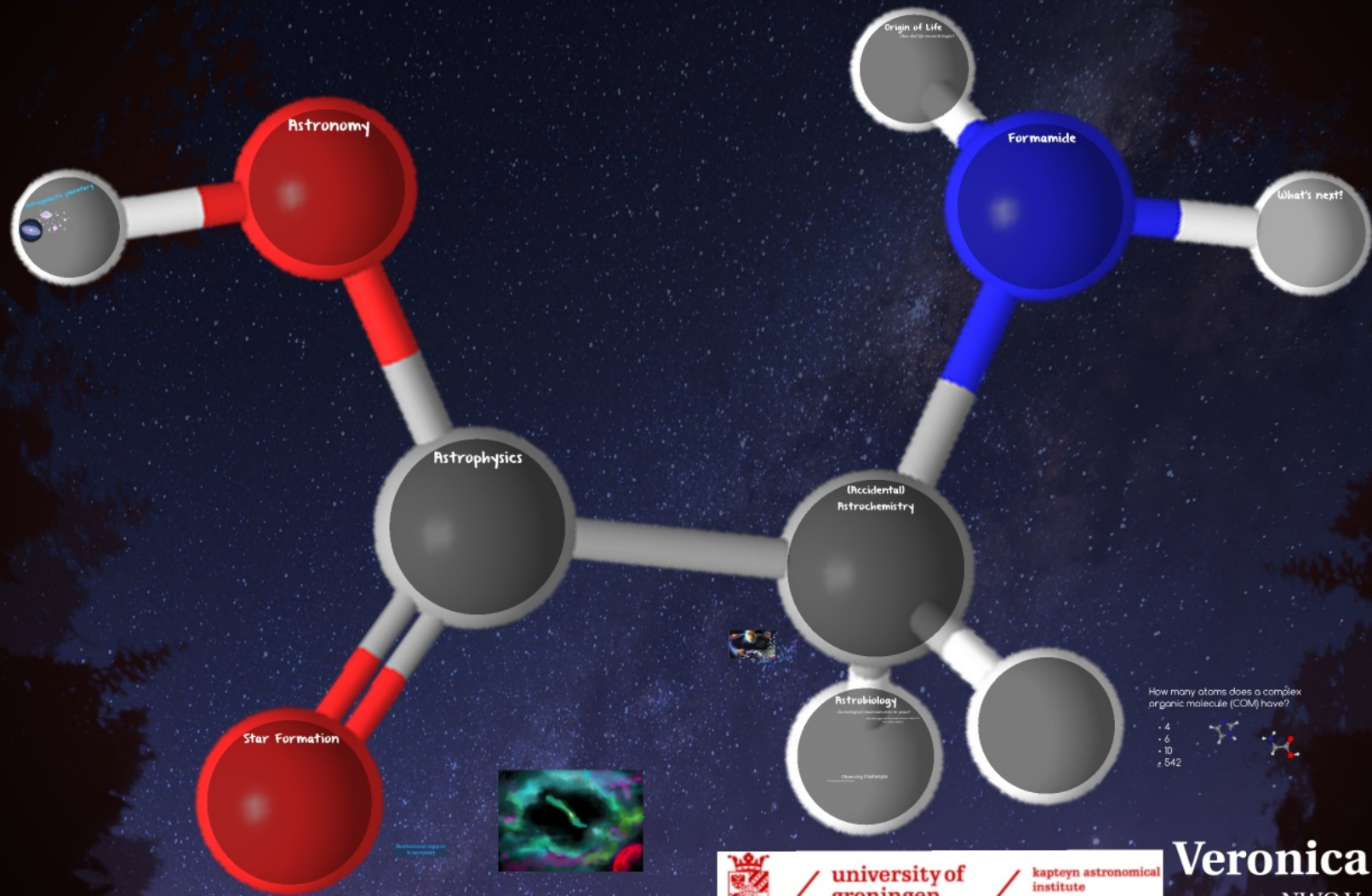


Astro-everything and our place in space



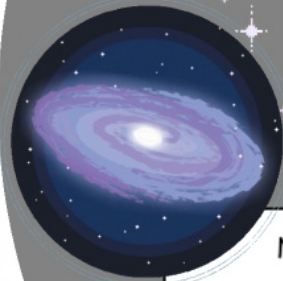
Intragalactic planetary



Intragalactic planetary



Intragalactic planetary



NUMBER OF SEARCH RESULTS ON GOOGLE SCHOLAR

| | PHYSICS | CHEMISTRY | BIOLOGY | ENGINEERING | PSYCHOLOGY | THEOLOGY | DENTISTRY |
|---------------|-----------|-----------|-----------|-------------|------------|----------|-----------|
| THEORETICAL | 3,990,000 | 445,000 | 553,000 | 2460 | 15,500 | 726 | 41 |
| QUANTUM | 478,000 | 740,000 | 7,620 | 2,100 | 699 | 447 | NONE |
| HIGH-ENERGY | 844,000 | 9,600 | 3 | 119 | 1 | NONE | NONE |
| COMPUTATIONAL | 510,000 | 599,000 | 2,910,000 | 67,400 | 4,620 | 40 | 11 |
| MARINE | 3,920 | 136,000 | 945,000 | 108,000 | 35 | 6 | 1 |
| ASTRO- | 2,010,000 | 20,600 | 226,000 | 430 | 64 | 580 | NONE |

POTENTIAL RESEARCH OPPORTUNITIES: QUANTUM DENTISTRY,
HIGH-ENERGY DENTISTRY, ASTRODENTISTRY, AND HIGH-ENERGY THEOLOGY

<https://xkcd.com/2656/>

Astronomy



Astronomy



Astronomy

What is up there?



Astronomy

What is up there?

**Knowledge
must always
be accessible**

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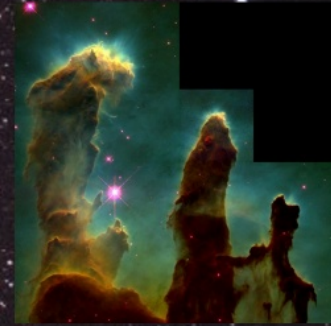


**Exposure to science
at a young age is
vital!**

Astronomy

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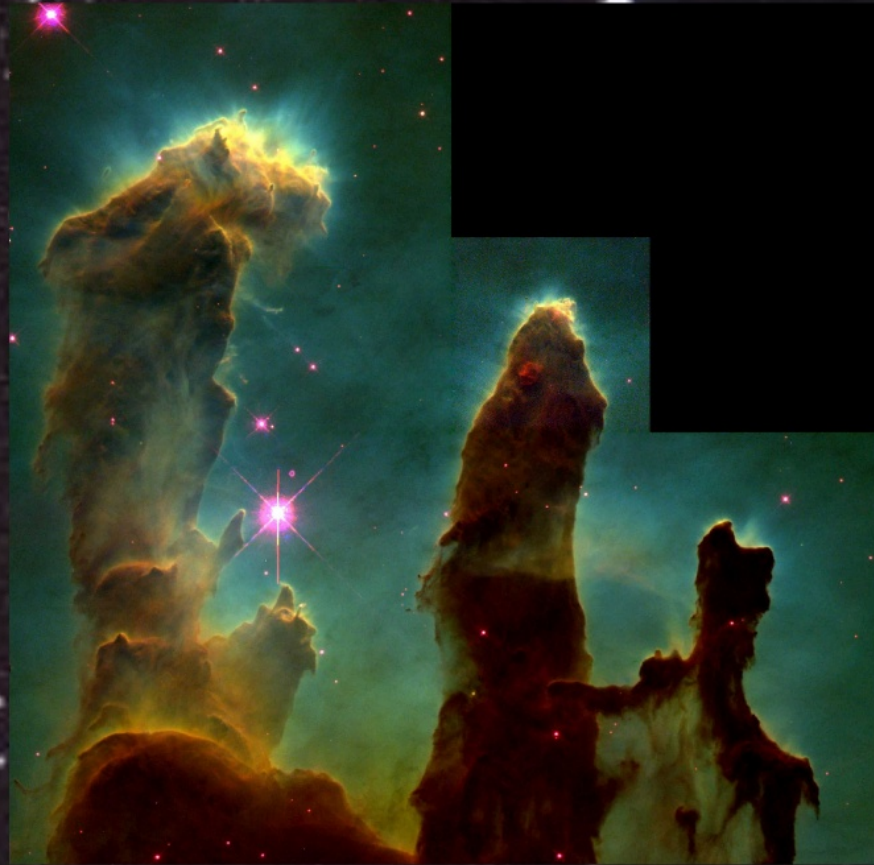
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Astrophysics



Astrophysics

How does it all work?

Astrophysics

How does it all work?



Astrophysics

How does it all work?



Astrophysics

How does it all work?



Astrophysics



How does it all work?

Neutron stars --

- "Dead" stars made entirely of neutrons
- Super dense
- Possible crystalline structure
- Hence starquakes

Astrophysics

How does it all work?



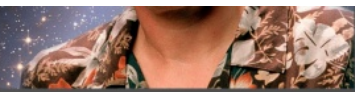
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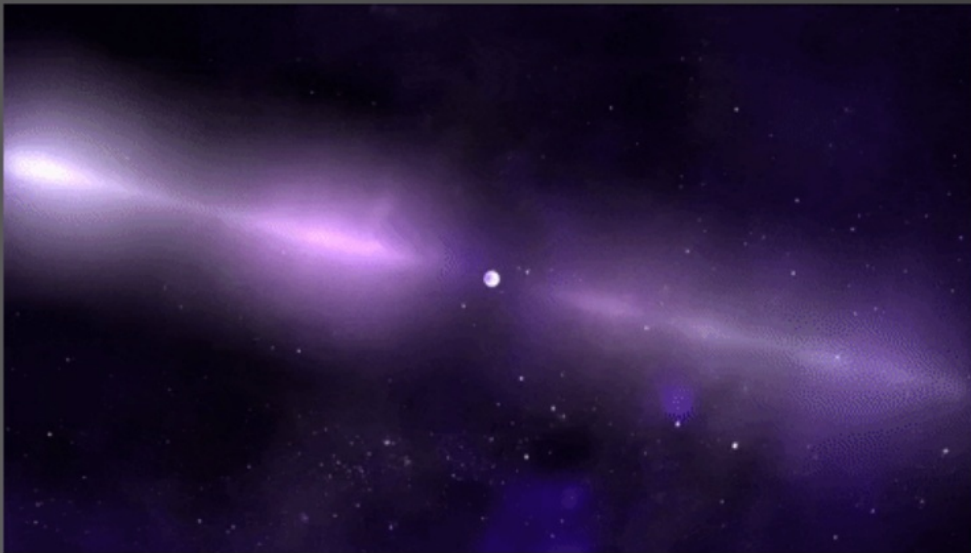
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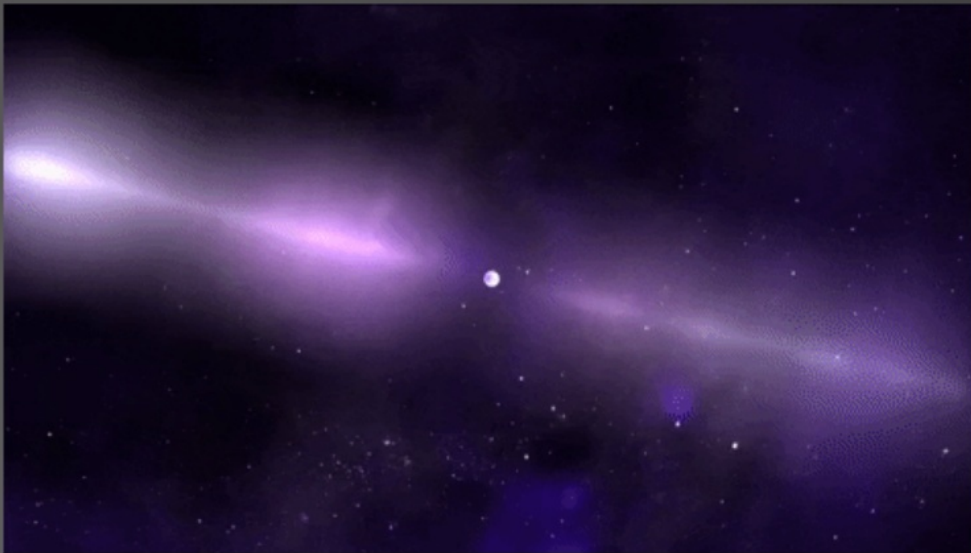
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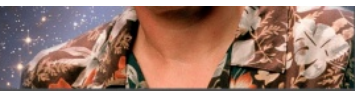


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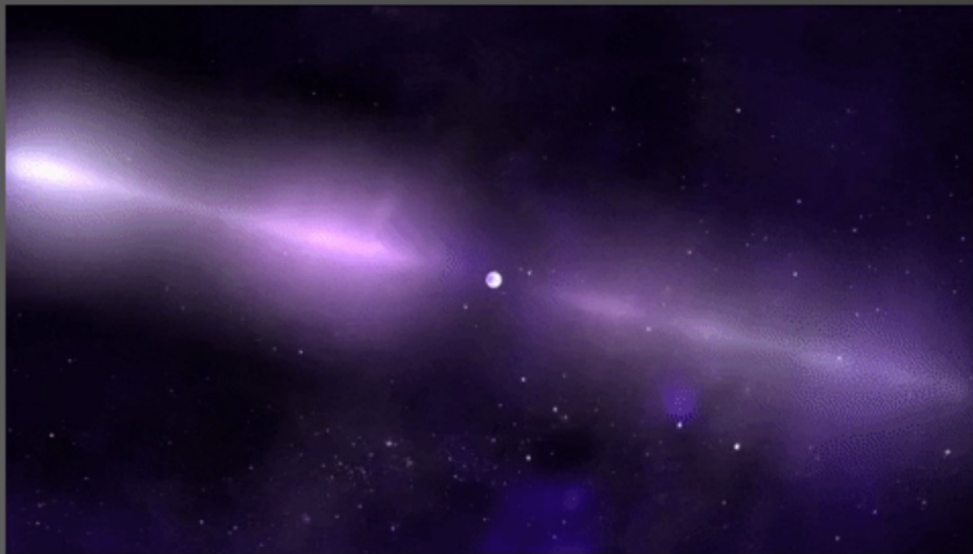


Spoiler: didn't solve this problem in 8 weeks



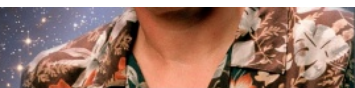
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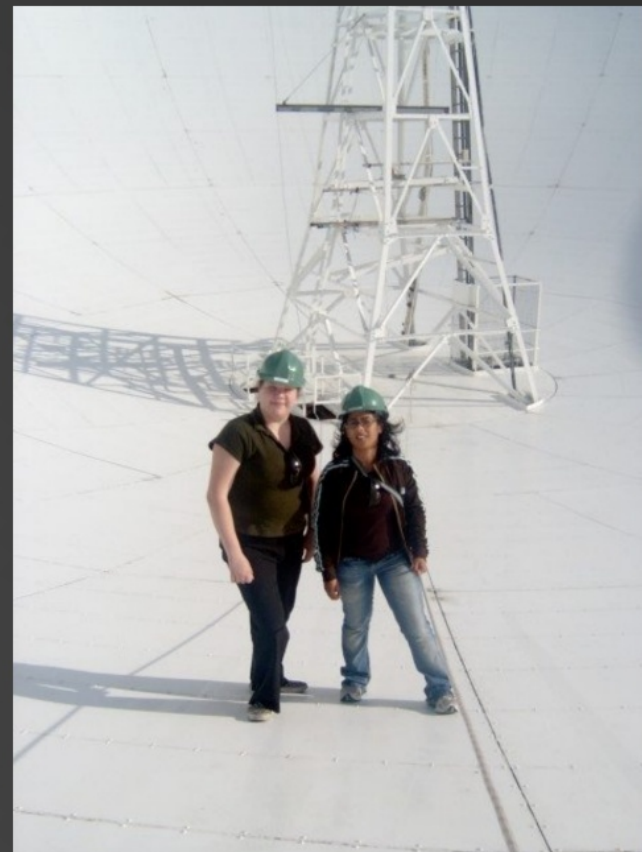
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**Research experience
should be available to
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Astrophysics

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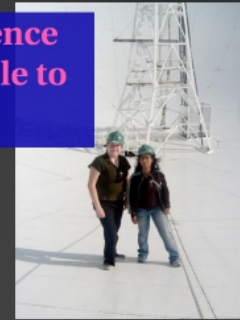
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<https://youtu.be/fsM5hLPAPxk>

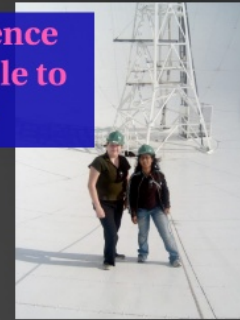
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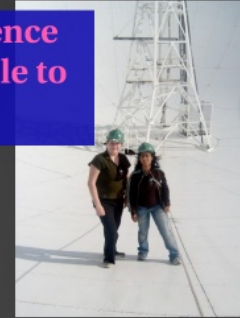
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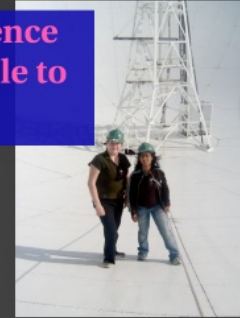
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Star Formation



Instit

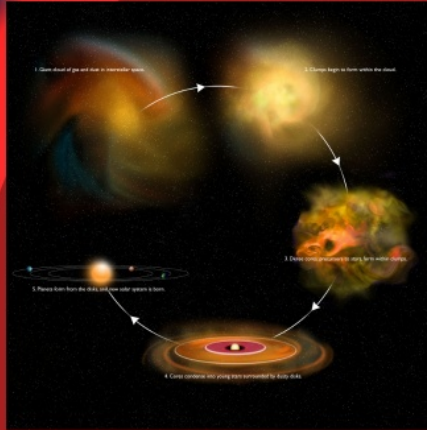
Star Formation

How do high-mass stars form?

