



Raspberries and Rum: The Chemistry of Interstellar Molecules

CASS Co-Learnium

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Australia's National Science Agency



Image: ESO/APEX & MSX/IPAC/NASA



Introduction

Ethyl formate responsible for smell of rum

Partially responsible for flavour of raspberries

3 sections of talk:

- Discovery
- Synthesis
- Significance

Hope to convince physicists that chemistry is fun and interesting!





1. Discovery of Ethyl Formate



Discovery of Ethyl Formate: Background

Complex is a relative term!

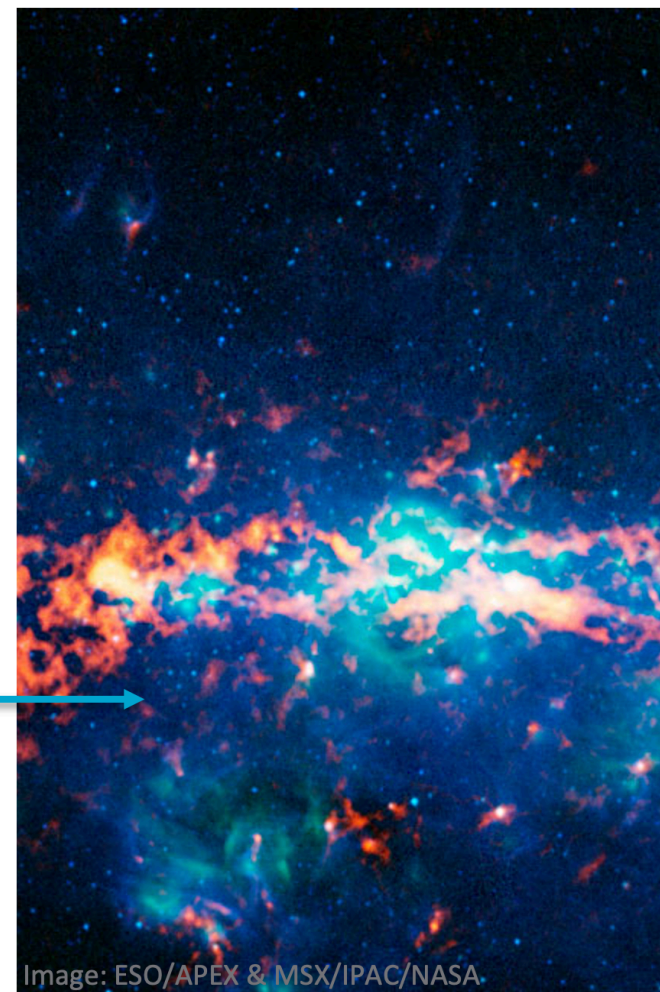
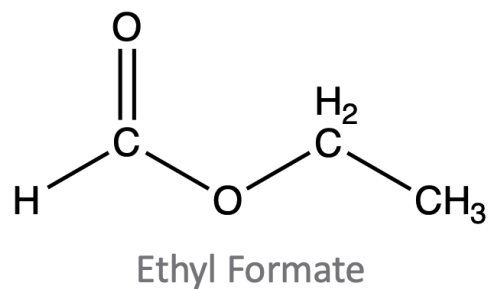
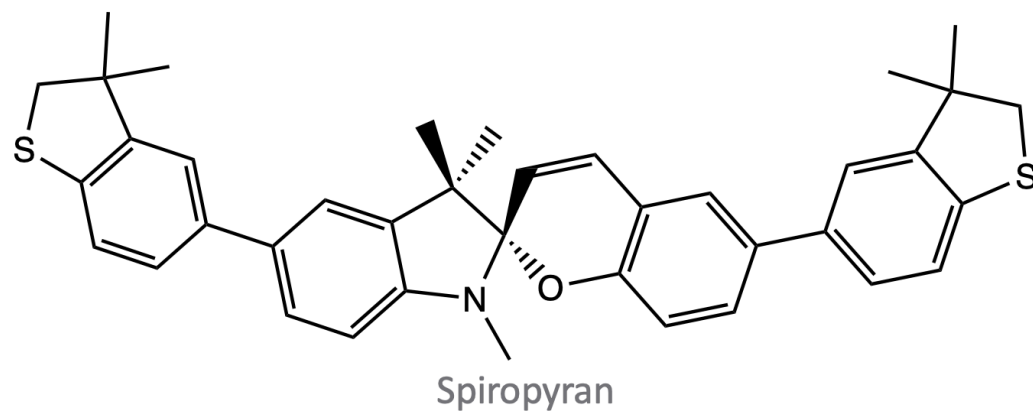


