



# Gaia Futures: GaiaNIR NearIR Detector Studies



Nicholas Walton

Institute of Astronomy, University of Cambridge

Airbus Space  
ESA/Gaia/DPAC



# What follows? Into the centre of the Milky Way GaiaNIR & ESA Voyage 2050

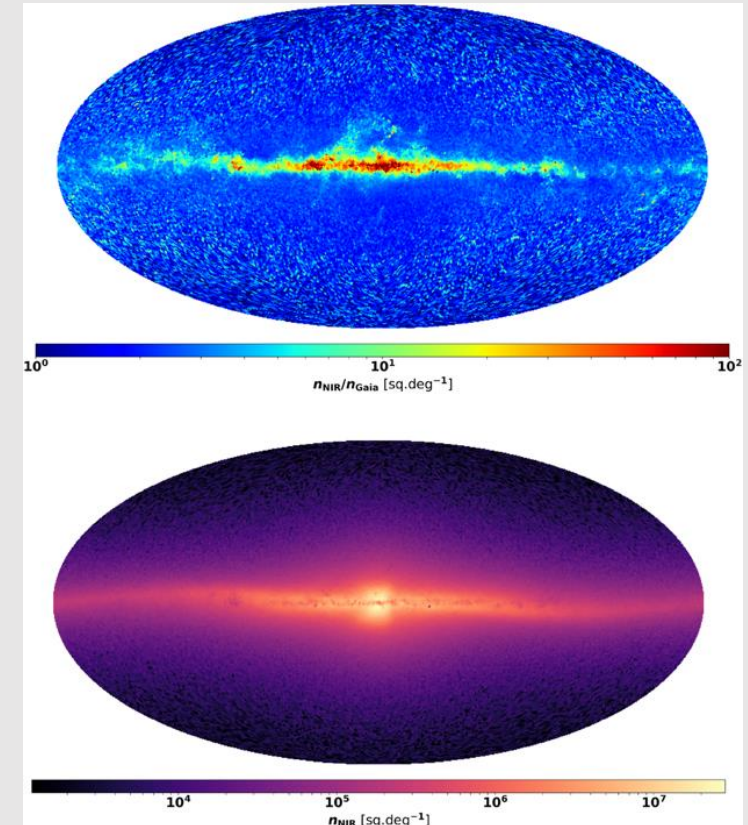
- Gaia like mission extending to the near infrared – probes x5 Gaia sources – implies > 50 Billion sources
- Three key science goals:
  - ▶ Penetrate dust obscured of the Milky Way to reveal the Bulge and Disk to disentangle the formation history of our Galaxy
  - ▶ Combine with Gaia data to increase the proper motion baseline to probe the outer regions of our galaxy
  - ▶ Maintain the Celestial Reference Frame and explore the fundamental physics of gravitational waves
- Key technical challenges include the development of InfraRed detectors

**A transformational L-class ESA Space mission**

See David Hobb's talk earlier in this meeting

## Voyage 2050

Final recommendations from the Voyage 2050 Senior Committee



Credit: Hobbs et al 2020

Gaia observes the visible sky in the optical, but to see through the dust to where the bulk of the stars are, we need the near IR!



# Near-IR Detector Challenge

- Earlier ESA CDF study for a GaiaNIR M size mission envisaged large format HgCdTe devices operating in traditional 'stare' mode
  - ▶ This required field de-rotation optics to allow GaiaNIR to operate a Gaia-like scanning law
  - ▶ Added complexity, risk and cost to the baseline mission design
- Considered a range of detector technologies
  - ▶ A hybrid detector HgCdTe layer bump bonded to a Si CCD – technology is challenging
  - ▶ Ge is very promising - scaling to large format arrays – but  $\lambda$  limited to  $\sim 1400$  nm
  - ▶ MKIDs - scaling to large format arrays – but active cooling needed
- Decided to study feasibility of HgCdTe Avalanche PhotoDiodes (APDs) with 'TDI like mode' signal processing technology



# GaiaNIR and the UK: NSTP Study Programme: 2021/22

(Cambridge, Durham, Leonardo, MSSL-  
UCL, UKATC)

From the Initial UK Study Kick-Off meeting: Dec 2021

‘This study will develop the capability of the UK technology and academic sector in taking leadership positions in a candidate mission concept for an ESA Large (L-class) mission as part of its upcoming Voyage 2050 programme.

