

# Science highlights

Yuichi Matsuda (NAOJ)

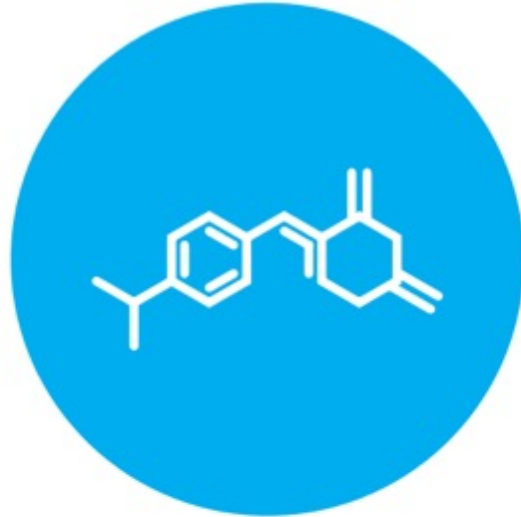
# Fundamental science drivers for ALMA



## ORIGINS OF GALAXIES

Trace the cosmic evolution of key elements from the first galaxies ( $z > 10$ ) through the peak of star formation ( $z = 2-4$ ) by detecting their cooling lines, both atomic ([CII], [OIII]) and molecular (CO), and dust continuum, at a rate of 1-2 galaxies per hour.

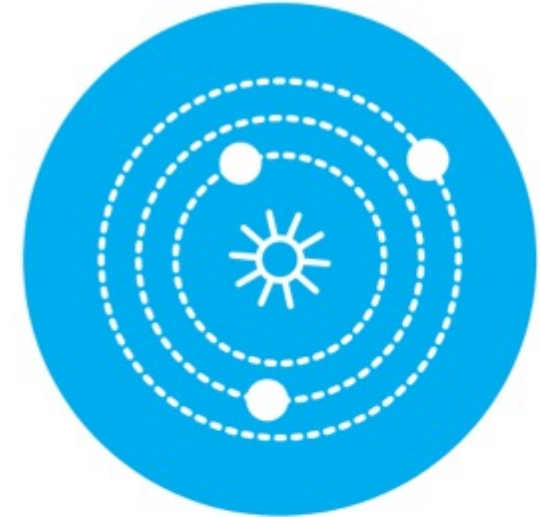
Rowland et al.  
Izumi et al.  
Salak et al.  
EHT Collaboration et al.  
Harada et al.



## ORIGINS OF CHEMICAL COMPLEXITY

Trace the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales ( $\sim 10-100$  au) by performing full-band frequency scans at a rate of 2-4 protostars per day.

Harada et al.



## ORIGINS OF PLANETS

Image protoplanetary disks in nearby (150 pc) star formation regions to resolve the Earth forming zone ( $\sim 1$  au) in the dust continuum at wavelengths shorter than 1mm, enabling detection of the tidal gaps and inner holes created by planets undergoing formation.

Doi et al.  
Speedie et al.  
Tokuda et al.

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## ORIGINS OF GALAXIES

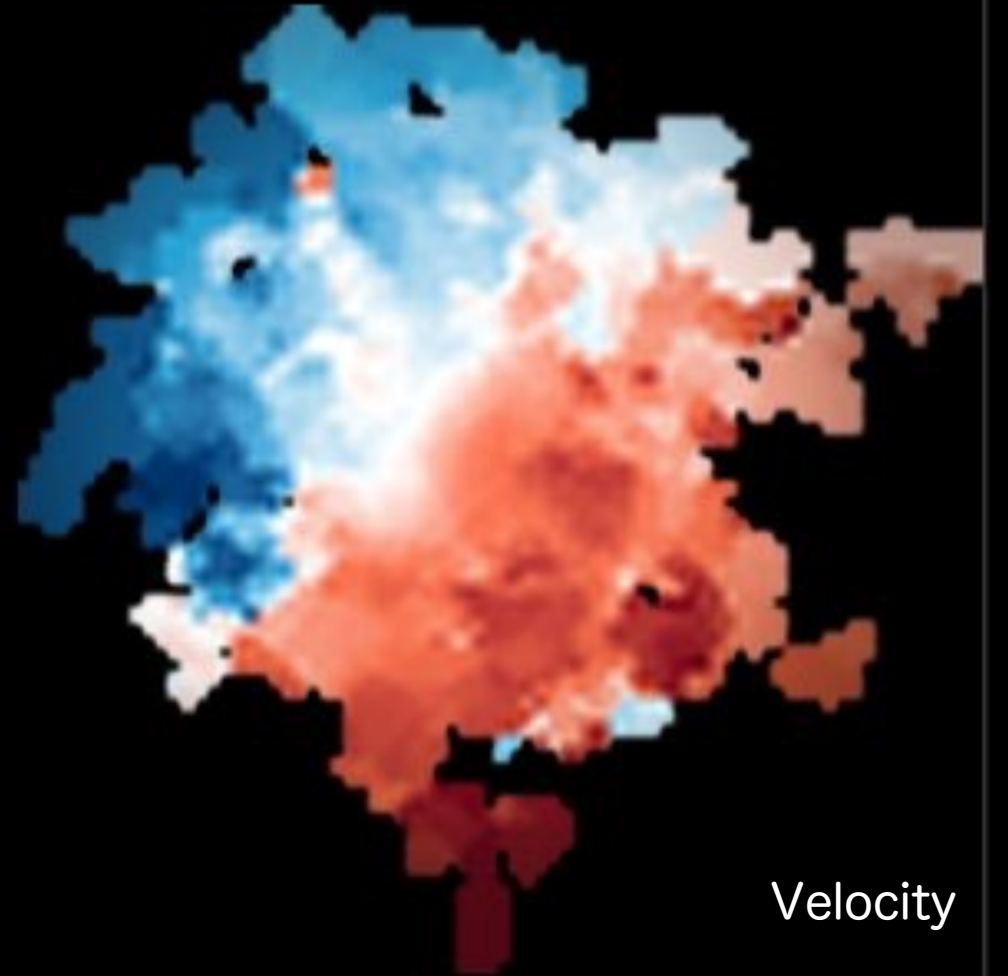
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# Space oddity: Most distant rotating disc galaxy found (Rowland et al.)

