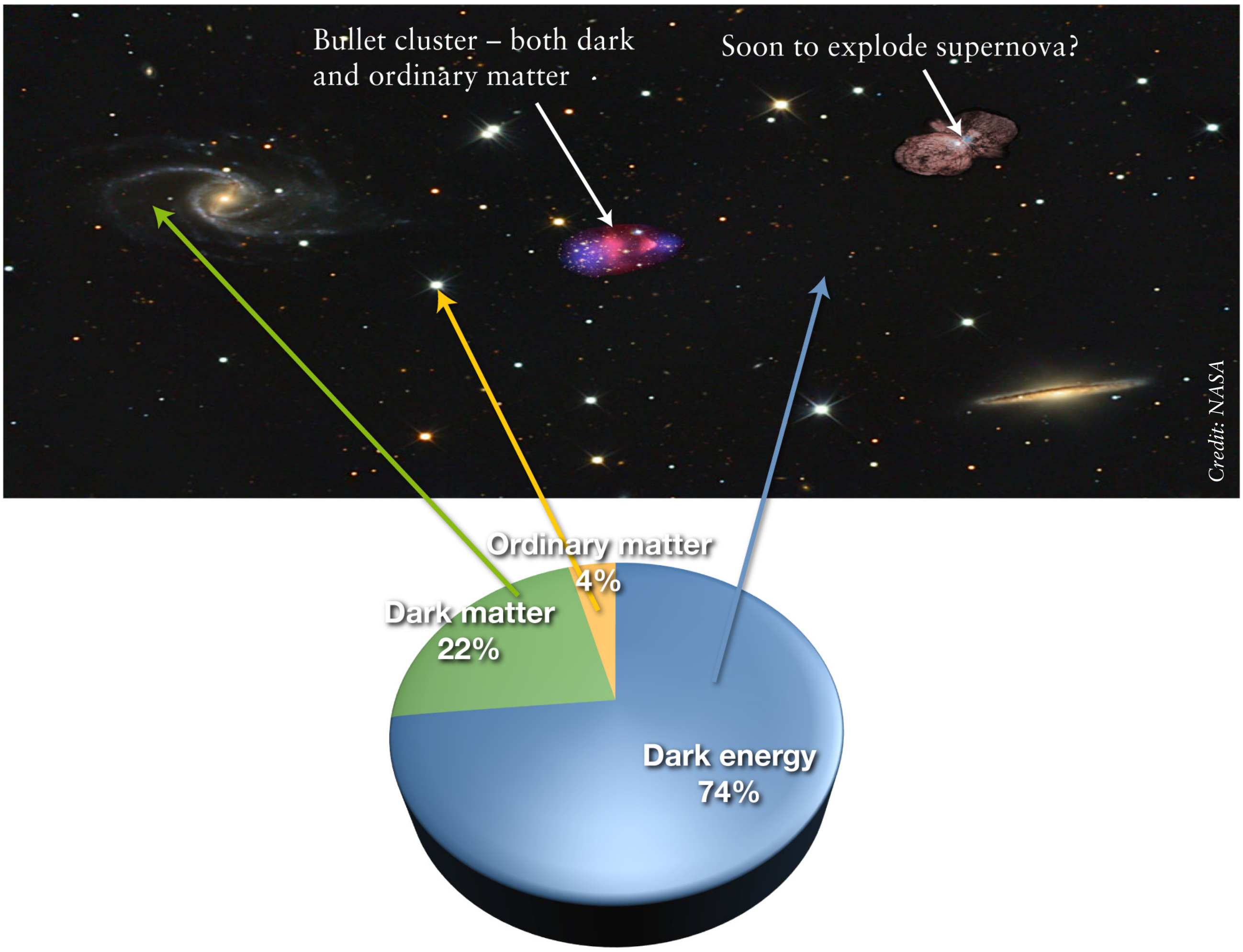
The CosmoParticle Collaboration (CPC)



Most of the Universe is made up of invisible matter, Dark Matter and Dark Energy. The Dark side of the Universe can be probed by its effects on ordinary material. This composite picture summarizes some of the astrophysical objects the CosmoParticle Collaboration (CPC) will study.

Dark matter is most likely made up of an unknown type of particle, and the properties of such particles will be explored by our particle physics group. This will enable us to interpret the coming results from a variety of experiments used by the collaboration – both for gamma-rays, antimatter and neutrinos. In the most successful case, the dark matter problem would be finally solved.

The other big question, the dark energy component of the Universe, will be addressed using gravitational lensing as well as supernovae as standard candles, to determine its properties. The detailed physics of supernovae, and of other compact objects like black holes and the objects causing gamma-ray bursts, is largely unknown and will be investigated by the CPC.

All these pieces of information gathered by the CPC, and elsewhere, will be synthesized in joint work between theorists and experimentalists/observers, who will push the limit of knowledge further, attempting to answer the questions: What is the dark matter? What is dark energy? What physics lies behind the most energetic processes in the Universe?

To solve these questions we propose to form the CosmoParticle Collaboration, CPC. This collaboration is made up of the following teams:

– the High-Energy Astrophysics group of the Department of Astronomy, Stockholm University,
– the Elementary Particle Physics group of the Department of Physics, Stockholm University,
– the IceCube group of the Department of Physics, Stockholm University,
– the Cosmology, Particle Astrophysics and String Theory (CoPS) group of the Department of Physics, Stockholm University, and
– the Astroparticle Physics group at the Royal Institute of Technology (KTH), Stockholm.

These groups are currently focusing separately on some of the questions mentioned and the main idea of this proposal is to gather our strengths and add resources, in particular in connecting current lines of research and forming new areas designed to solve these fundamental questions in our understanding of the Universe. We will therefore focus on three central themes:

Themes

The proposed research is focused on three central themes in modern astrophysics, elementary particle physics and cosmology:

A. Identifying theoretically, and probing observationally, measurable quantities of **dark energy** which can clarify the nature of this mysterious component of the energy density of the Universe.

B. Searching experimentally for particle candidates of **dark matter**, which naturally means going beyond the standard model of particle physics, and if found, determining their properties and elucidating the underlying theoretical framework.

C. Investigating the physics of extreme objects, such as **supernovae, neutron stars, and black holes.**

In the following pages, we will go through in more detail what our current understanding of the subject is, who we are and how we plan to pursue our main themes.

Overview of present and planned activities

Introduction - A New Era in Physics and Astronomy

Cosmology - the understanding of our Universe and the physical laws that govern the world – is at the moment going through what might be called a “golden age”. The last decade has seen enormous progress in the field, which has been transformed from a science of speculation and half-baked ideas to a discipline where precision studies and detailed predictions are possible. The pace of deployment of new instruments giving new insights will be even more rapid during the coming decade. As a result, our understanding of the Universe, which has already improved dramatically, will become even more complete and it will become possible to address, and perhaps answer, difficult, challenging and fundamental questions reaching deep into theories of elementary particles.
Foremost of these questions are the enigmatic problems of the identity of the dark matter in the Universe, and the mechanisms behind the so-called dark energy – the mysterious repulsive force of gravity which makes the present Universe expand at an ever faster rate. The discovery of the accelerating expansion, i.e., the presence of dark energy, involved two teams, where one of the signers of the present application (A. Goobar) played a pioneering role in one – The Supernova Cosmology Project (SCP) - and one other (J. Sollerman) was a member of the competing team - The High Redshift Supernova Search Team.

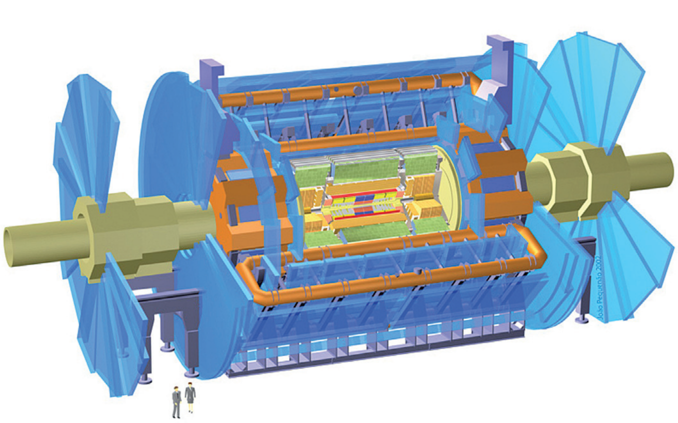
There is even stronger evidence of a large fraction of the energy density of the Universe being in the form of some type of invisible, or dark, matter such as heavy electrically neutral but yet undiscovered massive particles. Thus only about 4 % of the energy content of the Universe is in the form of matter as we know it (protons, neutrons and electrons, which compose all chemical elements), while 96 % is in forms which cannot be explained today.

