China’s Kunlun Station is an extraordinarily good site for deep infrared surveys

Michael Ashley
University of New South Wales
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China’s Kunlun Station at Dome A

- Superb seeing (0.31 arcsec median, 500nm at the zenith, see Ma Bin’s talk), with the lowest boundary layer height on Earth (14m median).

- Superbly low precipitable water vapour (and hence excellent transmission throughout the optical, IR, THz, sub-mm and beyond).

- The coldest and highest Antarctic station, with excellent fraction of clear skies.

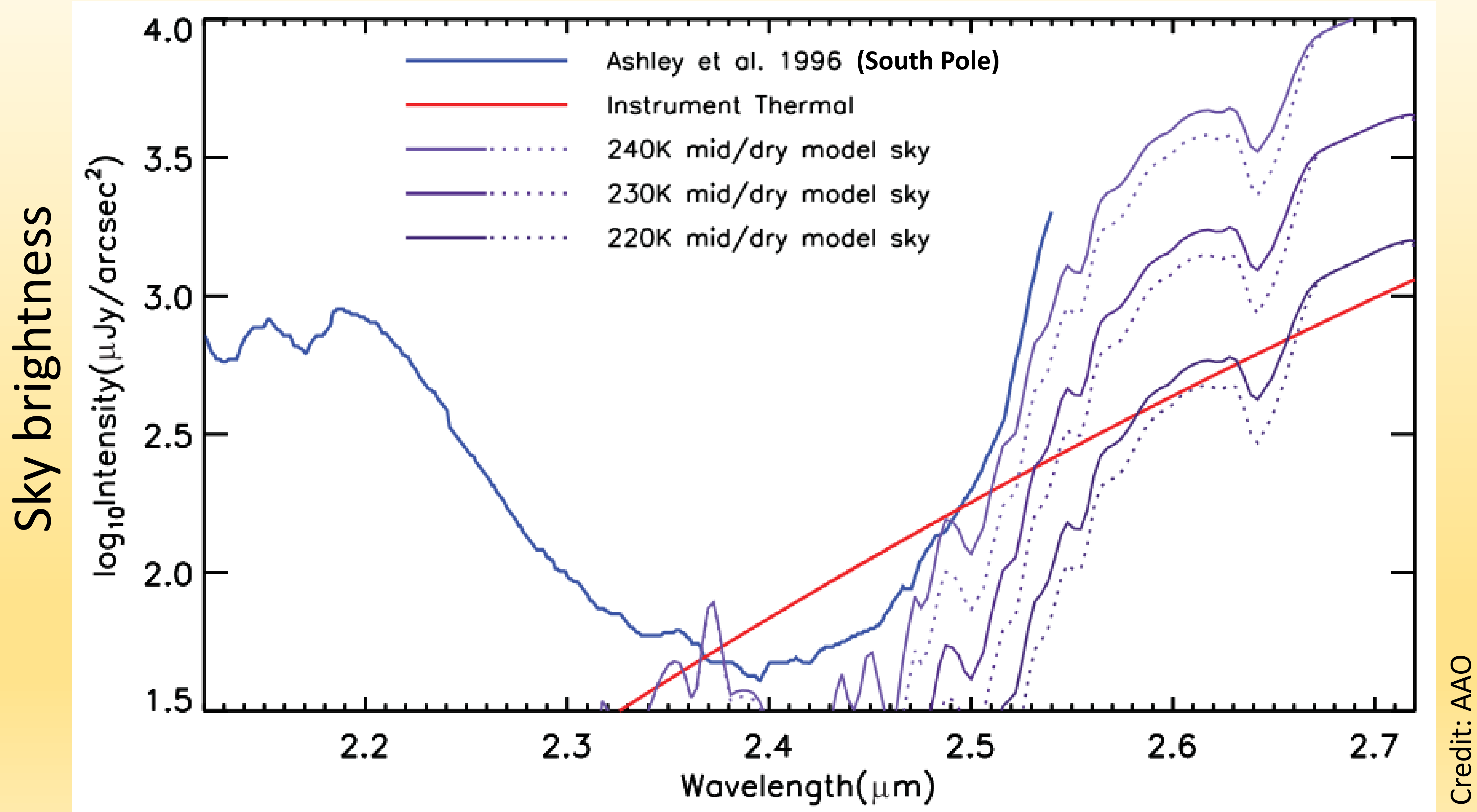
- This makes China’s Kunlun Station ***the best site for an observatory on Earth***, for all wavelengths apart from those close to auroral lines in the optical, and ionospheric noise at radio wavelengths such as 21cm.

- Note: Dome C, Dome Fuji, and South Pole are still excellent sites!

A (biased?) history of near-IR astronomy in Antarctica

- Harper (1989) postulated that the sky would be very dark at 2.4 μm from Antarctica.
- Ashley et al. (1996) and Nguyen et al. (1996) confirmed this with data from South Pole.
- **SPIREX** a 0.6m telescope with a 3-5 μm Aladin array operated at South Pole in 1998-1999 (Fowler et al. 1998).
- Then began a long process of developing science cases and try to raise funding for near-IR Antarctic telescopes. E.g., from ANU the **Polar Stratospheric Telescope**, from UNSW The **Douglas Mawson Telescope**, **PILOT**; from Boston U., a 2-m telescope at South Pole; from Europe & Australia, the **Polar Large Telescope**; from PMO, NIAOT, et al., **KDUST**.
- In 2014, **KISS** was proposed to use the **AST3-3** telescope for a near IR survey.
  - 2015 – the KISS camera was funded by an Australian Research Council LIEF grant (Mould et al.).
  - The KISS Project kick-off meeting, led by Lifan Wang and Jeremy Mould, occurred during the 2015 International Collaboration Meeting on Antarctic Survey Telescopes (AST3), in Hong Kong 2015.
  - China: responsible for telescope hardware and control, logistics, deployment.
  - Australia: responsible for instrument hardware and control, and power generation.

