Advancing Time Synchronisation for Global Quantum Sensing: From GNOME Insights to the GravNet Cavity-Network Framework

GravNet Collaboration Meeting

Daniel Gavilán Martín

Helmholtz-Institut Mainz/JGU

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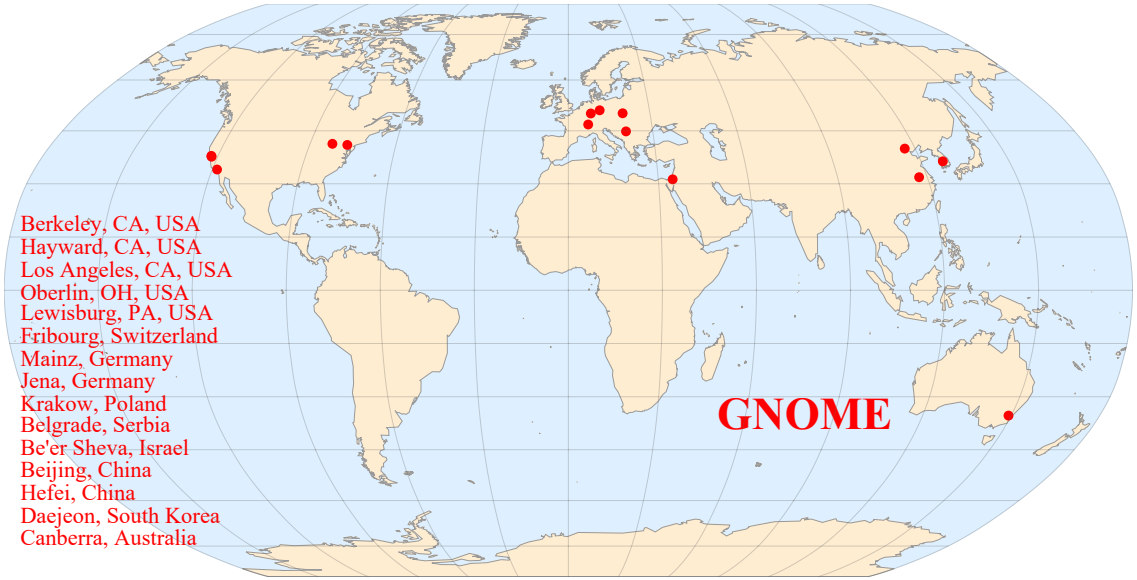
What is a GNOME?[1]

- **G**lobal **N**etwork of **O**ptical **M**agnetometers for **E**xotic physics searches
- Looking for transient and background dark matter signals
- Sensitive to Axion-nucleon coupling:

$$\mathcal{H}_N = g_{aNN} \nabla a \cdot \sigma_N \,,$$
$$\mathcal{H}_P = g_{aPP} \nabla a \cdot \sigma_P \,,$$



