Appendix: brief description of individual PhD projects.

The proposed research program is organized along five major scientific themes. For each of these scientific themes a number of PhD projects was identified, which are listed below. In total 15 projects are listed, of which 13 will be funded through the proposed FOM research program. Apart from the scientific tasks listed below, each PhD student will also contribute to the general operation of the Antares or Auger observatory.

- Point-source searches:

1. *Neutrinos from the galactic center* (P.M. Kooijman – UvA/Nikhef)
The air-Cherenkov telescopes H.E.S.S. and Magic have recently identified many prominent sources of high-energy photons in the galactic center, including several supernova remnants. As supernovae are expected to be strong sources of high-energy cosmic rays, it is imperative to search for neutrino-point sources in the galactic center. A one-dimensional source-tracking trigger has been developed for this purpose, which will be improved and applied to the data that will be collected by **Antares**.

2. *Neutrinos from Micro-Quasars or AGNs* (P.M. Kooijman – UvA/Nikhef, M.P. Decowski – Nikhef)
Micro-Quasars are stellar-sized black holes that are likely sources of galactic neutrinos. Outside the galactic system, Active Galactic Nuclei (AGNs) – which are believed to be powered by very massive black holes (10^{6-8} solar masses) – are the most prominent candidates. **Antares** will be used to search for high-energy neutrinos emitted from a pre-defined list of Micro-Quasars and AGNs using dedicated trigger and reconstruction strategies.

3. *Searches for anisotropies* (J.R. Hörandel, H. Falcke, J. Kuijpers – IMAPP)
As protons with energies above 10^{19} eV are hardly bent in (extra-) galactic magnetic fields, they can be used to search for particle-point sources. Systematic searches for anisotropies in the cosmic-ray sky maps measured at **Auger** will be performed making use of known astronomical data on AGNs, Micro-Quasars and other compact objects. These searches will also profit from the high-duty cycle and excellent pointing accuracy of the new radio-detection techniques developed in projects 8 and 9.

4. *Neutrinos from Gamma-Ray Bursts* (M. de Jong – Nikhef)
Gamma-ray bursts (GRBs) belong to the most energetic explosions observed in the Universe. By measuring the amount of neutrinos emitted by a GRB, it will be possible to distinguish between competing mechanisms proposed to explain the observed brief (< 5 minutes) flashes of intense gamma radiation. A dedicated satellite-based GRB trigger has been developed for the **Antares** neutrino telescope, which will be further improved and applied to the data.

- Dark matter:

5. *Dark-matter searches at Antares* (E. de Wolf – UvA/Nikhef, G. van der Steenhoven – Nikhef)
It will be investigated whether the Sun is emitting neutrinos with energies in excess of about 50 GeV. Such neutrinos may be the result of the annihilation of neutralinos, i.e. one of the candidate *dark-matter* particles. Dark matter is a completely unknown form of non-baryonic, non-luminous matter which according to astronomers makes up about 25% of the total energy content of the Universe. The search will be conducted at the **Antares** neutrino telescope using specially developed algorithms aimed at improving the acceptance of the telescope in the energy domain between 50 and 500 GeV.

6. *Alternative dark-matter searches at Antares* (M.P. Decowski, G. van der Steenhoven – Nikhef)
Apart from the Sun, there are various other celestial objects in which dark-matter particles may have accumulated. These include the galactic center, the Earth and Intermediate-Mass Black Holes (IMBHs). Moreover, it has also been speculated that dark-matter particles may be of the Kaluza-Klein type, implying that their mass-range would be between 400 and 1200 GeV. For these alternative dark-matter scenarios dedicated search strategies will be developed and applied to the **Antares** data.

- Composition of cosmic rays:

7. *Simulations of air-shower developments for Auger* (Th. Peitzmann – UU/Nikhef, O. Scholten – KVI)
Uncertainties in shower developments at extremely high energies are one of the limiting factors in the interpretation of ultra-high energy cosmic-ray data. In the framework of this project simulations of ultra-high energy air showers will be performed to address this issue. The simulations will be based on various possible implementations of the color-glass-condensate model and will utilize future knowledge derived from nuclear reactions at LHC and radio observations at **Auger**.