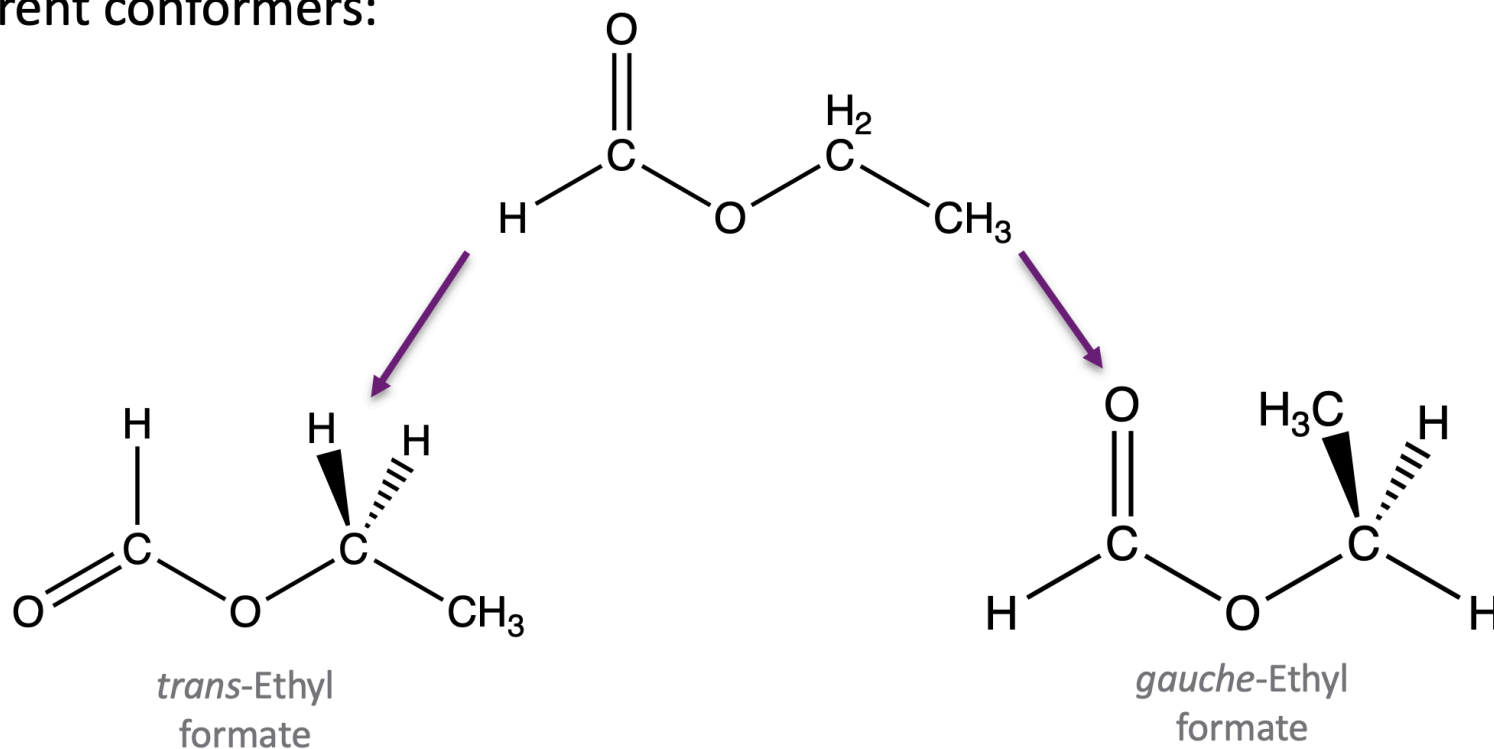
Image: ESO/APEX & MSX/IPAC/NASA



Discovery of Ethyl Formate: What Is It?

Contains ester functional group

Different conformers:





Discovery of Ethyl Formate: Energy Transitions...

