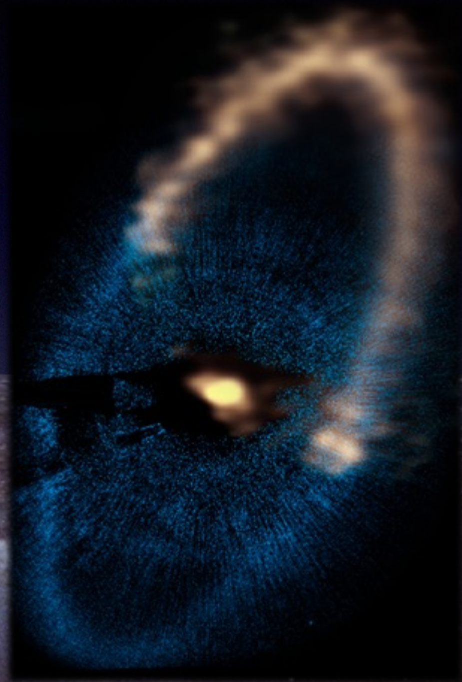
Detection of Submillimeter-wave [C I] Emission in Gaseous Debris Disks of 49 Ceti and β Pictoris



◯樋口あや, 坂井南美(理化学研究所), 佐藤愛樹, 塚越崇,百瀬宗武(茨城大学), 岩﨑一成(大阪大学), 小林浩, 石原大助, 渡邉華, 金田英宏 (名古屋大学),山本智(東京大学)

Announcement: Workshop on gaseous debris disks

October 10-11 @ RIKEN:

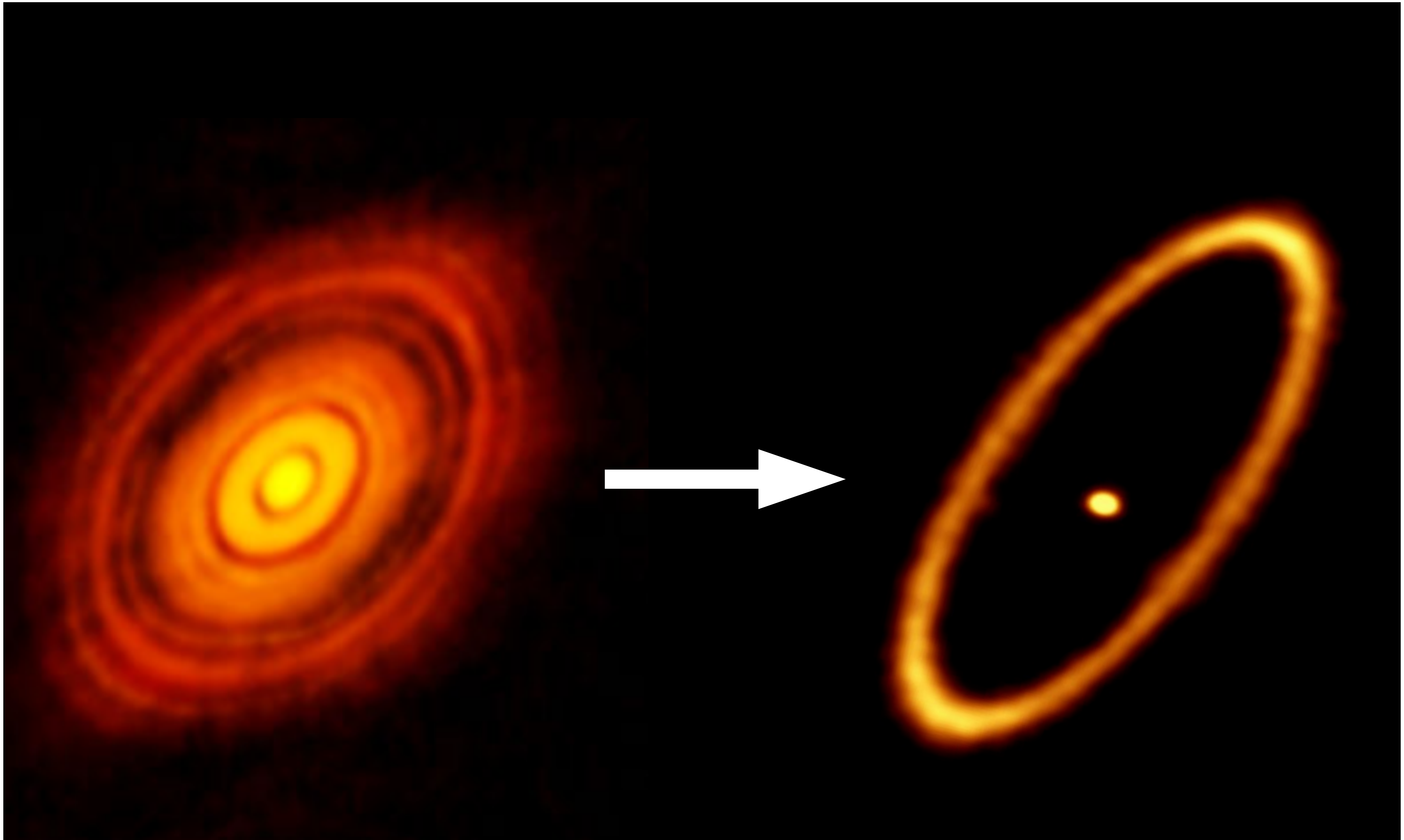
Two day workshop with up to 30 participants, aiming to bring together experts in
(i) observing gaseous debris disks,
(ii) theoretical models of planet formation,
(iii) astrochemical modeling of protoplanetary/debris disks, to discuss the implications for the origin of gas, gas compositions, and timescale of completion of the Solar System.

