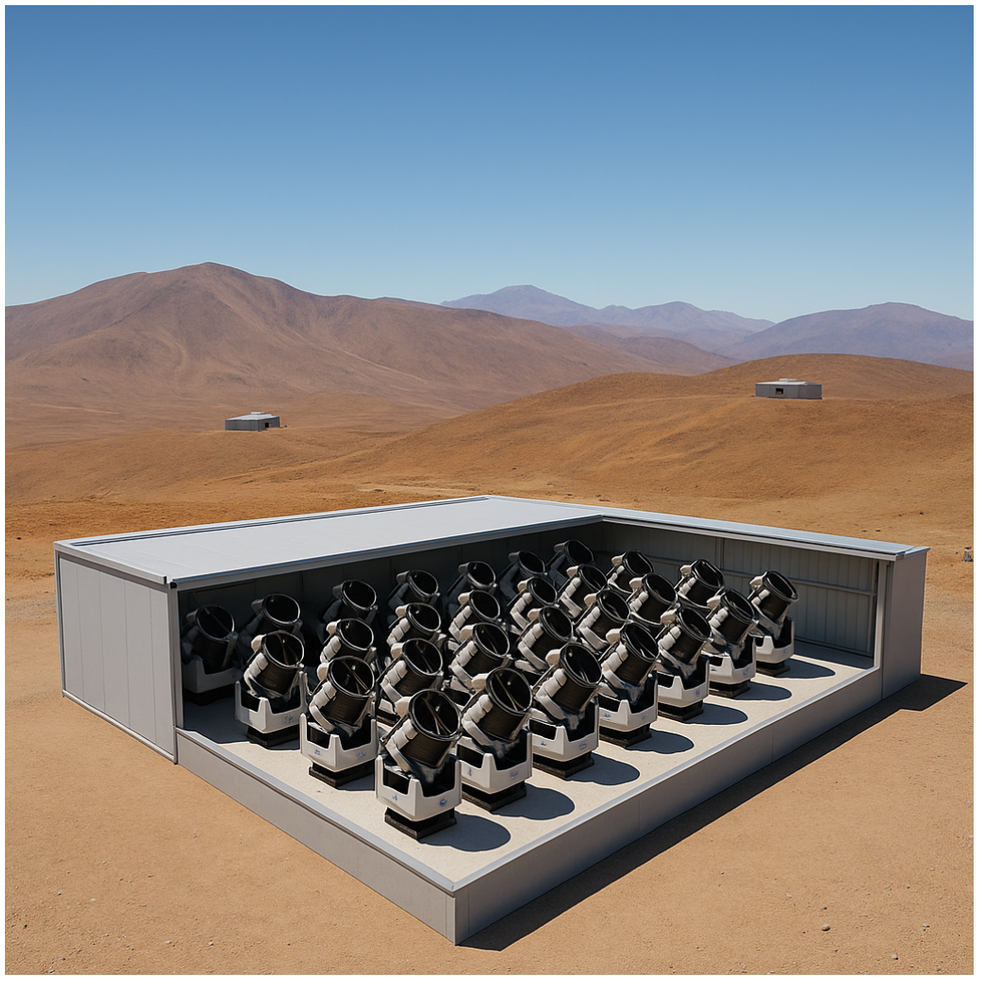
TIME DOMAIN TELESCOPE (TDT)

Spectra when you need them.
Anywhere, Anytime



Thomas Kupfer

On behalf of the TDT team

University of Hamburg / Hamburg Observatory

Email: thomas.kupfer@uni-hamburg.de

Universität Hamburg

European Research Council
Established by the European Commission

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

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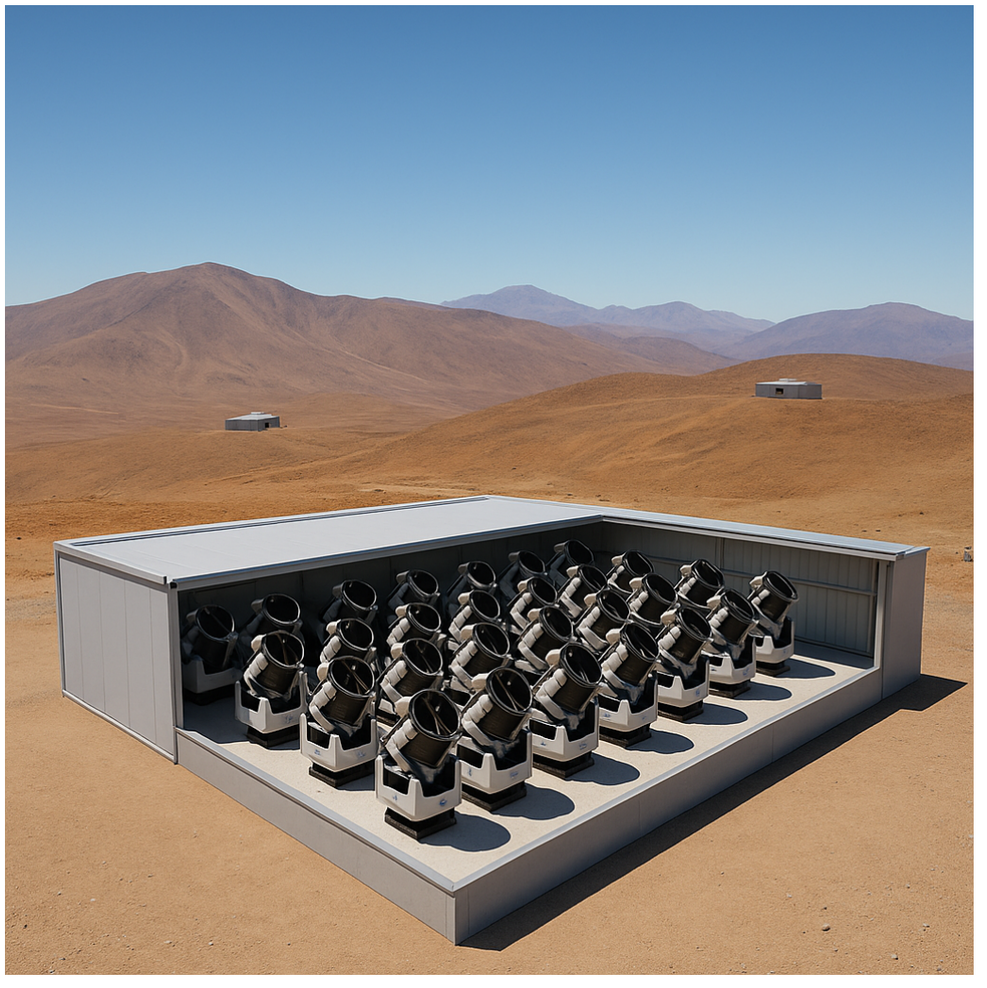

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The landscape in the 2040 for time-critical astronomy

By 2040:

- photometric of full optical sky, every hour (?), multi-color
  - Vera Rubin, Gaia-IR, ARGUS Array, …
- High energy and low energy full sky coverage
  - NewAthena, Einstein Probe, Gen-X, CTAO, SKA, DSA-2000
- Spectroscopic surveys have mapped a large part of the sky
  - SDSS, 4MOST, WEAVE, …
- Multi-messsenger full sky coverage
  - Einstein Telescope, LISA, IceCube-Gen2/Antares, …
- Large scale Follow-up facilities across the visible/NIR
  - ELT, VLT, La Silla?, GMT?,mid-size facilities? …

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What we don't have:

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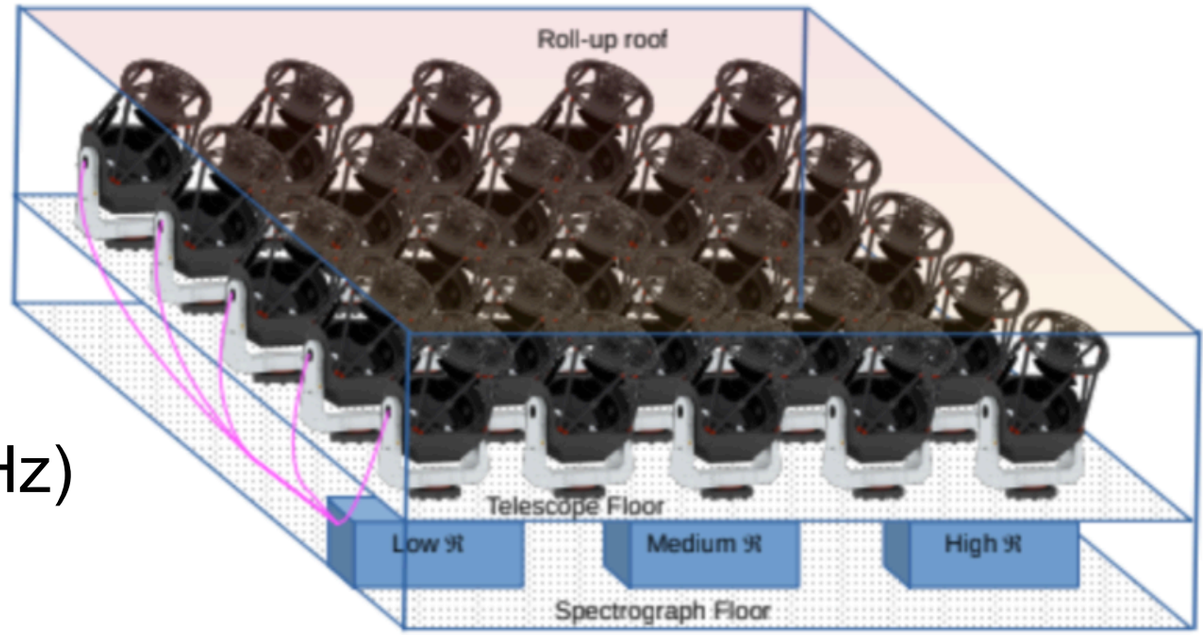
Overall setup - preliminary

