Exploring the Origins of Life: The Role of UV Light in Prebiotic Chemistry

Azra Haseki
Research Science Institute

Under the Direction of Dr. Sukrit Ranjan
The Department of Earth, Atmospheric and Planetary Sciences
Massachusetts Institute of Technology

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How did life begin?

Evaluating origin of life pathways

- different biotic molecules that came together to polymerise and replicate
- sensitive to prebiotic conditions

UV Light and Life

"Life doesn't like UV!.."

- modern life

Important on prebiotic Earth

- readily available on prebiotic Earth
- high energy: can power chemical reactions through photochemistry
  break molecular bonds, excite electrons, ionise atoms
- selector for biotic molecules

UV Environment on Prebiotic Earth

Life today requires water: indication it may have evolved there

Previous work

- greater fractional output by young Sun
- no ozone layer or significant oxygen
- most readily available source of energy for prebiotic chemistry?

We model the UV tranmission in water

Evaluate feasibility of origin of life pathways

Beer-Lambert's Law

$$\log_{10} \frac{I_0}{I} = \xi bc$$

ξ: Molar absorbtivity, $M^{-1}cm^{-1}$

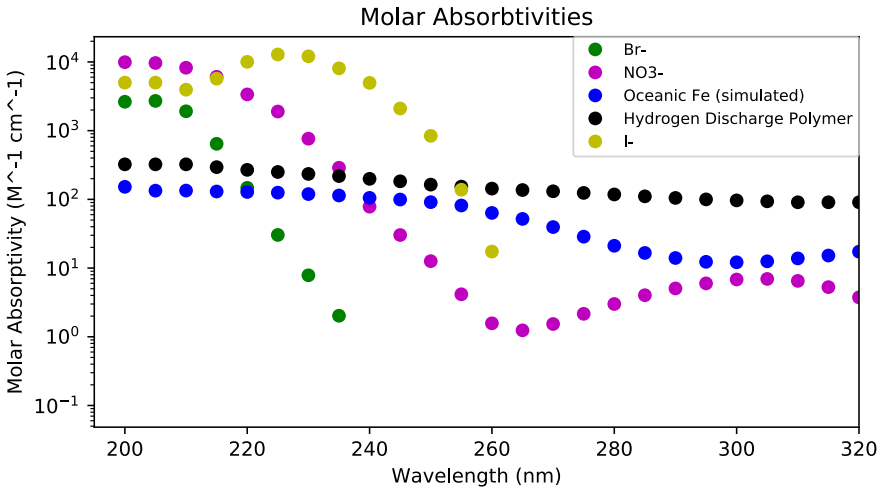