Multiple energy levels within ground state configuration

Hierarchy: Electronic > Vibrational > Rotational

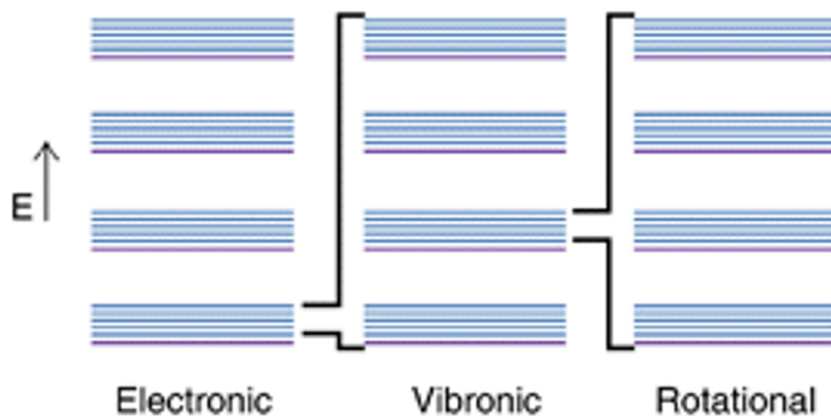


Image: Arizona State University

THE ELECTRO MAGNETIC SPECTRUM

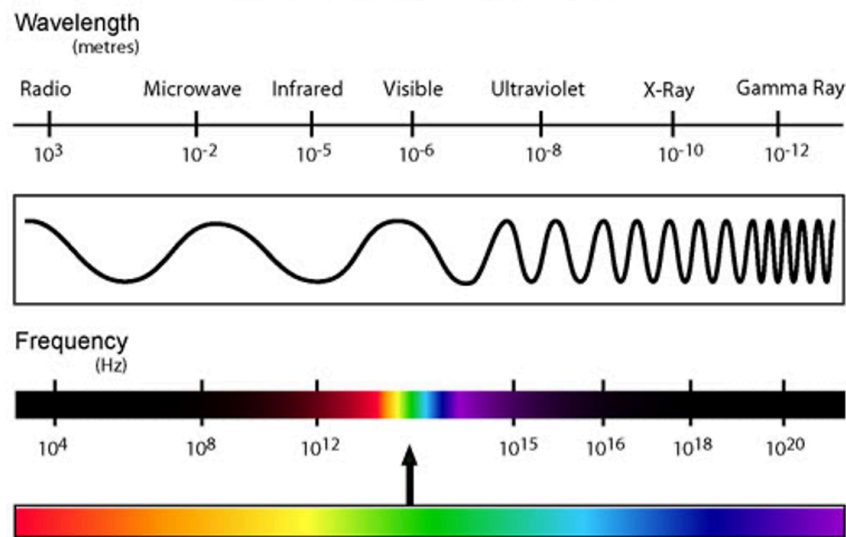


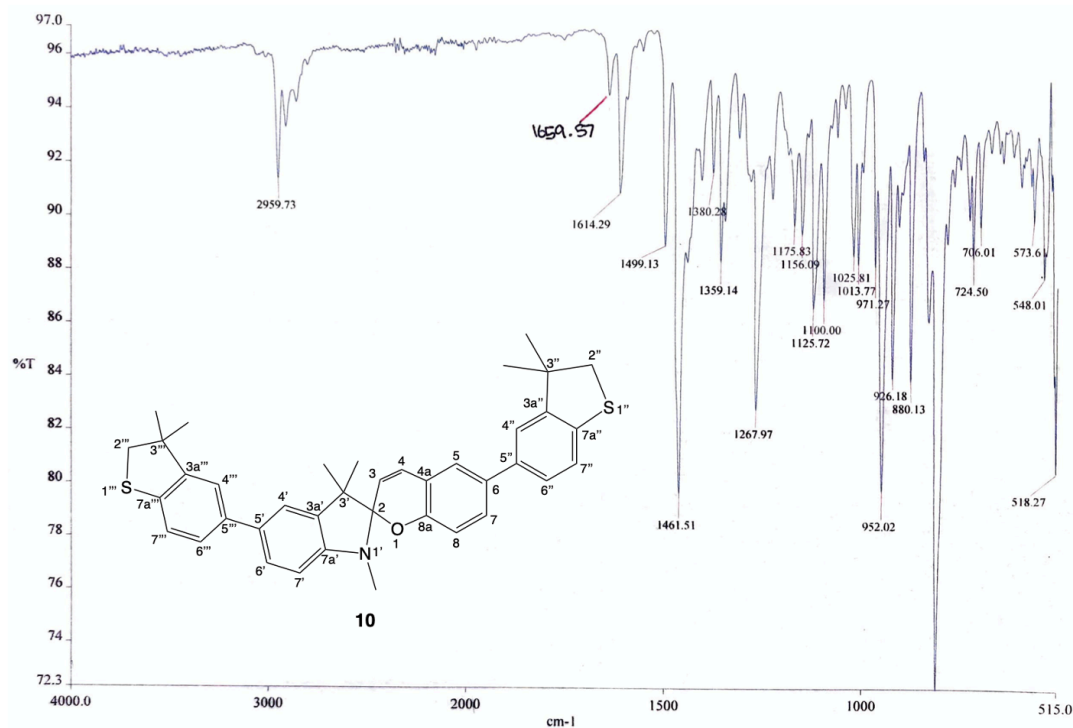
Image: University of Illinois



Discovery of Ethyl Formate: ...Make Spectra!

