Australian Facility For Noble-Gas Radio Isotope Measurements Using Atom Trap Trace Analysis

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Australian Government
Australian Research Council

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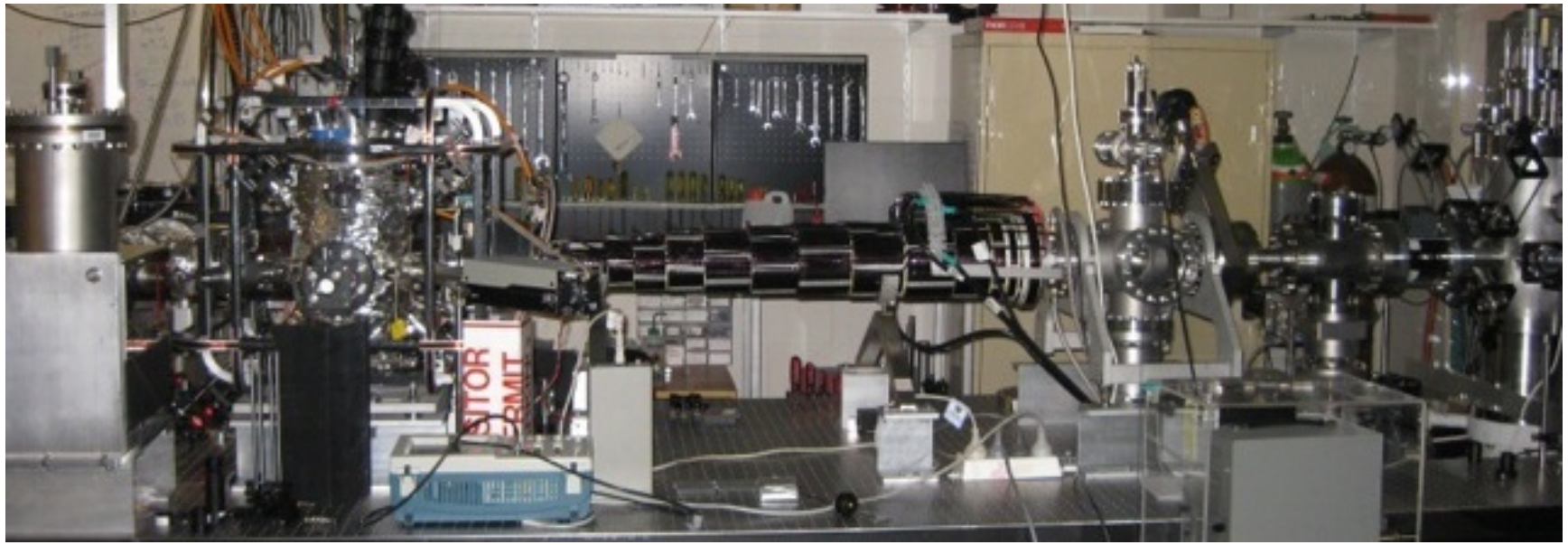
Linkage Infrastructure, Equipment and Facilities scheme (project LE160100025)

