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たんぽぽ計画: 地球低軌道での ペプチド生成とアミノ酸関連分子の安定性

Tanpopo Mission: Peptide formation and Stability of Amino Acid-Related Compounds in Low Earth Orbit

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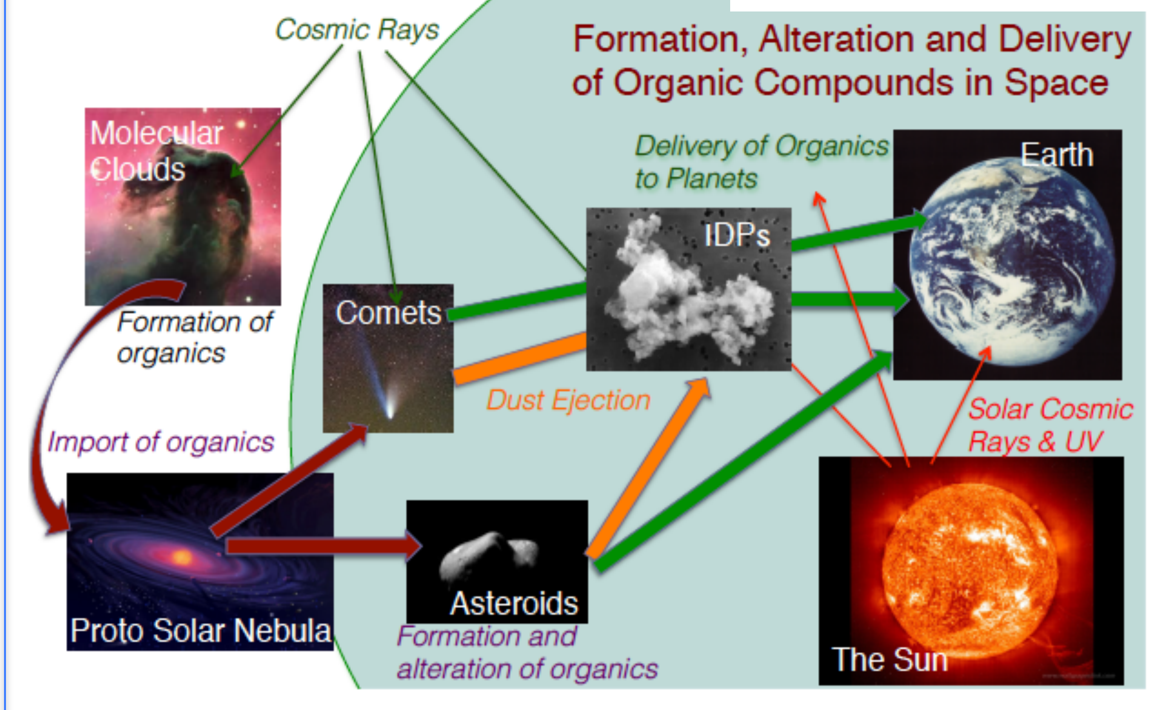
Organic Compounds for the Generation of Life: Formation in Space and Delivery by Cosmic Dusts

If primitive Earth atmosphere was not strongly reducing, endogenous production of organics (including amino acids) were restricted.

Formation of amino acids in strongly-reducing gas mixture

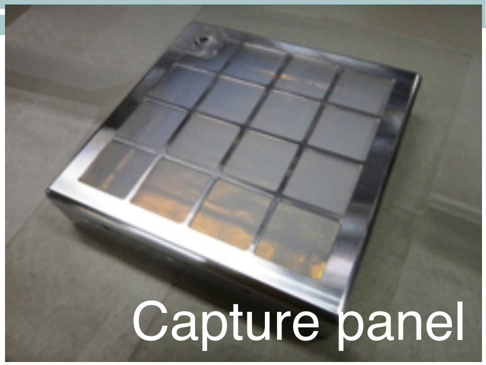
- ✓ Wide variety of organic compounds have been detected in extraterrestrial bodies [1]
- ✓ L-excesses of amino acids were observed in carbonaceous chondrites [2]