Simultaneously, the Standard Model of elementary particle physics has been tested with ever increasing precision in a truly enormous number of measurements. Data collected at the CERN electron-positron collider LEP have confirmed the electromagnetic and so-called weak interaction parts of the theory, while tests of the strong interaction – acting between quarks and gluons – at LEP and the Fermilab collider outside Chicago also show complete agreement between data and theory. A decade ago the top quark was discovered at Fermilab. With the direct detection in the year 2000 of the tau neutrino, this completes the set of predicted matter particles. There is, however, a strong consensus that the Standard Model cannot be a complete description. One reason for this is that neutrinos, previously thought by many to be massless, have been demonstrated to have a mass, a property which is not part of the Standard Model. In addition it is known that the Standard Model is internally mathematically inconsistent when applied to phenomena at high energies. One way to resolve these problems is to introduce supersymmetry, a symmetry between particles of different spin in which each Standard Model particle has a supersymmetric partner. This theory is extremely appealing in many ways: for instance, inclusion of supersymmetry leads to unification of the fundamental coupling constants of the strong, the weak and the electromagnetic interactions at one specific energy, something which points to a grand unifica-

Prizes and other awards.
The discovery of the accelerating expansion of the Universe, where A. Goobar was one of the pioneers, is recognized as being one of the major scientific discoveries of recent years, dubbed the “Breakthrough of the year” by Science magazine at the time of the discovery in 1998, and again in 2003 (combined with other, supporting, discoveries). In 2003, J. Sollerman was also part of this recognition as one of the members of the other supernova collaboration. A finding concerning short gamma-ray bursts (J. Sollerman) was listed as one of the major breakthroughs by Science 2005. Earlier this year (2007) Goobar was among the recipients of the prestigious Gruber prize for the discovery of the accelerating Universe. He has also been awarded the Gustafsson prize by the Royal Swedish Academy of Sciences (KVA). Other findings of members of the CosmoParticle Collaboration have resulted in the Edlund Prize of the KVA (J. Sollerman, G. Östlin, A. Goobar), selection as “Excellent researcher” by the VR (L. Bergström), election as members of the KVA (C. Fransson, L. Bergström, P.O. Hulth, B. Åsman). Several younger members of the collaboration are employed on prestigious positions such as researcher of the VR (J. Edsjö, C. Clement, G. Östlin), the KVA (J. Sollerman, D. Milstead) and the Swedish National Space Board (F. Ryde).

tion of these forces. One of the most attractive features is that supersymmetry, the most appealing way to go beyond the Standard Model, also provides a most natural candidate for dark matter. If this particle is observed, it would also likely solve the cosmological problem of dark matter.

In fact, it is an amazing property (by specialists in the field called a "miracle") that the weakly interacting massive particle (WIMP) dark matter candidates in these theories, with their number density computed from first principles, using the thermal history of the early Universe, rather precisely match what is needed to explain dark matter, if their mass is in the range up to a few hundred GeV. If that is indeed the case, the next generation of particle physics experiments such as ATLAS at CERN's Large Hadron Collider (LHC) stands an excellent chance of producing such particles and determine their properties. Even if supersymmetry would turn out not to be realized at LHC, ATLAS will investigate a number of other proposed WIMP candidates. Some of these would, if discovered, lead to fundamental new knowledge about the nature of space and time, for instance about the number of extra space dimensions in the Universe, a remarkable possibility that was originally hypothesized by one of the first professors of theoretical physics at Stockholm University, Oskar Klein (and independently by Theodor Kaluza of Germany).

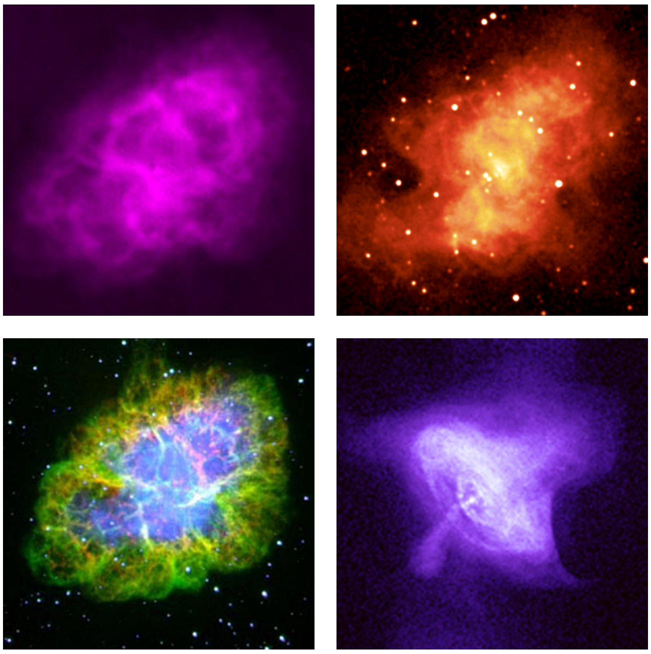


Is this where dark matter will first be identified? The ATLAS multipurpose detector at the CERN Large Hadron Collider, which will start taking data in mid-2008. Credit: ATLAS, CERN

Much of the recent fast development in cosmology is a result of the increased understanding of different astrophysical objects and phenomena. The discovery of dark energy was possible since one type of supernova is a light source of universal strength, being the result of the explosion of a nearly standardized white dwarf with a specific mass, the Chandrasekhar mass. Similarly, the most important probes of dark matter are the dynamics of galaxies and the evolution of structure in the Universe. A detailed understanding of these topics is therefore crucial for predicting accurate detection rates for dark matter searches, and controlling systematic errors, important for studies of dark energy, as well as for developing new methods for observational cosmology.

Apart from being useful as cosmological probes, objects like supernovae, gamma-ray bursts and black holes are of special interest themselves and involve some of the most extreme physical processes we know, with particles accelerated to even higher energy than in terrestrial accelerators. While supernovae are responsible for the formation of most of the chemical elements, one of the two types of supernovae is also the site of the formation of black holes and neutron stars. Among the most exciting developments in high energy astrophysics during the last five years has been the confirmation, involving one of the applicants (Sollerman), that one of the two classes of gamma-ray bursts is directly connected to the collapse of massive stars in a supernova explosion. The other class of gamma-rays bursts is still enigmatic, although also in this case there has been much progress recently, thanks to the combination of new satellites and the largest ground based telescopes. The main candidate is the collision of two neutron stars, forming a black hole. These events are also one of the most promising sources of gravitational waves. The exact nature of the formation of the black hole or possibly neutron star is, however, still far from clear. Here, numerical models and observations, using the largest ground based telescopes as well as satellites are used hand in hand. The next generation of instruments will provide new, unique opportunities in this area, as will the gamma-ray burst capabilities of the gamma-ray satellite GLAST, and possibly the neutrino detector at the South Pole, IceCube, which then would show unambiguously that also hadrons are accelerated in these events and not just electrons as in some models. The PoGOLite balloon experiment stands to open a new window on pulsars and black holes through the study of the polarization of the emitted gamma-rays. The CPC plays a leading role in this experiment thanks to a close collaboration between the KTH and SU astrophysics groups. This is clearly an example of the vital importance of the AlbaNova University Centre environment.

The origin of the highest energy cosmic rays is unknown, and may involve new physics beyond the standard model. Neutrinos, searched for in IceCube, are extremely penetrating and undeflected by magnetic fields. They therefore offer a completely new way of gathering information about the Universe, but their detection requires a very large detector volume. Neutrinos are expected to be produced together with high-energy gamma-rays at cosmic ray acceleration sites. Neutrinos may also be produced in the decay or annihilation of dark matter candidates. These investigations complement the gamma-ray, and antimatter, dark matter searches also performed by the CPC. A positive astrophysical neutrino signal would mark a true breakthrough that could shed light on the most energetic processes of the Universe and its basic constituents.

