ARENA*

A European Network for Astrophysics in Antarctica

at the Concordia station (Dome C)

THE UNIVERSE YOURS TO DISCOVER

INTERNATIONAL YEAR OF ASTRONOMY 2009

* **A**ntarctic **R**esearch, a **E**uropean **N**etwork for **A**strophysics

Credits: D. Mékarnia (Fizeau) / MODIS – NASA / E.Aristidi (Fizeau) / G. Durand (CEA)

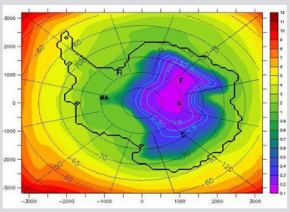
Dome C, a very promising site for astrophysics

The dream of astronomers is to observe from an ideal, highly transparent and stable site, far away from any sources of human pollution. On the Antarctic Plateau, Dome C benefits from exceptional atmospheric conditions which make it particularly promising for astronomy, in **between space and the best current ground-based observatories**. For several applications, the French-Italian station Concordia could challenge space missions and allow the deployment of much larger instruments at lower cost. Thus, a programme to qualify the site for astronomy is carried out since 2000 by various international teams.

Location: Antarctic high Plateau
Altitude: 3233 metres

Minimal disturbance from the atmosphere and far from light and chemical pollution caused by human or volcanic activities

Lowest temperature recorded: - 81.9 °C
Very little absorption or scattering (aerosols, water vapour) in the atmosphere
Low wind at ground level

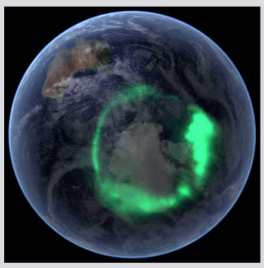


Cold, dry and stable atmosphere : access to new wavelengths and the ability to image astrophysical objects at higher angular resolution

Latitude: 75° South
Clear sky: more than 85 % of the time
Turbulent layer of approximately 30-metre height

Unique opportunity to monitor continuously the photometric and spectrometric variations of the Sun and stars over several months

Center of the auroral oval



No additional spurious light caused by the aurora during observations

The Concordia station has been built under a bilateral collaboration between the French and Italian Polar Agencies, IPEV and PNRA, respectively. Since the first winterover in 2005, it is one of three stations operated year-round in the interior of the Antarctic continent.

The 22 partners

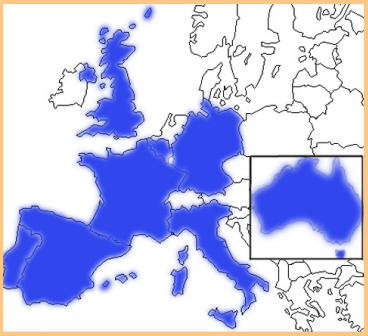
United Kingdom
• University of Exeter

Belgium
• Université de Liège
• AMOS, Liège

Germany
• MPIA, Heidelberg
• Astrophysikalisches Institut Potsdam
• DLR, Berlin

Australia
• University of New South Wales, Sydney

France
• CNRS (coordinator), Nice
• Institut Paul Emile Victor, Brest
• Observatoire de Paris
• CEA, Saclay
• SESO, Aix en Provence
• Thales Alenia Space, Toulouse
• SHAKTIWARE, Marseille



Portugal
• Centro de Astrofisica da Universidade do Porto

• European Southern Observatory

Spain
• Universidad de Granada
• CSIC, Barcelona
• Instituto de Astrofísica de Canarias, La Laguna

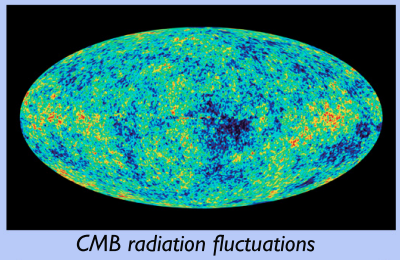
Italy
• INAF, Roma
• Università degli Studi di Perugia
• Programma Nazionale di Ricerche in Antartide, Bologna

