HYPERTELESCOPE
Kickstarter 2016 – Scientific elements

A breakthough

The new principle of Hypertelescopes is becoming applied to the project of a giant "dilute interferometric telescope". Its much larger size, with respect to conventional telescopes, greatly improves the image sharpness, or resolution.

Previously unseen details of stars will become observable in the direct images, as well as their planets, and will favor spectroscopic searches for life signature molecules.

Giant "diluted" mirror

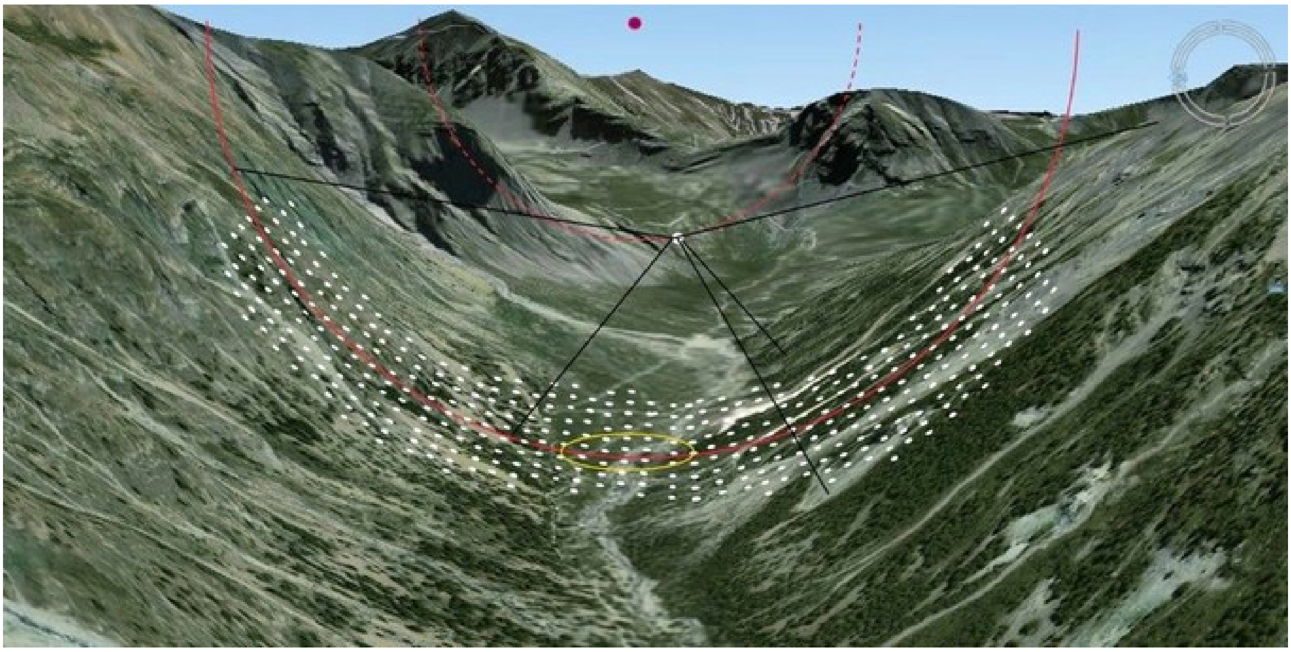
In certain solutions several telescopes may aimed at the same star, and combining its light into a single image on a camera, but at the cost of complex optics arrangements.

A much simpler approach is to build a "dilute giant concave mirror" by arraying many small mirrors. These can be 15cm in size, spaced meters apart, and accurately positioned on fixed tripods to match a virtual concave meta-mirror. The array, built in a natural depression or valley with coarsely matching shape, is not steerable but focuses the star's image onto a flying camera which tracks its motion caused by the Earth's rotation : This is "Carlina" Hypertelescope !

Carlina Hypertelescope architecture : static dilute mirror

This Hypertelescope architecture was given the name of the ground-hugging Carlina flower, a large thistle containing thousands of tiny flowers within its "meta-flower".

- **Its principle**: for sharper images, the Hypertelescope replaces the mirror of a standard telescope by a much larger, but dilute, mirror
- **Its purpose**: gain a sharper view of stars, their details and planets for searching evidence of life . Also galaxies and other objects which remain poorly understood.
- **Its advantage**: to leap-frog the conventional limitations of mirror size, with their rotating mount and protective dome. The costly optical delay lines, which are compulsory for conventional interferometers, are also avoided .
- **Its dimensions**: the Hypertelescope can count many mirrors, the array size being only limited by the width of the valley where it is nested.
- **Its efficiency**: to observe celestial details never seen before, even on smaller and more distant targets
- **Its cost**: a larger collecting area and higher resolution for a smaller cost of manufacturing, installation and operation
- **Its environment**: the dilute structure is deployable with minimal environmental disturbance
- **Its implementation**: the Hypertelescope observations can begin with a few mirrors before increasing progressively their number



