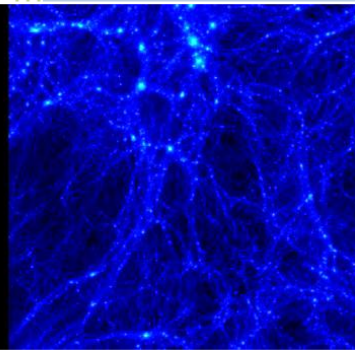


2010-2011

Activity Report

MultiDark

Multimessenger Approach
for Dark Matter Detection



MultiDark Project

Ref.: CSD2009-00064

multidark@uam.es

<http://www.multidark.es>

CONSOLIDER-Ingenio 2010 Programme
Secretary of State for Research



Consolider

January 2012

ABOUT MultiDark

Multimessenger Approach for Dark Matter Detection (MultiDark) is an excellence project in which most of the Spanish research community working in the field of dark matter is involved. The project is funded for a period of 5 years, starting December 2009, by the CONSOLIDER-Ingenio 2010 Programme of the Secretary of State for Research. 13 out of a total of 101 proposals in all branches of knowledge were selected that year.

MultiDark consists of 11 theoretical, experimental and astrophysics groups with researchers from 18 Spanish universities and research institutes. It also includes 11 senior researchers from foreign institutions. In total MultiDark involves presently about 120 researchers, more than 20 of which are directly hired by the project as postdocs, Ph.D. students, or technicians.

The main goal of MultiDark is to push forward the Spanish position in the field by creating synergies and collaborations among the participating groups, in order to contribute significantly to the worldwide efforts to identify and detect the dark matter. To this end, the most plausible particle candidates for dark matter are studied, the way these candidates are distributed in the Universe is investigated, the development of experiments aiming at their detection is supported, and, finally, the combination of LHC data with those from direct and indirect searches is analysed.

More information about the MultiDark project can be found in the web site: <http://www.multidark.es>

ABOUT the CONSOLIDER Programme

The CONSOLIDER Programme is part of the strategy INGENIO 2010 that was in force during 5 years in Spain between 2006 and 2010. It funds for a period of 5 years strategic actions based on scientific activities that promote a significant advance in the state of knowledge or establish lines of original research located in what is called the frontier of knowledge.

The CONSOLIDER term refers to teams that are recipients of such an aid, consolidated groups leading Spanish science with previous quality results, and with a sound and proven record within the international scientific community. The teams must have a critical mass of researchers, significantly higher than usual in the corresponding area of research.

The total number of CONSOLIDER projects awarded in these 5 years in all branches of knowledge was 77, out of which only 6 in the areas of Particle Physics, Astrophysics and Cosmology.



The Project

Participants

MultiDark consists of 11 theoretical, experimental and astrophysics groups with researchers from 18 Spanish universities and research institutes. It also includes 11 senior researchers from foreign institutions. In total the project involves presently about 120 researches, more than 20 of which are directly hired by the project as postdocs, Ph.D. students, or technicians. See the item [Participants](http://www.multidark.es) at <http://www.multidark.es>, for the complete list of participants.

- Groups, participant institutions and PI's

	Group PI	Institution PI
1. UAM/IFT Universidad Autónoma de Madrid (UAM) & Instituto de Física Teórica (IFT)-UAM/CSIC Instituto de Física de Cantabria (IFCA)-UC/CSIC Universidad de Granada (UGR) Universidad de Salamanca (USAL)	- C. Muñoz	- S. Heinemeyer - M. Masip - M.A. Pérez-García
2. IFIC-AHEP Instituto de Física Corpuscular (IFIC)-UV/CSIC	- J.W.F. Valle	
3. UHU Universidad de Huelva (UHU)	- M.E. Gómez	
4. UCM-Th Universidad Complutense de Madrid (UCM)	- A.L. Maroto	
5. IAA Instituto de Astrofísica de Andalucía (IAA)-CSIC Instituto de Astrofísica de Canarias (IAC)	- F. Prada	- J. Betancort-Rijo
6. UZ Universidad de Zaragoza (UZ)	- M.L. Sarsa	
7. IFAE Instituto de Física de Altas Energías (IFAE)	- A. Moralejo	
8. UCM-GAE Universidad Complutense de Madrid (UCM)	- J.A. Barrio	
9. IFIC-Exp Instituto de Física Corpuscular (IFIC)-UV/CSIC	- J.J. Hernández-Rey	
10. UPV Universidad Politécnica de Valencia (UPV)	- M. Ardid	
11. U5 Universidad de Alcalá (UAH) Universidad de Santiago de Compostela (USC) Universidad de las Islas Baleares (UIB) Universidad de Murcia (UMU) Centro Extremeño de Tecnologías Avanzadas (CETA)-Ciemat	- M.D. Rodríguez-Frías	- G. Parente - A. Sintès - J. Bussons Gordo - R. Ramos