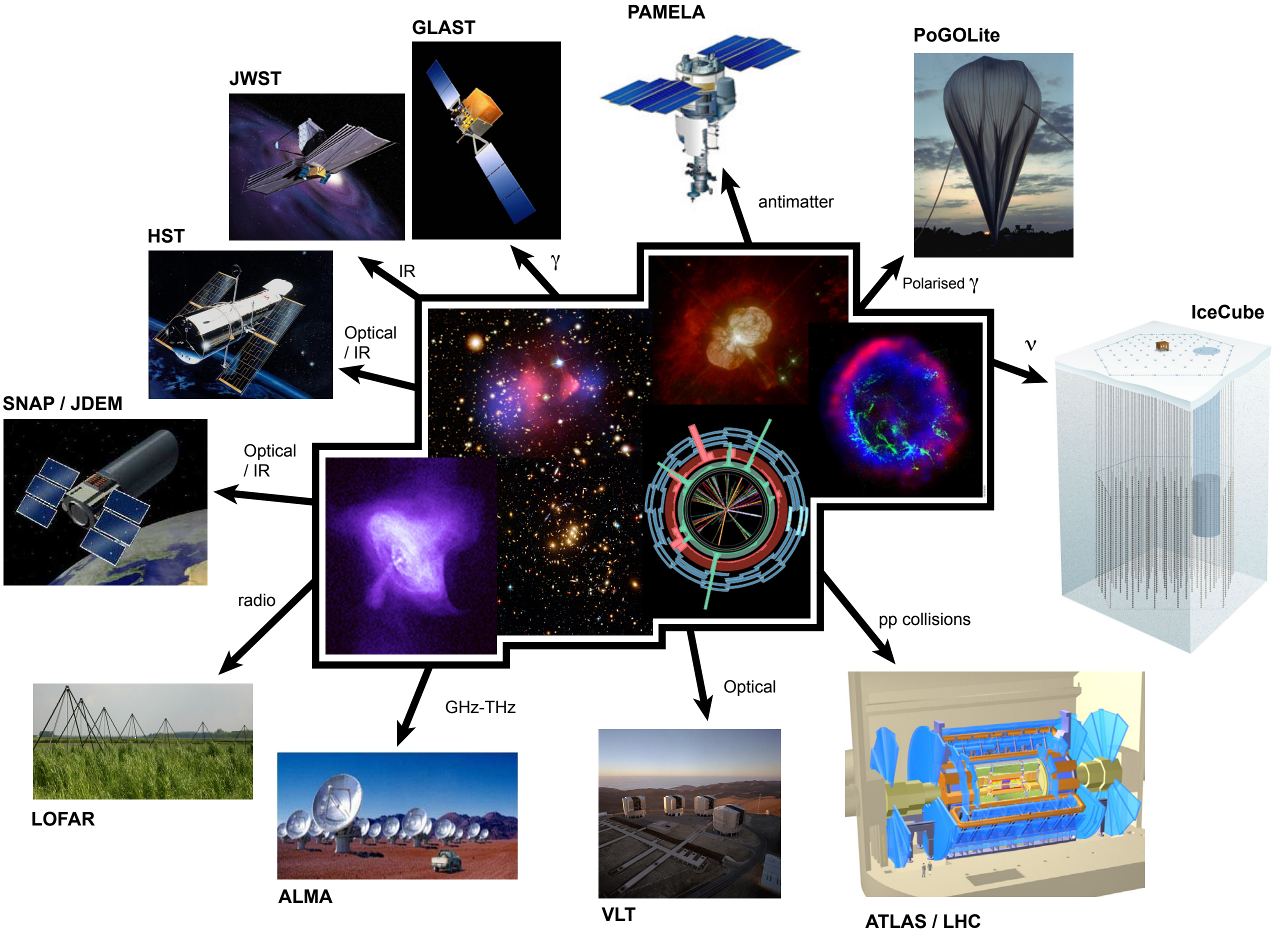


Images, in different wavelength bands, of the Crab nebula, a remnant of a supernova that was seen on the sky by Chinese and Arab astronomers in 1054. This picture clearly shows the virtue of studying the sky with different instruments, and combining the knowledge thus obtained (the observations are in radio, infrared, optical and x-ray). Credit: NASA

An interesting question, which the CosmoParticle Collaboration is eminently suited to answer, concerns the influence of particle dark matter on the first generation of stars and the first supermassive black holes. On large scales, the distribution of galaxies and clustering can be studied by e.g., gravitational lensing. Some dark matter detection experiments are very sensitive to the occurrence of inhomogeneities in the dark matter distribution. Eminent expertise in this field is present at the NORDITA institute, which has recently moved from Copenhagen to Stockholm, where it is strongly supported both by Stockholm University and the Royal Institute of Technology. We will establish strong connections to this newcomer in the already strong AlbaNova environment. In connection to galaxy formation, the possibility to probe the epoch of the first star formation period in the Universe, known as the re-ionization, is rapidly becoming one of the most interesting areas, involving cosmic microwave background studies, optical infrared and radio wave studies. Members of the CPC are active in all these areas.

The improved understanding of our Universe at its largest and smallest scales described above has driven a further convergence of studies at these two scales, and this is the main idea behind this proposal, the CosmoParticle Collaboration. We will most likely not be able to make progress in our understanding of the Universe without remedying the difficulties with the Standard Model of particle physics. Similarly any effort to move beyond the Standard Model of particle physics will have implications for the cosmological model which need to be understood and interpreted, filling in the crucial missing components of dark matter and dark energy. In theoretical physics, a new generation of scientists who have the training to encompass both these fields, will emerge. We notice that the competition for the best of these young scientists is currently very high, in Europe and elsewhere. With the CPC proposal, we believe that we will establish an environment which can match the best elsewhere.

Finally, we point out that our main themes are all among the highest priority areas of the Science Vision for the ASTRONET roadmap at the initiative of the European research councils (see in particular Chapters 2 and 3 at http://www.astronet-eu.org/).



The figure shows an overview of the various telescopes, satellites and experiments that will be used in the projects proposed in this application (see the frame on the next page and the table of acronyms at the end of this appendix for an explanaition of them). Credit: NASA, ESO, ESA, CERN, IceCube.

Summary of the projects with CPC participation

In the coming ten years the CPC plans to be involved in a number of important experiments coming on-line. These connect particle physics, astrophysics and cosmology, and are likely to contribute to solving the questions of dark energy, dark matter and the nature of compact objects. All these projects are highly international, with CPC contributions being substantial. We expect to continue to be successful in the application for investment grants, from VR and large foundations (notably the Wallenberg Foundation). This application therefore entirely concerns the manpower needed to change the current diverse, but separately quite successful, projects into a more focused programme with high international visibility. We will in particular recruit, internationally, young people with a PhD, i.e. postdocs and junior researchers ('forskarassistent'), to make the age structure more optimal, and give challenging and career-promoting tasks to this young generation of promising physicists. For convenience, on next page we summarize the main projects that CPC participates in, or plans to participate in.

The CPC also contains strong theory groups, which have built a strong international platform specializing in models for dark matter, in particular supersymmetric ones (which for example has given rise to the ambitious, internationally much used DarkSUSY simulation package), models for dark energy, string models for cosmology, detailed models for supernovae and other compact objects, and simulations of the earliest structure formation in the Universe. The theory groups continuously give in-house theory support to the various experiments.

Research Groups and Past Achievements

The CoPS group, Stockholm University

The group of Cosmology, Particle Astrophysics and Strings (CoPS) at the Physics Department ("Fysikum") of Stockholm University was formed three years ago by members of the experimental particle physics group involved in supernova cosmology under the leadership of A. Goobar joining with members from the field and particle theory group led by L. Bergström, with activities in astroparticle physics and cosmology-oriented string theory. Members from both groups had in fact been collaborating since several years, with several joint publications and the university textbook used in many countries, "Cosmology and Particle Astrophysics" (Wiley/Praxis for the first edition, Springer/Praxis for the second, student-priced edition) emerging as a collaboration between Bergström and Goobar. The interest in the activities of the group is very high among physics students, and the group is continuously increasing in size, at present numbering some 20 people, of which 10 are graduate students. It is the core of Fysikum's involvement in the AlbaNova High-Energy Astrophysics and Cosmology (HEAC) VR-funded excellence centre.

Main experiments with CPC involvment

Below is a summary of the main projects which members of CPC are currently involved in or are planning to join.

ALMA and LOFAR, two upcoming large radio telescope arrays which will be able to study processes in the earliest epochs of the Universe. Numerical simulations of these most intriguing processes, which gave birth to galaxies and further structures, are being done by members of the CPC.

ATLAS, a huge experiment at the CERN LHC which is expected to commence data taking in June 2008. This project will give unique data at the highest energies and could, if their mass is not too high, actually produce the dark matter particles. Light may also be shed on the nature of dark energy. The group in CPC has important functions in the collaboration.

GLAST, a gamma-ray space telescope, to be launched in 2008. GLAST will open a whole new energy range for the search for predicted signals from current models of dark matter. It will also give novel data on gamma-ray bursts at higher energies than previous detectors. The working group on Dark Matter and New Physics is currently led from Stockholm and people in CPC were responsible for the electromagnetic calorimeter.

HST (Hubble Space Telescope), the enormously successful telescope which will soon get another servicing mission to prolong its life by several years. Members of CPC have been very successful in obtaining observation time on this superb instrument. In 2013, it will be followed by the even more spectacular next space telescope (JWST) mission, where astronomers of the CPC are involved.

IceCube, a very large (cubic kilometer) international neutrino detector at the South Pole in which the CPC group played a pioneering role. IceCube will be completed in 2011 and will search for traces of dark matter particles gravitationally trapped in the interior of the Sun. It will also answer questions related to the highest energy cosmic rays in the Universe – whose birthplace is still not known.

