Padova, June, 27th 2024

MORFEO Science Team activities

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OSSERVATORIO ASTRONOMICO DI PADOVA

We present the status of ongoing projects from each MORFEO Science Team Working Groups.
Specific contributions from the Padova team span in the main area of:Planetary Science: observations and simulations of non-sidereal planetary objects, discussing strategies for high-precision astrometry and photometry. This includes the study and characterization of both small bodies (asteroids and comets) and outer Solar System objects (icy satellites, KBOs and TNOs) and the development of new observational techniques.
Resolved Stellar Populations: investigations into the metallicity and kinematics of stellar populations in the Milky Way and nearby galaxies. Supported by extensive simulations, their research provides crucial insights into the lifecycle and distribution of stars within these systems.
Galaxies and AGN: focus on advanced simulations and observational strategies for studying high-redshift galaxies and AGNs. Leveraging the capabilities of MORFEO and MICADO, for understanding formation of star clusters at high redshifts.
Astrometry: development of methodologies to achieve precise astrometric measurements. Working on simulations to model PSF variability and efforts to improve accuracy, ensuring that MORFEO and MICADO can meet the high standards required for cutting-edge astronomical research.

MORFEO-MICADO: Advancing Astrometry with the ELT

MORFEO (formerly MAORY):

- is the adaptive optics module for Multi-Conjugate Adaptive Optics (MCAO) of the Extremely Large Telescope (ELT).
- Corrects atmospheric distortions to enhance image quality over a uniform 2 arcmin FoV
- Feeds MICADO and Second Port instrument still to be defined

MICADO:

- Near-infrared camera and spectrograph I to Ks
- Designed for high-resolution imaging and precise astrometry
- Deliver (its own) SCAO correction or MORFEO-MCAO on 3x3 4Kx4K detectors

(Astrom) Science cases:

Galactic Centre Studies:

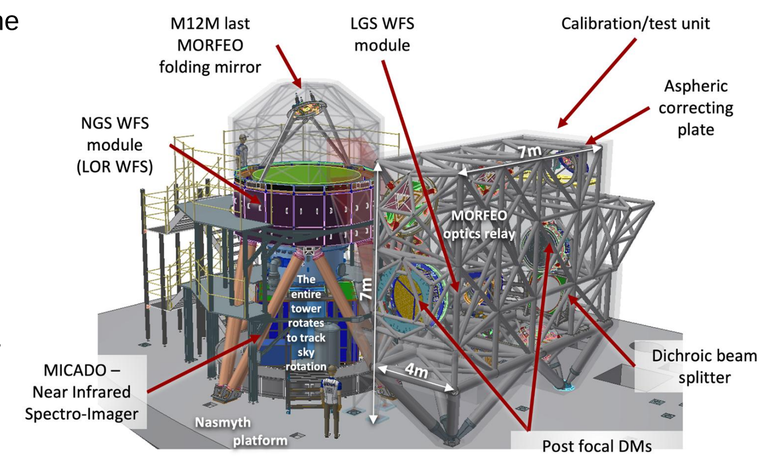
- Track orbits of stars around the supermassive black hole.
- Test theories of general relativity and SMBH growth.

Exoplanet Detection:

- Detect exoplanets through stellar wobble.
- Characterize exoplanetary systems and their habitability.

Stellar Dynamics:

- Study star motions in globular clusters and dwarf galaxies.
- Insights into dark matter distribution and stellar evolution.



Stellar Populations studies

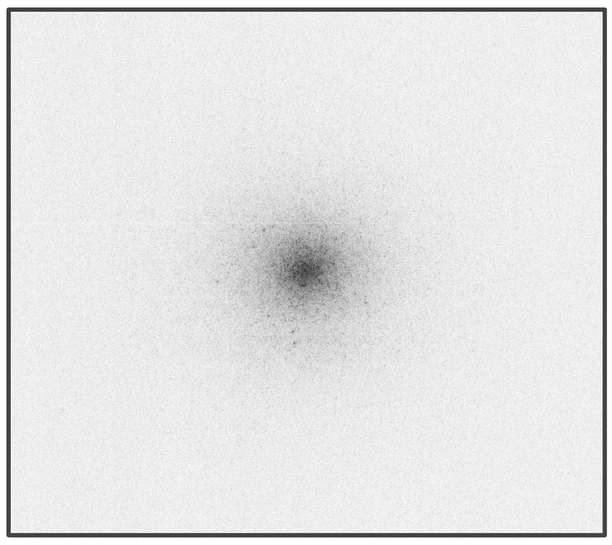
1. Stellar Dynamics in Dense Environments

Globular Clusters

- Resolve individual stars in crowded environments.
- Study internal kinematics and dynamics.
- Understand star formation and evolution processes.

