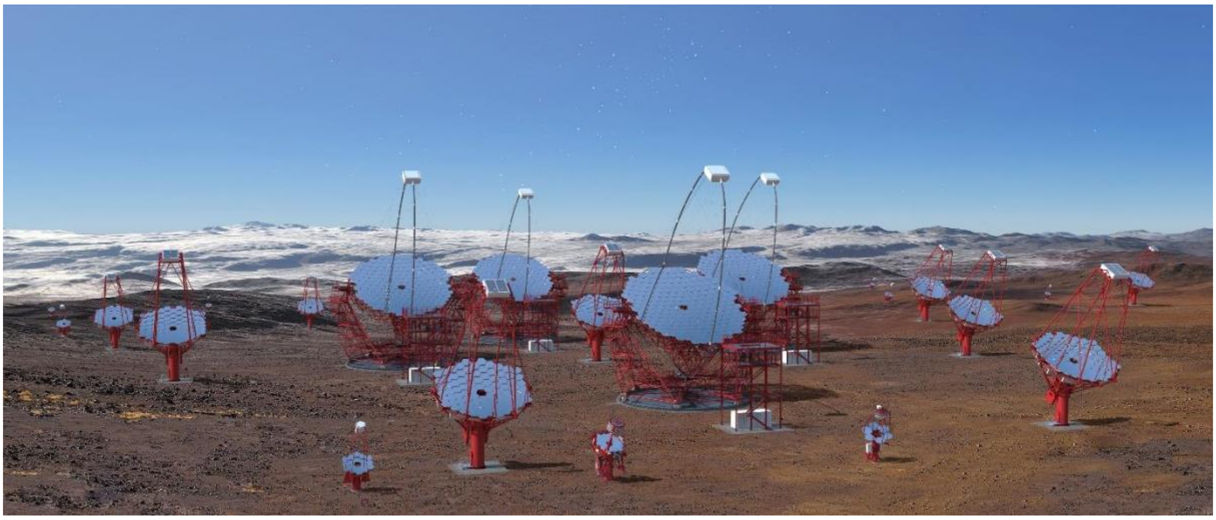
CTA Science Prospective
at IN2P3



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Abstract

The Cherenkov Telescope Array (CTA) will be the major global observatory for very-high-energy γ-ray astronomy in the coming decade and well beyond. Capitalising on the success of the current generation of experiments, such as H.E.S.S., it will consist of a Northern and Southern array of imaging Cherenkov telescopes, each of unprecedented scale, which will achieve a sensitivity, spatial resolution and range of energy coverage which exceeding this current generation. Currently, 8 IN2P3 laboratories (APC, CENBG, CPPM, IPNO, LAPP, LLR, LPNHE, LUPM) are contributing to the design, construction and science preparation of CTA. In this report, the science topics to be explored with CTA will be briefly presented, with particular focus on the leading role that the IN2P3 teams will play therein.

Introduction

The Cherenkov Telescope Array, CTA, will be the major global observatory for very-high-energy (VHE) γ-ray astronomy over the next decade and beyond. CTA consists of arrays of imaging Cherenkov telescopes (IACT), with three classes being realized in order to cover the energy range from 20 GeV to 300 TeV: the large, medium, and small-sized telescopes (LST, MST and SST), which trade energy threshold against cost. The Observatory will operate arrays on sites in both hemispheres, La Palma in the Canary Islands and Paranal ESO site in Chile. The two sites are optimized for different science cases, with the Southern site optimized to observe Galactic sources where angular resolution and performance at the highest energies are critical, and the Northern site optimized to observe extragalactic sources for which low-energy performance is required due to the increase of cosmological optical depth with energy.