Spectrum = 'Map' of intensity vs. frequency

Tell you at what frequency transitions between energy states have occurred

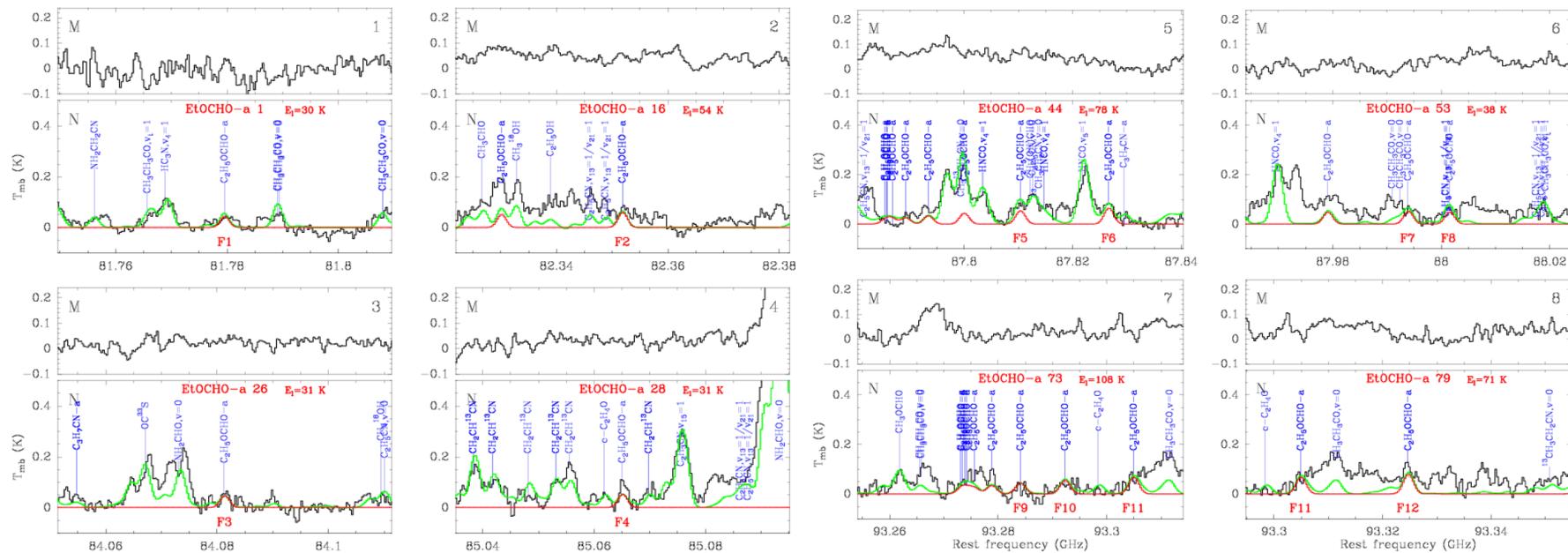


Peak at 952 cm⁻¹
corresponds to C-O bond

Discovery of Ethyl Formate: The Discovery

Observed in microwave region of Sagittarius B2(N) with IRAM 30 m telescope¹

Survey spanned $\sim 81.7\text{-}93.4\text{ GHz}^1$



Images: Belloche et al., 2009

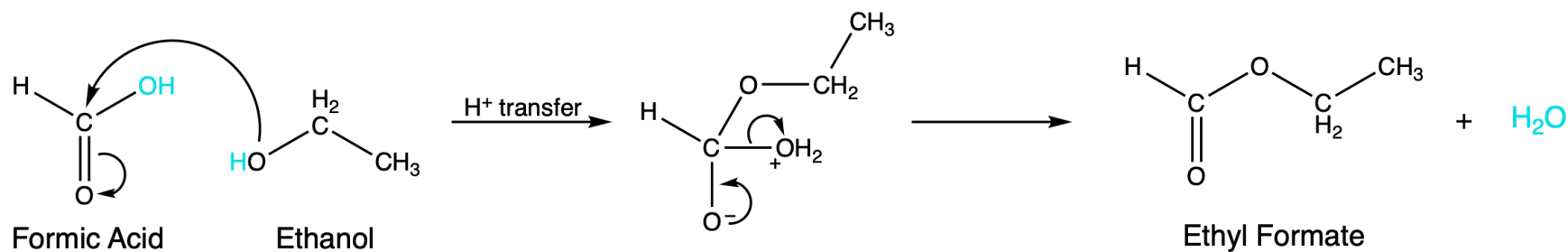
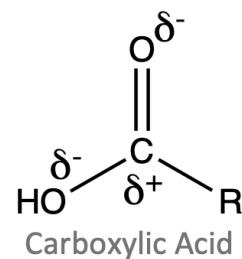
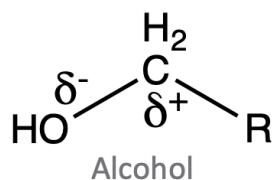


2. Synthesis of Ethyl Formate



Synthesis of Ethyl Formate: In the Lab

Fischer esterification = Condensation reaction between alcohol and carboxylic acid



