Evolution of Interstellar Organics to Meteoritic and Cometary Organics: Approaches by Laboratory Simulations

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Outline

• Origins of meteoritic organics and origins of life
• Possible formation and alteration of interstellar complex amino acid precursors
• Cosmic dusts (IDPs) as carriers of organics to the Earth
  
  *The Tanpopo Mission*: Capture of cosmic dusts and exposure of organics in space
• Conclusion
Wide variety of extraterrestrial organics have been detected.

- Meteorites (Yamato791198)
- Comets (Wild 2)
- IDPs

- Complex organics
- Amino acids
- Organics seemed to be formed at low temperature
Origins of meteoritic amino acids

• Strecker synthesis in parent bodies of meteorites
  \[ \text{HCN} + \text{RCHO} + \text{NH}_3 \rightarrow \text{NH}_2\text{CHRCN} \rightarrow \text{amino acids} \]

• Fisher-Tropsch-type synthesis in solar nebula
  \[ \text{CO} + \text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{amino acids} \]
  \( \Delta \) (metal catalysts)

• Alteration of interstellar complex organics
  \[ \text{H}_2\text{O} \rightarrow \text{amino acids} \]
Particles Irradiation of Simulated Interstellar Media (Ice / Liquid / Gas)

Protons @ Tandem Accelerator (TIT) → Heavy ions @ HIMAC (NIRS) ↓

- Molecular weights: Some thousands
- In situ formation of complex (solid) organics
- Amino acids were yielded after hydrolysis
- Nucleic acid bases were formed
Formation of amino acids from complex organics (Garakuta molecules)

\[
\begin{align*}
\text{CO} & \rightarrow \text{C} + \text{O} \\
\text{NH}_3 & \rightarrow \text{NH}_2 + \text{H} \\
\downarrow & \\
\text{NH} & + \text{H} \\
\text{H}_2\text{O} & \rightarrow \text{H} + \text{OH} \\
\downarrow & \\
\text{O} & + \text{H}
\end{align*}
\]

Garakuta Molecule (MW: ca. 1000)

Glycine (MW: 75)

\[\ldots\text{-CO-CH}_2\text{-NH-CH}=\text{C(OH)}-\]

\[\ldots\text{-CO-NH-CH}_2\text{-CO-NH-C=N-}\]

\[\text{-CH}_2\text{-CH}_2\text{-C(=NH)-O-CO-}\ldots\]

\[\text{NH}_2\text{-CH}_2\text{-COOH}\]

Quench

Hydrolysis
Heavy ion bombardment of Simulated Interstellar Ices

KEK Digital Accelerator

Gas mixer

Cryostat@10 K
Alteration of Interstellar Organics (CAW) in Protosolar Nebula by Soft X-rays

- Decrease of Hydrophilic C=O → (E) Amidyl
- Increase of Hydrophobic C=C → (B) Aryl, vinyl-keto

⇒ Formation of Insoluble Organics
Delivery of Organics to Earth: Meteorites vs. Cosmic Dusts (IDPs)

- **IDPs** delivered more organics to the Earth than meteorites and comets.
- **IDPs** delivered organics more safely than meteorite and comets.
- **IDPs** are directly exposed to solar / cosmic radiation.
- **IDPs** are easily contaminated from terrestrial biosphere.
UV Irradiation of Amino Acids & Their Precursors

Xe-excimer lamp (172 nm)
4 x 10^{14} photon/cm^2/s
4 d irradiation = ca. 1 yr @ LEO

New SUBARU BL-6
(>130nm)
1 d irradiation = 1.5 d @ LEO

Amino acid precursors are much more stable than free amino acids against UV, X-rays, radiation and heat.
The Tanpopo Mission: Capture of Cosmic Dusts & Exposure of Organics

Aerogel (0.01 g cm$^{-3}$)

ExHAM

JEM Exposed Facility
Amino Acid Analysis in Silicate Matrices

HF digestion gave much more amino acids from samples with mineral matrix

Sample:
Antarctic Soil (Sta. 5)
Exposure of Organic Compounds in the Tanpopo Mission

Amino acids and their precursors

- Glycine
- Hydantoin (A precursor of glycine) →
- Isovaline \((\alpha\text{-methyl non-protein amino acid})\)
- 5-Ethyl-5-methyl hydantoin
  (A precursor of Isovaline)
- “CAW” (Complex amino acid precursors produced by proton irradiation of a mixture of CO, NH\(_3\) and H\(_2\)O)

Alanine Thin Film (as a VUV dosimeter) →
Summary

- Complex organic compounds with high molecular weights can be formed in simulated interstellar environments by high energy particles bombardment.
- Meteoritic organics could have been formed by alteration of interstellar complex organics: Soft X-rays from the young Sun could be important energy source for it, as well as aqueous / hydrothermal alteration in parent bodies of meteorites.
- Major carriers of extraterrestrial organics could have been cosmic dusts (IDPs).
- Cosmic dusts will be collected in space with aerogel in the Tanpopo Mission.
- Amino acids in cosmic dusts will be analyzed after HF digestion.
Thank you for your attention!

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