b: path length, cm

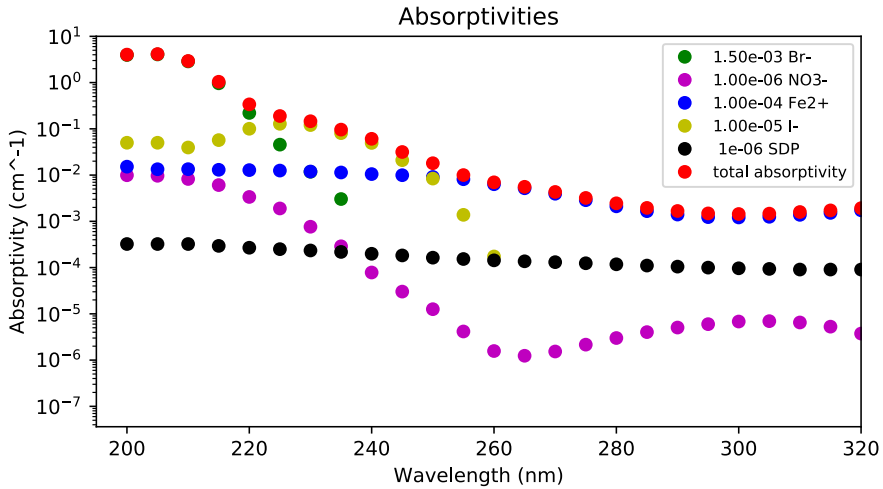
c: concentration, M

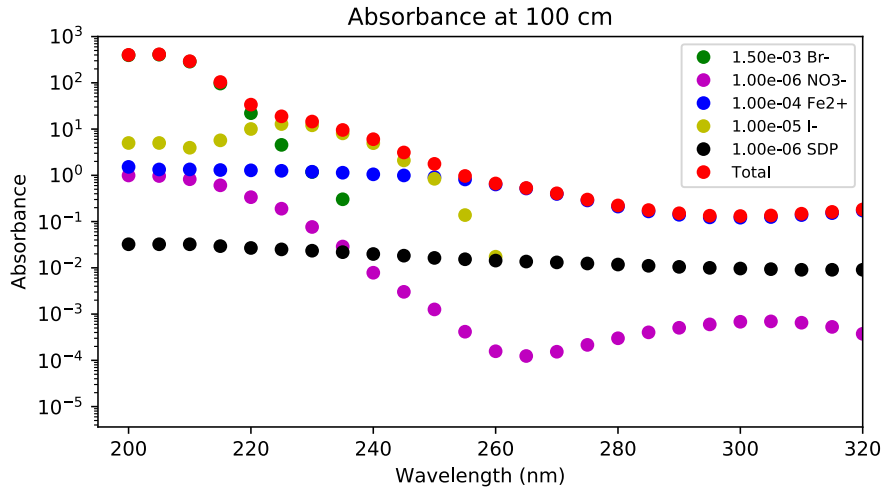
Absorbance $= A = \xi bc$

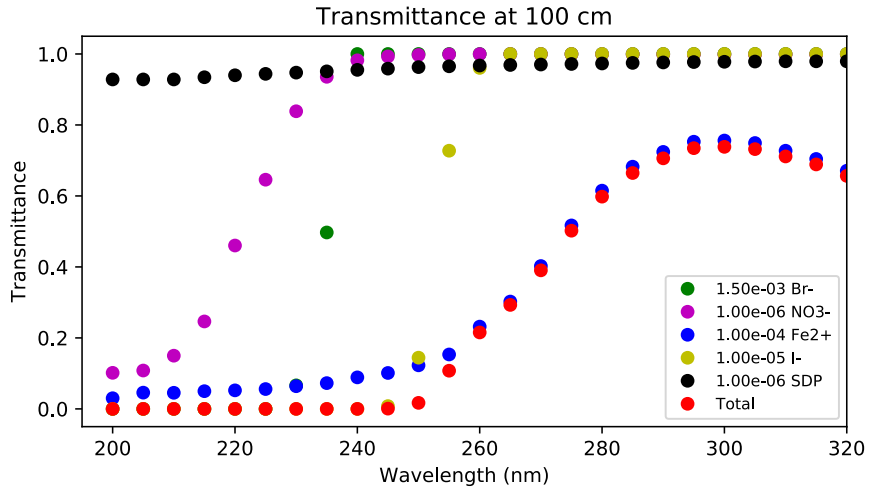
Transmittance $= 10^{-A}$

Constructing the prebiotic ocean









Pure Water

The lowest bound of UV absorbance

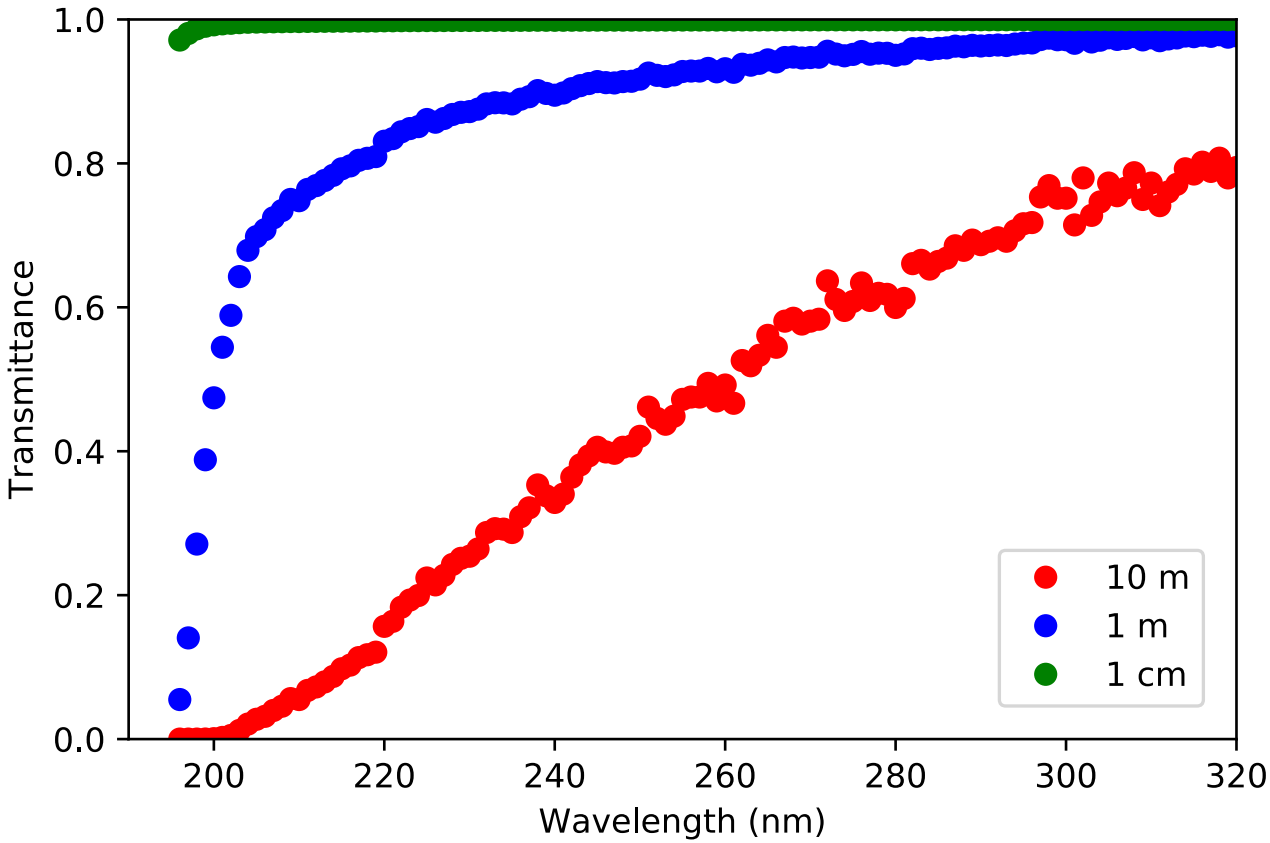


Figure 1: Data taken from Quickenden 1980

Comparing Modern and Prebiotic Oceans

Modern Oceans	Prebiotic Oceans
Br^-	Br^-
NO_3^-	Fe^{2+}
NO_2^-	NO_3^-
I^-	SO_4^{2-}
	Cl^-
	I^-

- How do we know the prebiotic ion makeup?
- Can we consider these ions individually?