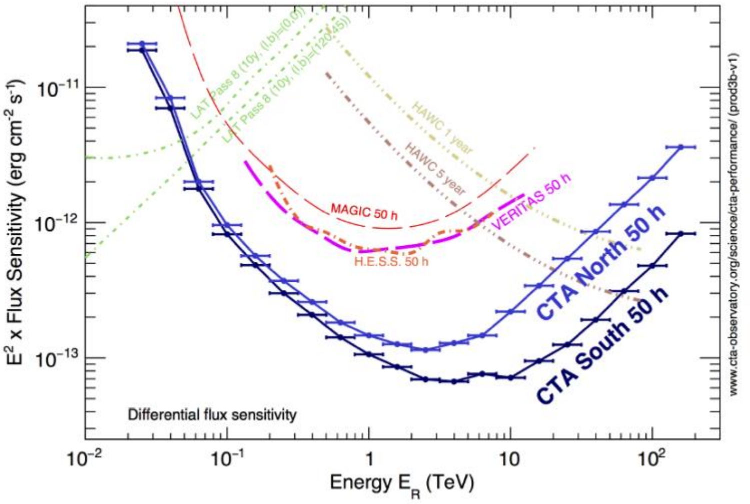

Figure 1: The differential sensitivity of CTA and other instruments. The sensitivity curve is defined as the minimum flux needed by CTA to obtain a 5-sigma detection of a point-like source.

Covering more than four decades in photon energy from 20 GeV to 300 TeV, CTA will improve on all aspects of performance with respect to current instruments. Its wider field of view and improved sensitivity will enable CTA to survey hundreds of times faster than previous TeV telescopes. The angular resolution of CTA will approach 1 arc-minute at high energies enabling detailed imaging of a large number of γ-ray sources. A one-to-two order-of-magnitude collection area improvement makes CTA a powerful instrument for time-domain astrophysics; it will be three orders of magnitude more sensitive on hour timescales than *Fermi*-LAT at 30 GeV. Fig. 1 shows the expected sensitivity of CTA compared to current-generation instruments.

The French CTA teams have important contributions in all technical development areas:

- SST: design, realization, inauguration and testing of a two-mirror telescope prototype, GCT. Contributions to production of harmonised SST are under discussion.
- MST: design and realization of the NectarCAM camera, based on the Nectar ASIC, including mechanics, detector elements, front-end electronics, slow control, calibration equipment, data acquisition (DAQ), and integration.
- LST: design, construction and installation of the camera support arches, and the drive system. Responsibility for the DAQ (common component with NectarCAM).
- Data processing and simulations: major contributions to the observer portal and the proposal handling platform, the GRID infrastructure (*DIRAC*), simulations package (*CORSIKA* v7 & v8), the CTA low-level pipeline (*ctapipe*) and the science tools (*gammapy*, in which IN2P3 is strongly involved in coordination and development, and *ctools*).

Naturally during this development phase the major focus of the IN2P3 CTA teams is on the technical activities required to construct the instrument and infrastructure, however the focus of *this report* is on the scientific prospectives of CTA for the coming decade, and the implication of the French teams therein. CTA will address a wide range of major questions in and beyond astrophysics, which can be grouped into three broad themes:

Theme 1: Understanding the Origin and Role of Relativistic Cosmic Particles

- What are the sites of high-energy particle acceleration in the universe?
- What are the mechanisms for cosmic particle acceleration?
- What role do accelerated particles play in feedback on star formation and galaxy evolution?

Theme 2: Probing Extreme Environments

- What physical processes are at work close to neutron stars and black holes?
- What are the characteristics of relativistic jets, winds and explosions?
- How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?

Theme 3: Exploring Frontiers in Physics

- What is the nature of dark matter? How is it distributed?
- Are there quantum gravitational effects on photon propagation?
- Do axion-like particles exist?

The CTA Observatory (CTAO) will be operated as an open, proposal-driven observatory, with all data available on a public archive after a pre-defined proprietary period (of typically one year). The CTA Consortium (CTAC) has prepared a proposal for a Core Programme of highly motivated observations that will provide legacy data products and benefit future users of the Observatory, as well as the entire astronomical community. The programme is organized into ten Key Science Projects (KSPs): Galactic Centre, Galactic Plane Survey, Large Magellanic Cloud Survey, Extragalactic Survey, Transients, Cosmic Ray (CR) PeVatrons, Star Forming Systems, Active Galactic Nuclei (AGNs), Clusters of Galaxies and Dark Matter & Exotic Physics Programme. Furthermore, CTA will have important synergies with many of the new generation of major astronomical and astroparticle observatories. Multi-wavelength and multi-messenger approaches combining CTA data will be highly valuable in understanding the non-thermal properties of the most extreme accelerators in the cosmos.