PAMELA, a satellite experiment that will measure antimatter to unprecedented precision, where one possible source is positrons or antiprotons from dark matter annihilations. PAMELA was launched in 2006, and the first data will very soon be presented. The KTH group, now in CPC, designed and produced the PAMELA anticoincidence systems.

PoGOLite, a balloon experiment proposed to measure for the first time the polarization of soft gamma-rays. Polarized gamma-ray emission is expected from a wide variety of astrophysical sources including pulsars, accreting black-holes or neutron stars, and active galaxies. The team in CPC has been making major contributions to the instrument design and production.

SNAP (SuperNova/Acceleration Probe), a satellite aiming at probing the nature of dark energy and dark matter through observations of type Ia supernovae and gravitational lensing. In the recent report by the American National Academy of Sciences on "Beyond Einstein" projects, the large project first in line for funding is the dark energy satellite mission JDEM. One leading contender for this mission is SNAP, where the CPC team is strongly involved.

Activities of the group are centered on many aspects of observational and theoretical supernova cosmology, gravitational lensing, determination of cosmological parameters, models for dark matter, and string cosmology. The group is playing an important international role in supernova cosmology. The group is also well known for supersymmetric models for dark matter. J. Edsjö is the main responsible for the widely used DarkSUSY computer package. The group is the key organizer of one of the main conferences, “Identification of Dark Matter”, in Stockholm in 2008. Theory connected to the dark matter search possibilities of the GLAST gamma-ray satellite is presently emphasized, and members of the group contribute to the GLAST working group for dark matter and new physics. The potential for the IceCube neutrino telescope has also been theoretically investigated by the group, as has the potential of the antimatter detection satellite PAMELA. In fact, the theory group in CoPS is one of the leading in the field of predicting indirect detection rates of various dark matter particle candidates. The Swedish investment in the GLAST instrument (for the electromagnetic calorimeter, funded by a 20 MSEK Wallenberg Foundation grant) was administered by Bergström. Recently, a junior researcher (J. Conrad) has taken main responsibilities in GLAST and has entered the GLAST collaboration as a full member. The group has recently published new results on possible striking gamma-ray signatures of dark matter.

The DarkSUSY code is a cornerstone in connecting theoretical dark matter calculations with experiments and observations.

The High-Energy Astrophysics Group, Department of Astronomy, Stockholm University

The activity of the high energy astrophysics group at the Department of Astronomy can be divided into two broad categories. One includes high energy astrophysics, involving supernovae, neutron stars and black holes, while the other includes processes related to galaxy formation. The group consists of 11 senior researchers and 15 graduate students, of which about half are female students. The group has extensive international collaborations, has recently been part of two EU networks on Type Ia supernovae and gamma-ray bursts, and is part of the VR financed excellent environment HEAC.

The activity on supernovae focuses on observations and modeling of supernova explosions and their interaction with the circumstellar environment, as well as related aspects connected to gamma-ray bursts and neutron stars There is also a strong overlap with the use of Type Ia supernovae for cosmology, where J. Sollerman is member of the ESSENCE team (Equation of State: SupErNova trace Cosmic Expansion). The physics and nature of gamma-ray bursts has been a major activity, where the identification of the long gamma-ray bursts with supernovae (J. Sollerman) is one of the highlights. Another important aspect is the radiation mechanisms of the highly relativistic ejecta. More recently also the short gamma-ray bursts have been identified with optical counterparts, although no underlying supernovae were found. Complementary to these activities, work is going on relating theoretical and observational models for compact objects, like black hole accretion and pulsars.

The activities concerning galaxy formation have been focused on observations of local counterparts to distant low mass galaxies. These are extremely difficult to study at large distances, but certain local dwarf galaxies share many of the properties of their high redshift cousins. Another interesting aspect is the observations of the emission in the Lyman-alpha line (the transition between the ground state and the first excited state) and continuum of Hydrogen from these galaxies. This is highly relevant for understanding the re-ionization epoch in connection to the formation of the first stars, and modeling of this epoch is performed by G. Mellema. Members of the group collaborate with CoPS on the effects of gravitational lensing of supernovae, and this is one area where a more concerted effort is planned through this proposal.

The Particle Astrophysics Group, Royal Institute of Technology (KTH)

The astroparticle physics group at the KTH Department of Physics conducts research on the high-energy Universe through the experimental study of X- and gamma-radiation and cosmic rays. The fundamental scientific questions addressed concern particle acceleration and radiation processes in cosmic plasmas, in the galaxy and around compact objects, and the understanding of dark matter and gamma-ray bursts. The focus is on satellite- and balloon-borne instrumentation. There is a broad span of activity, from design to construction and from operations to scientific analysis and interpretation. The group has actively participated in experiments measuring different aspects of the cosmic radiation for more than a decade. It consists of 2 senior researchers, 1 emeritus, and presently hosts 6 PhD students (3 female). A postdoc position will be filled shortly. The group is one of the founding members of HEAC, the VR financed excellent research centre. The cosmic ray activity focuses on the international PAMELA satellite experiment which was launched in 2006. The primary goal is a high precision study of the energy spectrum of antiparticles in the tens of MeV to 100 GeV range. The KTH group designed and produced the antimatter satellite PAMELA's anticoincidence systems. The group's gamma-ray activity concerns the international GLAST satellite and PoGOLite balloon experiment. The group provided CsI(Tl) crystals for the GLAST electromagnetic calorimeter. The analysis activity focuses on studies of gamma-ray bursts in the keV to GeV range. PoGOLite is proposed to make pioneering measurements of the polarization of soft gamma-rays. The group leads the Swedish Consortium (KTH and Astronomy at SU) which works together with groups in USA, Japan and France. The group's responsibility is the BGO anticoincidence shield, and parts of the attitude control system. The PoGOLite engineering model is being built at AlbaNova, with a first flight proposed for 2009–10. We participate in ESA's Cosmic Vision call for future satellite experiments through the GRIPS (GRB Investigations with Polarimetry and Spectroscopy) proposal to study GRBs in the energy range 200 keV–50 MeV, including polarimetry in the range 200–1000 keV. Using the special competence of the group in scintillating materials, our initial contribution concerns a novel $LaBr_3$ calorimeter with capability of measuring polarization.

The IceCube Group, Stockholm University

The predecessor of IceCube, the AMANDA neutrino telescope at the South Pole, has dominated the field of high energy neutrino astronomy for the last fifteen years, and has now been greatly surpassed by the fraction of the IceCube array which is already deployed and running.

The collaboration has grown correspondingly, from the initial two dozen people to more than 200 physicists from four continents. The AMANDA/IceCube group at Stockholm University was formed as the new field of astroparticle physics emerged, and was among the few to initiate the AMANDA project, in the beginning of the 1990s. The Stockholm group has retained a central position in the collaboration. P. O. Hulth served as the first elected IceCube spokesperson for four years and is now convening the IceCube searches for dark matter, K. Hultqvist is responsible for the IceCube simulation effort and a member of the publication committee and Ch. Walck has played an important role in statistical analysis, in particular concerning ice properties. S.-H. Seo, a new junior researcher in the group, has been an IceCube postdoc at Penn State, and she has specialized in trigger issues and tau neutrino topologies. In addition to the four people mentioned above the group currently has four graduate students. There is a close collaboration with the IceCube group at Uppsala University.

Several important AMANDA/IceCube analyses were carried out by Stockholm students. Analysis has focused on detection of neutrinos from dark matter annihilations in the Sun or Earth at the lower end of the accessible energy range, and on ultra-high energy neutrinos at the opposite end.

The hardware involvement includes the amplifier system for AMANDA which was designed, built, and maintained by the Stockholm group. While the AMANDA amplifiers are placed on the surface, the IceCube optical modules (almost 5000 in total) include amplifiers and digitalization electronics and communicate with the surface via TCP/IP. In Stockholm, 840 such modules are being built. In total, the Wallenberg foundation and VR have granted 52 MSEK for investments in AMANDA and IceCube.

The Elementary Particle Physics Group, Stockholm University

The Elementary Particle Physics group is the largest group in experimental particle physics in Sweden, in spite of several previous members of the group having left the group and initiated successful careers in neighbouring disciplines like astroparticle physics and cosmology. The proposed CPC programme brings these lines of research more closely together again. The group consists of seven tenured physicists, of which two professors are female, and includes one KVA fellow and one VR researcher. It has one junior researcher, one post-doc and three graduate students (two of which are female). The recruitment of two more graduate students is in progress.

For over a decade the group has been engaged in the design and construction of the ATLAS detector, one of the two large all-purpose detectors at CERN's Large Hadron Collider (LHC). Hardware contributions are electronics for the hadron calorimeter and parts of the first level calorimeter trigger.