Preliminary design idea:

- **100x2m** telescopes; D=20m
- **Four** clusters of **25 telescopes**
- Connected by fibers per cluster
- **Three spectrographs** per cluster
- Each telescope also high-speed (>>1Hz) optical/NIR photometry
- Flexible configuration: 100x1, 25x4, 24x4+4, 1x100, 1x98+2, etc



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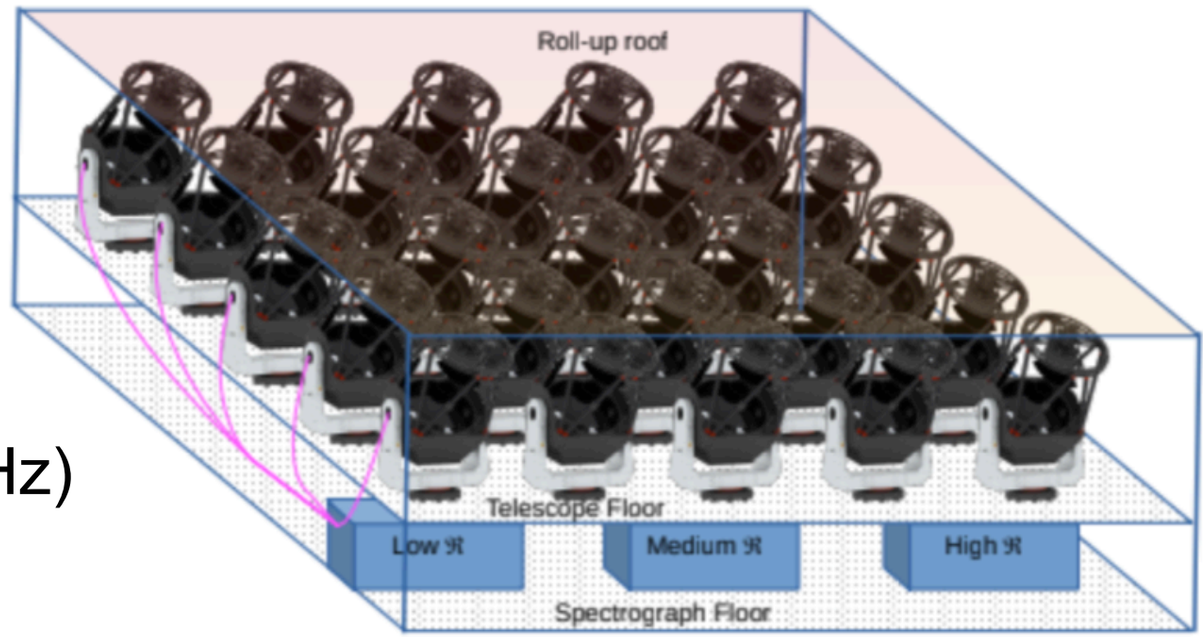


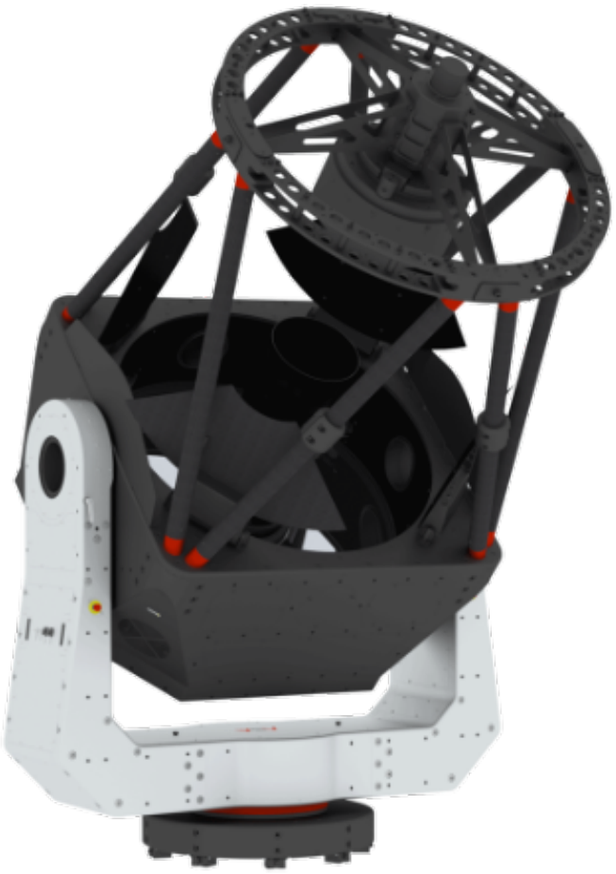
Science cases will drive final configuration

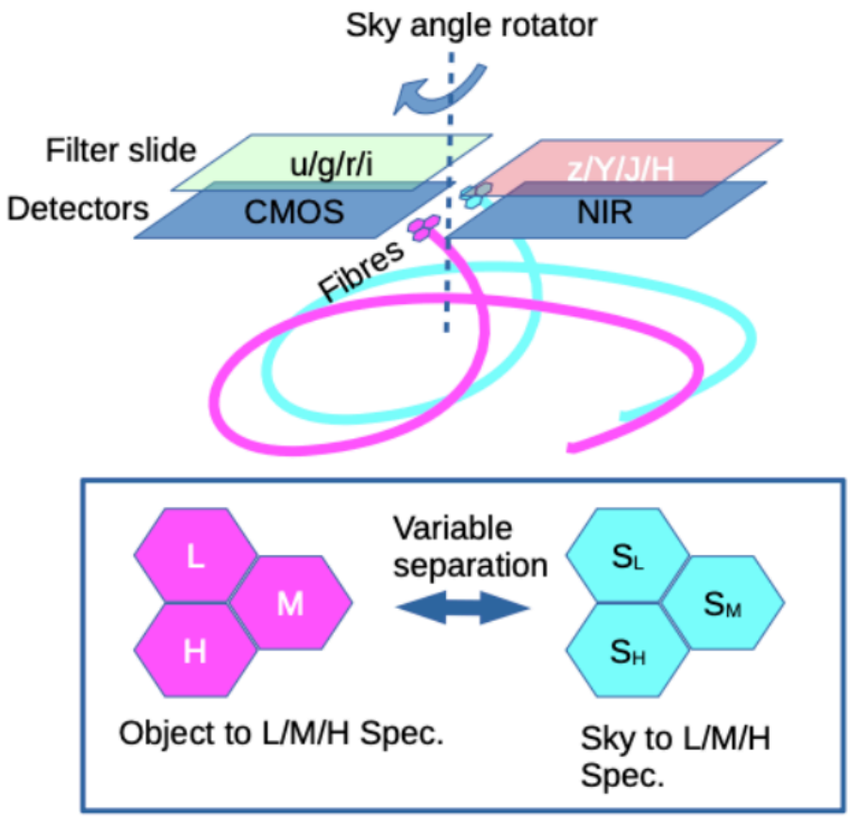
Advantages compared to single telescopes:

- *Flexibility:* Each telescope can point to different parts of the sky, or all telescopes point to the same part
- *Expandability:* Can easily be expanded or reduced depending on funding
- *Cost:* much cheaper than single 20m telescope; cost per m^2 mirror not constant

Unit telescope (conceptual design)

- Off-the-shelf 2m telescope with ~5'x5' fov (or mix of multiple apertures)
- Fully steerable
- Could implement simple Tip Tilt AO technique to improve image quality
- Single instrument instrument unit:
  - Combined acquisition camera + OIR high-speed camera
  - Fiber unit for feed into low (10^3) / medium (10^4) / high-resolution (10^5) spectrograph