On-sky operations of CTA will begin during the coming decade. Initially, there will be an engineering phase during which telescopes are installed, commissioned and calibrated by the instrument teams, and then accepted by CTA. This phase has already started (with the LST). As the installed instrumentation grows past a site-dependent threshold, the key-science phase will be triggered, unleashing a predefined program of observations that addresses the primary scientific goals, the KSPs. In parallel to the KSP program, the Observatory will be progressively in transition to an open, proposal driven phase in which all members of the astronomical community from countries contributing to CTA can participate. IN2P3 scientists will contribute to all phases of this operation. Experience with the building and with the commissioning of the telescopes will naturally lead to expertise that will be invaluable in the KSP phase. Similarly, experience gained in the KSP phase will mean that IN2P3 scientists will be well placed to participate in the open proposal phase.

A complete description of CTA science as well as the references related to each KSP can be found in Ref. [1].

CTA science at IN2P3

Currently about 140 IN2P3 permanent scientists, engineers, postdocs and students working in 8 laboratories (APC, CENBG, CPPM, IPNO, LAPP, LLR, LPNHE, LUPM) contribute to the design and construction of CTA, and to the preparation of science with CTA. The IN2P3 scientific community has long experience in VHE γ-ray observations and has also pioneered the development of this field. In particular, the strong involvement of the scientists to the very successful H.E.S.S. experiment gives a very solid base for their research program with CTA.

In the following, some of the main science topics that will be developed by the IN2P3 community, in collaboration with French scientists from INSU, CEA and scientists from other countries, are briefly described. A table indicating the involvement of different IN2P3 laboratories in the KSPs and other CTA science topics, is also given.

Galactic Centre

The Galactic Centre KSP is comprised of a deep exposure of the inner few degrees of our Galaxy, complemented by an extended survey to explore the regions not yet covered by existing VHE instruments at high latitudes, to the edge of the bulge emission. This program covers a wide range of scientific topics due to its rich environment. The central VHE source was first detected in 2004, and although well studied by current-generation IACTs (H.E.S.S. and VERITAS), it still remains unidentified due to source confusion and limited sensitivity to variability and small-scale morphology. The emission may originate from close to the supermassive black hole, Sgr A*, from winds driven out from it, from a background pulsar wind nebula (PWNe), or from a variety of other possibilities. CTA, with its arc-minute resolution at high energies and dramatic improvement in sensitivity for rapidly variable phenomena, will have the opportunity to resolve this question.

Furthermore, the diffuse γ-ray emission along the Galactic ridge provides both the best case for studying γ rays produced by hadronic interactions and to understand the acceleration history of the central engine. A large number of supernova remnants (SNRs) and PWNe will be covered by a deep exposure of the Galactic-Centre region providing a significant increase in the number of detected objects. While the Galactic-Centre KSP will allow us to explore new domains in both space and energy, it will also drastically improve upon the existing observations from current or past γ-ray telescopes. In particular, it will build upon the knowledge gained from *Fermi*-LAT at GeV energies and from H.E.S.S. and VERITAS observations at higher energies. For several IN2P3 scientists, the Galactic Centre will be an important area of investigations, both for the astrophysics of the sources as well as for searches of dark-matter signature in the halo around the Galactic Center, as discussed below.

Galactic Plane Survey

Astronomical surveys of the Galaxy provide essential, large-scale data sets that form the foundation for Galactic science at all photon energies. CTA will perform a complete Galactic Plane Survey (GPS), providing 2–4 mCrab survey sensitivity and average 15 h of exposure depending on Galactic coordinates. This makes the CTA GPS a factor of 5 – 20 more sensitive than surveys carried out by earlier or existing atmospheric Cherenkov telescopes. The major scientific objectives for the CTA GPS include: discovery of new and unexpected phenomena in the Galaxy, discovery of PeVatron candidates (see below), detection of many new VHE Galactic sources (especially PWNe and SNRs) enabling comprehensive population studies, measurement of the large-scale diffuse VHE γ-ray emission. Periodically released source catalogues will be among the major outcome of the CTA GPS. The figure below shows a simulation for the CTA image of the Galactic plane.