REBELS-25: Discovery of a Dynamically Cold Disk Galaxy at  $z=7.31$

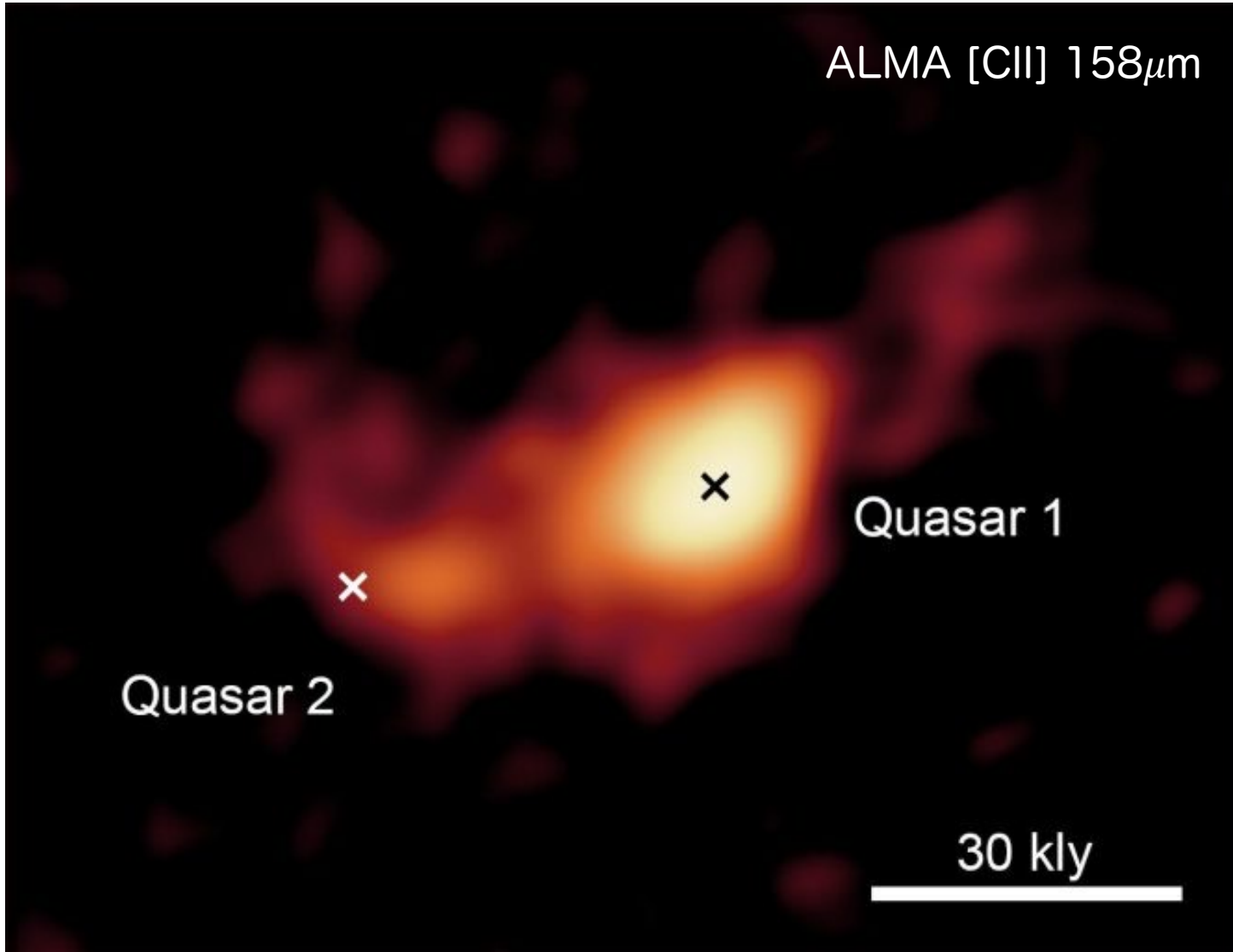


ALMA [CII] 158μm



Velocity

# Dancing Galaxies Make a Monster at the Cosmic Dawn (Izumi et al.)



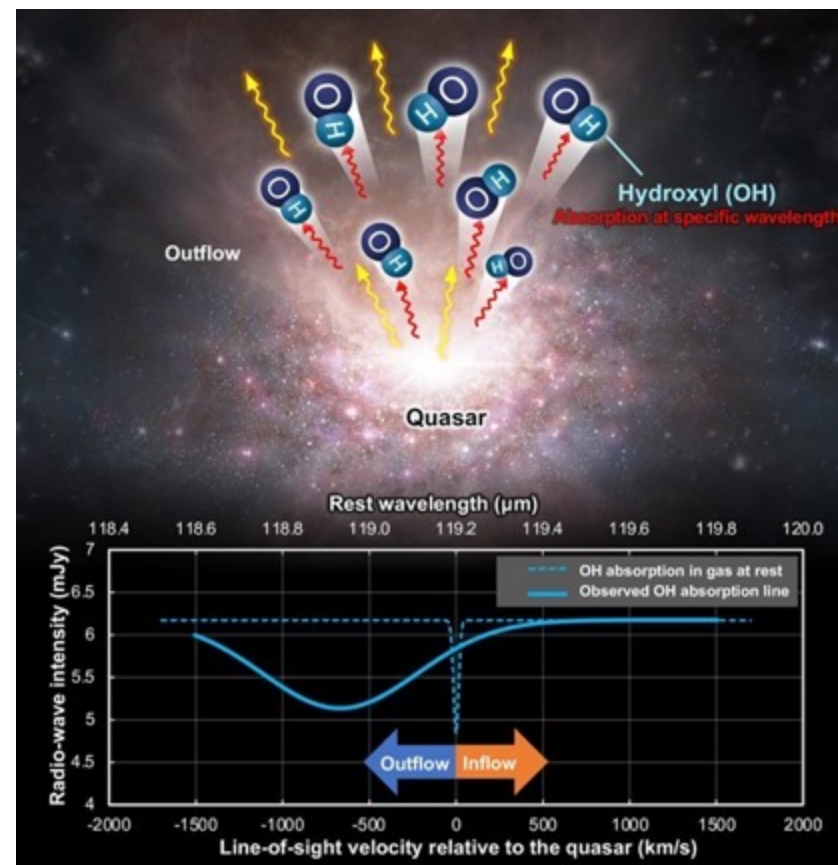
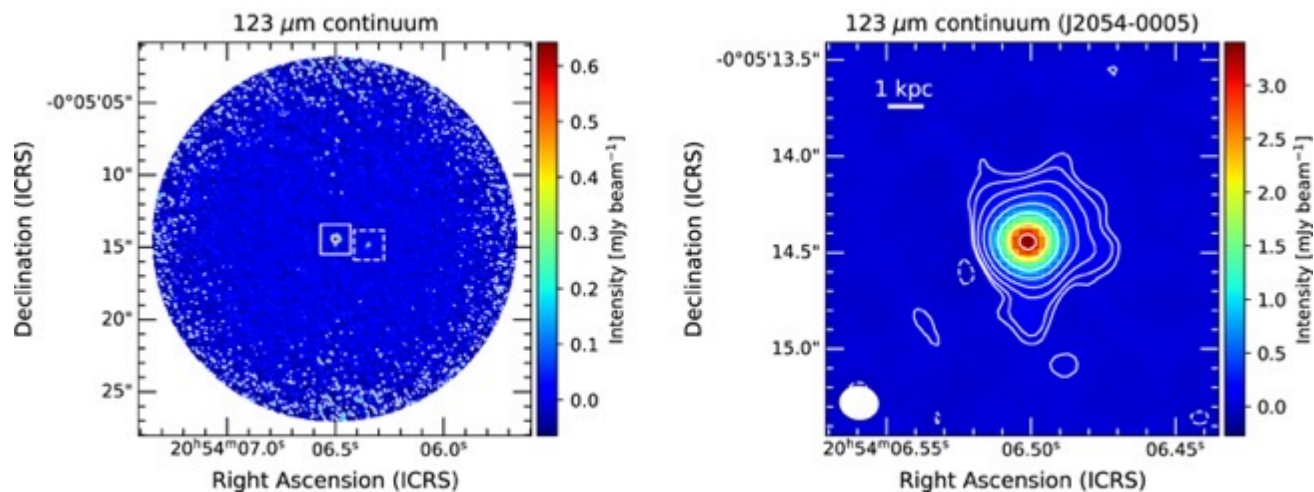
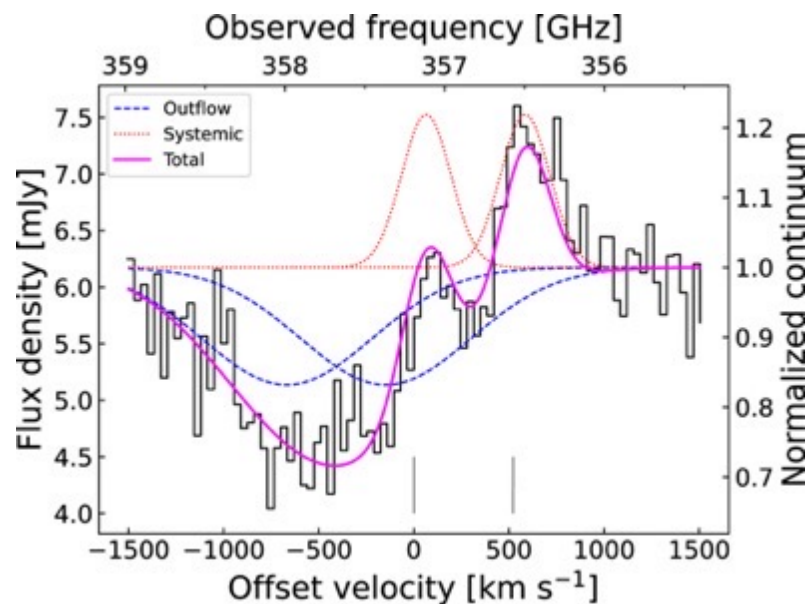