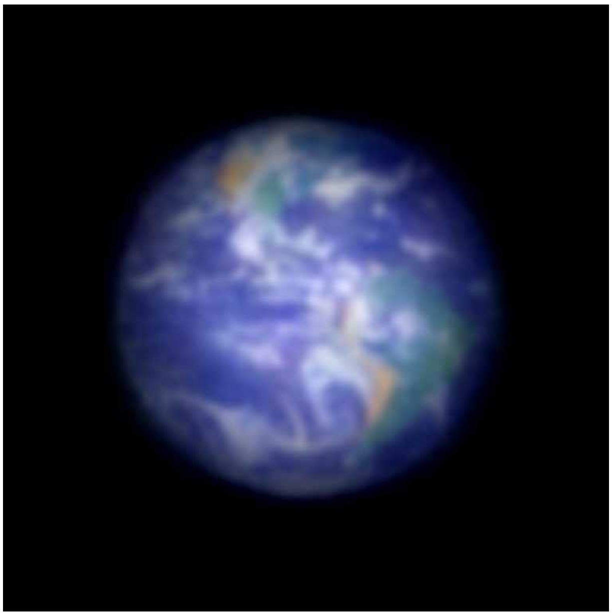
This dilute mirror focuses light from the observed star onto a camera attached to a cable 100 meters above. The oblique cables, driven by a computer, move the gondola for tracking the star image.

Looking for extraterrestrial life

Antoine Labeyrie, today emeritus Professor at Collège de France, pioneered interferometry in astronomy and its extension toward Hypertelescopes. He conceived and started prototyping, with his teams, the first full-scale giant Hypertelescope, in the Ubaye range of the French Southern Alps.

The purpose of this first prototype is to build a dilute mirror, 57 meters in diameter, with possible expansion to 200 meters. With 800 mirrors, 15 centimeters in diameter, it will provide three times more collecting area than the Hubble Space Telescope, with an 80x gain in angular resolution for the expanded array. With respect to the future 39-meter European Extremely Large Telescope (E-ELT), under construction in Chili, planned for 2024, 1,600 mirrors of 1 meter would match its collecting area, and the resolution gain is 5x.

The teams forecast the construction of an EL Hypertelescope, about one kilometer in diameter, to be installed in a meteor crater, or in the ancient crater of a volcano, or in some high valleys of the Andes or the Himalayas.



The Ubaye instrument is also considered as a precursor of much larger versions in space in the form of a mirror flotilla up to hundreds or thousands of kilometers in size.

A 100 kilometers flotilla suffices in principle to see details of 100 kilometers on the surface of an exoplanet at 10 light years from Earth.

Colored seasonal variations, if detected, may be strong indicators of photosynthetic life.

From conception to crowdfunding

The development of Hypertelescope was supported from start by Collège de France, in association with the Observatoire de la Cote d'Azur (OCA). Professor Labeyrie retired in 2014, and the project's funding was discontinued.

The non-profit association Hypertelescope LISE was then created to further support the project, together with OCA which contributes staff members and logistics. It also benefits from the support of LOMA (Laboratoire Ondes et Matière d'Aquitaine) and IOGS (Institut d'Optique Graduate School).

In a spirit of open science, numerous amateur astronomers, students and researchers are joining the teams. They efficiently contributed to develop and build the first full-scale Hypertelescope prototype in a high mountain valley, selected for its topography and climate.

Much progress has been achieved, but more work is needed to fully build and demonstrate the system. Additional research, engineering and equipment are needed.