Kdark at 2.4 microns is particularly promising from the Antarctic plateau



KISS: the Kunlun Infrared Sky Survey

KISS is the first near-infrared sky survey longward of H band aimed at time varying objects. These include supernovae, protostars, dying stars and the nuclei of galaxies.

KISS is led by Professors Lifan Wang and Jeremy Mould and is jointly supported by the Chinese Academy of Sciences and the Australian Research Council.

A team of 20 astronomers and engineers is involved from institutions including Purple Mountain Observatory (PMO), the Australian Astronomical Observatory, the Nanjing Institute of Astronomical optics and Technology, Swinburne University, UNSW, ANU, TAMU, UTas and the University of Sydney.

Australian Research Council Infrastructure Grant (LIEF 2015)

Jeremy Mould	Swinburne University
Michael Burton	UNSW, now Armagh Observatory
Karl Glazebrook	Swinburne University
Lifan Wang	Purple Mountain + Texas A&M
Michael Ashley	UNSW
Jon Lawrence	Australian Astronomical Observatory
Peter Tuthill	University of Sydney
Anna Moore	Caltech, now ANU
Michael Ireland	Australian National University
Ji Yang	Purple Mountain Observatory

Australian Government
Australian Research Council

KISS camera specifications

Telescope aperture	0.5 m
Central Wavelength	2.375 µm
Filter Bandpass	0.23 µm
Wavelength Range	2.26-2.49 µm
Delivered Image Quality	1.35” (diffraction + seeing + tolerance)
Pixel Scale	1.35”/pixel
Focal ratio	f/4.5
Camera FOV	28.1’ × 46.1’ (0.36 sq deg)
Detector Pixels	2 x 1280 x 1032
Pixel Size	15 µm
Read noise	9e- (Fowler), 30 e- (CDS)
Sky background	17.0 mags/arc^2, 100 uJy/arc2
Background limited exposure time	228 secs
1 sigma 30 x 2 secs	18.2 (Vega)
10 sigma 1 hour	21.4 mag
Saturation limit in 60 secs	10.7 mag

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Scientific Goals of the Kunlun Infrared Sky Survey (KISS)

Michael G. Burton[1,2,11], Jessica Zheng[3], Jeremy Mould[4,5], Jeff Cooke[4,5], Michael Ireland[6], Syed Ashraf Uddin[7], Hui Zhang[8], Xiangyan Yuan[9], Jon Lawrence[3], Michael C. B. Ashley[1], Xuefeng Wu[7], Chris Curtin[4] and Lifan Wang[7,10]

[1]School of Physics, University of New South Wales, Sydney, NSW 2052, Australia
[2]Armagh Observatory and Planetarium, College Hill, Armagh, BT61 9DG, Northern Ireland, UK
[3]Australian Astronomical Observatory, 105 Delhi Road, North Ryde, NSW 2113, Australia
[4]Centre for Astrophysics and Supercomputing, Swinburne University of Technology, PO Box 218, Mail Number H29, Hawthorn, VIC 3122, Australia
[5]ARC Centre of Excellence for All-sky Astrophysics (CAASTRO), Sydney, NSW 2006, Australia
[6]Australian National University, Canberra, ACT 2611, Australia
[7]Purple Mountain Observatory, Chinese Academy of Sciences, 2 West Beijing Road, Nanjing 210008, China
[8]School of Astronomy and Space Science, Nanjing University, Nanjing 210008, China
[9]Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, 188 Bancang Street, Nanjing 210042, China
[10]Texas A&M University, College Station, Texas 77843, USA
[11]Email: M.Burton@unsw.edu.au

Examples of possible survey cadences, areas, depths for KISS

Table 3. Parameters for sample survey programmes.

Cadence	Samples per winter	Integration time (s)	Camera fields	Area covered (deg^2)	3σ sensitivity (mag)
1 h	2 000	1 min	6	3.5	16.5–17.9
1 d	100	1 min	144	85	16.5–17.9
1 week	12	1 min	1 008	600	16.5–17.9
1 month	4	1 min	4 320	2 600	16.5–17.9
1 d	100	9 min	16	9	17.5–19.0
1 week	12	9 min	112	66	17.5–19.0
1 month	4	9 min	480	280	17.5–19.0
1 d	100	1 h	2.4	1.4	18.7–20.2
1 week	12	1 h	17	10	18.7–20.2
1 month	4	1 h	72	43	18.7–20.2

Cadence is the time between return visits to each field. Camera fields is the number of fields that would be surveyed in one winter season, with the corresponding areal coverage listed given the camera FOV. The range in 3σ sensitivity reflects the extrema in observing conditions at Dome A, as discussed in Section 3. Each survey is assumed to use 10% of the available observing time over the Antarctic winter. An integration time of 1×60 s per frame is taken. Sensitivities if 30×2 s were taken instead would be reduced by 0.4–1.0 mag.

From Burton et al. (2016), for the original H2RG detector; for the Leonardo detectors, the area covered should be multiplied by 0.6.

AST3-NIR Camera Exposure Time Calculator

KISS Camera Exposure Time Calculator

Target flux distribution:
- Object magnitude: 18.5
- Observation Wavelength(um): 2.375

Target geometory:
- Target geometory: Point source

CCD parameters:
- Pixel size(um): 18
- Dark current(e^-1/s): 1
- Read noise(e^-1/s): 3
- Quantum_efficiency: 0.7
- Full Well Depth: 80000
- SNR(defined by user): 10
- Exposure time(s,defined by user): 300

