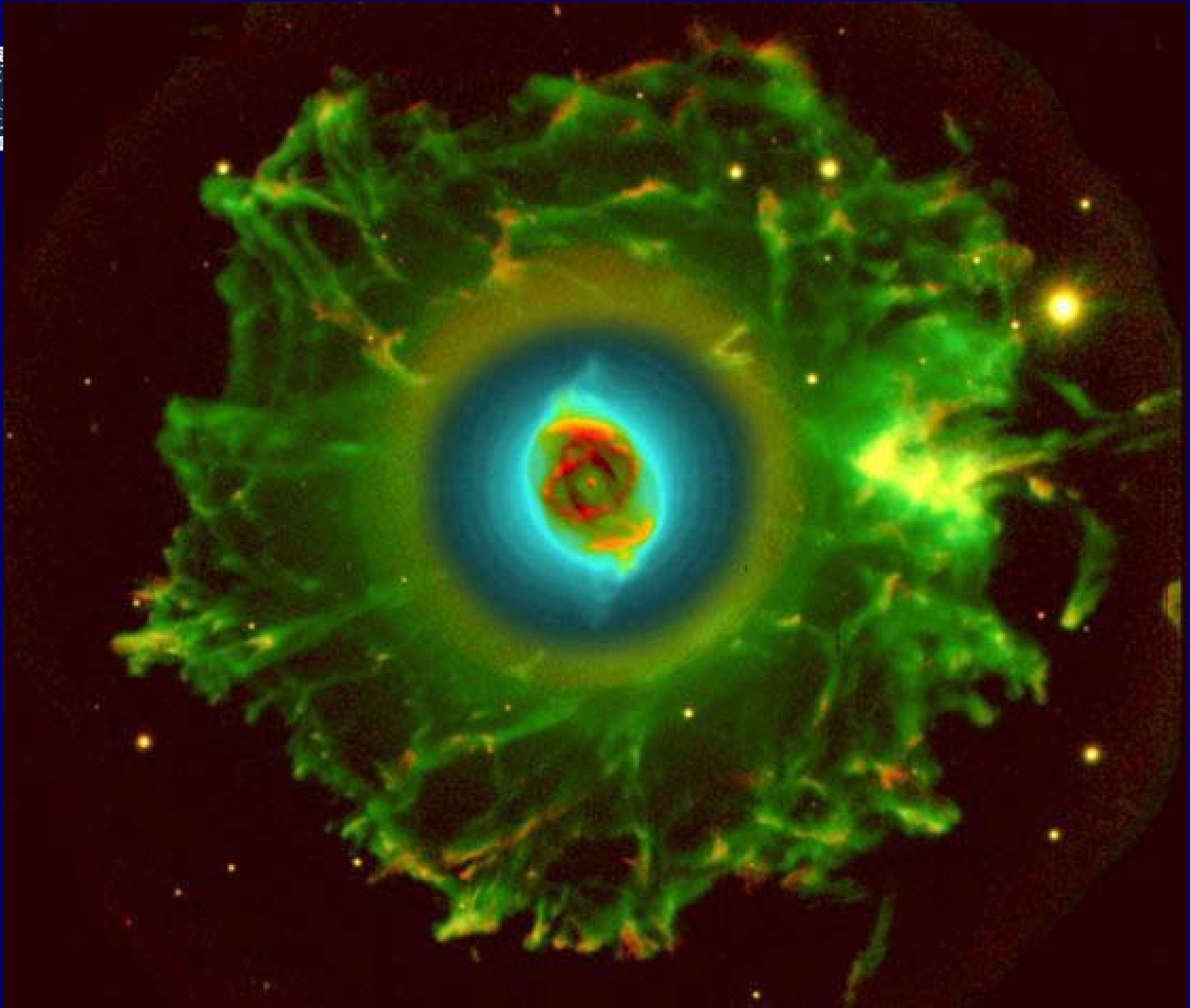
- Study of damped Ly_α absorbing systems
  - Provide constraints for dark matter scenarios.
- Determination of redshifts of faint objects
- Wide field imaging of large z clusters
  - OSIRIS' field (8 arc min) specially suited for the the size of clusters at z =3-4
- QSO environment at z=1
  - Follow up studies of the 2DF and Sloan surveys to understand the relation between QSO and galaxy clustering
- Local group Dwarf Spheroidal galaxy masses
  - Very low mass systems that are either unstable to tidal disruption by the Milky Way or dark matter dominated