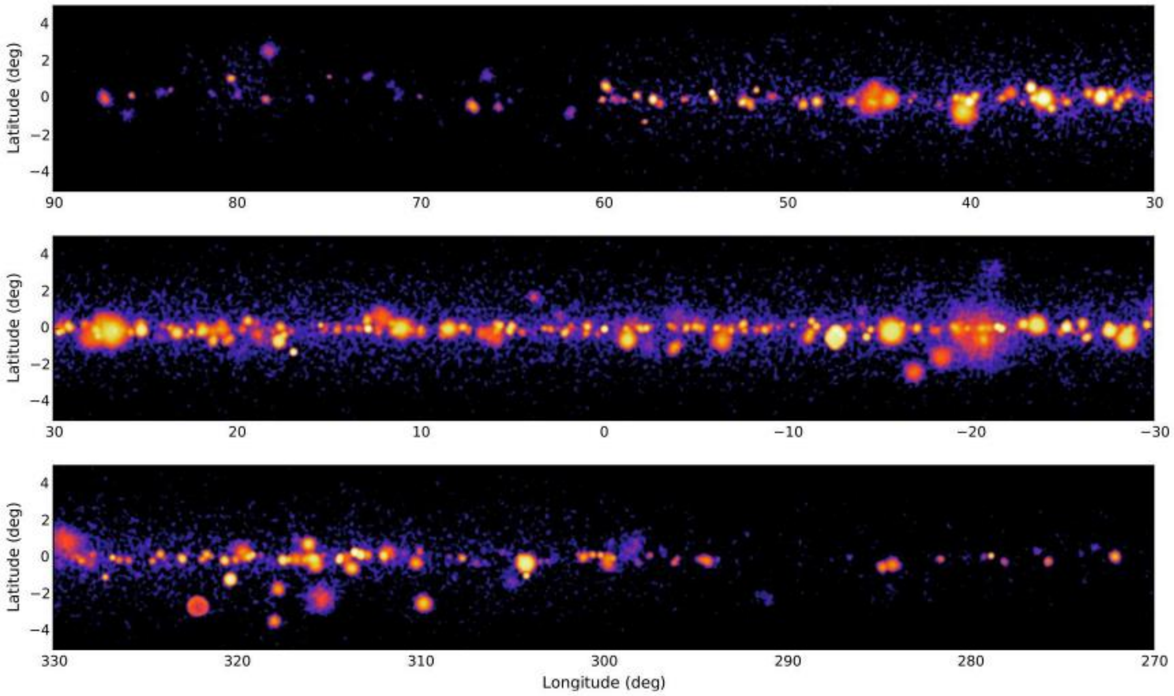

Figure 2: Simulated CTA image of the Galactic plane for the inner region -90° < l < 90°, adopting the actual proposed GPS observation strategy, a source model incorporating both supernova remnant and pulsar wind nebula populations as well as diffuse emission.

LMC Survey

The Large Magellanic Cloud (LMC) is a satellite galaxy of the Milky Way at a distance of about 50 kpc and at high Galactic latitude. It has the shape of a disk seen nearly face-on. Considering the typical angular resolution of γ-ray telescopes, the LMC is perhaps the only object which can provide us with a global and significantly resolved view of an external galaxy at γ-ray energies. The LMC hosts many interesting astrophysical sources: the largest star-forming region in the Local Group of galaxies, one of the densest stellar clusters known, the most massive stars ever observed, more than a dozen super-bubbles, numerous giant shells, more than 50 catalogued SNRs, and the remnant of the recent supernova SN 1987A. The LMC was detected in high-energy γ rays and characterised by *Fermi*-LAT after just one year of data. Recently, powerful VHE emitters have been detected by H.E.S.S. This KSP has many scientific objectives: population studies on SNRs and PWNe, transport of CRs from their release into the interstellar medium to their escape from the system, and the search for signatures of the elusive dark matter component of the universe. The deep scan by CTA of the LMC will offer a rich variety of targets for studies of IN2P3 scientists.

Transients

Transient phenomena are of great scientific interest, being associated with catastrophic events involving relativistic compact objects such as neutron stars and black holes that manifest the most extreme physical conditions in the universe. However, their dynamic nature has often hindered detailed observational characterization and robust physical understanding. One of the key strengths of CTA is the unprecedented sensitivity in VHE γ rays for transient phenomena and short-timescale variability, which can revolutionise our knowledge of cosmic transients. Its relatively large field of view is also a crucial asset in discovering transient events on its own, as well as in following up alerts of transients issued by monitoring instruments.