Sky conditions:
- Seeing(arcsec): 0.5
- Sky background Mag : 16.89

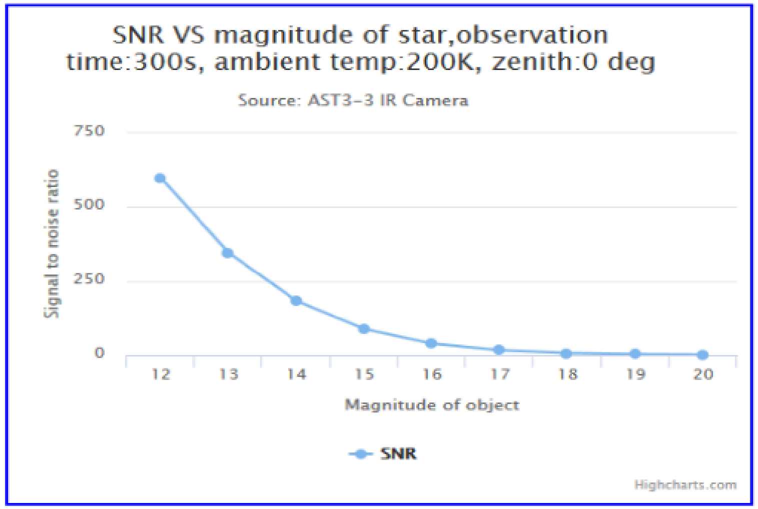
Instrument setup:
- Start wavelength(um): 2.25
- Stop wavelength(um): 2.5
- Ambient temperature(k): 200
- Zenith distance(degree): 0

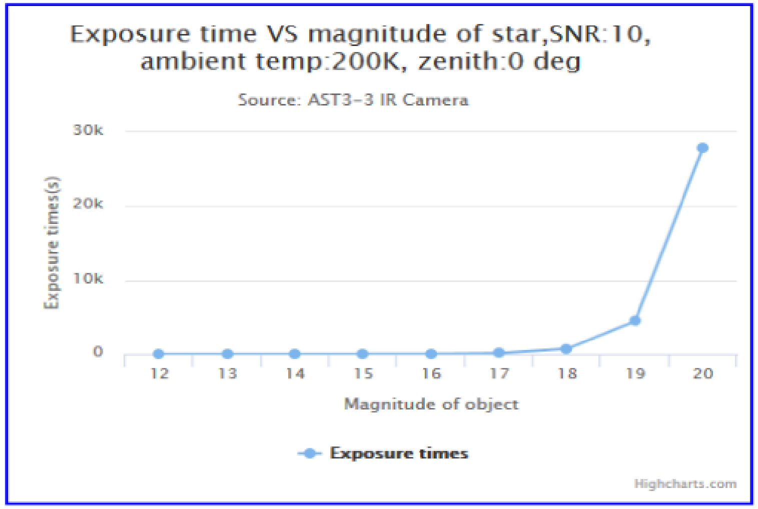
Calculation results

Results:

Calculate

- Photons from object(/s): 3.467
- Photons from sky(/px/s): 27.838
- Photons from thermal(/px/s): 1.030
- Exposure time(s, At Given SNR): 1785.913
- SNR(At Given Exposure Time): 4.097
- Max exposure time(s, Half of Full well depth): 1317.278





http://newt.phys.unsw.edu.au/~mcba/ETC_WebModel/TELESCOPE.html

AST3-3 on its near alt-az mount, with the KISS camera and support electronics.

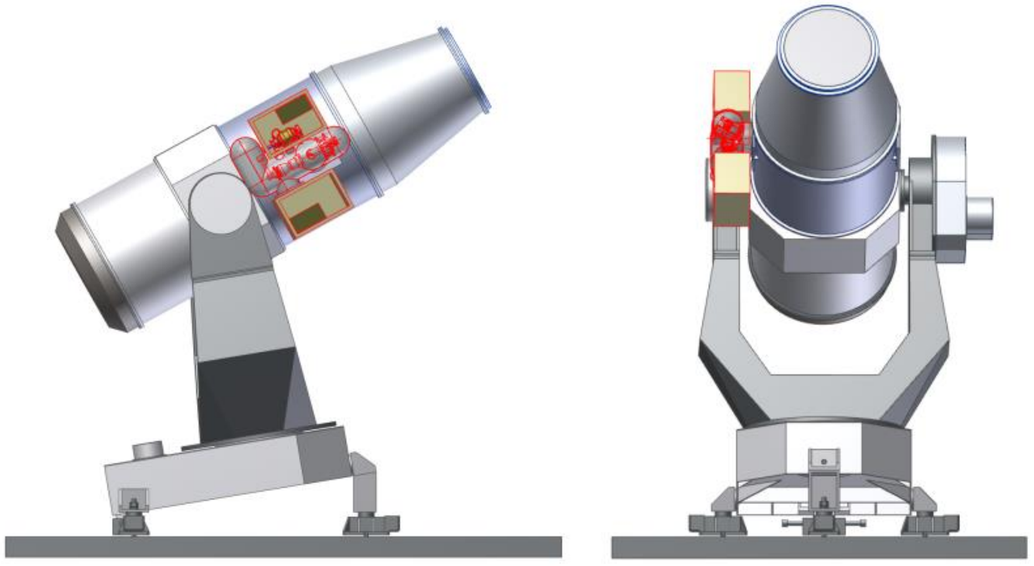
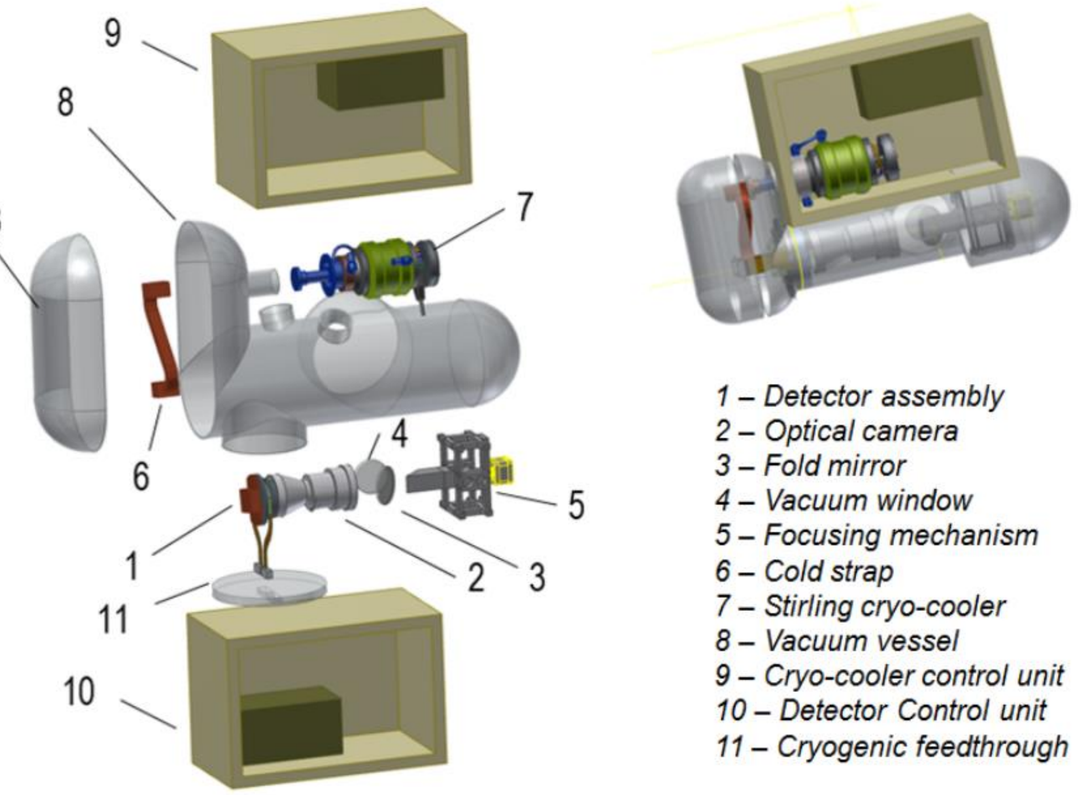


