# AAA – implementation plan 2015 – 2018

# August 2014

## Executive summary

In its first four years, SCAR AAA has worked hard to meet its initial objectives; providing a forum to facilitate international cooperation, clarify science goals, consolidate comparative site testing data, and raise the profile of SCAR within the international astronomical community and the general public.

In its second four years, SCAR AAA wishes to build upon the progress made so far by developing a robust international platform for astronomical cooperation in Antarctica. Specifically, SCAR AAA takes on board the recommendations of the external reviewers, who called upon us to:

- Formulate a clearer vision with informative advice on what type of observations are needed where,
- Encourage collaboration by all countries towards new accomplishments, not repetition of existing results,
- Extend the site-testing database to cover astronomical data, including consideration of joining the Astronomical Virtual Observatory,
- Increase education/outreach, especially to general public, colleges, high schools, museums,
- Build more capacity in countries with less developed Antarctic astronomy programs.

AAA met formally on 26 August 2014 in Auckland at the time of the SCAR OSC, in addition to holding many informal discussions and email exchanges. From this, the following operational plan for 2015 – 2018 has emerged. The key goals for this period will be to:

I. Create an Antarctic Plateau International Astronomical Observatory (APIAO),
II. Extend the current site-testing searchable database to become a data portal,
III. Increase outreach activities directed towards the general public and the international astronomical community, especially in those countries with less developed astronomical programs in Antarctica.

These key goals are described in more detail below.

To implement this plan, SCAR AAA has reviewed its internal structure and concluded that its four working groups are currently well-suited to these tasks – no change is needed. However, some rotation of the key roles within SCAR AAA is desirable, especially if this can be done in a way that improves gender balance and generational representation.

# I. Create an Antarctic Plateau International Astronomical Observatory (APIAO)

**Summary**
APIAO will be an international observatory with carefully chosen projects that cannot be carried out by individual groups/countries and need international collaboration, for example future large (>2m) optical/IR telescopes or interferometers. APIAO will not be located at a single site. Rather, the world's astronomers will cooperate to design, resource, build and operate the best facilities at the most appropriate locations – based on site conditions and logistic feasibility – to deliver the best science at the lowest cost. There will be an emphasis on robotic and autonomous observatories, able to gather data with no (or minimal) on-site human presence.

**Background**
The concept of APIAO emerged from extensive discussions by AAA WG4 at the Taronga Zoo kick-off meeting in 2011. In the years since, SCAR AAA has organised regular meetings of the international astrophysics community, many of whom have conducted experiments at the various Antarctica sites (Dome A, Dome C, Dome F, South Pole, Ridge A, McMurdo), allowing everyone to better understand the individual interests and competencies of each institution, and identify and encourage possible collaborations.

Site testing over a period of more than two decades has confirmed that the high Antarctic plateau offers exceptional conditions for astronomy. Unfortunately, for many kinds of astronomy the best sites are also those that present the greatest logistical challenges. This suggests that development of large scale, cutting edge facilities must be done in a staged manner:

a. Clarify and articulate science goals,
b. Deploy prototype instruments for site characterisation,
c. Deploy technology demonstrators,
d. Design instruments to address these scientific questions,
e. Identify and secure resources for construction, operation and deployment of large-scale facility.

Some scientific questions have reached a stage of maturity where major facilities have already been deployed and are reaping rich rewards: examples include Long Duration Ballooning, the South Pole Telescope, BICEP2 and Ice Cube. Other areas, those where SCAR AAA can add the greatest value to national Antarctic programs, are currently at the stage where international project teams need to be brought together to bring ambitious new facilities to fruition.

**Proposed elements of APIAO**
APIAO is not proposed as a single telescope at a single site, but rather a set of facilities, each deployed to whichever location offers the optimum combination of site qualities and logistic feasibility for that particular facility.

**Current status**
Many projects already exist at the Antarctic different sites, covering a wide variety of science topics. For example:

- Particle physics

- Cosmology (cosmic microwave background, the dark Universe, first stars/galaxies)
- Time domain studies (Supernovae, AGN, quasars, exoplanets)
- Solar physics.