Insti

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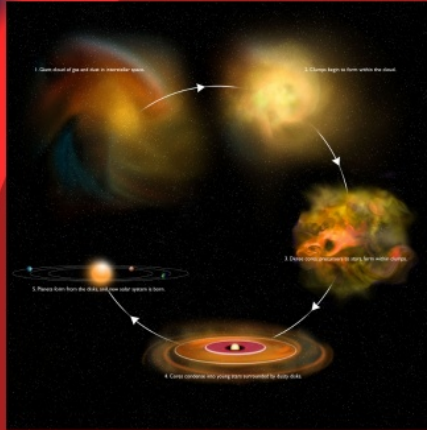
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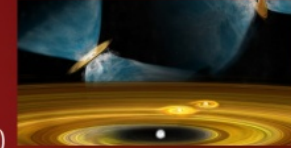
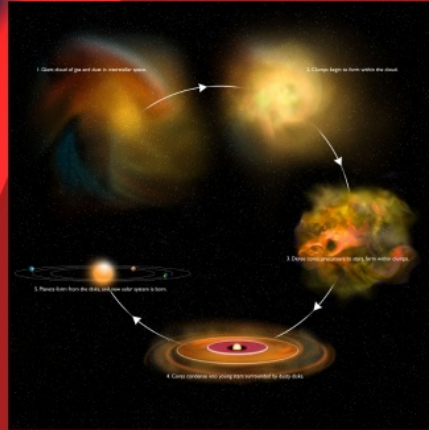
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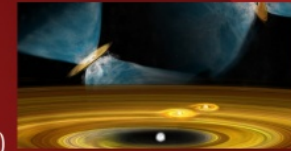
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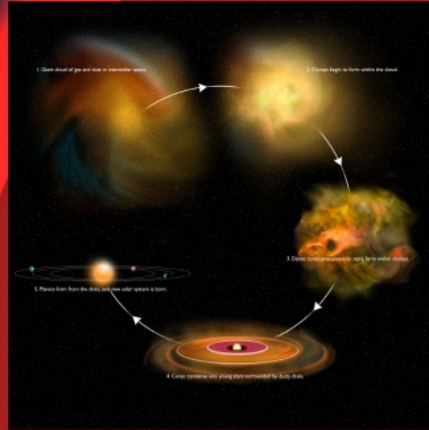
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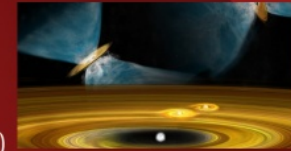


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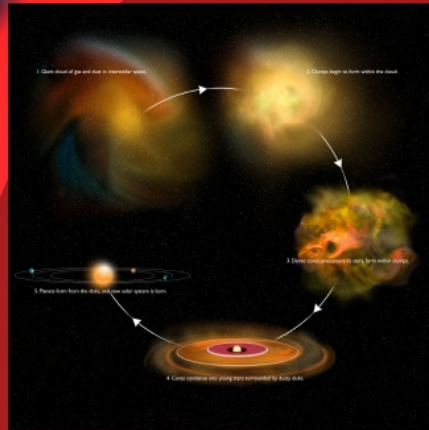
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MPhys thesis
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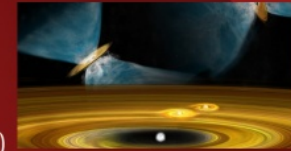
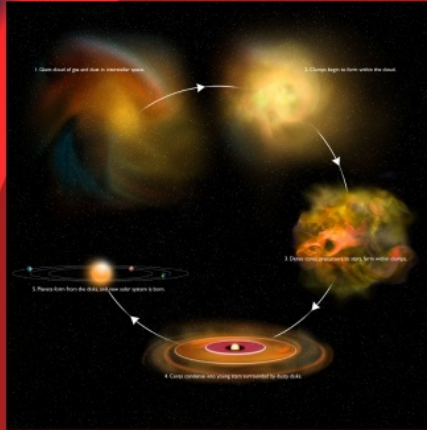
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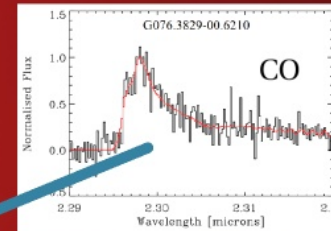
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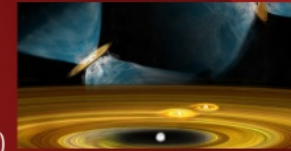
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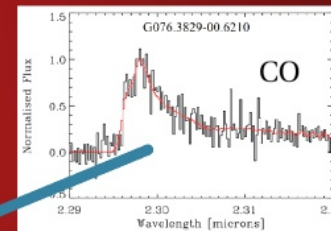
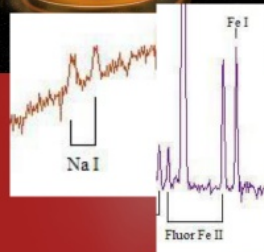
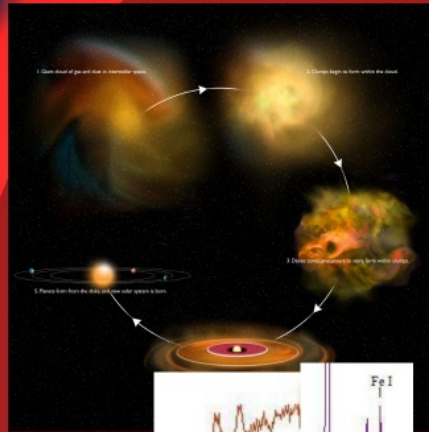
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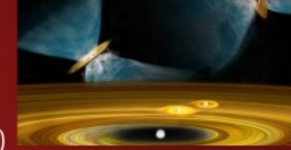
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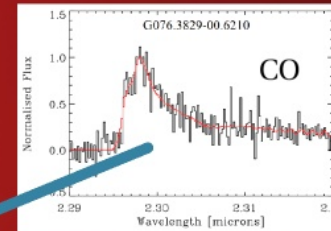
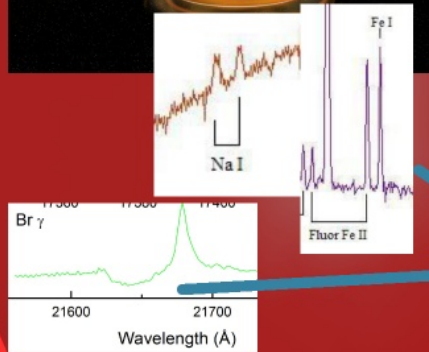
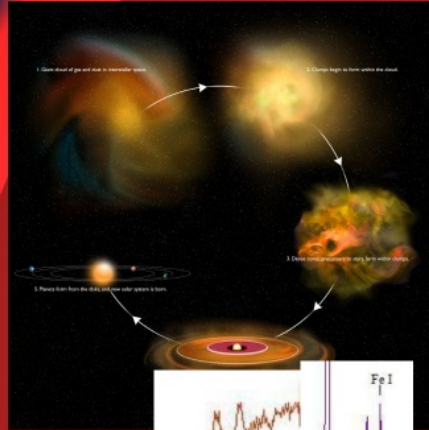
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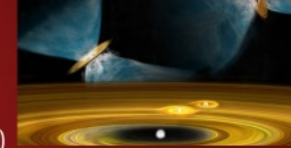
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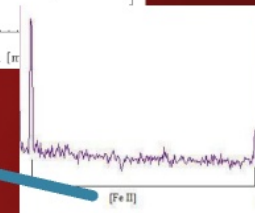
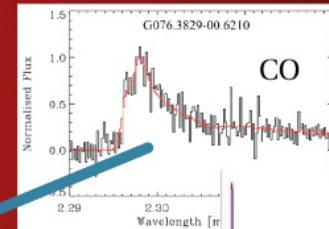
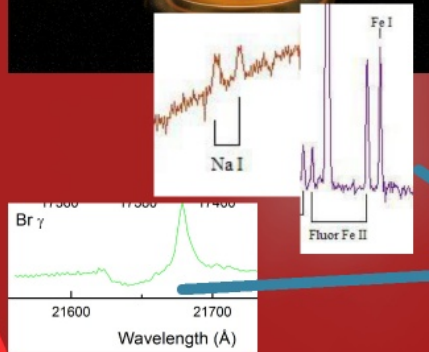
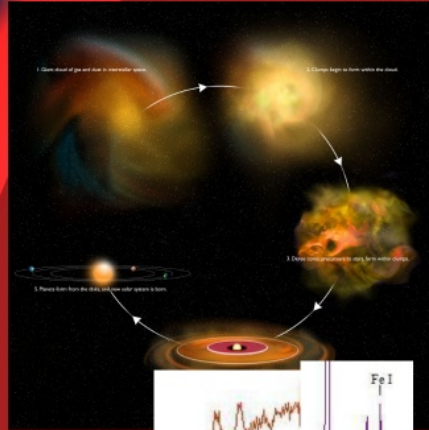
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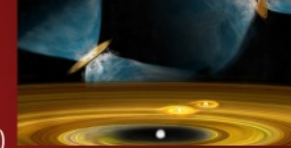
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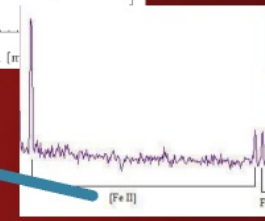
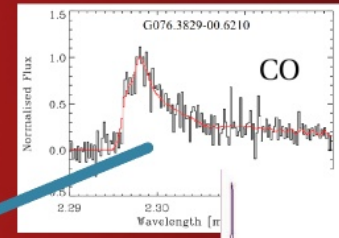
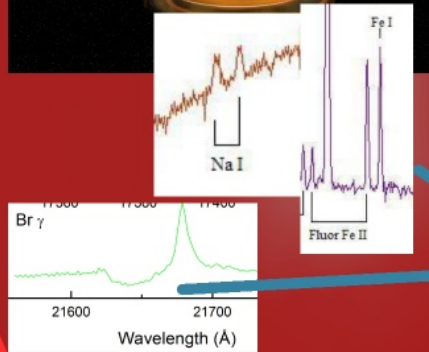
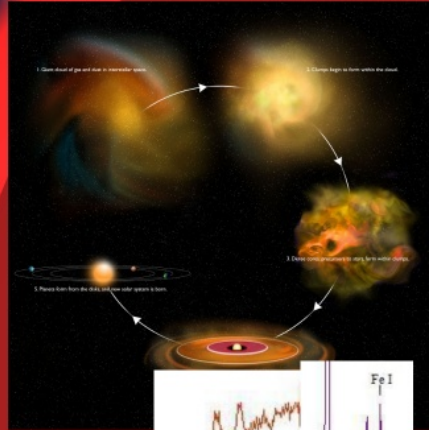
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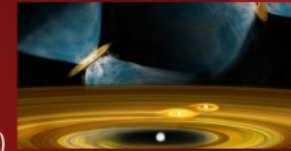
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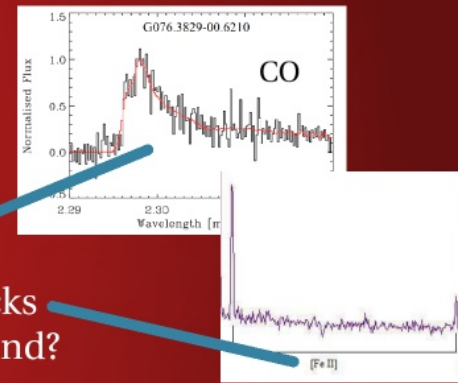
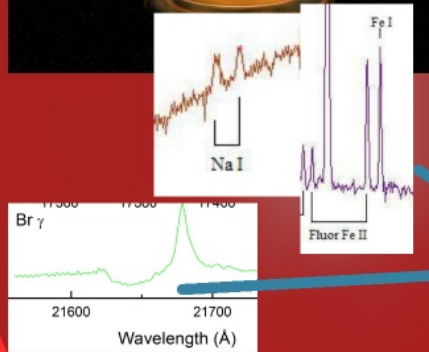
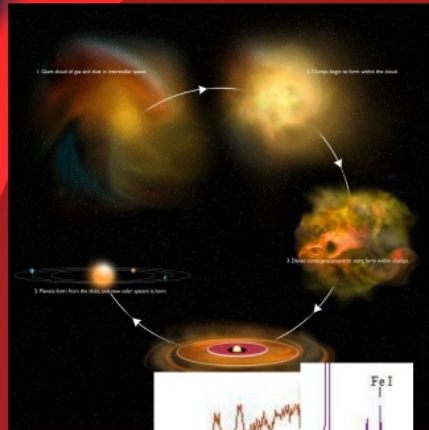
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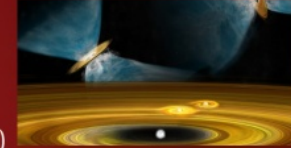
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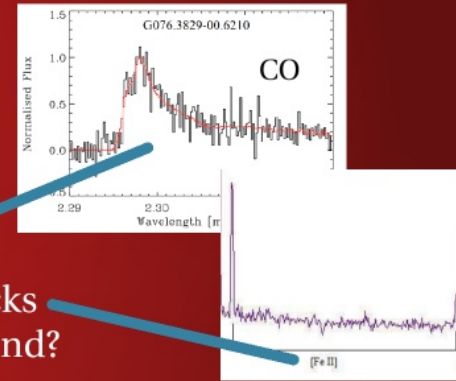
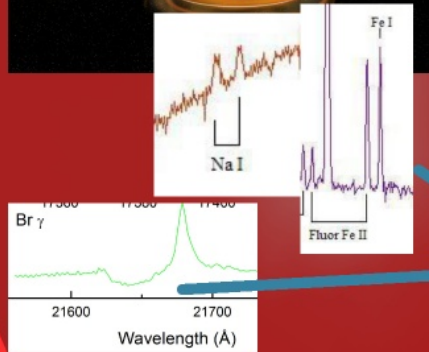
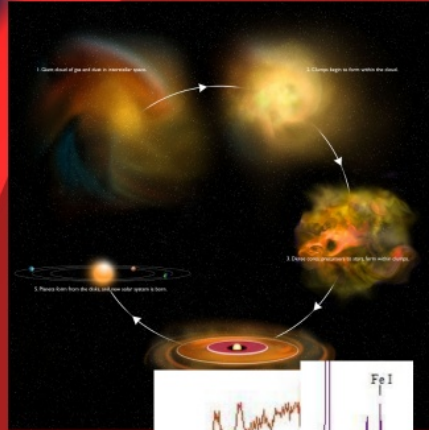
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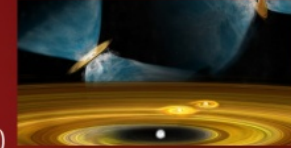
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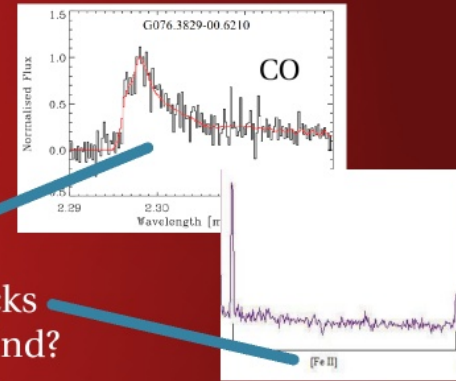
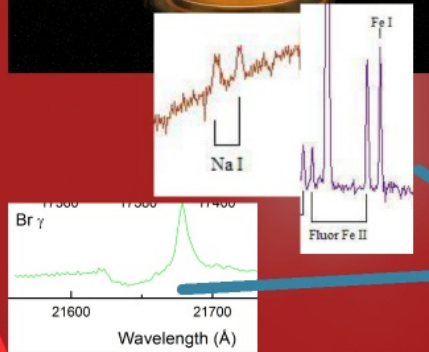
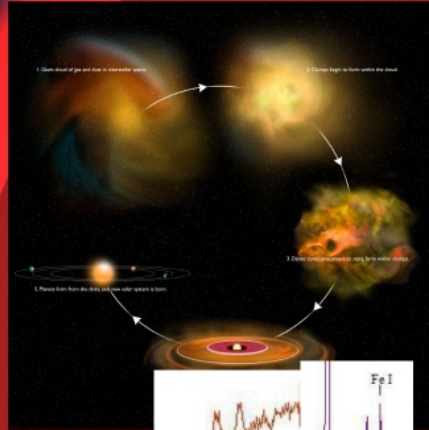
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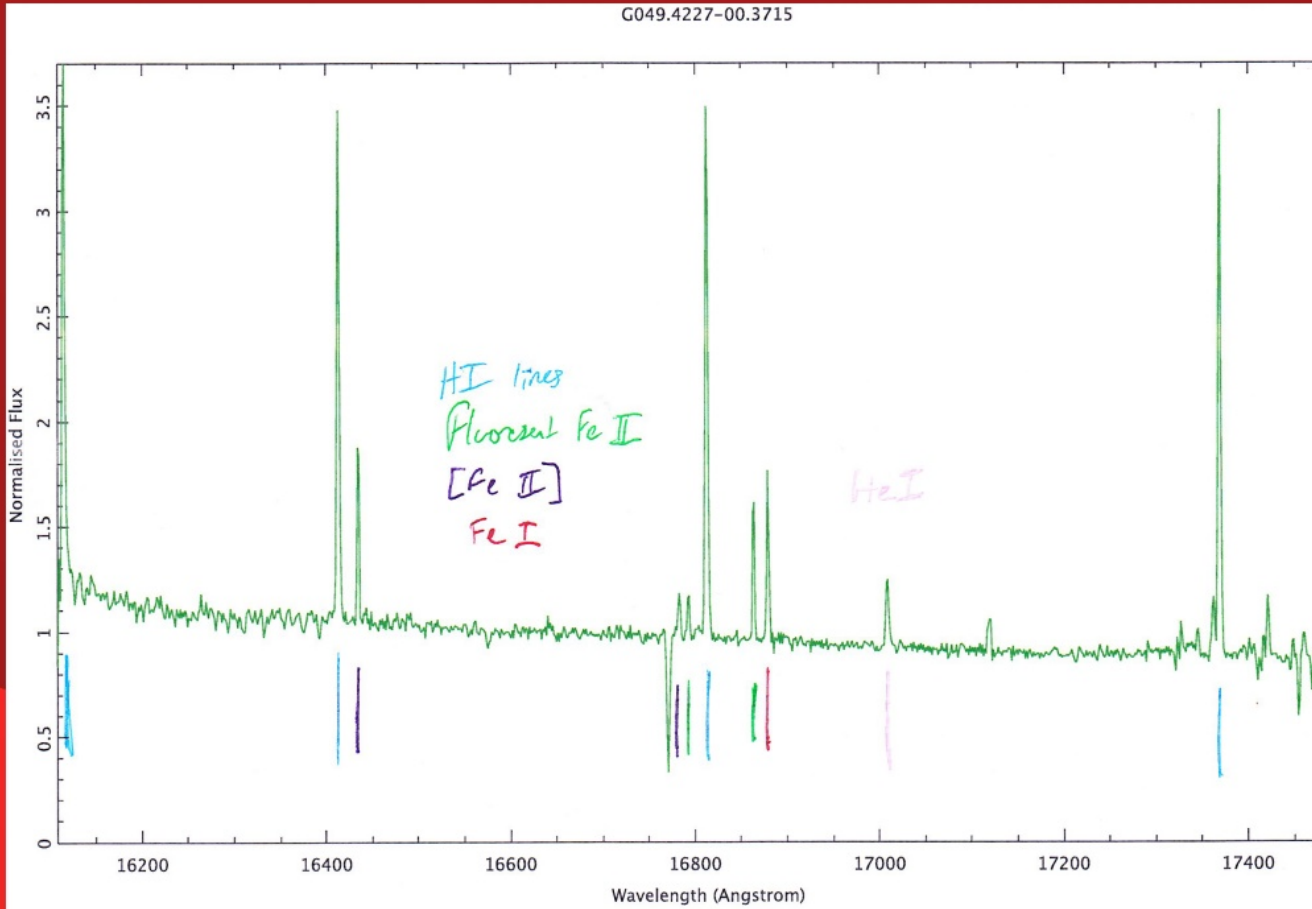
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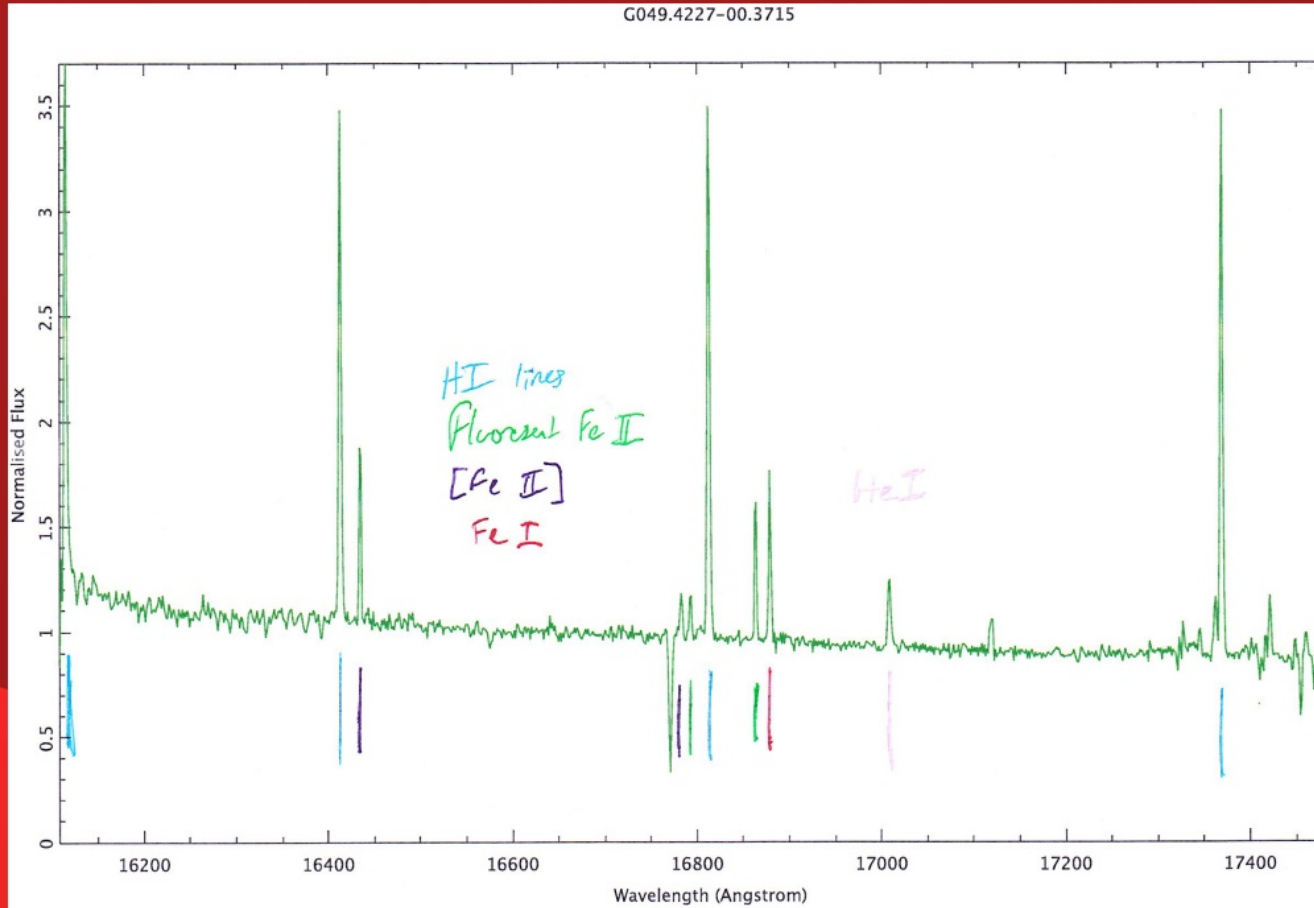


