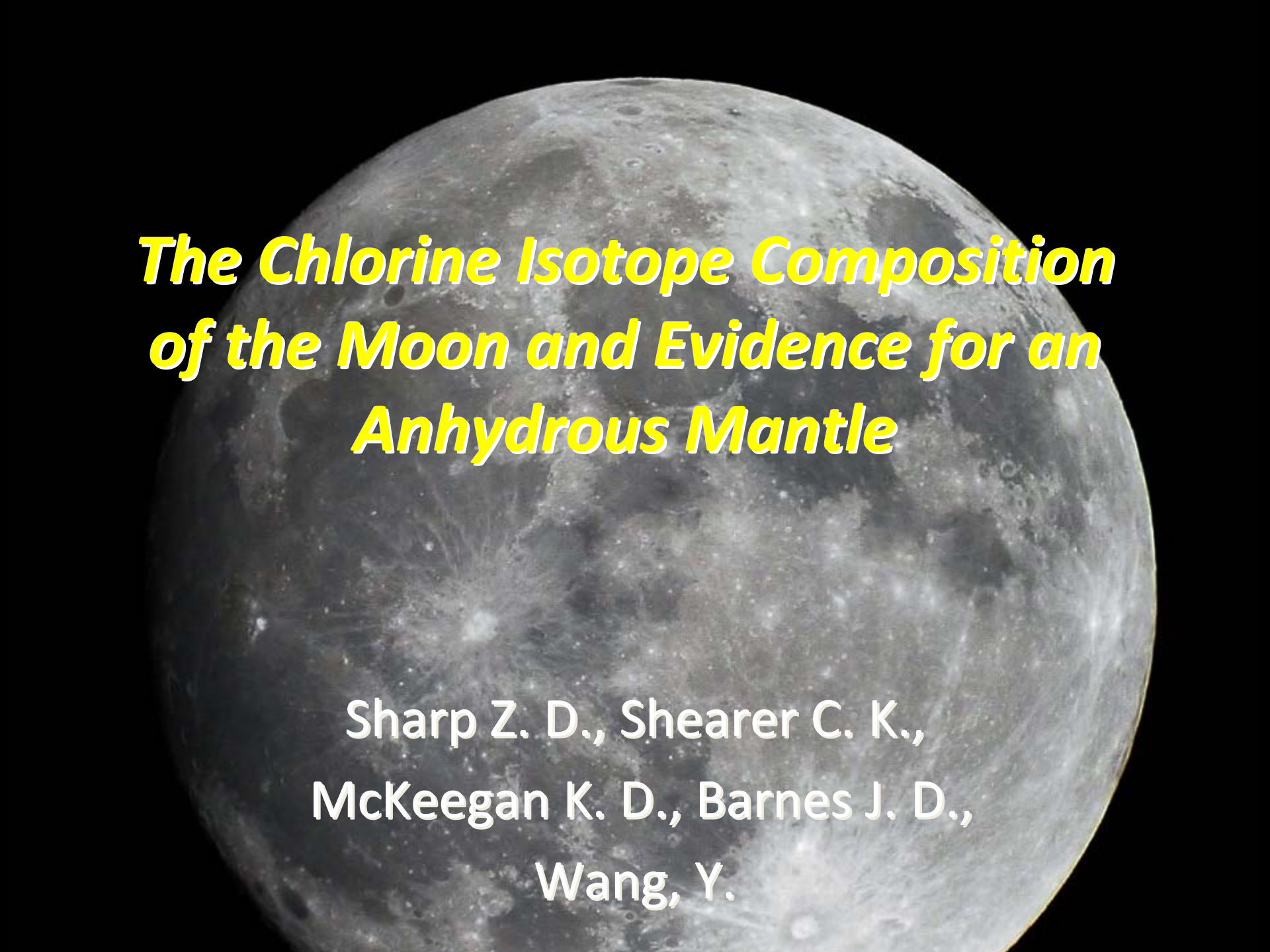

The Chlorine Isotope Composition of the Moon and Evidence for an Anhydrous Mantle

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Chlorine Isotope Geochemistry

- Two stable isotopes of Cl:

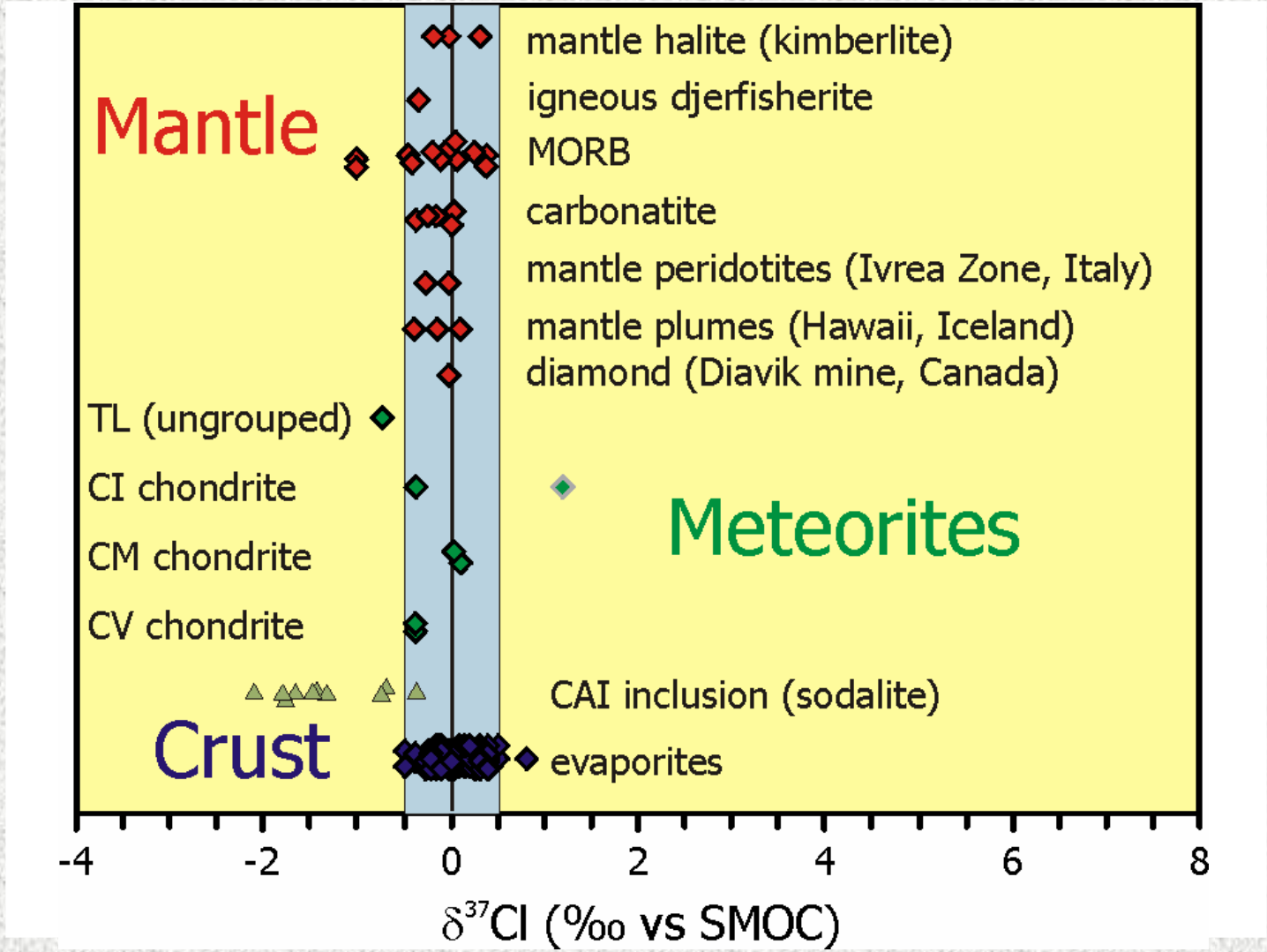
  ^{35}Cl (75.8%); ^{37}Cl (24.2%) AMU = 35.45

- Data are given in conventional delta notation

- $$\delta^{37}Cl = \left(\left(\frac{^{37}Cl}{^{35}Cl} \right)_{sa} \Big/ \left(\frac{^{37}Cl}{^{35}Cl} \right)_{std} - 1 \right) 1000$$

- Standard is SMOC (*Standard Mean Ocean Chloride*)

Chlorine isotope composition of primitive Terrestrial and meteorite materials



Rationale for Lunar Samples

- Chlorine is a volatile, hydrophilic element. On Earth it strongly tracks with water.
- Primitive mantle materials & carbonaceous chondrites are all close to 0‰.
- The isotopic composition of the Moon could indicate:
  - Similarity to Earth (no fractionation during Giant impact).
  - Differences due to
    - impact fractionation?
    - different source?
    - late addition of volatiles to Earth?