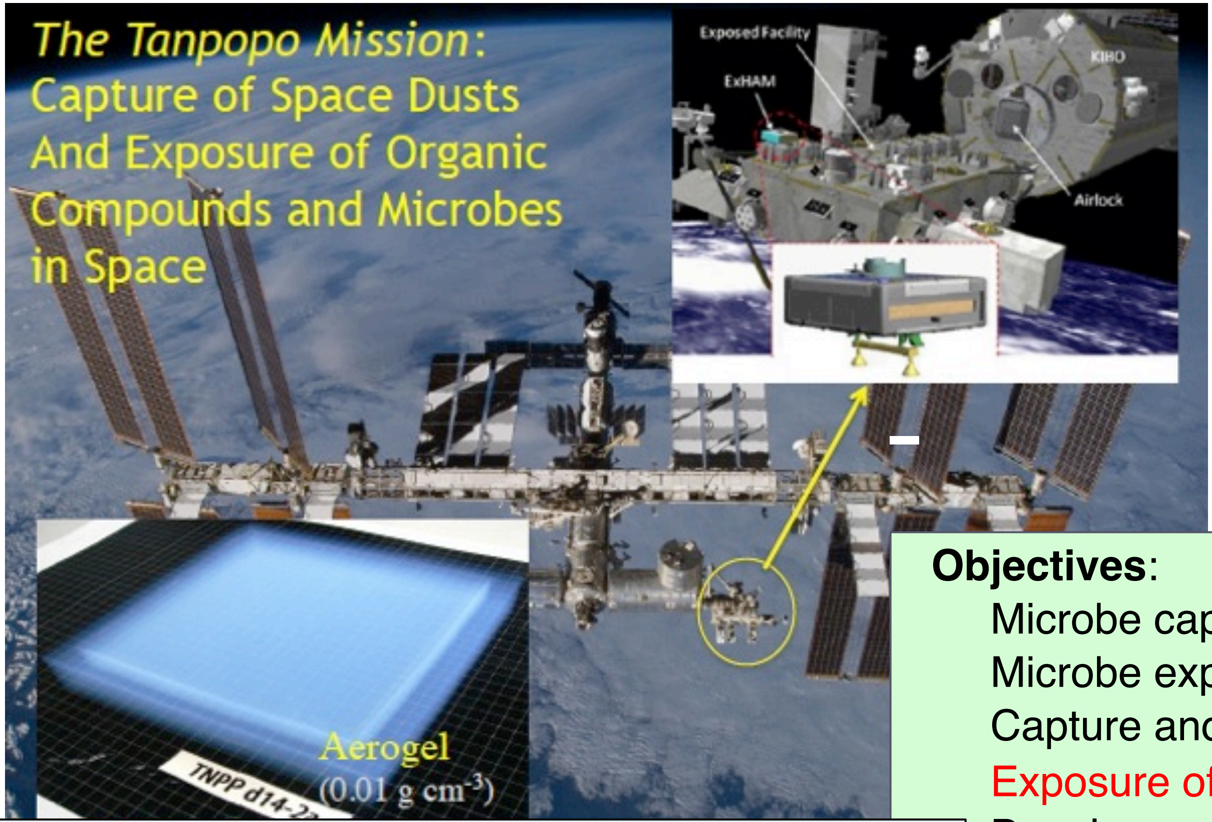
Extraterrestrial organics were essential for the generation of life on the Earth.

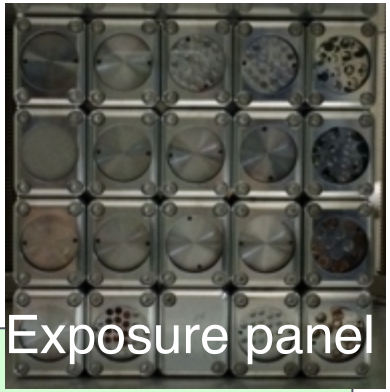


- ✓ Could chemical evolution occur in space environments?
- ✓ Could cosmic dusts deliver exogenous bioorganic compounds to the Earth? [3]

The Tanpopo Mission on the Exposed Facility of JEM, ISS







Objectives:

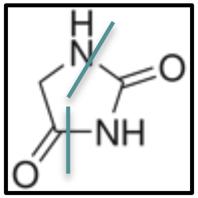
- Microbe capture
- Microbe exposure
- Capture and Analysis of IDPs
- Exposure of organics*
- Development of new aerogel
- Monitoring of space debris