Confirmed speakers:

Alexis Brandeker (Stockholm University), Bill Dent (JAO), Daisuke Ishihara (Nagoya University), Gianni Cataldi (NAOJ/subaru), Kazunari Iwasaki (Osaka University), Luca Matrà (cfa), Mark Wyatt (University of Cambridge; video or in person), Mihkel Kama (University of Cambridge), Meredith Hughes (Wesleyan University; video), Attila Moór (Konkoly Observatory; video), Aki Roberge (NASA; video)

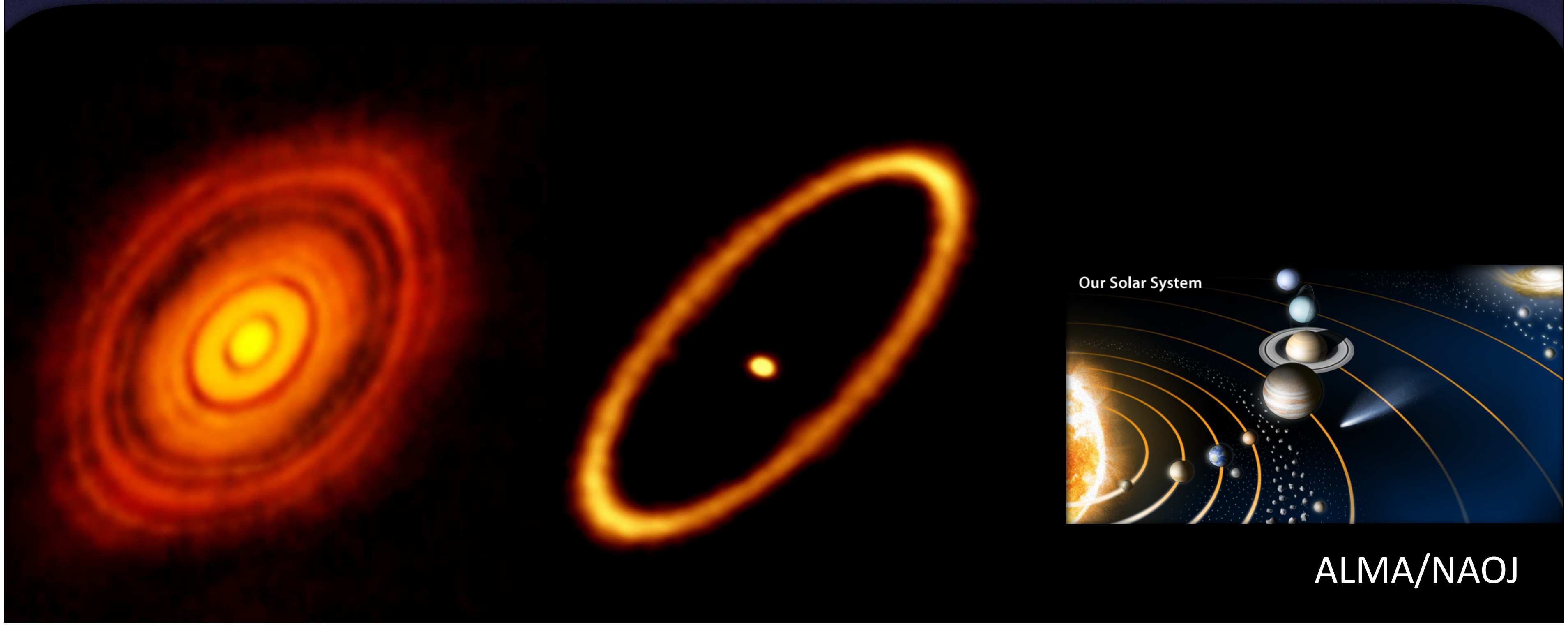
SOC: Aya Higuchi (Chair, RIKEN), Bill Dent (JAO), Hiroshi Kobayashi (Nagoya University), Satoshi Yamamoto (The University of Tokyo)
LOC: Nami Sakai, Satoshi Ohashi, Kento Yoshida (RIKEN)