Australian Facility For Noble-Gas Radio Isotope Measurements

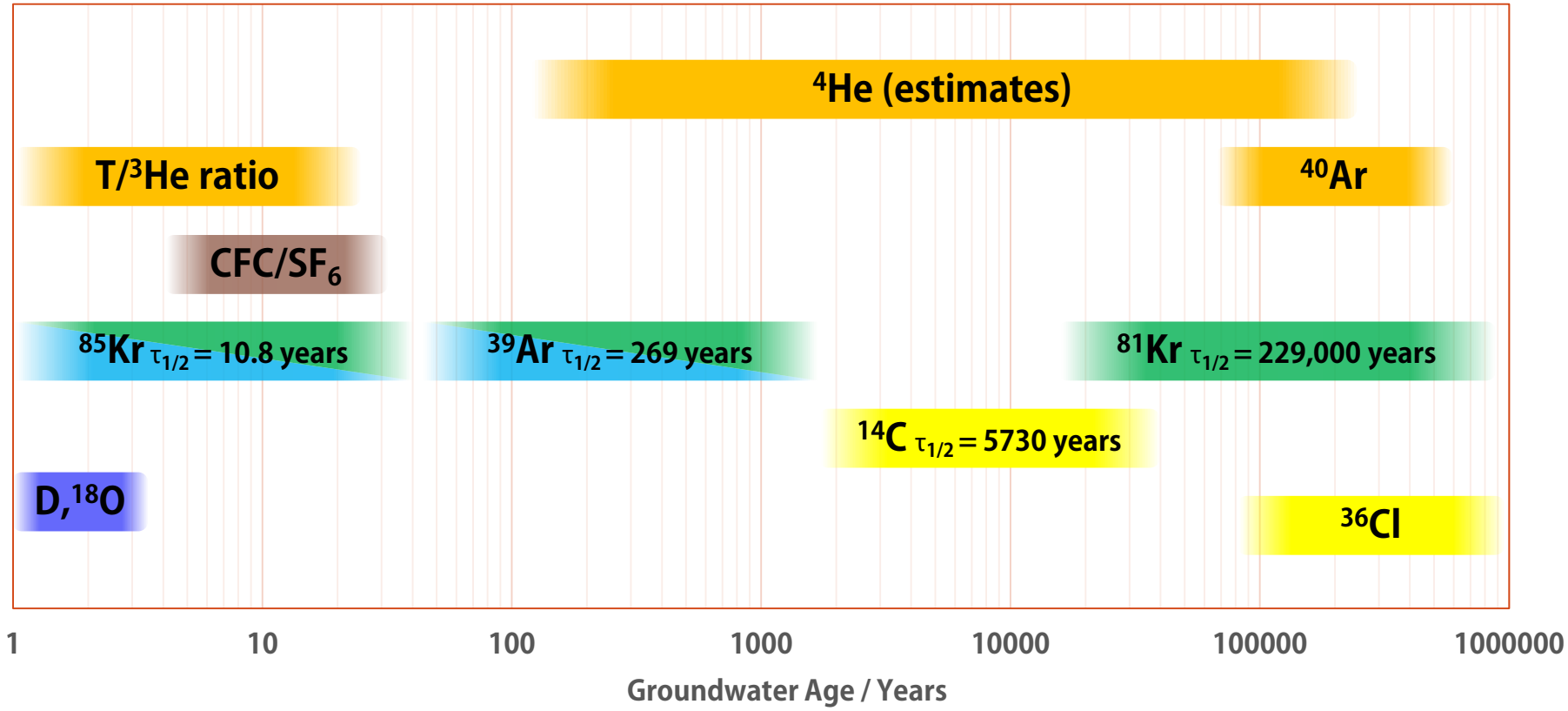


A new facility for fast and accurate measurements of noble gas radio-nuclide ratios

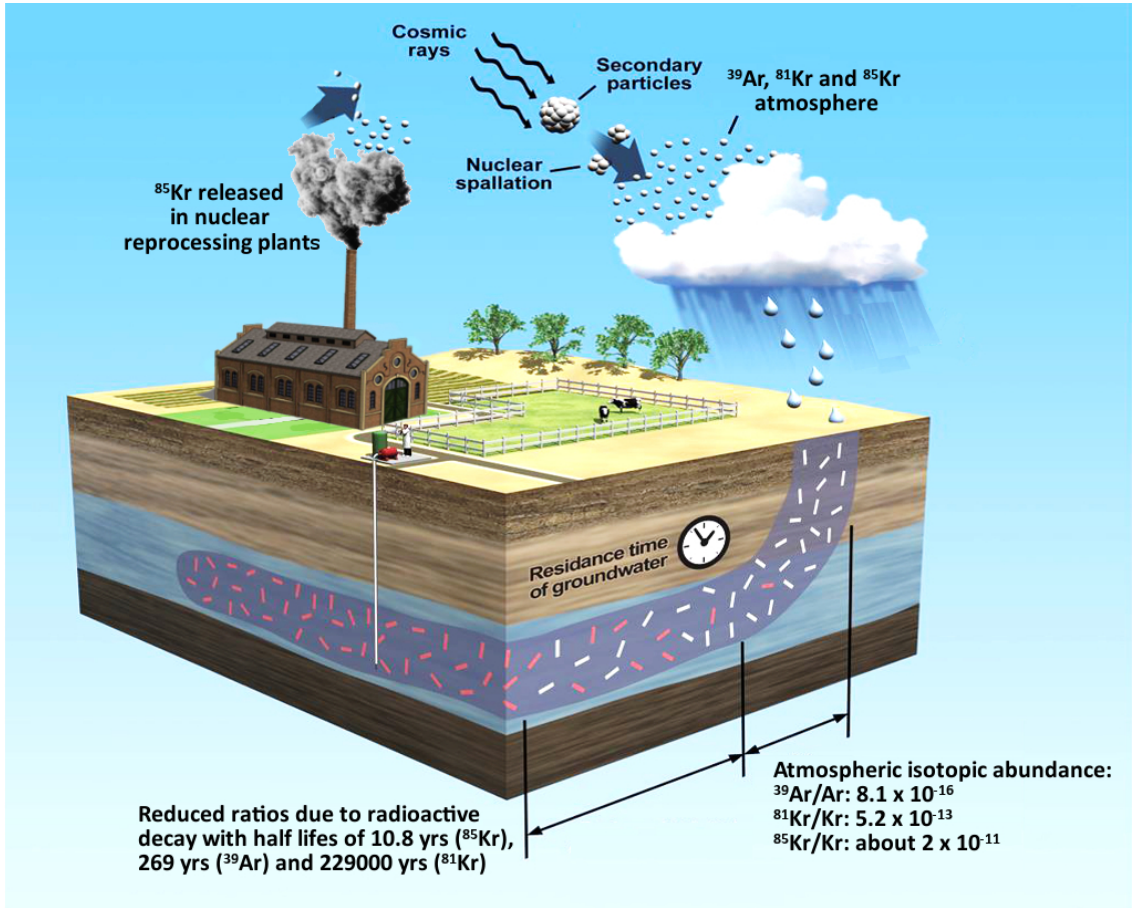
$^{81}Kr/Kr$, $^{85}Kr/Kr$, $^{39}Ar/Ar$