Merging Gas-rich Galaxies that Harbor  
Low-luminosity Twin Quasars at  $z = 6.05$ :  
A Promising Progenitor of the Most  
Luminous Quasars



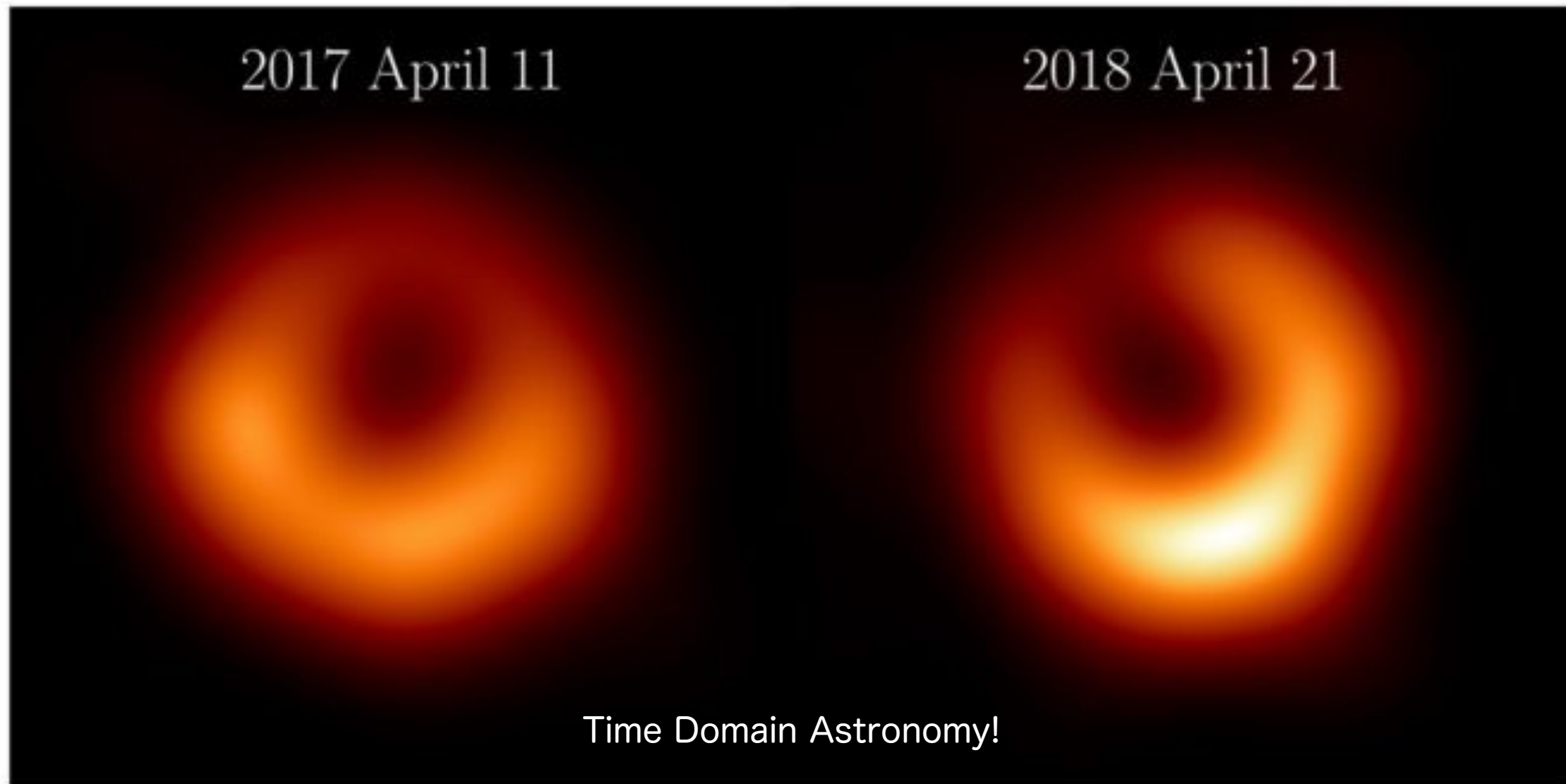
# Gas on the run – ALMA spots the shadow of a molecular outflow from a quasar when the Universe was less than one billion years old (Salak et al.)