- Payload (nearIR detectors), Data, Science
- Plan the future development roadmap
- Timely: next down-select in ~2024/25’

# UK NSTP Study Programme Outcomes: 2021/22

## Key Study Outputs

WP1: Science → identified key cases and fed through requirements

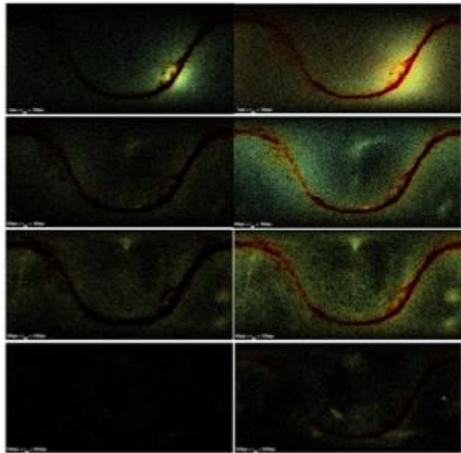
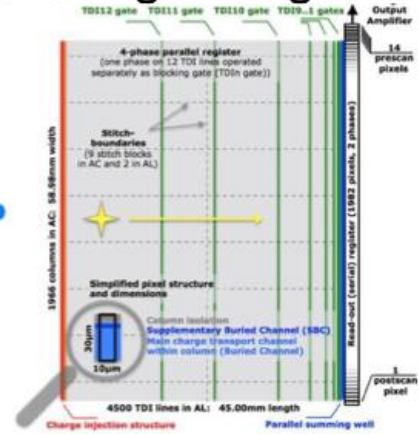


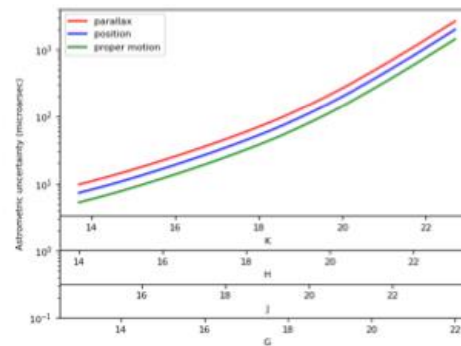
Fig 1 All-sky maps for halo stars in Auriga-6. The left panels are Gaia mocks, and the right are GaiaNIR. Each row shows a different range of Galactocentric radius, from the inner to the outer halo.

WP2: Detectors → TDI mode feasible over much of the required wavelength range



Schematic view of a Gaia CCD detector. Stars move from left to right as the along-scan direction (yellow arrow). Charges in the readout register are clocked from bottom to top. The first line of the CCD (left) contains the charge-injection structure (veto). The last line of the CCD before the readout register (right) contains the summing well and transfer gate (veto). Charges, grey lines indicate stitch-block boundaries. Solid, green vertical lines indicate TDI gates (the three longer lines are selected at the top of the CCD). The inset shows some details of an individual pixel. See Sect. 3.2.2 for details.

WP3: Data → process to improve crowded field object handling/ assessment of errors in astrometry