Geographical distribution of the 18 institutions participating in MultiDark

- Members from foreign institutions

11 senior experts in dark matter research from foreign institutions, participate in MultiDark complementing the project in specific theoretical and experimental areas:

G. Bertone	- GRAPPA/University of Amsterdam, The Netherlands
M. Casolino	- INFN/Roma Tor Vergata, Italy
A. Morselli	- INFN/Roma Tor Vergata, Italy
K. Choi	- Korea Advanced Institute of Science and Technology, South Korea
J. Collar	- KICP/University of Chicago, USA
N. Fornengo	- University of Torino & INFN, Italy
S. Gottlober	- Leibniz-Institut für Astrophysik Postdam, Germany
A. Klypin	- New Mexico State University, USA
Y. Mambrini	- Laboratoire de Physique Theorique d'Orsay/Universite Paris Sud 11, France
M. Ricci	- INFN/Laboratory Nazionali di Frascati, Italy
J.D. Vergados	- University of Ioannina, Greece

Organization

To ensure a proper operation, the functional structure of the project regarding the scientific and administrative management is the following:

- The managing institution is the Universidad Autónoma de Madrid (UAM).
- The Steering Committee (SC) consists of the Coordinator, C. Muñoz, the Deputy Coordinator, J.J. Hernández-Rey, and four Area Coordinators:
 - *Analysis and Modeling* – J.W.F. Valle
 - *Astrophysical Aspects* – F. Prada
 - *Direct Detection* – M.L. Sarsa
 - *Indirect Detection* – J.J. Hernández-Rey

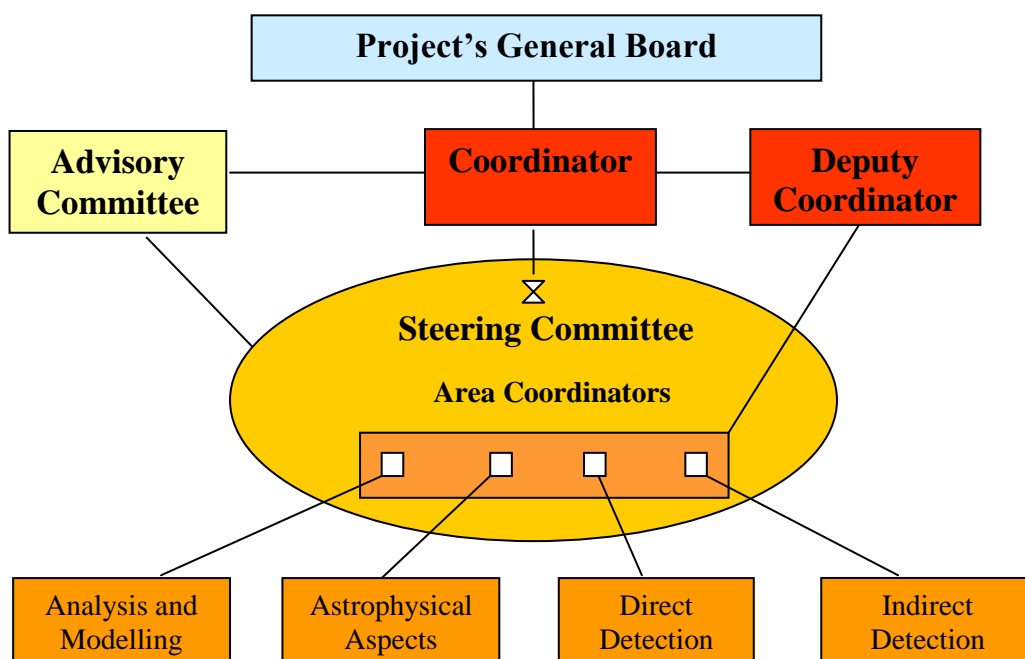
- The Project's General Board (PGB) consists of one representative of each of the 11 groups participating in the project:

UAM/IFT – C. Muñoz	IAA – F. Prada	IFIC-Exp – J.J. Hernández-Rey
IFIC-AHEP – J.W.F. Valle	UZ – M.L. Sarsa	UPV – M. Ardid
UHU – M.E. Gómez	IFAE – A. Moralejo	UAH – M.D. Rodríguez Frias
UCM-Th – A.L. Maroto	UCM-GAE – J.A. Barrio	

- The Advisory Committee (AC) is formed by highly reputed scientists:

- D.O. Caldwell, Univ. California Santa Barbara
- B. Moore, Univ. Zürich
- K. Olive, Univ. Minnesota
- G. van der Steenhoven, NIKHEF and Univ. Twente
- J. Silk, Univ. Oxford

The SC and the PGB hold numerous meetings for the management of the project and decisions making. Suggestions and support from the AC members are also received.