*Amino acids and their precursors

Glycine	Hydantoin
Isovaline	5-Ethyl-5-methyl hydantoin

"CAW" (Complex amino acid precursors) [5]

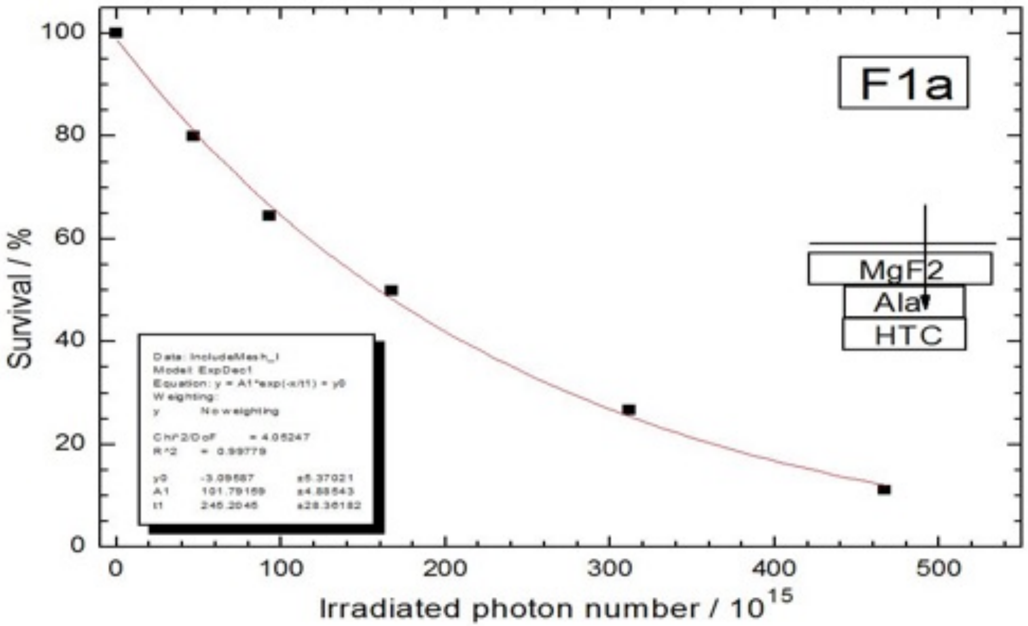
Alanine (thin film: as VUV dosimeter)



Hydantoin

CAW (imaginary) and glycine

Results (1): UV Dosimeter by Using Alanine Thin Film



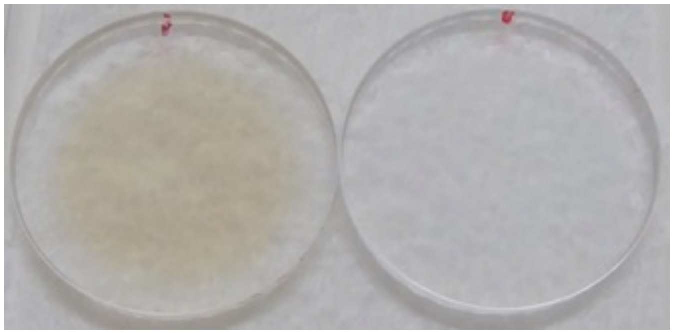
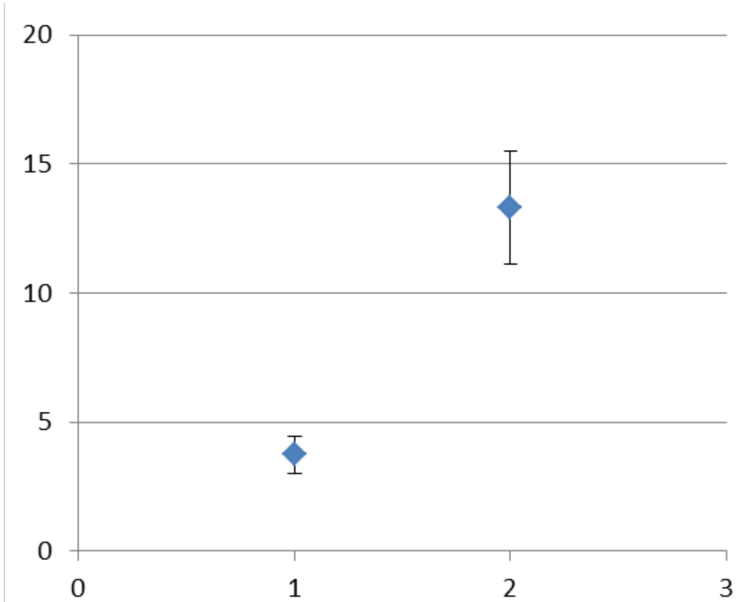