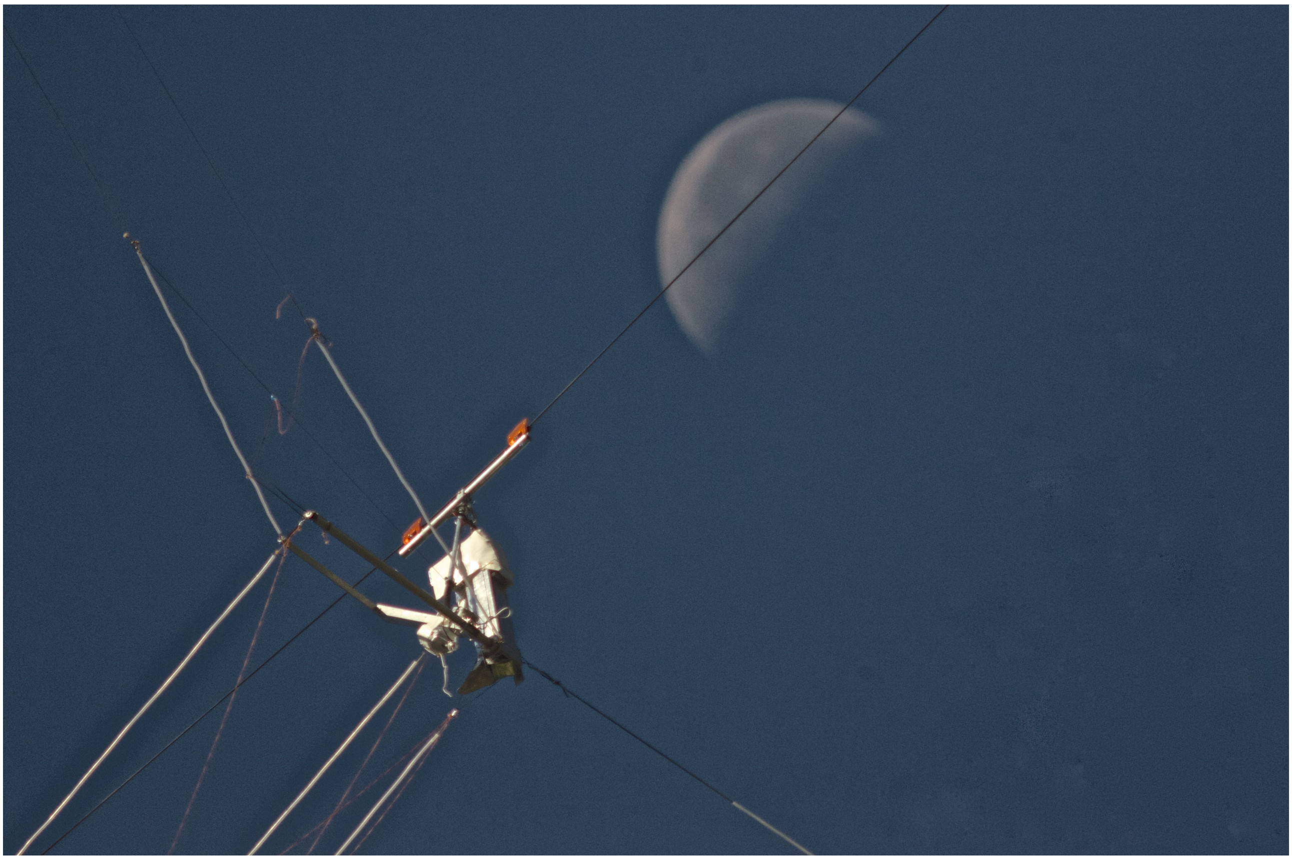
The funding raised through the generosity of donators and members of the association has been invaluable for pursuing this exciting project. In order to help funding the 2016 scientific campaign, we expect to further expand the contributors community through Kickstarter.

The valley where the prototype develops.

Our scientific targets for 2016

- Fully automate the control system which drives the focal gondola, with millimetric accuracy. Specially developed autoguiding sensors have to be installed and tested on the star Vega.
- Enough reliability must be obtained for consistent tracking, night after night, as needed to record usable science data.
- With the two mirrors already installed, both images of Vega must coincide in the focal plane, with equalized optical propagation path lengths. This requires a fine tuning of the mirror alignment techniques regarding their orientation and height.
- To form interference fringes with the star light reflected by the two mirrors
- To build a drone, also with millimeter accuracy, able in the future to carry the optical system of the gondola
- To conduct experimental flights of this drone

We need 70 000€ to meet these goals. If we reach 100 000€, we will develop a drone capable of carrying the optical gondola, as well as a miniaturized gondola. If we reach 150 000€, we would purchase a tracking theodolite (topographic instrument for measuring angles and distances), for directly controlling the mirror positions, the motion of the focal gondola, and other system elements. We will also install more mirrors.



The gondola in summer day's sky

Who we are...

Antoine Labeyrie, emeritus professor at Collège de France, inventor of the Hypertelescope

The project was initiated by Professor Antoine Labeyrie. Inventor of interferometer forms such as the Speckle interferometer, multi-telescope interferometer, and the Hypertelescope. He also participated with NASA to conceiving the Hubble Space Telescope, as a member of its Instrument Definition Team. He also described Laser Trapped Mirrors for space, and a flotilla version for large Hypertelescopes. He is emeritus Professor at Collège de france and member of the Académie des Sciences.

Denis Mourard, astronomer at the Observatoire de la Cote d'Azur

Denis Mourard is astronomer at the Observatoire de la Cote d'Azur. He specialized in long baseline interferometry and contributed to early experiments in optical interferometry with Antoine Labeyrie. He also developped the principle in the USA, where he built the VEGA instrument for the visible spectrum on the large CHARA interferometer at Mount Wilson, California. This system is today remotely controlled by his team at the Observatoire de la Cote d'Azur.