Synthesis of Ethyl Formate: Collision Theory

Most fundamental theory of chemical reactions

3 primary tenets:

1. Molecules must collide
2. With sufficient energy to overcome activation energy
3. With the correct orientation to facilitate a reaction

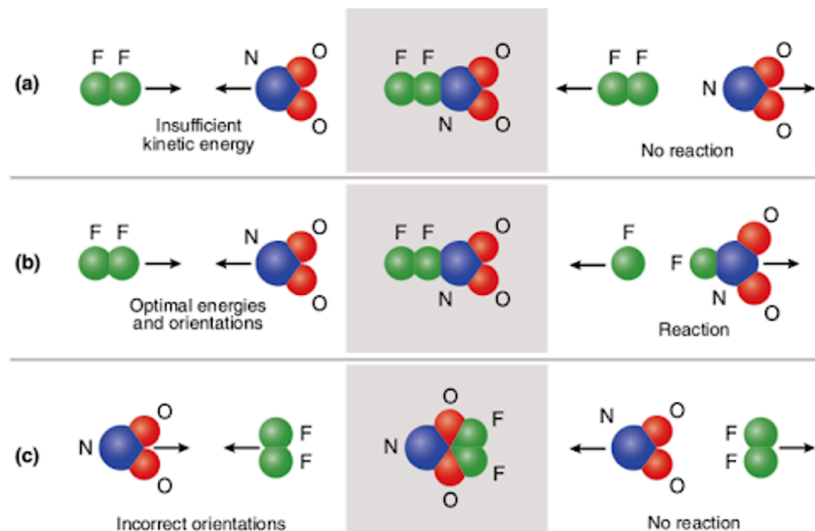


Image: A Level Chemistry

Synthesis of Ethyl Formate: Interstellar

Very different conditions to lab

Some ethyl formate precursors detected in survey¹

Interstellar dust grains can act as catalyst → 3 primary roles:²

1. Binding site for molecules to diffuse and react
2. Provides body to dissipate energy released in exothermic bond formations
3. Lowers activation barriers of reaction