[1] Phys.Dark Univ. 22 (2018), 162-180

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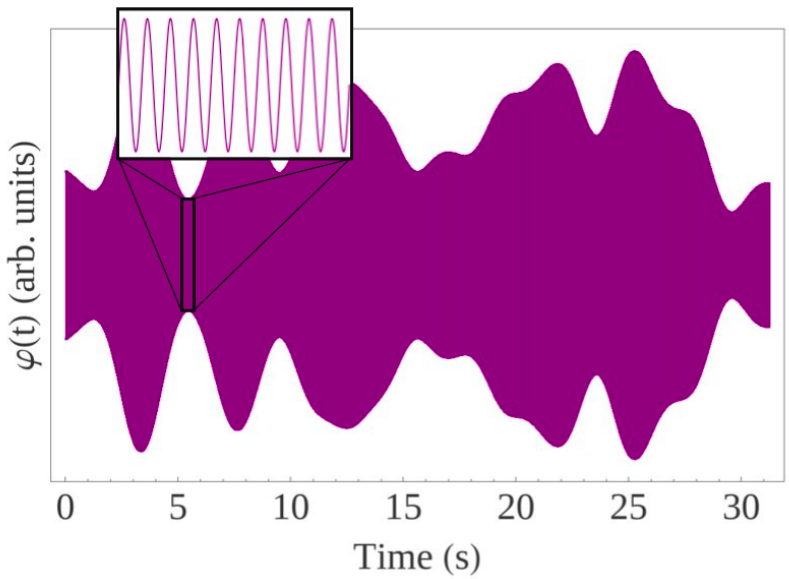
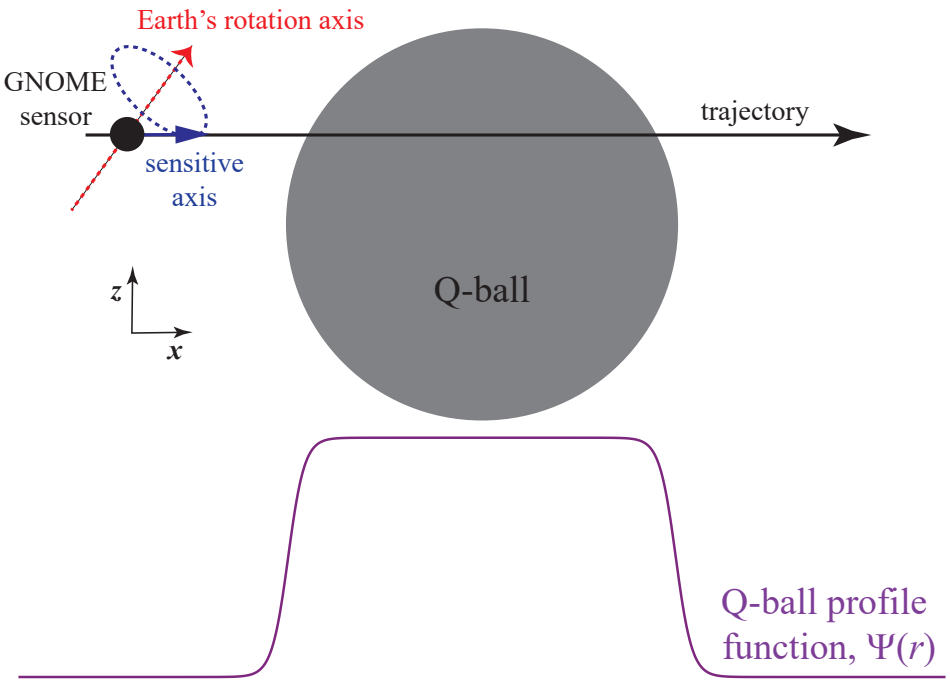
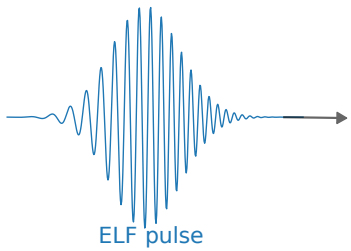
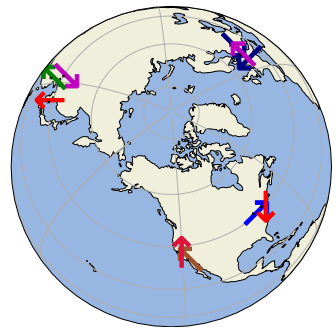
What can a GNOME do?[2]

- Stochastic ALP DM field fluctuations
- Exotic Low-mass Fields (ELFs)
- Q-balls
- and much more!









[2] Afach et al. ANNALEN DER PHYSIK 2023, 2300083

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Requirements for GNOME DAQ

- GNOME bandwith < 100 Hz
- Abbility to distinguish real signal from noise
- Data is streamed to a common server
- Calibration and sensitivity monitorization