Figure 5. Instrument mounted to the side of the telescope tube.



Credit: AAO

The AST3-3 is now commissioning at Yaoan Observatory in Yunnan province. Preliminary results indicate that the telescope optics are excellent. See the talk by Xiaoyan Li.

The KISS camera will be mounted where the grey box is.

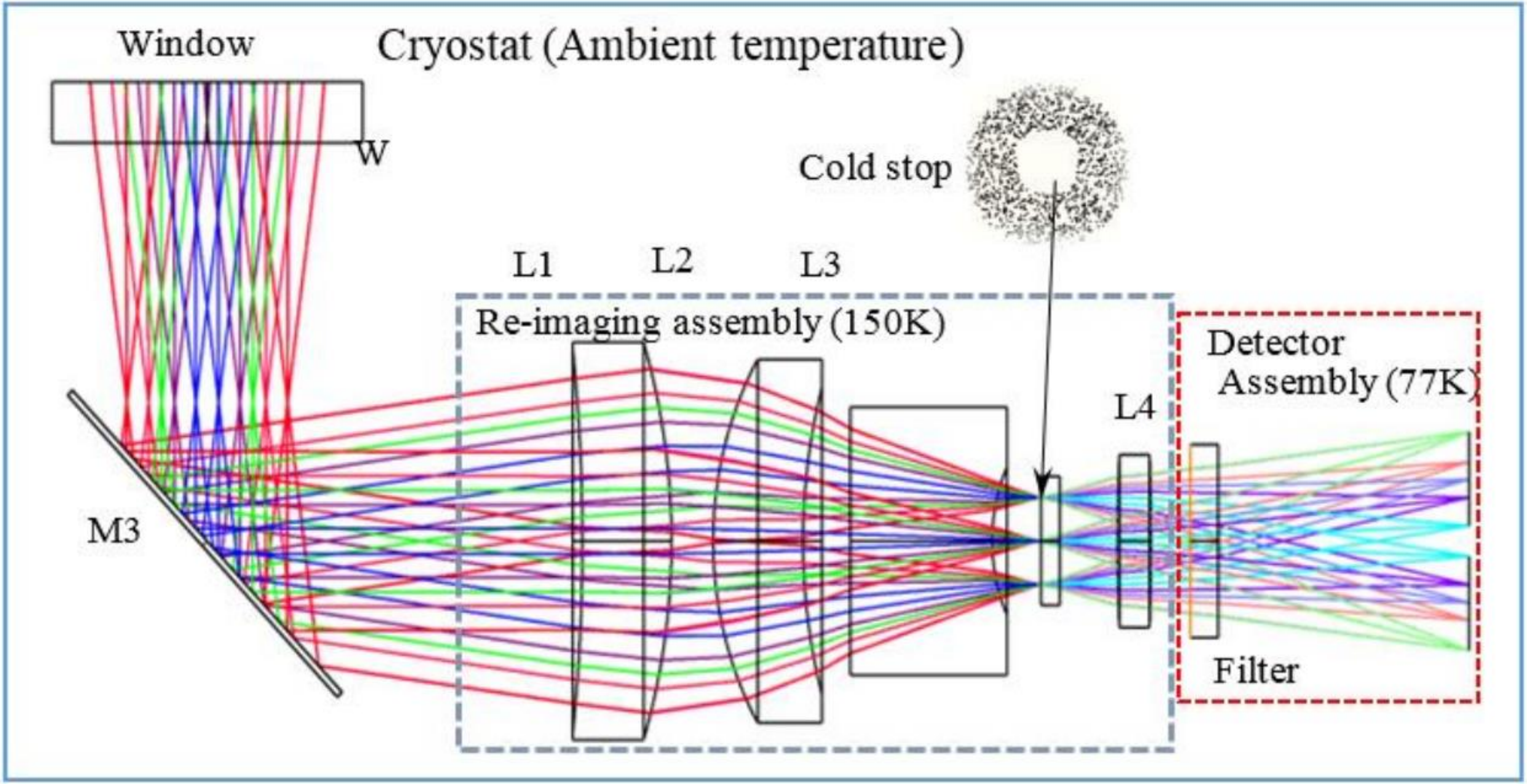
Credit: Xiaoyan Li, NIAOT

The AST3-NIR Camera for the Kunlun Infrared Sky Survey

Jon Lawrence*[a] Michael Ashley[b], Michael Burton[b], Xiangqun Cui[c], Vladimir Churilov[a], Robert Content[a], Peter Gillingham[a], Karl Glazebrook[d], Bozhong Gu[c], Michael Ireland[e], Xiang Jiang[c], Haiping Lu[c], Anna Moore[f], Jeremy Mould[d], Nicholas F. Staszak[a], Julia Tims[a], Peter Tuthill[g], Lifan Wang[h,i], Xiangjan Yuan[c], Kaiyuan Zhang[c], Ross Zhelem[a], Jessica Zheng[a]

