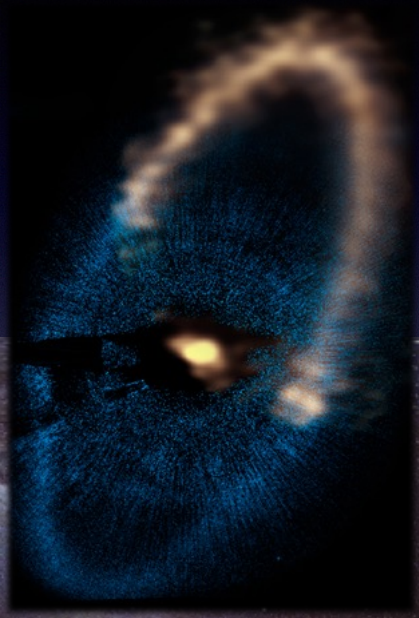
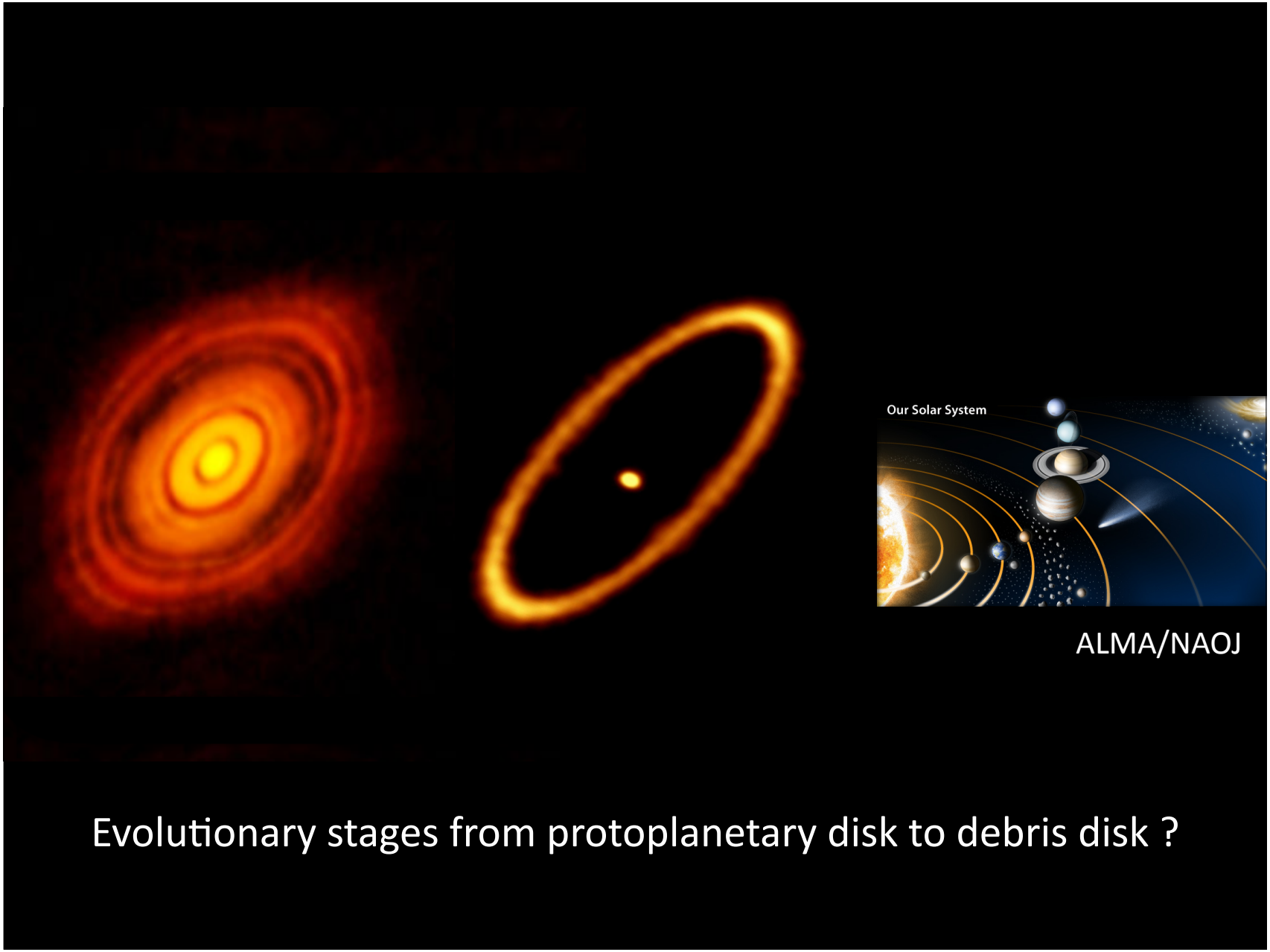
Detection of Submillimeter-wave [C I] Emission in Gaseous Debris Disks of 49 Ceti and β Pictoris



