Sensors for cosmology

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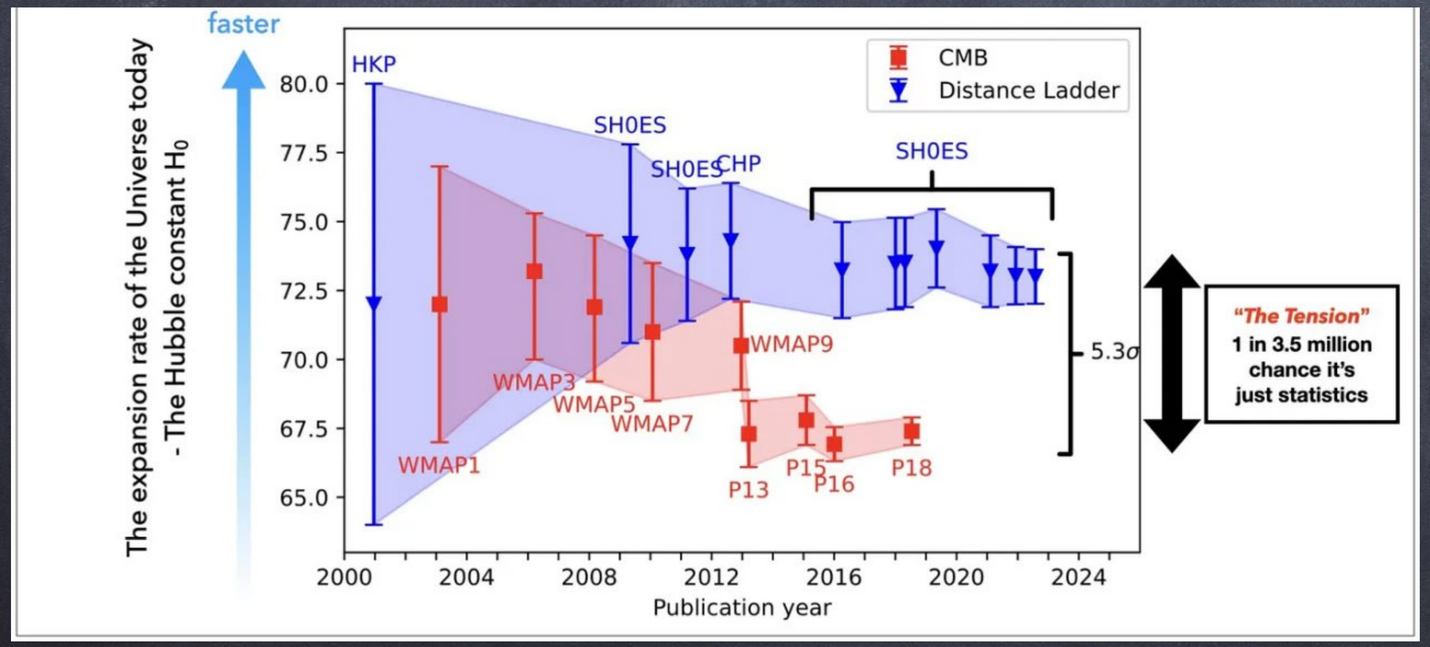
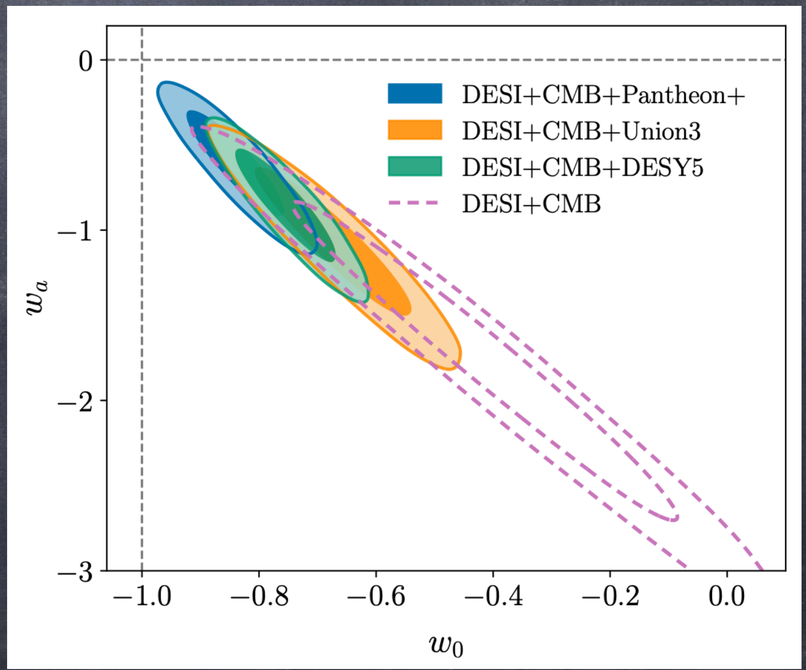
Why ?

