Agència de Gestió d'Ajuts Universitaris i de Recerca

UNIÓ EUROPEA
Fons Social Europeu

Memòria justificativa de recerca de les beques predoctorals per a la formació de personal investigador (FI)

La memòria justificativa consta de les dues parts que venen a continuació:
1.- Dades bàsiques i resums
2.- Memòria del treball (informe científic)

Tots els camps són obligatoris

1.- Dades bàsiques i resums

Títol del projecte ha de sintetitzar la temàtica científica del vostre document.
Search for Dark Matter using VHE Gamma-ray Telescopes

Dades de l'investigador (benficiari de l'ajut)

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Institut de Fisica d'Altes Energies (IFAE)
Ed.Cn. Campus UAB

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Paraules clau: cal que esmenteu cinc conceptes que defineixin el contingut de la vostra memòria.
Dark Matter, Cherenkov Telescopes, Gamma-ray Astronomy, Indirect detection, Data Analysis

Data de presentació de la justificació
10/01/2011

Generalitat de Catalunya
Departament d'Innovació, Universitats i Empresa

Resum en la llengua del projecte (màxim 300 paraules)

One of the unresolved questions of modern physics is the nature of Dark Matter. Strong experimental evidences suggest that the presence of this elusive component in the energy budget of the Universe is quite significant, without, however, being able to provide conclusive information about its nature. The most plausible scenario is that of weakly interacting massive particles (WIMPs), that includes a large class of non-baryonic Dark Matter candidates with a mass typically between few tens of GeV and few TeVs, and a cross section of the order of weak interactions.

Search for Dark Matter particles using very high energy gamma-ray Cherenkov telescopes is based on the model that WIMPs can self-annihilate, leading to production of detectable species, like photons. These photons are very energetic, and since unreflected by the Universe's magnetic fields, they can be traced straight to the source of their creation. The downside of the approach is a great amount of background radiation, coming from the conventional astrophysical objects, that usually hides clear signals of the Dark Matter particle interactions. That is why good choice of the observational candidates is the crucial factor in search for Dark Matter.

With MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov Telescopes), a two-telescope ground-based system located in La Palma, Canary Islands, we choose objects like dwarf spheroidal satellite galaxies of the Milky Way and galaxy clusters for our search. Our idea is to increase chances for WIMPs detection by pointing to objects that are relatively close, with great amount of Dark Matter and with as-little-as-possible pollution from the stars. At the moment, several observation projects are ongoing and analyses are being performed.

Resum en anglès(màxim 300 paraules)

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2.- Memòria del treball (informe científic sense limitació de paraules). Pot incloure altres fitxers de qualsevol mena, no més grans de 10 MB cadascun d'ells.

Modern cosmology has progressed very rapidly in the past few decades and, with the help of the new measurements and instruments, the history of the Universe has been traced down to its earliest stages, long before stars and galaxies formed. Today, we can say with significant certainty that these objects, together with everything else we can see, are just a small fraction of the Universe – less than 5%. Everything else, the remaining 95 percent, is dark.

The dark content of the Universe is what helps it be the way we see it today. Also, this 'unseen' part played a very important role in the Universe's formation and evolution. It is assumed that some 23% of it is made of Dark Matter, while the rest (over 70%) is some exotic Dark Energy.

There are compelling evidences suggesting the existence of Dark Matter, from local to large scales. One of the most convincing and direct proofs are rotational curves of spiral galaxies, that in stead of dropping with radius, as expected from Keplerian laws in cases where mass follows light, stay flat or even show signs of increase in the last measured point. This discrepancy between the luminous and gravitational mass components in the galaxies points out that more mass is present: what we see is not all there is – Dark Matter is needed.

So far, observations and theoretical predictions, as well as powerful simulations, favor the existence of Dark Matter. However, it is important to mention that Dark Matter is not the only possible explanation for the phenomena we see in our Universe. In the last decades, many alternatives have been offered, like Quantum Gravity and Modified Newtonian Dynamics (MOND). Still, at present day, Dark Matter remains the most widely accepted explanation for the observed anomalies. But this assumption is not complete, since the most important question remains unanswered: what is Dark Matter?

There are many hypothesis and models describing the particles or objects the Dark Matter is made of. The most plausible candidates, consistent with the current LambdaCDM picture (the simplest model that is in general agreement with observed phenomena in the Universe, and assumes the existence of cold Dark Matter and Dark Energy), are Weakly Interactive Massive Particles (WIMPs). WIMPs are of non-baryonic origin, thought to be very massive and slow, neutral, long-living or slowly-decaying particles that interact only through gravitational (and possibly weak nuclear) force, and therefore do not emit the electromagnetic radiation we observe with telescopes. WIMPs are believed to be created in the early Universe, when the temperature was high enough for production of such massive particles. However, since they almost do not interact with 'ordinary', baryonic matter, they are still present in the Universe today.