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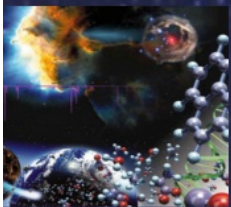
Institution





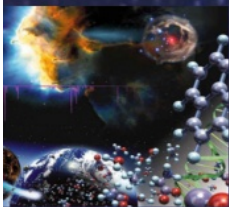
What do the brackets [] mean???

(Accidental) Astrochemistry



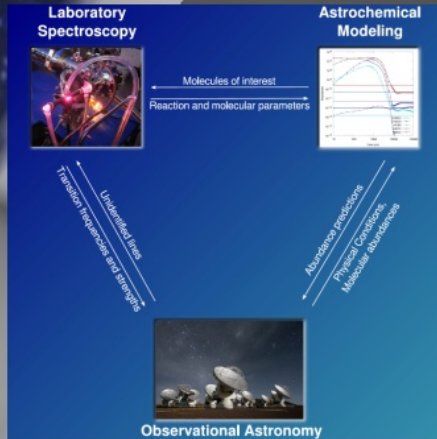
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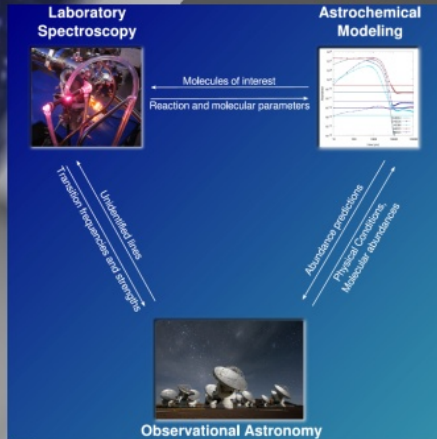


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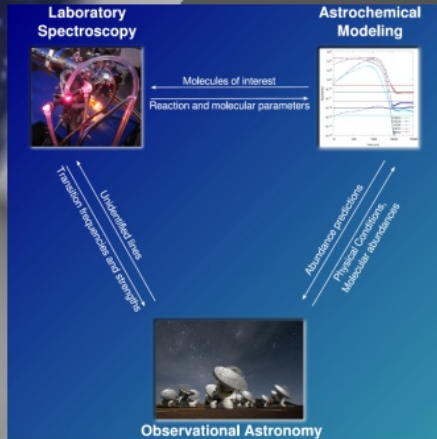


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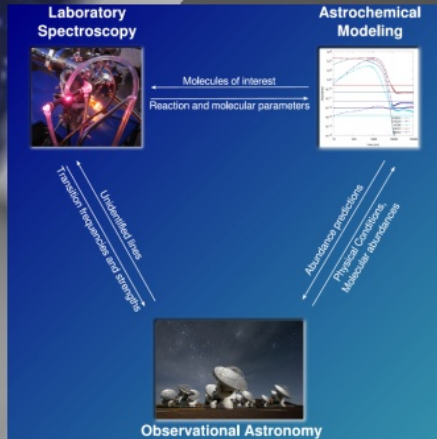
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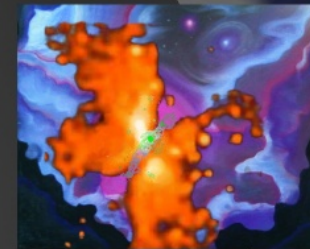
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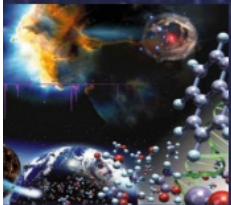
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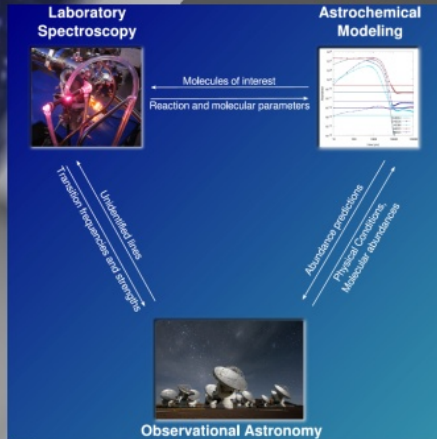
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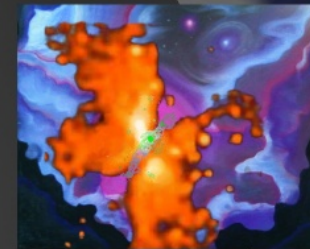
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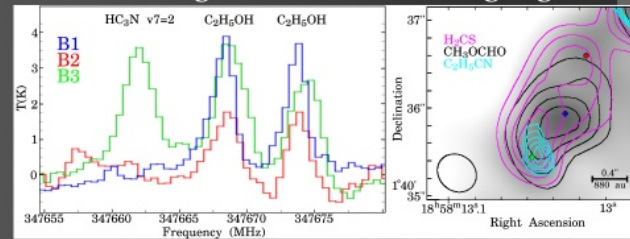
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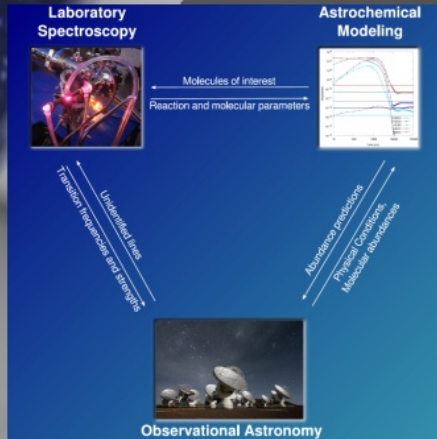
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Allen et al. 2017

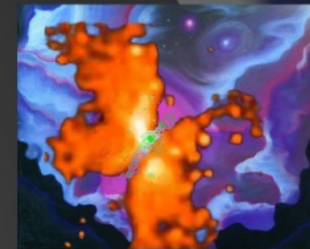
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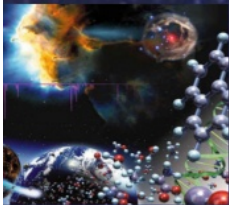
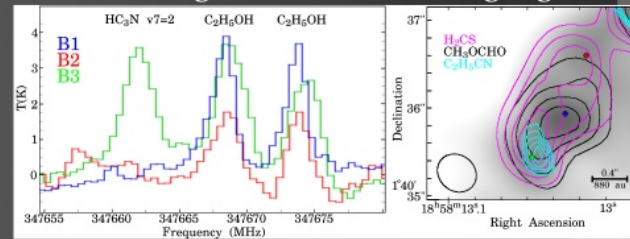


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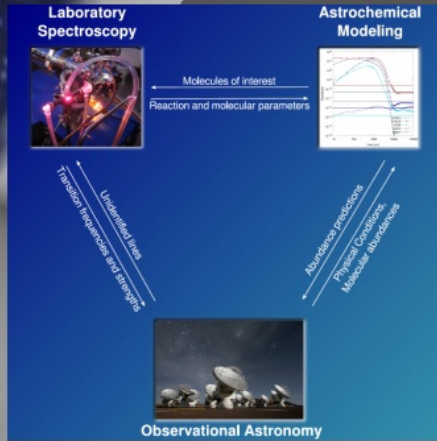


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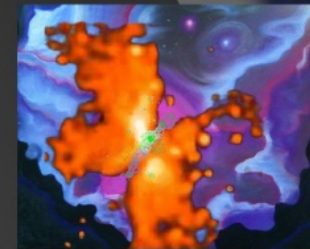
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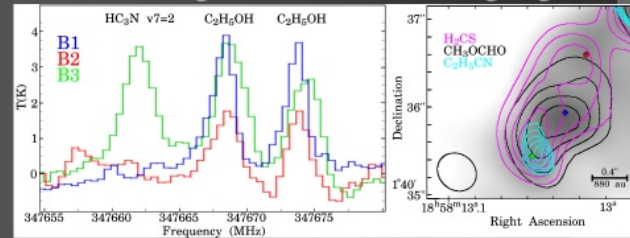


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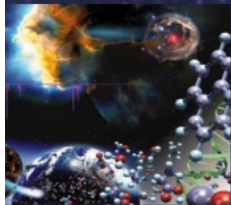
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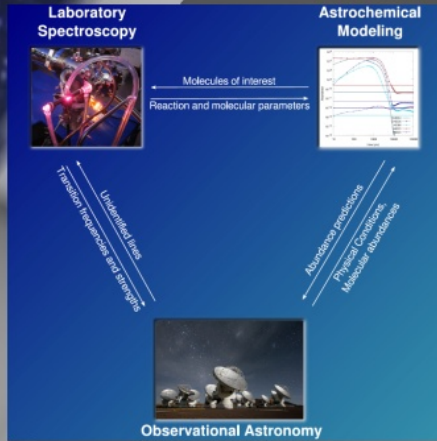


Allen et al. 2017



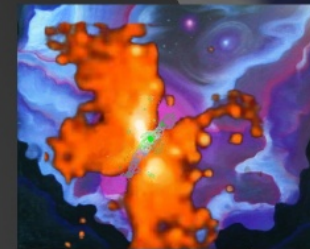
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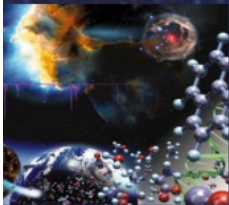
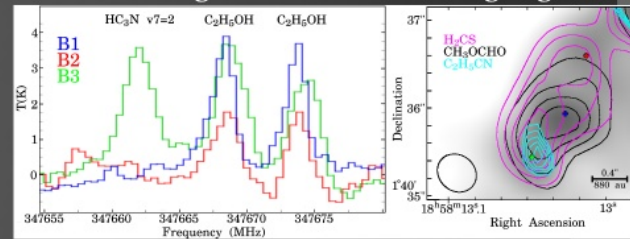


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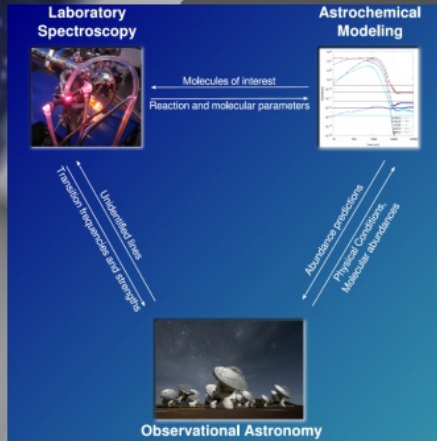


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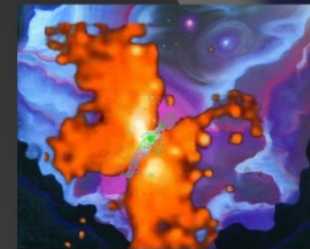
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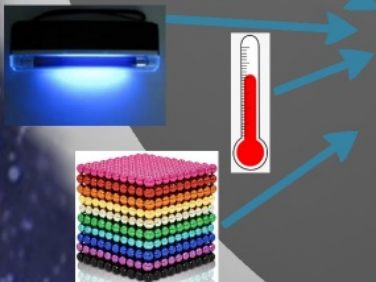
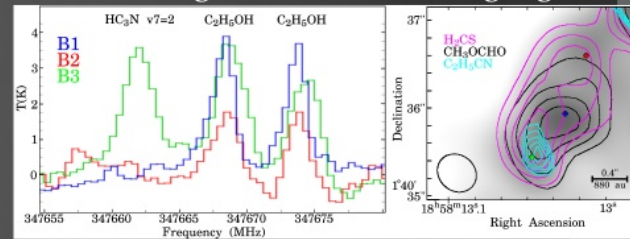


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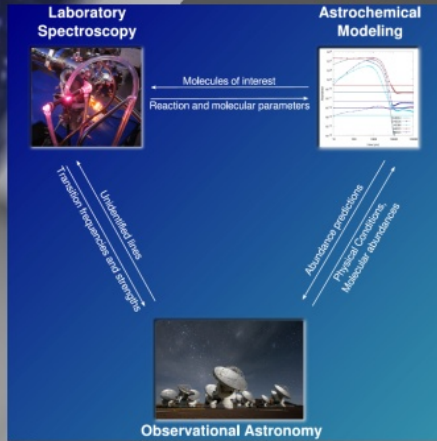


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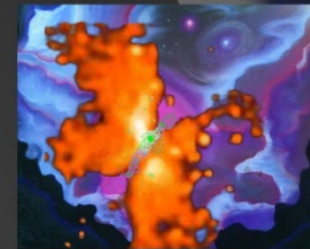
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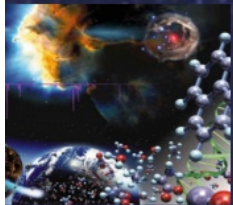
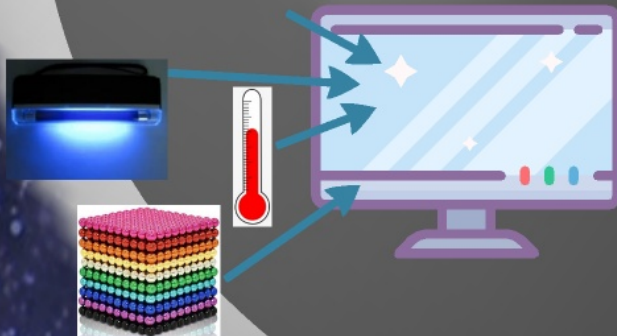
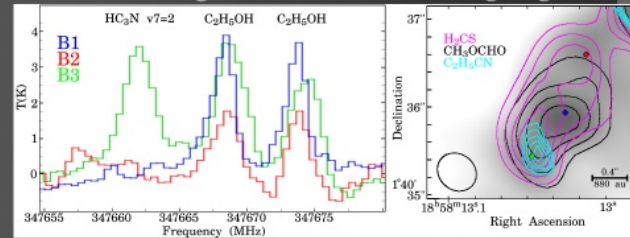


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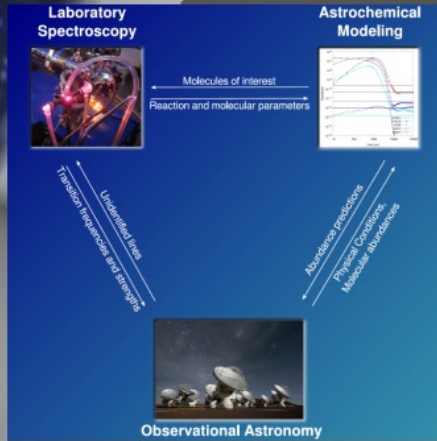