- Composition of cosmic rays:

8. *Developing radio-antennas for Auger* (A.M. van den Berg – KVI, Ch.W.J.P. Timmermans – IMAPP)
By adding new detector systems to the Pierre Auger Observatory, it will be possible to study the primary composition of cosmic rays. It is the aim of the present project to develop radio-detection systems for this purpose. By co-locating 10 prototype radio antennas near existing (and new) water tanks at **Auger**, it will be possible to benchmark the radio data in the energy range $10^{17\text{-}18}$ eV.

9. *Developing solitary radio stations* (Ch.W.J.P. Timmermans – IMAPP, A.M. van den Berg – KVI)
A 20 km^2 radio array will be built in a designated area of the Pierre **Auger** Observatory. The construction of such a large radio-antenna array requires the development of radio-quiet solar power systems, low-power electronics, self-triggering systems, and high-rate wireless communication systems spanning large distances. Once operational, the radio and water-tank data will be combined to study the composition of cosmic rays beyond 10^{17} eV.

10. *Horizontal air showers and searches for UHE neutrinos* (H. Falcke, S.J. de Jong – IMAPP)
Earth skimming neutrinos produce horizontal air showers. The determination of the age of such air showers can be used to identify the composition of the primary cosmic rays (i.e. whether they are neutrinos or hadrons). The baseline **Auger** detector and the radio stations developed by projects 8 and 9 (and the simulations developed in the framework of project 7) will be used to study the profile of horizontal air showers as a tool to determine their composition. Ultra-high neutrinos identified in this method can be compared to those measured at Antares in the framework of project 11.

- Ultra-high energies (UHE):

11. *Developing UHE neutrino reconstruction algorithms* (M. de Jong – Nikhef, E. de Wolf – UvA/Nikhef)
The spectrum of cosmic rays extends well beyond 10^{16} eV, where the Earth becomes opaque to neutrinos. To observe neutrinos in this domain, special techniques need to be developed. For that purpose, downwards moving neutrino-related muon tracks need to be reconstructed and distinguished from the large amount of downwards moving atmospheric muon tracks. Using simulations of UHE neutrino signals trigger and reconstruction algorithms will be developed and applied to the **Antares** data. This project may result in the first observation of *cosmogenic* neutrinos (see lower inset on p. 4).

12. *Novel techniques for UHE neutrino detection* (N. Kalantar, H. Löhner – KVI, J.J.M. Steijger – Nikhef)
To observe ultra-high neutrinos downwards going muon tracks need to be identified amidst a huge background of atmospheric muon tracks. It will be investigated whether a multi-element optical module consisting of a large number of selected standard-sized phototubes configured in a spherical arrangement – as proposed for future km^3-size neutrino telescopes – is beneficial for the detection of UHE neutrinos. Both simulations and prototype studies (most likely at **Antares**) will be carried out.

13. *Determining the neutrino flux at the highest energies* (O. Scholten – KVI)
When ultra-high energy neutrinos or charged particles hit the Moon, radio signals are emitted in the frequency domain covered by the radio antennas developed for Lofar and **Auger** (see project 8 and 9). Observations based on this so-called *Askarian* effect enable the search for neutrinos with energies well beyond 10^{20} eV. Making use of optimized triggering conditions that are presently being developed at the Westerbork radio observatory, the actual search for such extremely high-energy particles can be applied to the data collected by the two mentioned observatories.

- Exotics:

14. *Monopole searches at Antares* (M. de Jong, P.M. Kooijman – Nikhef)
Magnetic monopoles – if they exist – can be identified in **Antares** on the basis of the very large number of (Cherenkov) photons that are produced if they pass the detector. Moreover, the δ-rays produced by monopoles along their path provide the additional possibility to identify monopoles with velocities down to 0.55*c.* In the framework of this project a monopole trigger will be developed and applied to the Antares data to search for the existence of magnetic monopoles.

15. *Nuclearite searches at Antares* (M.P. Decowski, J.J.M. Steijger – Nikhef)
It has been hypothesized that small clumps of strange quark matter could have been formed in the early Universe. Evidence for such *nuclearites* can possibly be found in high-energy cosmic rays. Nuclearites may have masses ranging from that of heavy nuclei to macroscopic values, and typically have anomalously low charge to mass (Z/A) ratios. Nuclearites can be identified in Antares as relatively slowly moving downward going tracks with correspondingly large crossing times in **Antares**.