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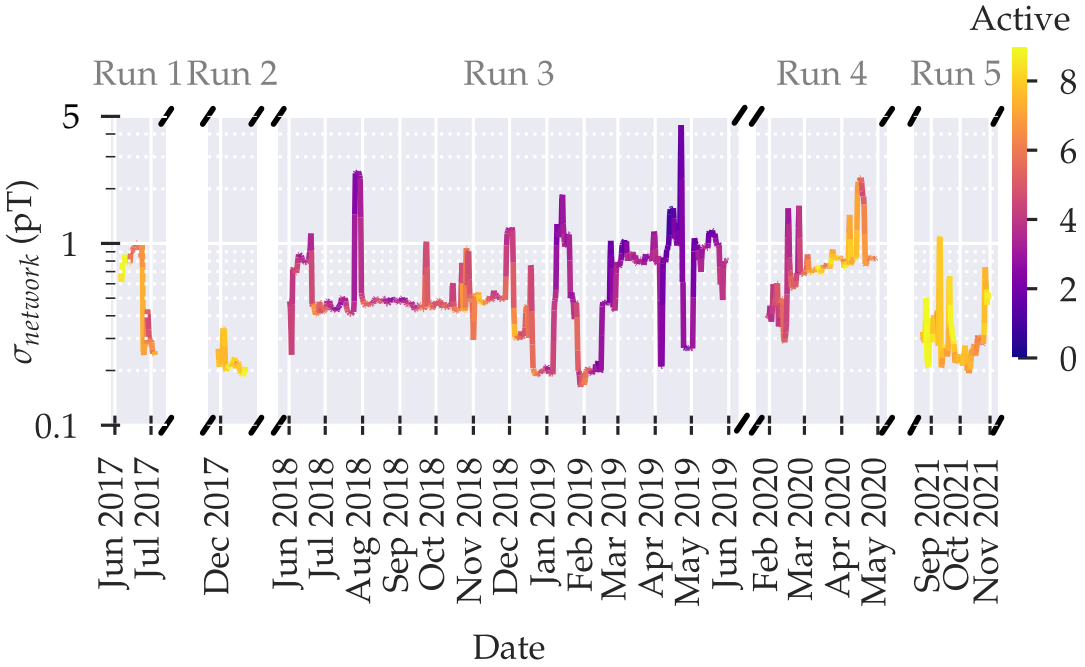
- 5 Science Runs since 2017
- Science Run 6 starting now!



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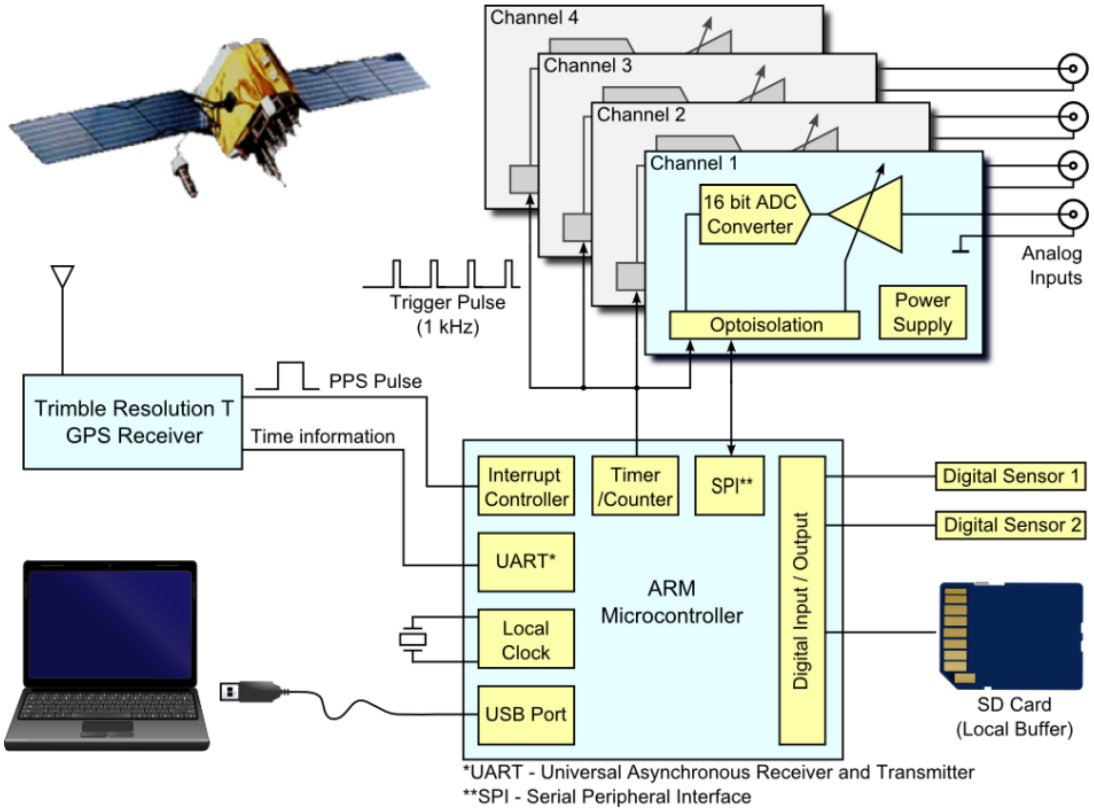
GNOME DAQ system