Time to sample the Moon!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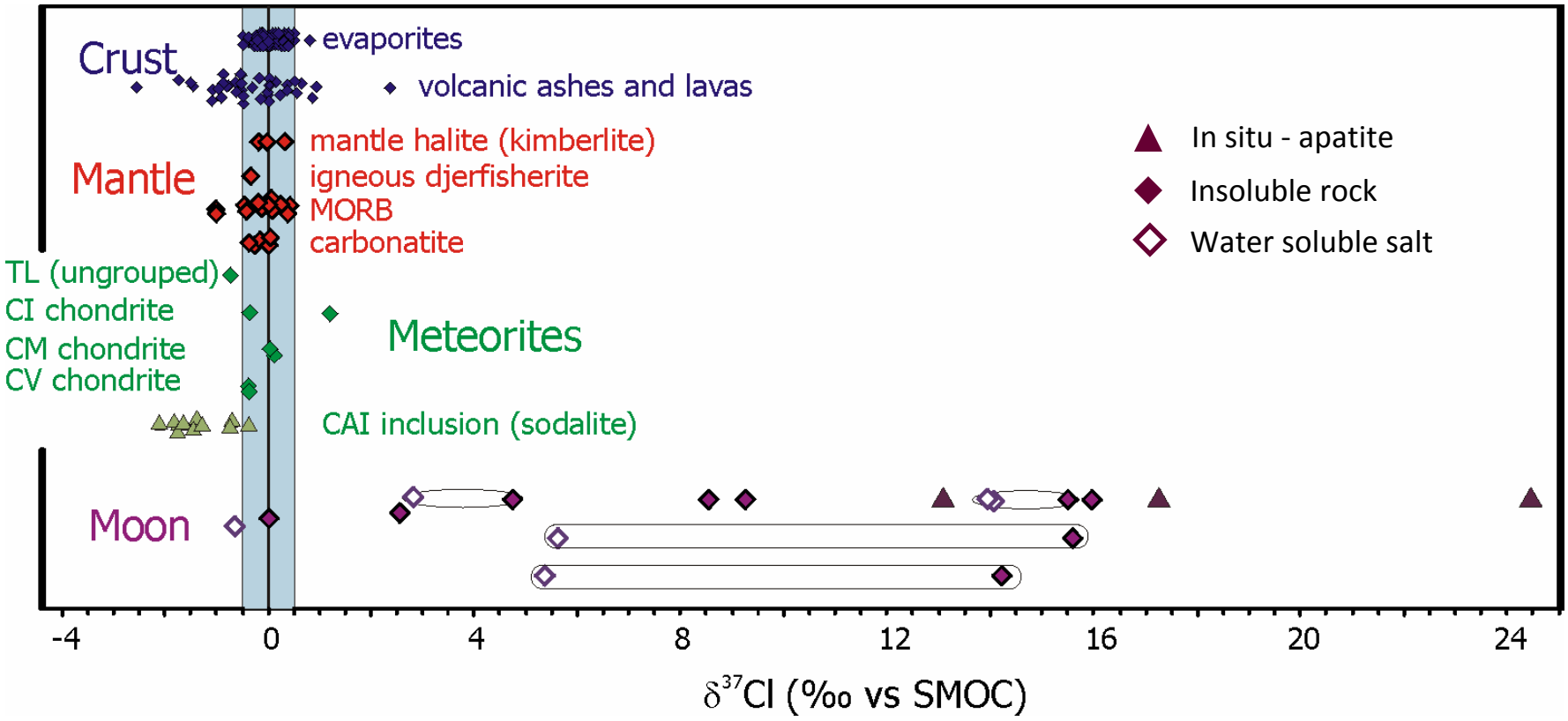
MAIN MOM
TALK

Sample Suite

- Olivine basalt (12040, 15555)
- Pigeonite basalt (12052)
- high-Ti mare basalt (10017)
- Regolith breccia (12034)
- Immature soil (61220)
- Mature soil (64501)
- Impact melt rock (66095)
- KREEP pigeonite basalt (72275)
- Orange volcanic soil/glass (74220, 74002)

Chlorine isotope composition of Lunar materials



Why the spread?