Complex-dependant Absorbance

Absorbance cannot be modeled as additive for $FeSO_4$ and $FeCl_2$

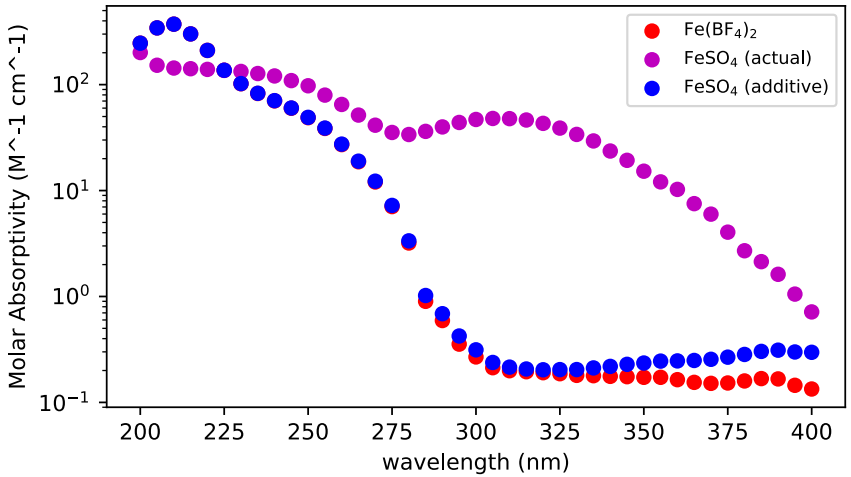


Figure 2: Additive and actual molar absorptivity values for $FeSO_4$

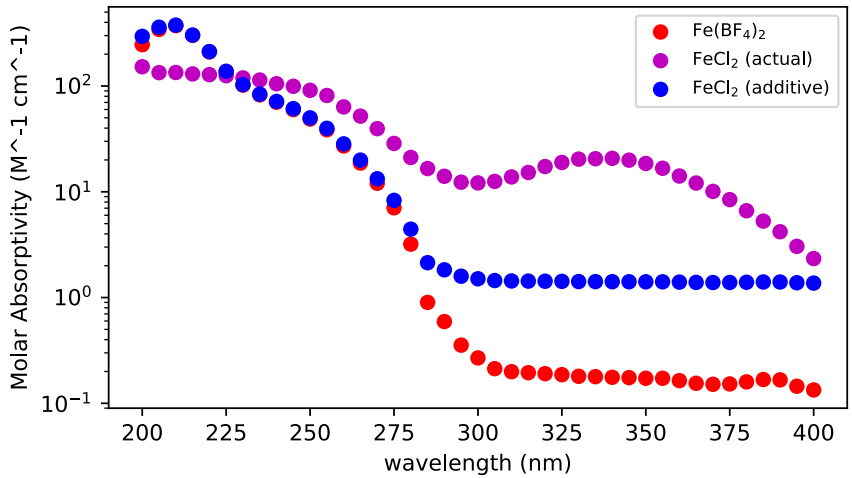


Figure 3: Additive and actual molar absorptivity values for $FeCl_2$

Modelling Oceanic Iron

- Used molar absorptivity values for $FeCl_2$ and $FeSO_4$, not additive
- Assumed equipartition of Fe^{2+}
- prebiotic ocean: $[Cl^-]$=0.5 M $[SO_4^{2-}]$=40 μM