- Critical questions in cosmology : dark energy and cosmological principle
  - need <u>precise</u> measurement of universe expansion and of isotropy
  - measured using redshift -> **spectroscopy** !

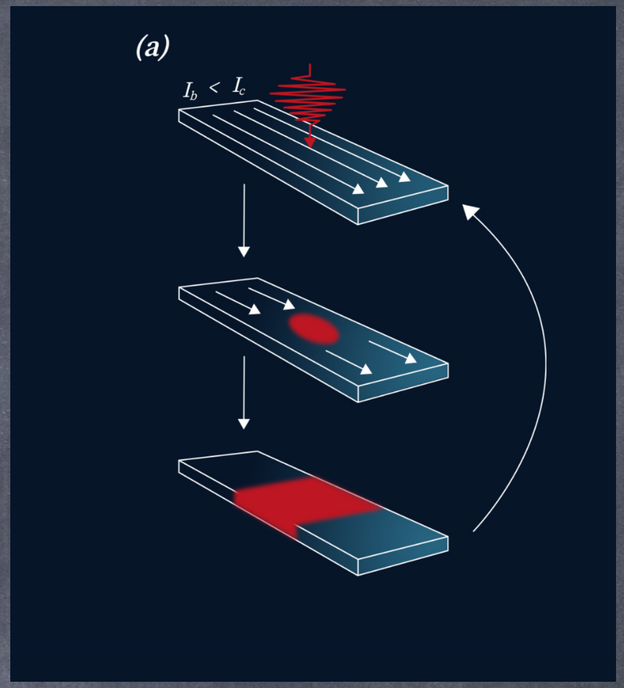
- **Need very precise spectroscopy of very far (faint) galaxies**