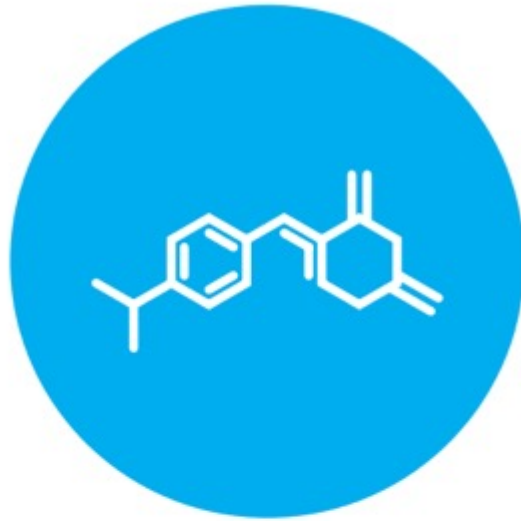
$z = 6.04$

Molecular outflow in the reionization-epoch quasar J2054-0005 revealed by OH 119  $\mu\text{m}$  observations.



# M87\* One Year Later: Proof of a persistent black hole shadow (Event Horizon Telescope Collaboration et al.)





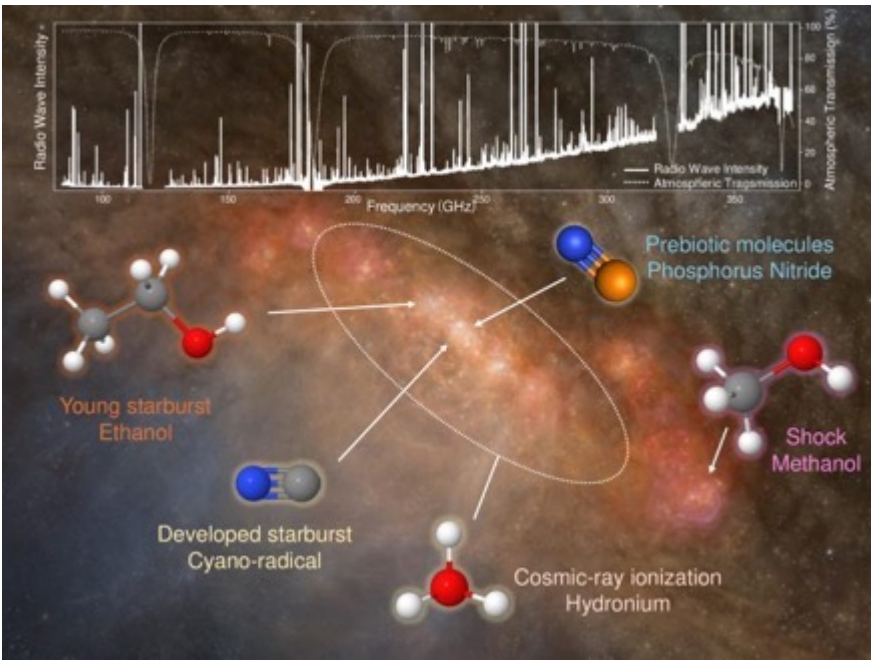
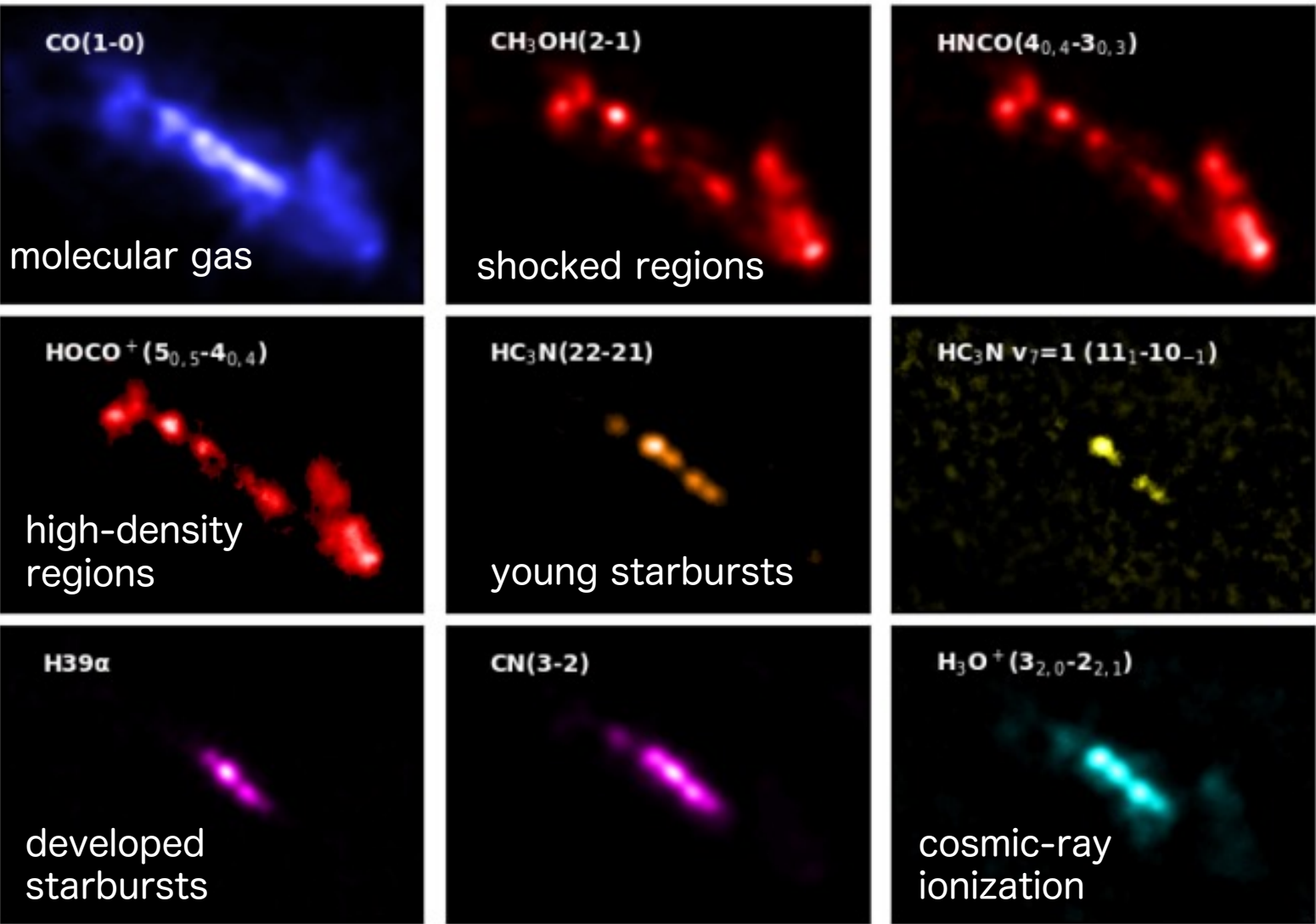
### **ORIGINS OF CHEMICAL COMPLEXITY**

