K-Ar
(and noble gas cosmic ray exposure age)
(and U/Th-He)
Dating

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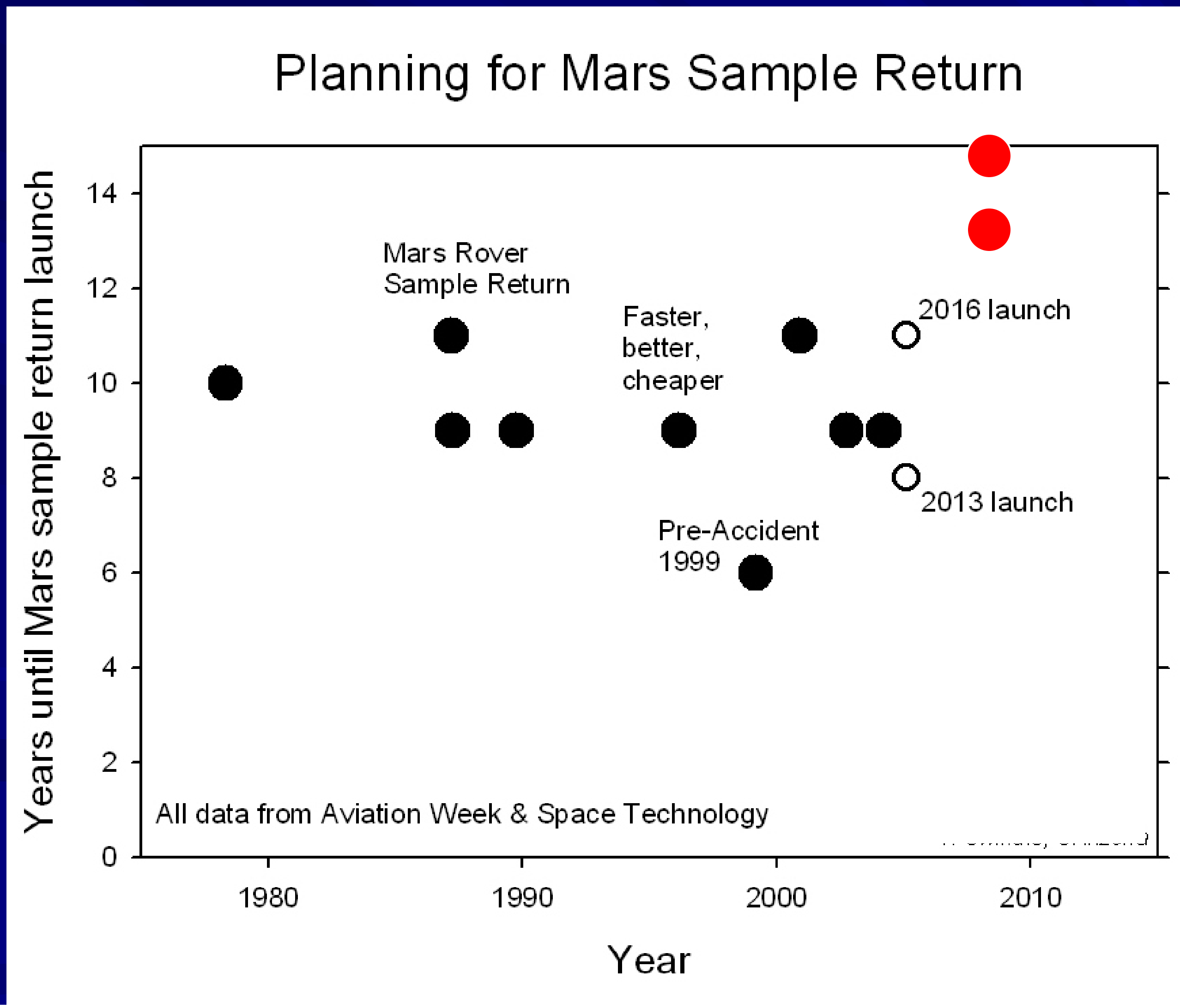