• The working groups (WGs) are the structures that organize and carry out the different scientific tasks within the project. Currently, after small adjustments motivated by the scientific evolution of the project, the WGs of MultiDark and the corresponding coordinators are the following:

- *Direct detection* M. Ardid, D.G. Cerdeño, J. Collar and E. García
- *Indirect detection: gamma rays and cosmic rays* J.A. Barrio, G. Bertone, N. Fornengo, R. Lineros, M.A. Sánchez-Conde
- *Indirect detection: neutrinos and high energy cosmic rays* M. Masip, G. Ros, J.D. Zornoza
- *LHC, particle physics and dark matter* M.E. Gómez, S. Heinemeyer, M. Hirsch
- *Cosmology* S. Gottlober, A.L. Maroto

Specific distribution lists such as e.g. multidark-gamma@pegaso.ific.uv.es facilitate the work within each WG. More general lists, such as e.g. multidark-info@pegaso.ific.uv.es are also useful to enable the exchange of information among all members (and collaborators) of MultiDark.

Infrastructures

MultiDark groups participate in the following collaborations related to dark matter searches:

EURECA, ROSEBUD, ANAIS
MAGIC
CTA
GAW
ANTARES, KM3NeT
AUGER
JEM-EUSO
LISA

UZ
IFAE, UCM-GAE, IAA (IAA)
IFAE, UCM-GAE, U5 (UMU)
IAA (IAA), UHU
IFIC-Exp, UPV
U5 (USC, UAH), IFIC-AHEP
U5 (UAH)
U5 (UIB)

Foreign members belong to:

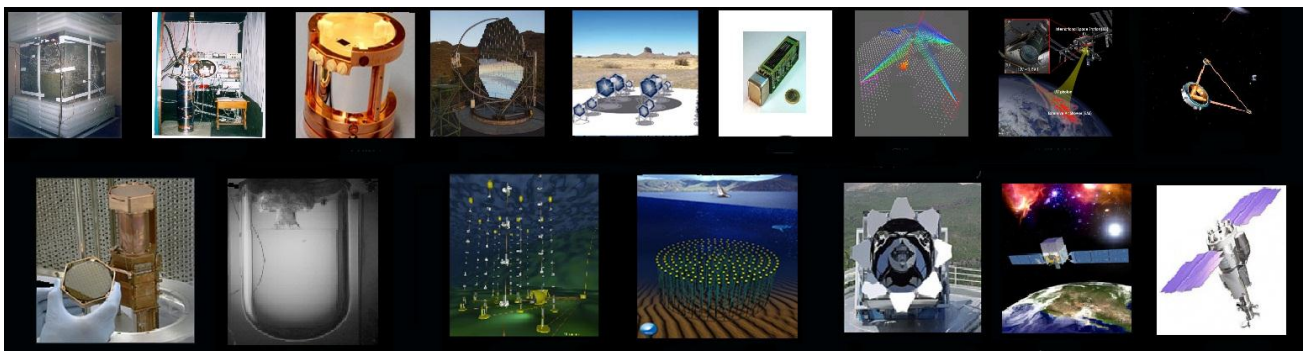
Fermi-LAT
PAMELA
JEM-EUSO
COUPP, CoGeNT

A. Morselli
M. Casolino, M. Ricci
M. Casolino, M. Ricci
J. Collar

Due to the initiatives taken by the project, currently there are MultiDark groups that belong to other important collaborations such as:

CDMS
COUPP
SDSS-III/BOSS

UAM/IFT (UAM&IFT)
UPV
IAA (IAA)



Summary of activities initiated during the first two years (2010, 2011)

International Collaborations

The most relevant initiatives undertaken in the referred period are listed below. See also the item [Collaborations](#) at <http://www.multidark.es> for more details.