- 1) ~~Initial lunar heterogeneity~~
- 2) Solar wind/micrometeorite bombardment
- 3) Fractionation during degassing

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- 3) Fractionation during degassing
  - Conditions on Moon are different from Earth?

Solar Wind/Micrometeorites?

- There is no correlation with degree of exposure and $\delta^{37}Cl$ value.
  - The highest $\delta^{37}Cl$ value is for shielded apatite from KREEP pigeonite basalt 72275.
  - No correlation with sulfur isotopes
- Our high energy hydrogen bombardment of a NaCl thin film produced no fractionation.

Fractionation due to anhydrous basalts: Earth

- Cl degasses as HCl (*g*)
- Two fractionation mechanisms occur:
  - preferential loss of ^{35}Cl to vapor phase (higher translational velocity – Graham's Law)
  - preferential enrichment of ^{37}Cl in HCl (*g*) due to stronger bonding

- Overall, the two effects cancel one another and no Cl isotope fractionation is observed.

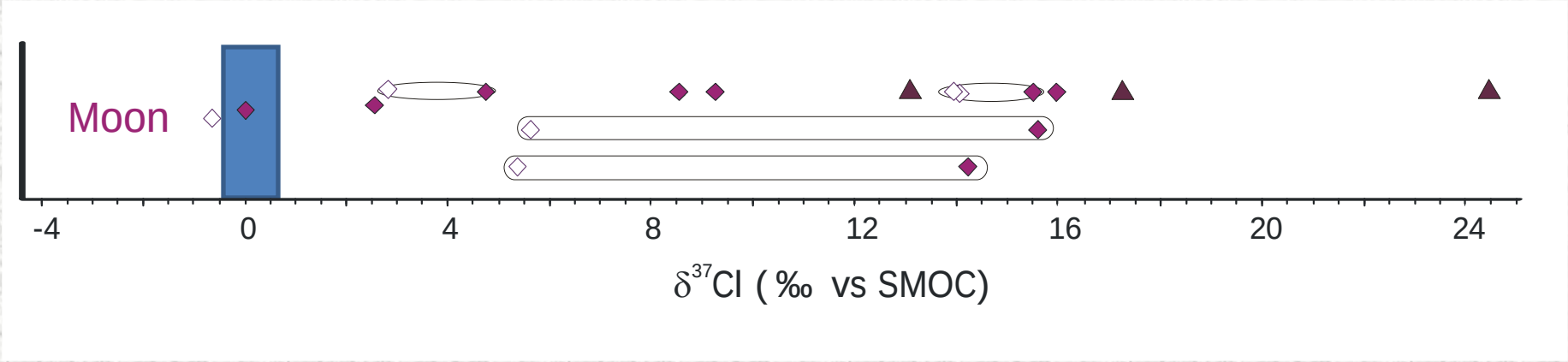
Fractionation due to anhydrous basalts: Moon