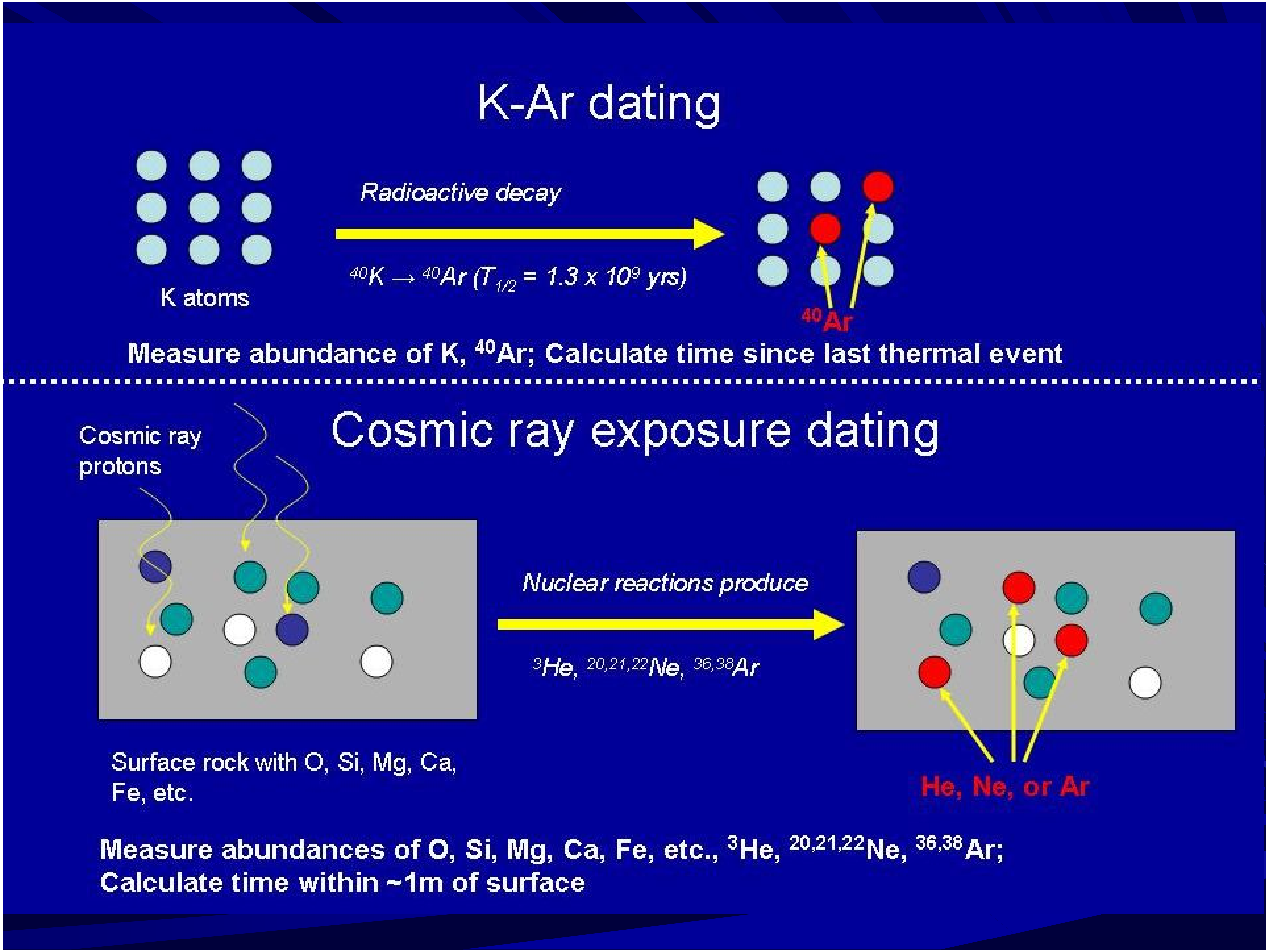
Why consider in-situ dating for 2020 when there will be a 2022 sample return?