図1 A2F1a A2F1b

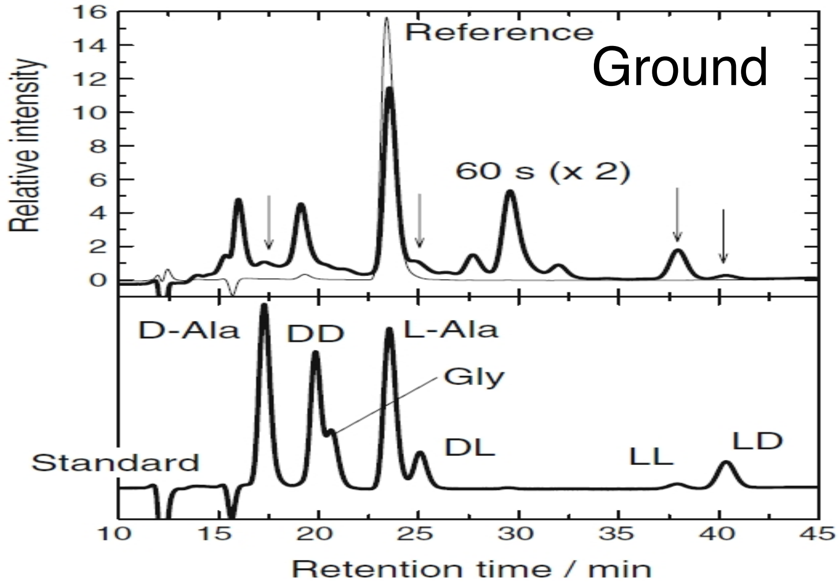


- ✓ Decomposition rate of alanine as thin film on MgF_2 substrate depended on irradiated photon number, so that it used as a UV dosimeter in the Tanpopo mission.
- ✓ Resuts: Total dose in the first year was 35 Equivalent solar days (ESD), while that in the second year was 125 ESD.

✓ The alanine dosimeter could be used to evaluate VUV/UV dose in space.

Results (2): Space Exposure of Alanine Thin Film

VUV/UV Irradiation of Alanine Thin Film:
A Ground Experiment (Left) and the Space Experiment (Right)



Space

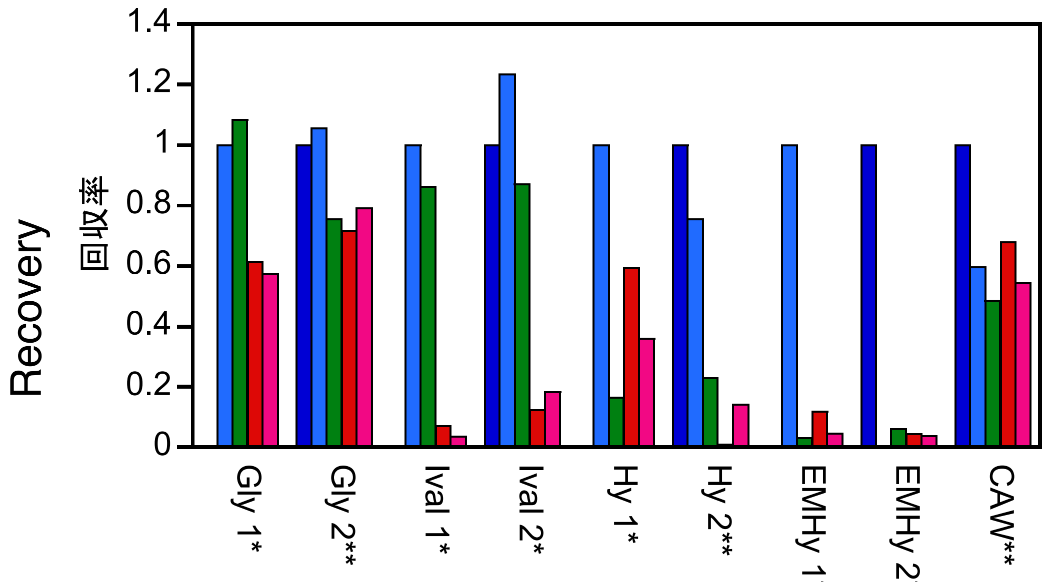
An L-alanine thin film was irradiated with UV photons (172 nm) from an Excimer Lamp.
8% was decomposed, 0.1% was converted to L-alanyl-L-alanine. Racemization was limited [6].