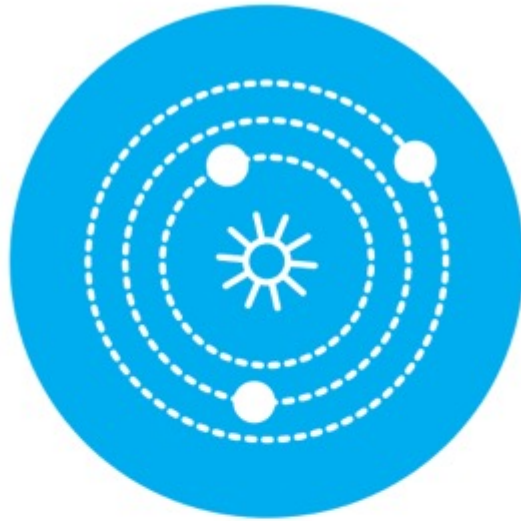
Trace the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales (~10-100 au) by performing full-band frequency scans at a rate of 2-4 protostars per day.



# A Glimpse by Molecules - a Production Line Inside a Busy Star Factory in a Starburst Galaxy (Harada et al. )

NGC 253

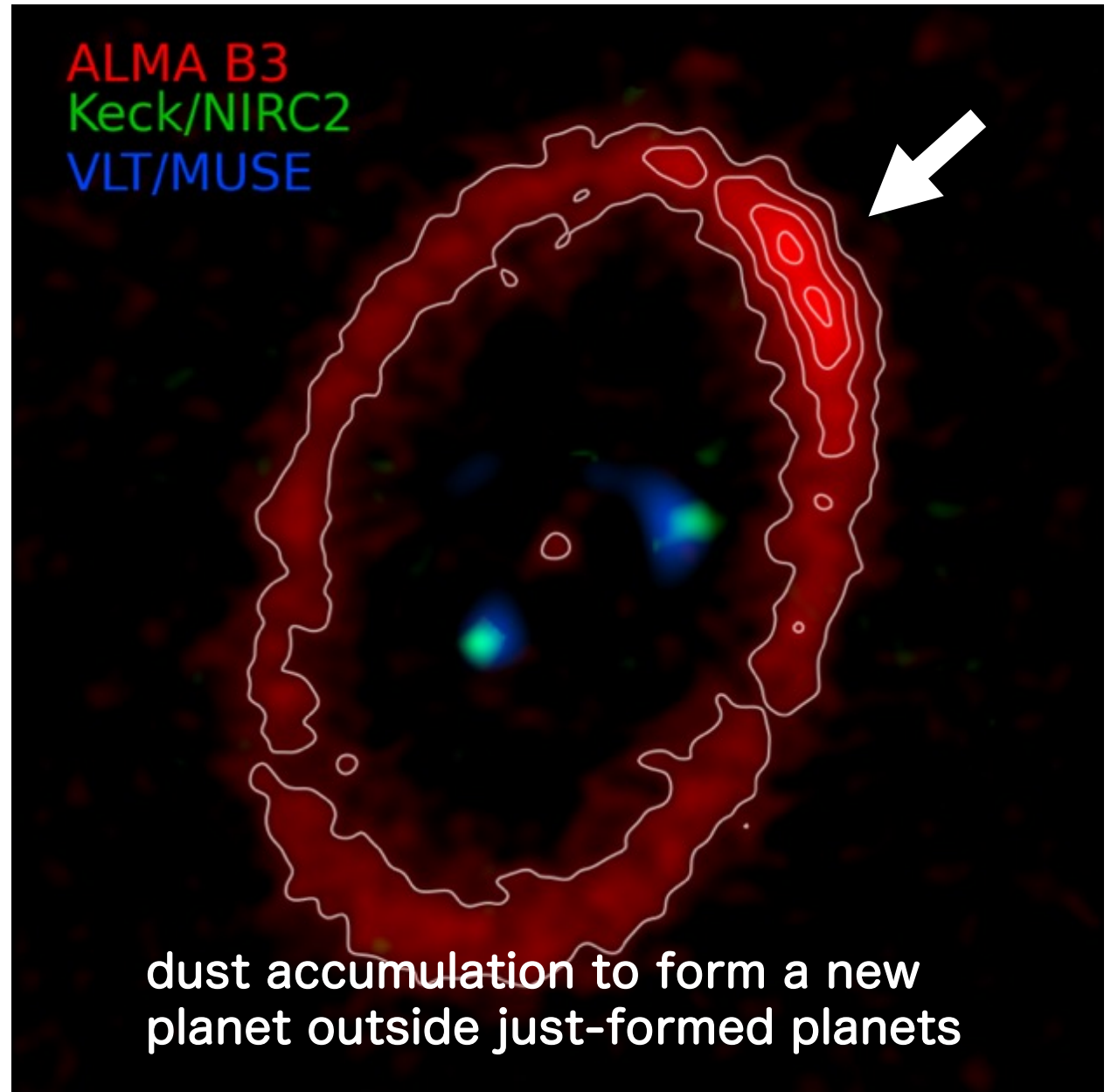