Similarly, there is a wide variety of technology required, much of it already tested under Antarctic conditions:

- Particle detectors (South Pole)
- Cosmic microwave background polarisation detectors (South Pole and Dome C)
- Terahertz cameras and detectors (Ridge A, Dome A, Dome C, Dome F, South Pole)
- Optical and infrared telescopes and cameras (South Pole, Dome A, Dome C, Dome F)

**Building upon existing collaborations**

International collaboration has been a key element in all of the most successful astronomical endeavours on the Antarctic plateau. For example, site testing instruments and technology demonstrators have involved the combined efforts of astronomers from Australia, China, France, Italy, Japan, the UK and the US. The collaborations thus formed create an excellent basis upon which more substantial projects can be brought to fruition.

SCAR AAA's role is to provide a forum for the development of these collaborations, and to coordinate the creation of a project plan for the funding and construction of APIAO.

**Science drivers**

Five key science goals for APIAO have been identified by SCAR AAA. These align particularly well with the top astrophysics questions that emerged from the SCAR *Horizon Scan*, and are outlined below.

**1. Understanding what happened in the first second after the Universe began. (Related to *Horizon Scan* Question #69).**

To explain the homogeneity of the Universe on its largest scales it is conjectured that an extremely brief period of exponential expansion (i.e. faster than light) of the Universe occurred within the first second after the Big Bang. The signature of this "inflationary" epoch is imprinted into the cosmic microwave background radiation. This radiation is now evident as the emission from an almost perfectly uniform radiation glow at microwave frequencies. The signal of inflation will be apparent in the structure of polarisation properties of this cosmic background radiation, when measured to an accuracy of approximately one ten millionth of the signal level itself.

- Technology requirements: precision measurements of the polarisation properties of the cosmic microwave background radiation.

- Site requirements: the most stable sky emission backgrounds at microwave frequencies, as found above the Antarctic plateau.

**2. ZETA (Z=20 from Antarctica): searching for the light from the first stars, born at the end of the Dark Ages of the Universe. (Related to *Horizon Scan* Question #70).**

The first stars were born from gas clouds at the end of what we call the Dark Ages of the Universe – a time a few hundred million years after the Big Bang when stars first lit up the Universe. The intense radiation from these stars also heats up and ionises the clouds of hydrogen gas from which they formed. The very brightest emission line from this hydrogen occurs at ultraviolet wavelengths of around 100 nm. "Redshifted" by a factor of about $z = 20$, this radiation should now be detectable at 2 microns wavelength; i.e. in the infrared portion of the spectrum.

- Technology requirements: deep, wide-field, high spatial resolution surveys to image the hydrogen Lyman alpha emission, lit up by the first stars and red-shifted into the infrared.

- Site requirements: the lowest sky background signal in the infrared so as to achieve the highest sensitivities, together with a stable atmosphere to provide for the sharpest imaging. Such conditions are found from the highest places of the Antarctic plateau, a combination of the extreme cold, the stable climate and the low boundary layer.

**3. The Galactic Carbon Trail - finding the dark gas to trace the life cycle of our Galaxy (Related to *Horizon Scan* Question #69).**

The stars and the gas are phases of a continuous life cycle that drives our Galaxy's evolution, with gas clouds collapsing under gravity to form stars, and the enriched chemical products of nucleosynthesis inside these stars returned to the interstellar gas to then be incorporated into another generation of stars. Parts of this life cycle have so far remained hidden, in particular the condensation of clouds of molecular gas out of an atomic substrate. The hydrogen molecules in these clouds are invisible, too cold to emit radiation. The transformations of the gas may be witnessed through following the emission from lines of the element carbon, which are readily excited in the prevailing conditions of interstellar space.

- Technology requirements: Wide-field, spectral line imaging of the neutral and ionised lines of carbon, emitted in the terahertz wavebands from forming gas clouds in the Galaxy.

- Site requirements: the driest locations on the Earth, with the very lowest levels of water vapour through the atmosphere and hence consistently good transparency in the THz windows.