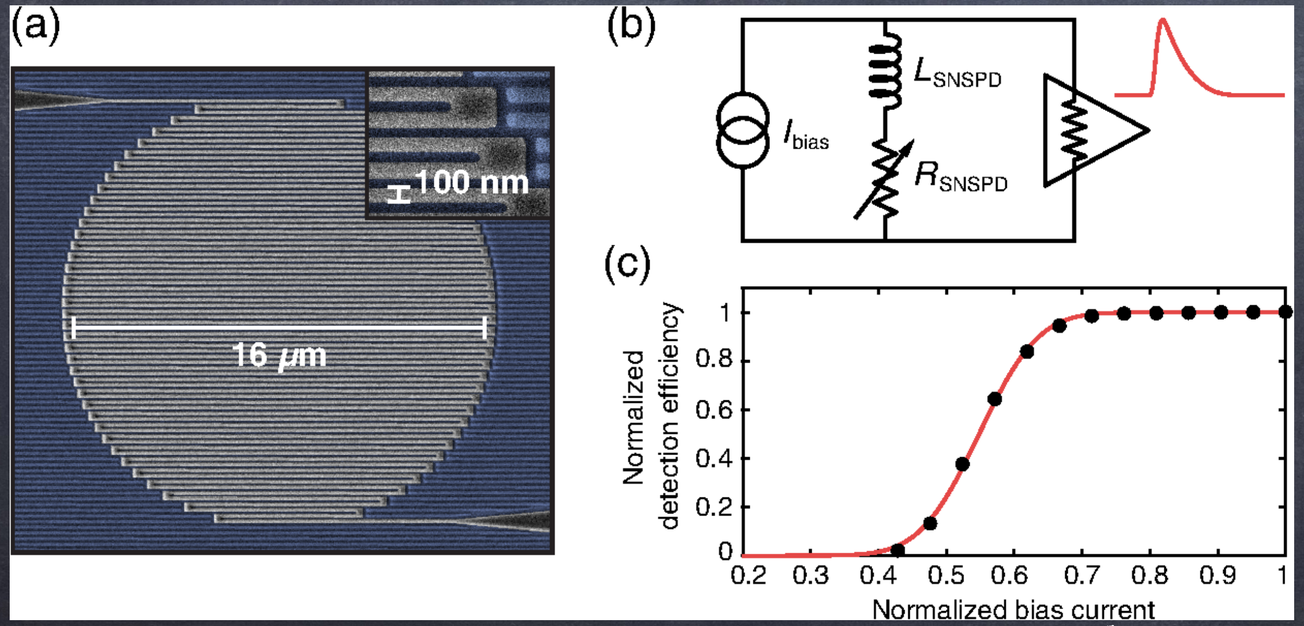


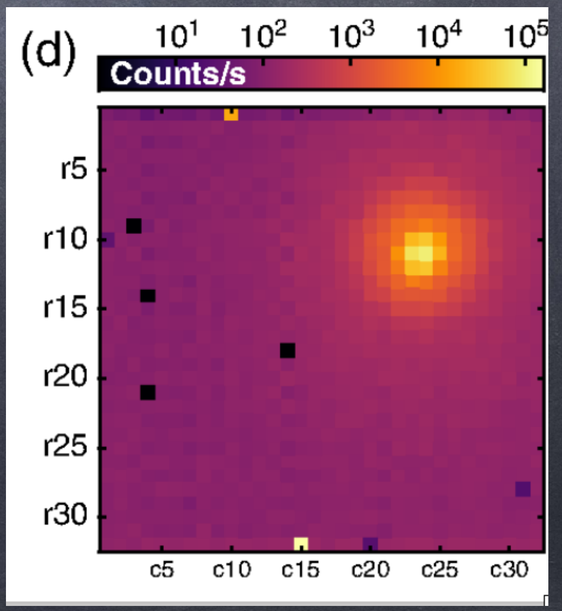


SNSPD

- Superconducting nanowire Single photon detector
- young techno (2005)







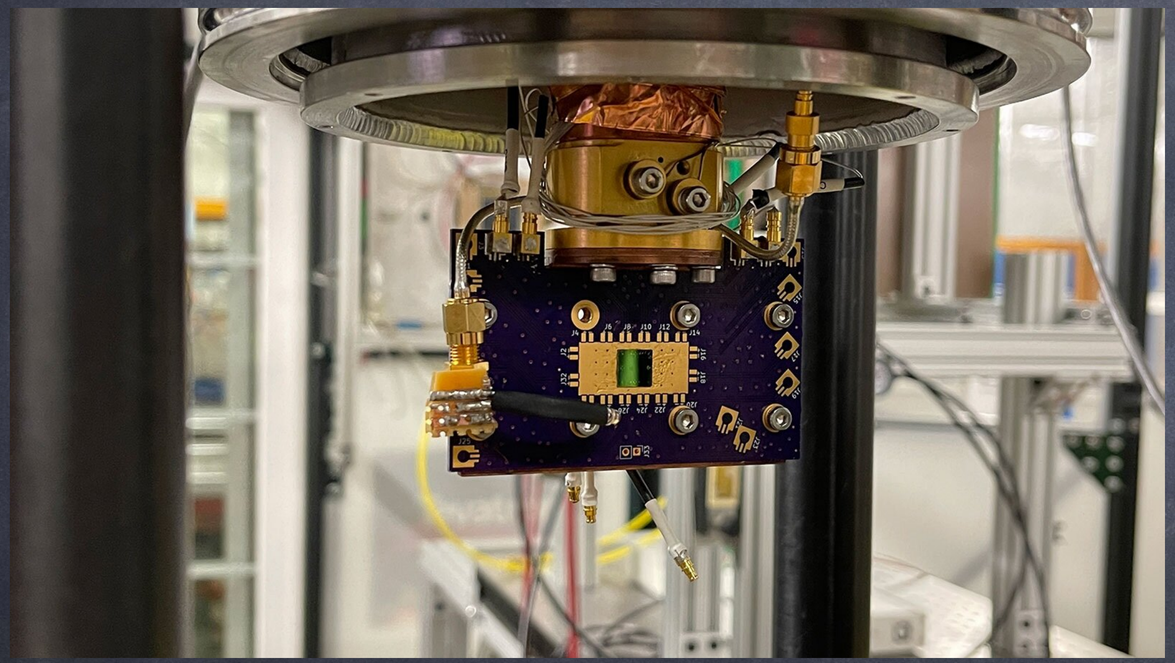
Advantages

- output signal essentially digital (stability)
- from UV to near-infrared (for now)
- System detection efficiencies > 90%
- ultra fast: <100 ps for the system to come back to initial state
  - 2 to 4 orders of magnitude faster than detector like MKIDS (microwave kinetic inductance detectors) or for TESs (transition edge sensors)
- uncertainty in the photon arrival time ~3 ps (visible wavelengths)
- maximum count rates of a few MHz

SNSPD use

- dark-matter search : link
- exoplanet search: link (identify elements in the atmospheres)
  - element search (Origins Space Telescope)
- high-energy protons detection (EIC): link
- and also : quantum cryptography, advanced optical sensing (precision measurement using light), quantum computing, deep space communication