OSIRIS Key Features

- Large FOV required for
  - Cosmology studies (OSIRIS: 10Mpc @ z=3)
  - Evolution of field and cluster galaxies
  - Mapping nearby galaxies
- Tuneable Filters
  - Increase versatility for high-z line imaging
  - Possible future FP upgrade will give R: 20000
- Multi-object spectroscopy
  - up to 500 objects per field
- Modern panoramic CCD arrays (2 x 2Kx4K)
  - Versatile read out schemes (Charge shuffling) allowing
    - Much better systematic & background noise subtraction
    - Time resolved observations

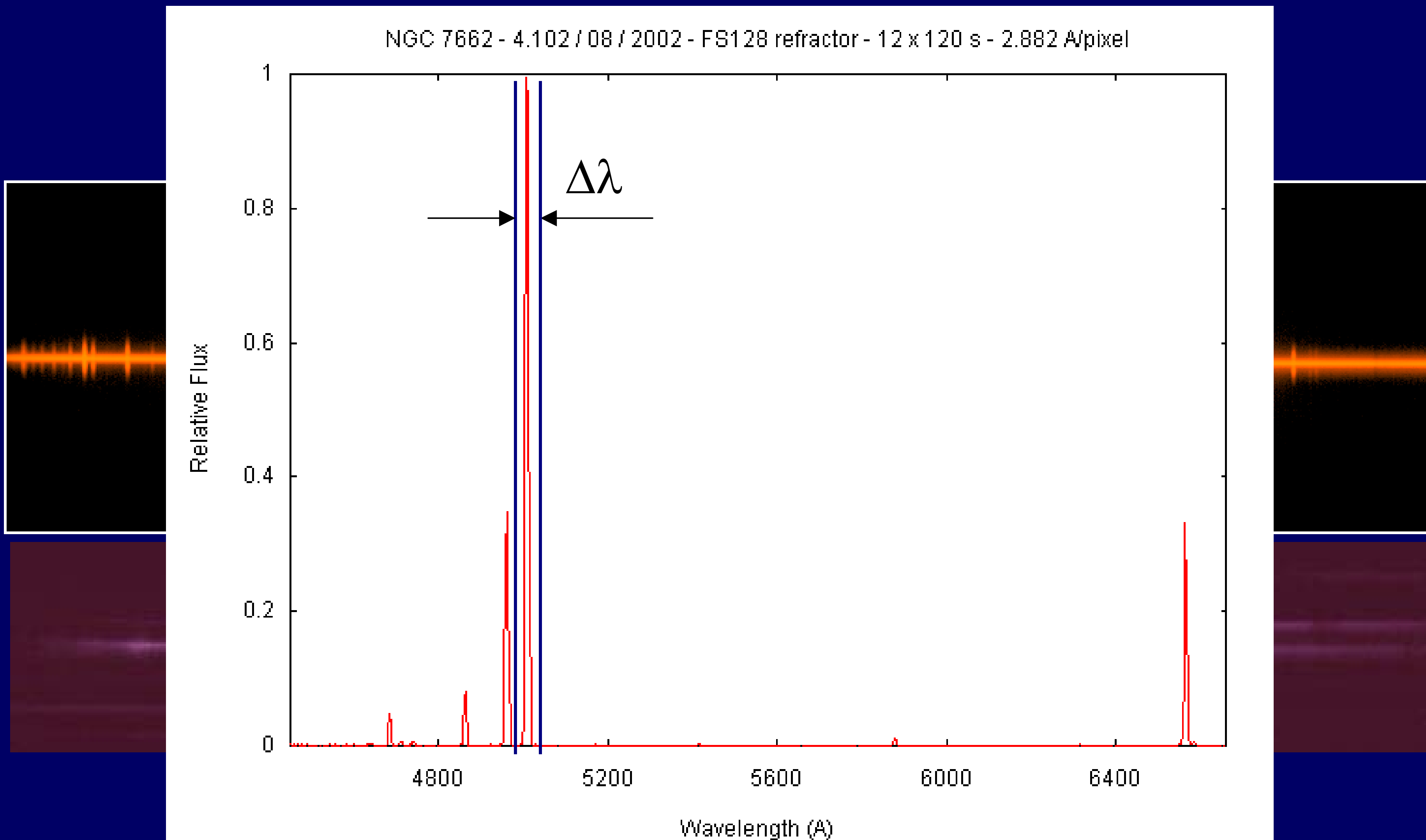
Using PN for dark matter searches

- Search for intergalactic Planetary Nebulae to determine their dynamics
- OSIRIS TF can be tuned to the strong [OIII]5007 Å from PN and perform a scan in frequency to measure velocities
- PN can also be detected in tidal tails far away from colliding galaxies



Planetary Nebulae in M33

PN Spectrum


NGC 7662 - 4.102 / 08 / 2002 - FS128 refractor - 12 x 120 s - 2.882 A/pixel
Relative Flux
1
0.8
0.6
0.4
0.2
0
4800
5200
5600
6000
6400
Wavelength (A)
Δλ

