



---

# Science Highlights - Disks

Eiji Akiyama  
NAOJ Chile Observatory

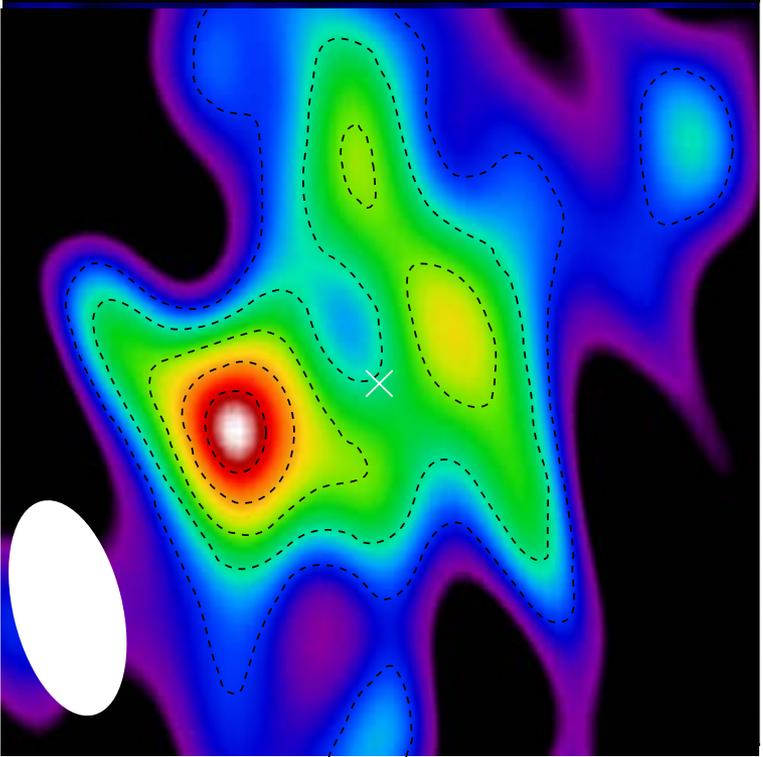
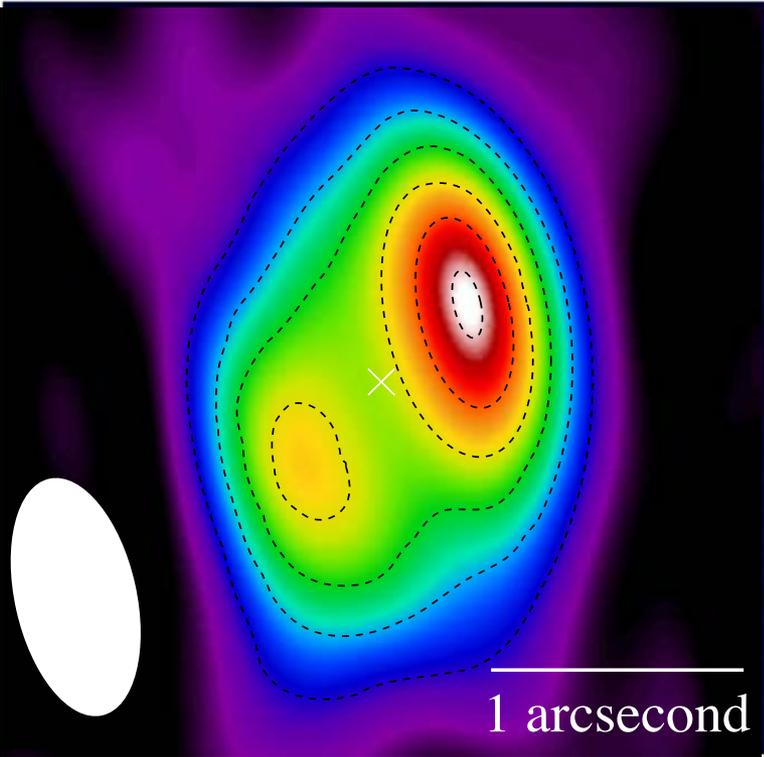
Dec. 26 2017  
ALMA/45m/ASTE Users Meeting 2017