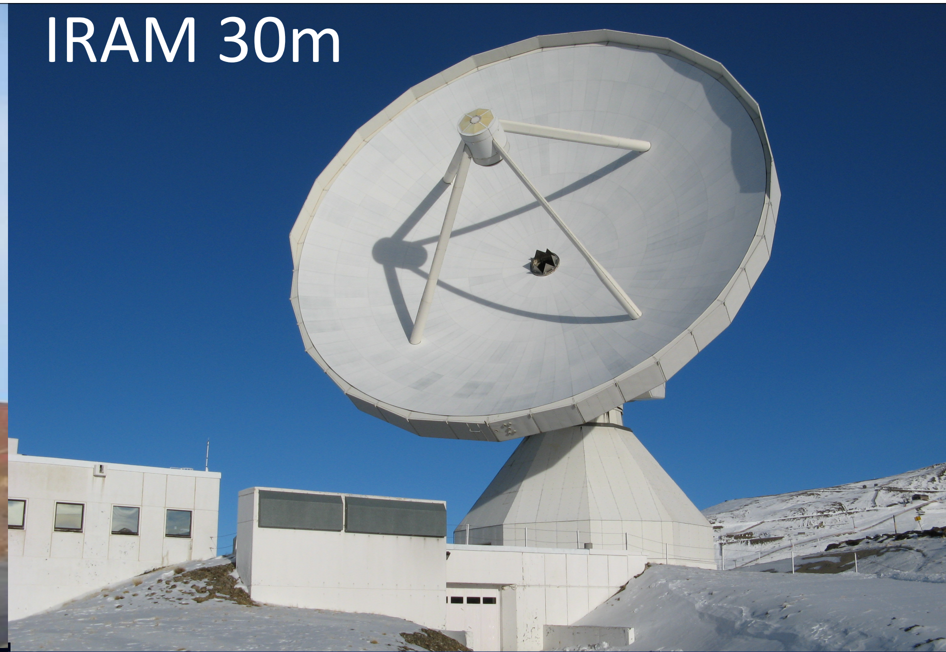
RIKEN



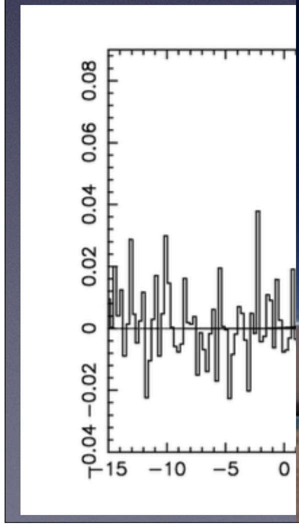
Evolutionary stages from protoplanetary disk to debris disk ?