An L-alanine thin film beneath a MgF_2 (A2F2) or a SiO_2 (A2G2) substrate was exposed to solar UV/VUV in the Tanpopo Mission. A2G1 is a control (no UV). L-Alanyl-L-alanine was detected in the both films. D-Alanine nor peptide with D-alanine was not detected.

- ✓ Alanine was exposed to space environments in such missions as EXPOSE-E (PROCESS) [7] and EXPOSE-R (AMINO) [8] missions, and decomposition of alannine was reported, but formation of peptides were not observed.
- ✓ In the Tanpopo mission, alanine dimer was detected after space exposure for the first time.

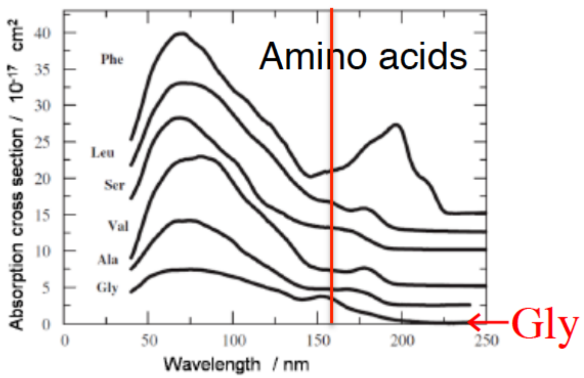
Results (3): Stability of Amino Acids and Their Precursors

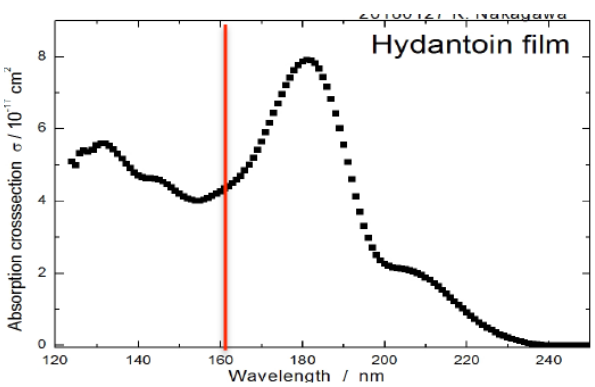
Recovery of the Exposed Organics

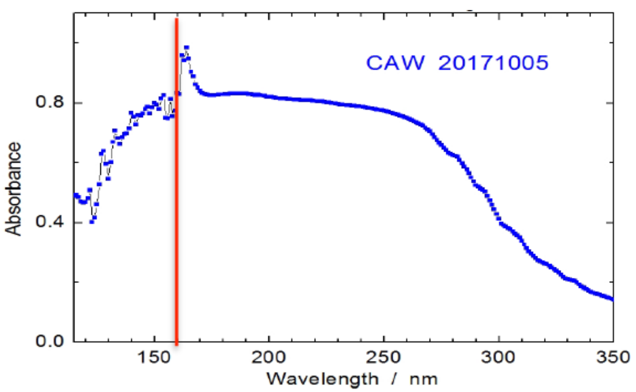


*Without hydrolysis (Cabin control =1)
**Determined as amino acids after hydrolysis (Ground control =1)
Gly1, Ival 1: Determined by LC/MS;
Hy 1, EMHy 1: Determined by GC/MS;
The others: Determined by HPLC