This was exemplified in recent years, when a new window into multi-messenger and transient studies opened up, thanks to the detection of the kilonova AT 2017gfo associated to the gravitational wave event GW 170817. Also noticeable is the indicative association of the neutrino event IceCube-170922A and the active state of the blazar TXS 0506+056 at high energies. The very recent detection of VHE emission from GRBs with H.E.S.S. and MAGIC, deep into the afterglow phase in the former case, questions as well the current phenomenological paradigm on these cataclysmic events.

In the electromagnetic channel alone, it has been known since decades that multi-wavelength observations are crucial to unveil the full picture of non-thermal processes at work in e.g. AGNs, GRBs or Galactic transients. In connection with the extragalactic survey (see below), CTA has a great potential for detecting many transients on its own, while strong connections with multi-wavelengths and multi-messenger partners are key to quickly repoint the CTA telescopes to catch new, exciting events. It should be noted that the French community is organising around this theme, see the dedicated contributions [2, 3, 4] to the IN2P3 prospective.

Cosmic Ray PeVatrons

CRs are primarily energetic nuclei, dominated by protons. Their energy spectrum observed at Earth shows a major spectral feature called the knee, where the differential power-law spectrum steepens from $E^{-2.7}$ to E^{-3} at an energy of a few Peta-electronvolt (1 PeV = 10^{15} eV). CRs up to the knee are believed to have originated in our Galaxy.

One of the KSPs of CTA is the search for PeVatrons, cosmic-ray accelerators able to accelerate nuclei at least up to the knee. The goal is to address some of the fundamental questions of high-energy CR acceleration and provide information on the distribution of PeVatrons in our Galaxy. The PeVatron sources are expected to have hard power-law spectra (i.e. not much steeper than E^{-2}) that extend up to 50 TeV and beyond. A firm detection of 100 TeV intrinsic spectral cutoff will most likely make a source a PeVatron candidate. In such a case, at least 1 PeV CRs would be needed at the source region to explain observed VHE emission, assuming a conservative proton / γ-ray energy ratio of 10. Furthermore, multi-wavelength studies, combining the CTA data with observations from radio, X-ray instruments and *Fermi*-LAT, will enable radiative model fitting to evaluate the leptonic and hadronic contributions to the measured energy spectra.

The CTA GPS will provide an unprecedented dataset for the search of Galactic PeVatrons. Many new sources will be detected during the survey and the PeVatron search program proposes 50 h deeper observations of the best PeVatron candidates. The French CTA community is leading since few years the effort to prepare future PeVatron observations.

Magnetospheres of Neutron Stars and Black Holes

Pulsars were discovered more than 5 decades ago and stand among the most powerful accelerators in the universe. γ rays have proven as invaluable probes into their magnetospheres. Although great progress has been made in the last decade in interpreting the high-energy emission of pulsars, thanks in particular to the wealth of data in the < 100 GeV range from *Fermi*-LAT, major questions concerning the acceleration and radiative processes at play, as well as the regions involved, are still open. VHE γ-rays, which are beyond the reach of *Fermi*-LAT, are produced by the highest energy particles and constitute valuable probes for testing acceleration and emission processes in their extreme energy limit. The discovery of VHE pulsations up to 1 TeV from the Crab pulsar (VERITAS and MAGIC), and the more recent discovery of a distinct and hard spectral component from the Vela pulsar reaching energies beyond 7 TeV by H.E.S.S., have brought important constraints to emission models. In the past year, the number of pulsars detected from ground has raised to four objects. These discoveries have opened unexpected and important prospects for studying the magnetospheres of neutron stars and their winds with CTA. The progress in this area is also relevant to the study of the close vicinity of black holes — which are believed to harbour magnetospheric phenomena, although not identical, but analog to pulsars — and to the understanding of merging neutron stars and other compact object mergers, which are the likely counterparts of short GRBs and will be prime targets for CTA.

IN2P3 teams are among the leaders in the discoveries made in this field, both with the *Fermi*-LAT satellite and with the current-generation IACTs of the H.E.S.S. array. They are strongly involved in the preparation of this physics with CTA, and in its coordination with other facilities at various wavelengths.