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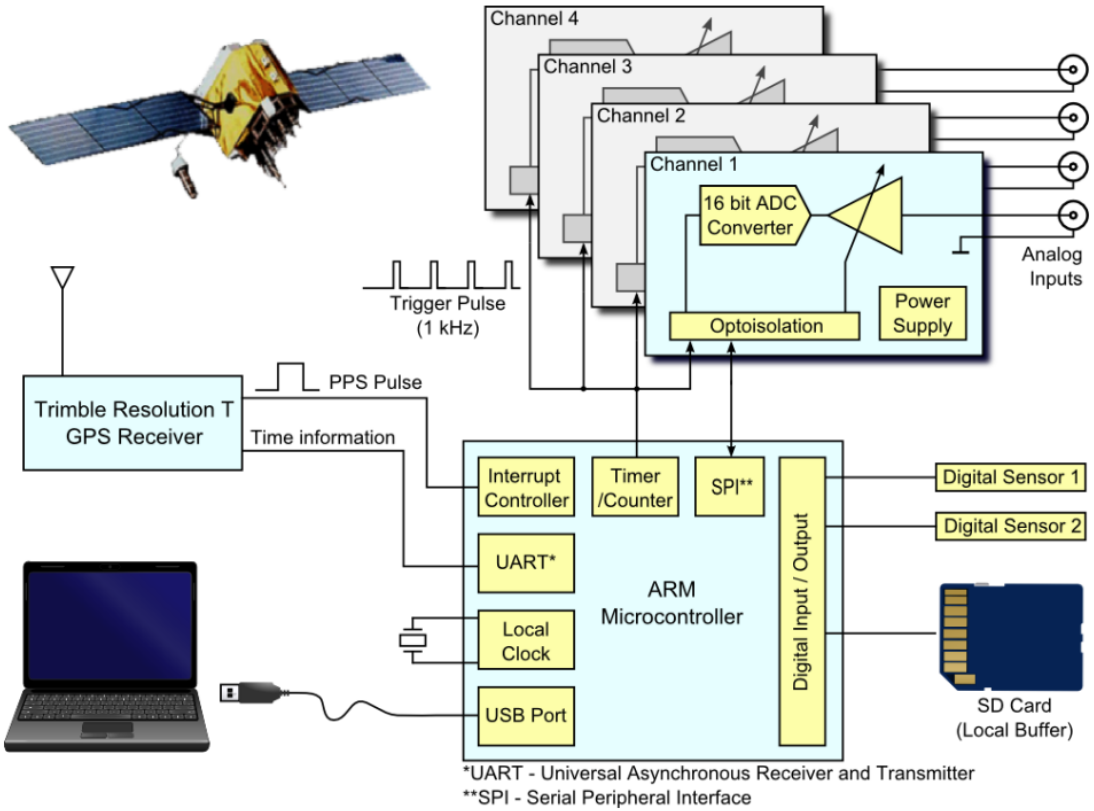

Source of Error	Min. Delay	Max. Delay	Max. Uncertainty
Antenna cable delay*	0	+ 200 ns (50 m of cable)	±10 ns
GPS synchronization error (3σ)	-45 ns	45 ns	±45 ns
Program delays (t_s) **	1450 ns	1630 ns	±90 ns
Estimated onboard propagation delays	40 ns	110 ns	±35 ns
ADC Aperture delay	40 ns	40 ns	±20 ps
Total	**1485 ns**	**2025 ns**	**±180 ns**

* The system provides compensation if the cable delay is known.
** Possible to eliminate in the next version, hardware changes required.

Sanity channel

- Marks bad data as insane
- Calibration pulses are not considered sane data
- External sensors, including gyroscope , temperature and magnetic sensor

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