

EUCLID satellite © ESA

FORMATION INSTRUMENT SCIENTIST

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CTA telescopes © CTA

ATLAS © CERN

ELT © ESO

CPPM & LAM work on the largest international infrastructures in Astrophysics and Particle Physics : CTA, Euclid, ELT, KM3NeT, LHC, SVOM, KM3NeT, etc. The instruments equipping these infrastructures are developed by large international consortia of 100s to 1000s of people.

Instrument Scientists with a strong background in the physics of the instruments and of the science they address are key positions in the teams developing these instruments. These profiles are also important for leading R&D programmes in the early design phases.

In these endeavours, CPPM and LAM work with companies in industry, with the agencies in charge of the infrastructures (CERN, CNES, ESA, ESO, NASA) and contribute to the creation of start-up companies. These companies and agencies also need ***physicists specialised in instrumentation*** to ***develop, integrate*** and ***test*** the ***scientific instruments*** that they contribute to develop for the scientific community.

→ CPPM & LAM are ideally positioned for training the young generation of scientists that will develop the future instruments of the largest infrastructures in Astrophysics and Particle Physics.

OVERVIEW OF THE FORMATION

This formation aims at training future generation of instrument scientist:

- Providing a solid background in **physics & instrumentation (hardware, software & system)**
- Understanding the **properties of great and complex scientific instruments** in the field of **astrophysics** and **particle physics** (LHC, ELT, Space born experiments, ground observatories, ...)
- Train future generation of **scientists capable** to **participate to the design** and **development** of **instruments** and to their data analysis and scientific exploitation.

Integrate the formation to the “parcours de physique” of the Fun. Phys Master:

- Introduce a lecture on **Large research infrastructure for Astrophysics and Particle Physics**
- Propose **seminars** dedicated to **open questions in Astrophysics and Particles Physics** to the **Scientific watch**
- Propose projects dedicated to Astrophysics and Particle Physics on **Numerical Methods and Experimental work**
- Introduce lectures on **advanced instrumentation** for astrophysics and particle physics divided in 3 parts and distributed **over 3 semesters**
- Introduce lecture on **Open question in particle physics**
- Introduce lecture on specific **data processing** used in astrophysics and particle physics research

Ideally S1 - 3 ECTS (30 hours)

Reviews how the large multi-messenger physics infrastructures can answer the outstanding questions introduced in the accompanying course 'Big questions in Astrophysics, Cosmology and Particle Physics' → introduces some of the largest ground and space-based telescopes and particle physics experiments and accelerators existing or in development

Multimessenger astrophysics

High energy telescope

Optical telescope

Astrophysics Instrumentation

Gravitational Waves

Production and acceleration of particles

Different environment to probe different questions

Large scale infrastructure for particle physics research

Limits of current facilities and new projects

Advanced Instrumentation I

S1 - 4 ECTS (40 hours)

Recalls and introduces essential concepts required when dealing with astrophysics and particle physics instrumentation.

