Opportunities for astronomy from Antarctica: optical/IR/THz

A facility white paper for the Astronomy Decadal Plan Mid Term Review

Michael Ashley / UNSW / 30 September 2019

Australian astronomers are resigned to that fact that Australia has no good sites for optical/infrared/THz astronomy. However, the world's best sites at these wavelengths – *by far* – are within the Australian Antarctic Territory. In the Dome A region of Antarctica the median optical seeing is 0.25 arcseconds (with associated factors of ~2.5 improvement in scintillation noise, coherence time, and isoplanatic angle), the sky background is 50-100 times better than Maunakea at 2.3 microns and 10 times better throughout the mid-IR, and the THz transparency allows operating above 1 THz for more than 70 days per year, compared to just a few days from Atacama. Dome C and Dome Fuji are also excellent sites.

Science overview

The science that is possible from Antarctica is very broad. Any suitably winterised optical/infrared/THz telescope will perform significantly better in Antarctica than at any temperate latitude site. Depending on the details of the observing program, a 2.5 m telescope in Antarctica can rival a 6-8 m telescope elsewhere. Moreover, the cost savings in the telescope and instrumentation, combined with the fact that logistics come for free from national Antarctic programmes, more than offsets the engineering challenges.

Antarctica enables some science that is otherwise only possible from space or from high-altitude balloons or airborne observatories. For example, the superb natural seeing is a game-changer for studies in weak-lensing – while adaptive optics can mitigate poor seeing at temperate latitude sites, it introduces photometric and astrometric distortions. We note as an aside that there are excellent opportunities to leverage Australia's growing expertise in adaptive optics in Antarctica. Antarctica also offers unique 24/7 coverage for transient science such as kilonovae, which is an increasingly important area in astronomy. An ARC-LIEF funded deep 2.3 micron wide-field all-sky survey (KISS) is close to beginning at Dome A, and opens up an unexplored area of parameter space. Wide-field THz surveys are impractical from Atacama, but are easy from Dome A and are complementary to science from ALMA and the Cherenkov Telescope Array. Mid-IR and THz interferometers become possible in Antarctica due to the superb phase coherence of the atmosphere.

How does the science connect with the priorities set out in the Decadal Plan?

All of the science priorities listed in points 1 through 5 in table 7.1 on page 43 of the Decadal Plan are accessible to Antarctic telescopes.

What are the current issues and key risks?

Current issues and risks are (1) the KISS project referred to above is nearing deployment at Dome A; we need infrastructure funding for the operational phase, (2) we have a $3.6 m funding proposal to the ARC (see the costing sections below); if this is unsuccessful, it will be difficult to maintain momentum, (3) the existing optical telescopes in Antarctica are pathfinder experiments that are establishing the framework for major facilities to be funded by China; such funding is highly likely, but not guaranteed; a decision is expected in 2020, (4) Australia has been a leader in Antarctic astronomy since the early site-testing experiments, and it is important to keep our options open now that serious funding is opening up and state-of-the-art facilities are being planned by other countries. Australia can continue to play a leadership role with a very modest funding investment.

What are the synergies with other Decadal Plan priorities?

The Decadal Plan emphasises the **global nature of astronomical science**, and the need for international collaboration. This is certainly true with Antarctic astronomy, and Australian astronomers have excellent collaborations in place with China, France, the US, and Japan. China in particular is planning a large ($450m) expenditure on astronomy at Dome A for a 2.5 m optical telescope, a 5 m THz telescope, and associated infrastructure, with Australian astronomers being close collaborators. The AAO would likely be a prime contractor for optical/IR instrumentation for the 2.5 m telescope. France has plans for expansion at Dome C, with close links to ANU.

Industry engagement and spinoffs are key issues in the Decadal Plan, and our Antarctic work has an excellent track record here. For example, ex-UNSW PhD student Colin Bonner co-founded the company Fulcrum-3D based on his Antarctic instrumentation work; the company has gone on to win three ARENA grants in the area of renewable energy, and exports its products globally.

The Decadal Plan acknowledges the need for a **skilled workforce** – Antarctic astronomy has a track record of producing instrumentalists who have gone on to play key roles in Australian astronomy.

Finally, Antarctic astronomy is specifically mentioned in the Decadal Plan:

"Substantial opportunities exist, at relatively modest investment levels, … and Antarctic facilities for infrared and terahertz observations of distant star-forming galaxies. Australia is a partner in the High Elevation Antarctic Terahertz (HEAT) telescope at Ridge A—the world's pre-eminent THz site, which provides THz data to the Australian community. Additionally, continued Australian involvement in Antarctic astronomy with a focus on current and planned infrared observatories such as AST3 offers strategic links with China."

What is the best engagement model likely to be?

As with almost all new major astronomical facilities, international collaboration is the best model to raise funding. Uniquely, the Antarctic Treaty mandates the sharing of data, which is beneficial to maximising the science outcomes. Australian astronomers are well-placed to be preferred collaborators in Antarctica due to our two decades of experience on the continent, existing networks, and access to telescopes for follow-up observations.

What are the approximate costings - a) for the remainder of the decade; b) 2025+? Indicate the level of (un)certainty.

An ARC SRIEAS proposal (CIs: Ashley, Lawrence, Moore, Travouillon, Wolf, Mould, Glazebrook, Cooke, Guillot) for $3.6 m over 7 years is in the current round, with a decision expected in November 2019. Combined with $1m cash from Australian universities (UNSW, MQ, ANU, and Swinburne) and $1m cash from China, this provides sufficient funding for significant Australian collaboration with China and France at Domes A and C respectively until 2027. If the SRIEAS grant is successful, we will request support at the level of $50K per annum from NCRIS. Over the next 5 years, ARC LIEF proposals are envisaged for new experiments such as a planned Caltech/ANU/UNSW collaboration for a wide-field infrared LIGO follow-up telescope. Beyond 2027, the level of investment is uncertain, and will depend on what has been achieved to that date.

It is important to note that Antarctic astronomy opens up new funding streams through mechanisms such as ARC SRIEAS, the Australian Antarctic Division, and the national Antarctic programmes of our collaborators. Astronomy forms a notable part of the Antarctic Science Decadal Plan, and it would be anomalous if the opportunities were not recognised in the astronomy Decadal Plan.