Dwarf Spheroidal Galaxies

- Measure stellar motions with high precision.
- Investigate dark matter distribution and its role in galaxy dynamics.



2. Star Formation Histories

Young Star Clusters:

- Analyze the distribution and age of stars.
- Study the initial mass function and star formation rates.
- Insights into cluster formation and early stellar evolution.

Galactic Disks and Bulges:

- High-resolution imaging of stellar populations.
- Examine the structure and formation history of galaxies.
- Understand the processes driving galactic evolution.

3. Chemical Composition and Evolution

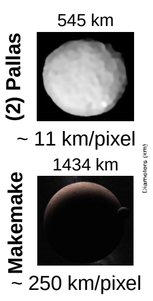
Metallicity Gradients

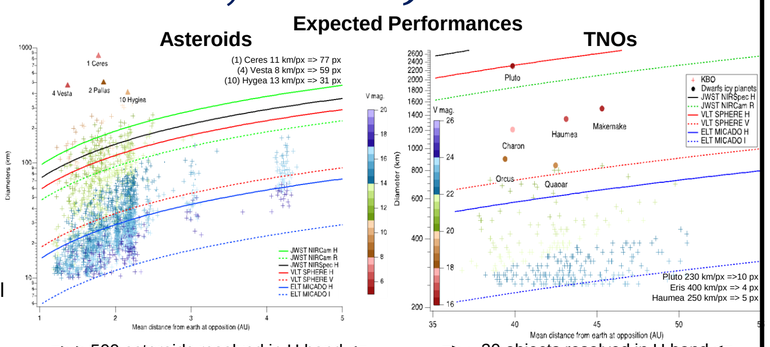
- Measure the metallicity distribution within star clusters.
- Understand the chemical evolution and enrichment processes.
- Correlate with star formation history and dynamics.

Small Bodies (Asteroids, Comets, Centaurs, Dwarf Planets, TNOs)

Imaging and spectroscopy: size, shape, colors, and chemical composition of the main **Asteroids**, **Comets**, **Centaurs**, and **Trans-Neptunian Objects** (**TNOs**);

High-resolution astrometry: determination of orbital and internal properties (density) of **Asteroids and TNOs in multiple systems**.





=> > 500 asteroids resolved in H band <=

=> ~ 20 objects resolved in H band <=

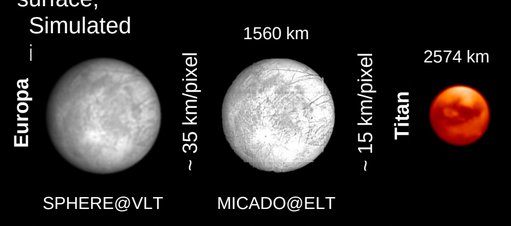
Asteroids: Shape diversity – shapes close to equilibrium? Impacts affecting shapes & internal structure?
Bulk density of large asteroids => relationship with surface composition?
Differentiation among those bodies? Density comparable to small (D ≤ 300km) TNOs?
Formation mechanisms for companions around large asteroids?

TNOs: Icy remnant planetesimals 3500 discovered since the 90's (70,000 > 100 km expected) 30 to 2,500 km in diameter, M_{KBO}>100 $M_{asteroids}$, different groups based on dynamics and visible colors CH_4, N_2, CO, H_2O, NH_3, C_2H_6, the least altered material of the Solar System (SS), constraining the formation of the early SS.