Aya Higuchi, Nami Sakai (RIKEN), Aki Sato, Takashi Tsukagoshi, Munetake Momose(Ibaraki Unv.), Kazunari Iwasaki (Osaka Unv.), Hiroshi Kobayashi, Daisuke Ishihara, Hidehiro Kaneda (Nagoya Unv.) and Satoshi Yamamoto (UT)



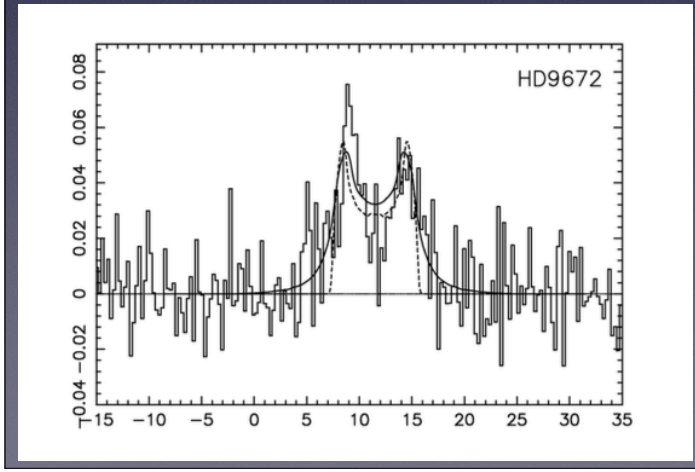
ALMA/NAOJ

Evolutionary stages from protoplanetary disk to debris disk ?

	Protopranetary Disks	Debris Disks
dust	Primordial $> 10\ M_{\oplus}$ $L_{disk}/L_{*} > 0.01$ optically thick	Secondary (?) $< 1M_{\oplus}$ $L_{disk}/L_{*} < 0.01$ optically thin
dust condition	protected by gas	affected by radiation presssure
gas condition	primordial gas/dust mass ratio ~100	primordial or secondary
disk structure	thick	thin
age	< 10 Myr	10Myr - 10Gyr

