

THERE IS ONLY ONE ROSETTA (AL RASHID) STONE IN THE SOLAR SYSTEM: IT'S IN THE BRITISH MUSEUM

T.OWEN
NASA AMES 19/2/15

CONSIDER THREE MAJOR QUESTIONS:

1. HOW DID EARTH GET ITS VOLATILES?
2. HOW DID GIANT PLANETS GET ATMOSPHERES?
- (3. IS THERE EXTRATERRESTRIAL LIFE
IN THE SOLAR SYSTEM?)

1. HOW EARTH GOT ITS VOLATILES

- ~~ENDOGENIC~~

- EXOGENIC

- ICY PLANETESIMALS AKA COMETS

- ROCKY PLANETESIMALS AKA ASTEROIDS, METEORITES

- COURIERS MUST HAVE a) Deuterium/Hydrogen $= (D/H) = 1.6 \times 10^{-4}$
(IN WATER)

- b) Krypton/Xenon $= Kr/Xe > 100$

EXOGENOUS SOURCE

- ICY (NOT ROCKY) PLANETESIMALS

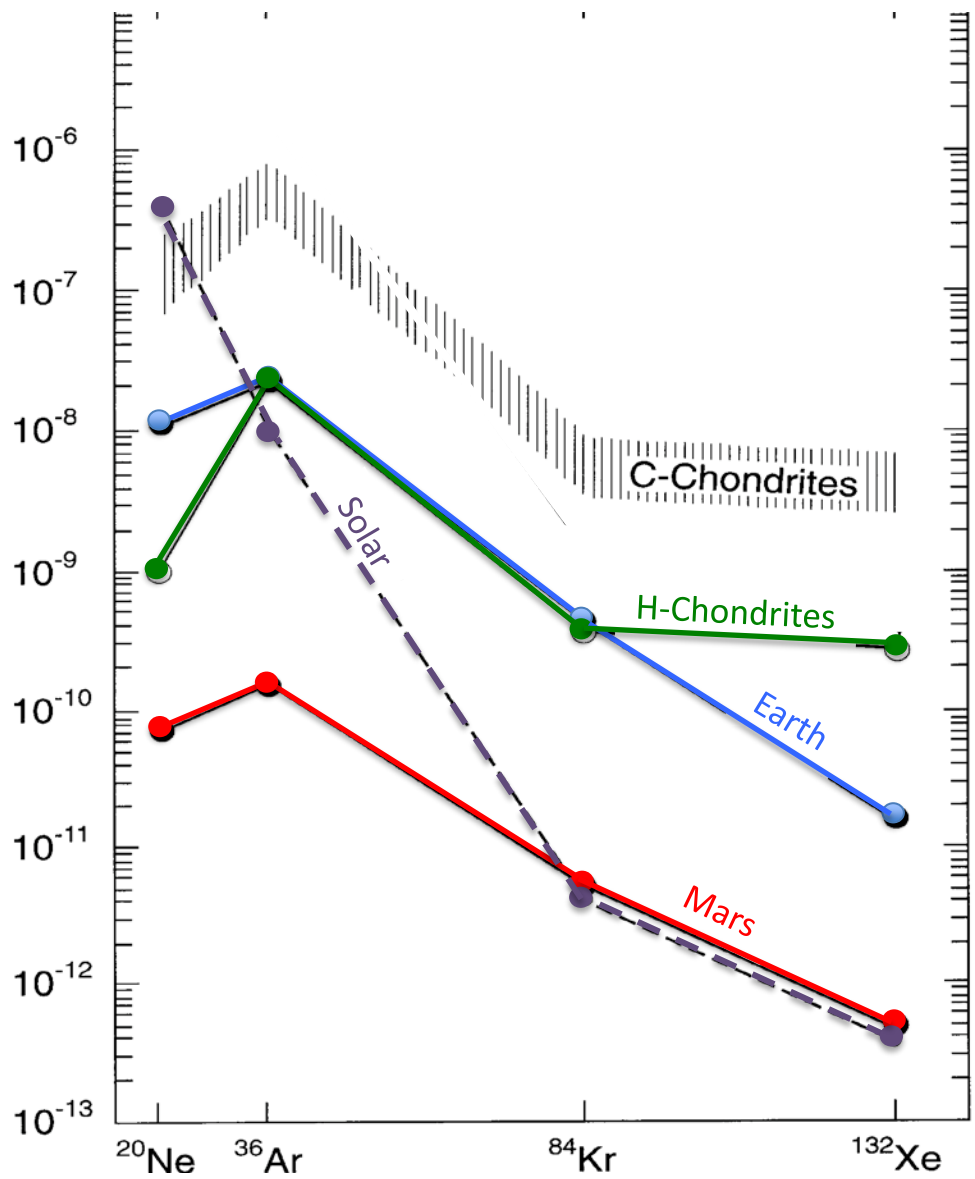
WHY?