Last updated 2005, but …


K-Ar dating
K atoms
Radioactive decay
40K → 40Ar (T1/2 = 1.3 x 10^9 yrs)
40Ar
Measure abundance of K, 40Ar; Calculate time since last thermal event
Cosmic ray exposure dating
Cosmic ray protons
Nuclear reactions produce
3He, 20,21,22Ne, 36,38Ar
Surface rock with O, Si, Mg, Ca, Fe, etc.
He, Ne, or Ar
Measure abundances of O, Si, Mg, Ca, Fe, etc., 3He, 20,21,22Ne, 36,38Ar;
Calculate time within ~1m of surface

Advantages of noble gas geochronology

- Multiple techniques with single system
  - Complementary
    - Measure different identifiable conditions, may be same event
- Intrinsically simple – using techniques that were used 50 years ago in terrestrial labs

Requirements for in situ noble gas geochronology system

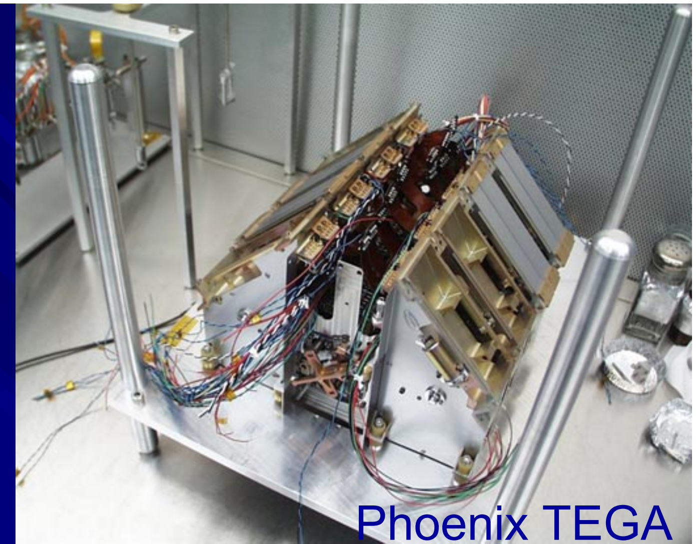
- Measure noble gases
  - Mass spectrometer
    - MSL SAM, Beagle2, many others
- Measure major elements plus K
  - XRS (many flown)
  - LIBS
    - MSL ChemCam
- This sounds easy!
  - What’s needed to make those measurements?

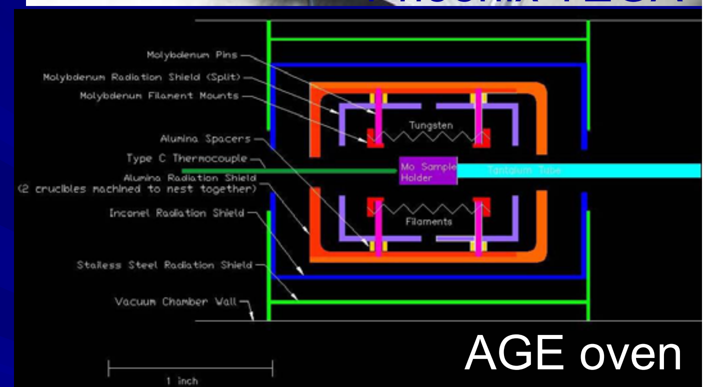
The tough requirements

- Acquire sample (10 mg)
- Heat sample
  - – For CRE, many terrestrial labs use 1600ºC
  - – SAM, Phoenix TEGA 900-1100ºC
- Weigh sample
  - – XRF, LIBS give fractional abundance; mass spectrometers give absolute
- Interpret the results