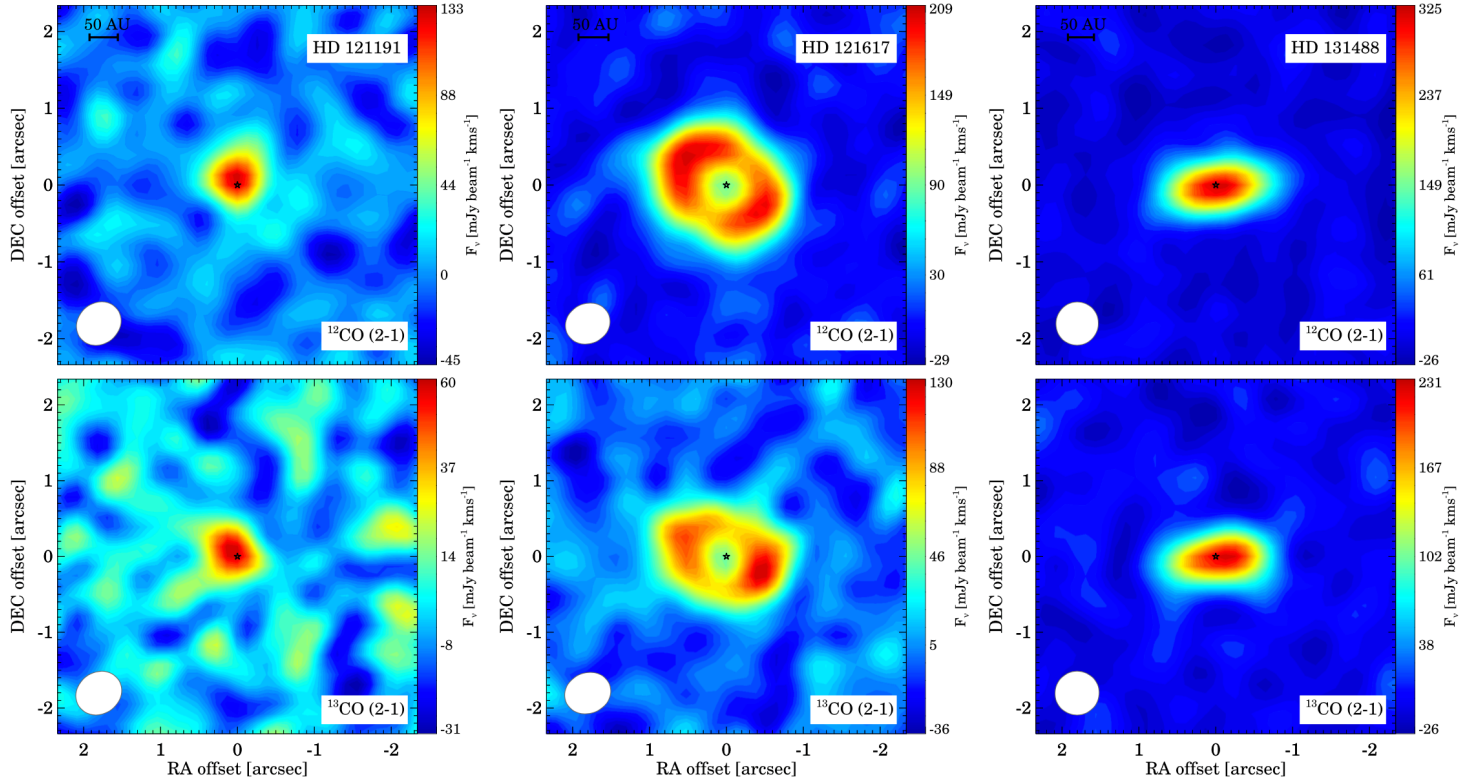
CO gas survey

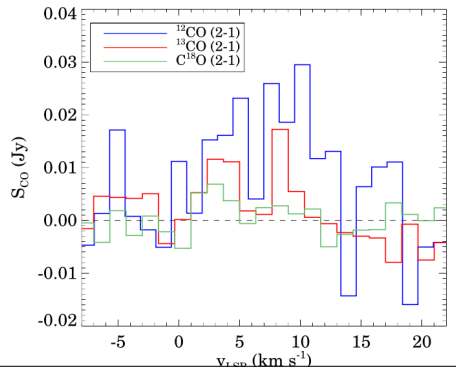
- Previous CO survey
  - Zuckerman et al. (1995, IRAM), Dent et al. (2005, JCMT), Hales et al. (2014, APEX+ASTE), Moor et al. (2011, 2015, APEX+IRAM).
    - 3/70 objects - CO detection
      - 49Ceti (Zuckerman et al. 1995, Dent et al. 2005)
      - HD 21997 (Moor et al. 2011)
      - HD131835 (Moor et al. 2015)