Star Forming Systems

The star-forming system KSP addresses the following question: can collective effects of stellar winds accelerate CRs at PeV energies? Indeed, massive stars are characterized by significant mass loss in the form of stellar winds. These winds can combine and produce a shock wave in the interstellar medium that could accelerate CRs. In regular star forming regions, several mechanisms can accelerate charged particles and thus emit non-thermal radiation. However, it is very difficult to know whether CRs are produced by collective effects (interaction of stellar winds / supernova) or if they come directly from evolved objects (supernova, pulsars). In young star forming region, only collective effects may accelerate particles and therefore enable particular investigations on stellar-wind acceleration.

Today, no young clusters of stars have been detected in VHE γ-ray astronomy. However, modeling constrained by the limits from H.E.S.S. and *Fermi*-LAT led to an upper limit on the amount of energy transmitted to particle acceleration within this type of objects. CTA, with a sensitivity ten times higher, will be the key instrument in detecting emission from young star forming regions. If not, upper limits should strongly constrain modeling and exclude stellar-wind interactions as a major PeVatron source.

Active Galactic Nuclei

AGNs are galaxies that harbour a supermassive black hole (10^6 - 10^9 $M_\odot$) at their centre, which are often associated with collimated outflows of relativistic plasma in the form of jets. The majority of AGN from which γ rays are detected are *blazars*, a subclass of AGN in which one of the jets is beamed towards us. Blazars are highly variable on all timescales (from years to minutes) from optical to γ rays and are prime targets for multi-wavelength observations. The mechanisms powering these objects are not clearly understood. The nature of the particles accelerated in the jet plasma, the role of shocks therein, and the radiative processes at play are also unclear. In addition to striving to understand the astrophysical processes at play in these sources, their study can help us to address long-standing open questions in physics, such as "where are the ultra high-energy CRs accelerated?" and "how are supermassive black holes formed?". They are a unique tool to study the physics of extreme environments, including accretion physics, jet formation and general relativity.

A major component of blazar research is concerned with understanding the broad-band emission of blazars from optical, X-ray, MeV energies up to VHE γ-ray regime; how it depends on blazar sub-class (the existence or not of the so-called blazar sequence); how it varies with emission state; the nature of the radiating particles that power the γ-ray emission, for which leptonic and hadronic models, and more recently, lepto-hadronic models have been developed (with prominent French contributions). Were blazars to be shown to have a significant hadronic component in their emissions, they would be a prime candidate for the accelerators of ultra high-energy CRs; neutrino observatories can play a key role here.

The AGN KSP is designed to address the issues outlined above by employing various observational strategies on carefully selected target AGN, including many which French scientists have studied individually with *Fermi*-LAT and current IACTs. Through detailed spectra, lightcurves that cover more of the variability frequency range (long term and fast flaring timescales), and dedicated multi-wavelength and multi-messenger observation programs, CTA will allow us to study the γ-ray emission from AGN in a way that has not been possible before. The prospectives for AGN astrophysics with CTA are detailed in a separate contribution to GT04 [5].

Extragalactic Survey

To complement the detailed, targeted observations of AGN, CTA will perform the first survey of the extragalactic sky at GeV-TeV energies. Our current view of the extragalactic sky at these energies is heavily biased by the somewhat irregular observation strategies of the previous generation of instruments, targeting the most opportune fields. The CTA extragalactic survey KSP will allow us to construct an unbiased extragalactic source catalogue with a sensitivity to objects nearly 200 times fainter than the Crab Nebula, yielding a larger sample of blazars from which the properties of these enigmatic objects can be determined : distribution of object type, flaring duty cycle and timescales, and ultimately the luminosity function. Another objective of the survey is to search for unexpected and serendipitous VHE phenomena over a large portion of the sky, including the discovery of extreme blazars, the serendipitous discovery of fast flaring sources, the discovery of γ-ray emission from as-yet undetected source classes such as, for example, Seyfert galaxies or ultra-luminous infrared galaxies. We refer the committee to the dedicated AGN contribution [5] for more details.