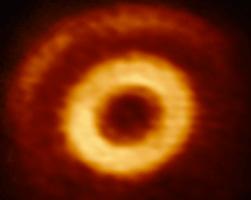
# Outstanding Improvement

ASIMMA

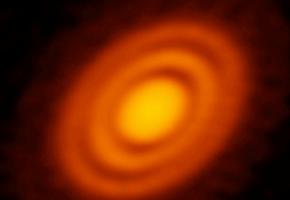




# Gallery of Disks



V1247 Ori



HD163296



HD142527



HK Tau



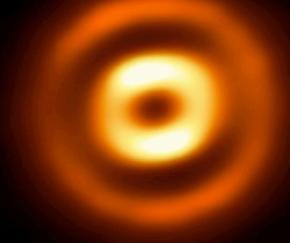
Elias 2-27



HL Tau



TW Hya



HD169142



V883 Ori



Fomalhaut



AA Tau



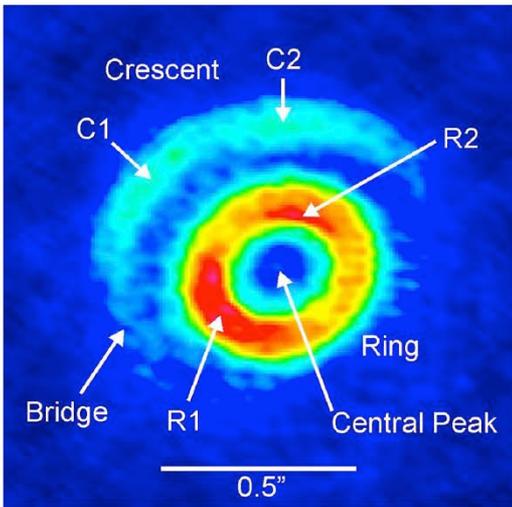
HD 95086

rich in diversity

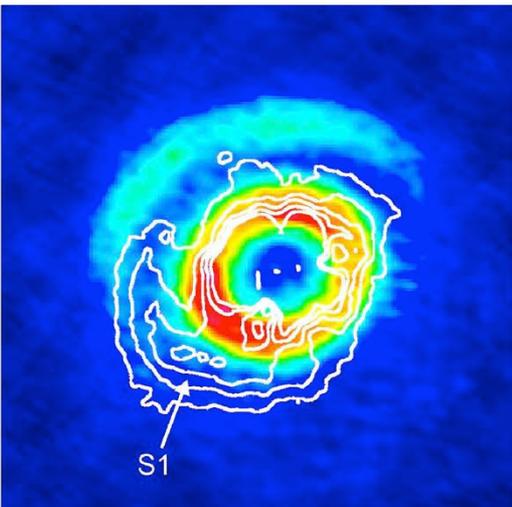


# Dust Trapping

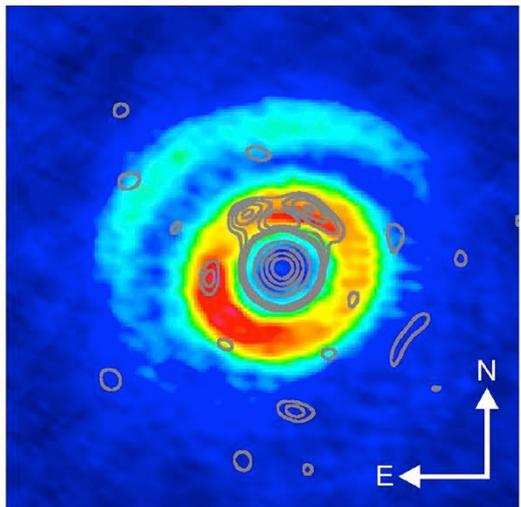
Kraus et al. 2017,  
van der Marel et al. 2013, 2016



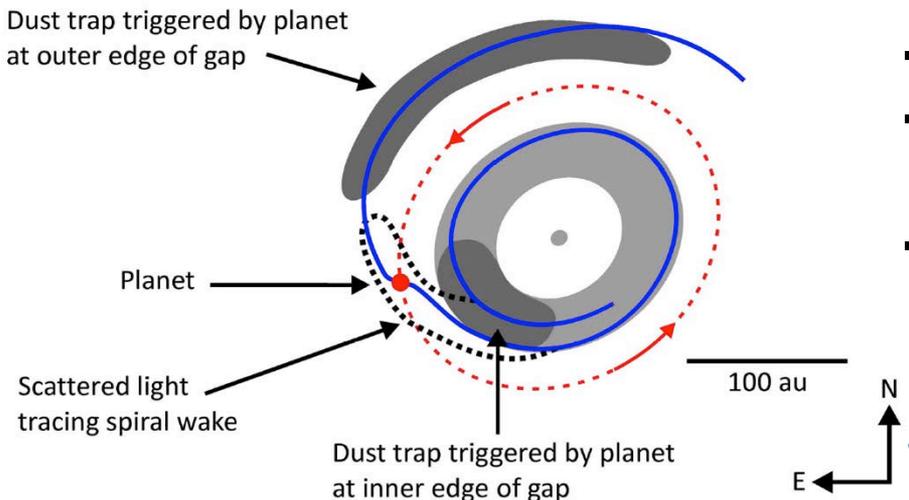
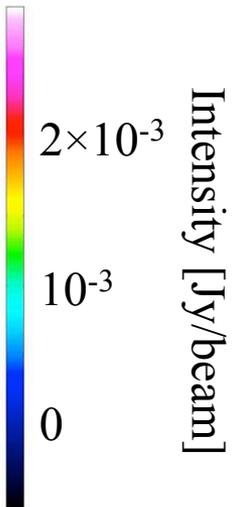
ALMA 870µm



ALMA + H-band



ALMA + L'-band



- Crescent structure implies dust trapping.
- High pressure may be generated by an orbiting planet.
- The presence of a planet is supported by NIR result (spiral feature).