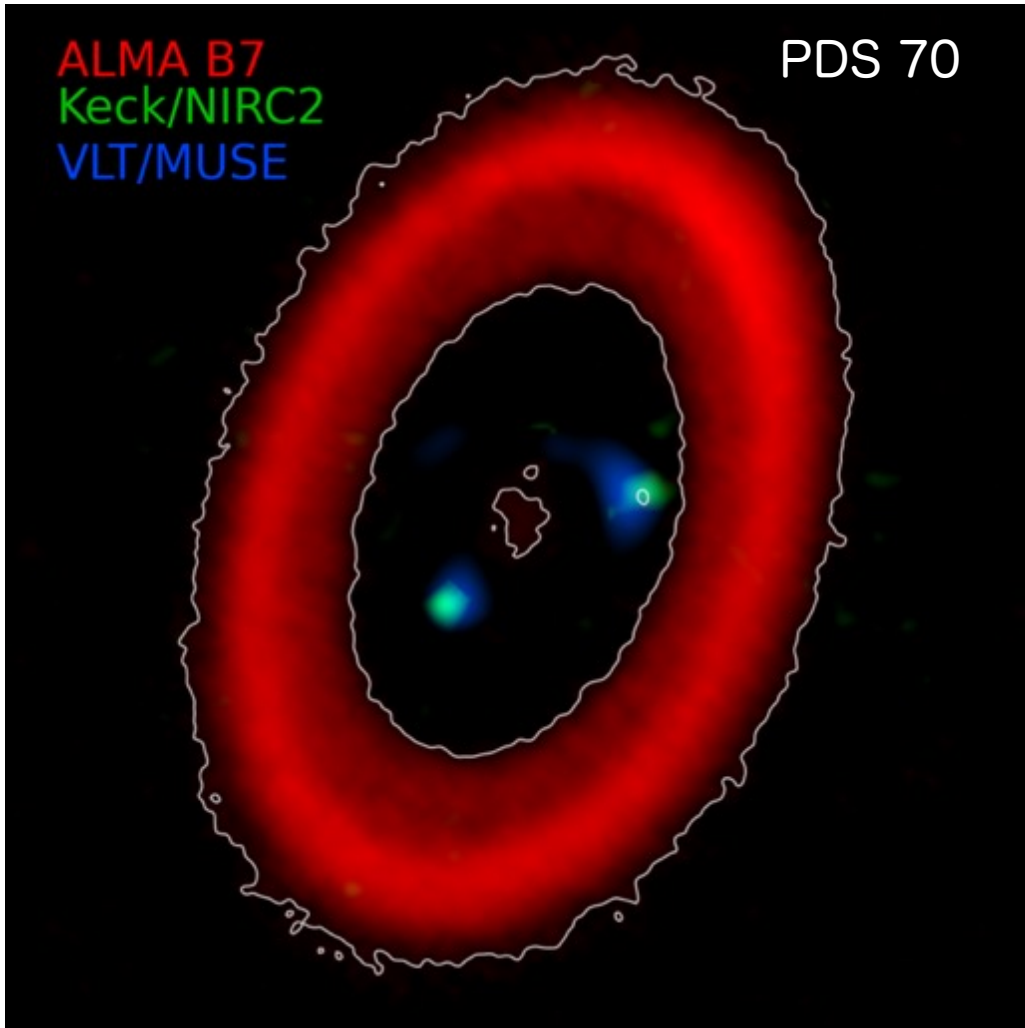




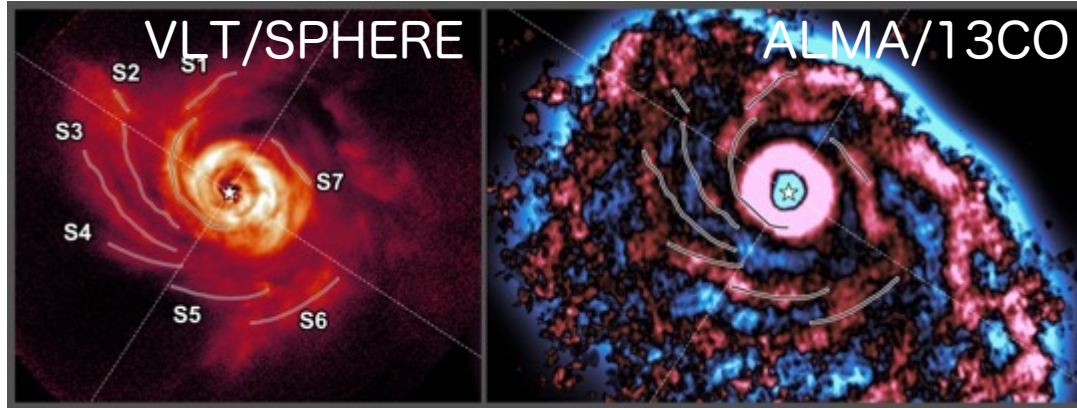
### **ORIGINS OF PLANETS**

Image protoplanetary disks in nearby (150 pc) star formation regions to resolve the Earth forming zone ( $\sim 1$  au) in the dust continuum at wavelengths shorter than 1mm, enabling detection of the tidal gaps and inner holes created by planets undergoing formation.