[a]Australian Astronomical Observatory, North Ryde, NSW 2113, Australia; [b]School of Physics, University of New South Wales, Sydney NSW 2052, Australia; [c]Nanjing Institute of Astronomical Optics and Technology, National Observatories, Chinese Academy of Science, Nanjing 210042, China; [d]Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorn, VIC 3122, Australia; [e]Research School for Astronomy & Astrophysics, Australia National University, Canberra ACT 2611, Australia; [f]Caltech Optical Observatories, California Institute of Technology, Pasadena, CA 91125, USA; [g]School of Physics, The University of Sydney, NSW 2006, Australia; [h]Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, 210008, China; [i]Department of Physics, Texas A&M University, College Station, TX 77843-4242, USA

The optical layout of the KISS camera



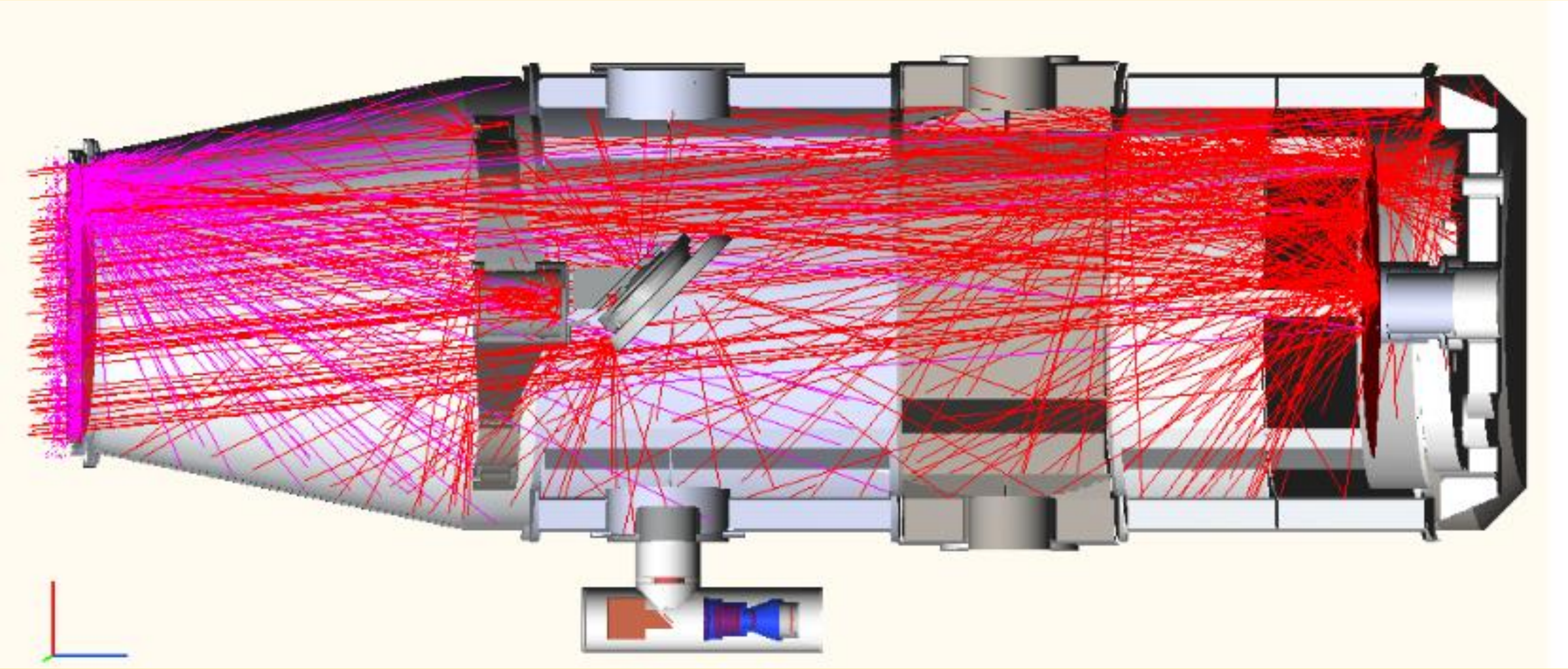
CryoTel® GT

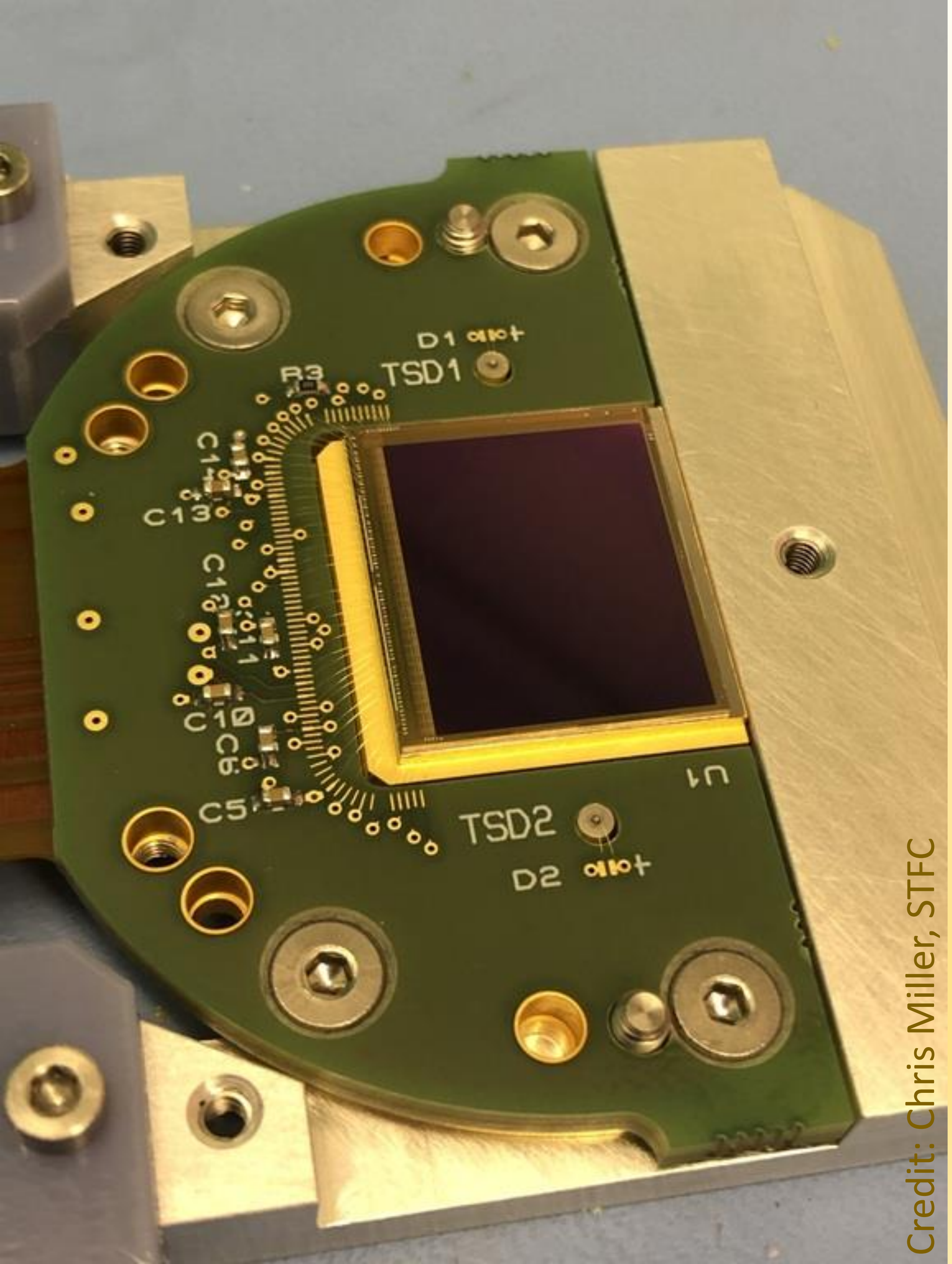
16W Cryocooler

Nominal Lift @ 77K (23° C reject)	16 W
Nominal Input	240 W
Cooler Mass	3.1 kg
Temperature Stability	+ 0.1K
Power Supply	DC 48V
Overall Length	275.5 mm
Outside Diameter	83 mm
Lowest Temperature	40 K
Orientation	any
Operating Frequency	60 Hz
MTTF	200,000 hrs