ONLY on MARS Kr/Xe ~ EARTH Kr/Xe

Not So in Meteorites!!

or in sun, or in Jupiter

Common Bombardment by Comets??



COMETS AS SOURCE OF EARTH'S WATER??

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- TWO PRINCIPAL COMET FAMILIES:
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-
- OORTCLOUD ORIGIN: KUIPER BELT
- JUPITER FAMILY (JFC) ORIGIN: URANUS<>_NEPTUNE
-
-
-
- TEST THAT ICE IN AN IMPACTOR MUST PASS:
-
- DEUTERIUM/HYDROGEN (D/H) IN A COMET'S ICE
-
- **MUST = D/H IN OCEANS, ICE, YOU, ETC.** **D/H = 1.6 X10⁻⁴**
- (SAME VALUE FOUND IN WATER IN METEORITES)
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-
-
-
-
- MANY VALUES EXIST IN SOLAR SYSTEM: e.g, Jupiter 2.6 X10⁻⁵

THE COMETS WITH KNOWN D/H

<u>FAMILY</u>	<u>DESIGNATION</u>	<u>YEAR</u>	<u>D/H</u>
● HALLEY	HALLEY	1986	3.2×10^{-4}
● OORT	AVERAGE OF FIVE	MSC	3.0
● JFC	103 P HARTLEY 2	2011	1.6
● JFC	67P CHUR.-GER.	2014	5.3
● JFC	45 P H-M-P	2014	<2}

THE RIDDLE OF THE MARBLE JAR:

IMAGINE A JAR FILLED WITH MARBLES.
YOU CAN'T SEE INSIDE THE JAR.

NOW REACH IN AND TAKE OUT ONE
MARBLE—IT'S BLACK!

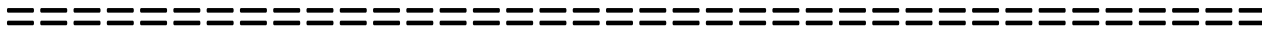
"A HA!" YOU EXCLAIM, "THE MARBLES IN
THE JAR ARE BLACK"

NOW YOU TRY AGAIN. THIS TIME THE
MARBLE IS WHITE." IT'S A MISTAKE, AN
ACCIDENT,

IT'S NOT REALLY A MARBLE." BUT THE
NEXT ONE IS ALSO WHITE. "MAYBE THE
BLACK ONE
IS THE MISTAKE" ETC., ETC.

CONCLUSIONS

- DID COMETS BRING THE OCEANS TO EARTH?
 - MAYBE YES, MAYBE NO
 - Need more observations!!