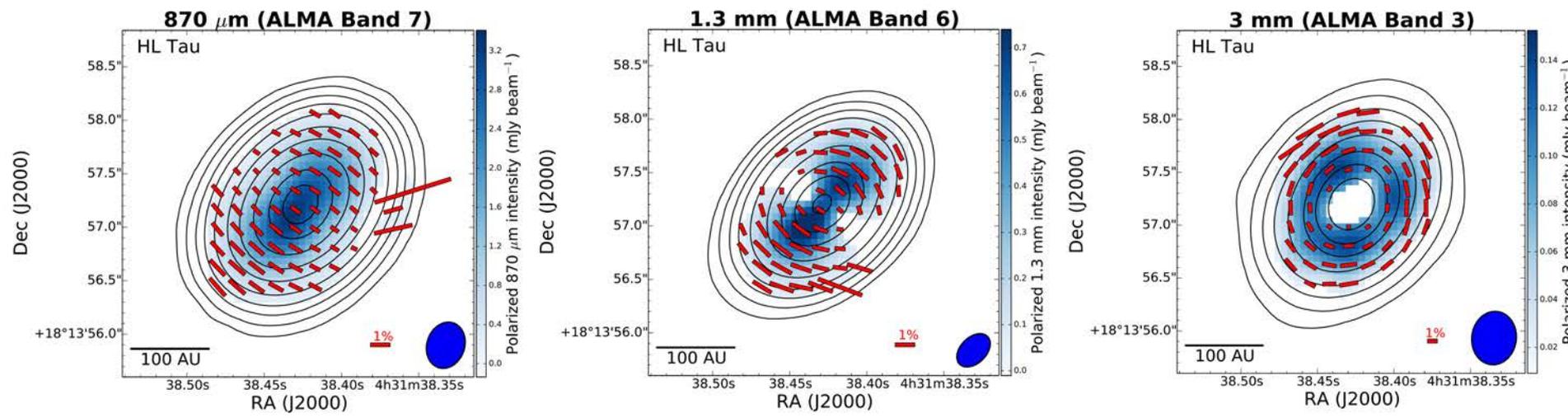




# Polarization Obs.

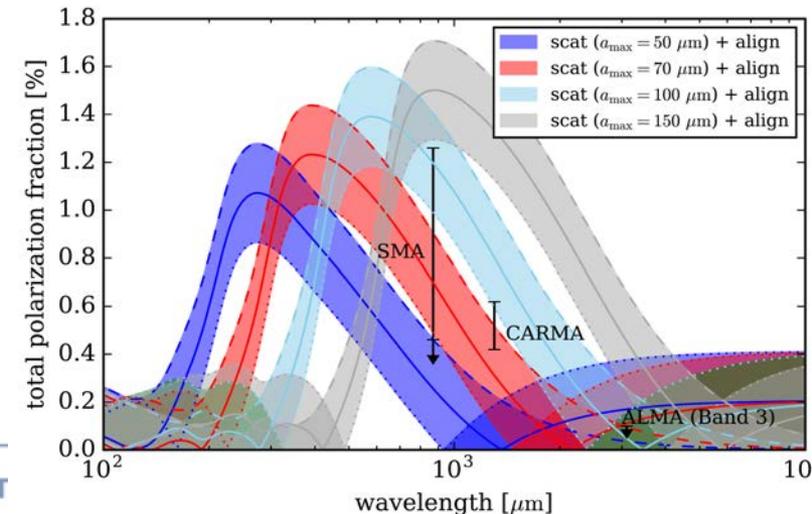
Kataoka et al. 2016a, 2016b, 2017  
Stephens et al. 2017

## Polarization due to self-scattering



- Polarization fraction strongly depends on wavelength
- Another method for confining dust size

Derived dust size  $\sim 100 \mu\text{m}$

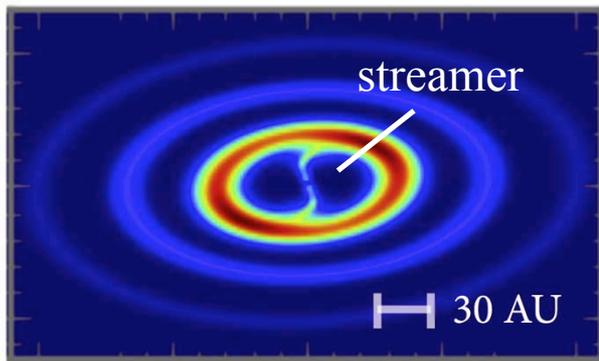
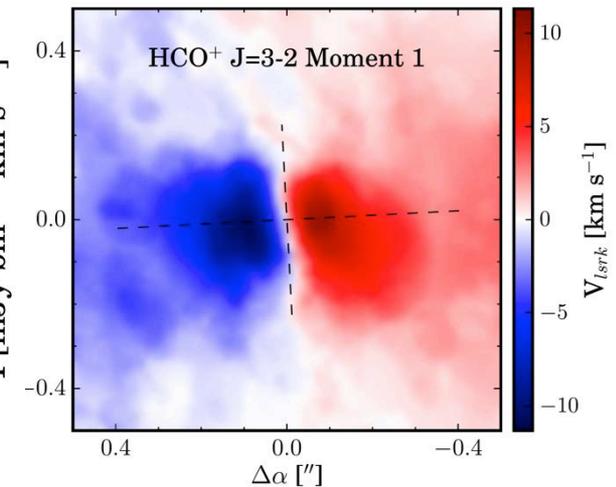
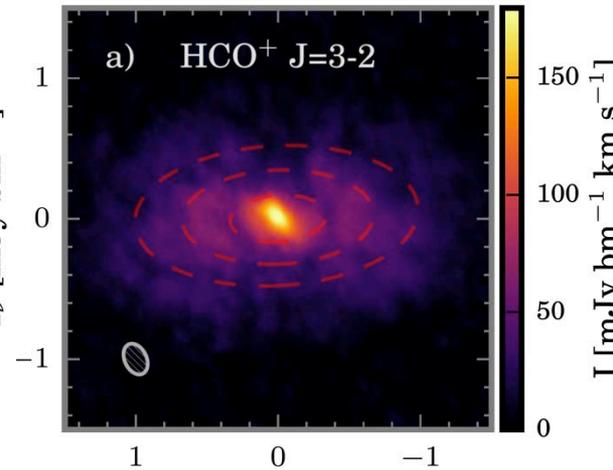
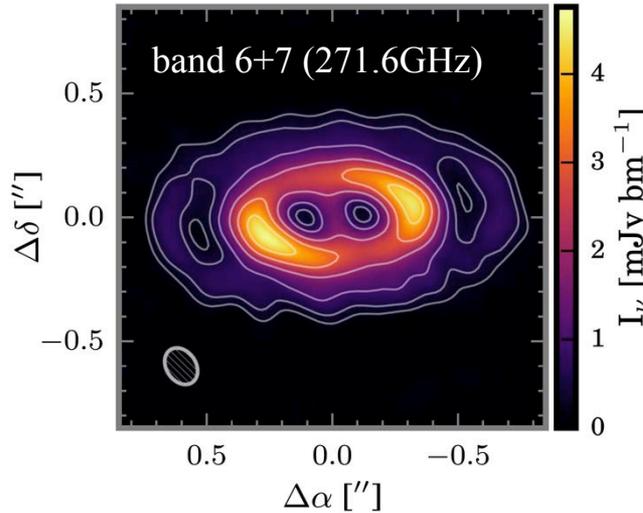




# Mass Streamer

Loomis et al. 2017  
Casassus et al. 2013  
Dutrey et al. 2014

## AA Tau



simulation

- 3 rings at 49, 95, and 143 au are found.
- Streamer structure was found at inner region.  
eg. HD142527, GG Tau
- Warped disk structure ?