The AAO has produced a superb optical design for the camera

The figure below shows a model of the scattered light



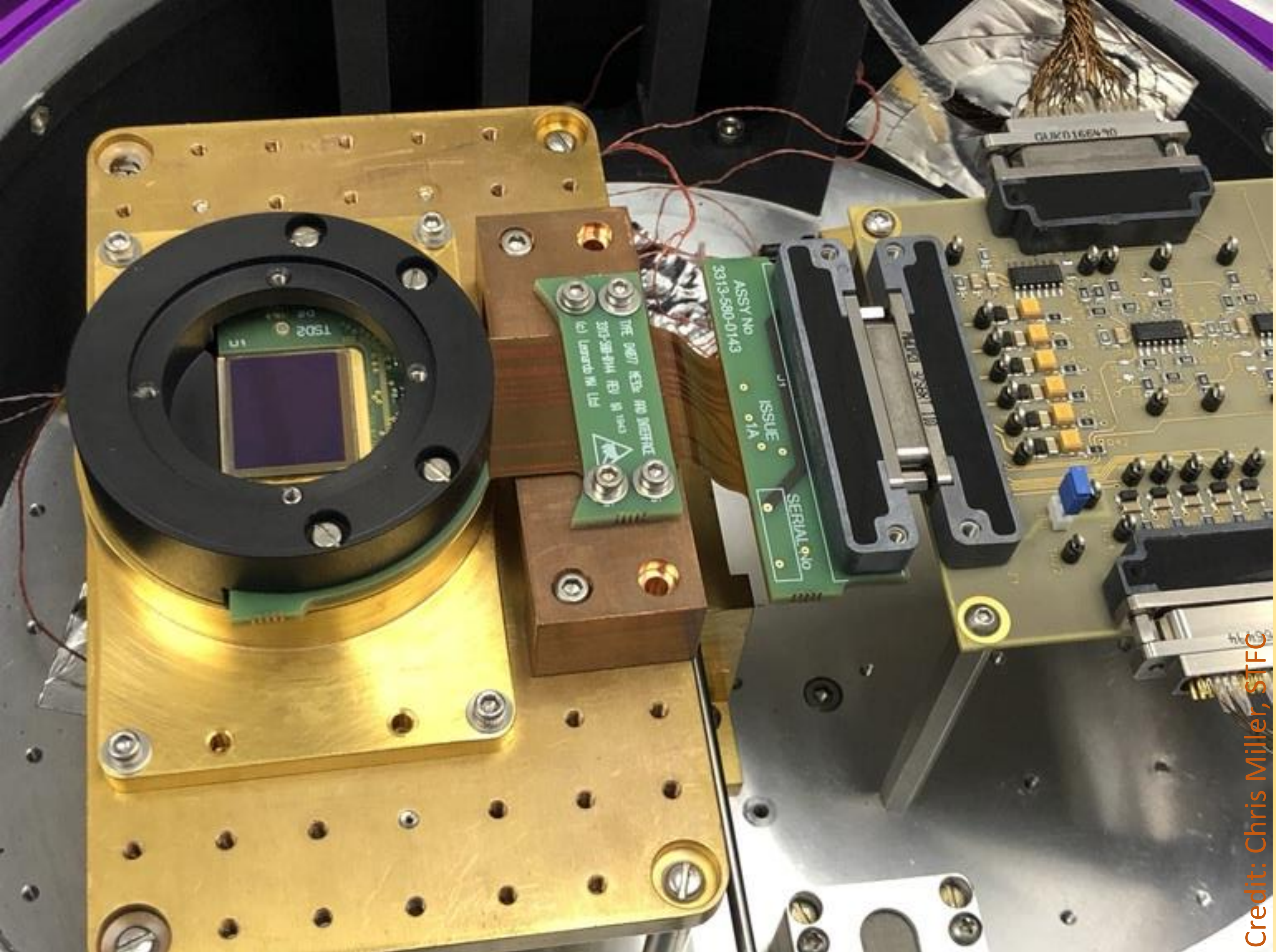


Credit: Chris Miller, STFC

The Leonardo MCT array detector. One of two in the KISS camera.

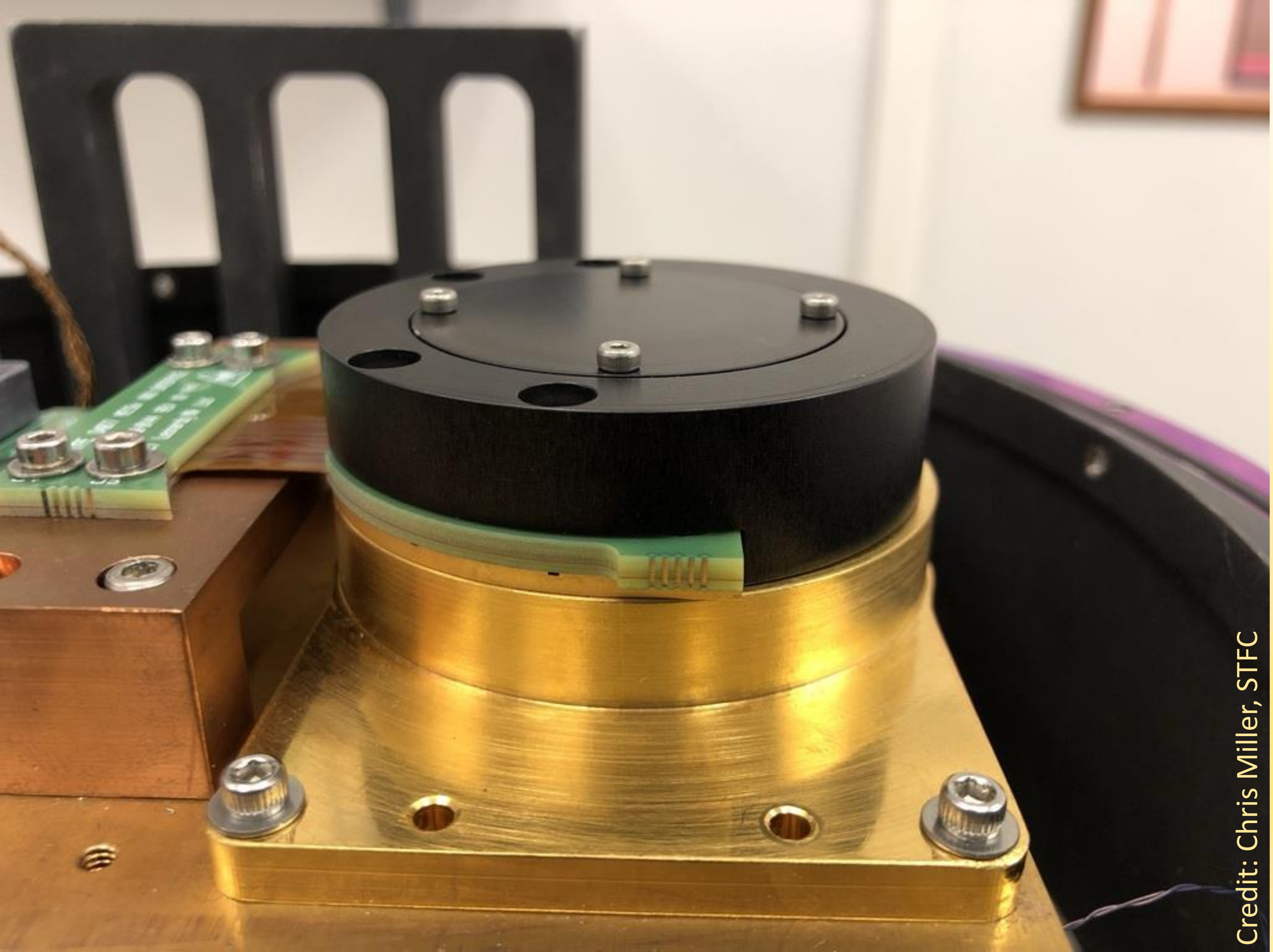
Our original choice for the detector was the H2RG, but despite not being on the ITAR list, we found it impossible, after two years of negotiations, to export it to China.

So we moved to the Selex (now Leonardo) detector, which has similar properties, although the dark current isn't quite as good.