TO PROGRESS:

RETURN TO HARTLEY 2—Study Noble gases Plus compare all with Chur-Ger

NEED STATISTICS: MINI-ROSETTA FLOTILLA

JFC PLUS OORT? (STORE S/C IN “GARAGE” WAIT)

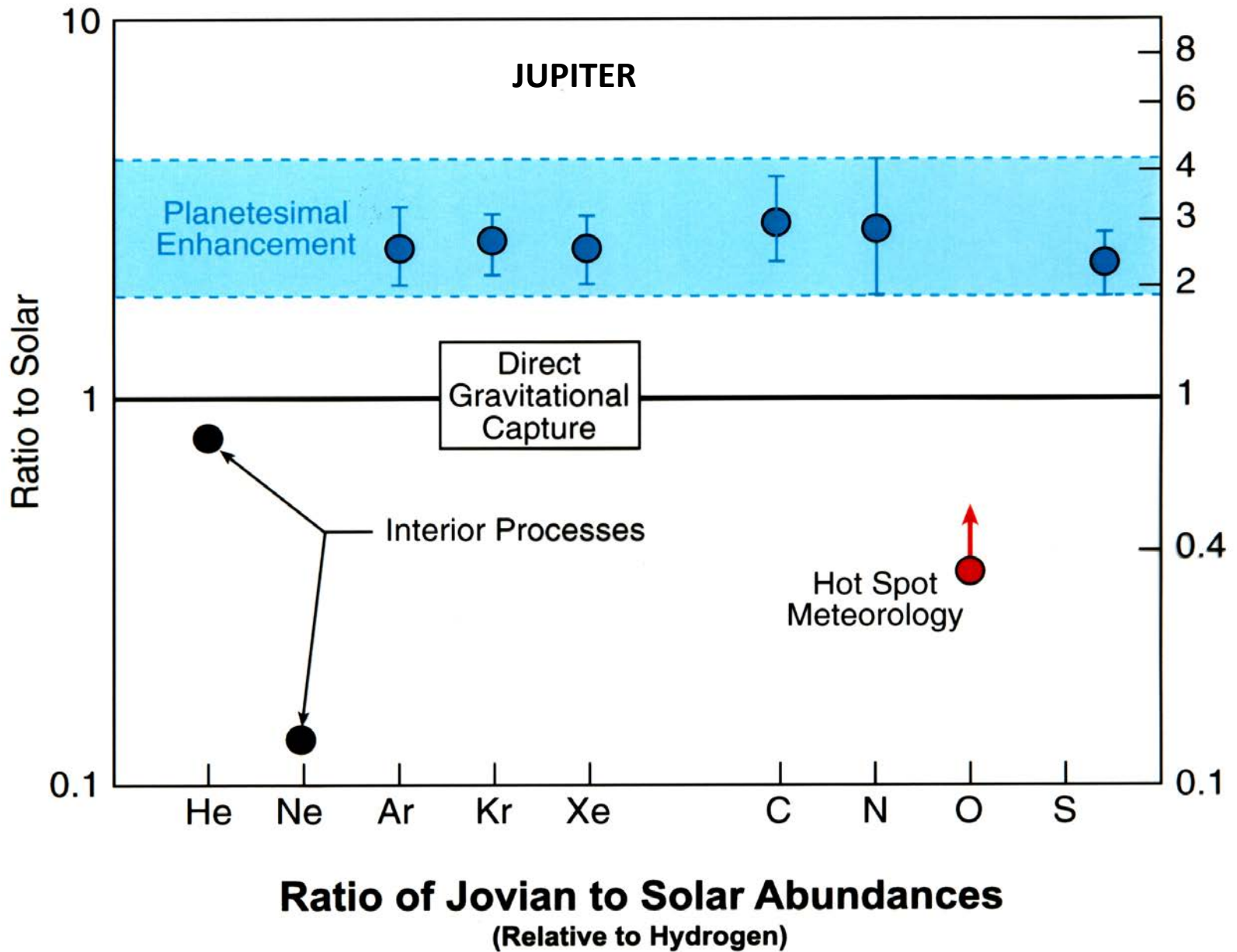
DESIGN VERSATILE LANDER=> SMALL, LIGHT, TOUGH, CHEAP

INCLUDE STUDY OF ORGANICS

Comet relatives: MBCs, Trojans, Hildas, Satellites, Kuiper Belt

INTERNATIONAL COLLABORATION ESSENTIAL !!