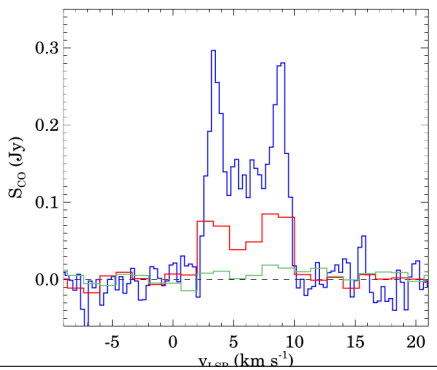


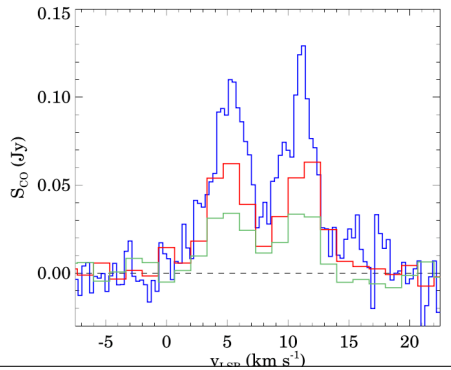
CO(3-2) JCMT Dent et al. (2005)

CO gas survey









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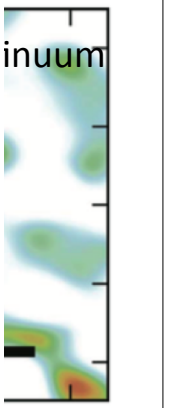
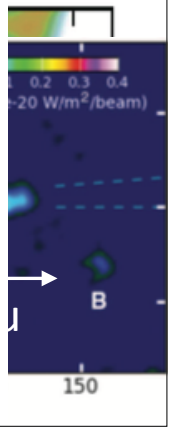




Origin of gas

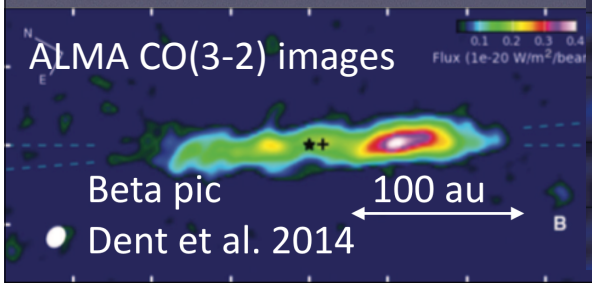
- Primordial
  - Remnant gas of protoplanetary disks (e.g., Kospal et al. 2013).
  - Gas composition: ISM abundance (e.g., X(CO) = 10^{-4}) as in protoplanetary disks
- Secondary
  - Sublimation of dust grains (e.g., Kobayashi et al. 2008) or planetesimals (Lagrange et al. 1998), collision of comets or icy planetesimals (Zuckerman & Song 2012).
  - Gas composition
    - CO : main gas, only a small amount of H_2 is expected.
    - CO : photodissociation —> C, C^+

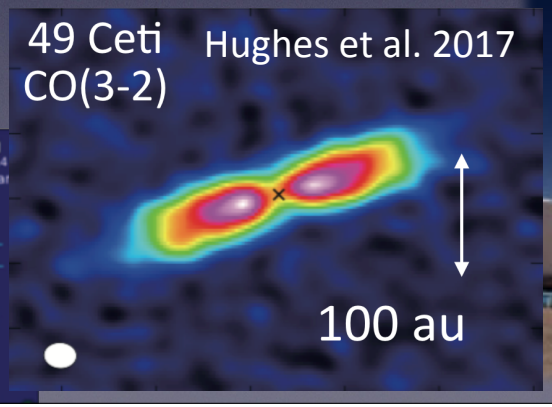
Observations

Atacama Submillimeter Telescope Experiment (ASTE)