Noble Gas Radio-Isotope Tracers

- Environmental markers to study ground and ocean water movement



Noble Gas Radio-Isotope Tracers

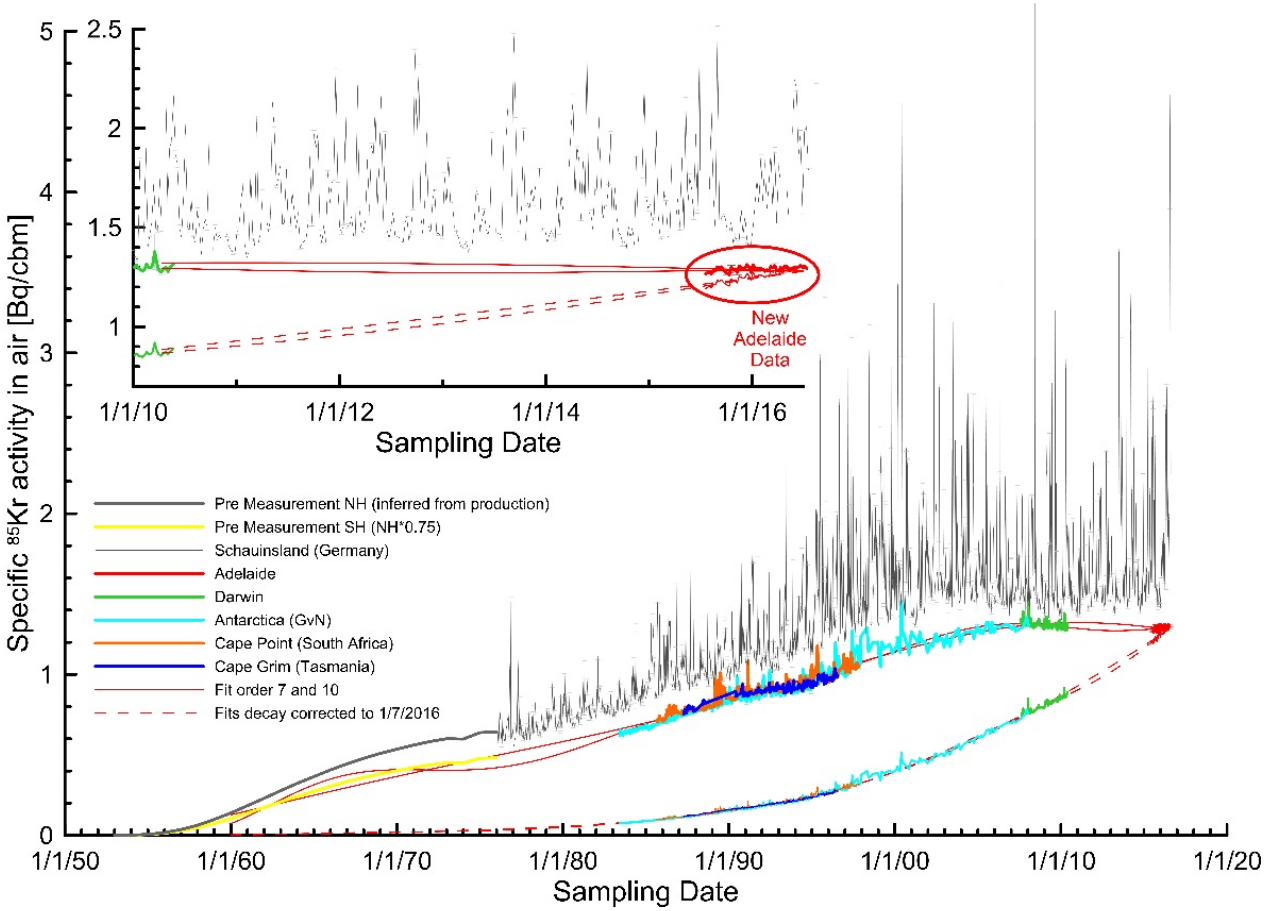


Picture credit: Axel Suckow, CSIRO

- Application to water dating:
  - ^{39}Ar, ^{81}Kr, ^{85}Kr† are cosmogenic nuclides