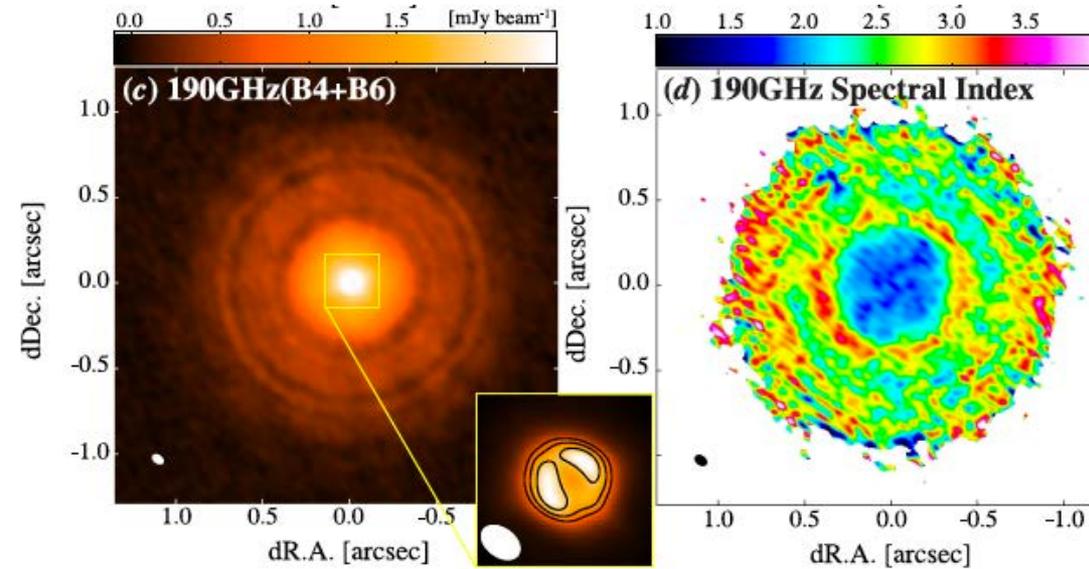




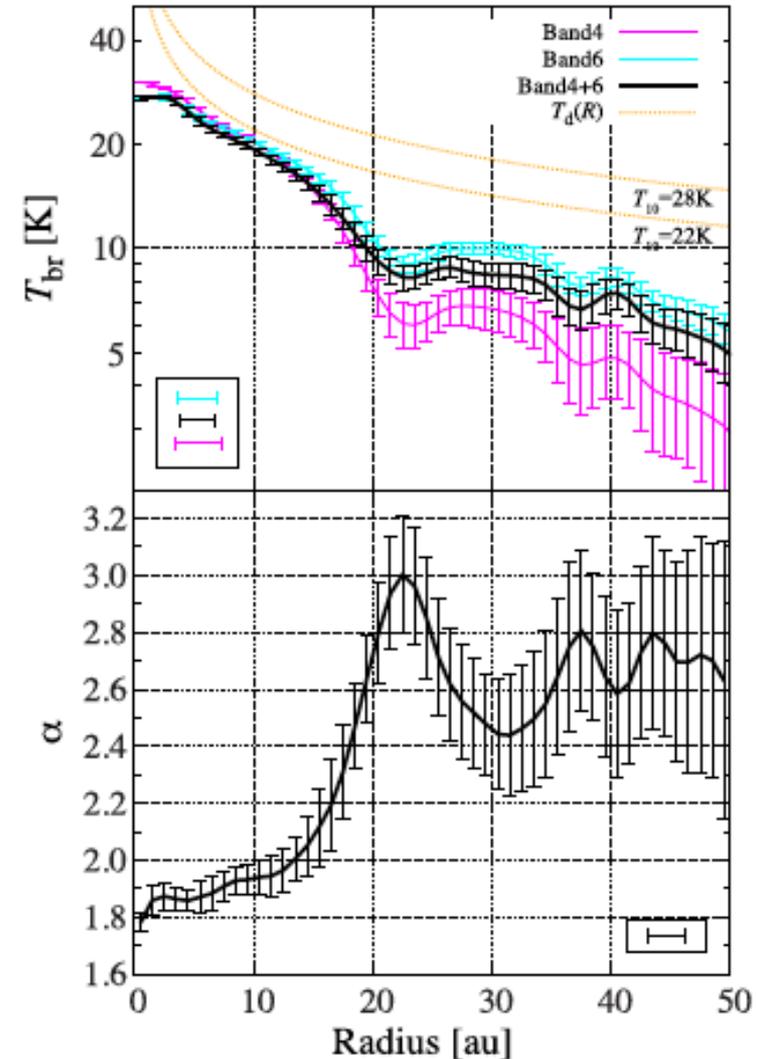
# Multiple Gaps

Tsukagoshi et al. 2016  
Andrews et al. 2016

## Dust Observations



- Little large dust grain exist at the ring gap.
  - The ring gap at 22 au can be explained by a Neptunian planet.
- ref. Kanagawa et al. 2015, 2016