**4. Life in the Universe: imaging exo-solar planets to search for analogues of the Earth (Related to *Horizon Scan* Question #47).**

We currently believe the best chances for the detection of life elsewhere in the Universe will come from finding analogues of the Earth in planetary systems around other stars. To detect the signatures of life from such exo-planets we need first to make direct detections of them, so as to isolate their faint light from their host stars, which are typically more than a billion times brighter. Extremely sharp imaging is necessary, and can only be provided by interferometers – i.e. networks of telescopes whose light is brought together to synthesise the higher spatial resolution available from a much larger telescope. We need first to be able to detect the light from the exo-planets, and then to measure the emission from molecules in their atmospheres to search for bio-signatures that may denote the presence of life.

- Technology requirements: interferometers operating in the infrared and terahertz wavebands, capable of the highest spatial resolution to distinguish the faint light of planets from their host stars.

- Site requirements: extremely stable conditions in both the atmosphere and in the interferometers so as to bring together and combine the planar wavefronts arriving at each individual telescope.

**5. Discovering the origin of the highest energy particles in nature (Related to *Horizon Scan* Question #69).**
A fundamental question in physics is what is the origin and evolution of the cosmic accelerators that produce the highest energy particles that are known in nature. These have energies of up to $10^{20}$ eV. These particles can travel only relatively short distances in space before they interact with the cosmic microwave background and produce ultra-high energy neutrinos. Such neutrinos in turn can then travel virtually unimpeded directly to us from their sources of cosmic origin, and so provide a messenger from the highest energy processes in nature that may be captured by a neutrino telescope.

- Technology requirements: a telescope capable of detecting neutrinos via their interaction with atomic nuclei.

- Site requirements: vast quantities of pure, transparent ice to be used both as a particle absorber, and to allow the unimpeded passage of the radiation from these interactions to detectors.

## II. Extend the current site testing searchable database to become a data portal

The AAA site testing database has been completed, and currently contains over 200 papers searchable via a number of user-specified flags. It provides the framework to allow the straightforward evolution into a “data portal” where data associated with any given paper may be accessed. It will, however, require further resources to ensure the database is up to date and that data links are provided. An example of data which is currently linked to the database is that from the *Nigel* spectrometer in 2009, which is linked to the Sims et al. 2012 PASP publication.

Database: http://www.astronomy.scar.org/WorkingGroupA/scar-db.php

## III. Increase outreach activities directed towards the general public and the international astronomical community, especially in those countries with less developed astronomical programs in Antarctica.

Public interest in astronomy is extraordinarily high. Astronomy is an attractor of young people to science. Many of us have found in our public lectures that astronomy from Antarctica captures a very broad audience. We have not always remembered to include SCAR in the story, but in future we shall be offering our speakers appropriate template slides to ensure that our audiences connect with the big picture of Antarctic research.

Public outreach in astronomy is rich in visual impact, as the pictures from the Hubble telescope have famously shown. However, Antarctic astrophysics has already had some of the highest intellectual impact of any of our 21st century discoveries in astronomy. These include the discovery from a balloon launched from McMurdo that more than 70% of the energy density of the Universe is of an unknown form and that a fossil record, discovered by a telescope at the South Pole, may have been preserved from the first femtosecond of the history of the Universe.

Our top goals for public outreach in the 2015 – 2018 period are to:

- Reach a larger worldwide audience with a message that science is producing new knowledge in Antarctica across a broad front, and,
- Engage our astrophysics and astrobiology colleagues in choosing the most appropriate vantage point from which to collect data to understand the Universe, be it space, Antarctica or temperate site observatories.

Our strategies for achieving these goals are to:

- Publish a brochure on astronomy and astrophysics in Antarctica to reach the broadest possible audience,
- Produce educational materials for teachers on the SCAR AAA program, and,
- Host a SCAR AAA booth at the General Assembly of the International Astronomical Union in August 2015 in Honolulu, Hawaii,
- Create SCAR branding of talk materials, a glossy brochure for distribution at astronomical meetings, and have a significant presence at the 2015 IAU GA and hold an off-site AAA workshop.

An important opportunity to review progress towards these goals will be this Third AAA Workshop in 2015.

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