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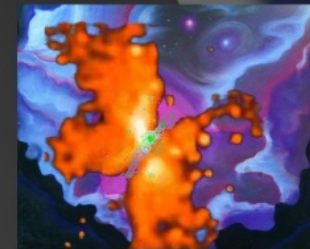
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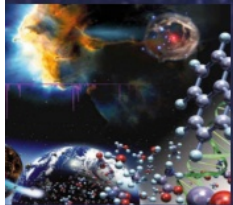
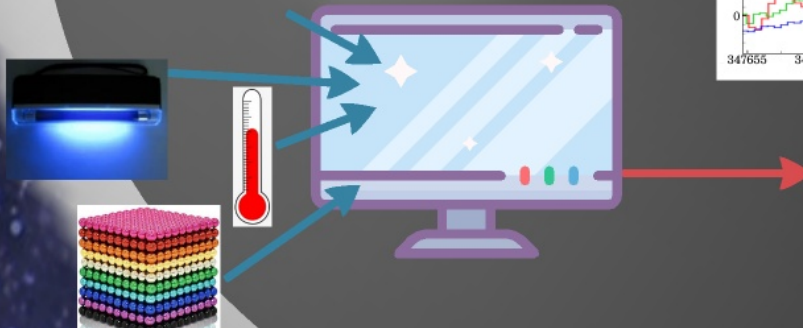
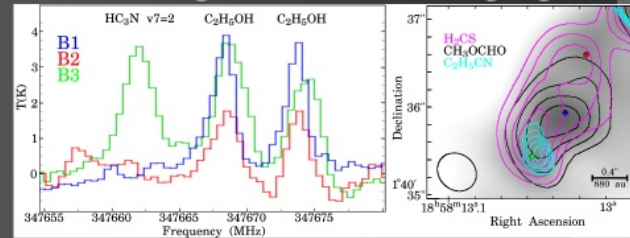


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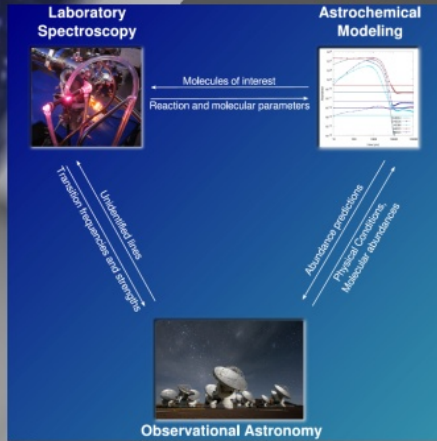


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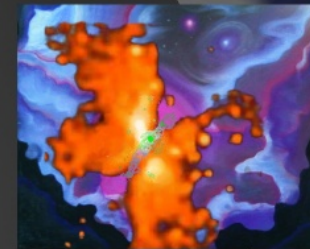
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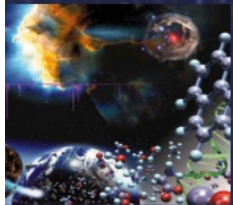
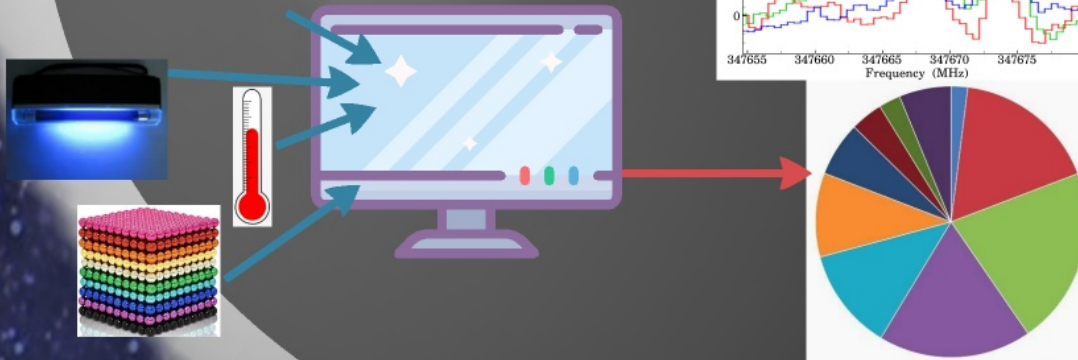
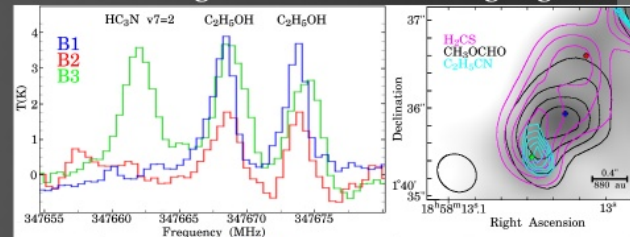


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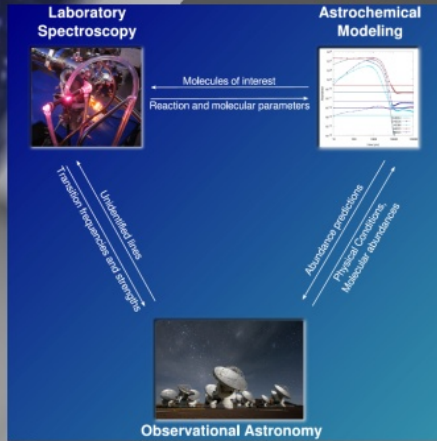


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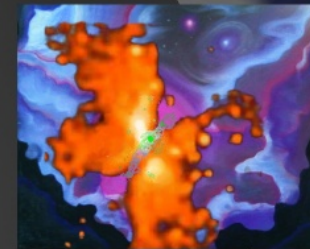
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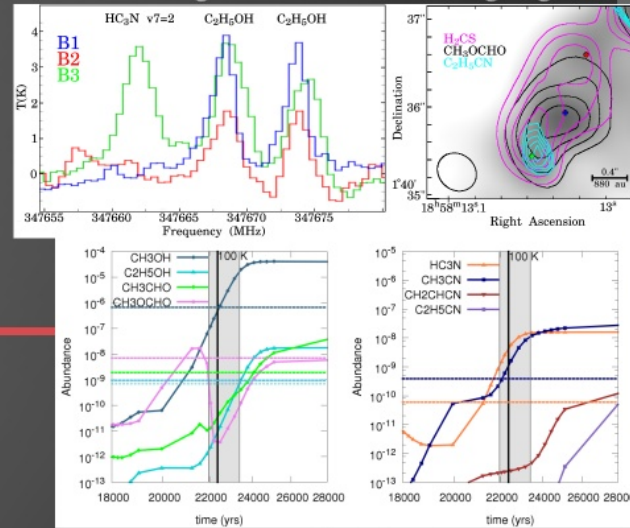


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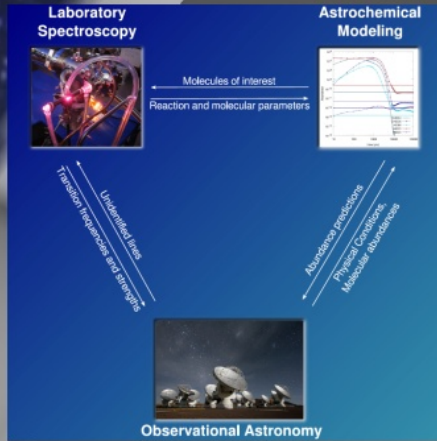


Allen et al. 2017

Allen et al. 2018

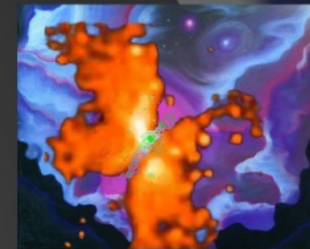
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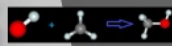


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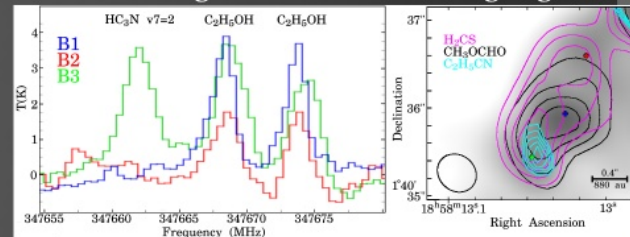
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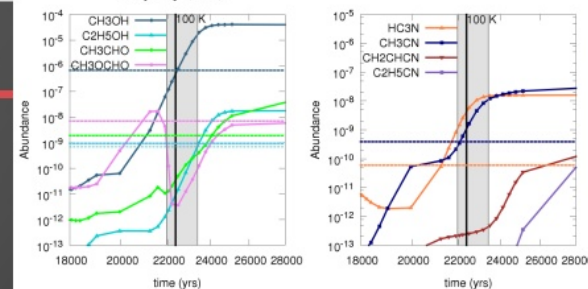
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x1000s



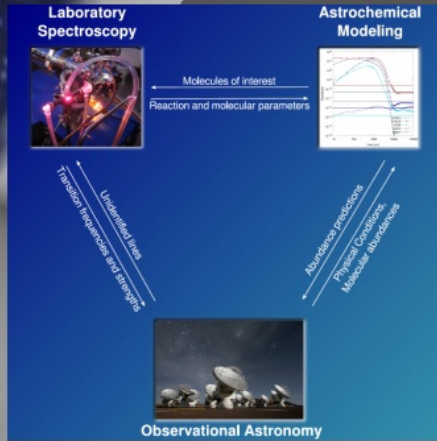
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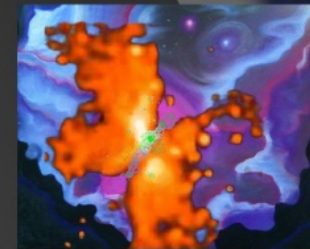
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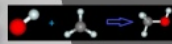


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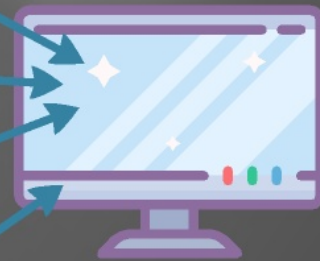
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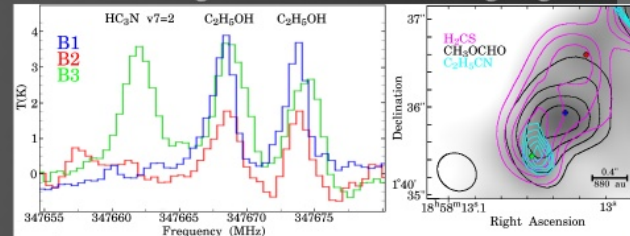
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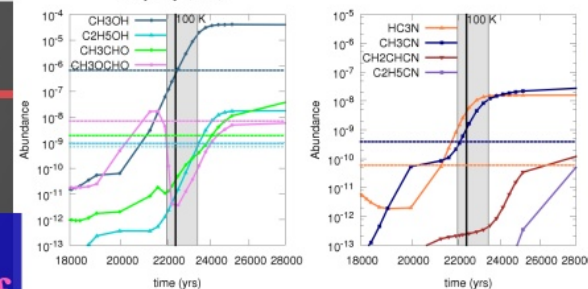
x1000s



The project can take you to amazing places if you release control

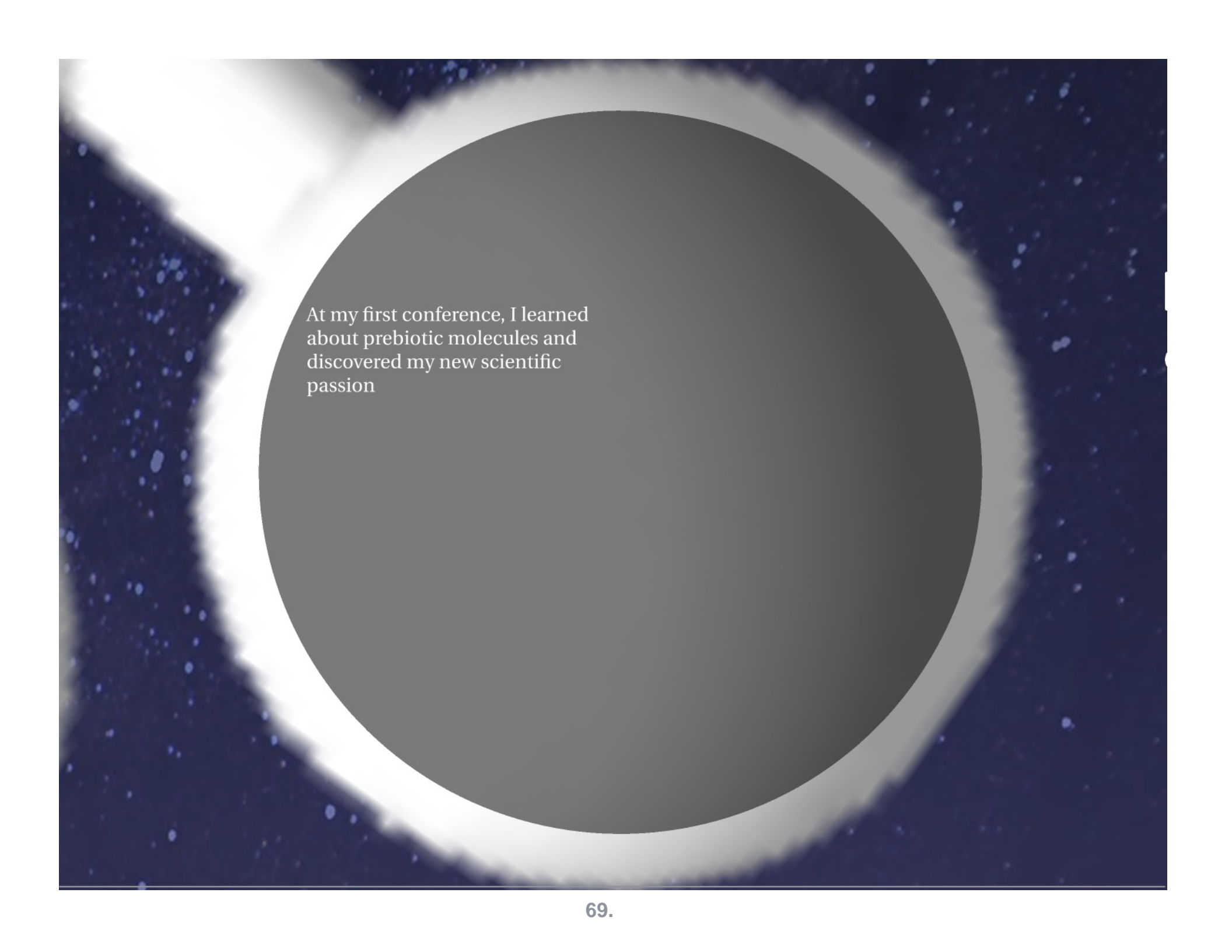


Allen et al. 2017



Allen et al. 2018





At my first conference, I learned
about prebiotic molecules and
discovered my new scientific
passion



Down the astrochemical rabbit hole

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How do molecules form?

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How do molecules form?

Formation of prebiotic molecules

- Observations - formamide and possible parents in gas (with ALMA) and ice (with JWST)
- Models - formation and destruction reactions progressing over time in different environments
- Lab - making molecules in vacuum chambers under different conditions

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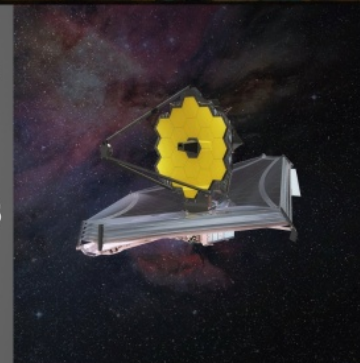
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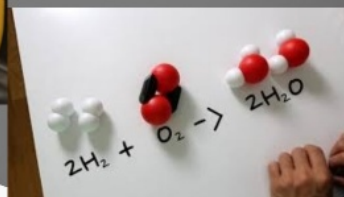
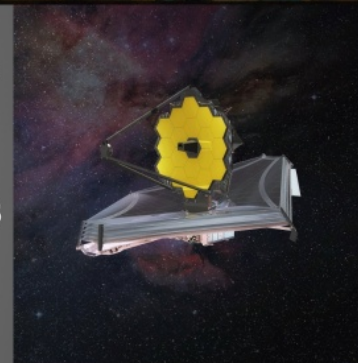
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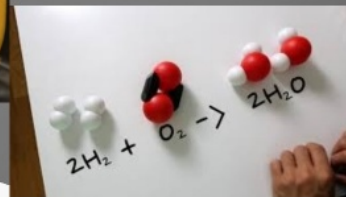
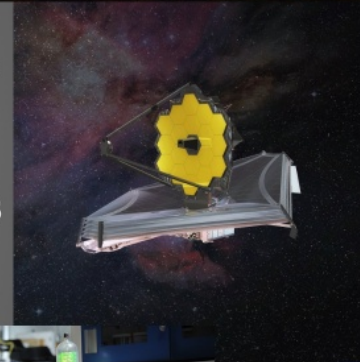
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Down the astrochemical rabbit hole

Networking is an important part of scientific work

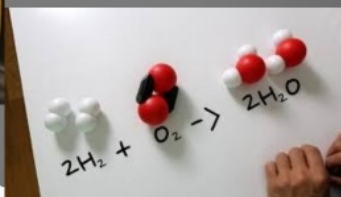
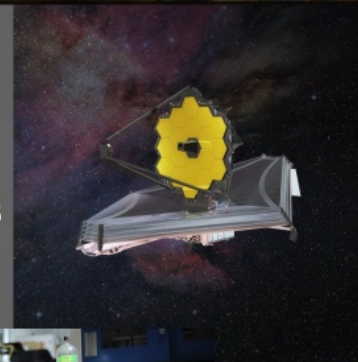
I learned molecules and scientific

How do molecules form?



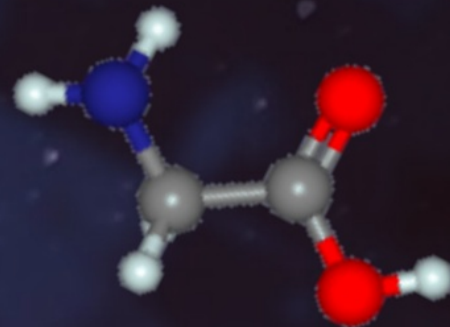
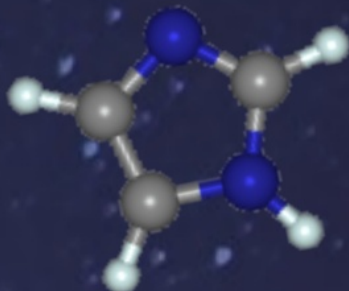
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How many atoms does a complex organic molecule (COM) have?

- 4
- 6
- 10
- 542





Formamide

Formamide

There is disagreement over how formamide forms
Previously **ice vs gas**, but now we're studying more formation routes
with different temperatures, ice mixtures, **UV fields**...