ELMER

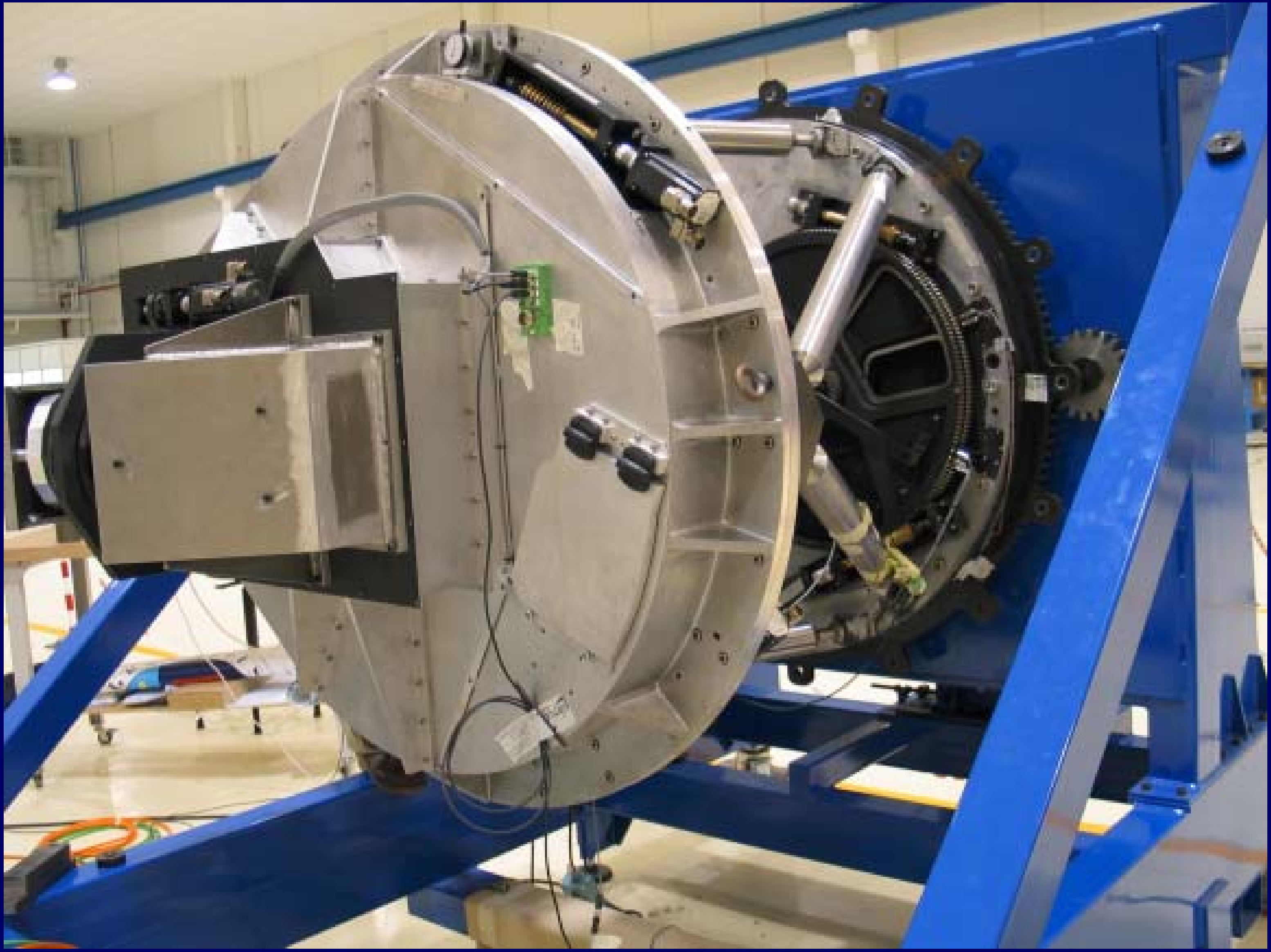
Spectral Range	0.365 µm – 1.000 µm
FOV	4.2arcmin ∅
Plate Scale	0.195 arcsec/pix
Detector	Marconi CCD44-82, 2K x 4K, 15 µm/pix Charge Shuffling and Frame Transfer capabilities
Image quality	EED_{80} < 2 pixels (@Imaging Mode) < 3 pixels (@Spectroscopy) for a 0.6 arcsec slit

Observing Modes

- Imaging — Broad and narrow band filters
- Long-slit Spectroscopy — Slits: length = 3', width: 0.6", 1.2", 2" and 5"
  R = 80-300 (prisms), 1000(grisms), 2500 (VPHs)
- Fast photometry — Slits: length = 3', width: 12.48",
- Time resolved photometry >98% duty cycle at 1Hz short burst up to 1kHz
- Slit-less multi-object Spectroscopy
- Fast slit Spectroscopy
- Charge Shuffling Spectroscopy
- Mask Multi-object Spectroscopy