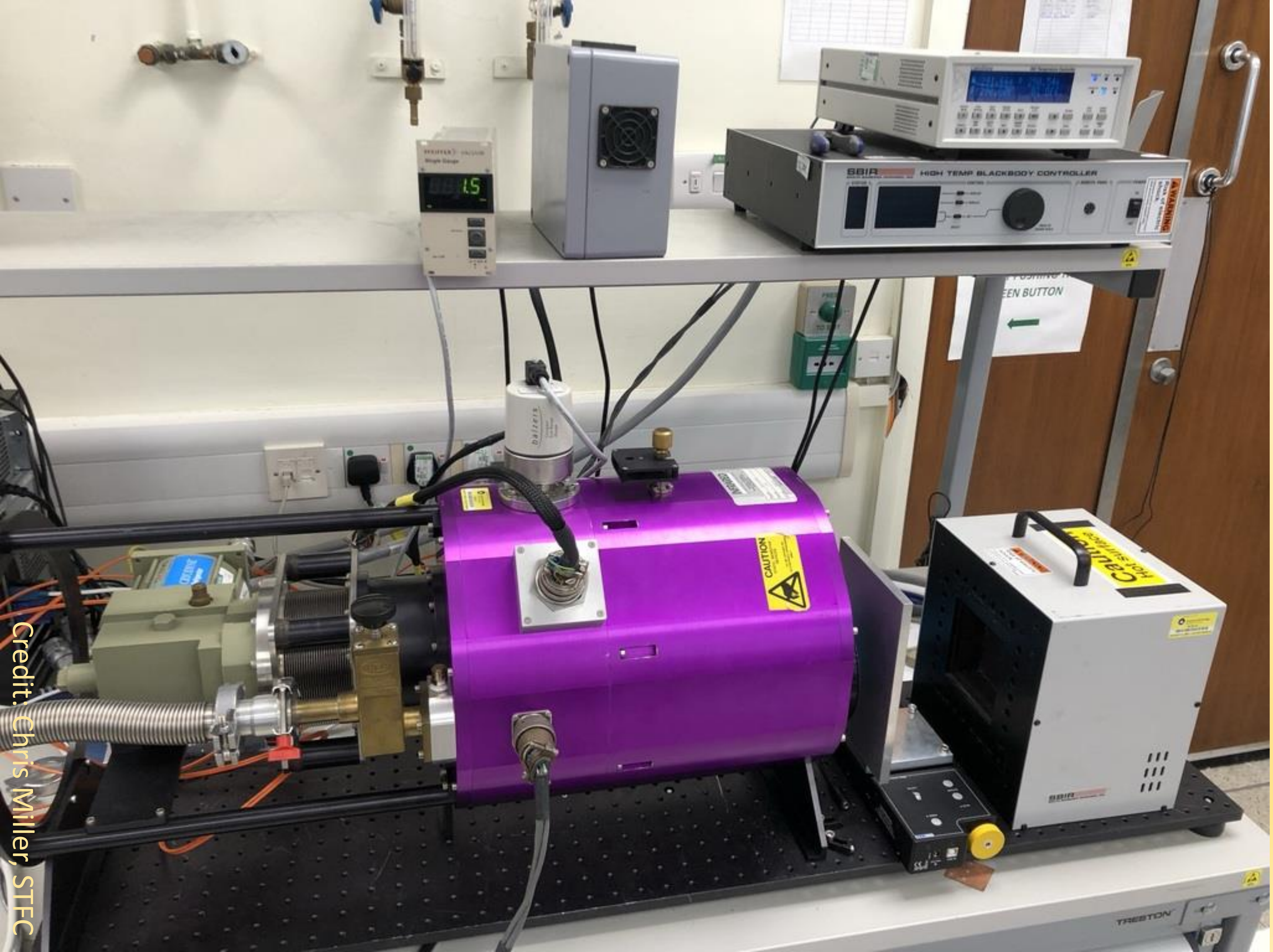


Credit: Chris Miller, STFC

The detector in the test cryostat, at UKATC in Edinburgh.



The setup for dark current measurement at UKATC in Edinburgh.



Credit: Chris Miller, STFC

The detector test setup at UKATC in Edinburgh.

UNSW: Ashley and Chen are working on the KISS cryostat control electronics, power supplies, and communications

- We have proven electronic solutions that can power up and operate at −80°C.
- We have proven software and communications that are reliable and requires no human intervention on site.
- We are exploring the use of Elon Musk’s ***Starlink*** ground terminals, which would be a game-changer for returning data from Antarctica – 20 Mbps upload speed.

Current status of the KISS project, September 2021

Telescope (NIAOT)

- Completed.
- Now commissioning at Yaoan Observatory.

Cryostat (AAO)

- All optics have been delivered.
- A minor amount of work is required to finalise the mechanical design.
- Almost ready to manufacture.

Detectors (UKATC)

- Have tested three devices against the specification.
- Just about to start full characterisation of the AAO devices.

Control electronics and power supplies (UNSW)

- Initial design complete.
- PCB boards and parts arrived last week.
- Prototype being constructed now.

KISS and its competitors

Project	Bands	Pixels	FOV	Collecting area	Site	Countries	Status
KISS	Kdark	2.6 M	0.36 sq deg	0.5m circle	**Dome A**	**China**, Australia	2-3 years from deployment
Gattini-IR	J	x 1.5	x 70	x 0.36	Palomar	US, Australia	Operating
DREAMS	Y, J, H	x 3	x 10	x 1	Siding Spring	Australia, US	Funded, under construction
WINTER	Y, J, H	x 4.5	x 3.3	x 4	Palomar	US	Commissioning
IceDrake	Kdark	x 220	x 130	x 5.8	Dome C	US, France, Australia	Pathfinder experiment (Cryoscope) funded
KDUST	Optical/IR	?	x 11	x 25	**Dome A**	**China**	Proposal

Note: See https://docs.fritz.science for information on the Fritz Marshal – very impressive open source software used by the Zwicky Transient Factory and the Vera Rubin Observatory for helping with transient object analysis.

Conclusion

- KISS is close to being ready to deploy to Dome A.
- KISS would realize a 27 year (!) old dream for a Kdark telescope in Antarctica.
- China's Kunlun Station is the best location on Earth for such a telescope.

- ***Concern:*** *2021/22 will be the third year in a row with no traverse to Dome A.*