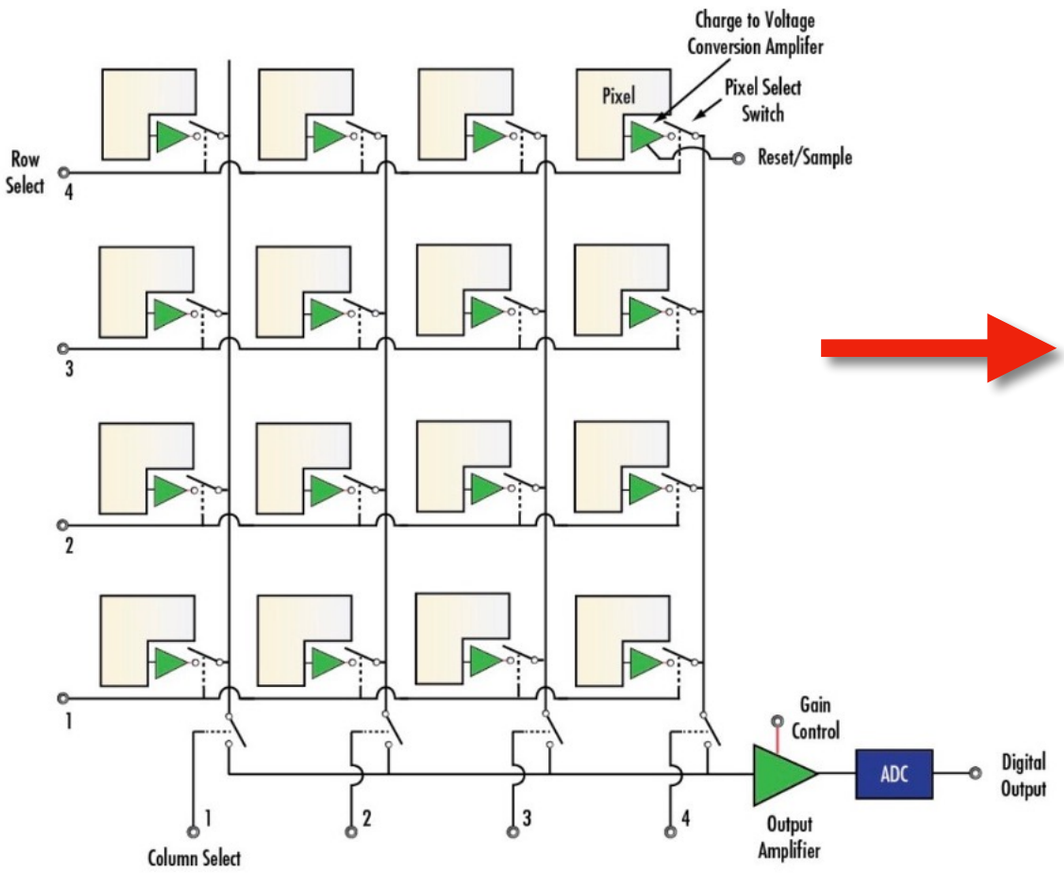


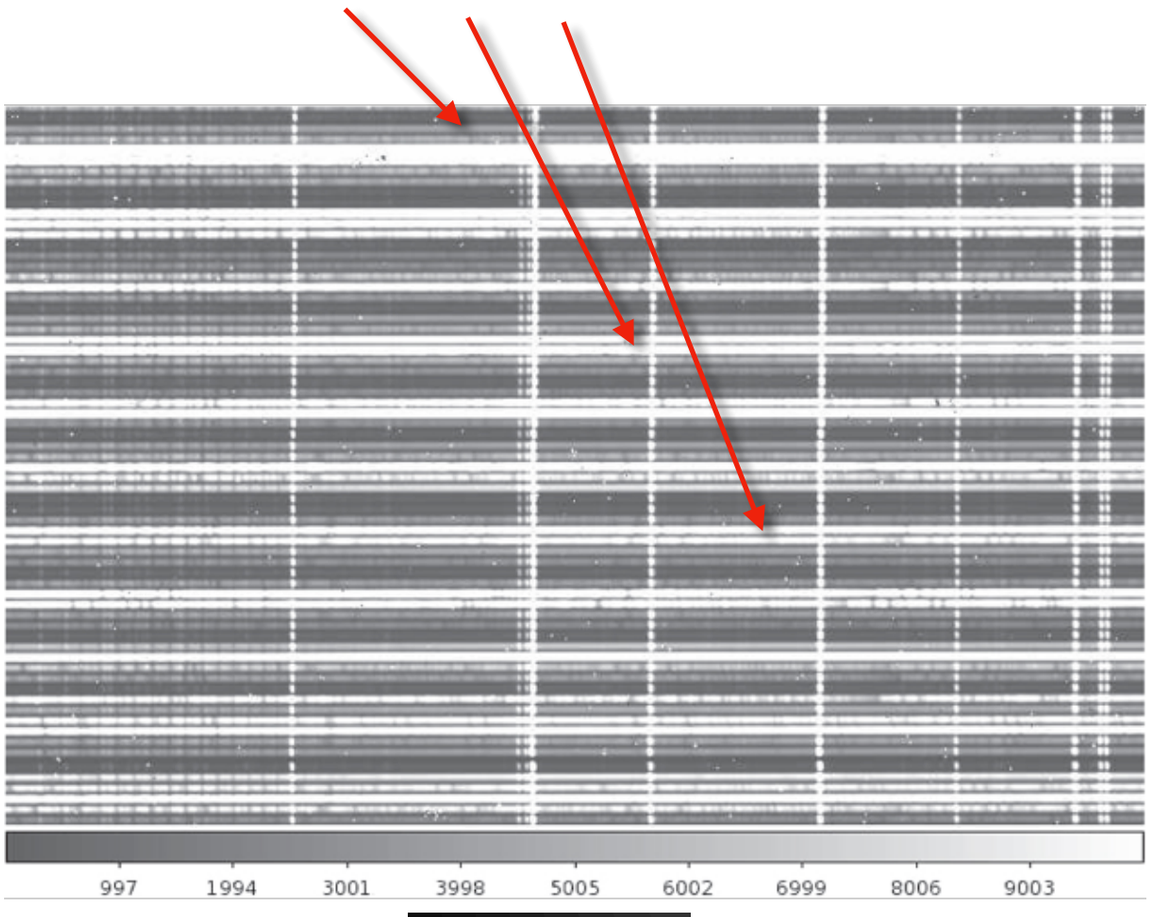


Detectors (conceptual design)

- State of the art qCMOS detectors:
  - lower(read) noise, faster readout & cheaper than CCDs
- Development is going very fast
  - Modern qCMOS have no readout penalty
  - Situation will be even more improved in the late 2030s

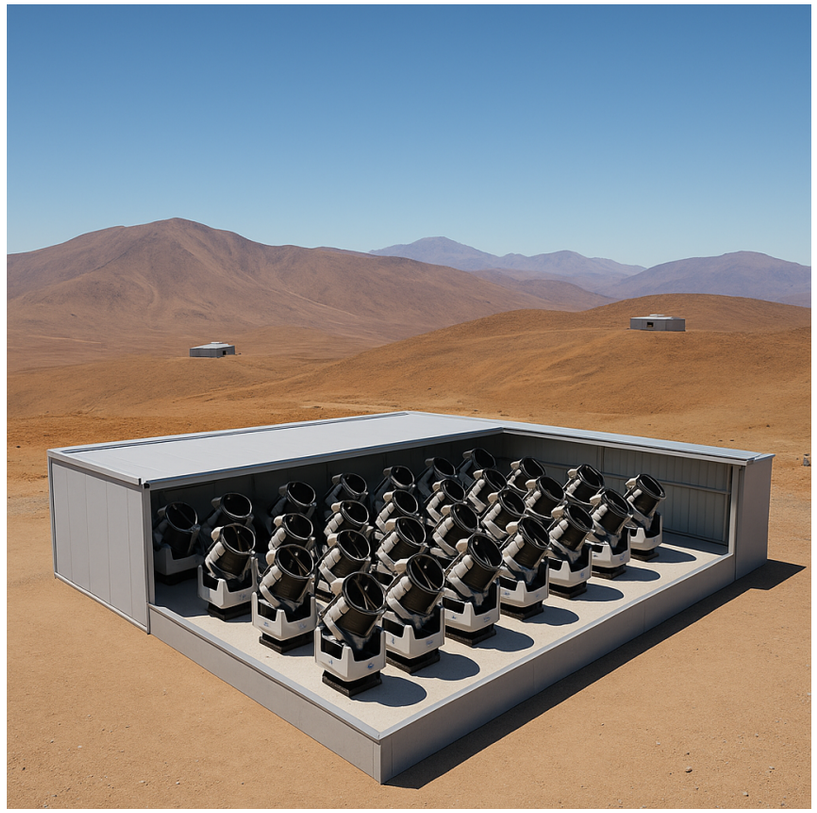
Every pixel (trace) is read out independently
Every telescope in the cluster creates an individual trace on the detector





Cluster of telescopes (conceptual design only)

- Per cluster ~25 telescopes (work combined as a single 10m telescope)
  - 4 cluster work as single 20m telescope
- Fibers of each telescope feeding into a low/medium/high res spectrograph
- Housed in low-squat building with retractable roof



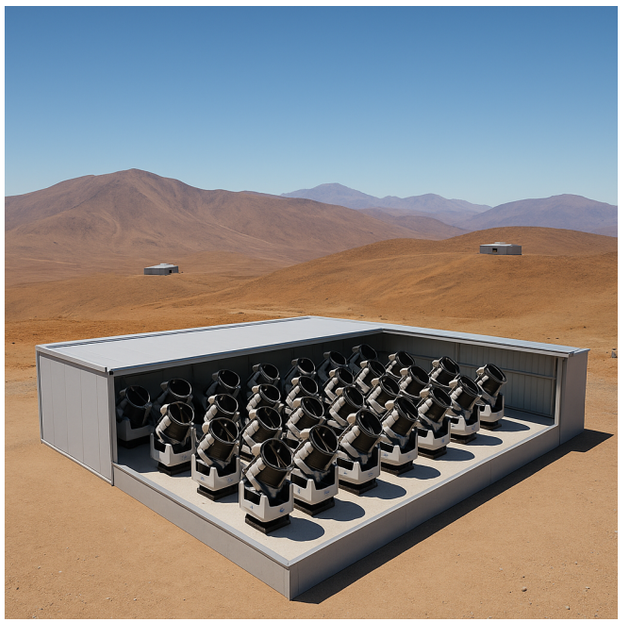
First cost estimate: ~350 M€

Critical part: Scheduling

Time is central parameter

- Low overheads in set-up: all automated
- Highly flexible
  - Single big telescope or large number of medium size telescopes
- Efficient scheduling: complicated matrix of demands
    - Hard ToOs, Soft ToOs, Time-constrained, Repeated, no time constrain at all
- **Scheduling** may be the hardest part of the entire project
  - AI driven scheduling
- Proposal driven (just like ELT, VLT, ALMA)

Not a survey telescope!