Gamma-ray cosmology

Gamma-ray astronomy is a promising tool to probe cosmology, namely the content and fabric of the universe, thanks to the interaction of γ-rays with intergalactic photon fields during their travel on cosmological distances to the observatories. This concerns in particular the characterization of the extragalactic background light, which encompasses the history of star and galaxy formation since the end of the dark ages, and constraints on the intergalactic magnetic fields in cosmic voids, whose characteristics (intensity, coherence length) and origin are poorly known today. More generally, γ-ray absorption studies could give an independent measurement of the Hubble constant, H_0, a contribution of high relevant in the current context of tension (3.5 - 4.4σ) between results from the cosmic ladder and the CMB.

The IN2P3 community has played a leading role in the first constraints obtained on these topics with current-generation γ-ray telescopes. The community is also strongly involved in the preparation of this science case with CTA. It is expected that CTA, with its enhanced sensitivity, will lead to breakthroughs in the young field of γ-ray cosmology, exploiting also strong synergies with major upcoming multi-wavelength observatories such as JWST or SKA. A more in-depth discussion is provided in two other contributions to the IN2P3 prospective: one devoted to γ-ray cosmology [6], and one focused on the measurements of the intergalactic magnetic field [7].

Clusters of Galaxies

Clusters of galaxies are the largest and most massive gravitationally bound systems in the universe, with radii of a few Mpc and total masses of 10^{14} - 10^{15} $M_{\odot}$. Galaxy clusters form via energetic processes (accretion, merging), which are expected to accelerate charged particles up to PeV energies. Additionally, member galaxies may also directly inject CRs into the intra-cluster medium. As CRs are confined in clusters, they should accumulate during cluster formation, leading to γ-ray emission primarily through the decay of neutral pions produced in p-p collisions. Therefore, γ-ray observations provide a measurement of the CR content in clusters and tests for acceleration and propagation mechanisms. As CRs are expected to contribute to a few percent of the diffuse gas energy budget, they might become relevant for precision cluster cosmology based on intra-cluster tracers in the next decade. While the presence of relativistic electrons and magnetic fields is now well established based on radio observations, their origin remains barely understood and γ-ray observations are essential to understand the non-thermal physics of clusters. Additionally, clusters are also prime targets for indirect dark matter searches, providing competitive probes. Given these motivations, the observations of clusters is one of the 10 CTA KSPs, aiming at the first clear detection of clusters in the γ rays. In particular, the aim is to develop a physically motivated model for the signal arising from CRs and apply it to CTA. This requires the use of X-ray, Sunyaev-Zel'dovich, and radio data and is also fundamental for disentangling the astrophysical background to the potential dark matter signal. We expect CTA to be able to probe CRs to thermal pressure down to a few tens of percent, depending on the shape of the CR energy spectrum and spatial distribution.

Dark Matter & Exotic Physics

Astrophysical measurements have today established the existence of non-baryonic dark matter that would constitute, according to the most recent measurements of the Planck experiment, 26% of the mass of the universe. The nature of dark matter remains unknown but one of the favourite candidates to explain it is a massive and very weakly interacting particle. The annihilation of these particles could produce high-energy γ rays in addition to conventional astrophysical signals. The goal here is to look at the astrophysical objects that have the highest expected dark matter density, while at the same time managing to separate the dark matter signal from conventional astrophysical signals. One of the best targets for indirect search of dark matter is the centre of the Milky Way, which contains a large concentration of dark matter, but also a great number of astrophysical sources. Another interesting target are the Milky Way satellite dwarf spheroidal galaxies, which are expected to contain a high proportion of dark matter, and for which the γ-ray signal from conventional sources would be negligible. The Large Magellanic Cloud is also a target of choice for CTA, with a large content of dark matter expected. It is interesting to note that these studies will reach masses of weakly interacting particles that are unachievable by the LHC, hence a very important complementarity.

Several tentative models developed on the road to a full theory of Quantum Gravity predict that the foamy or discrete structure of spacetime at the Planck scale (10^{19} GeV, 10^{-35} m) could have a measurable effect on γ-ray propagation. In particular, two effects will be looked for with CTA, both related to a modification of standard dispersion relations for photons in vacuum: an energy-dependent propagation speed, and a modification of the cross-section for the pair production process on the extragalactic background light: $\gamma\gamma \rightarrow e^{+}e^{-}$. The first effect would lead to the fact that photons emitted at the same time, but with different energies, would be detected with a time lag. This time lag increases with the energy difference of the photons and with the distance of the source. Flaring AGN, GRB and pulsars data will be used to constrain this effect. On the other hand, a modification of the threshold of the pair production process would lead to a dramatic increase of universe transparency above 10 TeV. Due to its unprecedented sensitivity, it is expected that CTA will give strong constraints on Quantum-Gravity models for both of these effects. It will also open a new era by making population studies possible.