Example: Proton detection



- Close-up view of a SNSPD mounted on a printed circuit board inside the cryostat at the Fermilab Test Beam Facility.
- This device was used in the first successful demonstration of high-energy proton detection using SNSPDs.
- Credit: Sangbaek Lee/Argonne National Laboratory

Limitations (for now)

- young technology
  - most technology development has been focused at telecom wavelengths (visible, near infrared)
- Size (max = 64 pixels !)
- performance worst (unknown ?) for mid-infrared

Visit of IDQuantique

- https://www.idquantique.com/ (Geneva)
- Meeting with Jeremie Diboine and Félix Bussières on Thursday April 3rd

Key Features

System characteristics:

- Fully autonomous 24/7 continuous operation
- Plug-and-play installation
- Web UI for remote operability
- Compact, 8U form factor with up to 16 detectors in one system
- Rack-mounted vacuum pump and compressor options available
- Optional: Advanced time-tagging, coincidence filtering and delay/pulse generation with the ID1000 Time Controller

Detector performance:

- Near-perfect detection efficiency
- Ultra-low noise: as low as < 1 cps dark count rate
- Superb timing precision with built-in cryogenic amplifiers
- Hardware-based true latch-free operation at any detection rate
- High count rates: ultrafast detectors with maximum detection rates above 200 Mcps for parallel devices, and above 1 Gcps for multi-pixel devices
- Up to 16 detectors, upgrade any time

Innovation highlight:

- Industry-leading photon-number resolution and ultrafast detection
- High efficiency down to 600 nm and up to 2 µm
- Detectors with > 80% system detection efficiency and < 10 cps (or less count rate at 1550 nm

IDQ's promise:

- Reliable and robust performance, with worldwide round-the-clock tech support

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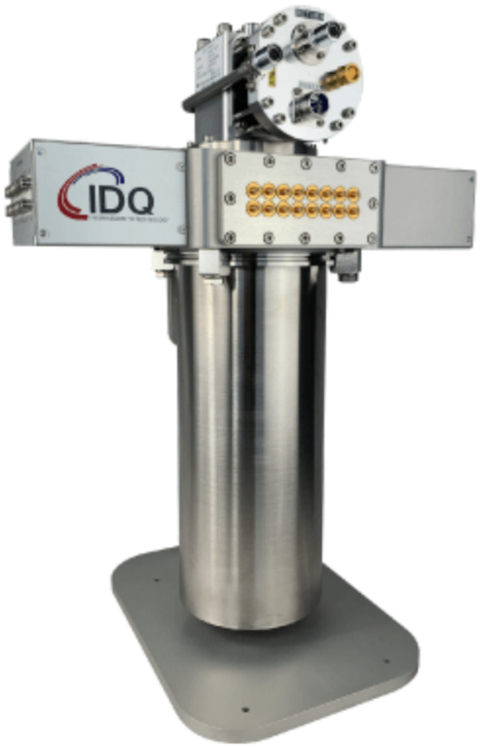

ID281 SNSPD System

The very best in single-photon detection, with ultra-stable performance

- Near-ideal detection efficiency: can exceed 95%
- Highly precise timing and low noise, true latch-free operation
- Ultrafast and photon-number resolving detection
- Mix and match up to 16 detectors, with options for rack-mounted systems

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Detectors for any occasion

The ID281's single-photon detectors are Swiss-made SNSPDs featuring high detection efficiency, low jitter, low noise, and short recovery time. The detectors (between 2 and 16 SNSPDs in one cryogenic system) are integrated into an automated closed-cycle cryostat, providing ease-of-use and unrivalled device performance for long-term multi-year operation.

ID281 Standard SNSPD: A single SNSPD with a linear nanowire meander, offering excellent overall performance in terms of system detection efficiency, detector noise, and timing precision. A polarization-insensitive version with a spiral meander is also available.

ID281 Parallel SNSPD: Several interleaved SNSPD pixels connected in parallel on a single readout line, offering ultrafast detection and photon-number resolution. These detectors accurately discriminate multiphoton states and achieve detection rates as high as 100 Mcps in some situations, while still benefiting from the efficiency, precision, noise performance and broadband operation of the ID281 SNSPD range.

ID281 Multi-Pixel SNSPD: Several independent SNSPD pixels each with their own readout lines, offering even faster detection rates > 1 Gcps and 'dynamic' PNR robust to longer pulse durations, while still benefiting from the efficiency, precision, noise performance and broadband operation of the ID281 SNSPD range.