- ◆ MultiDark sent in June 2010 a research proposal to the *Fermi Gamma-ray Large Area Space Telescope* (Fermi-LAT) collaboration, <http://www-glast.stanford.edu>, about “Dark matter implications of Fermi-LAT measurement of anisotropies in the gamma-ray diffuse background”. The Fermi-LAT publication board approved it in February 2011, and the research is in progress.
- ◆ MultiDark signed in July 2010 a Memorandum of Understanding (MoU) that enables its participation in the Sloan Digital Sky Survey (SDSS-III) as an Associate Member. The main area of interest is in the Baryon Oscillation Sky Survey (BOSS), <http://www.sds3.org>.
- ◆ MultiDark is taking active part in the Spanish participation in BigBOSS, <http://bigboss.lbl.gov>. A meeting was organized in September 2010 at IFT-UAM/CSIC with its responsible, Prof. D. Schlegel from LBNL (USA).
- ◆ MultiDark signed in September 2010 a MoU with the Leibniz-Astrophysical Institute Potsdam (AIP) to develop a new astrophysical database, under the name “MultiDark”. This was released on April 2011 and is available online, <http://www.multidark.org>.
- ◆ MultiDark signed in July 2011 a MoU that enables its participation as Member in the *Cold Dark Matter Search* (CDMS) collaboration for the direct detection of dark matter, <http://cdms.berkeley.edu>.
- ◆ MultiDark signed in August 2011 a MoU that enables its participation as Member in the *Chicagoland Observatory for Underground Particle Physics* (COUPP) collaboration for the direct detection of dark matter, <http://www-coupp.fnal.gov>.
- ◆ A Letter of Intent (LoI) between MultiDark and the German Network ‘Helmholtz Alliance for Astroparticle Physics (HAP)’, <http://www.hap-astroparticle.org>, is under preparation for January 2012. It will express their desire to cooperate in their respective efforts to advance Astroparticle Physics in general, and the research into Dark Matter in particular. Actually, a first proposal of cooperation is also under preparation between the Munich group (HAP) and UZ group (MultiDark), to measure CaCO_3 and WO_3 samples at Canfranc Underground Laboratory for CRESST and EURECA experiments.
- ◆ A similar Letter of Intent (LoI) between MultiDark and the Gravitation Astroparticle Physics Amsterdam Institute (GRAPPA) in Netherlands, <http://grappa.science.uva.nl>, is under preparation for April 2012.

Cosmological Database

As mentioned above, the collaboration between MultiDark and AIP allowed the development of the ‘MultiDark’ database. It is available online, <http://www.multidark.org>, and scientists around the world have free access and can use the data for their own projects. They have to include a mention to the MultiDark database in the acknowledgments of the resulting publications. Currently, the database contains the products of two state-of-the-art N-body simulations: Bolshoi and MultiDark. We provide halo/subhalo catalogs as well as, for the first time, access to raw dark matter particle and density/kinematic profiles for each halo/subhalo. Future work includes access to the merging trees and galaxy mock catalogs for the SDSS and BOSS surveys.

Equipment

MultiDark has contributed to the reinforcement of some of the experiments and collaborations where the groups of the project are participating, providing financial support to upgrade their equipment or buying new one:

- ♥ Two ultra-low radioactive background photomultipliers have been provided for the ANAIS and EURECA projects.
- ♥ Tapes have been provided for the upgraded of the MAGIC datacentre, and disks for the server analyzing GRB data.
- ♥ Contribution for the acquisition of MultiAnod Photomultipliers and a Bread Board Model of the Infrared Camera, for the balloon flight that will provide the JEM-EUSO project with background and calibration measurements.
- ♥ A disk storage system with 100 Tbytes to store the database with the results from the new MultiDark hydrodynamical simulations. The latter are available on line at <http://music.ft.uam.es>

Publications

During the years 2010 and 2011, MultiDark members have published 204 (45) articles in international journals (proceedings of international conferences), where 74 (18) of them are directly related to dark matter. The others cover connected subjects such as dark energy, cosmology, astrophysics, modified gravity, neutrino physics, beyond the standard model physics, supersymmetry, etc.

In all these 249 articles, MultiDark is mentioned in the acknowledgments. See the item [*Publications*](#) at <http://www.multidark.es>, for the list of all articles. It is worth noticing that 40 and 17 of them are articles and proceedings, respectively, written by experimental collaborations that have been reinforced by MultiDark. This is the case e.g. of MAGIC, ANTARES, BOSS, ROSEBUD, ANAIS, JEM-EUSO. Of these experimental works, 7 articles and 5 proceedings are focused on dark matter.

Workshops

The workshops organized by the project are listed below. In addition, many other workshops have been organized by MultiDark members. For more information see the item [*Workshops*](#) at <http://www.multidark.es>.