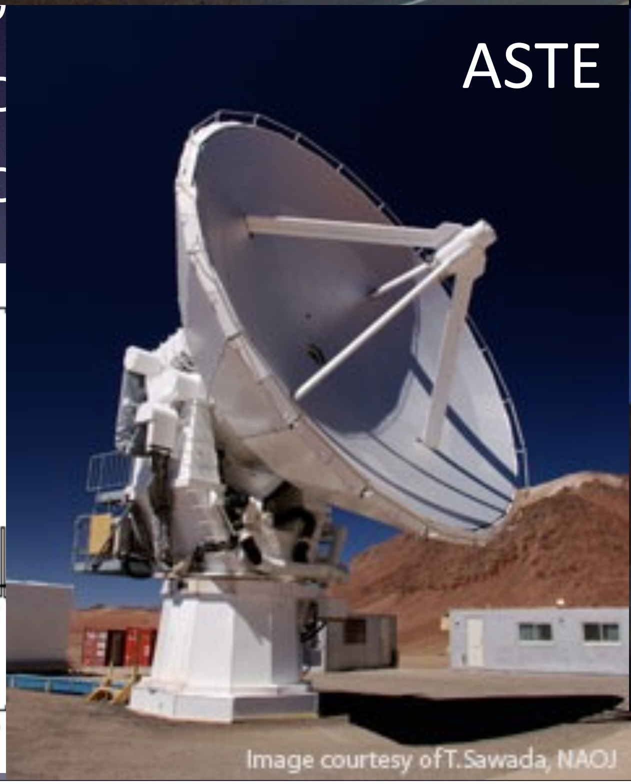
	Protoplanetary Disk	Debris Disk
stellar age	< 10 Myr	10 Myr - 10 Gyr
optical depth	thick	thin
dust mass	$> 10 M_\oplus$	$< 1 M_\oplus$
gas mass	100 × Dust	No or little
dust origin	Primordial	Secondary