Formamide

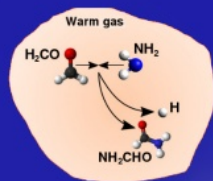
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From H_2CO in warm gas ($>70\text{ K}$)

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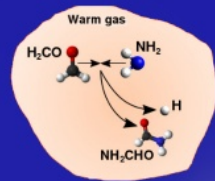
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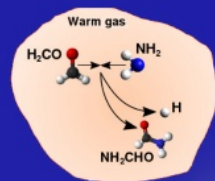


From HNCO on dust grains in ice ($10\text{-}20\text{ K}$)

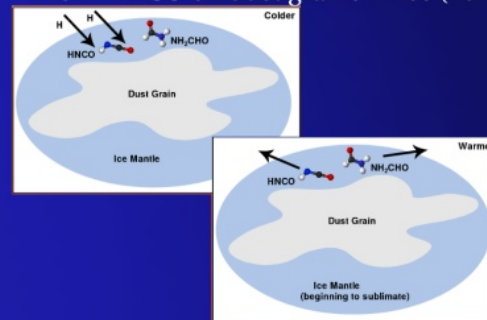
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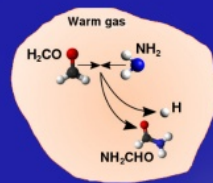
From HNCO on dust grains in ice ($10\text{-}20\text{ K}$)



Formamide

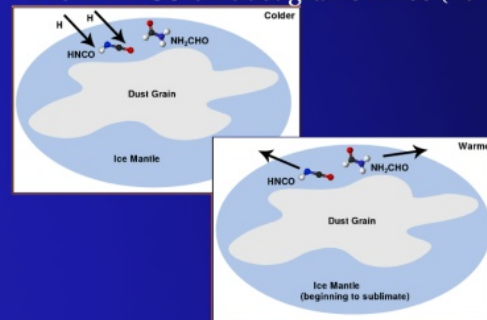
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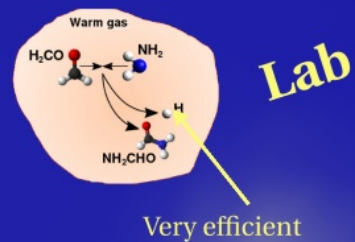
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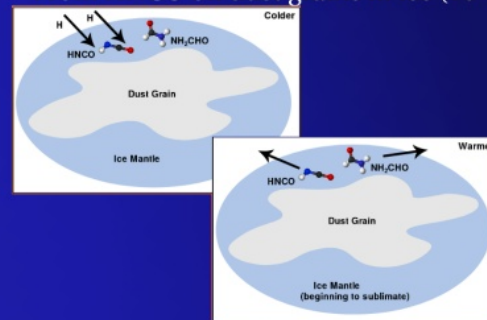
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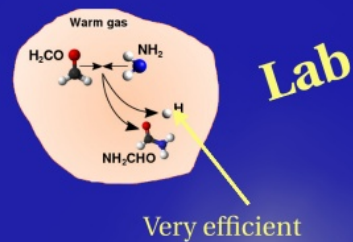
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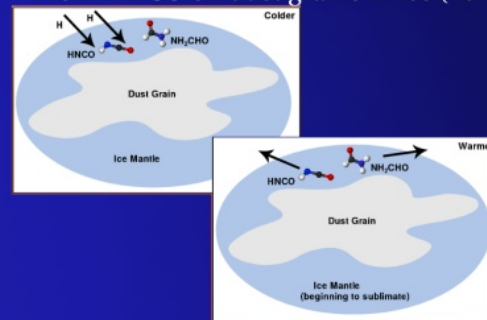
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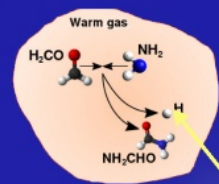


Doesn't work in normal environments

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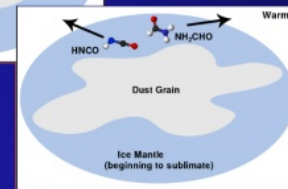
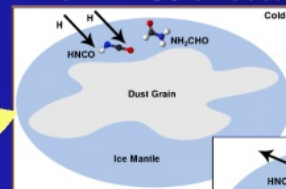


Lab

Works with high cosmic ray flux

Very efficient

From HNCO on dust grains in ice ($10\text{-}20\text{ K}$)

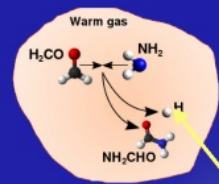


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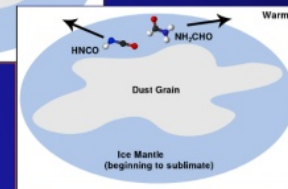
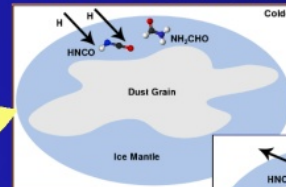


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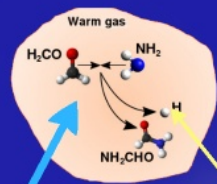
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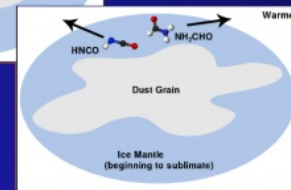
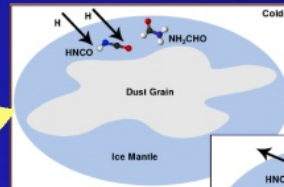
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Easy to make in
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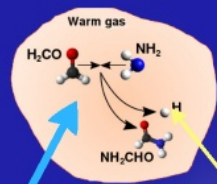


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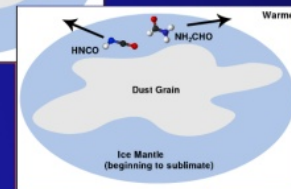
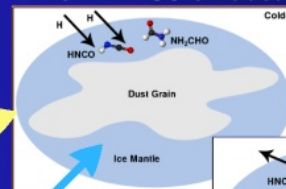
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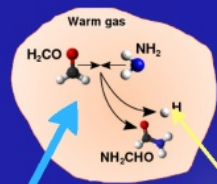
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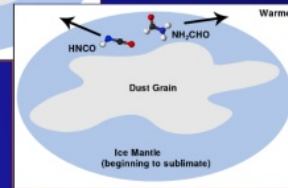
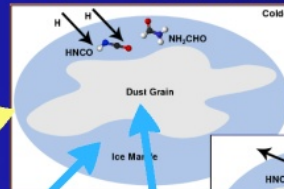
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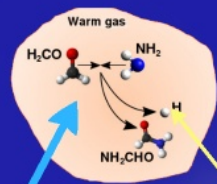
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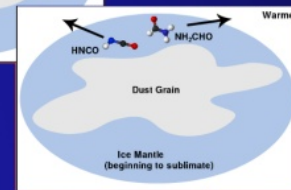
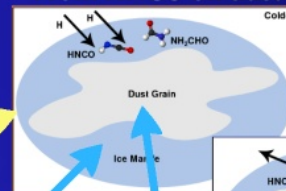
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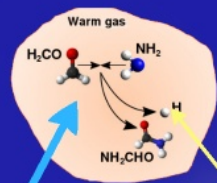
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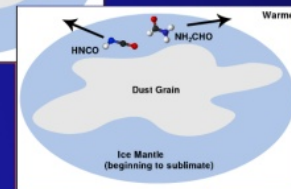
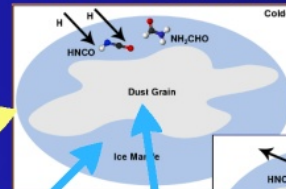
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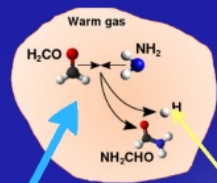
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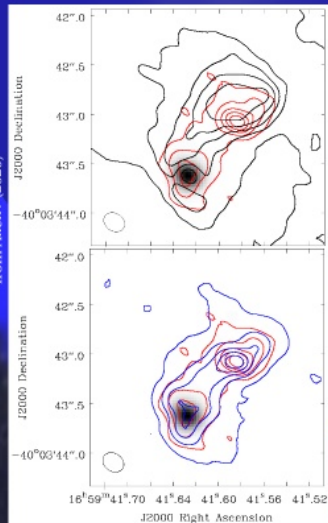
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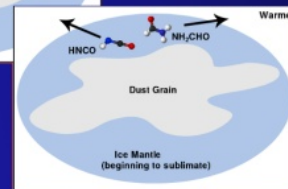
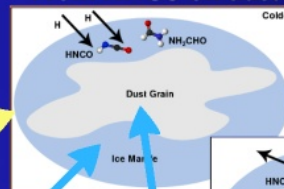
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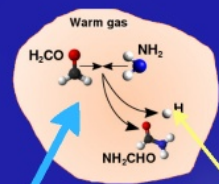
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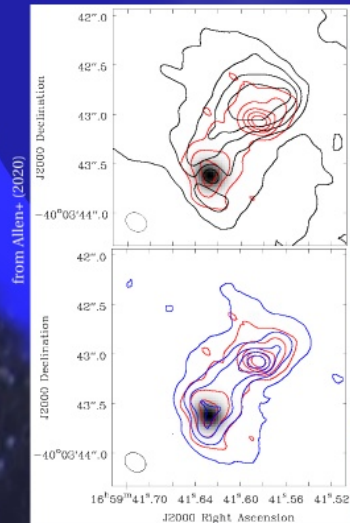
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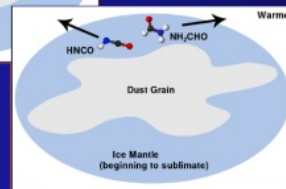
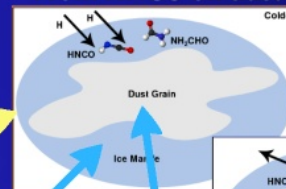
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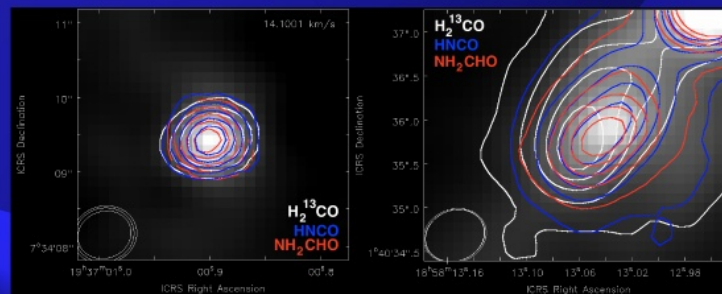
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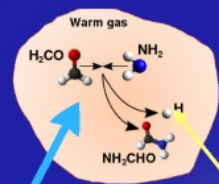
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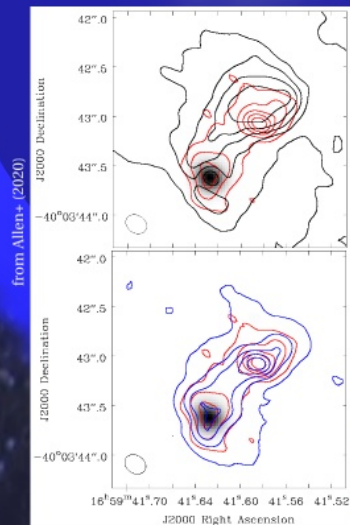
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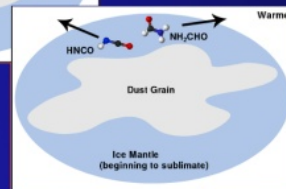
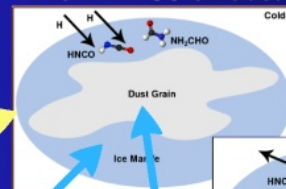
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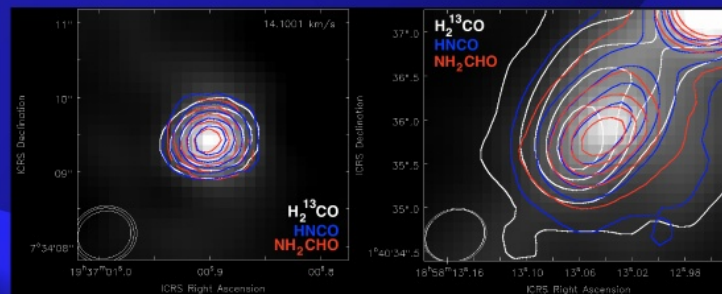
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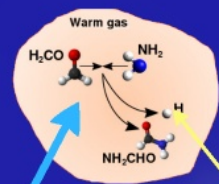
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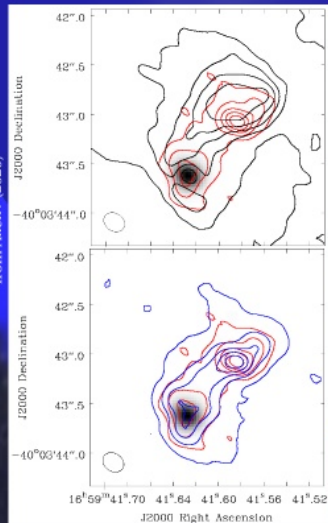
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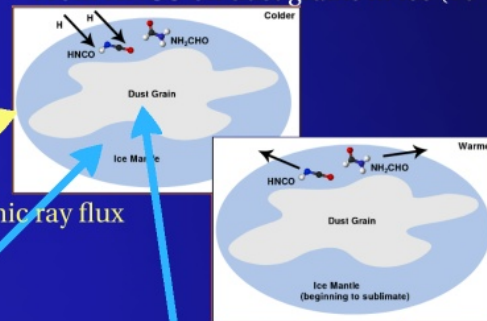
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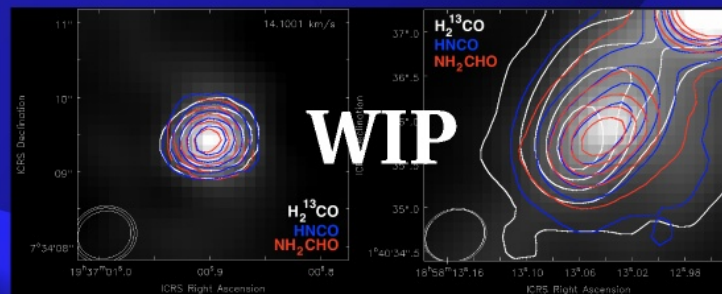
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Astrobiology

Do biological molecules exist in space?

Astrobiology and the most volcanic object in
the solar system

Observing Challenges

ACA proposal accepted

Do biological

Do biological



Goddard
SPACE FLIGHT CENTER

NPP
NASA Postdoctoral Program

Do biological

**Astrochemistry
Laboratory
Code 691**

Natasha Johnson

Perry Gerakines
(Associate Chief)



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Do biological



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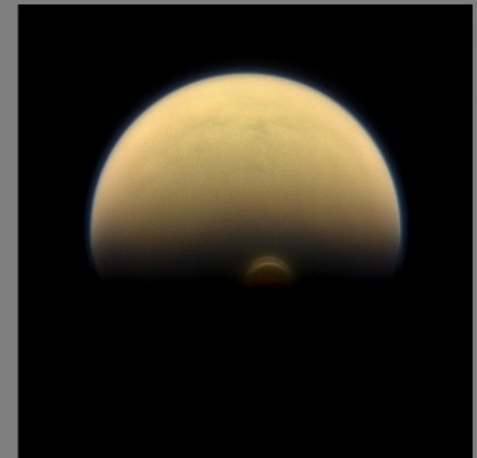
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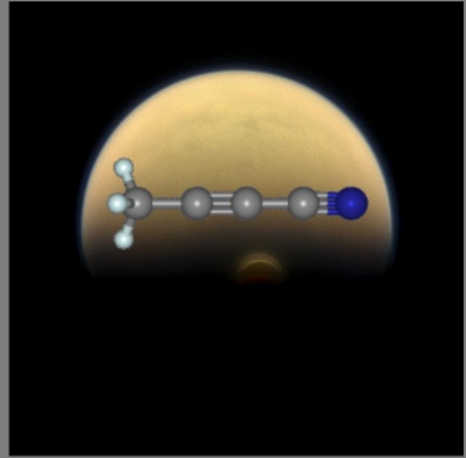


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Xander Thelen, Conor Nixon, Martin Cordiner
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What molecules exist in space?

Astrobiology and the most volcanic object in
the solar system

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Ingredients for life:

What molecules exist in space?

Astrobiology and the most volcanic object in the solar system

Ingredients for life:

water,

heat,

CHNOPS

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Hydrogen

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Io: tenuous atmosphere + volcanoes = little chance for life

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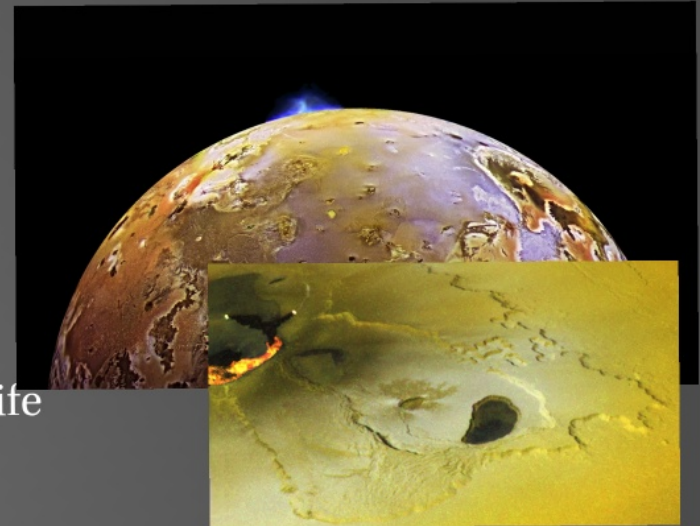
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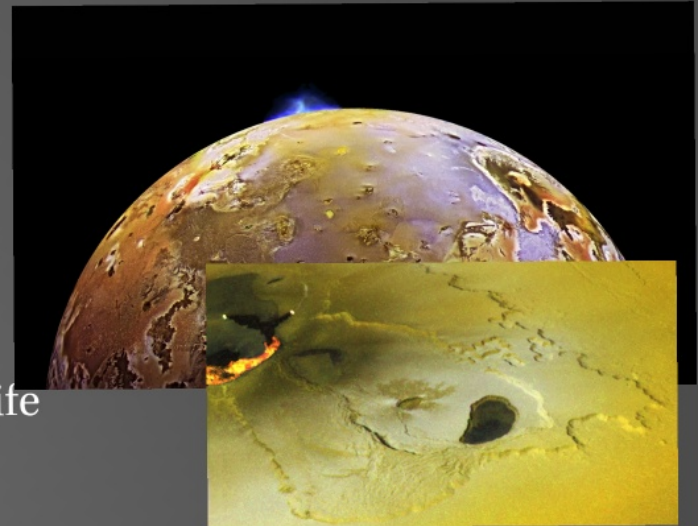
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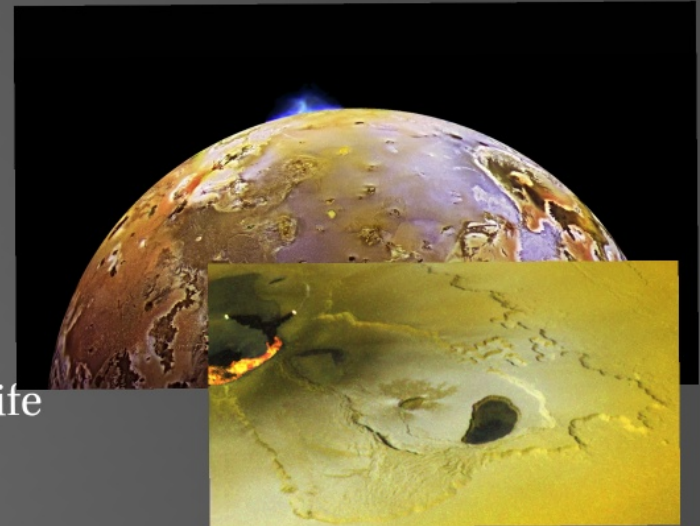
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But

Volcanoes release a lot of

SO₂



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Astrobiology and the most volcanic object in the solar system

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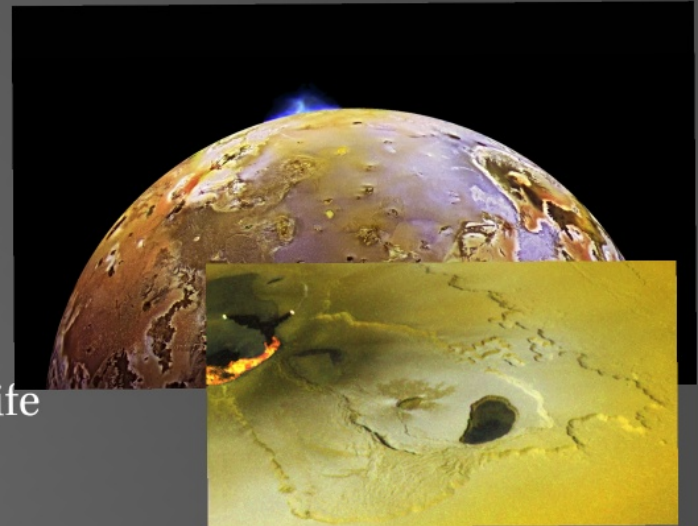
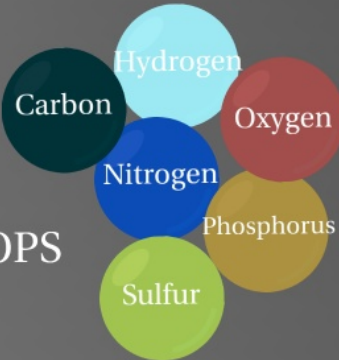


water,

heat,



CHNOPS

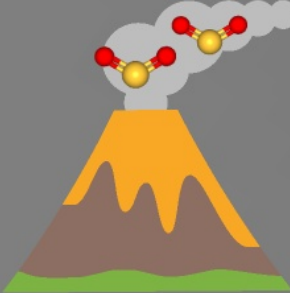


Io: tenuous atmosphere + volcanoes = little chance for life

But

Volcanoes release a lot of

SO₂



Do molecules exist in space?