- ♣ The 1st MultiDark Consolider Workshop, January 25-27, 2010, was held at UAM, Madrid, to discuss the Annual Working Plan for 2010. There were 57 participants.
- ♣ The 2nd MultiDark Consolider Workshop, June 28-30, 2010, was held at IFCA, Santander, with 55 participants. In addition to sessions with talks and discussions involving all participants, sessions of the five WGs about specific issues were also held.
- ♣ The 3rd MultiDark Consolider Workshop, November 15-16, 2010, was held at CETA, Trujillo (Cáceres), with 48 participants, and a similar distribution of sessions as in the 2nd Workshop.
- ♣ The 4th MultiDark Consolider Workshop, April 4-6, 2011, was organized by UAM/IFT group to celebrate the first year of the project. There were 102 participants, 37 speakers (14 of them external), 2 round tables focused on “dark matter direct detection: comparing present results and looking into the future” and “dark matter indirect detection-gammas”, respectively, and a session with 10 representatives of industries about “Technological and Industrial Opportunities of MultiDark experiments-Contacts with industry”. The members of the AC, K. Olive and J. Silk, were also participating in the Workshop.

♣ The 5th MultiDark Consolider Workshop, November 3-4, 2011, was organized by UHU group at Matalascañas (Huelva), with 48 participants, and focused on sessions of the WGs.

♣ The MultiDark Workshops for 2012 have already been fixed. The first one will be in Canfranc, April 12-15, organized by the UZ group. This time the workshop will be organized jointly with the Spanish Astroparticle Network (RENATA). The second workshop will be in Barcelona, in November, organized by the IFAE group.

Meetings

In addition to the Workshops, where all members of the project are involved, small meetings among several MultiDark groups or meetings of the WGs to discuss specific research topics are also taking place:

♣ A meeting organized by the WG on direct detection between UAM/IFT and UZ groups was held in Zaragoza in January 19, 2011, to discuss several issues on the prospects of combining different targets in the direct search of dark matter.

♣ A meeting among UAM/IFT, IAA and IFIC-AHEP groups was organized in February 8, 2011, at IFT. The meeting was intended as an update of the on-going projects within MultiDark and as a brainstorming for future projects.

♣ A 'MultiDark/Fermi anisotropy meeting' at IFT is under preparation by the WG on gamma rays for February 28-March 2, 2012. The meeting is thought to be an opportunity to bring together the people involved in the collaboration between MultiDark and Fermi for the study of the dark matter implications of the Fermi-LAT measurement of the angular power spectrum of anisotropies in the gamma-ray diffuse emission.

Seminars and Talks

♣ MultiDark contributed with 8 seminars in research centres during the first week of December 2010, to the organization in Spain of the "Dark Matter Awareness Week", a worldwide effort for disseminating specific information about the dark matter problem. In addition, during these two years many seminars on dark matter were also organized by MultiDark groups in their own institutions. See the item [Seminars](#) at <http://www.multidark.es>, for the list of seminars.

♣ MultiDark members have also given many seminars and talks at international research centres and congresses. See the item [Seminars](#) at <http://www.multidark.es>, for the list of [seminars](#) and [talks](#). It is worth noticing that MultiDark was invited to participate at the '3rd Roma International Conference on Astro-particle Physics', RICAP 11, May 25-27, 2011, with several speakers, including his Coordinator who gave an overview of the MultiDark project. The Coordinator has also been invited to give another overview in the First Topical Meeting -Dark Universe- of the German Network, 'Helmholtz Alliance for Astroparticle Physics (HAP)', January 26-27, 2012, KIT Karlsruhe.

Training

Schools

♣ A Training School on *Fermi Science Tools* was organized by UAM/IFT group in April 19-21, 2010, with 18 participants, in order to learn how to handle data on dark matter from the Large Area Telescope on board of the Fermi satellite. See for more details the item [Training](#) at <http://www.multidark.es>.

♣ A new school on *Fermi Science Tools* is under preparation for fall 2012, for the new hired members of MultiDark.

Summer Students

MultiDark has implemented a Summer Student Programme to promote awareness of the dark matter problem among undergraduate and master students. They spend one or two months learning experimental techniques for dark matter searches and also theory at MultiDark groups. See for more details the item [Summer Students](#) at <http://www.multidark.es>.

♣ The 1st Call for MultiDark Summer Students was in 2010 and received 42 online applications. As a result, 7 students were selected to work within five experimental groups of the project.

♣ The 2nd Call received 35 applications by May 2011, and 10 students were selected to work within eight experimental, theoretical and astrophysics groups.

Ph.D. Students

Several Ph.D. students have also been hired, and they are contributing to the development of the project. See more details below, in Hired Personnel.