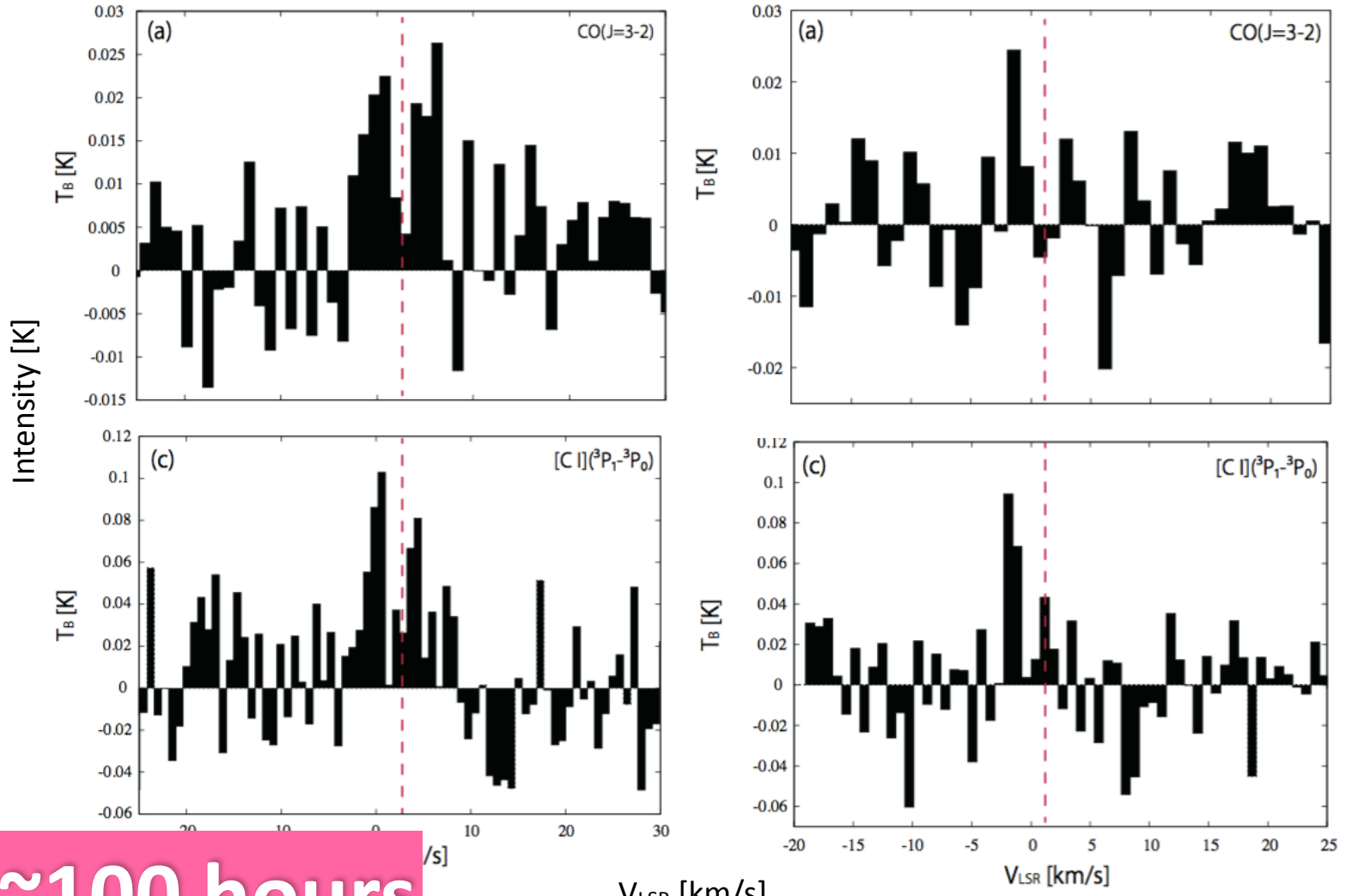
(Sep. - Oct. 2016)

- [C I]: 492.161 GHz (Band 8 receiver)
  - dv=1.1km/s
  - rms=25mK (in T_A)
  - Integration time(on source) > 15h
- CO(3-2): 345.796 GHz
  - dv=0.76km/s
  - rms=6mK (in T_A)