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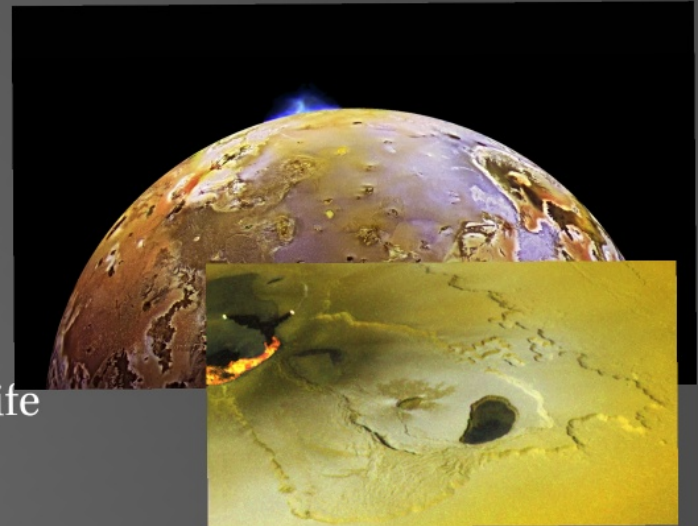
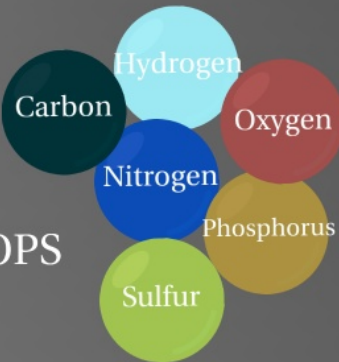


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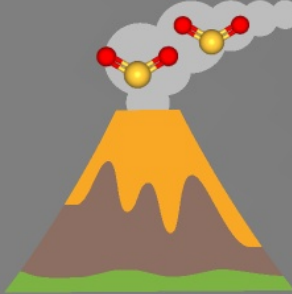
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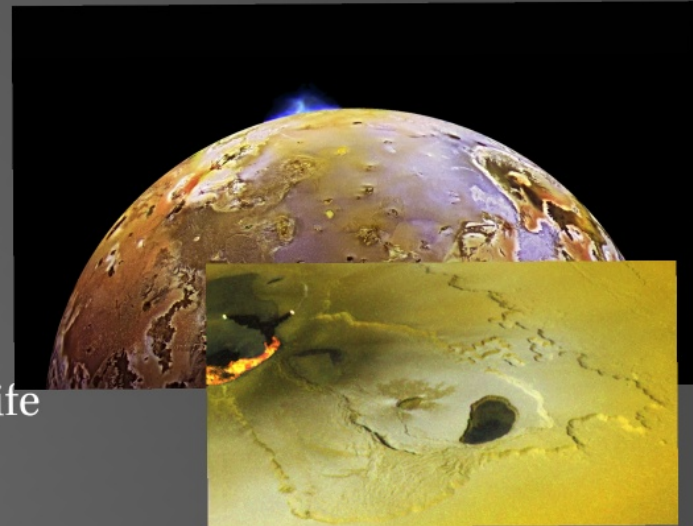
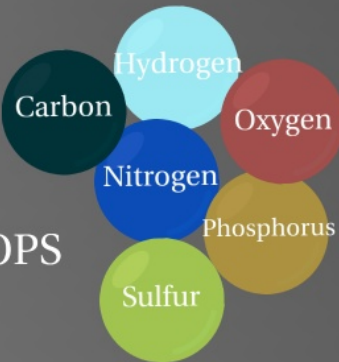


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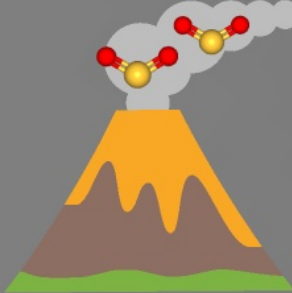
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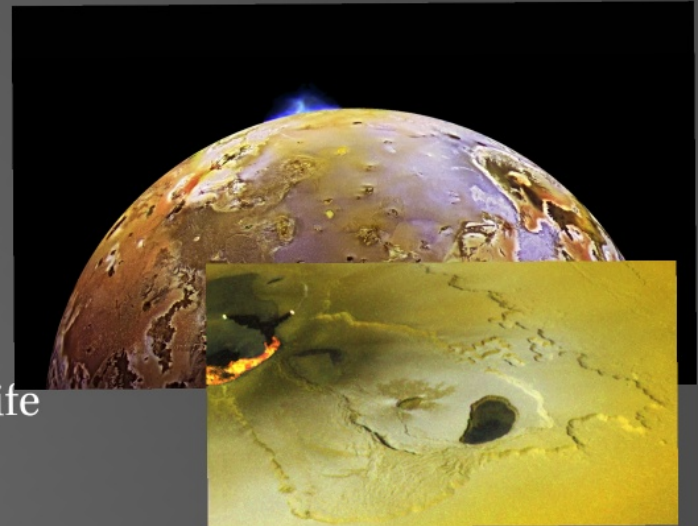
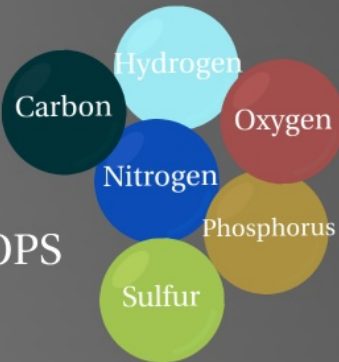


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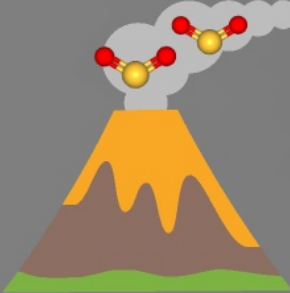
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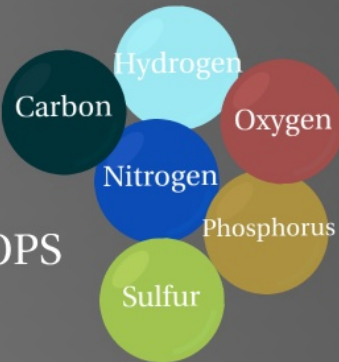


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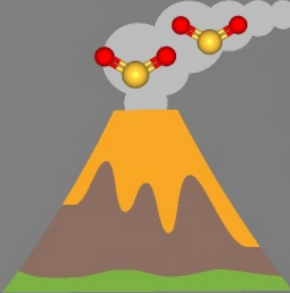
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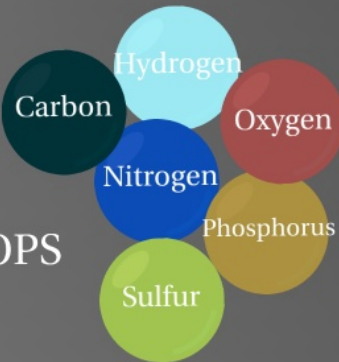


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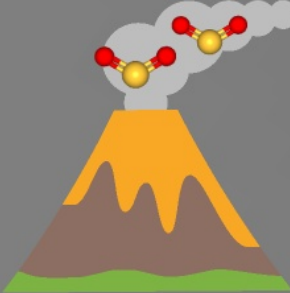
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SPACE FLIGHT CENTER

NASA Postdoctoral Program

Obs

ACA proposal



Volcanoes fill the torus with gas

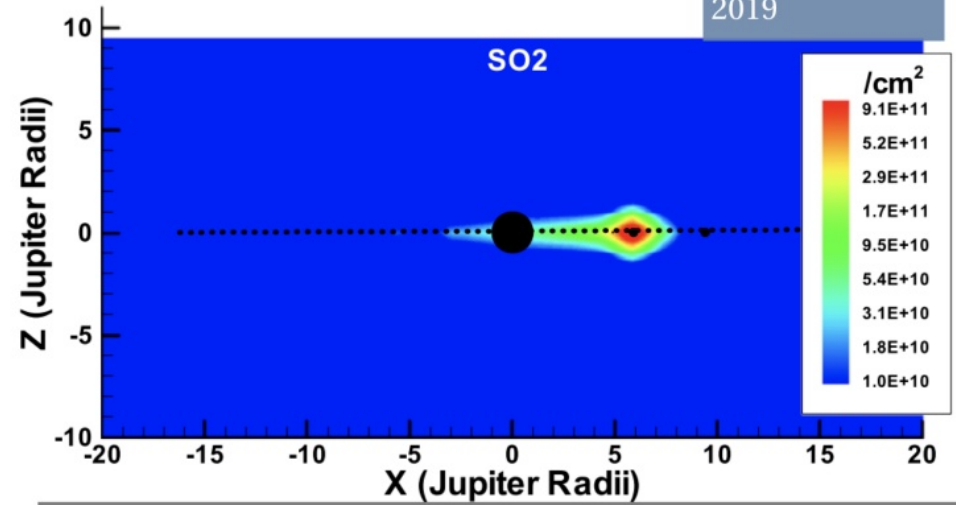
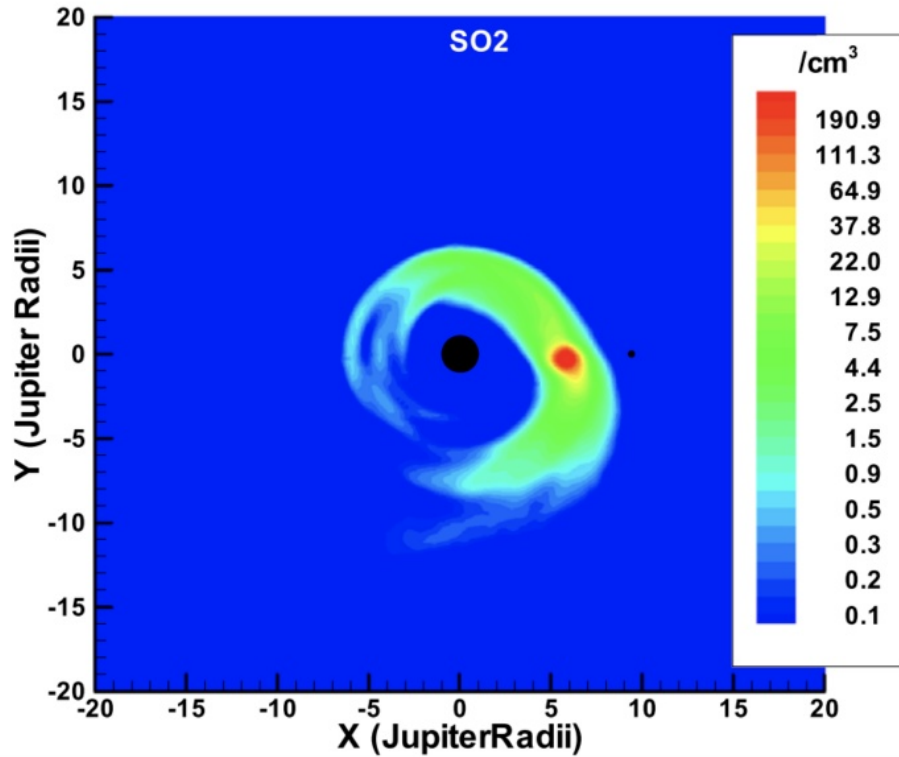
Obs

ACA proposal



Volcanoes fill the torus with gas

Smith et al.
2019



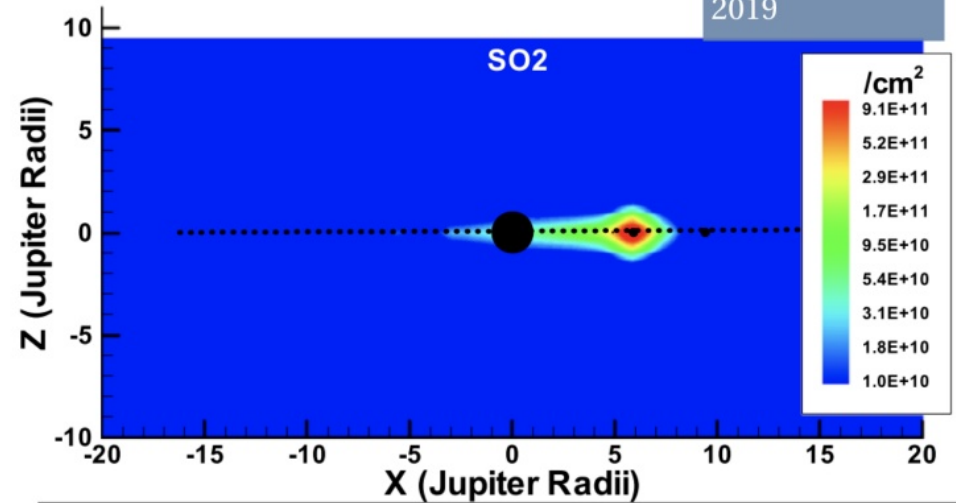
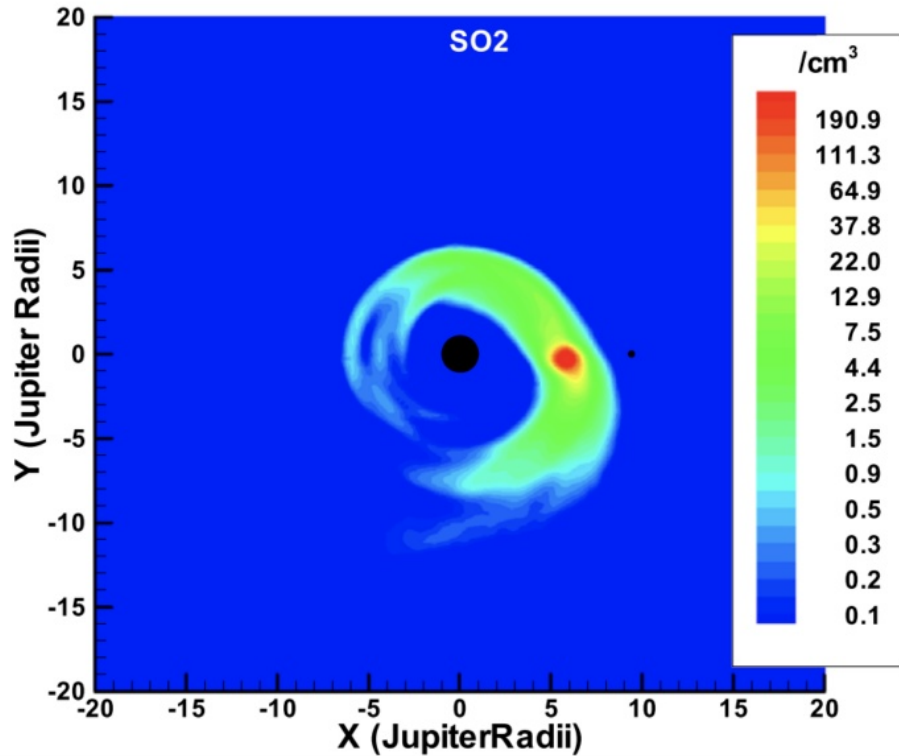
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ACA proposal



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Some remains when Io moves on