THE MOON WAS ANHYDROUS

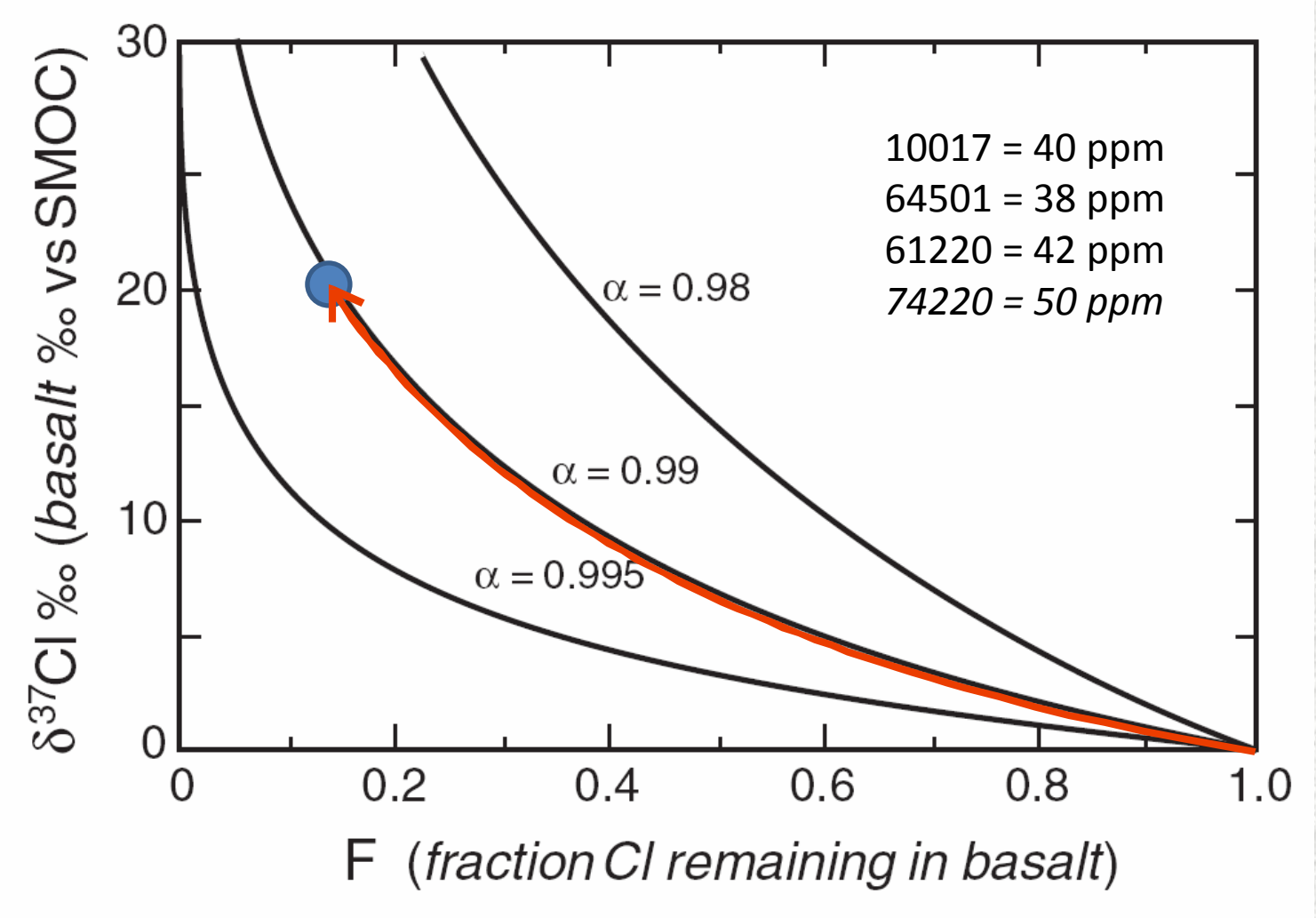
- Cl degasses as metal chlorides
- One fractionation mechanisms occurs:
  - preferential loss of ^{35}Cl to vapor phase (Graham's Law)
  - No preferential enrichment of ^{37}Cl in metal chloride gases – similar bonding to melt
- Degassing removes the light isotope of Cl

Evidence for anhydrous degassing

- $FeCl_2$, $MgCl_2$, $ZnCl_2$, NaCl, $PbCl_2$ have all been found as surface coatings on lunar samples
- Metal chlorides always have lower $\delta^{37}Cl$ values than coexisting basalt
- The lowest $\delta^{37}Cl$ values are similar to Earth's (0.0, -0.7‰)



Estimating initial Cl content



Initial H content

- Lower than Cl content
- Cl only volatilizes after 90-95% crystallization
- Primitive melts were concentrated in incompatible elements by a factor of ~10
- The H content of the lunar mantle was ~10 ppb or less (90 ppb H_2O).
- This is in agreement with McCubbin, but not with previous estimates which are higher by orders of magnitude.