Theses

The Theses defended by students financed or co-financed by MultiDark can be found at the item [Training](#) at <http://www.multidark.es>, and are for the moment:

♣ Alex Vañó from UIB, financed by MultiDark, defended her Master Thesis in June 2011 on 'Numerical evolution of the Einstein equations in spherical symmetry: the GBSSN equations and conformal compactification'.

♣ Daniel Nieto from UCM-GAE, co-financed by MultiDark, will defend his Ph.D. Thesis in February 2012 on 'Dark matter constraints from high energy astrophysical observations'.

Sponsorship

MultiDark has implemented a sponsorship programme to support important events related to dark matter research and organized by MultiDark groups. During these two years, 10 international conferences, 1 international school, 1 national school, and 1 national outreach activity were co-financed. See the item [Sponsorship](#) at <http://www.multidark.es>, for the list of events.

Dissemination of Information

Several initiatives concerning the dissemination of information in the media and social networks have been carried out:

▽ A programme of outreach and dissemination of scientific knowledge has been implemented. An Outreach Working Group was created to facilitate these activities. *Press releases* are produced on a regular basis, and members of MultiDark participate in numerous *interviews in written and audio-visual media*. See the items [Outreach](#) and [In the media](#) at <http://www.multidark.es>, for the list of these activities.

▽ MultiDark groups in Facebook, <http://www.facebook.com/multidark>, and Twitter, <http://twitter.com/multidark>, were created during the first and second year of the project, respectively.

Hired Personnel

Presently, more than 20 researchers are hired by the project as postdocs, PhDs, or technicians. See the item [Hired Members](#) at <http://www.multidark.es> for more details.

Postdoctoral Calls

♠ The 1st International Call for MultiDark postdoctoral positions received 74 online applications by January 2010. As a result, 8 postdocs were hired.

♠ For the 2nd Call, the PGB decided to ask the WGs to set priorities in view of the experimental needs of the project. The Call received 98 online applications by December 2010. Taking into account the WG recommendations, 4 postdocs were hired, one of them co-financed to 25% by MultiDark.

♠ For the 3rd Call, in December 2011, two research lines requiring further development within the project have been advertised. The Call received 40 applications, and 2 postdocs have been hired.

Ph.D. Call

Since the project will last for 5 years, there was only one International Call for predoctoral positions. By September 2010, 70 online applications were received. As a result, 10 Ph.D. students were hired, five of them co-financed to 20, 25, 25, 10 and 85% by MultiDark, respectively.

Technicians

2 technicians have been hired. One of them was hired in 2010 for three years, and is co-financed to 55% by MultiDark. The other one was hired for the year 2011.

Co-financing

Co-financing is an additional mechanism to further develop the project while saving money. As mentioned above, MultiDark co-finances several contracts for postdocs, Ph.D. students and technicians, and also important events related to dark matter research organized by the groups. It is also worth noticing that all research travels, congresses attendance and other expenses of all the hired members are financed by the groups where they are developing their work.

SUMMARY

Activities	Achieved in 2010 & 2011
Publications in international journals	204 (74 focused on dark matter)
Publications in proceedings	45 (18 focused on dark matter)
International collaborations established	5
Databases created	1
MultiDark Consolider Workshops	5
Meetings of the WGs	2
Presentations to international congresses	93
Training Schools	1
Master Theses defended	1
Scientific activities sponsored	13
Experiments and collaborations supported with equipment	4
Media interviews and public talks	> 20
Press releases	6
<u>Hired personnel</u>	
Postdocs	12 (1 of them co-financed)
Ph.D. students	10 (5 of them co-financed)
Technicians	2 (1 of them co-financed)
Summer students	17

Degree to which project objectives have been achieved

One of the main goals of MultiDark is to reinforce the existing Spanish dark matter groups and those groups interested in dark matter research, fostering synergies among them in order to attack the problem from a multidisciplinary perspective.

In order to construct a comprehensive evaluation scheme for the project, we consider that the following four main criteria are appropriated:

1. Increase, consolidation and cooperation of groups
2. Experimental projection
3. International projection
4. Scientific outcome

Taking all the above into account, we consider that the project objectives for the first two years (2010 and 2011) have been fully achieved and even surpassed.