The analysis effort is focused on beyond the Standard Model physics, with special emphasis on supersymmetry. The group has long experience of the search for supersymmetric particles at collider experiments. S. Hellman coordinated the search for supersymmetry in the upgraded UA2 experiment at CERN, and served as the first convener for SUSY studies in the ATLAS collaboration where he, together with G. Polesello, pioneered searches based on full chains of cascade decays. During the decade-long engagement in the DELPHI experiment at the CERN electron-positron collider one of the main areas of activity was the search for supersymmetry.

Members of the group initiated the Swedish DZero consortium, led by B. Åsman, which united the Swedish high energy physics groups in a consortium which participates in the DZero experiment at the Fermilab Tevatron. Members of the SU group participated in the determination of the production cross-section and characteristics of the top-quark. In addition to the important physics output of this engagement, it has given invaluable experience of analysis of data from an experiment at a hadron collider. This environment poses very different conditions and requires a different set of analysis tools and skills than what is the case at an electron-positron collider. The extensive experience from high energy hadron collider physics analysis by members of the group will prove to be an enormous asset once data from LHC become available.

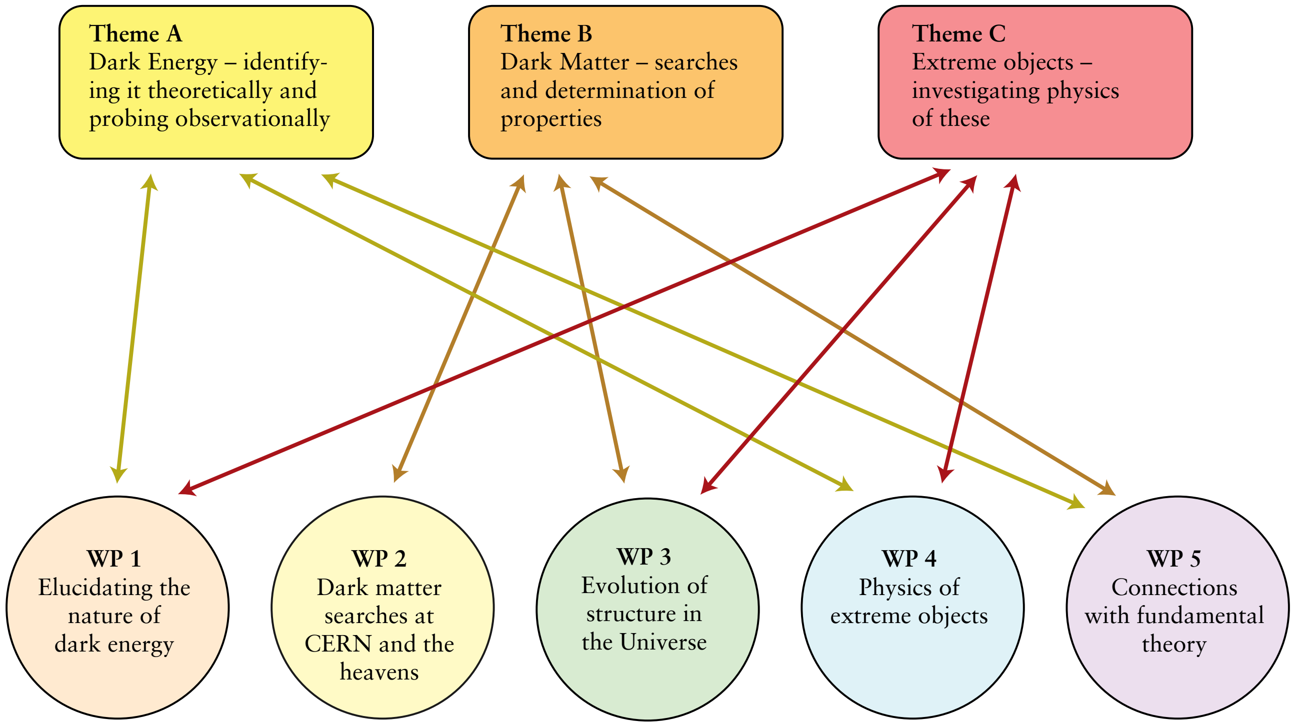
International collaborations and major funding

We have been asked to specify international collaborations. In fact, all members of CPC are active in international collaborations, so it would even be difficult to find work in the collaboration that is only confined to Sweden. Members of CPC have been very successful in obtaining large grants for investment in instruments, in particular from the VR, the Wallenberg Foundation and the Swedish National Space Board.

HEAC – a fore runner

The grant received for the AlbaNova High Energy Astrophysics and Cosmology (HEAC) centre was in a sense a predecessor of the Linnaeus grants in that it also concerns an excellence centre, funded by the VR. The sums were smaller, and the timescale is only 5 years, but it was granted along similar procedures, and was selected in 2004 as one of 10 proposals out of 160 applications that were successful. The funds given for HEAC, which involves groups from the Astronomy Department and the Physics Department of Stockholm University, and the Physics Department of the Royal Institute of Technology (all located in the AlbaNova University Centre) are used for funding graduate students, who follow a specially designed course package for training in high-energy astrophysics and cosmology. It is therefore a valuable complement to, and the natural starting point for the present application, which has a broader scope, more groups involved, and is more focused on funding actual research projects. Since our field, in Sweden as in many other countries, has a relative deficit of female researchers it may be encouraging to note that of the ten graduate students financed by HEAC, five are women. HEAC is thus educating a new generation of scientists with a less lopsided gender distribution than what used to be the case. If the present application is successful, the chance for these outstanding young scientists (selected out of 250 applicants in total) to contribute to forefront science also at later stages in their research careers will improve considerably.

Interconnections between themes and work packages



The main connections between the main themes and the workpackages. Naturally, the work packages will have some interconnections as well, not shown in the above figure.

Proposed research

As mentioned in the introduction, the proposed research is focused on three central themes in modern astrophysics and cosmology.To make this a successful research programme, we will organize the collaboration in the following topical categories (work packages). The interdependence of these themes and work packages is shown in the above figure.

Work packages

As our understanding of the phenomena being studied improves these topical categories will evolve, new categories may be introduced and some of the old ones terminated. Below we list the five categories that will be initiated as the collaboration is launched (see Appendix U for details of the actual organizational structure of the collaboration).

1. Elucidating the nature of dark energy (Conveners: Ariel Goobar and Jesper Sollerman)

Understanding what is causing the accelerated expansion of the Universe is among the biggest experimental and theoretical challenges in contemporary physics. However difficult, it addresses one of the most fundamental questions of our time about the very essence of space-time, what the Universe is made of and what the fate of the Universe may be. Cosmological tests for dark energy probe two key properties of the Universe as a function of redshift (z), i.e. cosmic time:

- The Hubble expansion rate, H(z)
- The growth function of structure, g(z)

Measuring *both* functions is required to assess the two possible classes of explanations to the dark energy puzzle: new energy terms may be needed in the energy-momentum tensor of general relativity, the prime example being the vacuum energy density, or the explanation may require modification of the curvature tensor, e.g. taking into account potential extra spatial dimensions.

Members of the CPC are involved in planning the SNAP satellite, one of the leading contenders for a dedicated satellite, JDEM, aiming at measuring H(z) by building a Hubble diagram of type Ia supernovae up to redshift z~1.7. The plan is to include over 2000 low extinction SNIa, spectroscopically selected to form a very homogeneous sample, thereby minimizing systematic effects. At the same time, the wide-field capabilities of SNAP are ideal for weak lensing measurements, sensitive to the distances to the sources and lenses, i.e. H(z) but also to g(z), as the distribution in redshift space of the galaxies acting as lenses affects the lensing signal. SNAP also has an interesting potential to detect hundreds of strongly lensed supernovae of all kinds, and measure H(z) through the time-delay between the multiple images of the same explosion. The nature of dark energy is explored by measuring the equation of state parameter of the dark energy fluid, w, which is the ratio of pressure and energy density, being equal to -1 at all redshifts (i.e. all times) if dark energy is the cosmological constant first introduced by Einstein. A detection of an evolution of this parameter with redshift would require dramatic changes to our understanding of fundamental physics. The interplay between SNAP and the next generation space telescope, JWST, is likely to become critical for studying the highest redshift supernovae and lensing systems. Several additional cosmological tools may be available by the end of the ten year program, e.g. the observation of gravitational wave “sirens”, the counterpart of standard candles in gravitational radiation produced by coalescing compact objects and detectable by LISA.

Short term activities
The road map leading to JDEM includes many smaller projects to build up the necessary astrophysical information to back-up high-precision measurements. Projects like ESSENCE and SNLS, where different CPC teams are participating, are providing large samples of supernovae at a wide range of redshifts as well as from different host galaxies. These CPC teams have recently together joined the SDSS-II supernova search effort and have contributed, along with other European groups, to the spectroscopic identification of a large fraction of the 400 intermediate redshift supernovae discovered to date. The Linneaus grant would allow us to dedicate significant resources in the next 2-3 years to analyze this unique data set at a redshift range where dark energy dominates.