An ambitious project for the next decade

ARENA is a **consortium of 22 European and Australian partners** including polar institutes, research laboratories and industrial companies, funded by the European Commission for a period of 4 years starting in 2006. The Laboratory H. Fizeau of CNRS located at the University of Nice Sophia Antipolis coordinates this network. Its main objective is to set up an ambitious programme of development for an international astronomical observatory, including:

•The **assessment of Dome C for astronomy** and the dissemination of the site qualification data through the Internet,
•The **identification of the key astrophysical programmes** that would take maximum benefit from the site in synergy with other large ground-based observatories and space missions,
•The **characterization and preliminary studies** of large instruments under the constraints of **a harsh and fragile polar environment**.

Dome C
addressing fundamental astrophysical questions



CMB radiation fluctuations

Instruments : BRAIN, COCHISE, AST

Investigating the formation of the Universe

The oldest accessible light that the Universe radiated, some 380,000 years after the Big Bang, is called the Cosmic Microwave Background (CMB). It represents the footprint of the primordial Universe and contains fine details (inhomogeneities, polarization) that reveal major aspects of the formation and early evolution of the Universe. Thanks to the unique transparency and stability of Dome C atmosphere, the BRAIN, COCHISE and AST instruments will allow the most precise analysis of this radiation from the ground to provide answers to two major issues of contemporary cosmology.

Inflation: during the very first fractions of a second of its existence, the Universe expanded exponentially. Cosmologists seek to detect the traces of these epoch in the tiny fluctuations of the CMB.

Dark energy: recent measurements have shown that the expansion of the Universe is accelerating, "pushed" by an energy opposed to gravity. To understand the evolution of this energy with time, cosmologists are studying the effects that massive clusters of galaxies, formed at various epochs, produce on the CMB.

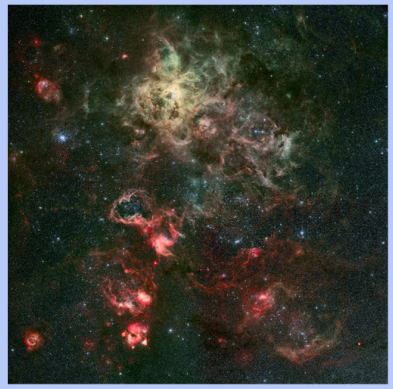
Understanding star and galaxy formation

The improved access to infrared and submillimetre-wave atmospheric windows at Dome C allows astronomers to study the earliest stages of stellar life when they are still hidden in their parent cloud of dust and gas. By observing very young objects in increasingly remote galaxies, astronomers can trace the cosmic history of star formation in the Universe and how it has been evolving with time. Major targets for future large infrared and submillimetre-wave telescopes in Antarctica, such as PILOT and AST, are:

Protostars in giant clouds of the Milky Way: the astronomers want to investigate at large scale the distribution of their properties and masses, and to study the physical conditions governing the collapse of a cloud of gas and dust under the effect of gravity.

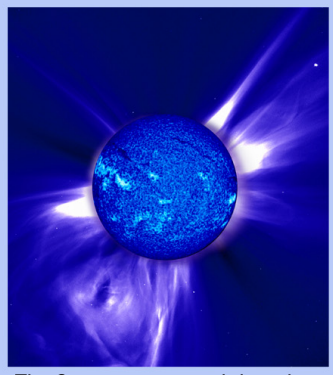
The Magellanic Clouds: our neighbouring galaxies can be observed under optimal conditions from Dome C. They constitute unique targets for the investigation in great detail of the star formation process and history in galaxies that feature very different chemical properties from our Milky Way.