Science cases

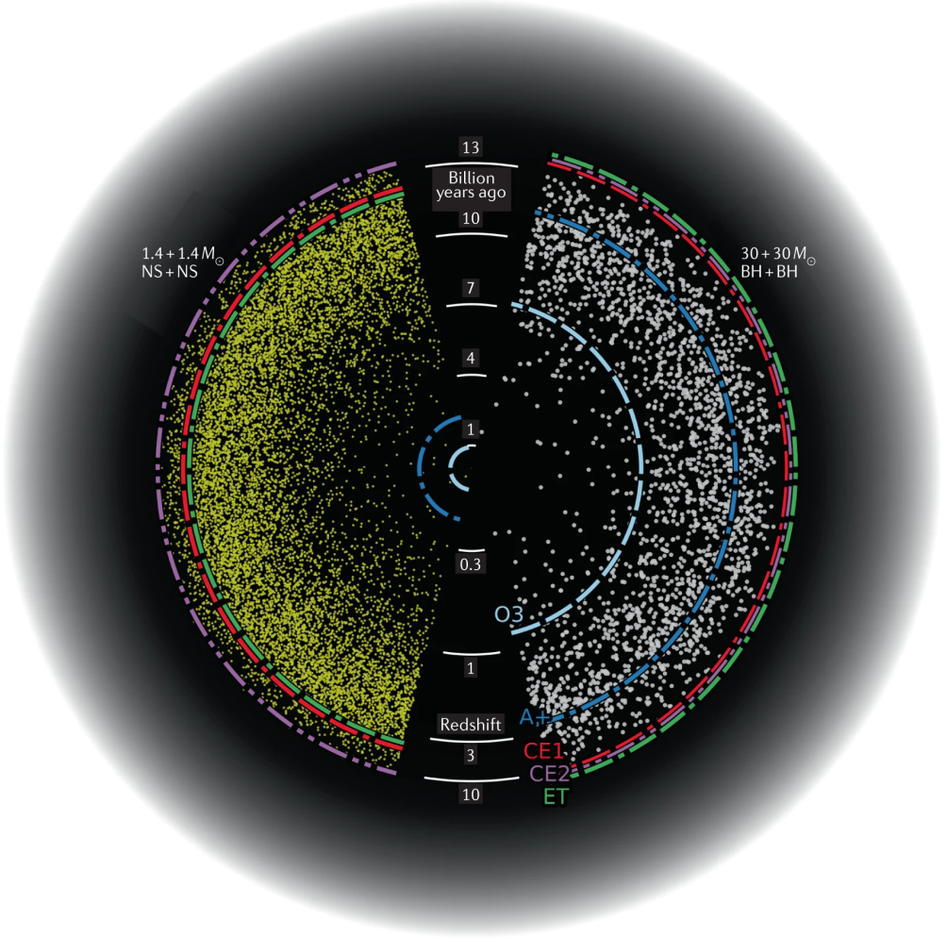
<u>Science Case:</u> time-*<u>critical</u>* astrophysics combined with regular queue scheduled observations

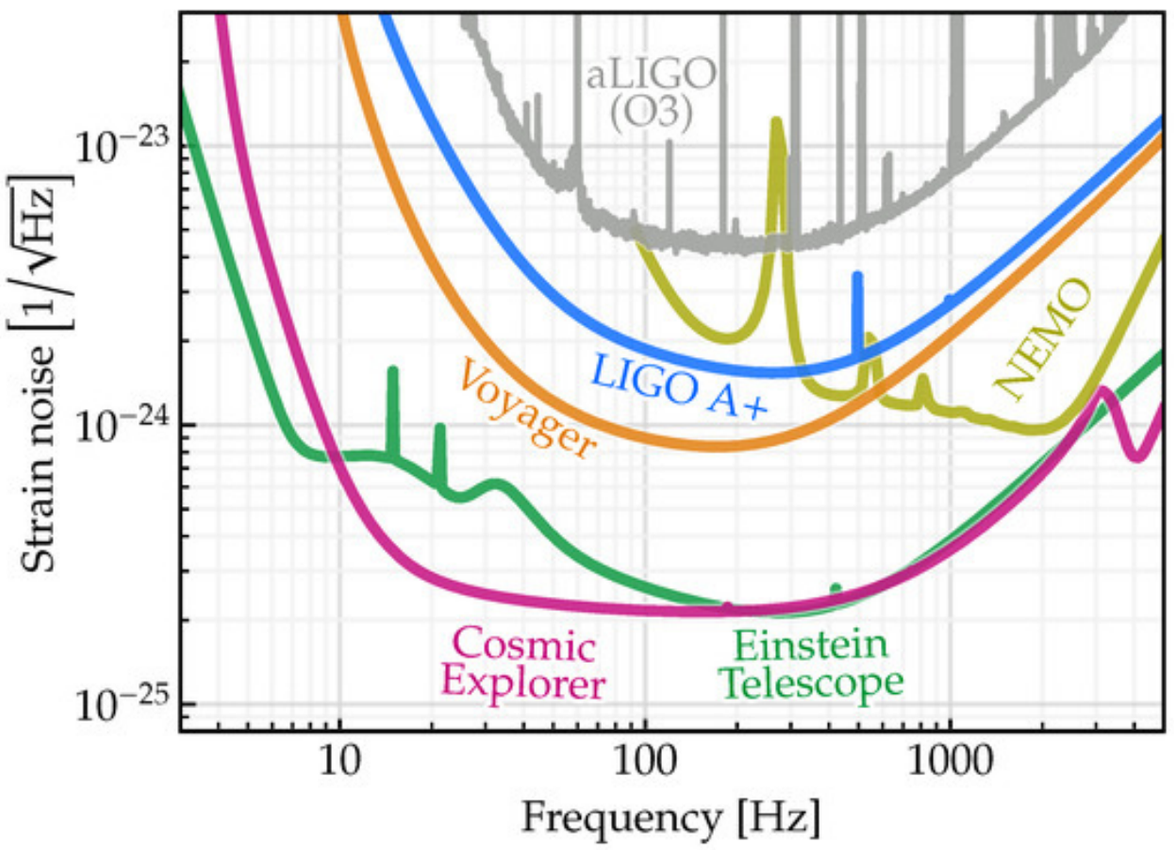
- Asteroseismology
- Exoplanets
- Stellar/Binary evolution and populations
- Physics of explosive transients and stellar end-points
- Cosmology with time-variable phenomena
- Multi-messenger Astrophysics

- **Understanding the Universe from rare and time-variable phenomena requiring large apertures and repeated and/or time-critical observations**
- Designing **<u>'time'</u>** as a fundamental parameter of the telescope

Spectra when you need them. Anywhere, Anytime

Time Domain Telescope for gravitational wave follow-up





Quote Samaya: *"Hundreds of thousands BNS mergers per year, tens being bright enough for EM facilities in the optical"*