One of the missing links in establishing H(z) with type Ia supernovae, possibly even after the JDEM era, would be the comparatively small number of low redshift ones needed to anchor the Hubble diagram. With the Linneaus grant, the CPC could allocate resources to investigate the feasibility of leading a new project to study low redshift SNe and other optical transients. One interesting possibility to be studied is to do follow-up observations (at ESO and the Nordic Optical Telescope) of supernovae to be discovered in large numbers (thousands per year) by the European GAIA satellite.

It would also be important to investigate cosmic microwave background anisotropies, and the associated baryon acoustic peak. These are areas where we lack expertise at AlbaNova and where new recruitments should have high priority. In particular, on the observational side, great progress is to be expected with planned instrumentation and we should not miss this exciting development.

In parallel, the CPC will look for hint of a solution of the dark energy puzzle based on laboratory experiments, mainly at the LHC. Scenarios involving extra dimensions, as first conjectured by Kaluza and Klein in the beginning of last century, will thus be tested both with terrestrial and astronomical measurements.

2. Connecting searches for dark matter at CERN and in the sky (Conveners: Christophe Clément and Klas Hultqvist)

Apart from directly detecting the interaction of the dark matter particles (WIMPs) passing through matter on Earth, a possible method to obtain information is to look for the secondary particles produced in their annihilation. These can be gamma rays, detectable by GLAST, cosmic ray anti-particles, searched for by PAMELA, or neutrinos searched for in IceCube, emitted from mass concentrations such as the centre of the Earth, the Sun, or the Milky Way. Dark matter particles may also be produced in the proton-proton collisions at LHC, which would make it possible to study their properties more directly. This is particularly true in the appealing case that the WIMPs are supersymmetric particles. The DarkSUSY code is one of the leading tools for analyzing supersymmetric parameter space and compute dark matter properties. The CPC will thus be in an excellent position to design, carry out, and interpret searches for the dark matter particles.

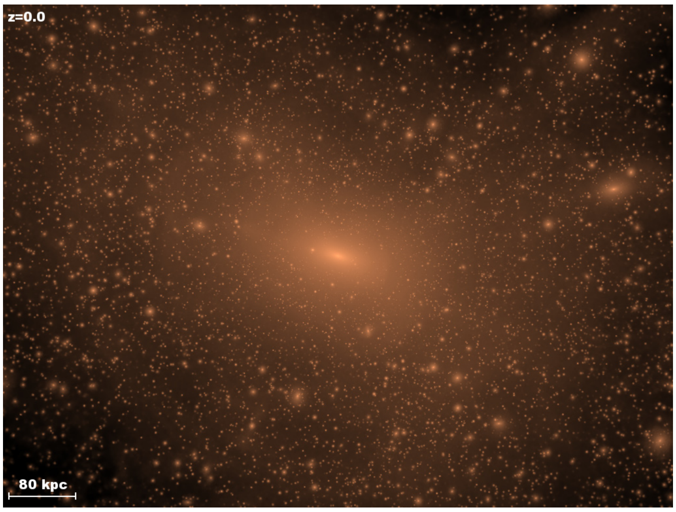
If SUSY particles exist with masses of the order of a few hundred GeV they will be copiously produced already at the low luminosities foreseen for the first years of LHC operation. In this case, a host of new particles, with properties closely tied to those of the dark matter, may be discovered and studied with ATLAS. The emphasis of the ATLAS group at SU is on the search for supersymmetric particles, concentrated along two lines, focusing on relatively inclusive signatures, with a view to optimize the potential for an early discovery. These analyses will be sensitive not only to supersymmetric particles but also to phenomena from a large group of possible extensions of the Standard Model.

The search for gamma-rays from dark matter annihilation in the galactic halo will, when GLAST comes into operation in 2008, have a potential of discovery that is more than two orders of magnitude greater than its predecessor, EGRET, because of larger area, better energy and angular resolutions and larger energy range. Current theoretical results obtained from N-body simulations indicate that the halo will be very clumpy, with dark matter annihilating at a much higher rate than previously thought, which additionally improves the detection possibilities.

To dramatically enhance the detection possibility of dark matter in IceCube, a new denser detector array, Deep Core, positioned at depth inside IceCube and sensitive to lower energies, has been proposed. Funding is being applied for from the Wallenberg foundation, and if granted this would give a whole new branch of physics and astrophysics capability where the CPC would play a leading role. Another alternative being explored is the possibility, present in some specific supersymmetric models, that exotic particles like supersymmetric leptons produced by interactions of high-energy neutrinos, can be detected in IceCube.

The funding applied for here will make it possible to extend and adapt DarkSUSY and related codes to the analysis frameworks of the experimenters, particularly that of ATLAS. If the ATLAS results indicate phenomena beyond the Standard Model, the next step is to characterize these in terms of a theoretically sound model, while in the less attractive scenario in which there are no early experimental discoveries, detailed understanding of phenomenological constraints and assumptions, and of the detector properties, will be needed in order to optimize the searches. Knowledge about the WIMP mass and couplings from ATLAS would make it possible to optimize the IceCube search for WIMP annihilations better, and information on mass-spectra or couplings from other sources would enable more optimized measurements at the ATLAS detector. An optimal effort in this area would require the expertise of a particle physics phenomenologist, and the hiring of such a specialist will be given high priority.

Although supersymmetry is a very attractive possibility, it is by no means guaranteed. Until SUSY has been unequivocally established, and the Dark Matter particles identified as supersymmetric, existing and emerging alternative scenarios should be explored theoretically, and experimental results concerning WIMP annihilation rates should be presented also in such contexts. To accomplish this, a junior researcher may be hired in order to identify models and questions which should be addressed experimentally, and to strengthen the data interpretation efforts in the experimental groups. Many of the modules in DarkSUSY are in principle usable also for alternative scenarios, but adapting them will also require human resources.



The dark matter halo of the Milky Way, according to the huge Via Lactea N-body simulation using 234 million particles. Credit: J. Diemand & al., 2006.

If a particle matching the requirements for Dark Matter is discovered at the LHC, or if a signal is found by direct or indirect detection, predictions will be worked out for signals in the different experiments performed by CPC (as well as others of interest), and also at an upgraded LHC, the SLHC, and the planned International Linear Collider. The rates for indirect detection will depend on details of how dark matter is structured on small scales in the Galaxy. A joint team will be formed with astronomers to determine properties of the smallest dwarf satellite galaxies to make a realistic model of the small-scale structure dark matter halo. This may involve a new postdoc with experience from N-body simulations. From this, predictions for gamma-ray, antimatter and neutrino detection can be made. Thus, this task will involve all the groups in CPC.

Short-term activities
In short-term, several important steps will be taken: The DarkSUSY software will be organized and harmonized with that used in ATLAS, so that experimental limits, and hopefully findings of new particles can be simultaneously treated by the two. This will require one new person (junior researcher or postdoc) with the appropriate background. The work will involve both the ATLAS and the CoPS group. One year after the start-up in 2008, ATLAS is expected to have collected at least one inverse femtobarn of data, which could be enough to give first indications of new physics if the mass-scale is close to present limits. After the second year of data taking one can expect the order of ten inverse femtobarns, which would allow discovery of SUSY particles up to masses of several hundred GeV.

The analysis of GLAST data will also constrain dark matter annihilation in the galactic halo by 2009, or lead to the discovery of this process. The expansion and continued data taking by IceCube/AMANDA will enhance the sensitivity to annihilations in the Sun and by 2011, with Deep Core, it will be a factor 10 beyond present limits on SUSY WIMPs from direct detection.

3. Formation and evolution of structure in a dark Universe (Conveners: Göran Östlin and Garrelt Mellema)

Dark matter potentials act as seeds for galaxy formation. Moreover, the growth rate of structure (galaxies and clusters of galaxies) depends on the dark matter and dark energy content of the Universe. Our ability to observe the evolution of cosmos however relies on baryonic tracers emitting the light which astronomers use to unveil the properties of distant galaxies and the gravitational lensing signal from intervening dark matter. The evolution of baryonic matter, which is also mostly dark, is more complicated to predict because of dissipation, radiative and mechanical feedback from star formation (e.g. in the form of supernovae) and massive black holes in galactic nuclei. Hence in order to understand the evolution of dark matter (baryonic and non-baryonic) it is necessary to understand the baryonic component and how it relates to the dark matter and dark energy evolution. In the coming years we intend to address these questions in various ways:

We will utilize numerical models to connect the baryonic and dark matter physics. One application will be to predict possible gamma ray signals from dark matter annihilations that will be searched for e.g. with GLAST, another one to aid in the complex interpretation of observational kinematical data of starbursts and faint galactic halos. Kinematical and photometric studies of faint dark matter dominated dwarf galaxies may constrain the nature of dark matter and address the missing satellite problem. ESOs VLT and other large telescopes may be employed to search for, and measure velocity dispersions of, ultra-faint dwarf galaxies. This is a very important problem for knowing how the dark matter clumps and therefore for the predicted rates of direct detection of dark matter. We also intend to investigate what role dark matter plays for the efficiency of baryonic transformation. Here starbursts and post-starbursts offer the opportunity to study feedback processes – a crucial component in galaxy formation and evolution.