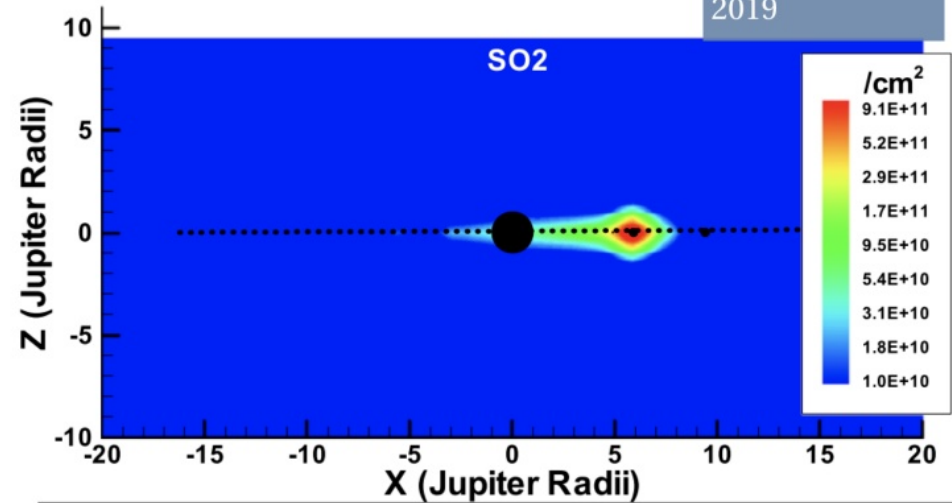
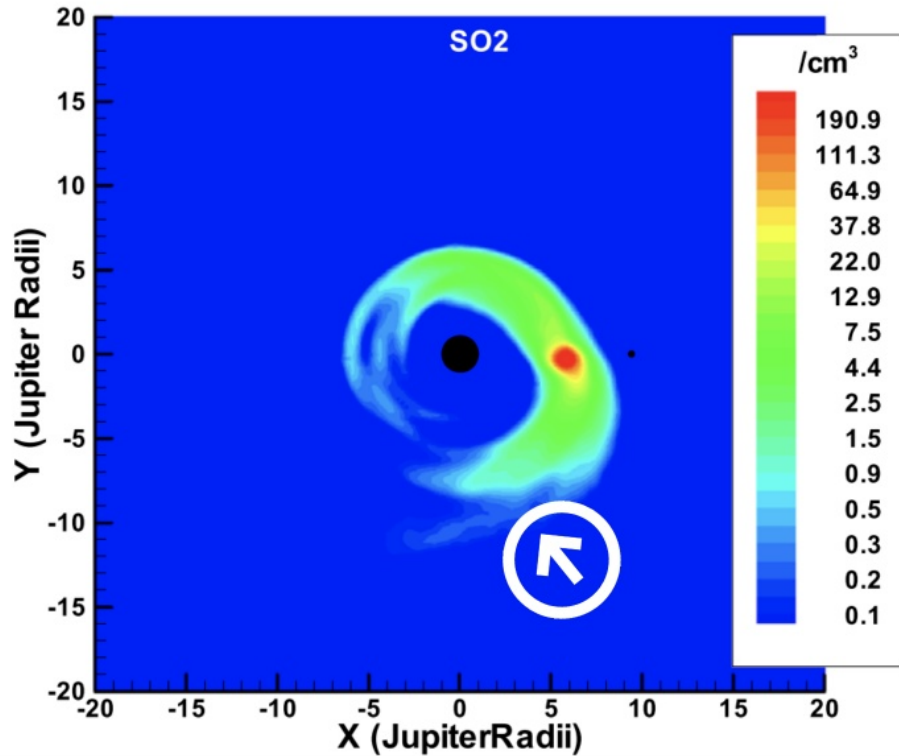
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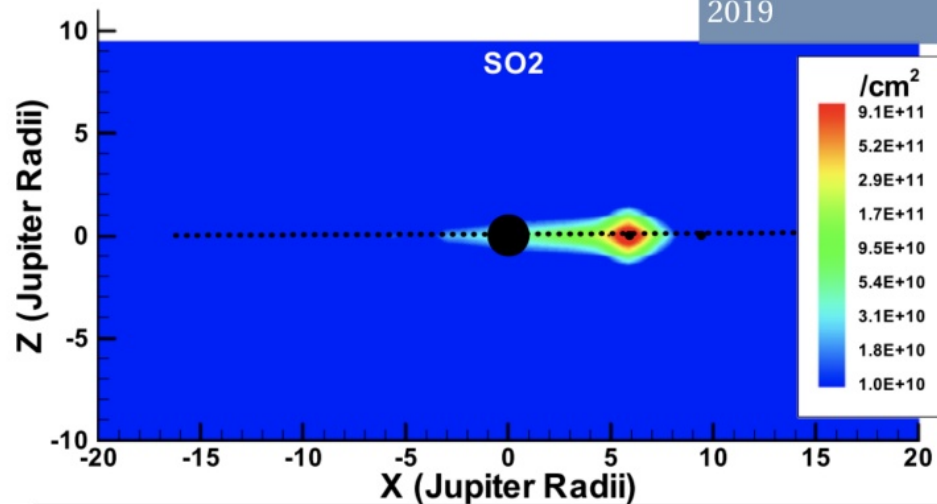
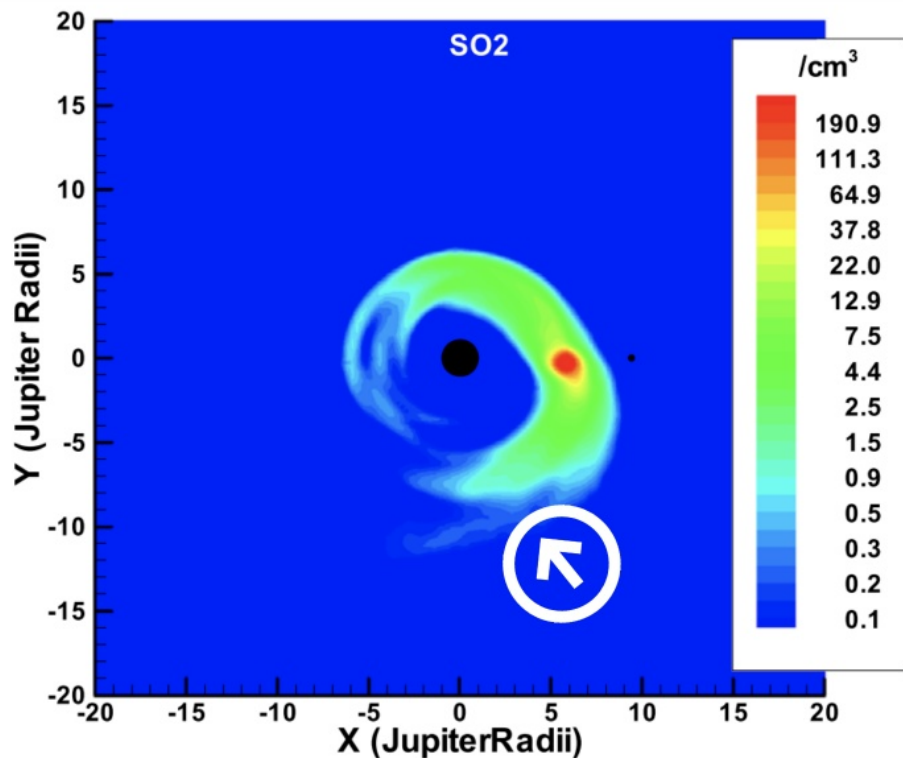
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ACA proposal



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Some remains when Io moves on
Some dragged forward by ions
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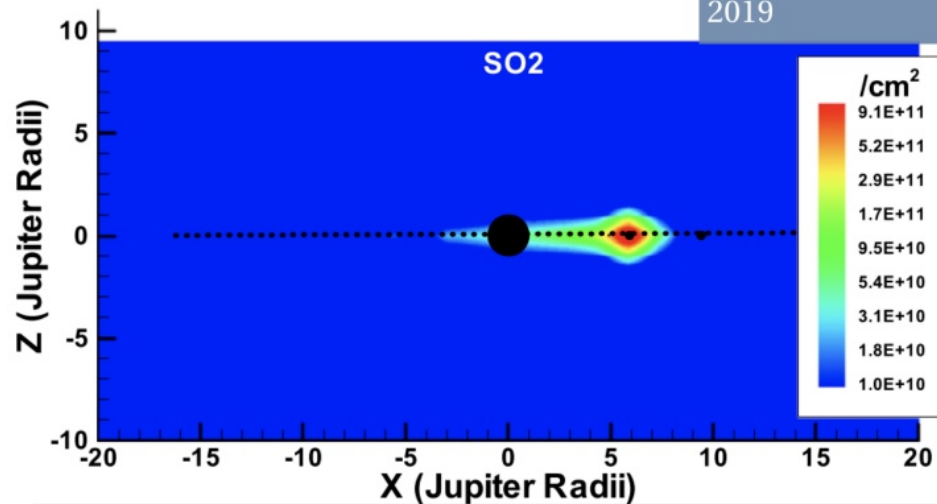
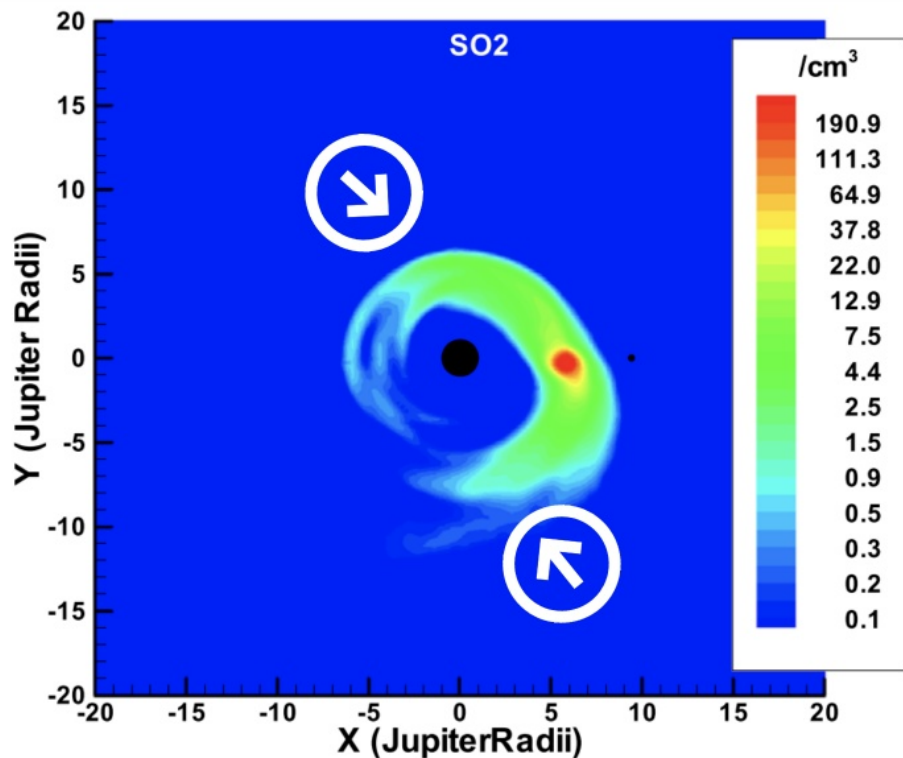
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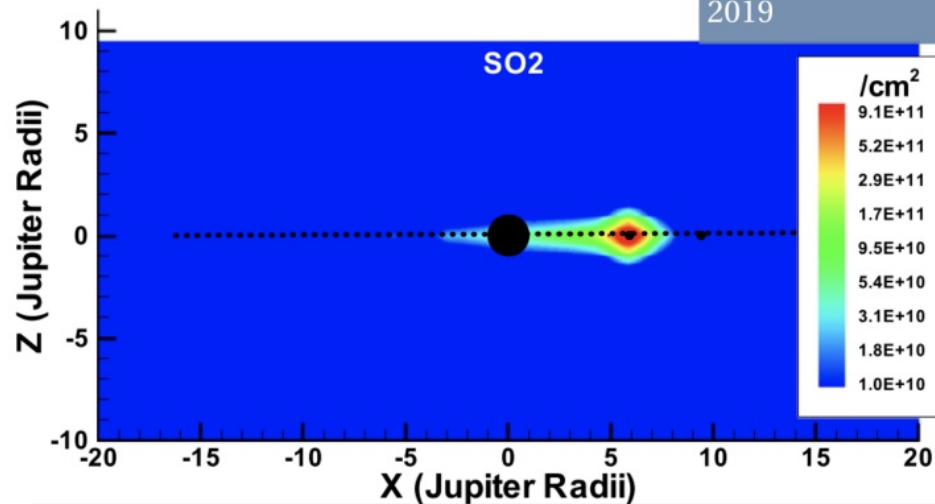
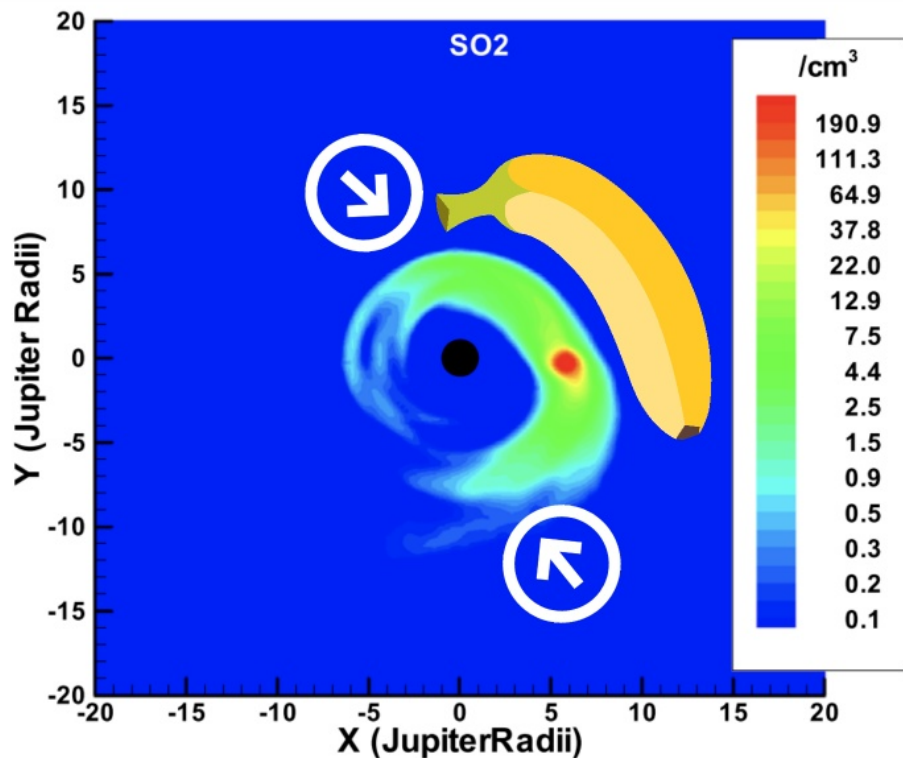
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Obs

ACA proposal

Δ (Jupiter Kaul)

me remains when Io moves on
me dragged forward by ions
pped in Jupiter's magnetic field

Observing Challenges

ACA proposal accepted

^ (Jupiter Kaul)

me remains when Io moves on
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Observing Challenges

ACA proposal accepted

Scheduled for Early 2020

▲ (Jupiter Radio)

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Scheduled for

Updated April 2, 2020.

Total Shutdown of ALMA

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Observed in summer 2021

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Most fields and spectral windows badly affected by
Jupiter photobomb

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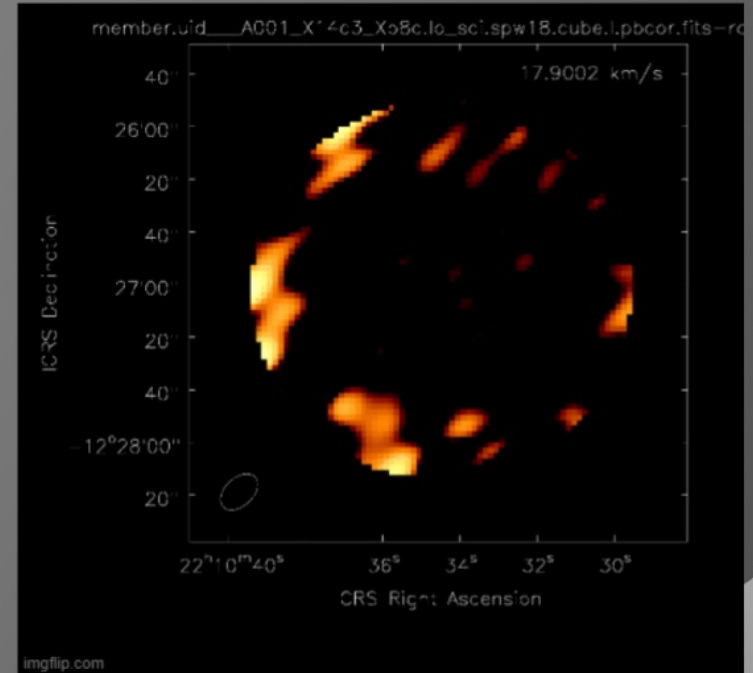
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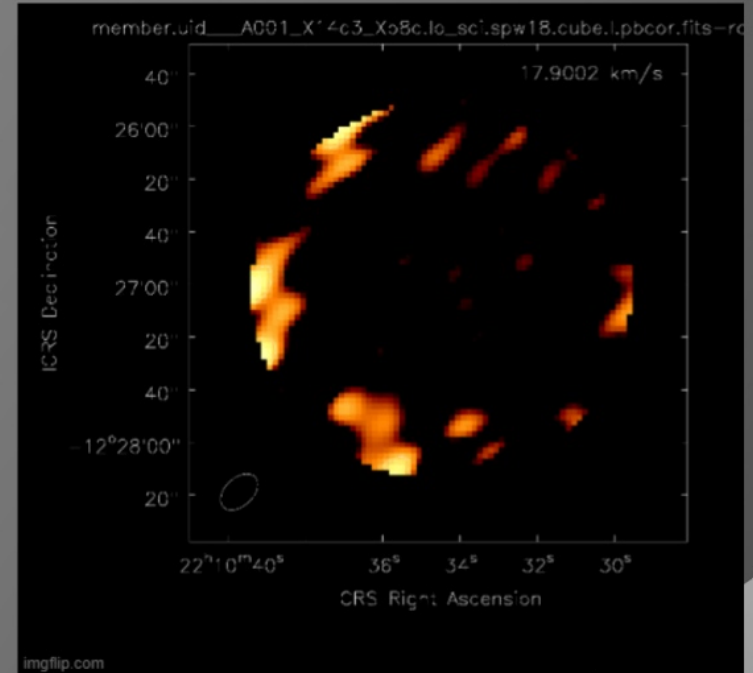