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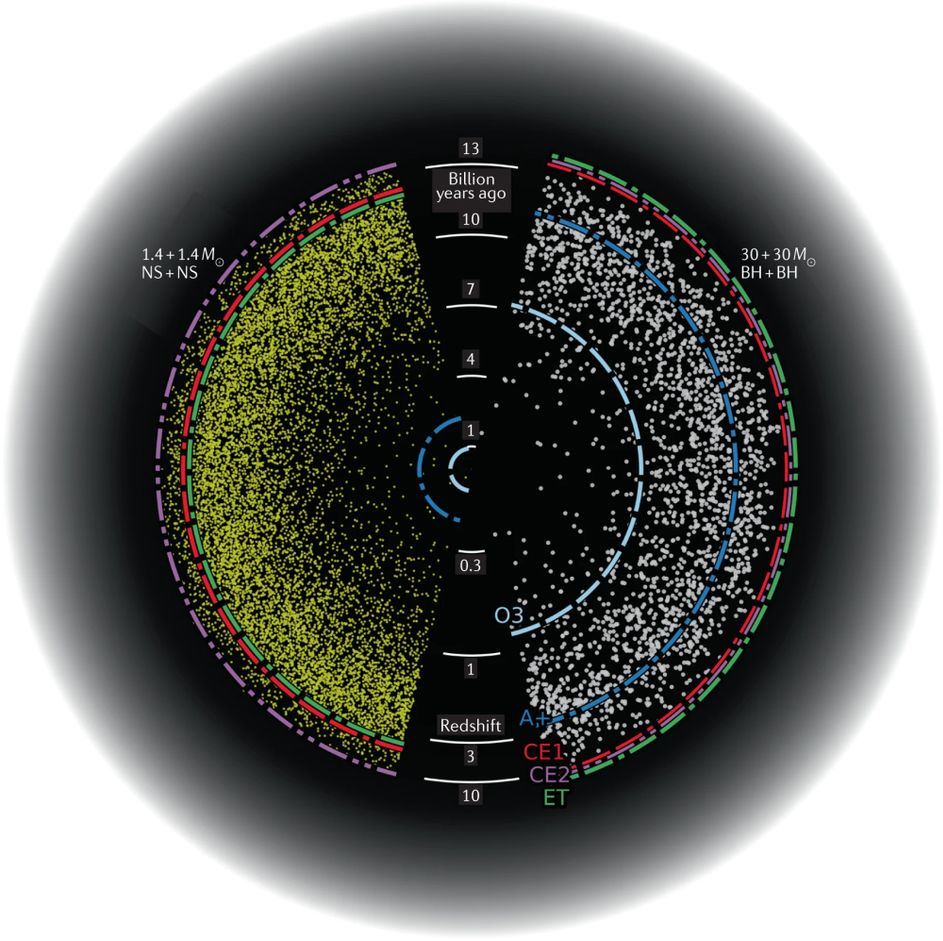
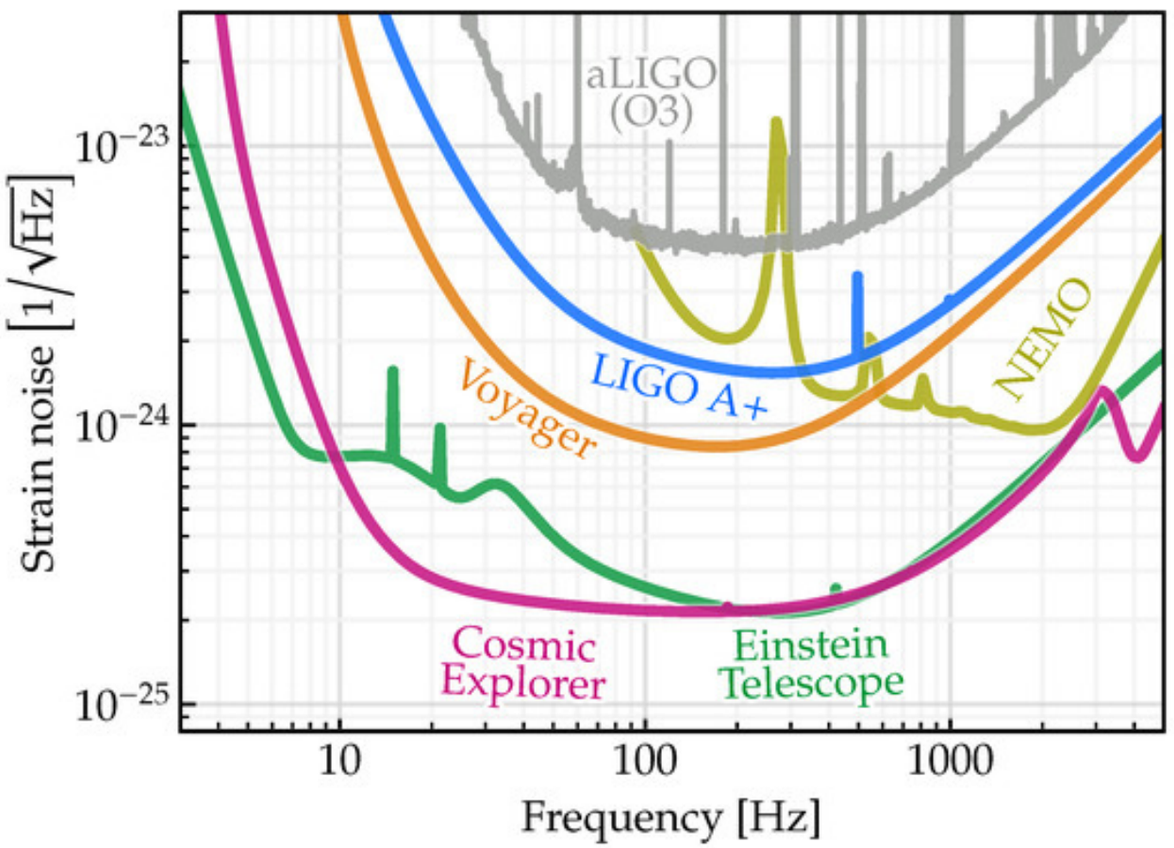


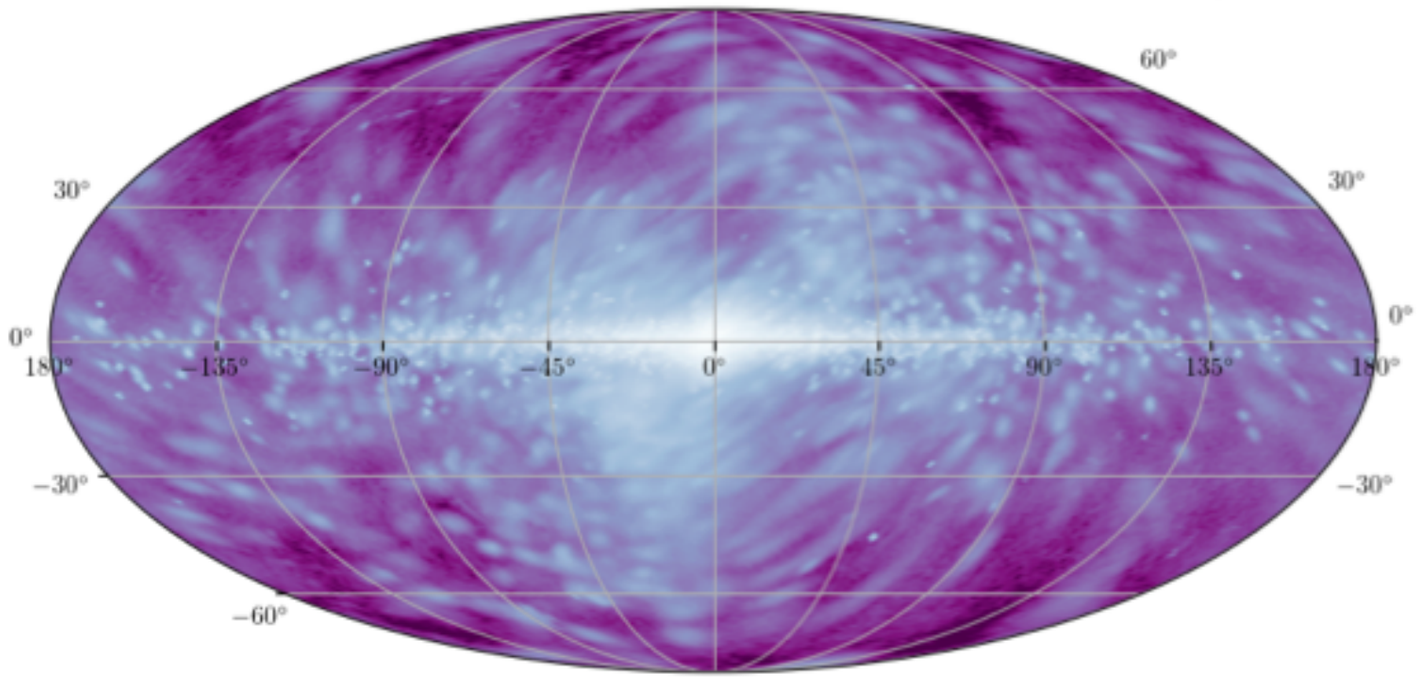


Quote Samaya: *"Hundreds of thousands BNS mergers per year, tens being bright enough for EM facilities in the optical"* ***-> Can't be handled by the ELT***

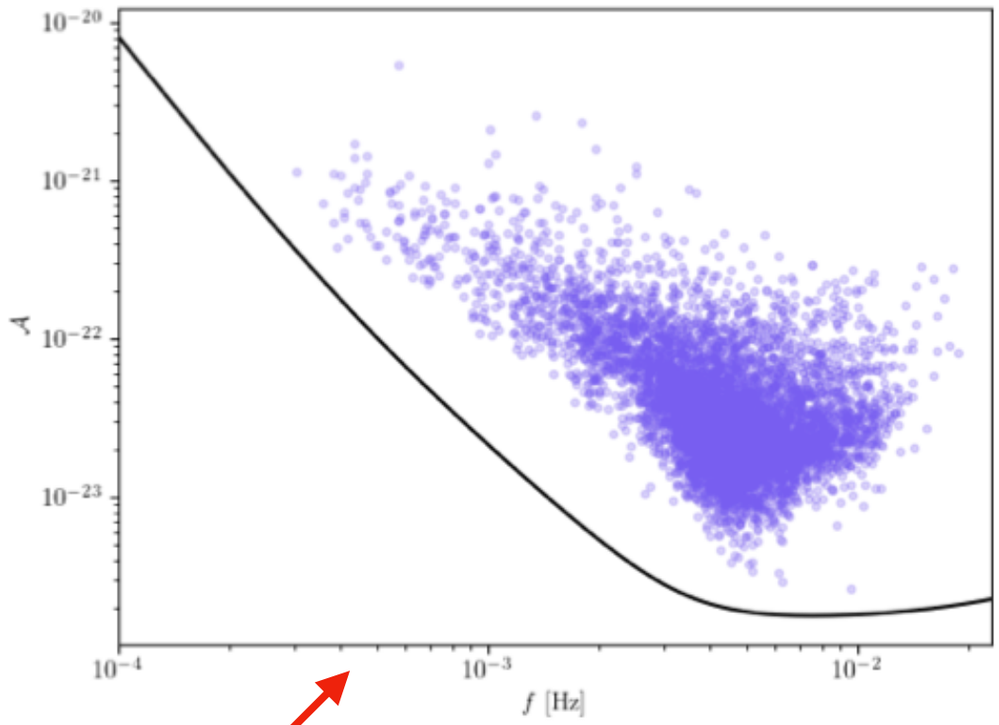
With several tens of EM counterparts:

- H_0 precision to comparable to other H_0 measurements
- Precise derivation for the Neutron star equation of state
- Precise derivation as the production site of heavy elements

Time Domain Telescope for gravitational wave follow-up



Littenberg & Cornish 2023



The LISA sky after 12months of LISA observations

Sky loc. < 1 sqd.