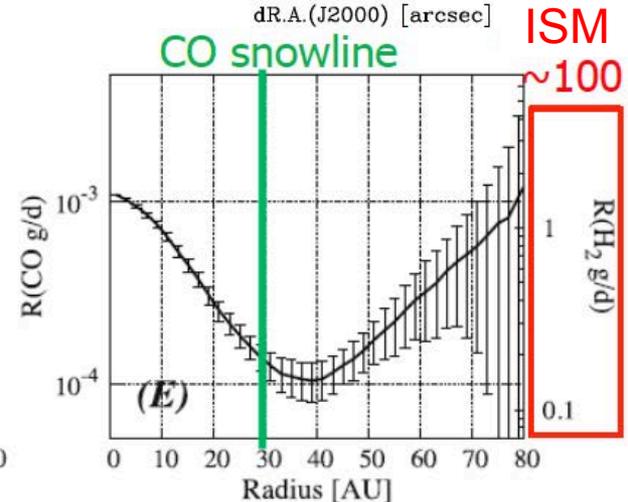
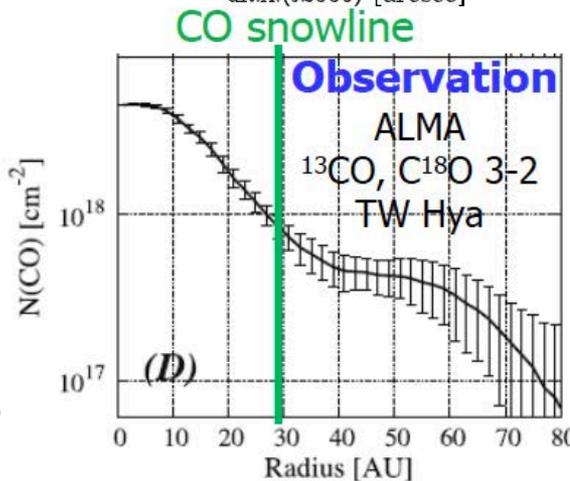
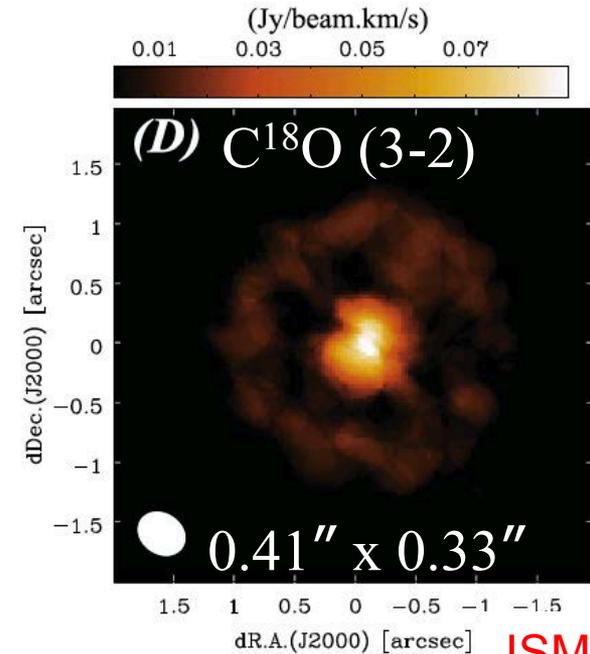
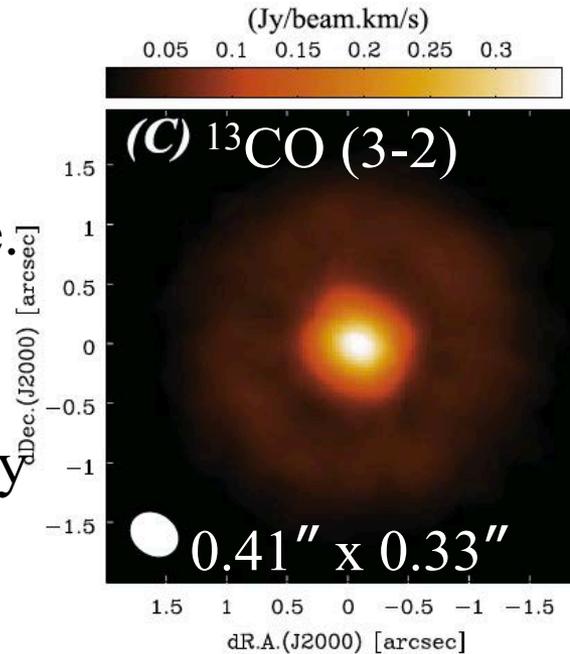


# CO Depletion

Nomura et al. 2016

## Gas Observations

- CO is drastically depleted inside of the CO snowline.
- $H_2$  gas / dust = 1 ~ 0.1  
ref. ~100 in ISM
- The amount of CO directly affects the planet atmosphere.
- Amino acid might be formed from a little CO gas (Aoki & Kobayashi's experiments).