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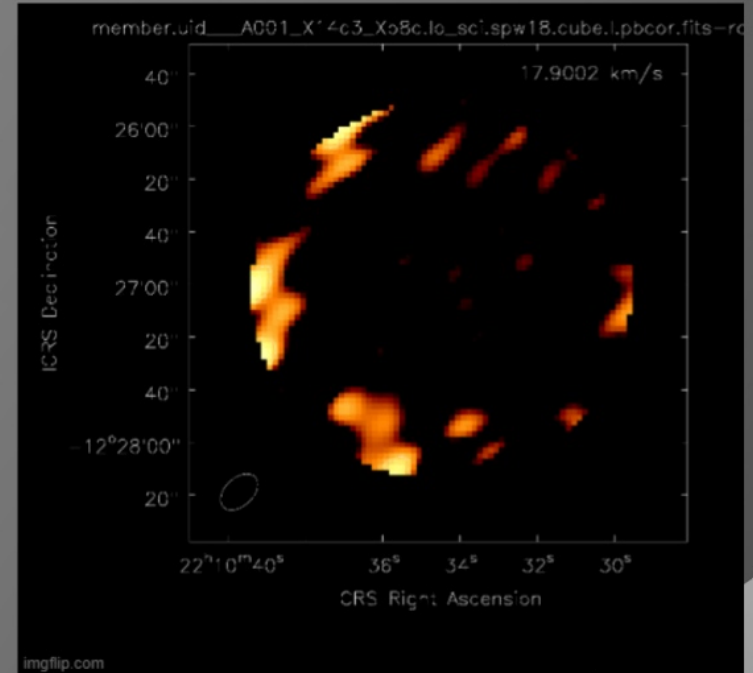
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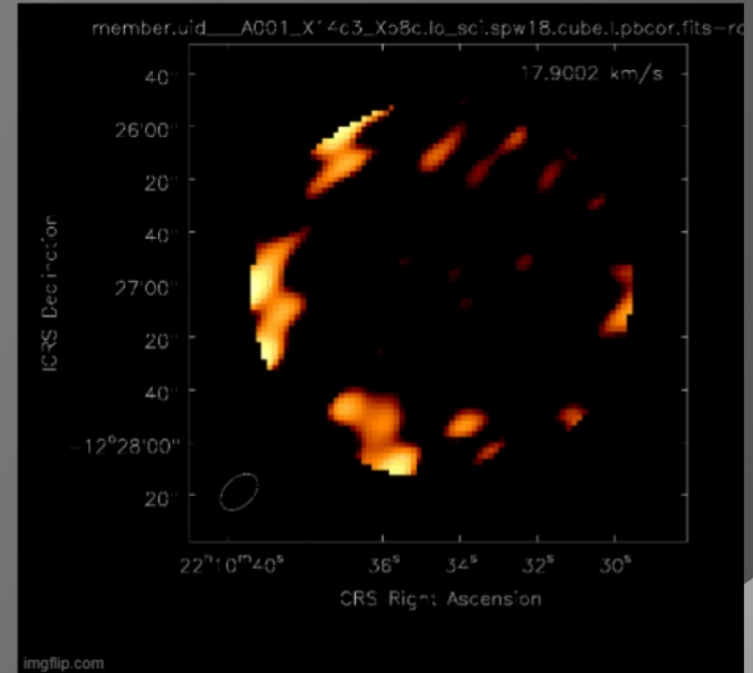
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Roth et al. 2020 (NOEMA Io atmosphere obs)



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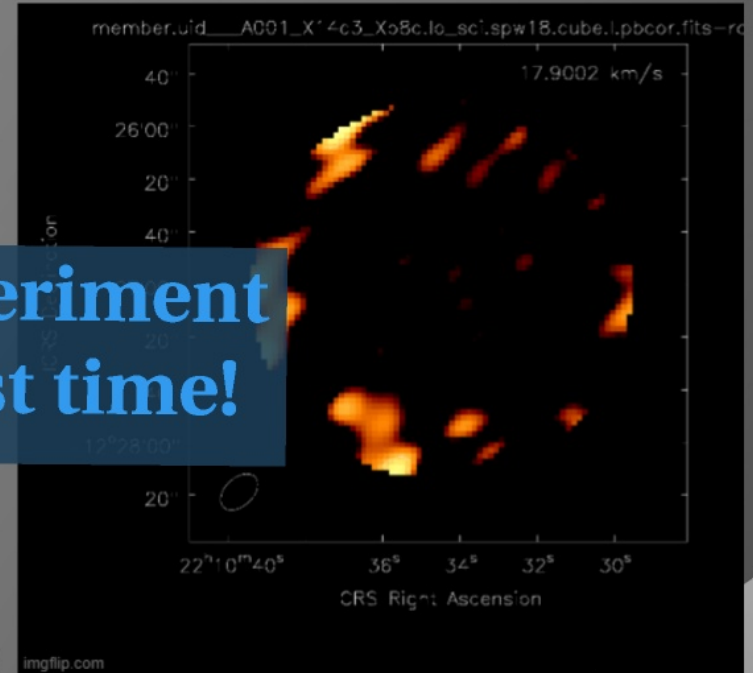
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Origin of Life

How did life on earth begin?

Origin of Life

How did life on earth begin?



Image Credit: National Geographic

Origin of Life

How did life on earth begin?



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Primordial soup

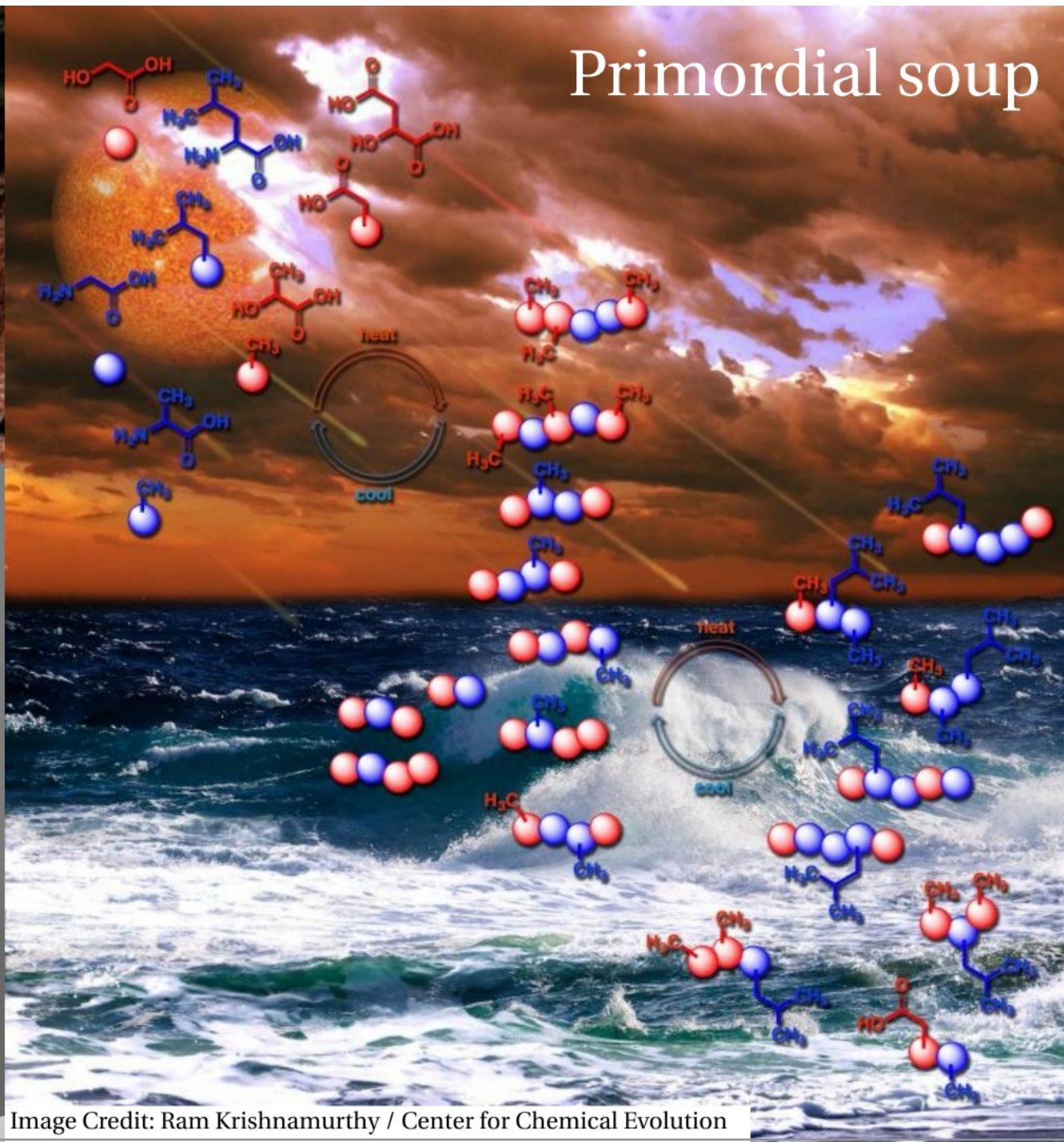


Image Credit: Ram Krishnamurthy / Center for Chemical Evolution

Primordial soup

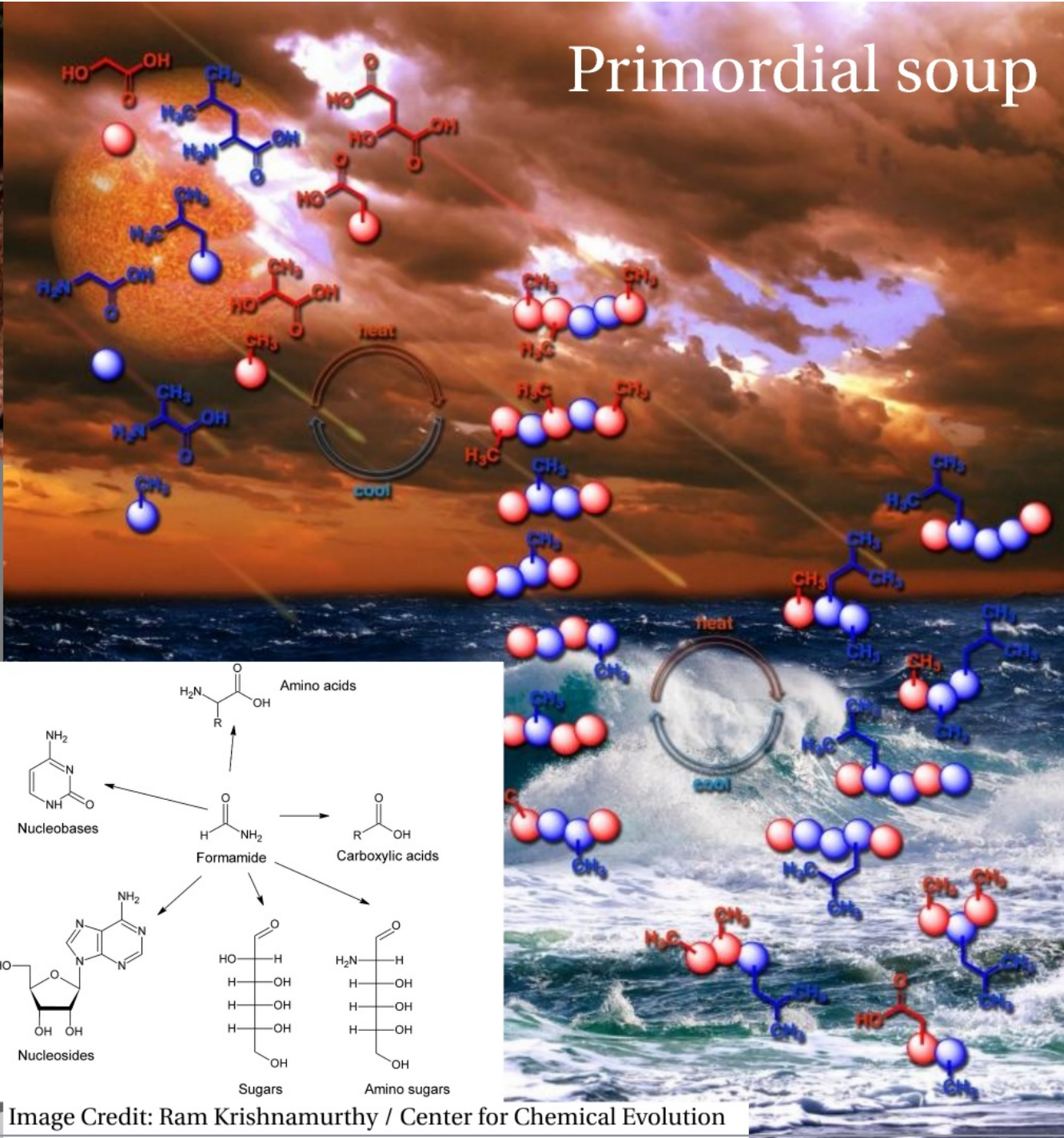


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Primordial soup

Communication
between fields needs
facilitators

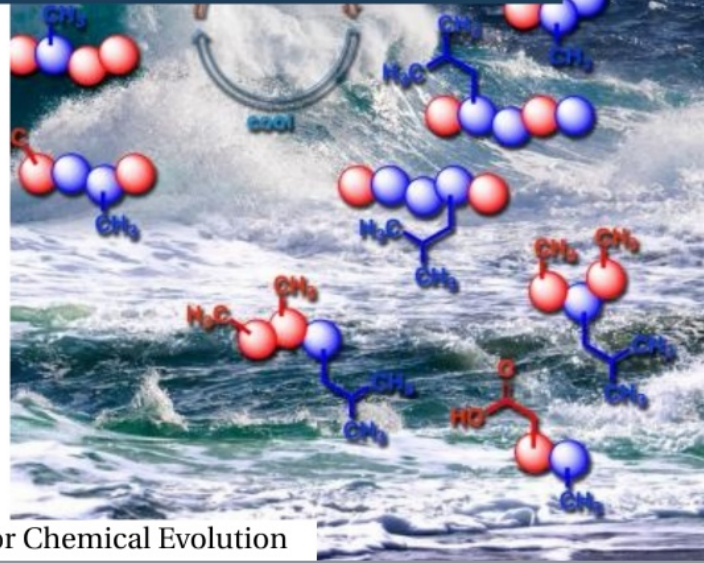
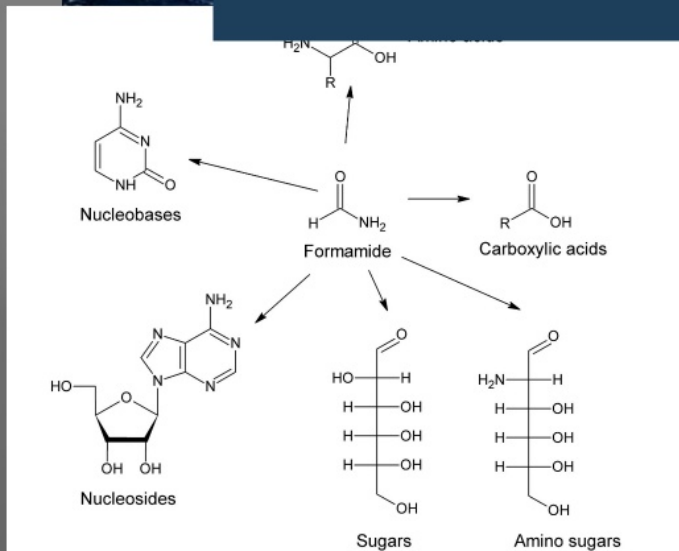


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What's next?

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Finish analysing my formamide observations

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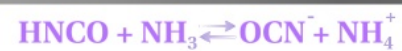
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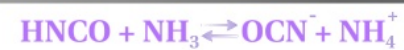
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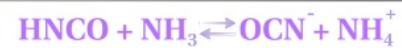


JWST ice observations

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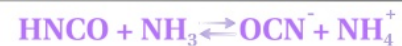
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Working together with other astrochemists and across fields

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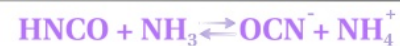
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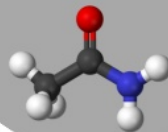
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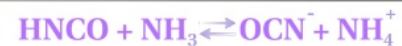
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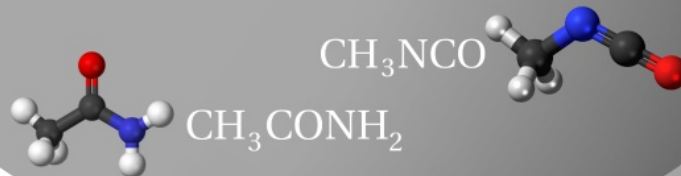
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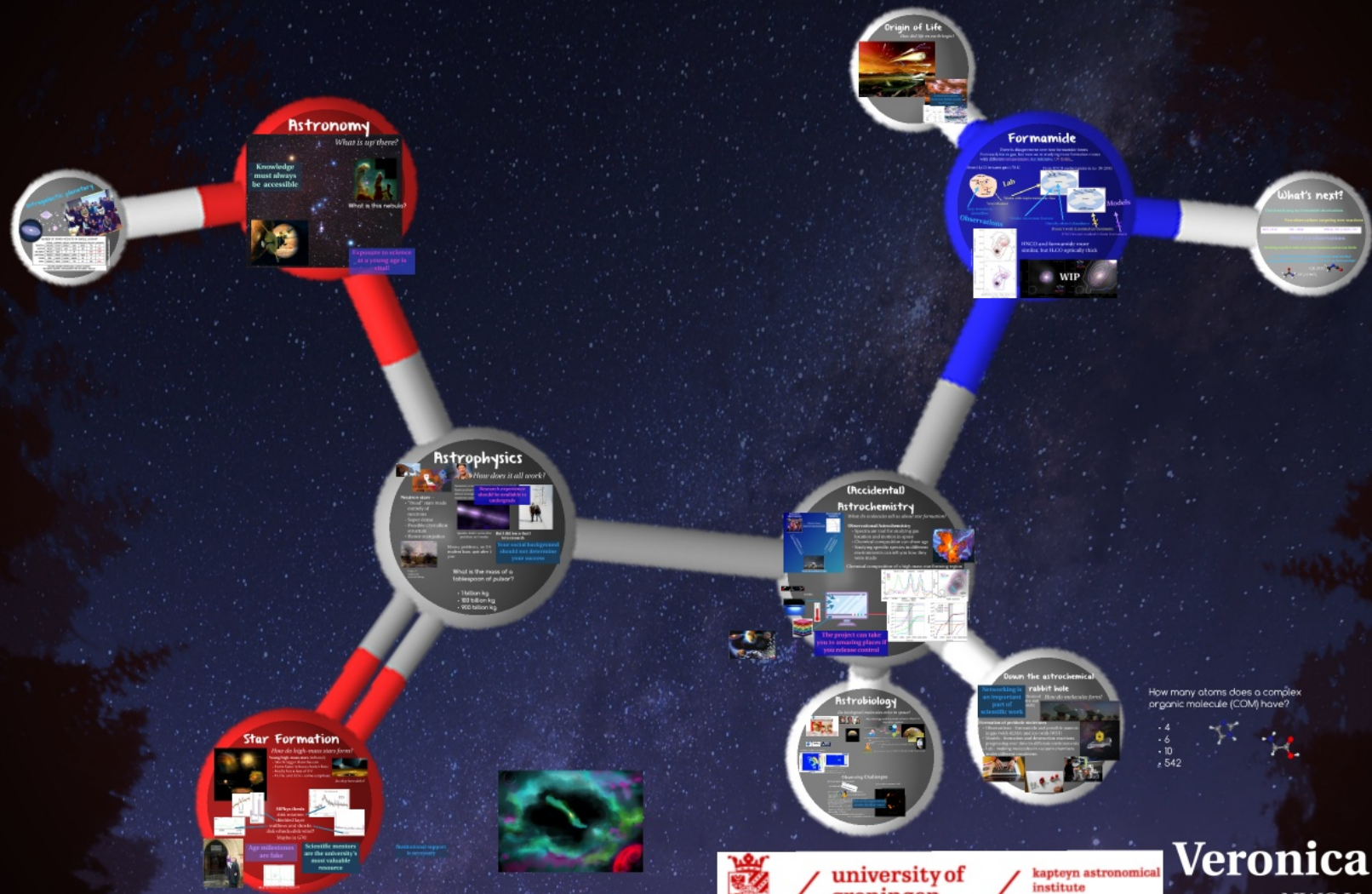
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Astro-everything and our place in space



Veronica Allen