Distance < 10%

	6 mo	1 yr	2 yr	4 yr
# detected	6,590	11,142	18,281	29,059
2D mapped	104	1,065	4,138	6,304
3D mapped	19	129	1,010	2,373
$\mathcal{M}$ measured	233	737	4,432	10,770

Table from
Cornish & Robson 2017

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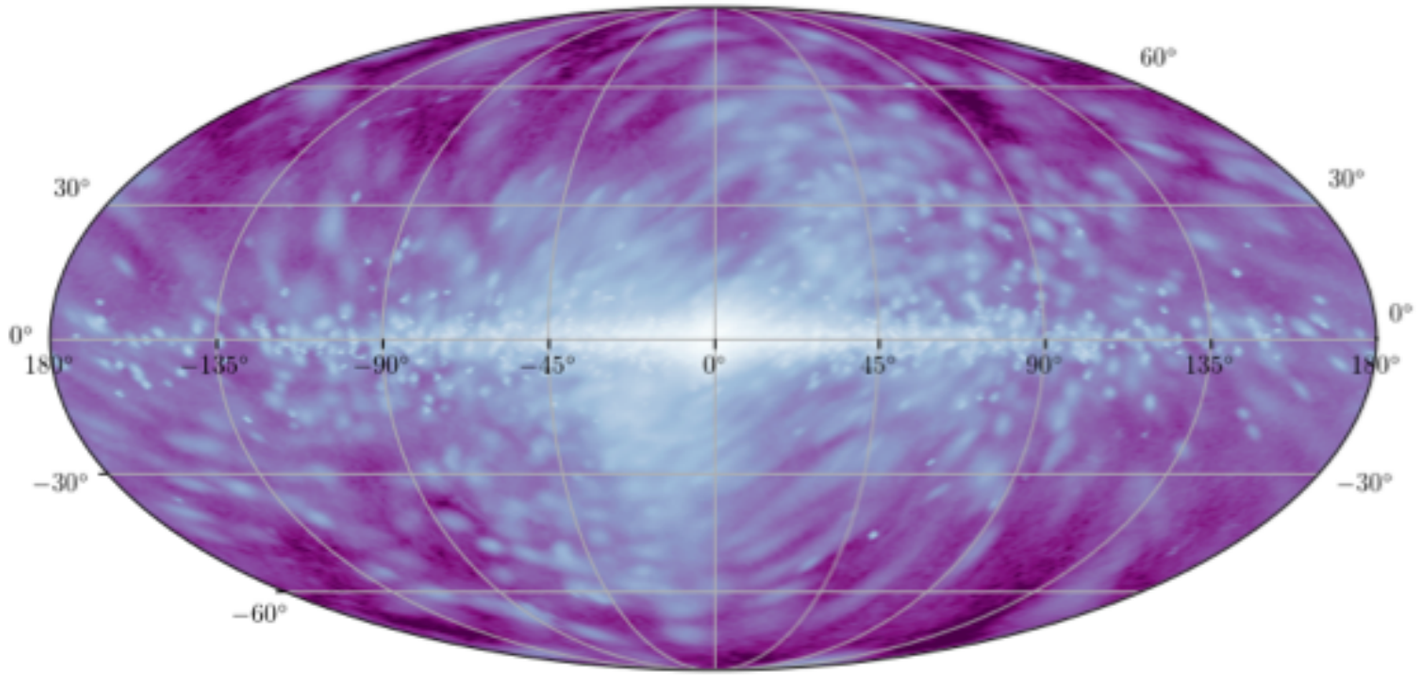

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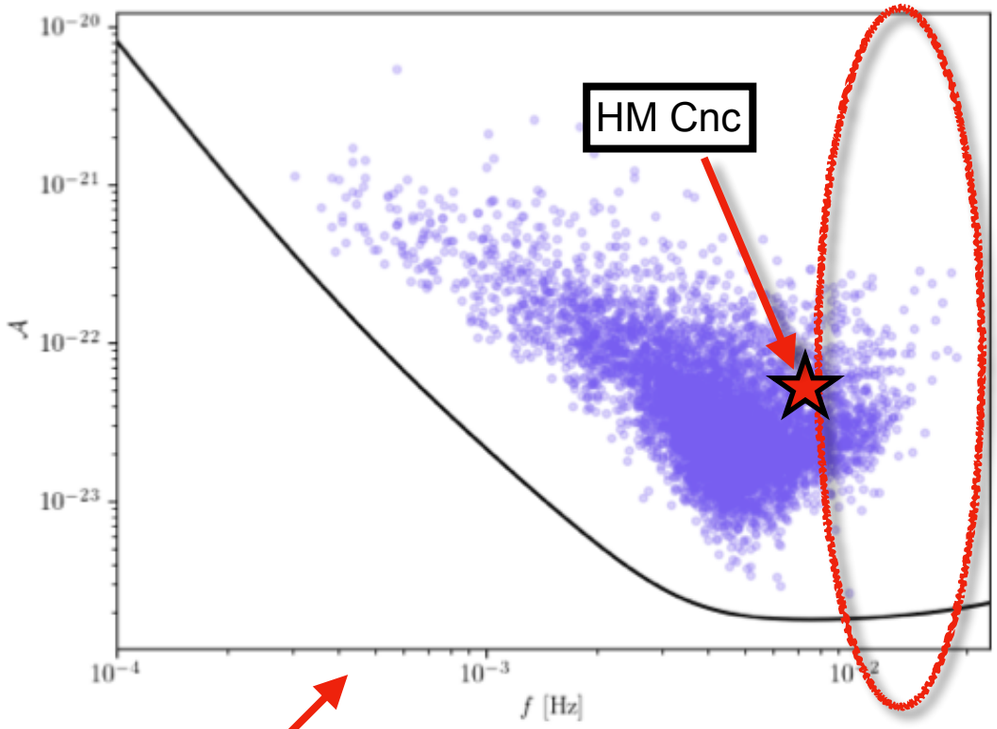

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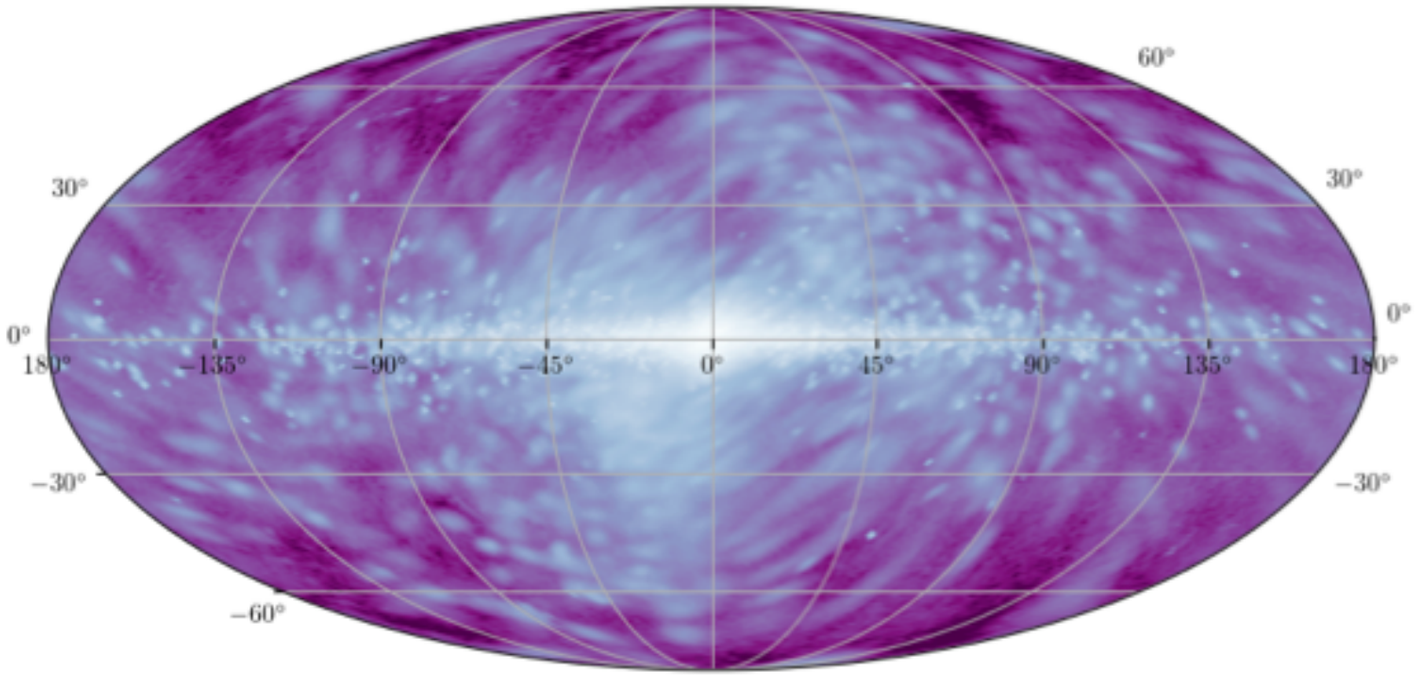