VUV/UV Spectra of amino acids and their precursors



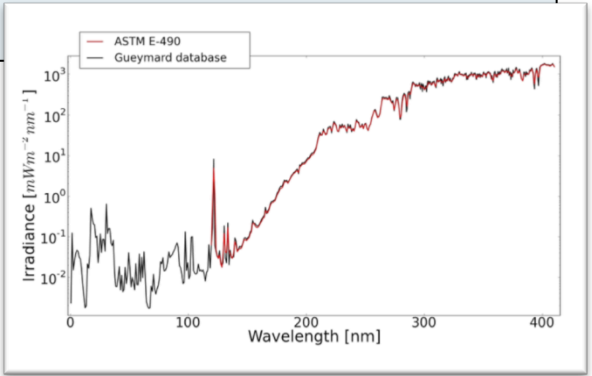




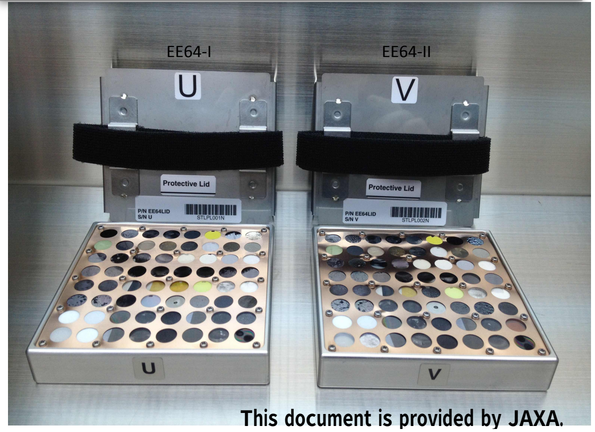
- ✓ After exposed to solar UV, hydantoins and isovaline were mostly decomposed, but glycine and CAW were less decomposed.
- ✓ Decomposition rate mostly depended on UV absorbance (λ > 160 nm); CAW was as stable as glycine in spite of CAW's absorbance was much larger than glycine.

Discussion and Future Prospects

1. The reason why glycine's decomposition was less than expected seems to be:
   a) Hexatriacontane cut the shorter VUV (λ <160 nm) that is critical for glycine.
   b) UV dosimetry showed that samples were exposed to solar UV for restricted period during exposure.
2. Recovery of glycine was much more than that of isovaline, hydantoin and 5-ethyl-5-methylhydantoin. Their decomposition rate is mostly cdark control. It might be due to volatility in space.
3. CAW had ca. 1000 times stronger VUV/UV absorption (λ <160 nm) than glycine, but still show as high recovery ratio as glycine. Complex precursors of amino acids could be robust molecules in space.
4. In the present space exposure experiment, solar UV whose wavelength was more than 160 nm was mainly used. Space experiments that utilize full solar VUV/UV spectrum will be conducted in the Tanpopo 2 mission that will start in 2019.



Top: Solar spectrum at 1 AU: http://inspirehep.net/record/1299595/plots
Bottom: QCC-type exposure Panel will be used for exposure experiments in the Tanpopo 2.



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Summary

1. Exposure of amino acids and their precursors to space environments were performed in the Tanpopo Mission, which started in May, 2015, and the samples returned to the Earth in 2016, 2017 and 2018. They were mainly exposed to solar VUV/UV at $\lambda > 160$ nm, since sample were covered with hexatriacontane film.
2. L-Alanine thin film beneath MgF_2 substrate was used as VUV dosimeter, since decomposition of alanine was intercorrelate with VUV photon number. Total VUV dose for the first two years of the Tanpopo Mission was determined as 160 equivalent solar days.
3. Formation of peptide (L-alanyl-L-alanine) in space environment was first observed. Racemization of alanine was hardly observed.
4. Decomposition rate of amino acids and their precursors depended on VUV/UV absorbance ($\lambda > 160$ nm), except that recovery of CAW (complex amino acid precursor synthesized by proton irradiation of interstellar media analogue) was as high as that of glycine although absorbance of CAW ($\lambda > 160$ nm) was about 1000 times larger than that of glycine.
5. Amino acids and their precursors showed different behavior in the space exposure experiments than expected from the ground simulation experiments.
6. We are planning to expose glycine and CAW without any windows nor covering films in the Tanpopo 2 mission, which is to start in 2019.

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