At the general level, the following initiatives fulfill **type 1** criterion:

◇ The WGs are indicative of the high degree of cooperation among the different research groups. This is shown below, where the MultiDark groups currently associated to each WG are shown:

- *Direct detection*
UAM/IFT (UAM&IFT, USAL), **IFIC-AHEP**, **UHU**, **UCM-Th**, **IAA** (IAA), **UPV**, **UZ**, **U5** (USC)
- *Indirect detection: gammas rays and cosmic rays*
UAM/IFT (UAM&IFT, USAL), **IFIC-AHEP**, **UHU**, **UCM-Th**, **IAA** (IAA), **UPV**, **IFIC-Exp**, **IFAE**, **UCM-GAE**, **U5** (UAH)
- *Indirect detection: neutrinos and high energy cosmic rays*
UAM/IFT (UAM&IFT, UGR), **IFIC-AHEP**, **UHU**, **UCM-Th**, **IAA** (IAA), **UPV**, **IFIC-Exp**, **U5** (UAH, UIB, UMU, USC)
- *LHC, particle physics and dark matter*
UAM/IFT (UAM&IFT, IFCA, UGR, USAL), **IFIC-AHEP**, **UHU**, **UCM-Th**, **IAA** (IAA), **UPV**
- *Cosmology*
UAM/IFT (UAM&IFT), **IFIC-AHEP**, **UHU**, **UCM-Th**, **IAA** (IAA, IAC), **UPV**, **U5** (UIB)

◇ Of the total 74 articles published in international journals, and focused on dark matter (see Table above), in 11 of them at least 2 MultiDark groups are collaborating. This is shown in the figure below, where red arrows indicate groups with publications in common. Black arrows indicate collaborations in progress. In particular, **UZ** and **UAM/IFT** (UAM&IFT) on direct detection, **U5** (CETA) and **UAM/IFT** (UAM&IFT) on GPUs applied to cosmological databases, **UHU** and **UAM/IFT** (USAL, IFCA) on indirect detection (USAL) and on LHC and dark matter (IFCA). It is worth mentioning that the latter collaboration between UHU and IFCA institutions includes the training in common of a Ph.D. student hired by MultiDark.

◇ The MultiDark Consolider Workshops and Meetings organized by different groups, where contributed talks and discussions involving all participants were held, in addition to WG sessions about specific issues. It is worth noticing here that, as a consequence of the session “Contacts with industry” during the 4th Workshop, the IFIC-Exp group was granted with an INNFACTO project in collaboration with the company INDUSTA.

◇ The training of undergraduate and master students through the Summer Student Programme established by MultiDark, will contribute to increase the size of the groups in the future.



Collaborations among MultiDark groups. As discussed in the text, red arrows indicate groups with publications in common, and black arrows collaborations in progress.

- ◊ The Training School on Fermi Science Tools that hosted participants from all MultiDark groups, including many young researchers.
- ◊ The opening of several Calls with the result that a large number of postdocs, Ph.D. students and technicians were hired, contributing to increase and consolidate all the existing 11 groups. We show below explicitly the 13 institutions that have received postdocs and/or Ph.D.s and/or technicians:

UAM&IFT	IFIC-AHEP	UCM-Th	UZ	UCM-GAE	UAH	UPV
IFCA	UHU	IAA	IFAE	IFIC-Exp	UIB	

These last two initiatives also contribute to fulfill **type 2** criterion:

- ◊ As an example of the benefits of the Fermi School, the IFIC-Exp group has already been able to contribute in a relevant way to two ANTARES publications based on the use of the Fermi data.
- ◊ Concerning the Calls, several of the postdocs hired contribute to increase the participation of the MultiDark groups in dark matter research within several experimental collaborations. This is e.g. the case of the IFIC-Exp group, which had no previous experience on dark matter research and now has two MultiDark postdocs working within the dark matter group of the ANTARES neutrino telescope. These two postdocs have a leading role in the analysis that will yield the first results on dark matter using the ANTARES data. We want to stress how cost-effective this is, since the investment previously made in this experiment in terms of money and human resources coming from other funded projects, is being exploited to its maximum by means of the relatively modest additional contribution provided by MultiDark. It is also the case of the UPV group, without previous

experience on dark matter either and that now has one MultiDark postdoc collaborating within the COUPP underground experiment. As another example, the IFAE and UCM-GAE groups have been reinforced with two predocs to contribute to dark matter analyses related to MAGIC and CTA gamma-ray telescopes.

Similarly, theoretical groups have strengthened their research on dark matter modelling. For example, IFIC-AHEP is now much more engaged in dark matter research tasks, such as the characterization of various dark matter candidates and their detection prospects, than previously, with one PhD Thesis fully dedicated to the topic, co-directed by one of the postdocs hired by MultiDark.

This has greatly increased the impact of these groups in the area of dark matter search, substantially enhancing their contributions to this topic in a highly cost-effective way.