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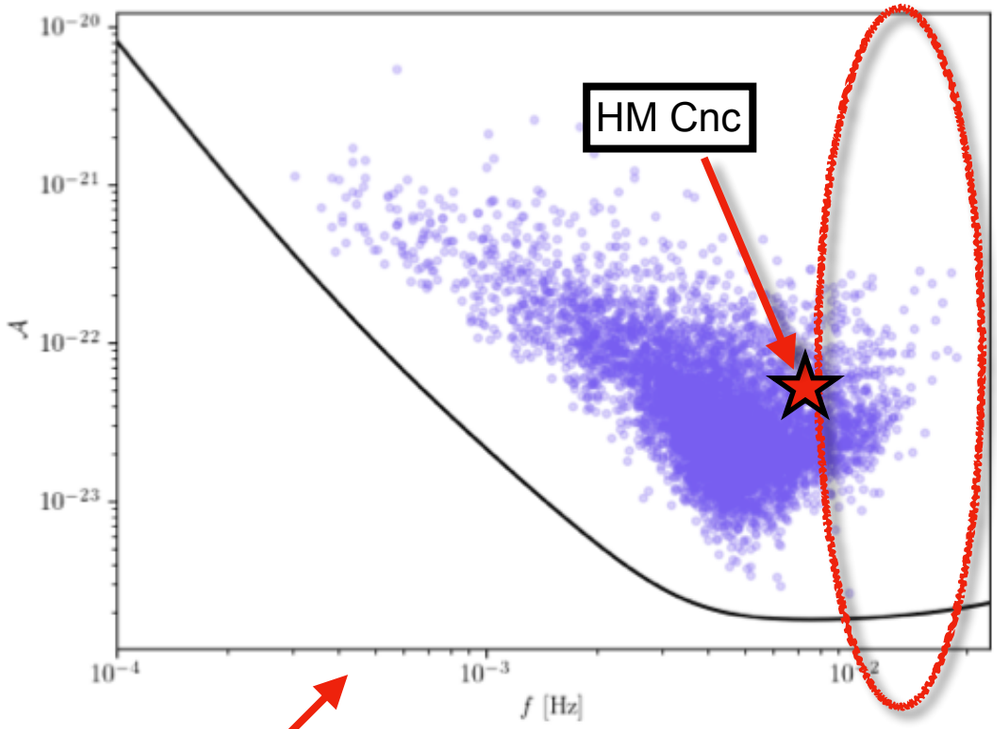

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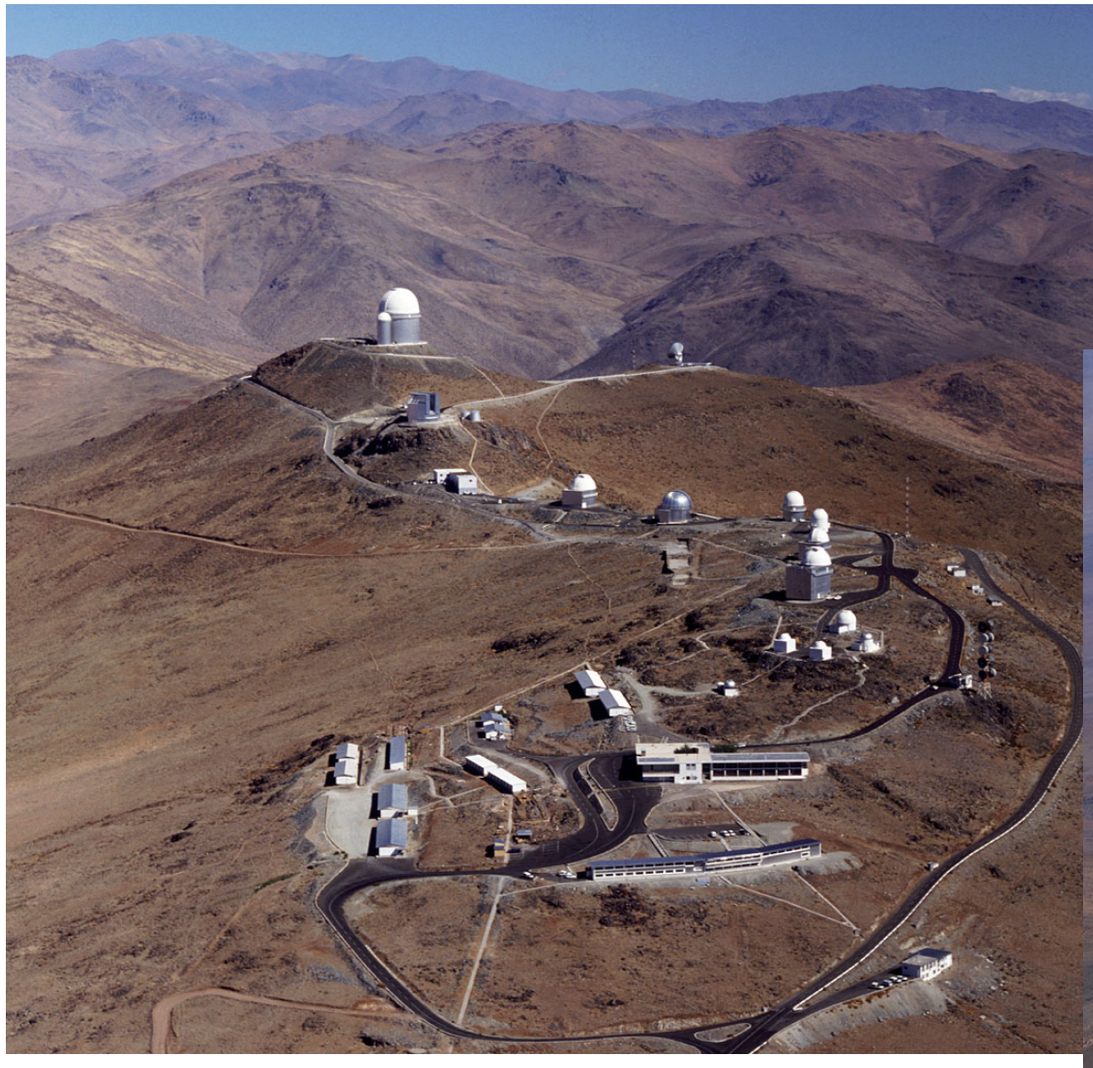
Time Domain Telescope will:

- Identification and spectral classification of hundreds of LISA sources
- Phase resolved follow-up of the most compact sources