  - Nearly ideal physical & chemical characteristics (e.g. unreactive)
  - Well defined input function at water/atmosphere interface

†^{85}Kr atmospheric concentration is primarily due to nuclear fuel reprocessing

Noble Gas Radio-Isotope Tracers



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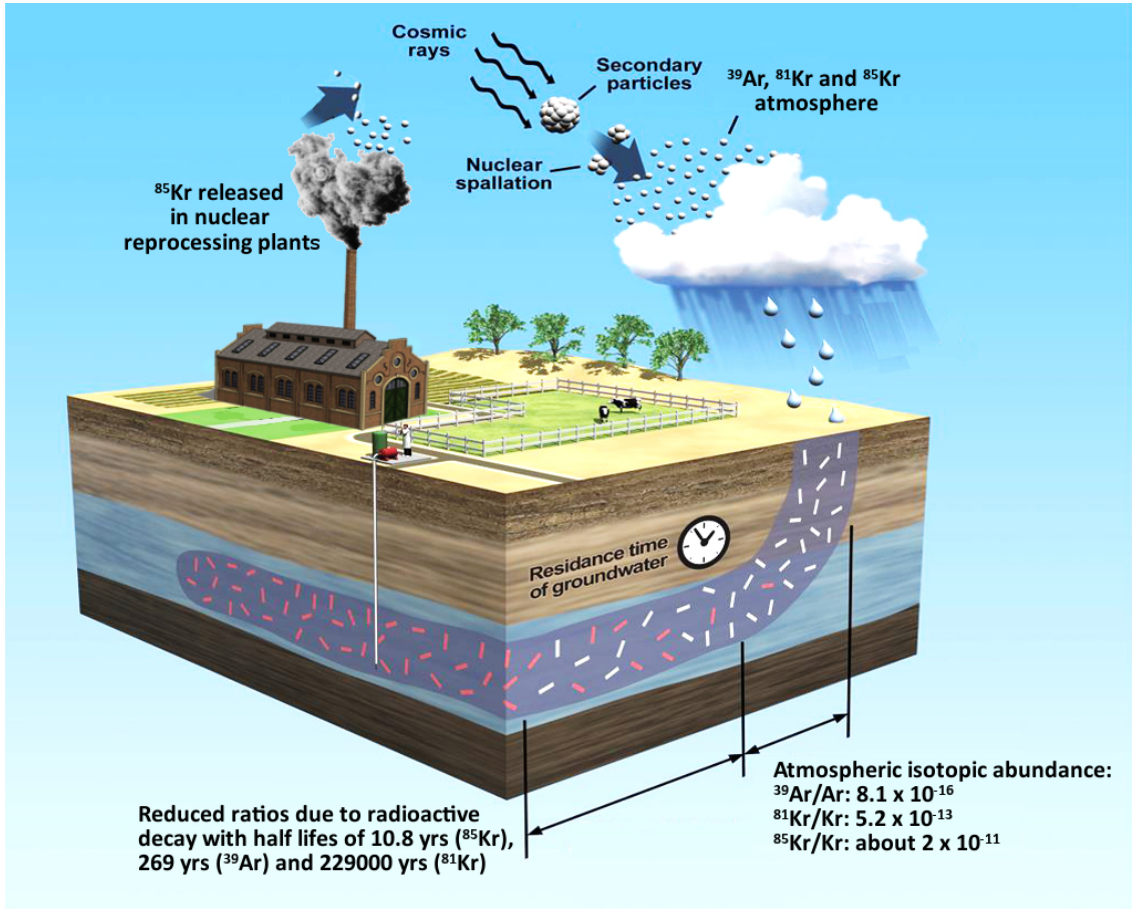