Elmer

ELMER

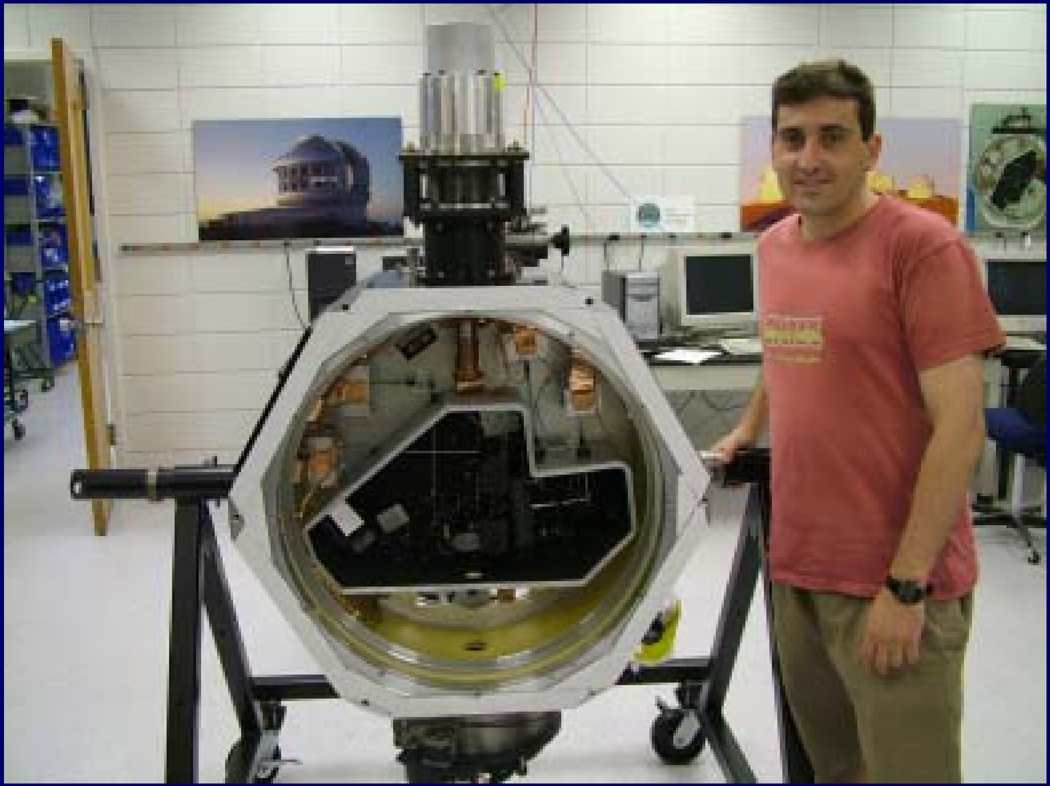


CANARICAM

- P.I. Charlie Telesco (U. Florida)
- Thermal Infrared imager (N & Q bands)
- Spectrometer
- Polarimeter
- Coronagrapher

Canaricam

- Already integrated in Florida
- Undergoing Laboratory test
- About to perform the first cool down



CanariCam Science

- Cool objects
- Dust enshrouded objects
  - Protostars
  - Obscured galaxies (Starburst, EROs, Ultraluminous sources,...)
- Brown dwarf and extrasolar planetary searches
- AGNs, QSO polarizations