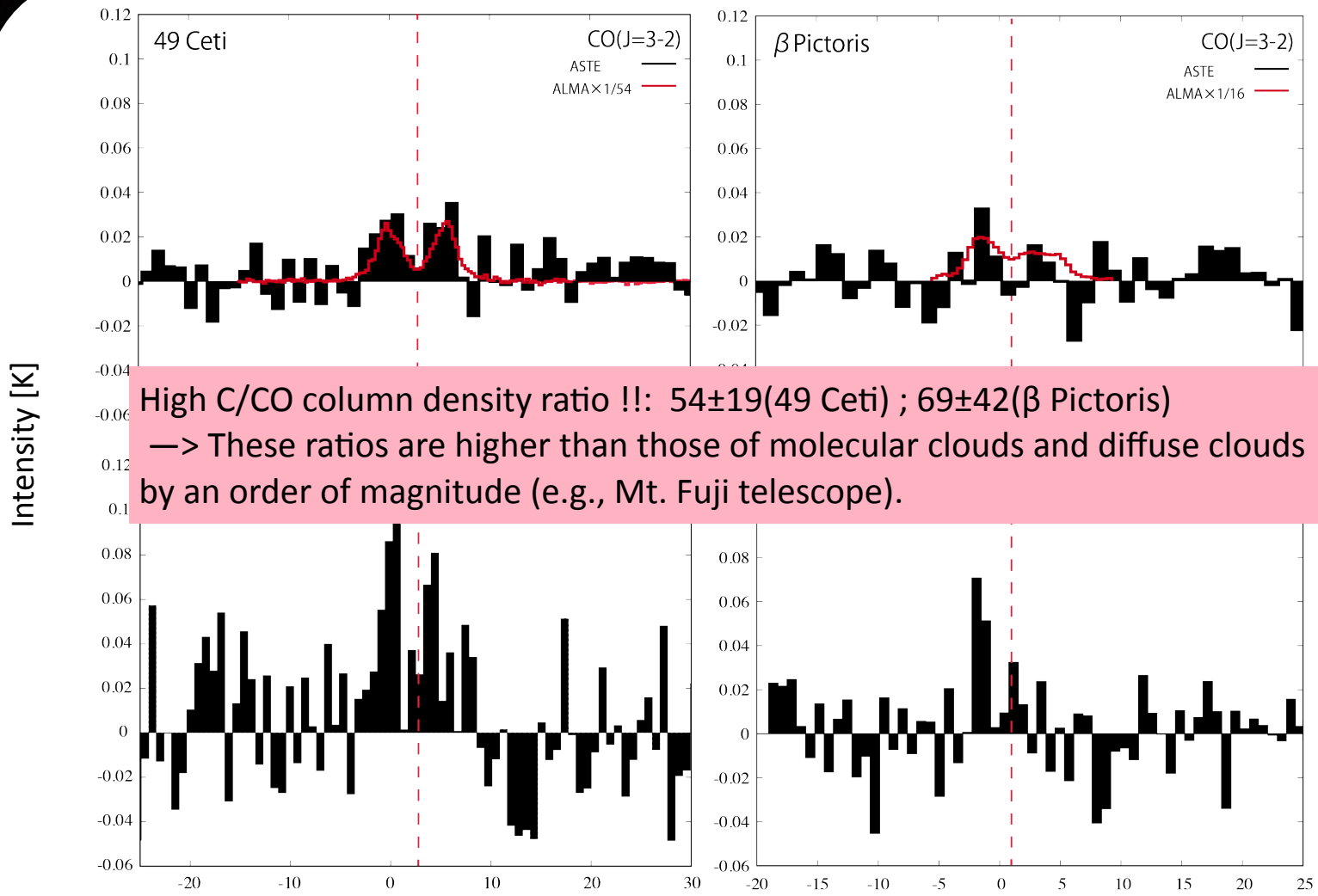




49 Ceti Higuchi et al. 2017 β Pictoris



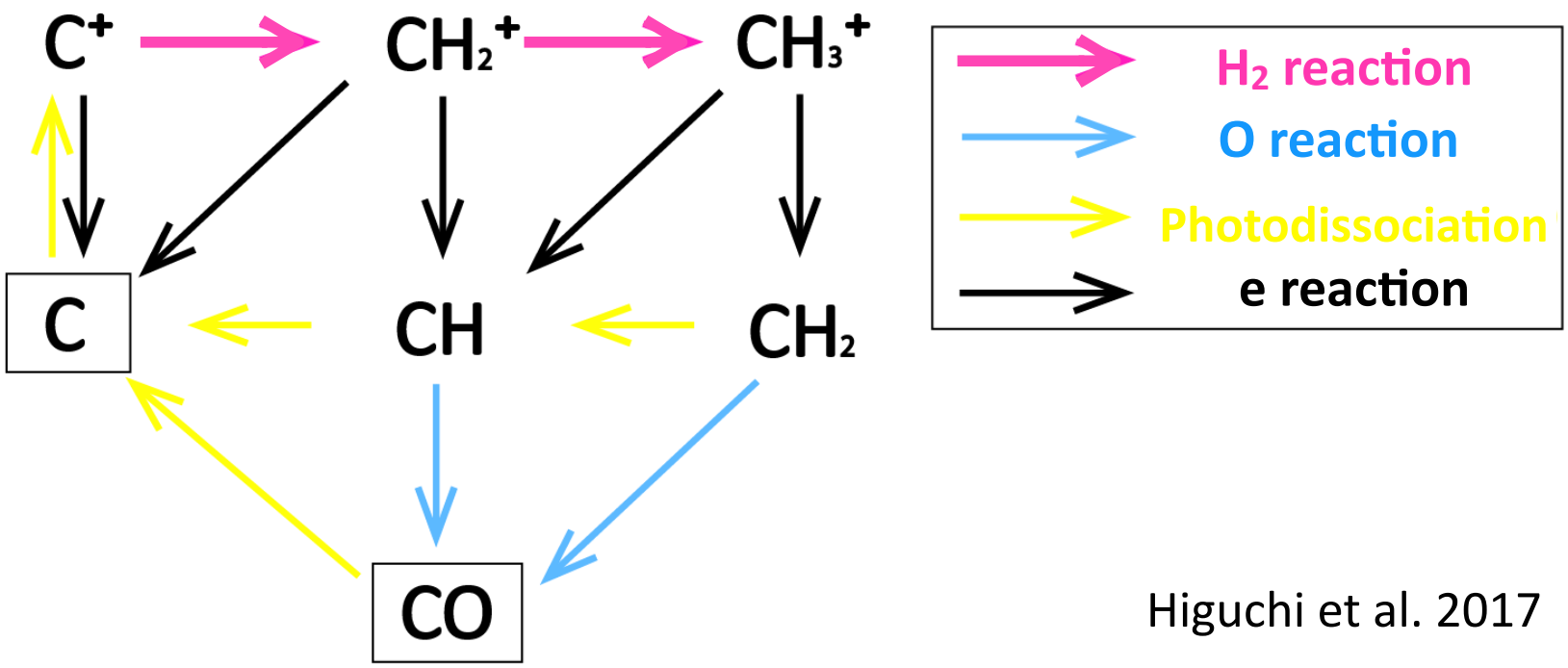
~100 hours



High C/CO column density ratio !!: 54±19(49 Ceti) ; 69±42(β Pictoris)
—> These ratios are higher than those of molecular clouds and diffuse clouds by an order of magnitude (e.g., Mt. Fuji telescope).

Chemical reaction of CO

If there is a large amount of H_2 molecular gas, C will easily return to CO.

