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Weak rates determining the production of the ^{205}Pb cosmochronometer in AGB stars

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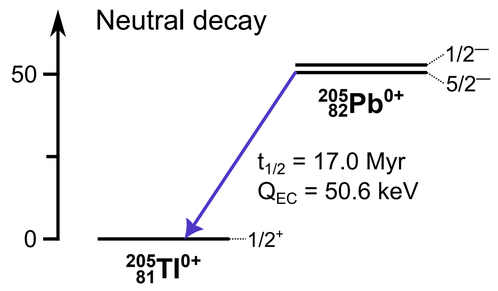
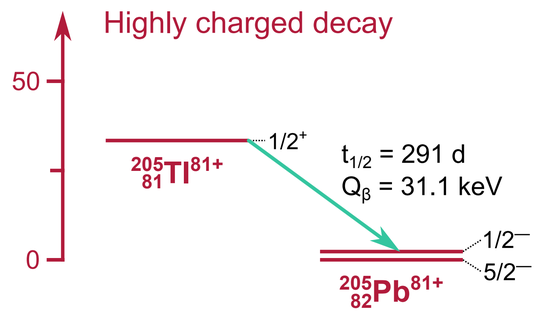
Motivation

- Due to its half-life ^{205}Pb can serve as a cosmochronometer for the age of the solar system.



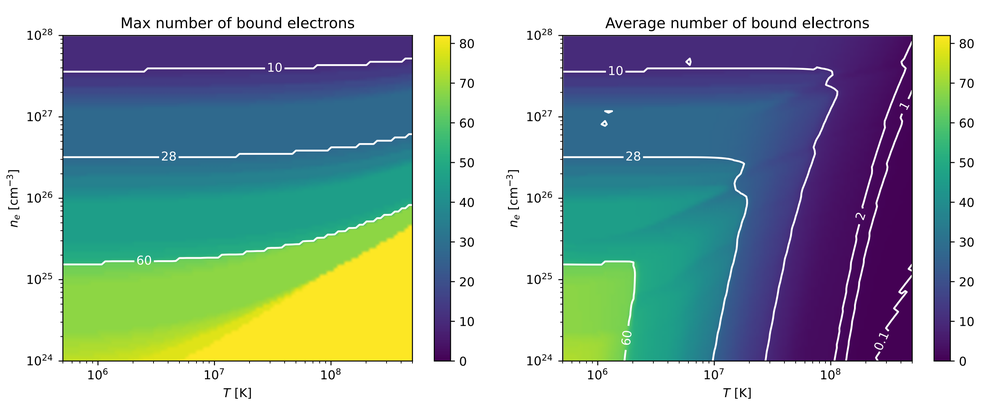
- ^{205}Pb is an *s*-process element produced in AGB stars — the exact production rate depends on:
  - the destruction of ^{205}Pb in the ^{13}C pocket at T~90 MK by electron capture from the thermally excited 1/2$^-$ state
  - the production of ^{205}Pb by bound β decay of ^{205}Tl at T~250 MK in He flashes
- **The transition between the 1/2$^+$ ground state of ^{205}Tl to the first excited 1/2$^-$ state at 2.3 keV in ^{205}Pb was measured for the first time by the E121 Collaboration with the ESR at GSI Darmstadt [1].**