# ALMA Reveals the Birthplace of a Planetary System (Doi et al.)

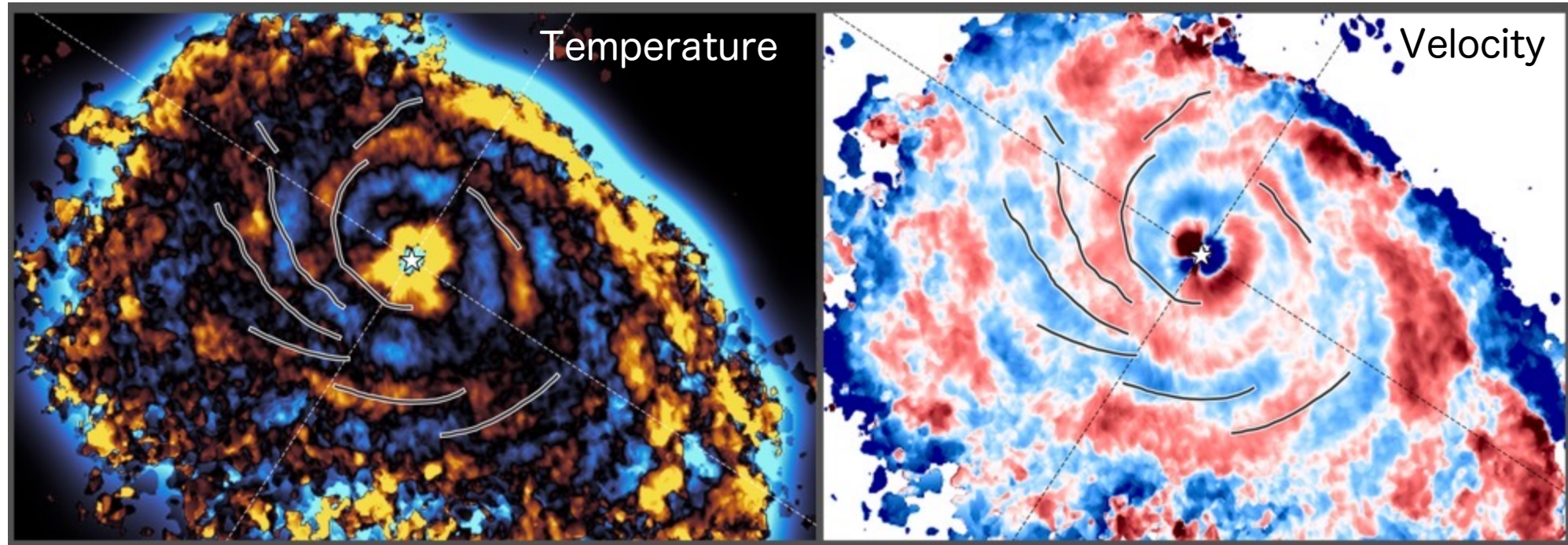


# ALMA Detects Hallmark “Wiggle” of Gravitational Instability in Planet-Forming Disk (Speedie et al.)

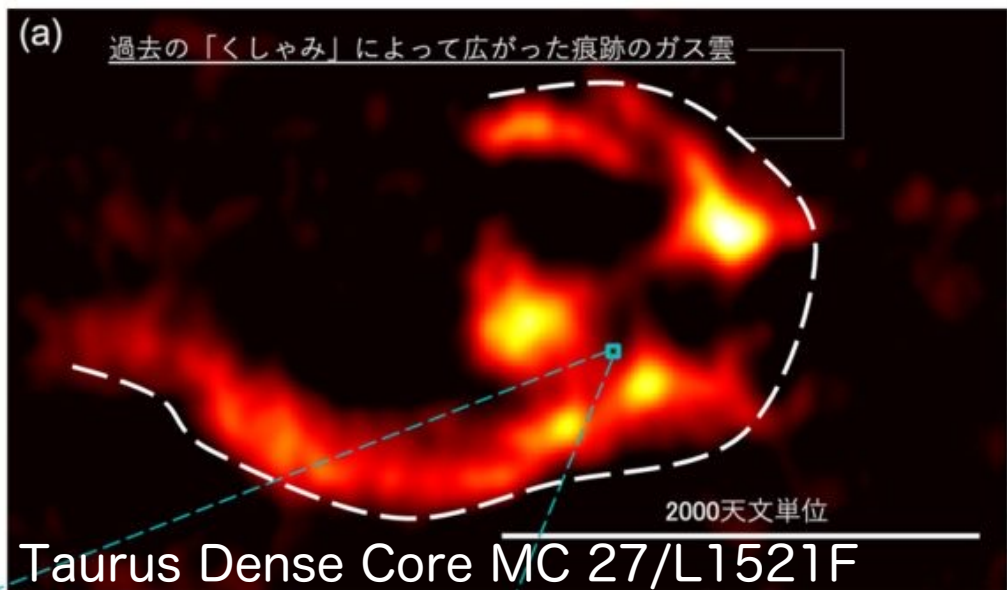


AB Aurigae circumstellar disk

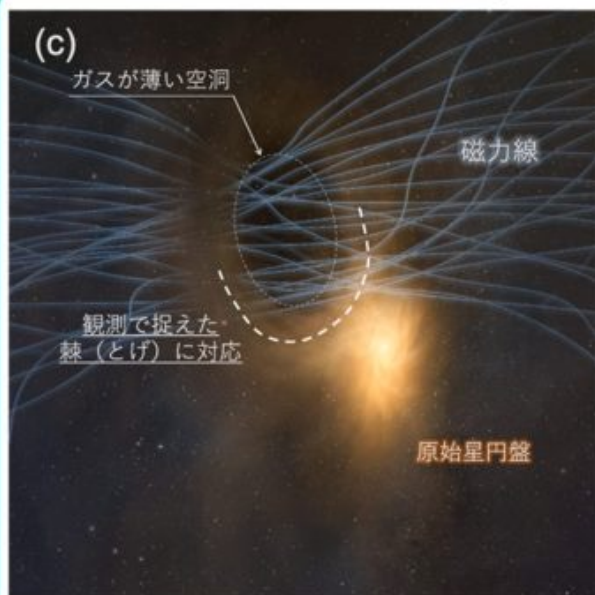
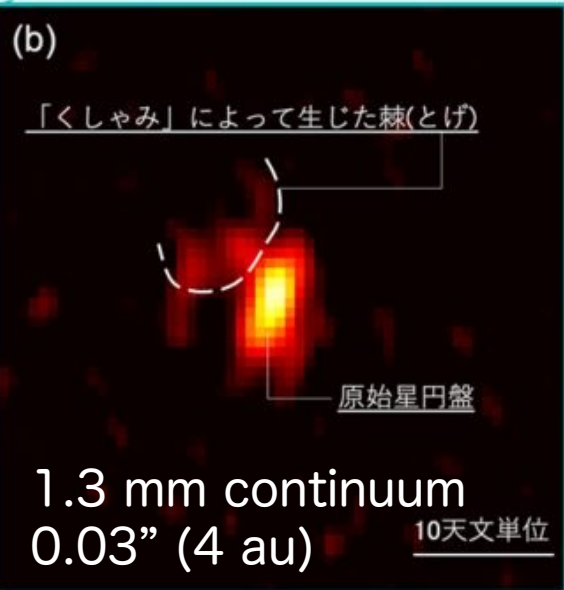
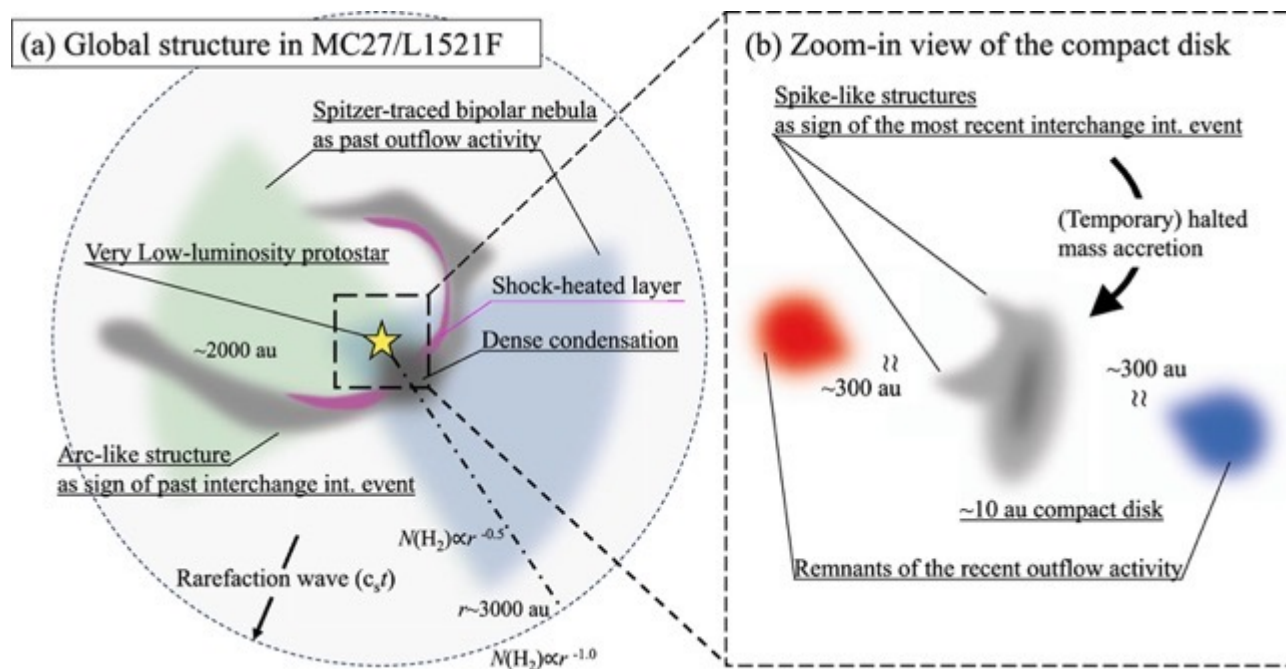
Circumstellar disk material in spiral arms fragments due to gravitational instability



