Water and HDO in Comet 103P/Hartley 2

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Water on Earth: A Debated Issue

<table>
<thead>
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<th>Some Hypotheses</th>
<th>Problems</th>
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<td>Present since Earth’s formation</td>
<td>Early Earth too hot for condensation</td>
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<td>Produced biochemically</td>
<td>Not enough species produce water as byproduct</td>
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<td><em>Delivered via extraterrestrial sources</em></td>
<td>Isotopic ratios measured <em>thus far</em> dissimilar to oceanic water (with uncertainty due to small sample size)</td>
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Comets: Possible Candidates

- Large bodies consisting largely of water ice and volatile chemicals
- Chemical composition measurable with spectroscopy
Comparing Comets to Earth’s Oceans

- Hydrogen (protium) and Deuterium can be identified in comet spectra, and a ratio of D/H can be established.
- Compared to known values for the Vienna Standard Mean Ocean Water (VSMOW).
Oort Cloud Comets

- Most comets come from "Oort Cloud"
- Originate in inner solar system and ejected by gas giants
- D/H Studies to date have all been of Oort Cloud comets
- D/H ratio of Oort Cloud comets: 2 x Earth’s Oceans (to date)
- Only a handful of comets analyzed
Kuiper Belt Comets

- Ring of comets beyond orbit of Neptune
- Prior to 2010: no analysis of Kuiper Belt D/H ratios
Comet 103P/Hartley 2

- Kuiper Belt comet
- Target of repurposed *Deep Impact* spacecraft’s mission (EPOXI)
- Recent close approach to Earth in October 2010
Data Collection

- **Telescope:** Keck II 10-meter telescope, Mauna Kea, Hawaii
- **Instrument:** Near-Infrared Spectrograph (NIRSPEC)
- **Dates:** Sept 18 and Oct 22, 2010
- **Bright standard star observed** to provide a flux calibration and constrain atmospheric water contributions
Analysis

- Spectroscopic images were flat fielded, dark subtracted, and spectrally and spatially aligned.
- Line-By-Line Radiative Transfer Model (LBLRTM) atmospheric model was used to calibrate the frequency of the data and subtract atmospheric lines.
- Detected molecules compared to theoretical fluorescence emission spectrum to obtain best fit.
Results

- Data dominated by noise
- OH and HDO extracted from data simultaneously due to overlapping spectral lines
- Upper limit of 5 x VSMOW obtained at the 3σ confidence level
Conclusion

- 103P/Hartley 2 has no more than 5 x VSMOW per this work’s findings
- Astronomers using Herschel space-based observatory find 1 x VSMOW for D/H ratio in 103P/Hartley 2 (same as Earth)
- Further analysis of Kuiper Belt objects required to determine whether comets are viable source of Earth’s water
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