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- Application to water dating:
  - ^{39}Ar, ^{81}Kr, ^{85}Kr† are cosmogenic nuclides
  - Nearly ideal physical & chemical characteristics (e.g. unreactive)
  - Well defined input function at water/atmosphere interface
- Rarely used due measurement difficulty

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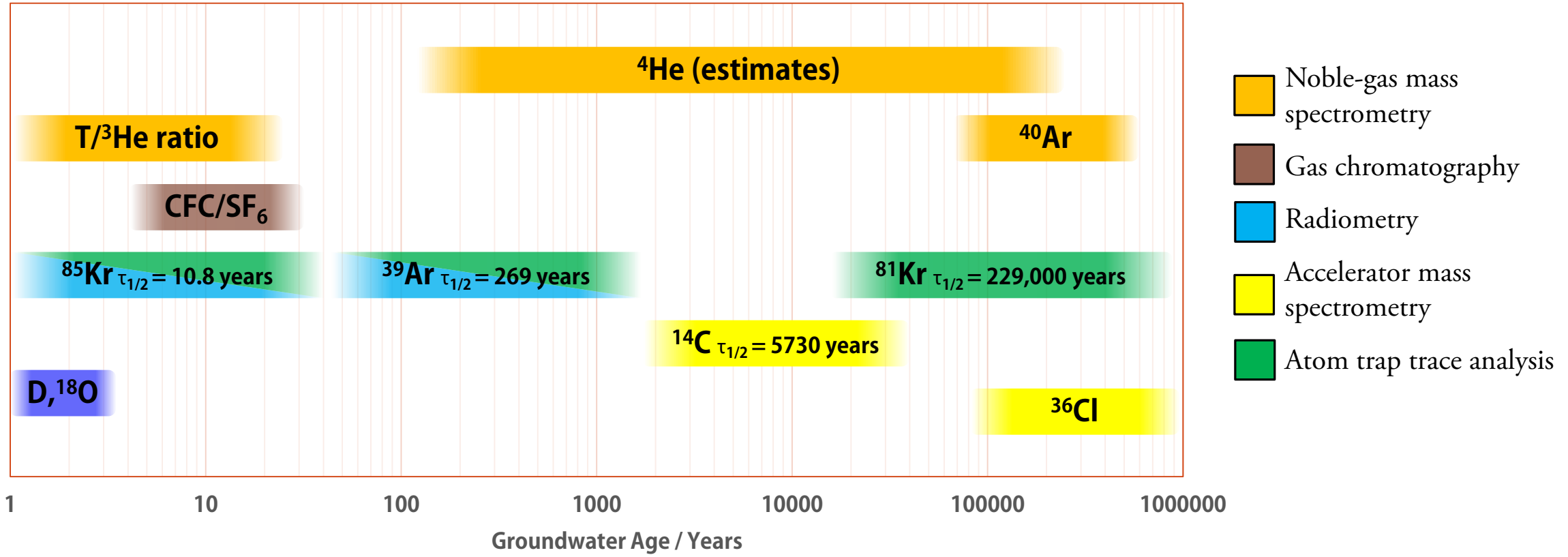
Noble Gas Radio-Isotope Tracers