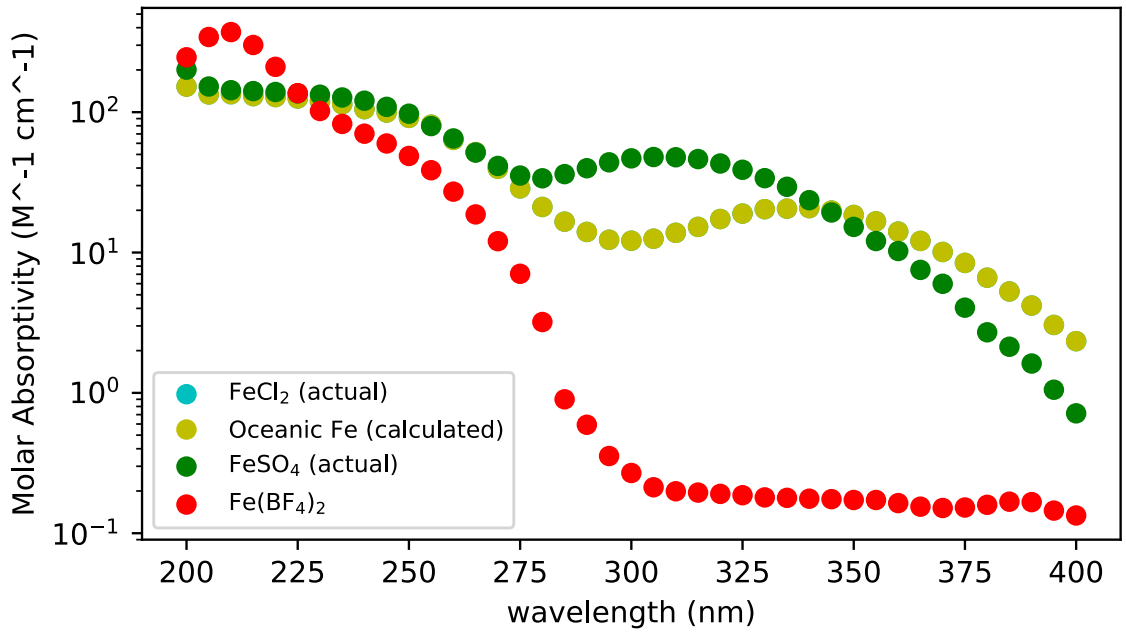


Figure 4: Constructed molar absorptivity of oceanic ferrous iron. $FeCl_2$ curve covered by oceanic iron curve