But, if they practically do not interact, how are we going to identify them? Well, it turns out that 'practically' is something scientists can work with after all. There are two main approaches to Dark Matter detection: direct and indirect.

Direct detection of the Dark Matter particles is based on measurements the recoil energy of a nucleus the WIMP particle collided with. This is a very challenging task, obstructed by high background and small WIMP interaction cross section, but it is still possible. Thanks to good noise rejection techniques and wise designs of the instruments, there are many underground experiments looking for Dark Matter and achieving interesting results.

As for the indirect detection, the approach is based on not detecting the WIMP particles themselves, but, instead, products of their self-annihilation or decay. Those products should be detectable species, like antimatter, photons and neutrinos.

In my project, the Dark Matter search is based on detection of high-energy photons created in the annihilation of WIMPs. Photons are optimal messengers, since they can travel through the Universe undeflected by magnetic fields and can be traced back to the source of their origin. On the other hand, probability for their emission by 'conventional' astrophysical objects is far greater, and that radiation represents a significant background in Dark Matter search.

The gamma-ray signal scales with the square of the WIMP density along the line of sight, so the best chances for Dark Matter detection are in Dark Matter dominated objects, like galaxy clusters and dwarf spheroidal galaxies. The most obvious choice would, of course, be our Galactic Center, since it is very close and contains large amounts of Dark Matter. However, it is also heavily populated with astrophysical sources, whose signal 'drowns' the photons created by WIMPs. Therefore, at present, we must look elsewhere in order to get our Dark Matter signal.

In the past few years, thanks to the Sloan Digital Sky Survey (SDSS), many new dwarf spheroidal galaxies were discovered. These objects are very faint, with small number of stars, and extremely Dark Matter dominated (some of them are estimated to contain hundreds, even thousands of times more dark than luminous matter!). The downside here are uncertainties in the theoretical models that are used to predict the distribution of the Dark Matter in the galaxy halo, but still, these objects are the best candidates so far and are definitely worth looking at.

The tool I am using in my search for Dark Matter is MAGIC, a ground-based system of two Imaging Air Cherenkov Telescopes. MAGIC-I (operational since 2004) and MAGIC-II (operational since 2009) are located in the Canary island of La Palma, at Observatory Roque de los Muchachos (2400m). They currently represent the best instruments of their kind in the world, with largest mirror surfaces (17m), very fast repositioning mechanism and highest sensitivity, especially at lower energies (below 150 GeV).

MAGIC is well suited for the searches for Dark Matter: according to most models, WIMP mass is expected to be somewhere within the range of tens GeV – few TeV. That means that even if the clear Dark Matter signal is not detected, MAGIC data can still be used to set constrains on various theoretical models whose predictions correspond to its energy range.

Plus, it has an additional help from the space, in the form of the Fermi Space Telescope. Fermi satellite performs scans of the gamma-ray sky with great resolution and so far, during the first two years since its launch, it observed over 2000 of most energetic sources. It also made discoveries of some new, unidentified objects, out of which some represent good candidates for Dark Matter searches. However, despite it advantageous position and excellent resolution, Fermi's energy range ends at few hundred GeV, where MAGIC is the most sensitive, and has better chances for detection of very massive WIMPs.

In the past year I have been working on expanding my knowledge on the subject – by attending conferences and workshops, exchanging ideas with people from different areas of the field, learning about new theoretical predictions and training myself in use of some relevant scientific tools, like DarkSUSY and Fermi Scientific tools. I would especially like to single out my membership in the Multidark Consolider, a project financed by the Spanish Ministry of Science and Innovation, that gathers most prominent Dark Matter experts working in the Spanish institutes and Universities.

As for the more 'practical' part of my work, I am participating in few observational projects that are, or are going to be, conducted by the MAGIC Telescopes, and which include some of the currently most 'attractive' Dark Matter candidates. I am Primary Investigator of one project, while in additional two I am contributing as an analyzer.

As an additional note, not so-much related to the subject of Dark Matter, I should mention that in the past years I have also been performing the service work for the MAGIC Collaboration – work needed to support the Collaboration that in return gives me free access to the data and resources. A part from participating in the data-taking shifts, I have been in charge of development and maintenance of the MAGIC-II Data Acquisition system. Also, I am working on developing tools that will integrate MAGIC public data into the Virtual Observatory. This is an very important task, especially because, after I complete it, the scientific community will, for the first time in Virtual Observatory, have access to the Very High Energy gamma-ray astronomy data.

As for my plans for the coming period, I will continue to expand my knowledge, attend conferences and present results, while primarily focused on analyses of the data from Dark Matter sources taken by MAGIC Telescopes in the forthcoming months. Hopefully, with a bit of luck and lots of good weather, soon we will obtain some significant results.