- Environmental markers to study ground and ocean water movement

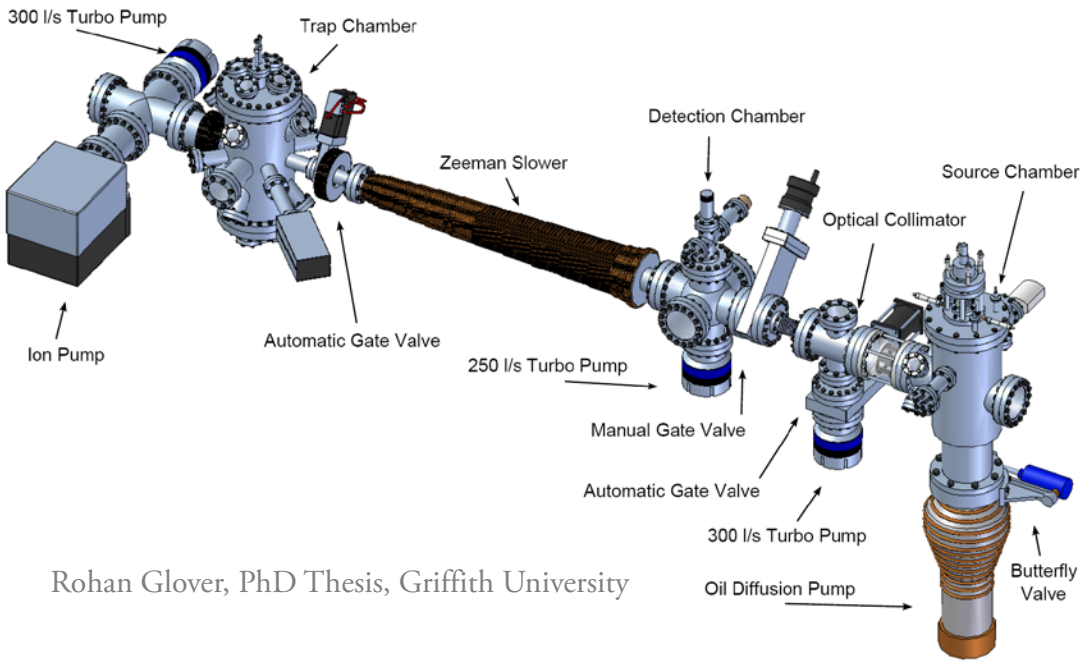


Radio-Isotope Measurements

- Measurements difficult due to small atmospheric abundance:
  - $^{85}Kr/Kr$: $2x10^{-11}$ $^{81}Kr/Kr$: $5.2x10^{-13}$ $^{39}Ar/Ar$: $8x10^{-16}$
  - 1L of surface water contains just ~9000 ^{39}Ar atoms & ~1500 ^{81}Kr atoms
  - Need to measure ratio to ~1% of atmospheric abundance in water dating applications
- Low-level decay counting (LLC) is traditional measurement technique
  - Large water samples required (2000-5000 litres for ^{39}Ar)
  - Long measurement times (8-60 days for ^{39}Ar)
  - Performed where a low background count is present
    - e.g. University of Bern, 35m below ground

Atom Trap Trace Analysis (ATTA)