Heating a sample

- Conduction (Phoenix TEGA)
- Radiative (MIDP AGE)
- In both cases, fighting
  - Radiative losses (σT^4)
  - Heating surrounding material
    - Outgassing, stressing materials
- Best alternative – diode lasers
  - Labs often use lasers, but not efficient enough for S/C
  - Until recently, efficient lasers were low-power (mW)
  - Diodes spec ~40% efficiency, 10s of W (~20W needed)


Phoenix TEGA

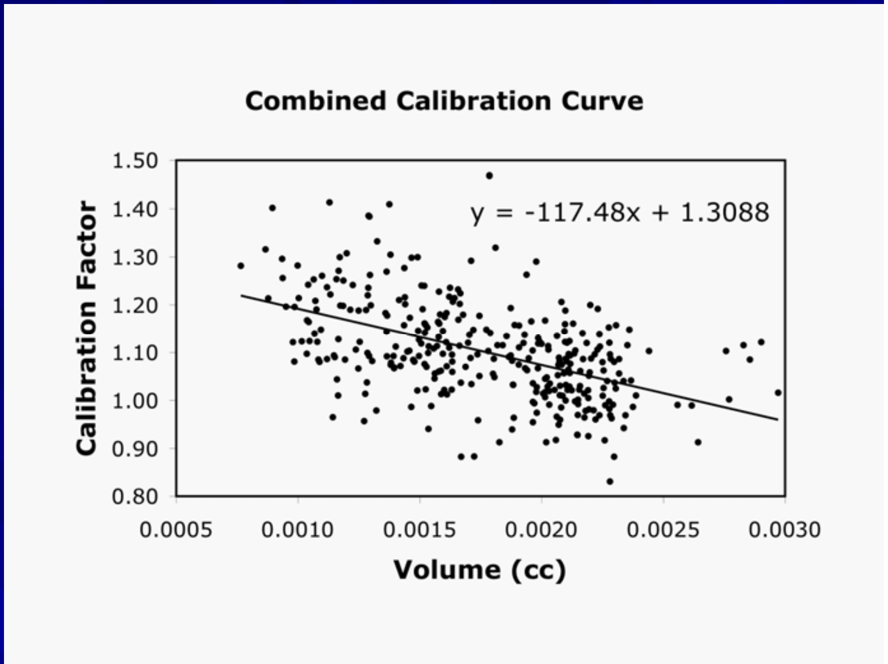


AGE oven


Coherent diode array (80W)

Weighing a sample

- Knife-edge balances unlikely to like vibe
- Calculate from volume of powder
  - Packing fraction?
- Melt & measure volume, calculate density
  - 7% relative uncertainty (1σ) for MIDP AGE
  - Requires melting
- Piezoelectrics?
- Vibration frequency?



"Calibration factor" (factor ρV has to be multiplied by to get the correct mass) for two basalts, a chondritic meteorite, and three peridotites. The calibration factor is necessary because the molten sample developos a meniscus. From Fennema et al. (LPSC XXXVIII, #1772).