Ultra-luminous galaxies: these very remote galaxies located between 9 and 11 billion light-years away from our solar system emit the bulk of their energy in the infrared range. To understand the source of this Cosmic Infrared Background (CIRB) would enable us to know more about the formation mechanisms of stars and galaxies in the early Universe.



Stellar formation
(here in the Large Magellanic Cloud)

Instruments : IRAIT, PILOT, AST



The Sun, its activity and the solar corona

Instruments : IRAIT, SIAMOIS, ICE-T, ADSIIC, AST

Probing the interior and atmosphere of the Sun and stars

Thanks to its high latitude, Dome C is ideally located for long-duration and high-precision time-series measurements of the Sun and stars over uninterrupted periods of weeks and months. The goal is to better understand the nature and the physics of the internal engine that produce the energy of a star, how it varies with time and how light, energy and matter are released to chromosphere, corona and circumstellar environment.

The Sun: our star constitutes an exceptional laboratory to test models of stellar structure. Helioseismology, aimed at measuring and interpreting the pulsation modes of the Sun, has been invented from Antarctic observations. The heating mechanisms of the solar chromosphere and inner corona, the direct measurements of the magnetic field and structures, will be addressed by specially designed instruments (ADSIIC) operating under a uniquely stable and clear sky, some conditions called "coronal" that frequently occur above Dome C.

Life and evolution of stars: to understand the evolution of stars throughout their life, it is necessary to know more about their inner source of energy and thus astronomers want to probe the interior of stars. For that purpose, they use a technique comparable to seismology by measuring the star's pulsation modes.

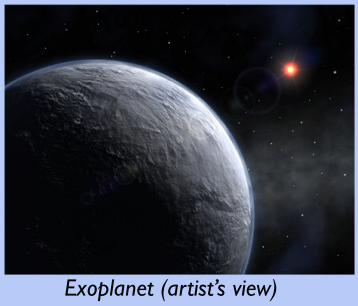
Death of stars: the final stage of a star's life is characterized by a strong mass loss of gas and dust. This matter that will give rise to future stellar and planetary systems, is most easily observed in the infrared and submillimetre-wave range. The IRAIT, PILOT and AST instruments will measure it.

Discovering new worlds, and possible extraterrestrial traces of life

The recent discovery of planets located outside our solar system has renewed the question of the origins of Life. The understanding of the links between the characteristics of a star and its planetary companions has become one of the major goals of contemporary astrophysics. The unique atmospheric stability and transparency of the Dome C atmosphere will allow the discovery of new extrasolar planetary systems and their properties using a range of instruments that spans from small telescopes (A STEP, ICE-T) to large interferometric arrays (KEOPS).

Counting extrasolar planets and probing their atmospheres: through a catalogue of a large sample of planetary systems and their characteristics (size, mass, orbital radius and period, atmospheric chemical composition), astronomers will be able to explain the formation of planetary systems within dust clouds.

Exo-Earths: one of the ultimate goals of the instruments of the future such as KEOPS will be to image a planet comparable to our Earth, and to detect chemical species that are possible life markers.



Exoplanet (artist's view)

Instruments : A STEP, ICE-T, ALADDIN, KEOPS

ASTRONOMY at CONCORDIA

The instruments : today, tomorrow... and in the future

COCHISE

Cosmological Observations at Concordia with High-sensitivity Instrument for Source Extraction

2.60-metre submillimetre-wave radiotelescope

Origin and evolution of dark energy

Operational since 2007

IRAIT

International Robotic Antarctic Infrared Telescope

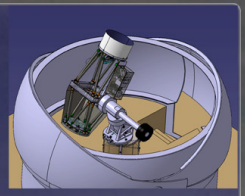
0.80-metre robotic infrared telescope

Star formation, mass loss from evolved stars

Installed in 2009

A STEP

Antarctic Search for Transiting Extrasolar Planets



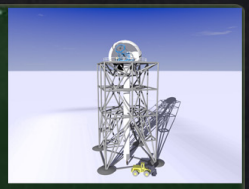
0.40-metre telescope, field of view of 1°x1°

Detection of planetary extrasolar transits

First winterover: 2010 (pathfinder operational since 2008)

PILOT

Pathfinder for an International Large Optical Telescope



2.50-metre telescope, field of view of 1°x1°, installed on top of a 30-metre tower to stay above the turbulent ground layer

Stellar and planetary formation regions, ultra-luminous galaxies, structure of the Universe

Horizon 2015?