Finally, CTA will also probe with unprecedented sensitivity another candidate for dark matter, constituted of weakly interacting slim particles, namely axion-like particles. These hypothetical particles, inspired from QCD axions and proposed in Beyond-the-Standard-Model approaches could couple to γ rays in astrophysical or cosmological magnetic fields, altering the absorption features induced by interactions on the extragalactic background light. As for weakly interacting massive particles, CTA has the potential regions of the parameter space where these particles could constitute all of dark matter.

The French IN2P3 teams have been involved in all the lines of research discussed in this section and are actively contributing to the dedicated efforts in the CTA Consortium.

Contributions of laboratories to KSPs and other science topics

Table 1, which can be found at the end of the document, gives a view of the current and planned contributions of the IN2P3 laboratories to all KSPs and related CTA science topics. As can be seen, the IN2O3 teams cover all the KSPs and have developed also other CTA science topics. Furthermore, the intense red color in the matrix indicates that the community has strong potential for leadership in a large number of topics. The CTA science can largely profit from investigations by other, non-CTA communities, and from collaborations with other instruments and science fields. We invite the French community to join the effort.

Conclusions

The Cherenkov Telescope Array will be the major global observatory for VHE γ-ray astronomy providing an unprecedented rich scientific domain, otherwise inaccessible with the current instruments. IN2P3 with its 8 laboratories (APC, CENBG, CPPM, IPNO, LAPP, LLR, LPNHE, LUPM) has strong contributions to the design and construction of CTA and is also currently actively preparing the science of CTA. The scientists and engineers of IN2P3 have been pioneers in the development of TeV γ-ray astronomy and in connected fields of astroparticle physics. Furthermore, they have developed and are playing a leading role with the current best instruments in this field. The IN2P3 community is committed since the very beginning in the concept of CTA and have strong visibility in the CTA Consortium.

Table 1 shows that the IN2P3 laboratories are covering the full spectrum of KSPs and related science topics addressed by CTA. Several teams have potential, or are already leading the investigations, in a large number of topics. It is also interesting to notice that the IN2P3 science topics concern both Northern and Southern hemispheres (note that some topics concern mostly our Galaxy which is the best visible in the Southern hemisphere while others, in particular the extragalactic science topics, will profit from observations both in the Northern and Southern hemispheres).

A particular strength for IN2P3, like for the French CTA community, is that it contributes significantly to all phases of CTA. Experience with building and commissioning of the telescopes will naturally lead to expertise that will be extremely valuable in the KSP phase and places the scientific community in a front position to participate in the open proposal phase.

It is now extremely important to take advantage of the expertise that IN2P3 already has in the field of VHE γ-ray observations and in the design and construction of CTA, and to ensure that the resources are adequate to match this expertise in the science phase. This will allow IN2P3 to have a leading role in many of the fundamental science topics of CTA.

	APC	CENBG	CPPM	IPNO	LAPP	LLR	LPNHE	LUPM
Galactic centre	🟥			🟦				
Gal. plane survey	🟥	🟥	🟦	🟦				🟥
LMC survey	🟦			🟦		🟦		🟦
Ex.Gal. survey				🟥	🟥	🟥	🟦	
γ-ray cosmology	🟦			🟥	🟥	🟥	🟦	
Transients	🟦		🟦	🟦	🟥	🟦	🟥	🟥
PeVatron	🟥	🟥	🟥	🟦				🟥
Magnetospheres	🟥	🟦						🟦
Star form. region		🟦	🟦		🟦			🟦
AGN	🟥	🟦		🟥	🟥	🟥	🟥	
Galaxy clusters						🟥		
DM & Exotic				🟦	🟥	🟦	🟥	🟦

Table 1: KSP and other science-topic participation matrix for IN2P3 labs. Red indicates primary interest of a lab; the lab expects to lead CTA investigations in this area. Blue indicates a secondary interest in the topic; the lab expects to participate in studies in this area.

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