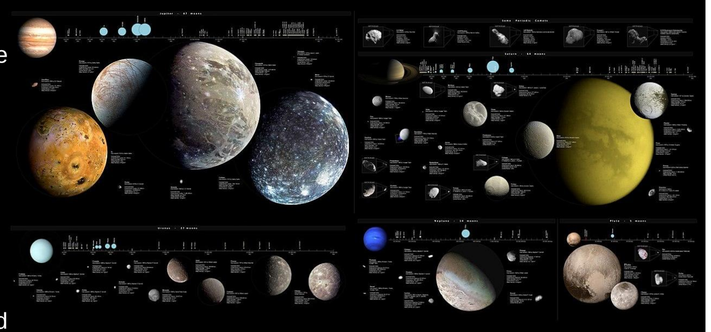
Science preparation: i) Observation strategies (SCAO and MCAO); ii) Image simulation for shape reconstruction; iii) Detectability of different species in SPEC mode for resolved/unresolved bodies; iv) Assessing astrometric precision for multiple systems.

Satellites of the Outer Planets (Gas Giants – Ice Giants)

- **Io**: distribution of SO_2 => surface & exosphere;
- **Europa**: distribution of ice and salts on the surface;

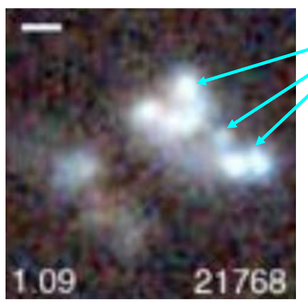


- **Titan**: Abundances of methane, nitrogen and hydrocarbons in the atmosphere. Clouds monitoring;
- **Titania, Oberon** and **Ariel**: H_2O and CO_2 (ices) observations => possible exogenous nature;
- **Triton**: monitoring to explain the surface/atmosphere seasonal evolutions.



Science preparation:
i) Observation strategies;
ii) feasibility of spectral mapping with MICADO;
iii) detectability of different species on different bodies in SPEC mode.

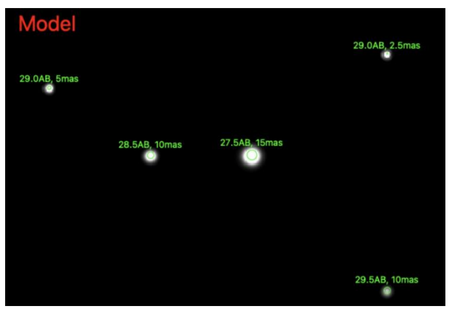
Star-forming galaxies at high redshift have irregular morphology with "clumps"

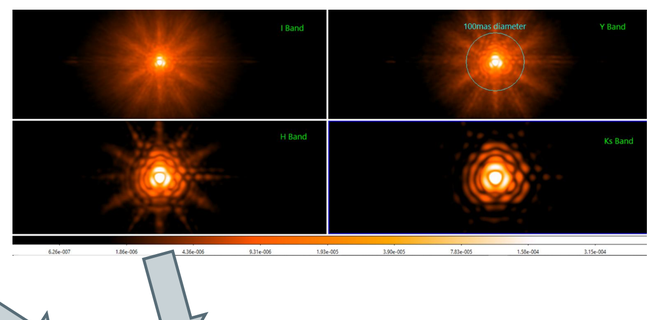


clumps = massive star-forming regions
In current field observations clumps are not resolved, size < kpc.
In lensed observations they have sizes ~10 - 100 pc.

With MORFEO-MICADO, can we measure the size of clumps in non-lensed galaxies?

Simulations using clump models convolved with MORFEO PSF:





In 5h we detect clumps with Re>2.5mas down to mag ~ 29 AB

In INAF – OA Padova the involvement on MORFEO focuses also on other aspects of the instrument as: Optics, Product & Quality Assurance, Instrument Control Software, Real Time Computer, Assembly, Integration and Verification.

The whole Padova team also includes: A. Balestra, A. Ballone, A. Baruffolo, F. Battaini, M. Bergomi, E. Carolo, S. Chinellato, E. Costa, S. Di Filippo, D. Diretto, D. Fantinel, J. Farinato, E. Giro, D. Greggio, S. Lampitelli, F. Laudisio, D. Magrin, L. Marafatto, A. Petrella, K. Radhakrishnan, R. Ragazzoni, B. Salasnich, D. Selvestrel, R. Sordo & G. Umbriaco.