Possible location(s) for the Time Domain Telescope



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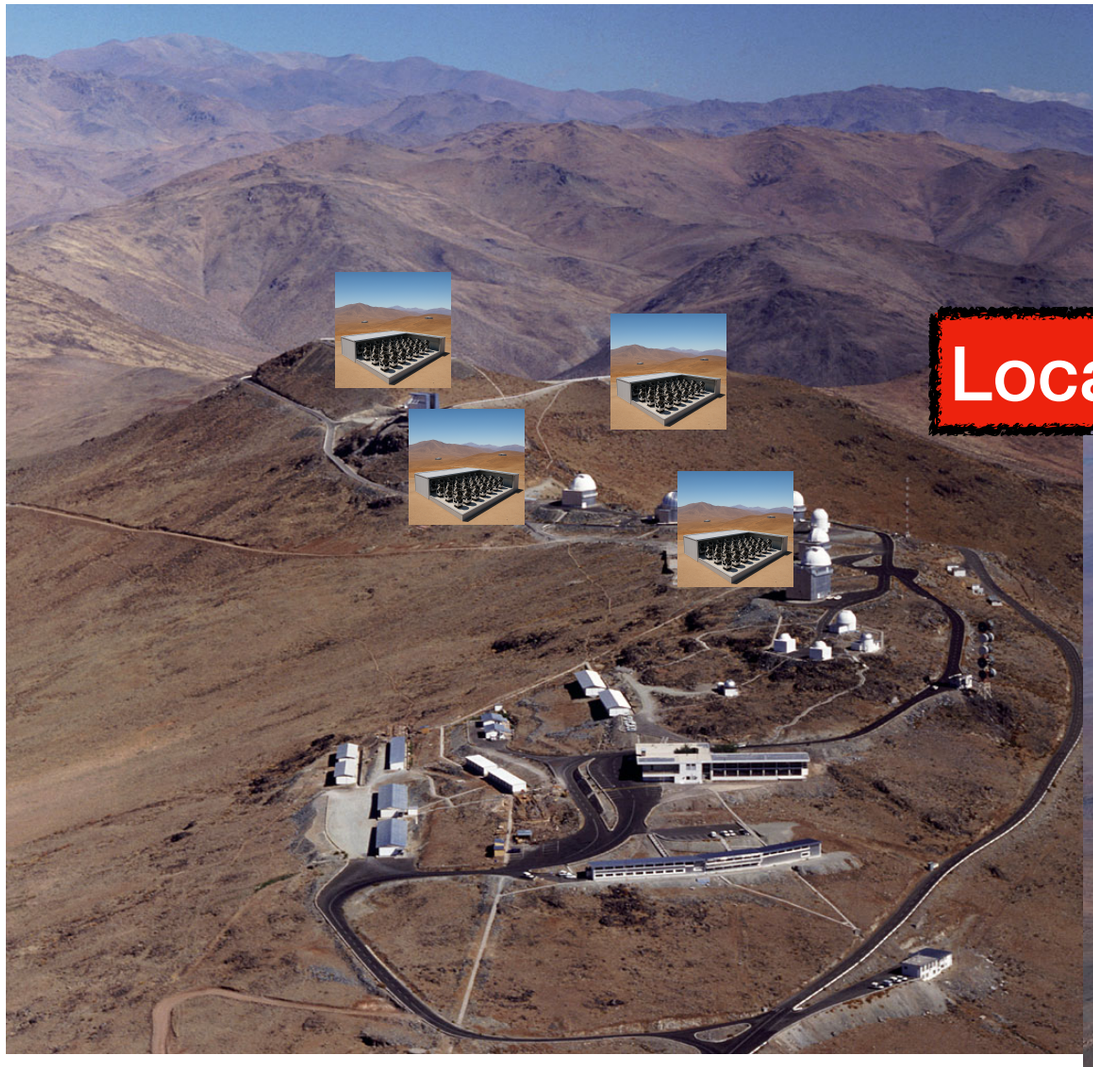

Located at an ESO site?

Possible location(s) for the Time Domain Telescope

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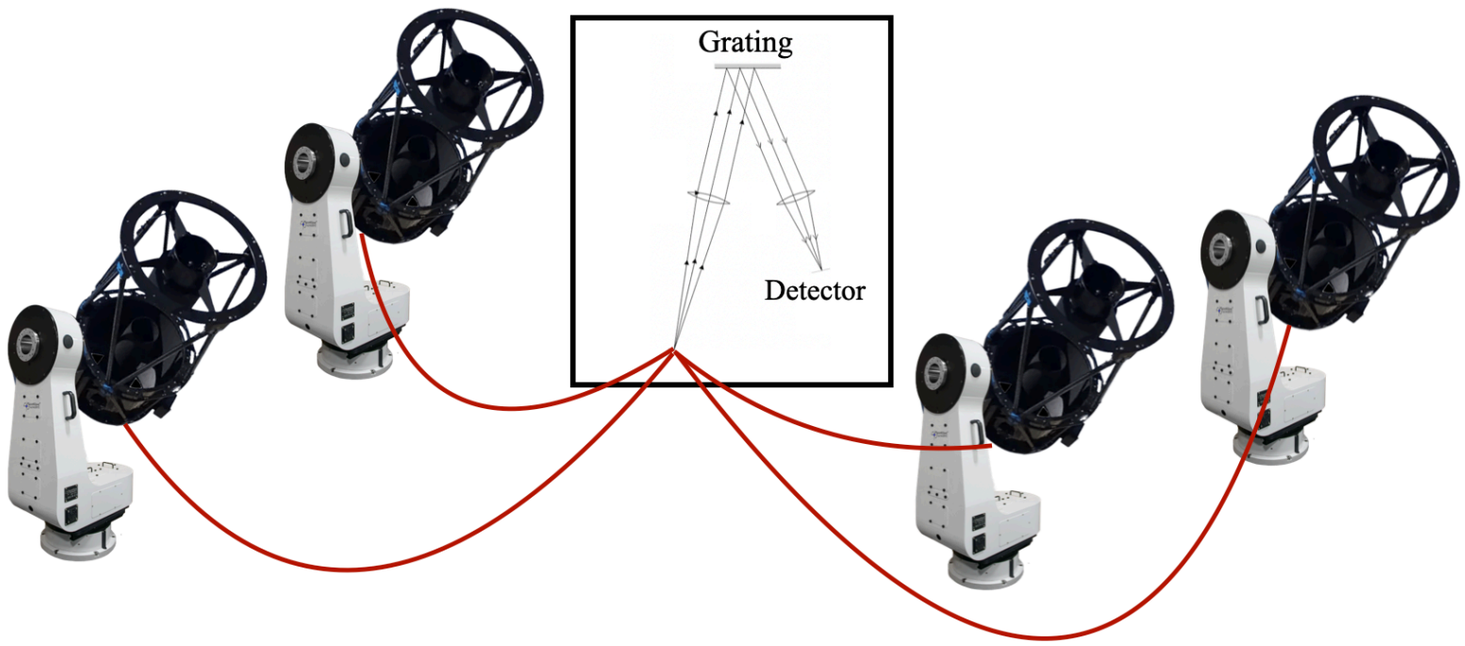
FAROS ***F***ibre-fed ***A***rray for ***R***apid ***O***ptical ***S***pectroscopy
- a Time Domain Telescope prototype -

- 3-4x60cm ASA telescopes; D=1 - 1.2m
- Low resolution spectrograph fed by fiber from each telescope
- Each telescope gets a guide camera which can be used as imager
- **Science cases:** Transient and variable follow-up (BlackGEM, LS4, Rubin, Ultrasat,…)
- Demonstration for the Time Domain Telescope
- Collaboration between Hamburg, DZA (Roth, Nissanke), Nijmegen (Groot), Weizmann (Ben-Ami, Ofek) ***-> Reach out if you are interested (thomas.kupfer@uni-hamburg.de)***
- Funding request to the Klaus-Tschira Foundation submitted (other avenues being explored)



Get involved

Working groups:

- Origin and Physics of Relativistic Transients
  - GW Mergers, GRBs, FRBs, FBOTS,...
- Physics of Supernovae: early and late
  - Shock break-out, thermonuclear supernovae, interactions, composition, progenitors...
- Physics of accretion on all scales
  - XRBs, AGN, TDEs, Micronovae, Changing-look QSO...
- Final fate of stellar and binary evolution
  - SNIa, LISA Sources, Pulsars, SNR, CE, LNR, GW progenitors...
- Physics of stellar interior & atmospheres
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- Exoplanets
  - Transit spectroscopy, planets & remnants, disrupted systems...
- Minor bodies of the Solar System
  - Asteroids, comets, trans-Neptunian objects...
- Cosmology and Fundamental Constants
  - Dark Energy, Dark Matter, and the expansion of the Universe...
- Synergies
  - LISA, Athena, and other multi-messenger approaches...
- Instrumentation
  - Telescopes, Detectors, Spectrographs, Automation & Software

> 200 interested members

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Let us know what you need for your science:

Contact me: thomas.kupfer@uni-hamburg.de

Or us: timedomaintelescope@gmail.com

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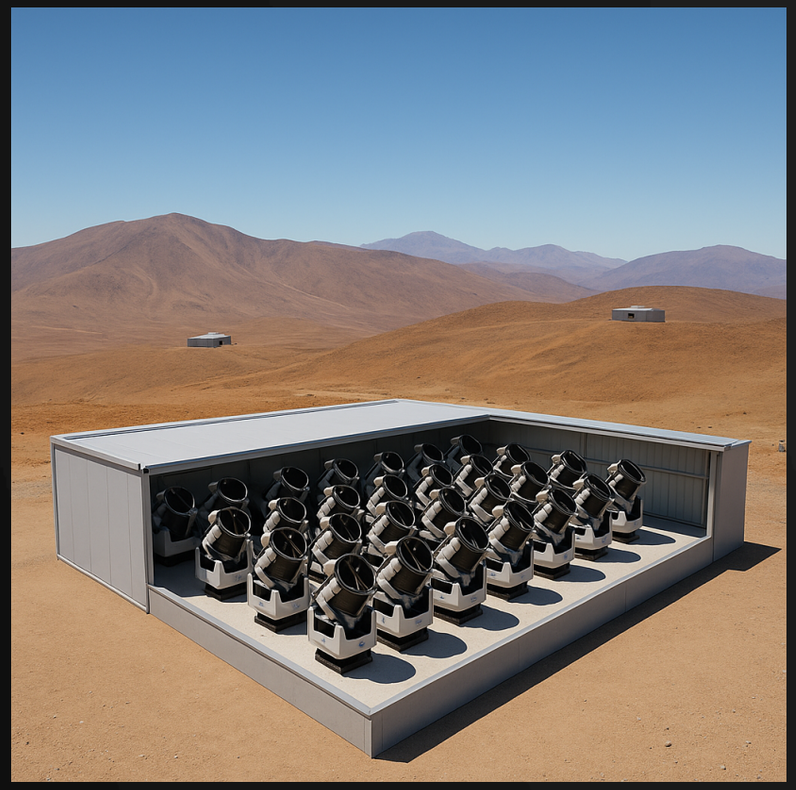

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