GIANT PLANETS



JUPITER

Conundrum:

- Enrichment of C, N, S, Ar, Kr, Xe mixing ratios
 -
 - CHALLENGES CLASSICAL MODEL FOR GIANT PLANET ORIGIN:
 - ABUNDANCES SHOULD ALL BE SOLAR
 - Solution
 - Deplete $H_2 \Rightarrow$ No enrichment

CLASSICAL MODEL PRESERVED

TEST

Saturn Probe

--Now know C/H = 10x solar

--Consistent with Smaller Mass ratio H₂/Core than Jupiter

--Need to know N/H, Ar/H

Also He/H, D/H, Ne/H $^{15}\text{N}/^{14}\text{N}$

And Probe gives much more!

Uranus and Neptune

• Shallow Probes: ~ 5 bars, μ -wave ?? bars

Bolton and Owen 2001

- MEASURE CARBON, ARGON, NEON, KRYPTON: ISOTOPES AND ABUNDANCES (
- H/He, D/H, H₂S? N₂? 15N/14N?
- ENRICHMENT VS. DEPLETION
- INTERNAL STRUCTURE ATMOSPHERE VS. “CORE”,

OTHER LIFE IN SOLAR SYSTEM?

- DISTINGUISH ORIGIN FROM ADAPTATION
- STRANGE FORMS OF LIFE IN WATER ON EARTH \neq LIFE ON EUROPA
- BEWARE MICROBIAL CONTAMINATION!!

GIANT PLANETS

1. ENDOGENIC
2. EXOGENIC

HOW TO DISTINGUISH?

Noble gases on Mars ~ Earth

A) Icy Planetesimals aka comets

B) Rocky planetesimals aka asteroids, => meteorites

HOW TO DISTINGUISH (IN WATER)

DEUTERIUM/HYDROGEN MUST MATCH

EARTH:

ON EARTH (OCEANS)

$$D/H = 1.6 \times 10^{-4}$$

ELSEWHERE?

DID COMETS CONTRIBUTE TO OCEANS?

<u>DESIGNATION</u>	<u>DATE</u>	<u>D/H</u>
HALLEY (OORT)	1986	3.2×10^{-4}
AVERAGE 5 OORT NO!!	.	3.2
3. HARTLEY 2 YES!!	2011	1.6
4. CHUR.-GER. NO!!	2014	3.5

WATER IN COMETS

ICY PLANETESIMALS, AKA COMETS

WHY? MARS NOBLE GASES => NOT IN ROCKS

TEST THAT ICE IN A COMET MUST PASS:

DEUTERIUM/HYDROGEN (D/H) IN A COMET'S ICE

MUST = D/H IN OCEANS, ICE, YOU, ETC.

$D/H = 1.6 \times 10^{-4}$

(SAME VALUE FOUND IN WATER IN METEORITES)

MANY VALUES IN SOLAR SYSTEM

HOW TO DISTINGUISH (IN WATER)
DEUTERIUM/HYDROGEN MUST
MATCH EARTH:

ON EARTH (OCEANS)

10^{-4}

$D/H = 1.6 \times$

ELSEWHERE?

ENDOGENIC

EXOGENIC:

- HOW TO DISTINGUISH? MARS NOBLE GASES ~ EARTH NOBLE GASES
- Icy Planetesimals aka comets
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• HOW TO DETERMINE SOURCE (IN WATER)

• DEUTERIUM/HYDROGEN MUST MATCH EARTH:

•

• ON EARTH (OCEANS)

$$D/H = 1.6 \times 10^{-4}$$

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- ELSEWHERE?
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1.SOURCES OF VOLATILES

- ENDOGENIC

- EXOGENIC

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- HOW TO DETERMINE SOURCE(IN WATER)
- DEUTERIUM/HYDROGEN MUST MATCH EARTH:

- ON EARTH (OCEANS) $D/H = 1.6 \times 10^{-4}$

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- ELSEWHERE?
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1. HOW EARTH GOT ITS VOLATILES=> WATER