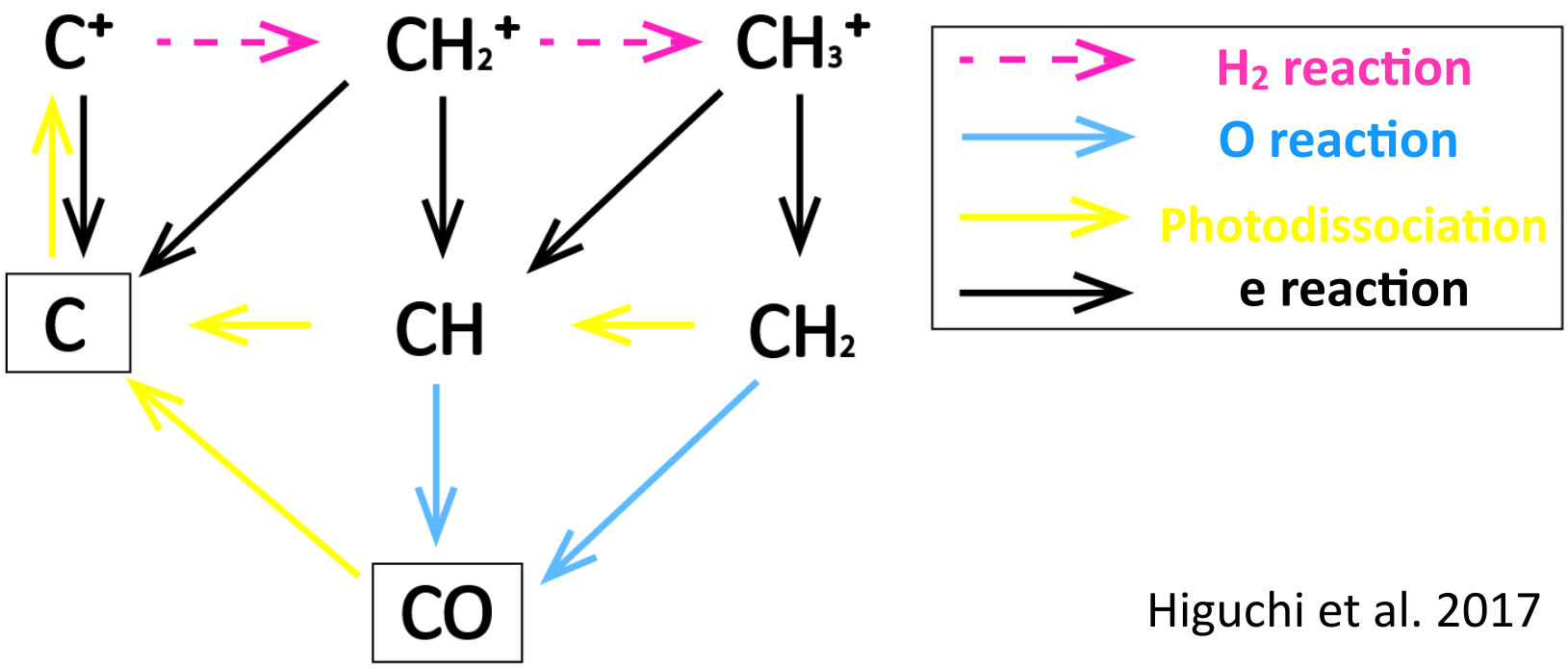


Higuchi et al. 2017

Chemical reaction of CO in the interstellar medium. CO is dissociated by ultraviolet radiation to become C and C^+. If there are large amount of H_2, C^+ will return to CO again.

Chemical reaction of CO

The high C/CO ratios are likely attributed to a lack of H_2 molecule ?



Higuchi et al. 2017

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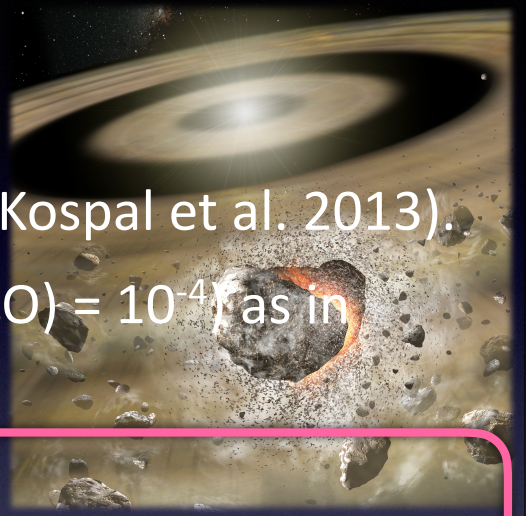
Origin of gas



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Summary

- We have firstly detected [C I] emissions in the gaseous debris disks of 49 Ceti and β Pictoris with the ASTE.
  - The line profiles of [C I] are found to resemble those of CO(J=3–2).
    - This result suggests that atomic carbon (C) coexists with CO in the debris disks and is likely formed by the photodissociation of CO.
    - The C/CO column density ratio is thus derived to be 54 ± 19 and 69 ± 42 for 49 Ceti and β Pictoris, respectively.
    - The high C/CO ratios are likely attributed to a lack of H_2 molecules.
  - This result implies a small number of H_2 molecules in the gas disk, i.e., there is an appreciable contribution of secondary gas from dust grains.