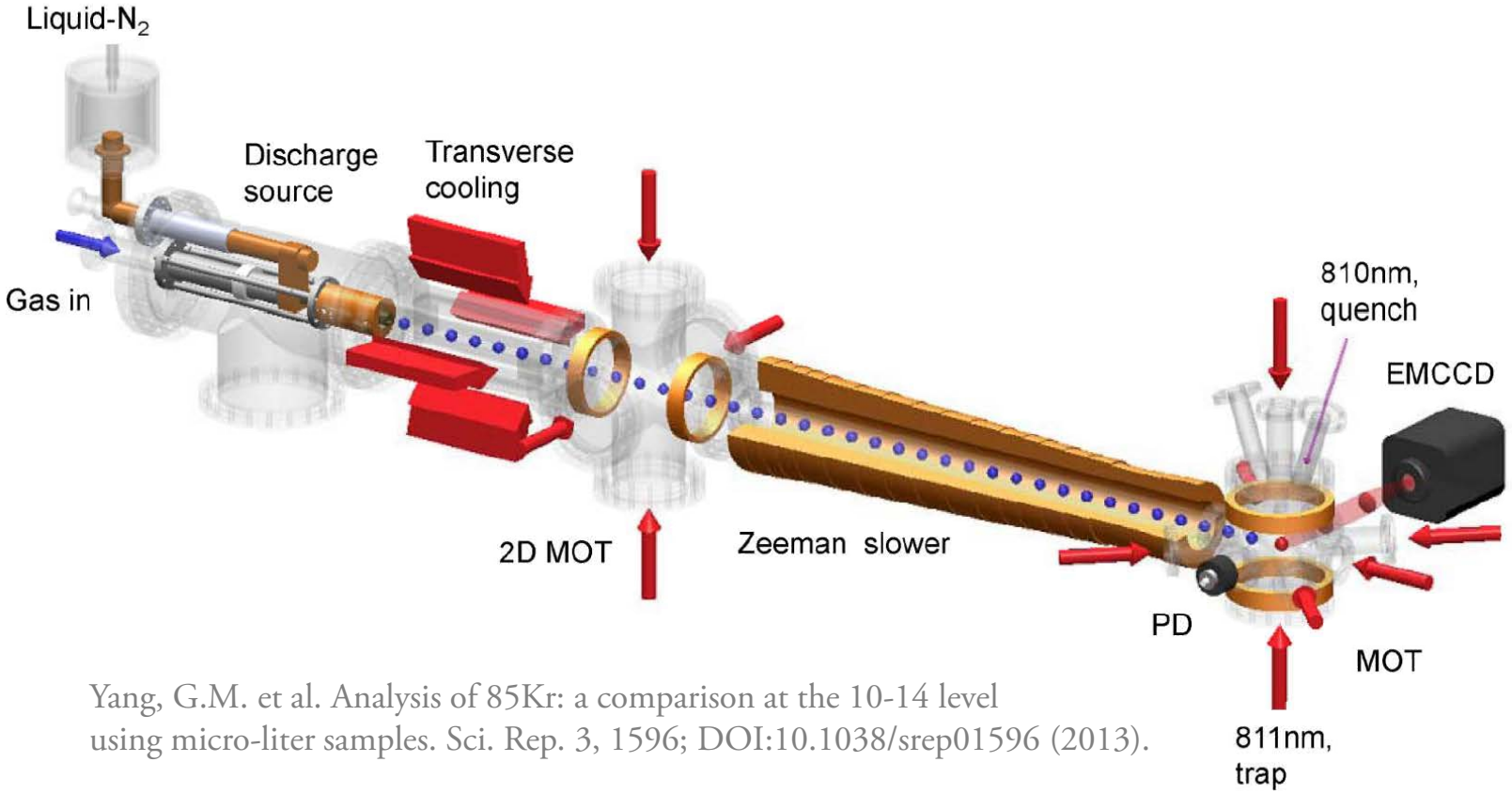
- Laser-based technique for measuring noble-gas radio-isotope ratios
- Atom-counting rather than decay-counting ➠ smaller samples, faster measurement
- Lasers used to cool specific isotope and hold in a magneto-optical trap
- Shifts in energy levels between isotopes permit selection of a single isotope by tuning laser frequencies

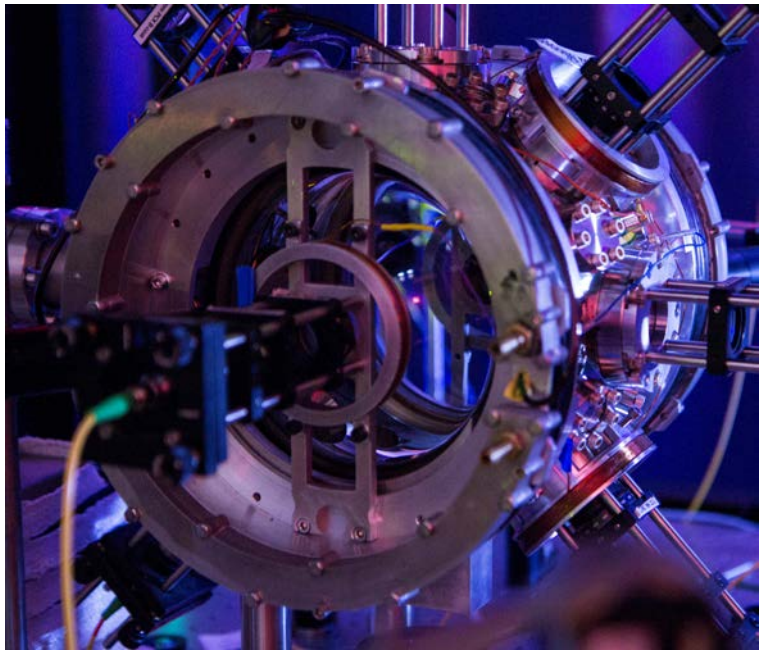


Rohan Glover, PhD Thesis, Griffith University

Atom Trap Trace Analysis

- Based on established laser cooling and magneto-optical trapping





Yang, G.M. et al. Analysis of 85Kr: a comparison at the 10-14 level using micro-liter samples. Sci. Rep. 3, 1596; DOI:10.1038/srep01596 (2013).