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B) EXOGENIC Hint from Mars

a) Icy Planetesimals aka comets

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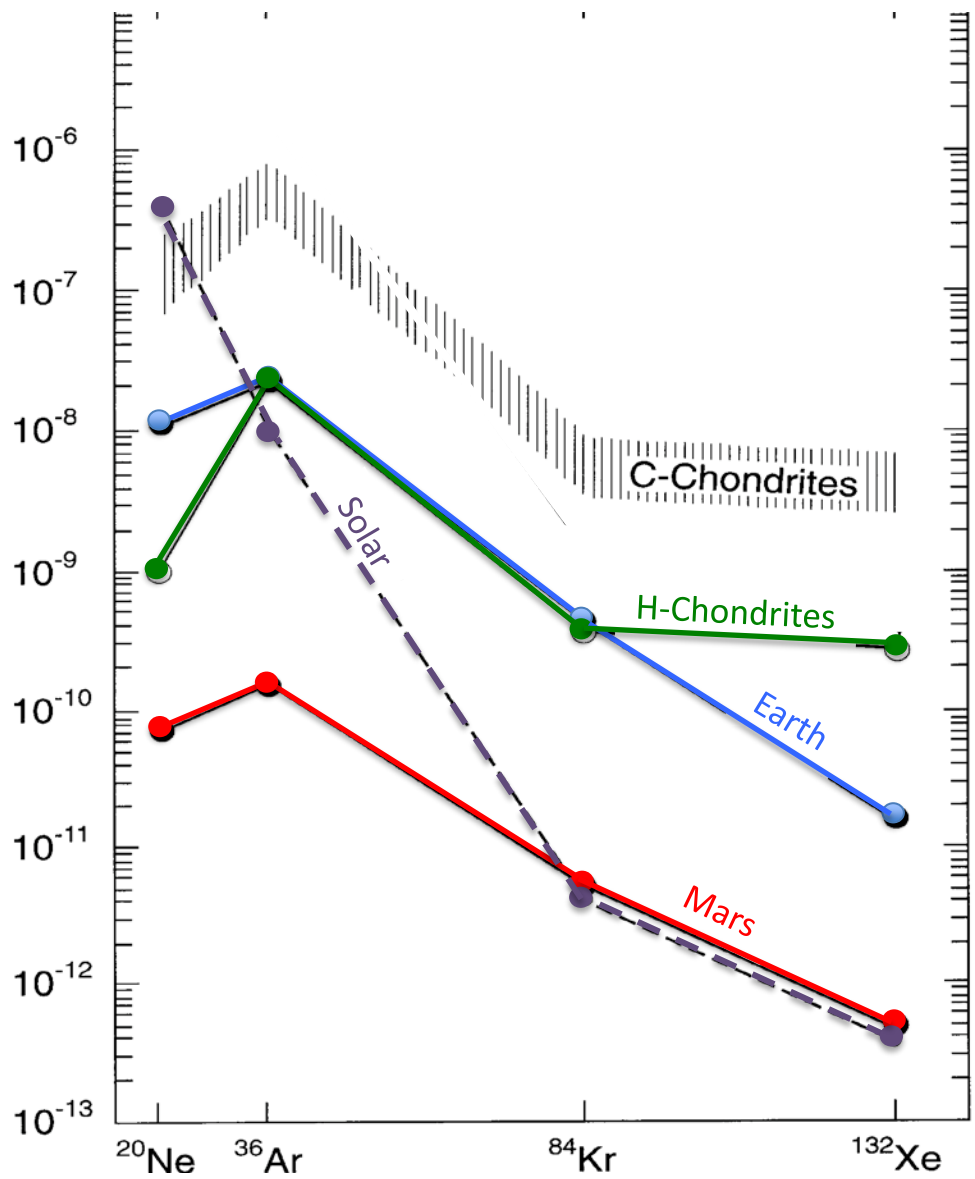
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EXOGENOUS SOURCE OF VOLATILES