Organics in the Prebiotic Ocean

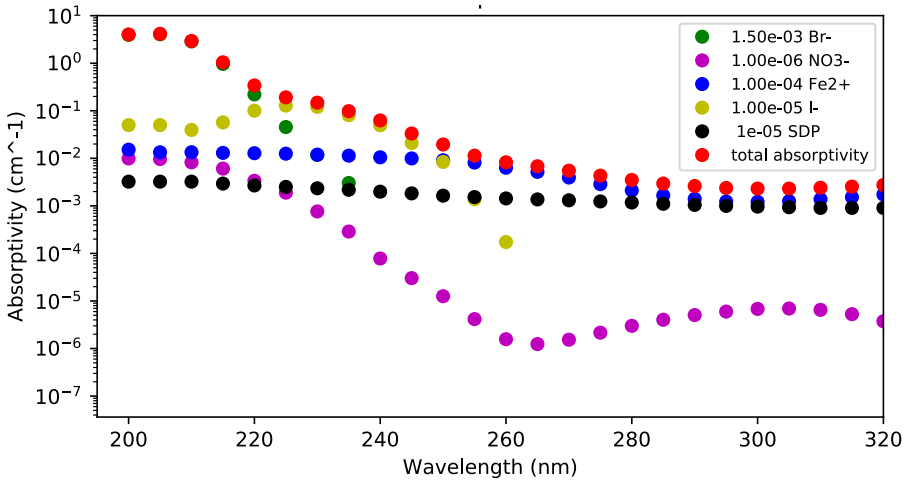


Figure 5: 10 μM Spark Discharge Polymer

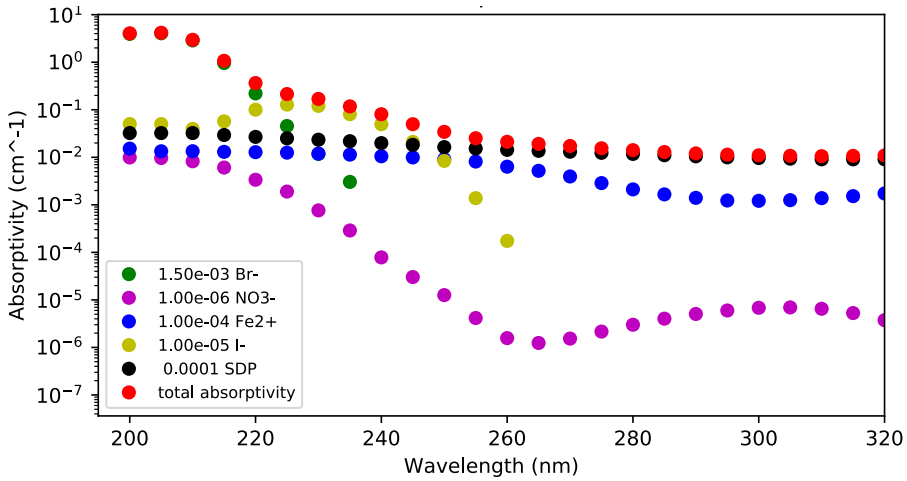
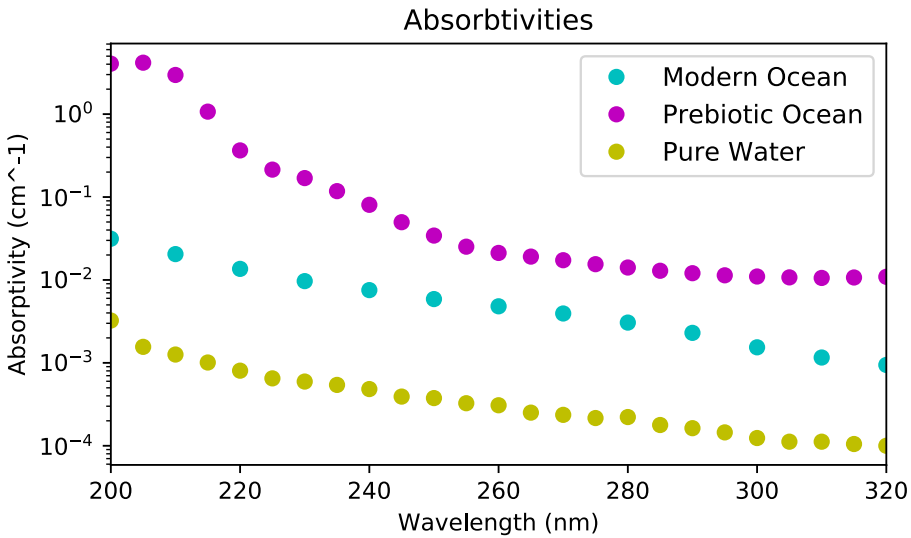
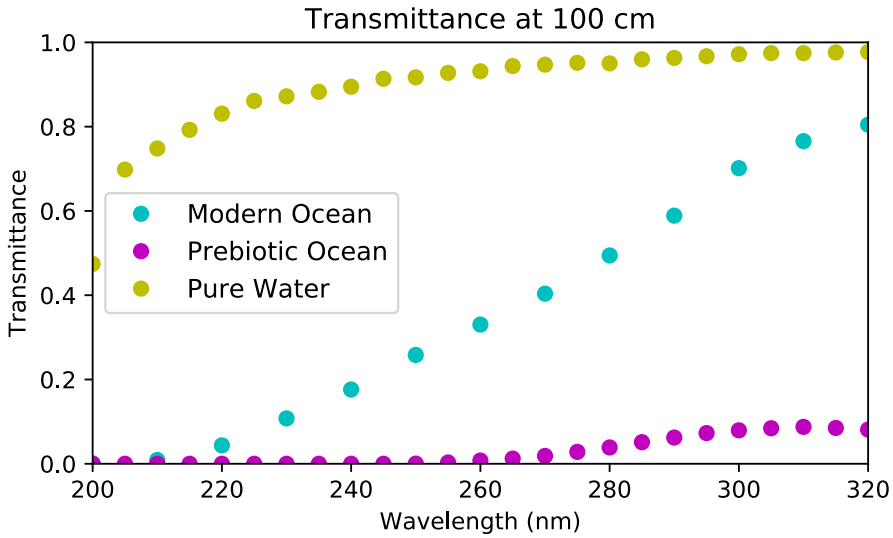