BRAIN

B-mode RAdiation INterferometer

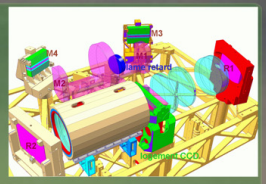
Bolometric interferometer

Inflation footprint on the Cosmic Microwave Background

First winterover: 2011 (pathfinder operationnal since 2006)

SIAMOIS

Seismic Interferometer Aiming to Measure Oscillations in the Interior of the Stars



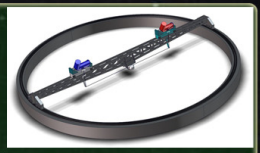
Spectrometer

Stellar seismology

Horizon 2013?

ALADDIN

Antarctica L-band Astrophysics Discovery Demonstrator for Interferometric Nulling



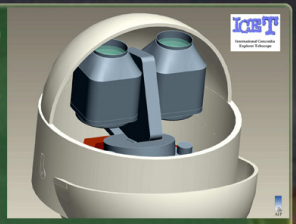
Interferometer made of two 1-metre infrared telescopes mounted on a 40-metre diameter circular structure

Characterization of the circumstellar clouds possibly hosting exo-Earths

Horizon 2015?

ICE-T

International Concordia Explorer Telescope



Two 0.60-metre telescopes for long time series measurements, field of view of 8° x 8°

Detection of extrasolar planetary transits, star/planets interactions

Horizon 2013?

KEOPS

Kiloparsec Explorer for Optical Planet Search

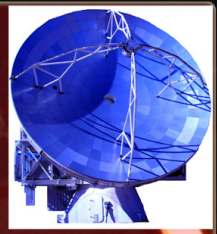
Infrared interferometric array of thirty six 1.50-metre telescopes

Exo-Earths detection and galactic nuclei imaging

Horizon 2020 – 2025?

AST

Antarctic Submillimetre-wave Telescope



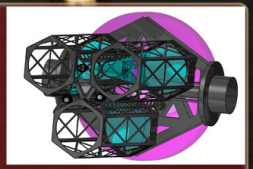
25-metre single dish telescope or interferometer

Young and cold universe, evolution of galaxies, formation of stars and planets

Horizon 2016?

ADSIIC

Antarctica Demonstrator of Solar Interferometric Imaging & Coronagraphy



Three cophased 0.70-metre off-axis telescopes installed on top of a 30-metre tower

Heating mechanisms and magnetic fields of the solar chromosphere and corona

Horizon 2013?

ARENA coordination
Laboratoire H. Fizeau - CNRS
Université de Nice Sophia Antipolis
Campus Valrose
F- 06108 Nice cedex 2

Coordinator – nicolas.epchtein@unice.fr
Project Manager – marie-laure.peronne@unice.fr
Communication – cyrille.baudouin@unice.fr
http://arena.unice.fr/
http://www.arena.ulg.ac.be

Credits: E.Aristidi (Fizeau) / G. Durand (CEA) / M.L Péronne (Fizeau) / J.B Daban (Fizeau) / A. McGrath (Anglo-Australian Obs.) / Obs. Paris / Thales Alenia Space / Astrophysikalisches Institut Potsdam / W. Hertmanni – F.Vakili (Fizeau) / V. Minier (CEA) / J.P Amans (Obs. Paris) – Design: C. Baudouin (Fizeau) - Partly funded by Agence Nationale de la Recherche