➡ poster by Iris Dillmann for more details

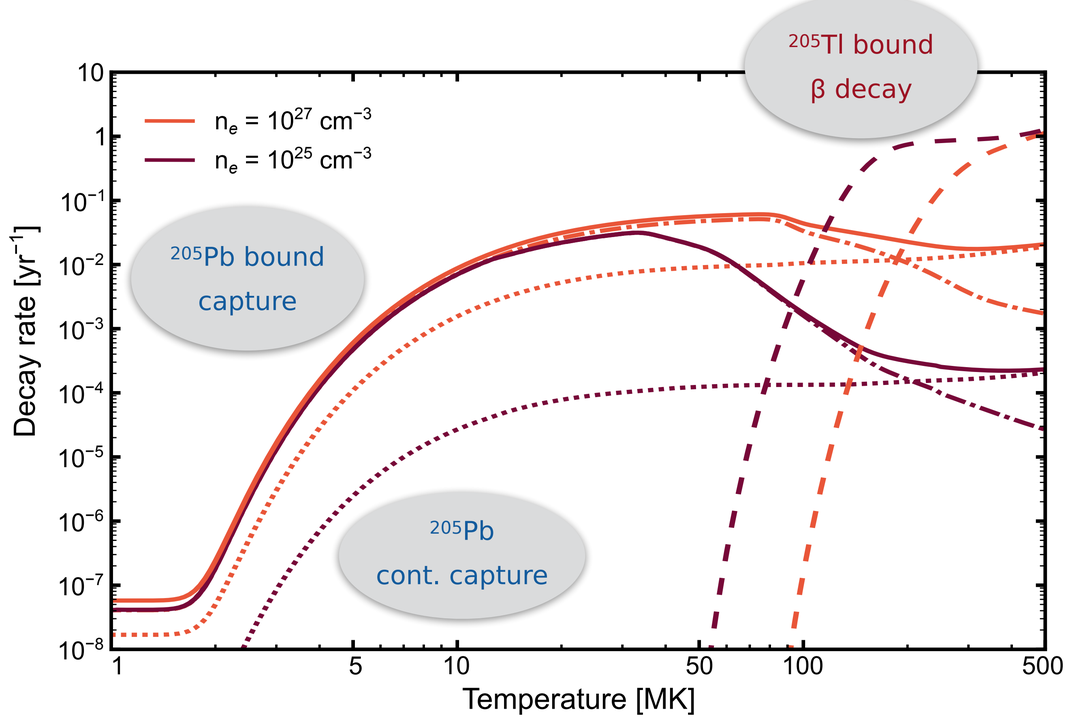


Method

- Following the basic approach of Takahashi and Yokoi [2] the ^{205}Pb electron capture and ^{205}Tl bound β decay rates depend on:
  - the nuclear matrix elements (fixed by experiment — consistent with shell model calculations of first-forbidden transition using KHH interaction)
  - the thermal population of the nuclear states, especially the 1/2$^-$ state in ^{205}Pb at 2.3 keV
  - continuum and bound electron wave functions of ions (calculated with DHF code)
  - the energies and occupations of atomic configurations — distribution of charge and excitation states of ions as a function of temperature and electron density determined by Saha equation
  - the interaction of the ions with the surrounding plasma changes the atomic ionization potentials

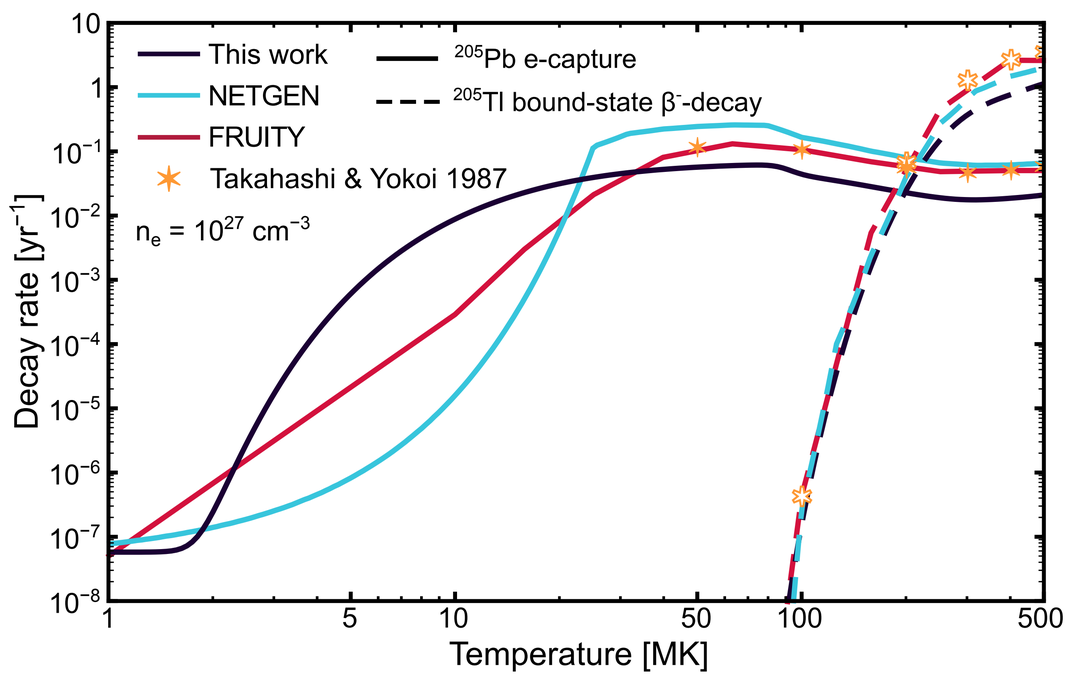


Electron capture and bound β decay rates



- ^{205}Pb bound capture rate rapidly increases with thermal population of 1/2$^-$ state at 2.3 keV.
- Bound capture rate starts to drop when atomic *L*- and *K*-orbits become depopulated.
- ^{205}Pb continuum capture rate depends on population of 1/2$^-$ state and increases rapidly with electron density.
- ^{205}Tl bound β decay requires vacancies in the atomic *K*-shell, only found at high temperatures, also sensitive to electron density.

Comparison with literature rates



- Rates used in FRUITY models and the NETGEN library are based on calculations by Takahashi and Yokoi [3] with different assumptions about the Q-value and are extrapolated to low temperatures.
- Our results [1] improve upon Takahashi and Yokoi mainly due to the experimentally determined nuclear matrix element and an improved Q-value but also because of a more detailed treatment of atomic states and wave functions and improvements in the ion-plasma interaction.

[1] Leckenby, *et al*, accepted for publication in *Nature*

[2] Takahashi, Yokoi, *Nucl. Phys. A* **404**, 578 (1983)

[3] Takahashi, Yokoi, *Atom. Data and Nucl. Data Tables* **36**, 375 (1987)

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