With a rest wavelength of 1216Å, the Lyman-alpha line (the transition between the ground state and the first excited state) of Hydrogen is a powerful tool for studying neutral gas and star formation in the high redshift Universe. It can be used to study galaxy formation and the cosmic reionization history, and is also of importance when estimating how much hot dark matter that can be allowed, and thereby give upper limits on the neutrino mass. However, being a resonant line, the Lyman alpha radiative transport is complex. We have initiated work to investigate this through detailed studies with the Hubble Space Telescope. We will address this question with radiative transfer modeling and observations from UV to radio (ALMA and LOFAR). The goal will be to allow us to use Lyman-alpha and 21cm tomography to understand the early structure formation and reionization. New postdoctoral recruitments that bridge the Lyman-alpha and LOFAR activities would here be vital.

From high resolution observations and modeling of the stellar populations in the vicinity of exploding GRBs and SNe, better constraints on the progenitor masses and metallicities of the various subtypes may be obtained. Core collapse supernovae are also useful to trace the evolution of structures through the direct relation between the explosion and star formation rate. Infrared and/or lensing cluster observations will allow us to probe more distant supernovae and their host galaxies. Eventually the JWST will allow supernovae to be studied prior to the epoch of reionization. Another possibility is to use high redshift GRBs as signposts of early star formation. All planned dark energy missions (e.g. SNAP) will produce rich legacy datasets of great value for galaxy/structure evolution studies.

Short term activities

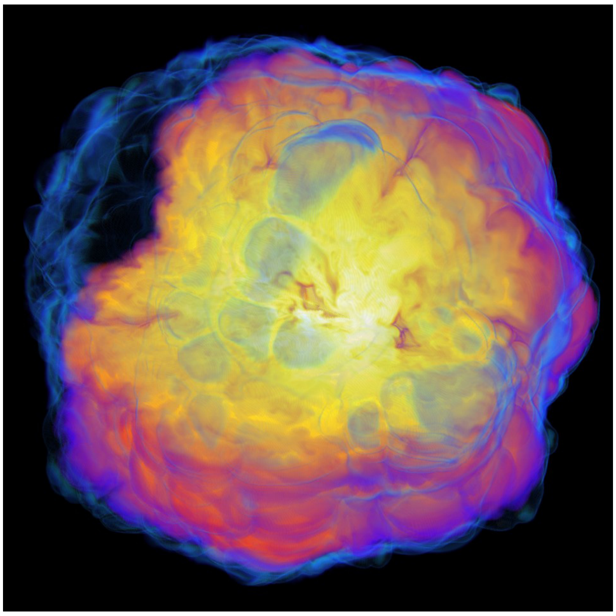
The largest space- and groundbased telescopes will soon be upgraded with new powerful instrumentation, and ALMA and LOFAR are soon to start operations. Our short term activities will use mainly these facilities. In the longer run, JWST, ELT and SKA are expected to be the most powerful tools.

The projects that will be initiated within the first years include:

- Investigating and quantifying Lyman-alpha escape from galaxies at low and high redshifts and their use in probing cosmic reionization and formation and evolution of structures such as galaxies and clusters
- Theoretical and observational work on reionization as probed by LOFAR
- Feedback processes from star formation (e.g. supernovae) and active galactic nuclei and their effect on the observed distribution of baryons, galaxy bias etc.
- Dynamics and Dark Matter structure of dwarf galaxies
- Using core collapse supernovae (and GRB) as probes of star formation in the distant Universe
- Investigating the nature of red light from galactic halos and possible connections to baryonic dark matter

4. Physics of Supernovae, Gamma-ray bursts and Black holes (Conveners: Claes Fransson and Felix Ryde)

The coming decade offers a multitude of new instruments and facilities which will give unprecedented opportunities for understanding supernovae and gamma-ray bursts, and the resulting neutron stars, black holes and high energy cosmic rays. These include instruments where our groups are directly involved, as well as general facilities. Furthermore, CPC teams are involved in large observational projects like supernova surveys. To fully exploit these opportunities a close interaction between instrument builders, observers, and theorists is necessary.



Model of a Type Ia explosion (from Hillebrandt & Röpke, MPA), used as input for calculations of spectra by members of CPC.

An important example is the study of supernovae and gamma-ray bursts. There is here a strong theoretical and observational activity at the Astronomy Department, while most of the experimental and instrument-building activity is at the KTH. For instance, after launch in 2008, GLAST will provide unprecedented data of the early phases of GRBs. Teams at CPC are part of the GLAST-GRB science working group and will have direct access to the data and data handling. In 2008 there will also be a new instrument at the VLT designed especially for optical/IR observations of supernovae and GRBs, to which members of CPC will have direct access. Observations of GRB at late epochs with these instruments can give unique new insights. In the longer term, the PoGOLite experiment will provide datasets from observations of polarized photon emission from compact objects, such as isolated and accreting neutron stars and accreting black holes, in the hard X-ray regime.

Related to this is the origin and acceleration of cosmic rays and non-thermal electrons. Cosmic rays with energy above the GZK cutoff are expected to reach the Earth in the form of neutrinos, and there is an active program to extend IceCube using acoustic or radio techniques in order to detect these. The standard cosmic ray data produced by PAMELA (proton and electron spectra in addition to the anti-matter spectra) is also of obvious interest here.

Type Ia SNe are the most important distance indicators today, and will remain so with JDEM, as well with future ground based projects. There are still many aspects of these explosions which are not well understood. This includes both the explosion mechanism and the nature of the progenitors . This fact makes it difficult to estimate systematic effects in their luminosity and spectra, which may be a major obstacle for their cosmological use. Both the teams joining here in CPC have extensive experience in observational work. Combining these efforts can provide a very important advance in this area.

Short-term activities
Our most important short term goals in this area are

- Testing explosion models for core collapse supernovae, in particular the role of large scale instabilities and the connection to gamma-ray bursts.
- Determining the burning mode of Type Ia SNe and systematic effects from metallicities and dust extinction on their luminosities.
- The production of high energy particles, neutrinos and gamma-rays from the interaction of SNe

and gamma-ray bursts with their environment.

- To bring to maturity new complementary observation techniques for compact objects based on the polarization of the emitted X-ray photons.

The CPC will make a concentrated effort, using both observations and modeling, to compare state-of-the-art explosion models from our collaborators at Max Planck in Munich with observations at the VLT and other telescopes. The new instrument at the VLT will allow observations of Type Ia supernovae at both higher redshifts and at later phases, allowing more detailed understanding of supernova physics and evolution. This will be a very important preparation for SNAP/JDEM, and will involve members of both teams (from the Department of Astronomy and CoPS), but will also require a new post-doc or junior researchers, who can further develop the models and coordinate the observations.

The third goal, which has important implications for the understanding of the acceleration mechanism of relativistic particles, involve the combination of observations from a large range of facilities, from radio to optical, gamma-rays and neutrinos. Combining the resources, we will use these instruments and models to determine the particle acceleration efficiency of these high energy cosmic rays. A post-doc or junior researcher working directly with the interpretation of observations of gamma-ray burst and core collapse supernovae from the various experiments entering the CPC could bridge the gap between these groups.

We would also like to strengthen activities not yet present at AlbaNova. An example is the search for neutrinos from GRBs using IceCube. Such searches have been performed before with AMANDA, as GRBs are prime candidates for extraterrestrial neutrino sources, but so far the data analysis has not been carried out in Stockholm. We therefore expect to extend the interpretation of GRB observations to IceCube and assign a graduate student to develop and apply the relevant detection techniques to the IceCube data set. Another example of possible future projects would be flights of opportunity for PoGOLite in response to flaring states observed with e.g. GLAST.

5. Connections with fundamental theory (Conveners: Joakim Edsjö and Marcus Berg)

Dark energy and dark matter are great mysteries of modern cosmology and physics. Equally great challenges abound in the physics of the very early universe, such as the specifics of cosmological inflation. Any progress towards solving these mysteries may have profound implications for particle physics models, thus connecting the largest scales in the universe with the smallest scales ever explored. For certain "minimal" candidate theories of dark matter, we have already described this relation on a practical level (work package 2). The work package in this section is more theoretically oriented, and more general, "non-minimal" extensions of the standard model of particle physics will be considered. The complementarity between work packages 2 and 5 is a great asset. This is because "minimal" theories always run the risk of being too minimal to reproduce new experimental data, but also because deeper connections between the aforementioned mysteries may be revealed by more general theoretical frameworks. Such frameworks will be explored in this work package.