Figure 6: 100 μM Spark Discharge Polymer

The Prebiotic Ocean





Results

- prebiotic ocean UV transmittant up to 10 m

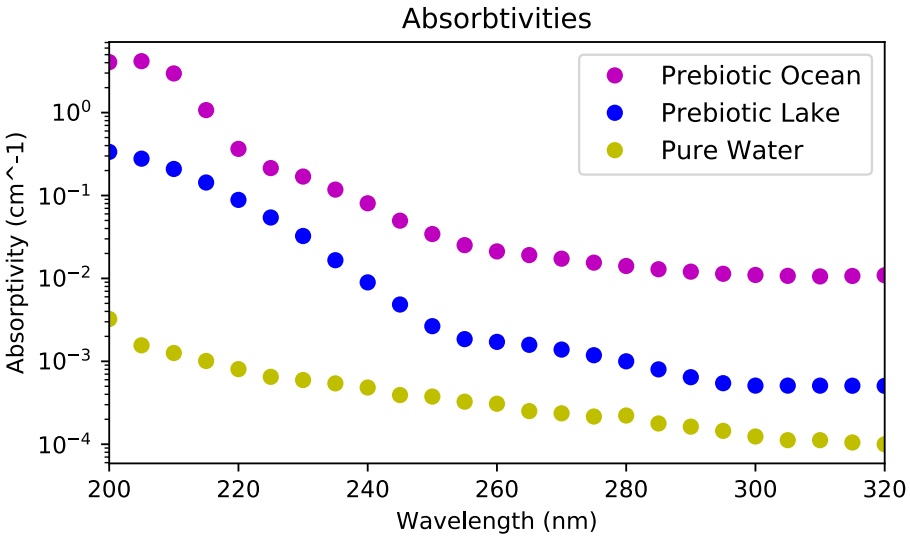
Results and Implications

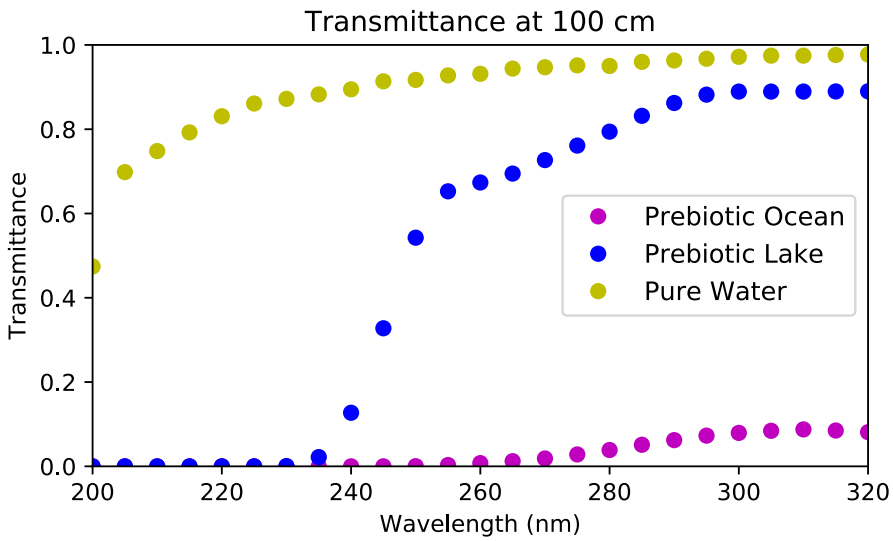
- larger depths shielded from damage
- viable source of energy limited to 10 m
- dissipation, decrease in reaction

Implications:

- prebiotic ocean an order of magnitude more absorbent than modern ocean
  - previous estimates using modern oceans must be revised
- if UV required for origin of life, oceans unfavourable
- if UV not required, ocean shielded

Prebiotic Lake





Minimal lake: shallow, ions with strong support

Results and Implications

- prebiotic lake up to 80% transmittant at 1 m
- Pearce et al.: 1 m pond water can absorb up to 95%
- dependant on composition of specific lake
- pathway for RNA polymerisation possible in subset of prebiotic ponds, not all
- prebiotic lakes diverse, specific UV absorbent material must be specified

Final Results and Further Work

Conclusions:

- UV absorption for prebiotic ocean, modern abiotic ocean, a prebiotic lake modeled, available on Github
- oceans viable setting for origin of life if UV not required, otherwise not
- prebiotic lakes diverse in UV absorbance, must be studied with specific composition and implications

Further Work:

- construction of prebiotic seawater in lab
- stability constants for ferrous iron calculation instead of equipartition
- likely concentration of spark discharge polymers in prebiotic waters

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