# Twinkle Twinkle Baby Star, 'Sneezes' Tell us How You Are (Tokuda et al.)



Discovery of Asymmetric Spike-like Structures of the 10 au Disk around the Very Low-luminosity Protostar Embedded in the Taurus Dense Core MC 27/L1521F with ALMA



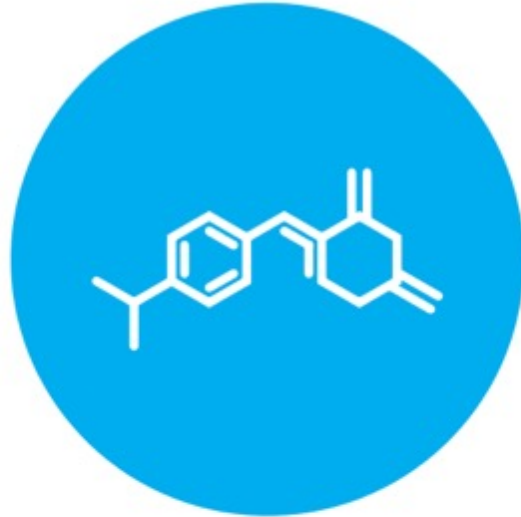
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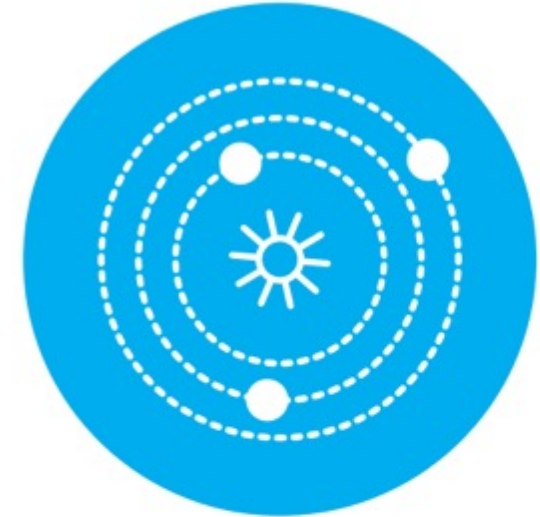
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