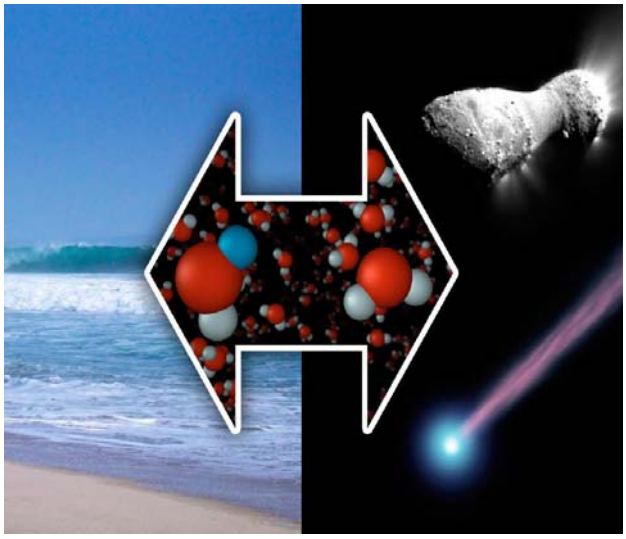

The abundance of heavy-water in Earth's oceans is about 0.015%. The abundance of heavy-water in Hartley-2 is about 0.016%, so comets like Hartley-2 could have impacted Earth and deposited over time Earth's ocean water. (Image courtesy NASA/JPL-Caltech)

New measurements from the Herschel Space Observatory show that comet Hartley 2, which comes from the distant Kuiper Belt, contains water with the same chemical signature as Earth's oceans. This remote region of the solar system, some 30 to 50 times as far away as the distance between Earth and the sun, is home to icy, rocky bodies including Pluto, other dwarf planets and innumerable comets.

Herschel detected the signature of vaporized water in this coma and, to the surprise of the scientists, Hartley 2 possessed half as much "heavy water" as other comets analyzed to date. In heavy water, one of the two normal hydrogen atoms has been replaced by the heavy hydrogen isotope known as deuterium. The amount of deuterium is similar to the abundance of this isotope in Earth's ocean water.

The deposition of Earth's oceans probably occurred between 4.2 and 3.8 billion years ago. Suppose that the comet nuclei consisted of three major types, each spherical in shape and made of pure water-ice: Type 1 consisting of 2km in diameter bodies arriving once every 6 months, Type-2 consisting of 20 km diameter bodies arriving once every 600 years and Type-3 consisting of 200 km diameter bodies arriving every one million years.

Problem 1 - What are the volumes of the three types of comet nuclei in km^3?

Problem 2 - The volume of Earth's liquid water oceans is 1.33×10^9 cubic kilometers. If solid ice has 6 times the volume of liquid water, what is the volume of cometary ice that must be delivered to Earth's surface every year to create Earth's oceans between 4.2 and 3.8 billion years ago?

Problem 3 - What is the annual ice deposition rate for each of the three types of cometary bodies?

Problem 4 - How many years would it take to form the oceans at the rate that the three types of cometary bodies are delivering ice to Earth's surface?

Space Observatory Provides Clues to Creation of Earth's Oceans

http://www.nasa.gov/mission_pages/herschel/news/herschel20111005.html

Problem 1 - What are the volumes of the three types of comet nuclei in km^3?

Answer: $V = 4/3\ \pi\ R^3$ so

Type 1 Volume = **$4.2\ km^3$**

Type 2 Volume = **$4{,}200\ km^3$**

Type 3 Volume = **$4.2 \times 10^6\ km^3$**

Problem 2 - The volume of Earth's liquid water oceans is 1.33×10^9 cubic kilometers. If solid ice has 6 times the volume of liquid water, what is the volume of cometary ice that must be delivered to Earth's surface every year to create Earth's oceans between 4.2 and 3.8 billion years ago?

Answer: $1.33 \times 10^9\ km^3$ of water requires
$6 \times (1.33 \times 10^9\ km^3) = 8.0 \times 10^9\ km^3$ of ice.

The average delivery rate would be about
$R = 8.0 \times 10^9\ km^3$ of ice / 400 million years
= **$20\ km^3$ of ice per year**.

Problem 3 - What is the annual ice deposition rate for each of the three types of cometary bodies?

Type 1: $R1 = 4.2\ km^3/0.5$ yrs = **$8.4\ km^3/yr$**

Type 2: $R2 = 4200\ km^3/600$ yrs = **$7.0\ km^3/yr$**

Type 3: $R3 = 4.2 \times 10^6\ km^3 / 1000000$ yrs = **$4.2\ km^3/yr$**

Problem 4 - How many years would it take to form the oceans at the rate that the three types of cometary bodies are delivering ice to Earth's surface?

Answer: The total deposition rate is R1+R2+R3 = $20\ km^3/yr$, so it would take
$T = 8.0 \times 10^9\ km^3$ of ice / $(20\ km^3/yr)$ = **400 million years**.