In addition, implications for fundamental theory of data assembled by instruments where the CPC is involved will be investigated directly, in conjunction with the theoretical studies. Examples include, but are not limited to, searches for Lorentz symmetry violation that can be deduced from arrival time data from gamma-ray bursts or active galactic nuclei, or breakdown of the weak equivalence principle from GRB neutrinos. There may also be tests of Lorentz symmetry violation at very high energy from gamma-ray polarization, birefringence and other effects to be studied by PoGOLite. Unlikely as it may be, if discovered these violations of closely guarded principles would pose great challenges for fundamental theoretical physics, that the CPC would be perfectly poised to address.

Returning to general theoretical frameworks, one can identify two levels of generality. First, one can consider “near-minimal” models of physics beyond the standard model of particle physics. Such models already exist, but explicit experimental predictions from them need to be worked out. Several early studies have already been performed by members of the CPC. On the next level, there has recently been significant activity of developing “string models”, very general models that not only aim at a reasonable phenomenological description of particle physics, but also include fields that could play the role of dark energy and the inflaton of inflationary cosmology. If a consistent and convincing picture of particle physics, dark matter and dark energy can be found that fits observational constraints, this would be a great advance in fundamental theory, and a significant step beyond “minimal” models.

For example, these string models tend to require the presence of hitherto undetected extra spatial dimensions, which can produce natural “non-minimal” candidates for dark matter. These extra dimensions may also affect the gravitational force (roughly speaking, gravitational field lines “leak into” the extra dimensions), which could have profound implications for cosmology. Finally, in these models, there are many fields appearing at intermediate to high energy scales ($10^{12} - 10^{16}$ eV). It is believed that some of these could play the role of the inflaton field in the early Universe, and that some other of these could be responsible for the dark energy. In the CoPS group, M. Berg has just joined us as a junior researcher and these are precisely the kind of questions he is interested in. S. Hofmann has recently started as a five-year guest professor at NORDITA in Stockholm and he also has strong interests in this field.

In the long run, many new observational constraints and/or observations are expected during the course of this project. Many of these questions will be covered in work package 2, but will also be addressed here on a more theoretical level.

As alluded to in the beginning of this section, mysteries such as dark energy are among the deepest and most difficult of theoretical physics today. It would be unrealistic to claim that they will be solved within the confines of this proposal. However, activities that seem promising in this direction include:

- implement cosmological inflation in string models
- construct dark energy models in string scenarios

As many of the questions addressed in this work package might have answers that we cannot even anticipate today, our work will provide important insight in future research directions, no matter if certain models of dark matter and dark energy are realized or not.

Short-term activities
In the first years, most of the work will be focused on developing the tools necessary to connect fundamental particle physics and theoretical dark energy models with coming observations. Most of the connections to particle physics will be carried out in connection with the dark matter projects of work package 2. Obvious activities in the first years of the project is to

- investigate the effects of “near-minimal” low-energy particle physics models for dark matter.
- study non-minimal string models of particle physics

To be able to tackle these challenging questions, we need to strengthen our resources and hire postdocs and junior researchers. In the long run, we may also decide to have a lecturer position in this field.

Milestones

We will here highlight the most important milestones and in particular show how the new collaborations formed through this proposal will be of crucial importance.

Short-term milestones (within 2 years)

Within the first two years of the project we will

- start-up the Steering Group (see appendix V), form the international advisory board (IAB), start-up the working packages and the work package forum, recruit the people needed (with guidance of the IAB) for the different work packages (mainly postdocs and junior researchers initially),
- analyze the data from GLAST, IceCube, PAMELA and ATLAS in the context of dark matter. We will also develop the first tools needed to do a cross-disciplinary analysis of these data sets,
- complete the data-taking of ongoing large ground-based supernova searches and prepare for SNAP and develop theoretical tools and collect observations for analyzing the explosion physics of Type Ia and core collapse supernovae, and
- study models for high energy emission for supernovae, gamma-ray bursts and compact objects applicable to observations from GLAST, IceCube and POGO.

Mid-term milestones (2–5 years)

In this time frame we expect the majority of our first results from the work packages to be ready, namely

- have finished a first full analysis of data from LHC, satellite experiments and IceCube to gain new understanding of the dark matter's properties, mostly in terms of supersymmetric models,
- have finished new major analysis of nearby (redshift $0<z<1$) type Ia supernovae to gain understanding of these both in their own right, but also for their use in cosmology
- obtained a much better understanding of the dynamics and structure of dark matter, both for interpreting dwarf galaxy data and for connections with dark matter searches from the sky
- tested models of extreme objects (like core-collapse supernova, gamma-ray bursts and black holes) against observations and used this knowledge to refine both our theoretical understanding of these objects and predictions of high-energy particles, neutrinos and gamma rays, crucial for upcoming observations like IceCube, and
- obtained a better understanding of the physical processes and nature of sources that reionized the Universe

Long-term milestones (5–10 years)

In the longer perspective, it gets more difficult to give precise answers to what the outcome will be, as it depends on the results from the previous years. However, we expect to

- have cornered in the dark matter candidate both from accelerator searches and more indirect searches from the heavens. We also expect to have made the necessary connections with fundamental theory to either confirm or refute hypothetical models of extensions of the standard model of particle physics.
- have gained a much better understanding of the properties of dark energy and made the connection between observed properties and theoretical modelling
- have found something completely new and unexpected!

We are ready to go!

Glossary / explanation of acronyms

ALMA Atacama Large Millimetre Array

AMANDA Antarctic Muon And Neutrino Detector Array at the South Pole, the precursor of IceCube. Occupies a volume of 0.1 cubic kilometers.

ATLAS Particle physics experiment in the LHC at the CERN laboratory. It will explore the fundamental nature of matter and the basic forces that shape our Universe.

CERN CERN is the European Organization for Nuclear Research, the world's largest particle physics centre. CERNs next flagship project, the LHC, is in its final comissioning phase

CoPS The cosmology, particle astrophysics and string theory group at Stockholm University

CPC CosmoParticle Collaboration, the name of the constellation behind the current application.

DarkSUSY Computer program for dark matter calculations (mainly in supersymmetric theories) developed by members of this proposal

DELPHI One of the detectors at LEP, CERN.

DZero (D0) One of the two big detectors at the Tevatron at Fermilab

ELT Extremely Large Telescope

ESSENCE Equation of State: SupErNova trace Cosmic Expansion

ESA European Space Agency

ESO European Southern Observatory

GAIA an ESA satellite that e.g. will measure the positions of ~1 billion stars in our galaxy

GLAST Gamma Ray Large Area Telescope

GRB Gamma Ray Burst

GRIPS GRB Investigations with Polarimetery and Spectroscopy

GZK the Greisen-Zatsepin-Kuzmin cut-off which predicts that ultra-high energy cosmic rays should not be able to reach the Earth from far away because of interactions with the cosmic microwave background radiation

HEAC High Energy Astrophysics and Cosmology centre, a fore-runner of this proposal

HST Hubble Space Telescope

IceCube neutrino telscope being built at the South Pole. Will be finished in 2011 and will then consist of 4800 photomultiplier tubes in a cubic kilometer of ice.

JDEM Joint Dark Energy Mission

JWST James Webb Space Telescope operating in infrared, scheduled for launch 2013

KTH Kungliga Tekniska Högskolan (Royal Institute of Technology)

KVA Kungliga Vetenskapsakademien (Royal Academy of Sciences)

LEP Large Electron Positron collider that collided electrons and positrons at CERN from 1989 to 2000.

LHC Large Hadron Collider at CERN.

LISA Large Interferometer Space Array, the next generation gravitational wave dectector

LOFAR LOw Frequency ARray

N-body simulations Simulations of structure formation (e.g. galaxies, galaxy clusters, etc) made by letting gravity act on the small perturbations present in the early Universe

NORDITA Nordic Institute for Theoretical Physics

PAMELA a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics, launched in 2006

PoGoLite the polarized gamma ray observer

SCP Supernova Cosmology Project

SDSS Sloan Digital Sky Survery

SKA Square Kilometre Array, the international radio telescope for the 21st century

SN Supernova

SNAP Supernova Acceleration Probe

SNLS Supernova Legacy Survey

SU Stockholm University

SUSY Supersymmetry, one of the most natural extensions of the standard model of particle physics

UA2 Experiment at CERN that codiscovered the W and Z bosons in 1983

VLT Very Large Telescope (ESO)

VR Vetenskapsrådet (the Swedish Research Council)

WIMP Weakly Interacting Massive Particle, one of the leading candidates for the dark matter of the Universe.