► Basic of Instrumentation

Basic of optics

Lenses, Telescope, Images, Aberation

Basic of Fourier optics

Wave interferences, Diffraction

Basic of signal processing

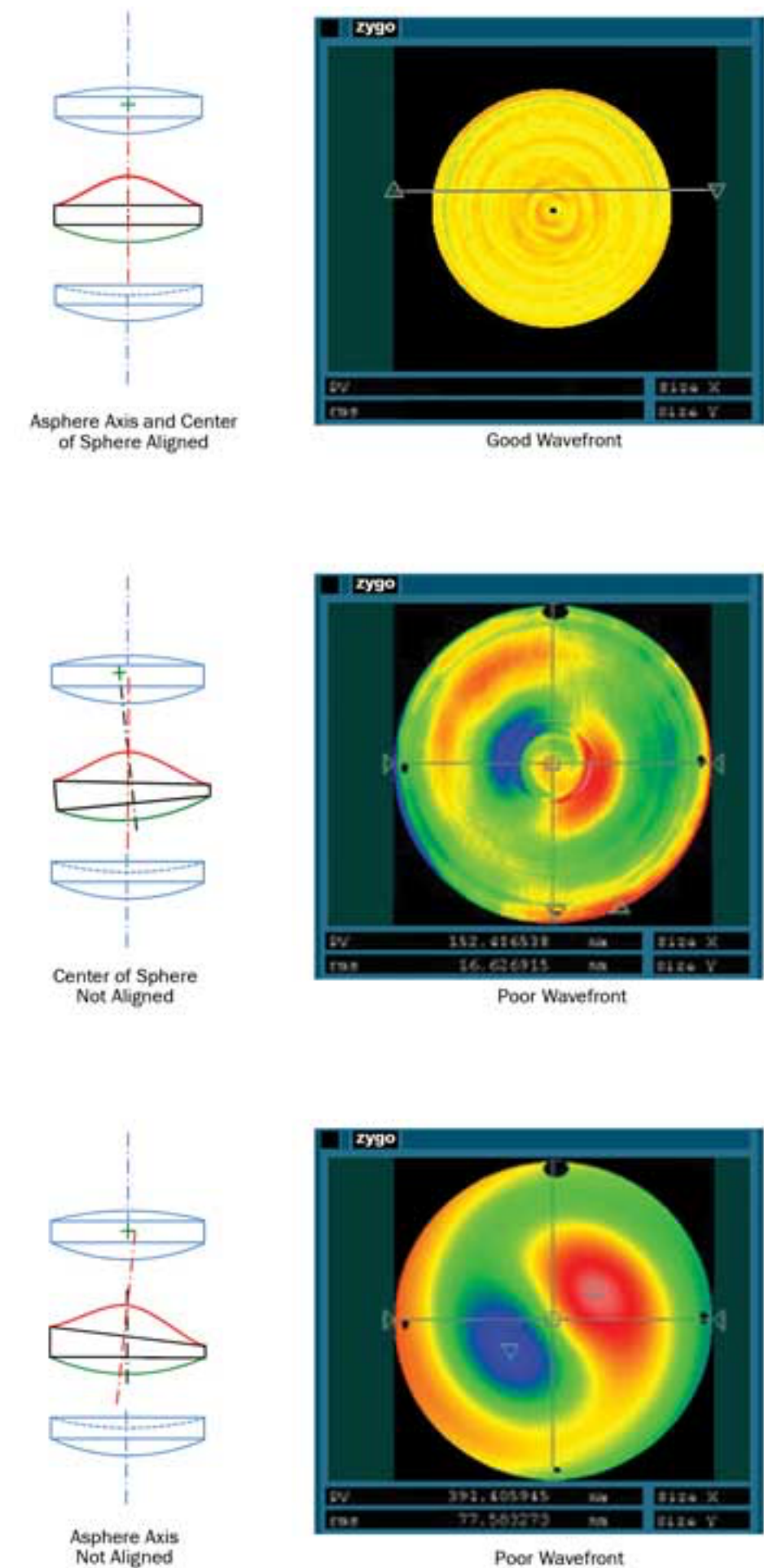
Impulse responses, convolution, power spectrum, signal-to-noise ...

Detection

Introduction to the physics of semi-conductors

Basic of electronics

From detectors to digital signals



Advanced Instrumentation II

S2 - 4 ECTS (40 hours)

Introducing the essential components (at sub-system level) that constitute most astrophysics and particle physics instruments.

Atmosphere

Transmission, emission dispersion

Imaging

Spectroscopy

Grating equation, Grism, VPH, Spectrograph design

High contrast imaging & Interferometry

Adaptative optics, chronography, atm. Optics

Interaction particles through matter

Bethe Bloch equation, dE/dx , Bragg peak ...

Photons interaction

Principle of particle detections

Tracker, Time of Flight, Transition radiation, Calorimetry

Detectors

Semiconductor detectors, Gaseous detectors

Calibration

Advanced Instrumentation III

S3 - 4 ECTS (40 hours)

Final course on Advanced Instrumentation introduces system engineering concepts and looks at a few specific instruments and projects with a global view.

System engineering

Requirement definition, Flowdown & errors budget, V-model

Technical risk management

Astrophysics instrumentation from examples

System analyses, parameter space, performance metric : Illustration from examples

Optical ground telescope → ELT

Space Telescope → EUCLID

Radio interferometer → SKA

Particle physics instrumentation from examples

System analyses, parameter space, performance metric : Illustration from examples

Large scale experiment and global project → LHC

Global experiment → ATLAS, LHCb

Trigger for particle detection

Data collection and reconstruction analyses

This course aims at describing the main steps involved in data processing for astrophysics and particle physics instruments.

S3 - 4 ECTS (40 hours)

Astrophysics data processing

Imaging

Instrument signature, Pre-processing, Image calibration, High contrast imaging

Spectroscopy

Spectral extraction, decontamination, spectral calibration

Interferometry

Image reconstruction

High energy

Cerenkov Air-shower reconstruction, coded mask for γ -astronomy

Particle physics data processing

Event reconstruction at sub-stem level

Shower, track reconstruction, charge measurement, ...

Multivariate analyses for particle identification

Event selection efficiency and contamination evaluation

GEANT 4 simulation

Objectives of the formation

Training the future generation of instrument scientists

We target students with interest in both astrophysics or particle physics and in instrumentation

We aim at 6 to 10 students per year

Gives opportunity to industry to participate to the formation (invited lectures, participation to project, training, ...)

Professional opportunities

PhD and scientists : careers in research

Industry : Physicists specialised in instrumentation, strong demand from our regional industrial partners

National and International Agencies : CERN, CNES, ESA, ESO

*to our knowledge there is **no equivalent 'Instrument Scientist' module focusing on instrumentation for Astrophysics and Particle Physics in any master degree in France***

Discussion with the Master has started. We are waiting feedback.

How to include those additional courses in the current program of the master

Check for duplication of existing courses, ...

The aim is to be able to start the formation next September, which requires advertising the formation as soon as possible to attract suitable candidates.