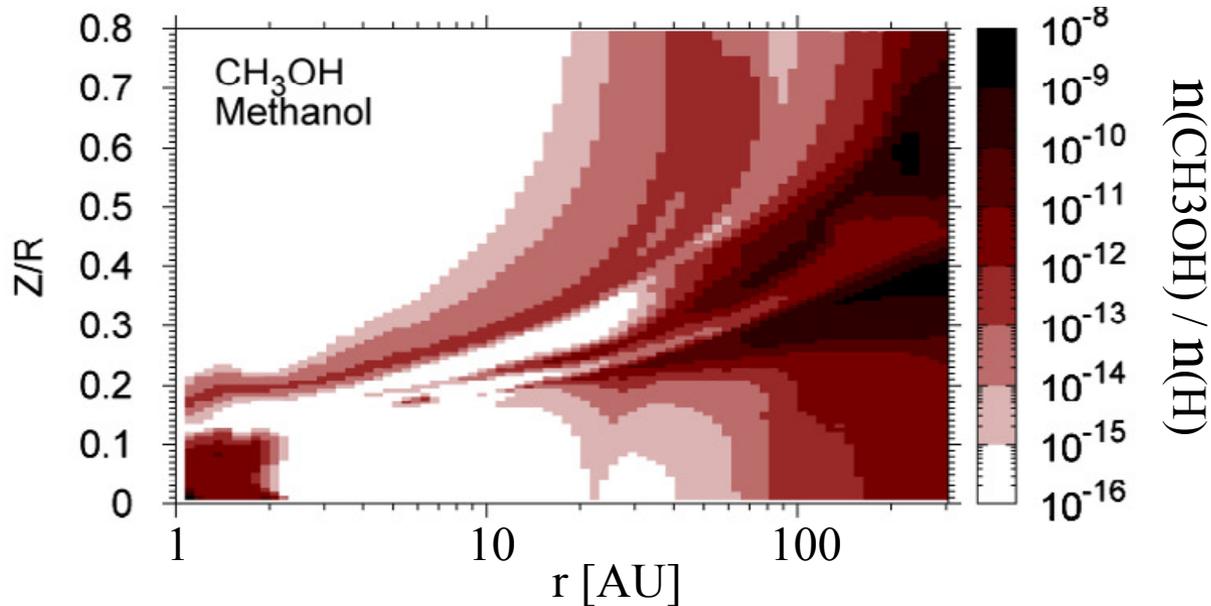




# Methanol Study

Walsh et al. 2014b  
Walsh et al. 2016

## Theoretical prediction of CH<sub>3</sub>OH in protoplanetary disk



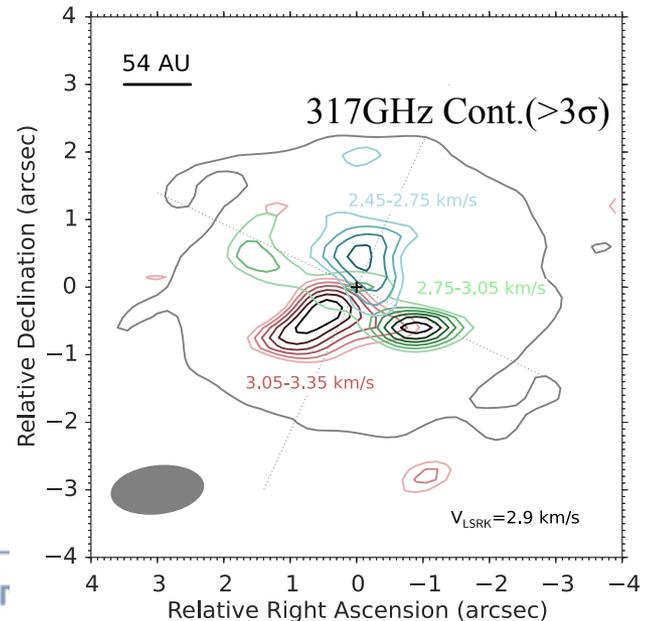
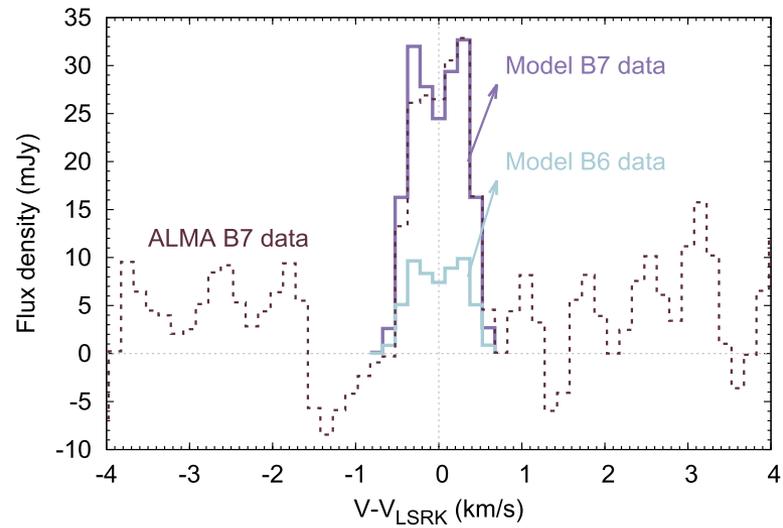
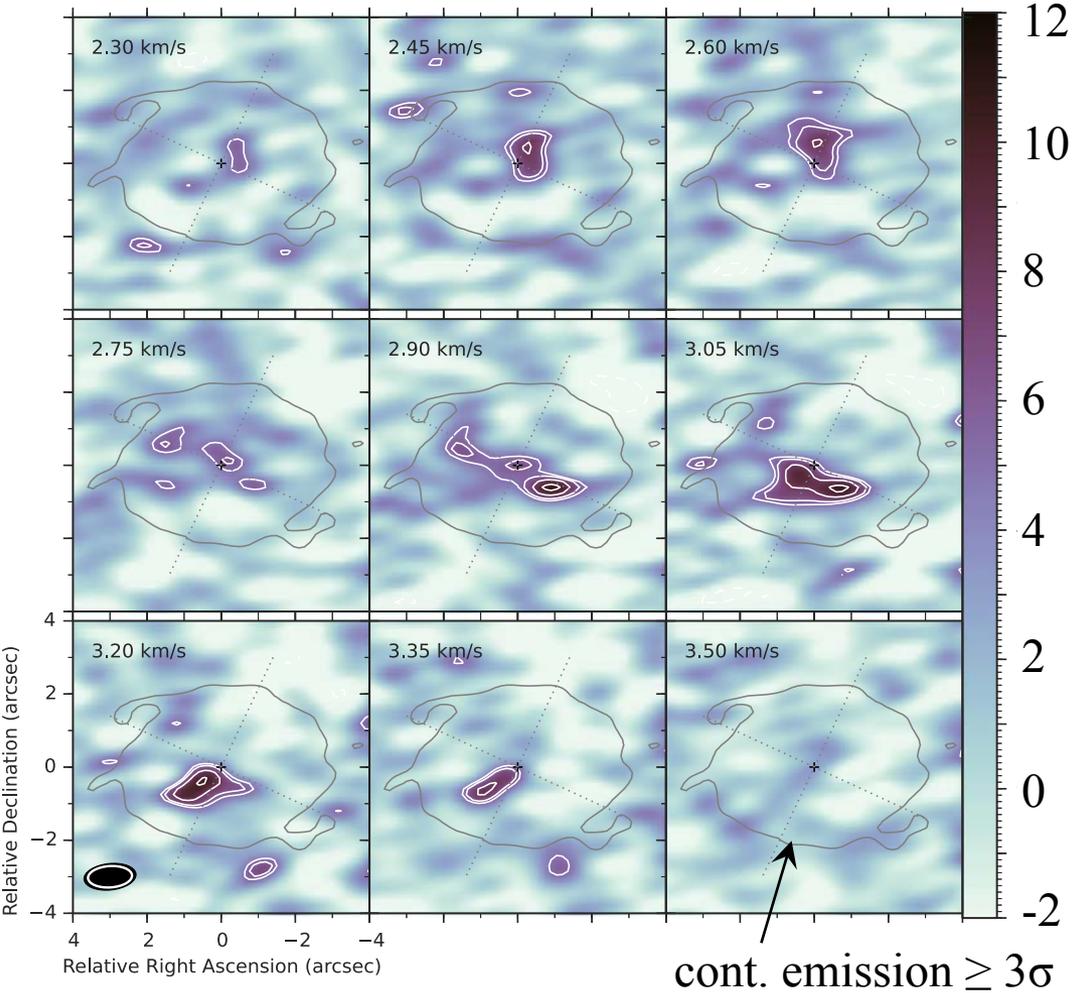
Species		Gas phase				Grain surface			
		10 AU	30 AU	100 AU	305 AU	10AU	30 AU	100 AU	305 AU
Formaldehyde	H <sub>2</sub> CO	3.7(12)	5.1(13)	1.5(12)	8.3(12)	6.7(09)	6.4(18)	3.4(17)	6.0(17)
Methanol	CH <sub>3</sub> OH	1.0(09)	2.2(11)	5.8(12)	1.7(13)	2.3(18)	8.4(17)	1.1(18)	8.8(17)
Formic acid	HCOOH	8.1(10)	7.5(11)	9.1(12)	8.2(12)	1.1(18)	2.4(17)	1.1(17)	3.3(16)
Cyanoacetylene	HC <sub>3</sub> N	2.0(12)	6.9(11)	2.1(11)	9.8(10)	1.7(18)	1.3(15)	8.2(12)	5.5(12)
Acetonitrile	CH <sub>3</sub> CN	5.5(12)	2.9(12)	6.9(11)	4.1(11)	1.2(17)	2.1(17)	2.7(16)	2.0(15)