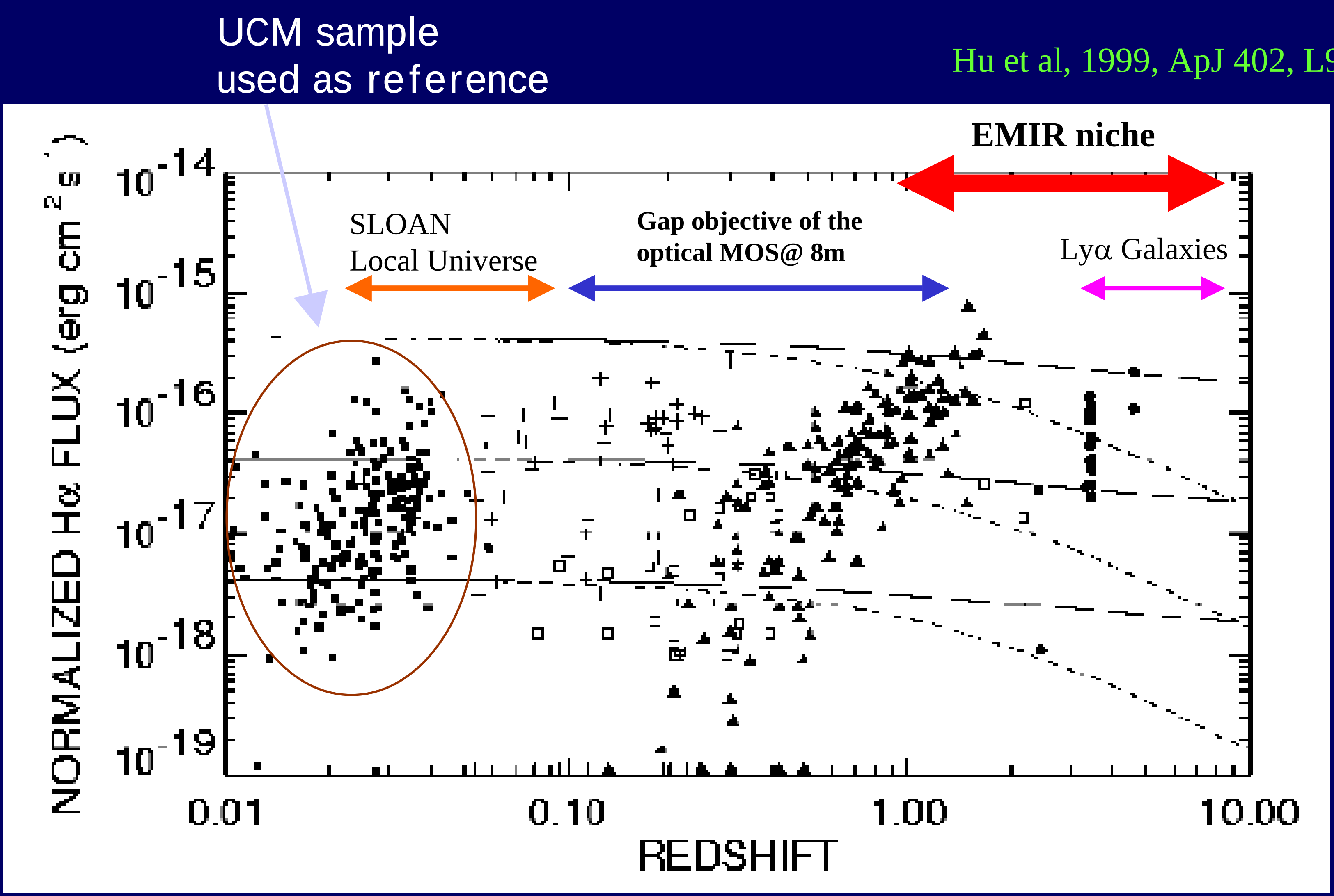
EMIR

- Near IR multislit spectrometer
  - High spectral dispersion to beat down the OH atmospheric lines
- Wide field (6 arc min)
- Cryogenic instrument to keep down the background
  - Cryogenic robot for mask configuration
- State of the art technology