Atom Trap Trace Analysis

- Current ATTA systems worldwide:
  - Argonne National Laboratory, IL, USA
    - Predominantly focussed on Kr measurements
    - Only facility currently open for general samples
    - Throughput ~100 samples / year
  - University of Heidelberg, Germany
    - Initial ^{39}Ar measurements demonstrated
  - University of Science and Technology of China, Hefei, China
    - Developing Kr capability

Performance

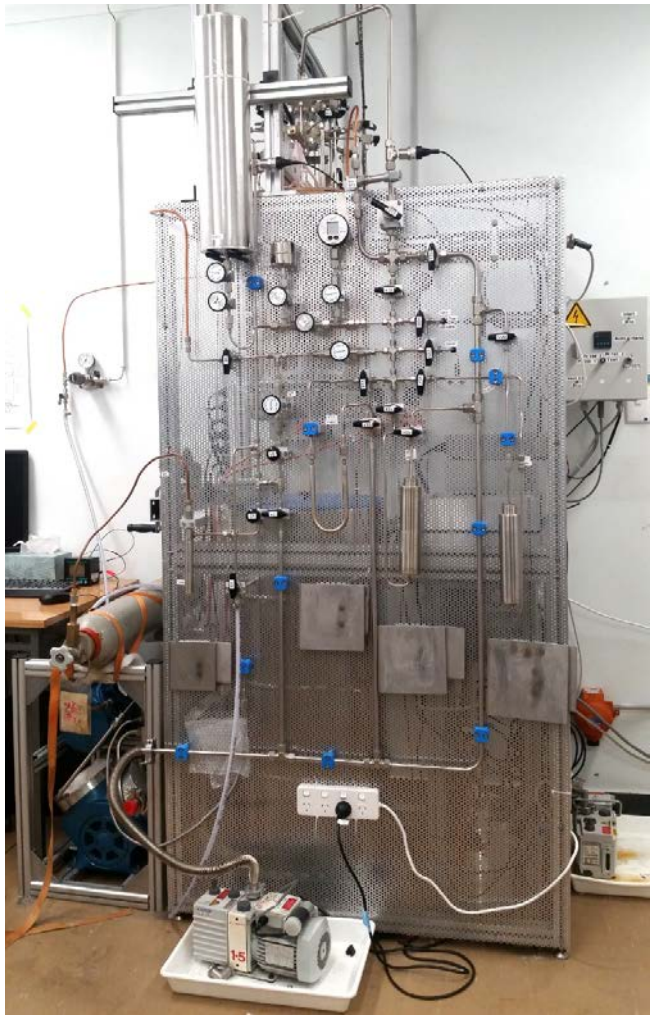
- Initial facility will offer ATTA measurements with performance comparable to existing labs
- Upgraded facility will offer reduced sample size and measurement time

	^{39}Ar			^{81}Kr			Total
	ml-STP	Water / L	Time	µl-STP	Water / L	Time	Samples / yr
AMS	-	-	-	400	8000	9 hours	
LLC	~700	~3000	8-60 days	-	-	-	
ATTA Facility - initial	1	5	~12 hours	5	100	~12 hours	100
ATTA Facility - upgraded	0.1	0.5	~5 hours	0.5	10	~5 hours	300

Sample Preparation

- ATTA measurement requires small gas-phase noble-gas sample
  - Mixed noble-gas samples are not a problem due to selectivity of atom-trapping
- CSIRO's Environmental Tracer and Noble Gas Laboratory in Adelaide can
  - Extract noble gases from water samples
  - Extract gas from water in the field, and separate out noble-gas components

Picture credit: Arne Kersting, Axel Suckow, CSIRO



Timeline

Q3 2016 — Construction commenced at University of Adelaide and Griffith University

Q4 2017 — Initial uncalibrated measurements available in Adelaide

Q3 2018 — Fully calibrated measurements – agreement with low-level counting

Q2 2019 — Laser excitation upgrade installation – smaller sample size

Q4 2019 — Fully calibrated measurements – increased sample throughput

Australian Facility For Noble-Gas Radio Isotope Measurements

- Fast, accurate measurements of ^{81}Kr, ^{85}Kr and ^{39}Ar radio-nuclide ratios
- Small sample size requirements (isotope dependent)
- Expected to commence sample measurement late 2017
- Funded through per-sample analysis fee

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