⋮  
etc.



# Methanol Observation

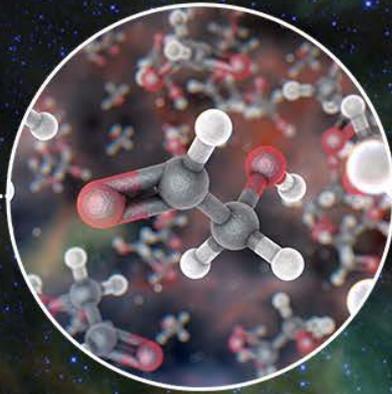
Walsh et al. 2016



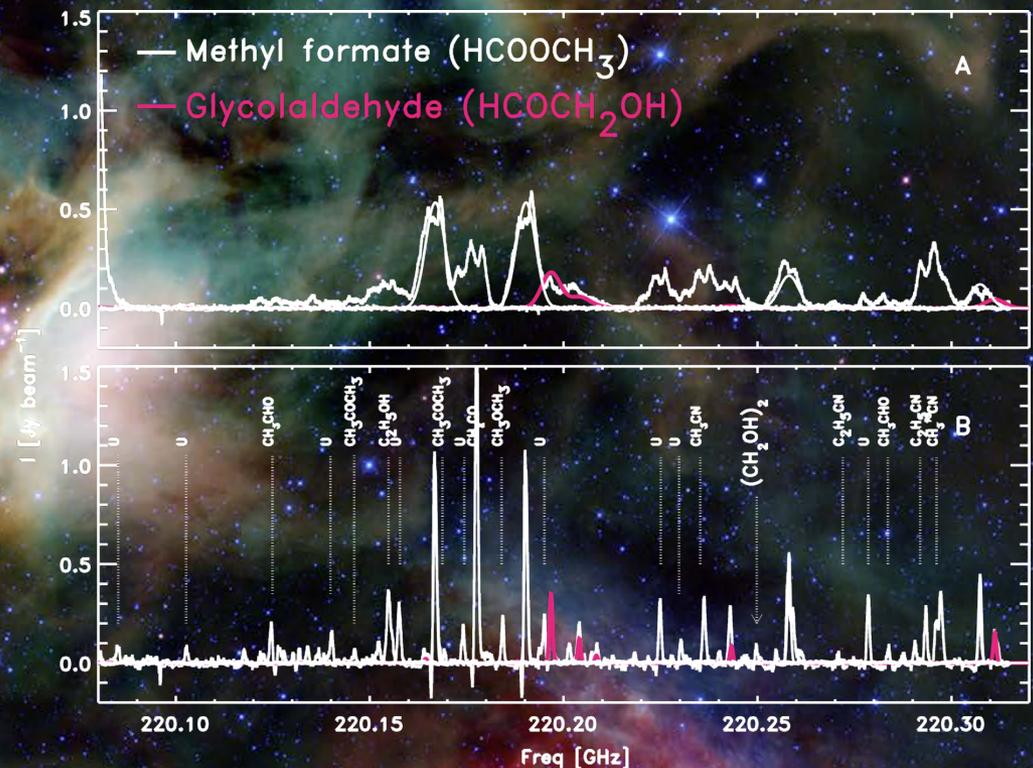
# Discovery of HCOCH<sub>2</sub>OH

Jorgensen et al. 2012

Large organic molecules were found in IRAS16293 – 2422 star forming region.