Type 3 criterion, but also **type 2** criterion, are fulfilled by the **international collaborations** established by MultiDark:

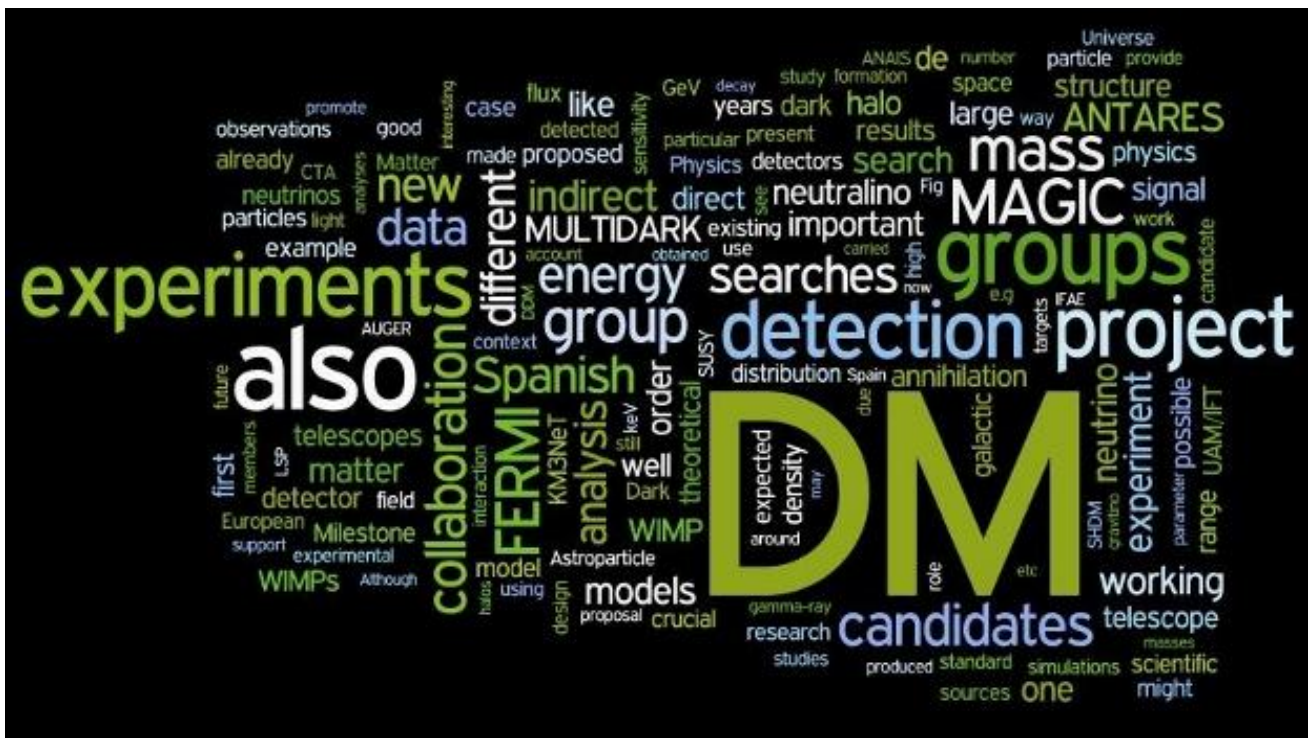
◇ Let us remark that the collaborations with Fermi-LAT, BOSS, AIP, CDMS and COUPP, would have been impossible without the existence of the MultiDark project. A special mention deserves the case of the UPV group, which had no previous experience on dark matter research, as mentioned above, but thanks to its expertise on acoustic detection techniques has become part of the COUPP underground experiment led by the MultiDark foreign member J. Collar. Actually, this collaboration also fulfills **type1** criterion since arose from the cooperation between MultiDark members. This is also the case of the collaboration with the AIP, since the scientist in charge, S. Gottlober, is a foreign member of MultiDark.

Another mention is deserved by the UAM/IFT group, which had no previous experimental experience but has become a Member of the CDMS collaboration, and is expected to contribute to the development of Monte Carlo background estimations, data analysis, and interpretation of superCDMS data together with theoretical developments in the field.

In the case of the IAA group, its existing experience and activities in the field of cosmology and dark matter research has been strengthen thanks to the *Fermi*-MultiDark agreement on anisotropies and making possible its participation in BOSS.

Finally, as can be deduced from the data in the Table above, the degree of achievement of **type 4** criterion during the first two years has been very high.

Summarizing, we can proudly say that, due to all scientific initiatives and activities mentioned above, MultiDark has become already a well recognized project at the international level.



MultiDark

Multimessenger Approach for Dark Matter Detection