GaiaNIR:UK NSTP Closeout Meeting

30 Mar 2022

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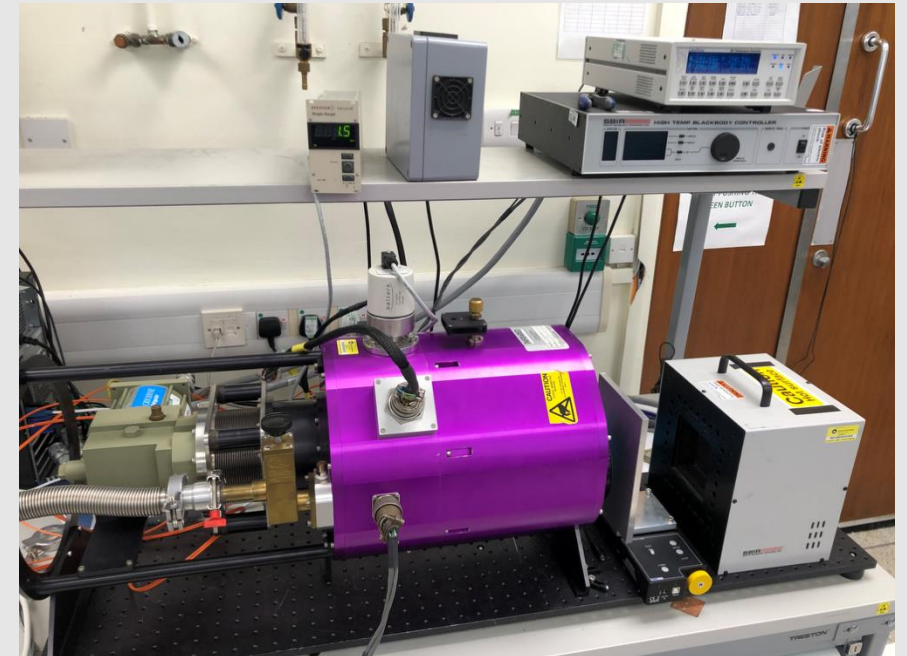
- Science assessment: no significant requirement <800nm
- Detectors: explore photon counting APDs in 'TDI-like' mode of operation
- Data: model on Gaia architecture. Assessment of crowding and on-board processing

Science cases taken from the Hobbs et al, Voyage 2050 white paper: Experimental Astronomy, 2021  
<https://doi.org/10.1007/s10686-021-09705-z>

# GaiaNIR Detector Studies in the UK

See Rob Wilson's talk  
earlier in this meeting

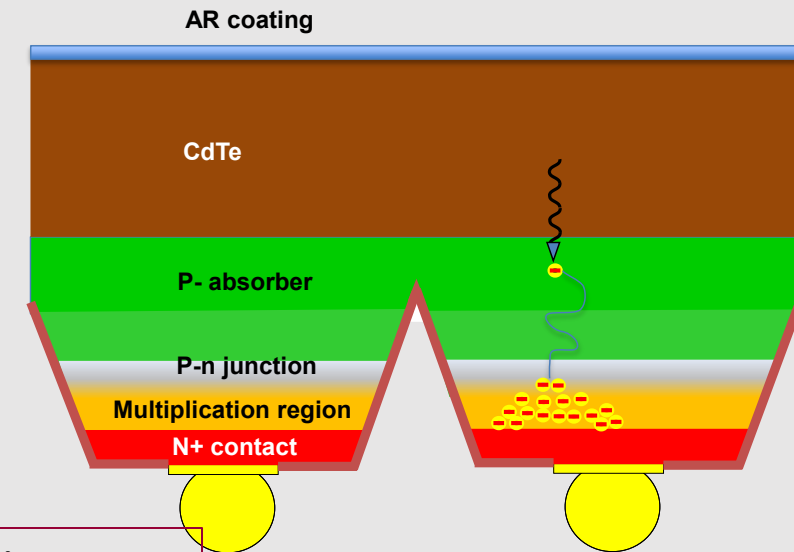
- Following on from the initial UKSA NSTP study
- Characterise Linear Mode Avalanche Photon Detectors (APD) as the IR detector operating in a 'TDI' like mode now being studied (Leonardo, Cambridge, UKATC, UCL/MSSL)
  - ▶ ESA CTP funded study (18 months: 2024-2026) now underway to carry out evaluation of physical devices
  - ▶ Requirements review: Sep 2024
  - ▶ Test Readiness review: Dec 2024
  - ▶ Mid Term review: Aug 2025
  - ▶ Final review: Jan 2026
- Initial results (e.g. 'read noise') indicate performance likely suitable for GaiaNIR





# GaiaNIR Detector Studies in the UK

- Range of Saphira devices being tested at both Leonardo and UKATC
  - ▶ four MOVPE devices with range of p-n band gaps
  - ▶ Comprehensive characterisation of each device, e.g. ...
  - ▶ Gain, Linearity, QE and QE stability
  - ▶ Read Noise, Dark Current
  - ▶ Persistence, Cross Talk
- Initial analysis of detector size (pixel and number of pixels), FPA packaging, optimisation of large-scale array configurations
- Generation of performance model
- Current ESA CTP study to complete Jan 2026
- Outcome: confirm feasibility of APDs for a GaiaNIR mission.



Credit:  
Leonardo:  
see Rob  
Wilson's  
presentation  
yesterday  
15/7/25