Glycolaldehyde  
(HCOCH<sub>2</sub>OH)



# Discovery of CH<sub>3</sub>NCO

Martin-Domenech et al. 2017

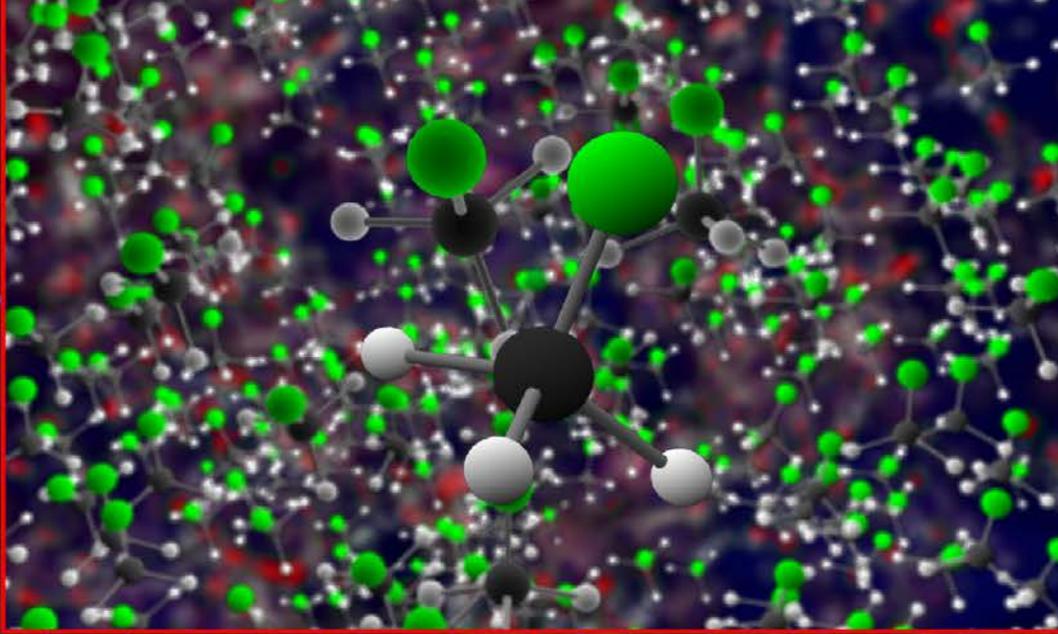
Ligterink et al. 2017

Methyl isocyanate  
(CH<sub>3</sub>NCO)



# Discovery of $\text{CH}_3\text{Cl}$

Fayolle et al. 2017



Methyl chloride  
( $\text{CH}_3\text{Cl}$ )

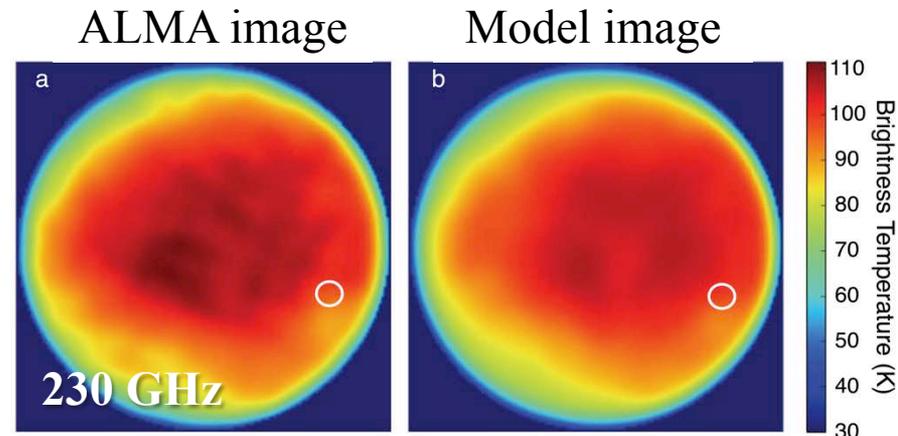
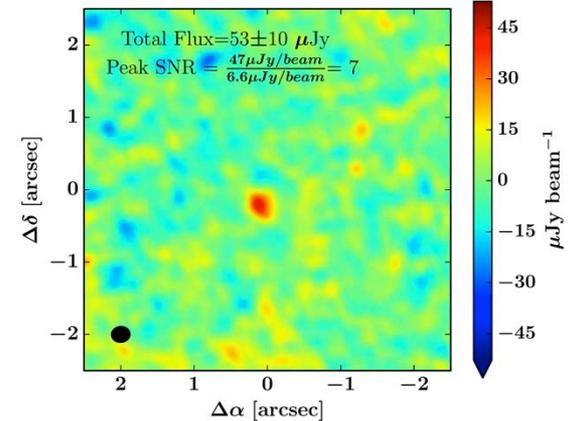
$\text{CH}_3\text{Cl}$  can not be treated as prebiotic molecule but complex organic molecules can be formed in star forming region.

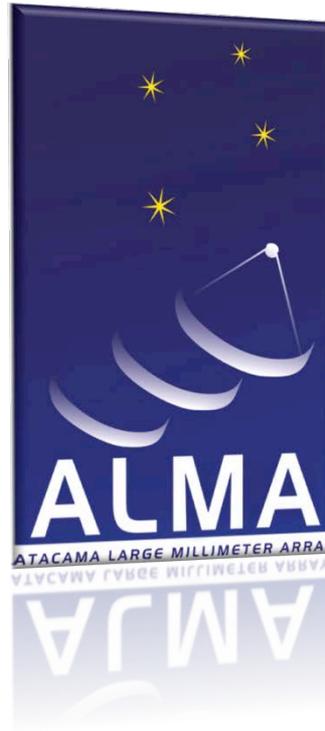


# Solar System Bodies

Gerdes et al 2017  
Trumbo et al. 2017  
Palmer et al. 2017  
Lellouch et al. 2017

- 2014UZ<sub>224</sub> TNO object at 92 au observation
  - As results of ALMA & Blanco telescopes, it could be dwarf planet.
  - $D = 635 \pm 70$  km
  - albedo =  $13 \pm 4$  %
- Europa, plume source investigation
  - nighttime (ALMA) & daytime (Galileo) image comparison
  - Heat excess in nighttime image is not due to endogenic heat flow but local thermal inertia.
- Titan, Vinyl Cyanide has been confirmed at the Titan's atmosphere.
- Pluto, CO and HCN was detected in Pluto's atmosphere.





**[www.almaobservatory.org](http://www.almaobservatory.org)**

*The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership among Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in Japan by the National Institutes of Natural Sciences (NINS) in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.*