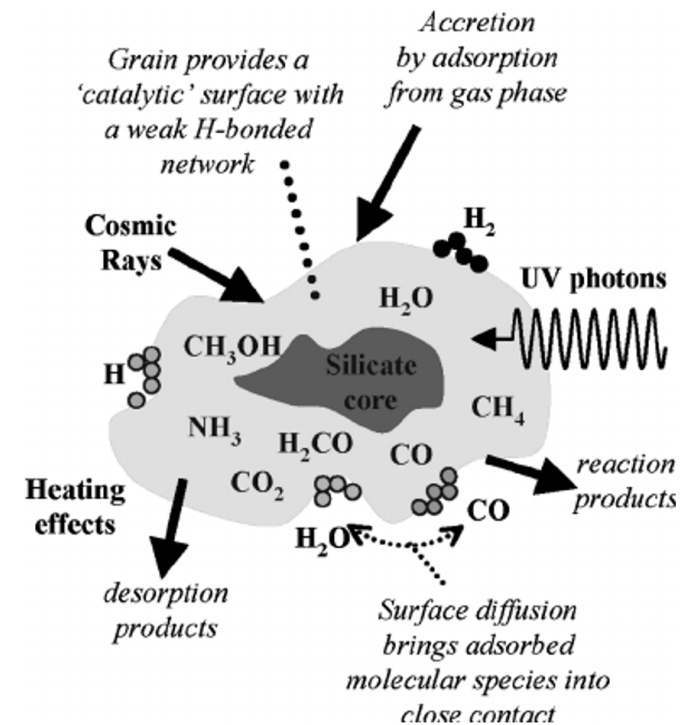


Image: McCoustra, 2002



3. Significance of Discovery

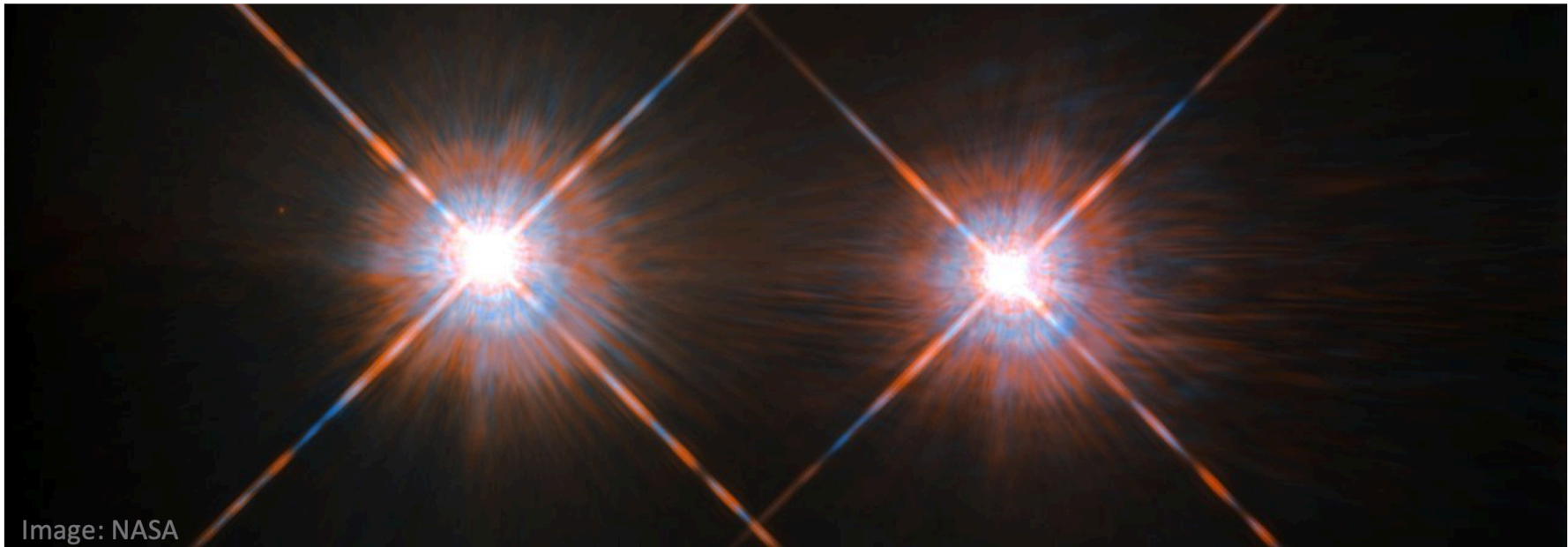


Significance of Discovery: Who Cares?

Interstellar medium more than just empty space!

Complex interstellar evolution of molecules → What else is out there?

If complex molecules can form in space (e.g. nucleic acids, amino acids),
what's to say life hasn't evolved elsewhere?





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Thank you!

Questions?

References:

1. Belloche A, Garrod RT, Müller HSP, Menten KM, Comito C, Schilke P. Increased complexity in interstellar chemistry: detection and chemical modeling of ethyl formate and *n*-propyl cyanide in Sgr B2(N)*. *Astron Astrophys.* 2009 May;99(1):215-232.
2. Potapov A, Theulé P, Jäger C, Henning T. Evidence of surface catalytic effect on cosmic dust grain analogs: the ammonia and carbon dioxide surface reaction. *Astrophys J Lett.* 2019 Jun 11;878(1)