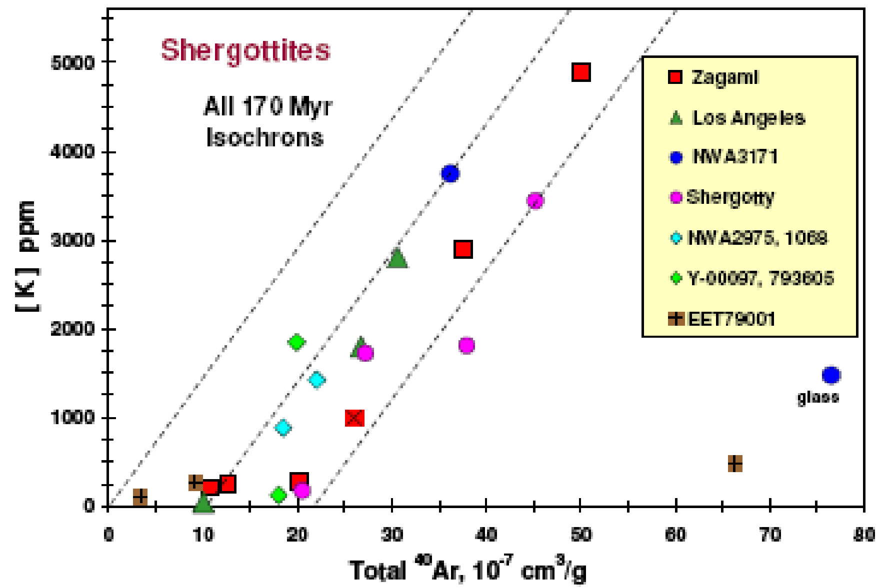
Interpretation

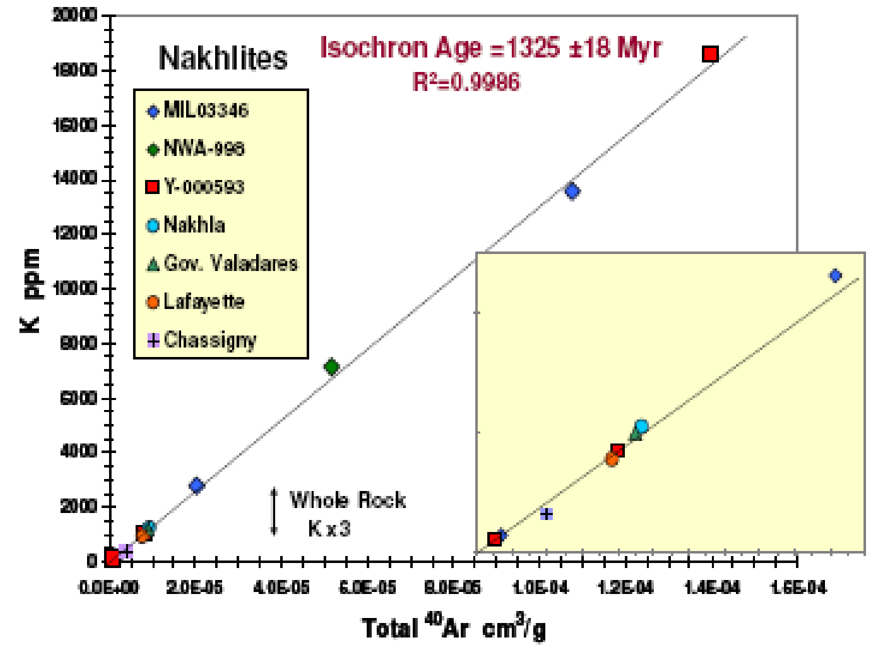
- Trapped atmosphere?
  - Adsorption?
    - 1% of P_{Earth}, but lower temperatures
  - Shock-implanted atmosphere unlikely to be problem
    - Heavily shocked rocks likely to be uncommon
- Partially reset ages?
  - Less likely to be problem than Earth (no plate tectonics, impacts not very effective at resetting)

Martian meteorite Elephant Moraine 79001, with its shock-produced glasses (dark patches) full of Martian atmospheric gases.

Interpretation (continued)

- Magmatic gases incorporated?
  - Could be problem for ^{40}Ar, particularly for young samples
    - Bogard – Shergottites incorporate ~constant amount of ^{40}Ar, not constant $^{40}Ar/^{36}Ar$ ratio
    - For very young samples, CRE age could be more accurate
  - Need multiple samples





Bogard (2008) LPSC XXXIX, #1100

The bottom line

- In situ noble gas geochronology is promising, but there are tough (not insurmountable) problems to solve
  - Sample heating (10 mg to 1500ºC)
  - Weighing a 10 mg sample
- Problems aren't unique to noble gas systems