Many scientists trained in astronomy and physics, teachers, engineers, amateur astronomers, students, and other benevolent persons share interest in the project, under the direction of Antoine Labeyrie and Denis Mourard and the team currently comprises 24 people.

The following contributed to the project as post-docs in astrophysics:

- Rijuparna Chakraborthy, from Institute of Engineering and Management; Kolkata, India
- Fatme Allouch, from Lebanon
- Paul Nuñez, from Colombia, currently at the Jet Propulsion Laboratory, NASA
- Wassila Dali Ali, from Algeria
- Arun Surya, from India, currently at the Indian Institute of Astrophysics, Bangalore

Additional scientists contributors are: André Rondi, Thierry Lépine and Bernard Trégon.

From day one of the project in Ubaye, around 50 other people contributed their ideas, strength and knowledge.

The Hypertelescope in Ubaye

Above the valley, 100 meters high, a traversing cable carries a focal gondola containing optics which collects the focused star light reflected by mirrors on the ground.

This gondola is accurately positioned and oriented by six thin oblique cables, through computer-controlled winches located at three positions spaced 300 meters apart.

They are powered by photovoltaïcs, together with the local WiFi network connecting them to the control computer, which drives the gondola along the focal sphere of the giant spherical mirror for tracking the star image motion caused by Earth rotation.

The collected light can be recorded by a camera embarked on the gondola, or on the ground if reflected again by a small movable onboard mirror.

Technical description of Hypertelescope.

The valley of la Moutière

For a broad sky coverage with the prototype Hypertelescope, we had to look for an East-West oriented high valley having a smooth curvature and favorable climate, to provide a broad seasonal sky coverage during an hour for stars crossing the meridian plane from East to West.

The site selected at la Moutière, at 2100-2300 meters altitude in the Ubaye range of the southern Alps in Haute Provence, on the borough of Uvernet-Fours not far from the lovely city of Barcelonnette, meets these criteria and has favorable conditions of low atmospheric turbulence.

The innovative imaging system

Once equipped with an adaptive corrector to compensate the turbulent behavior of the atmosphere, the prototype Ubaye Hypertelescope will provide direct images. It improves sensitivity with respect to conventional interferometers since they can only reconstruct images in a computer from a number of exposures made at different times to exploit the Earth's rotation.

The direct imaging which is achievable with the Hypertelescope also improves the information content of the images regarding contrast.

Diluted mirror, image intensity and angular resolution

Among the important optical properties of a telescope, image luminosity (intensity) varies as the surface area of the mirror, while image sharpness (resolution, the capacity to look at fine details on the observed object)), improves as its diameter, even when it is dilute. Diluting a segmented mirror in Hypertelescope fashion, by spreading apart its segments while densifying its pupil, does not affect the luminosity but improves its sharpness.

Experimental arrangement - mirror on its tripode, and laser viewfinder.

> Three steps forward

Development of the prototype of Ubaye

Like radio interferometers, with their array of many parabolic antennas, the Hypertelescope can be built step-wise by adding mirror segments. And it can similarly provide valuable scientific results before its final completion.

Three successive steps are foreseen toward developing the prototype of Ubaye Hypertelescope:

- **1- Pending the installation of adaptive optics** for correcting the atmospheric degradation a "speckle interferometric" observing mode will provide sharpened reconstructed images. The method, invented by Antoine Labeyrie in 1970, was then exploited by him and others to increase 50 times the resolution of the Palomar 200 inch telescope, then the world's largest
- **2- As adaptive optics will become installed** for co-phasing the wavefront, it will provide direct images with full sharpness. On nearby stars, such images can show surface details, of interest for better understanding these natural thermonuclear plants. Observing the dark disk of a transiting exoplanet against the bright disk of its parent star can give spectroscopic information on the planet's atmosphere, and the presence of bio-signature molecules.
- **3- With a laser guide star**: laboratory tests indicate that it could be possible to use a laser guide star with the Hypertelescope, as done with classical large telescopes. Adaptive optics would then become usable in the absence of a bright reference star, for producing direct images of even very faint sources such as the farthest galaxies detected by the Hubble Space Telescope. Cosmology would then benefit from the resolution gain.

Contribute to the development of the world's largest telescope

The Association hypertelescope LISE - Laboratory of Stellar Interferometry and Exoplanetary - is a non-profit international organization that brings together scientists and amateurs. She works actively to support the development of the giant telescope project interferometry invented by Antoine Labeyrie.

To actively participate in the funding of scientific campaign 2016 the hypertelescope is simple: in April and May 2016, join our crowdfunding campaign on Kickstarter platform:

www.kickstarter.com/profile/hypertelescope

… and choose your contribution

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More explanations on our website HYPERTELESCOPE.ORG