UN 197
LIQUIDO

Evolution of Hα Emitters

Hu et al, 1999, ApJ 402, L99



EMIR: GOYA

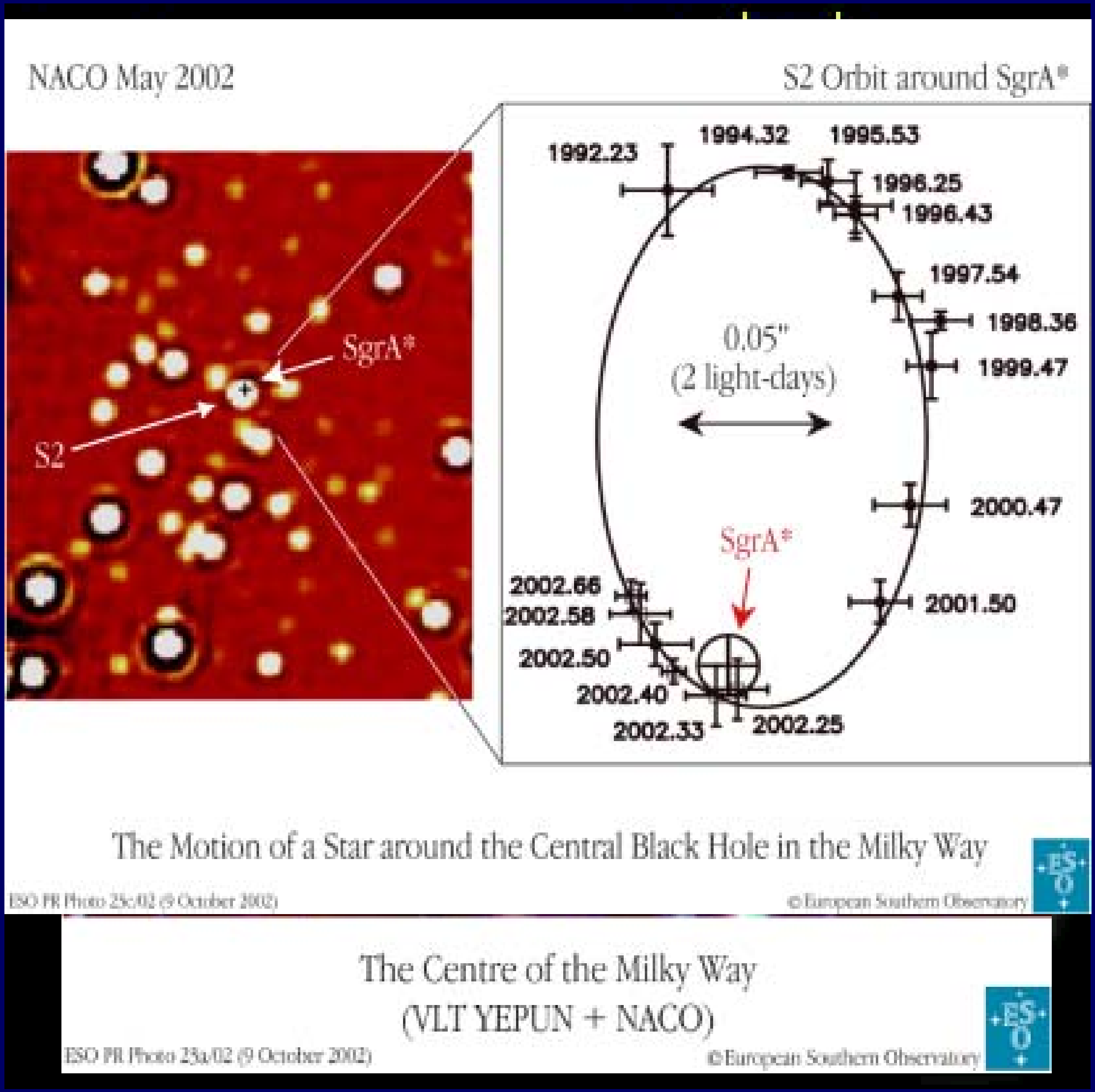
- GOYA: Structure, dynamics and populations of galaxies at high z
- Finding mechanisms by which galaxies formed the bulk of their stars and acquired their present structure and dynamics
- Stellar content of the Universe: Interplay between large scale structure formation (mass build up) and star formation physics
- Galaxy masses: key parameter in galaxy evolution over cosmological time scales
- Comparison of young galaxies at look back times with their present day counterparts
- Internal kinematics of the gas (emission line velocity widths and rotational velocities) as well as stellar dynamics from abs. lines

Adaptive Optics Programme

- AO to compensate atmospheric turbulence
  - Promises images comparable or better than the HST
- FRIDA will be provide diffraction limited 2D spectroscopy
  - AGN dynamics
  - Gravitational lensing imaging and dynamics
  - ....

The Galaxy Center

- Determination of the dynamics mass of the Galaxy center
- The Massive BH in the G.C.



Remarks

- The GTC is an open telescope
- The Spanish community is welcome to apply for time
- The High Energy community is welcome both to apply for time, and to collaborate with astronomers in devising new experiments to test issues of mutual interest.