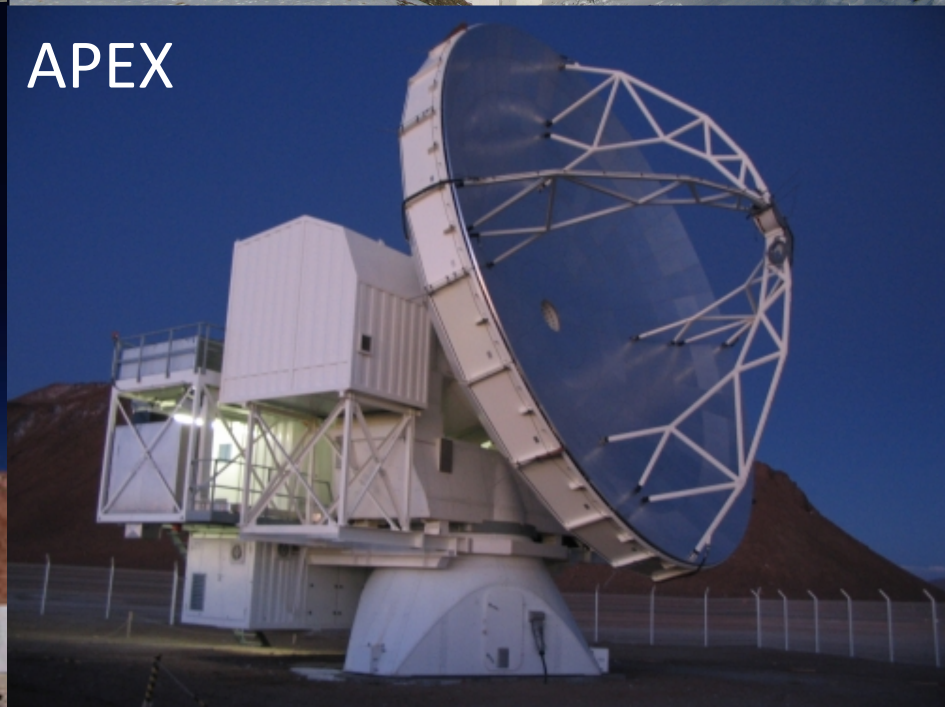




- 49
- HD
- HD



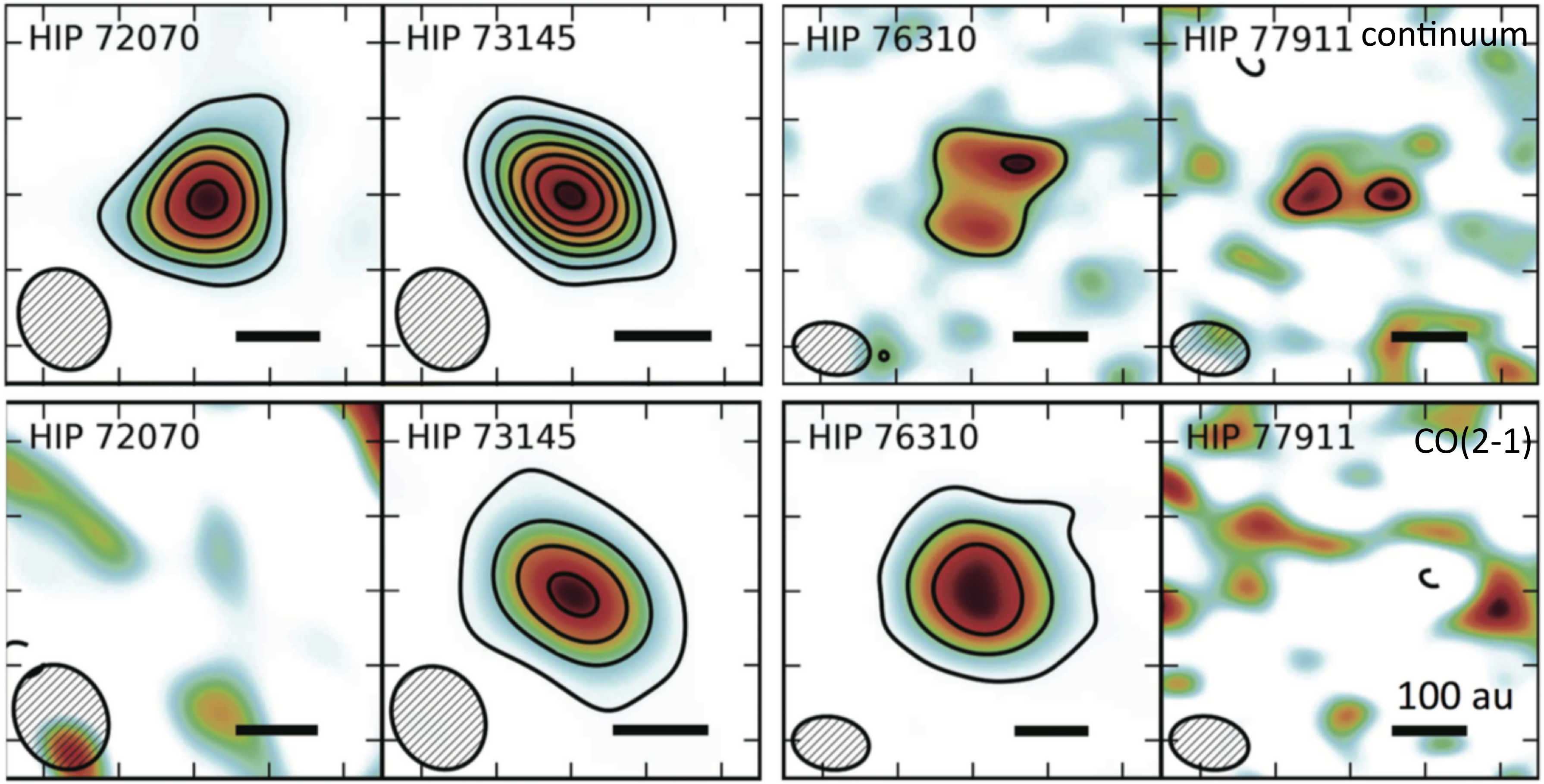




(3-2) JCMT Dent et al. (2005)

CO gas survey

- ALMA observations
  - Scorpius-Centaurus association (Lieman-Sifry et al. 2016) - 23 objects
    - CO detections: newly HIP 76310, and HIP 84881 + confirmation of HD 131835.



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^+

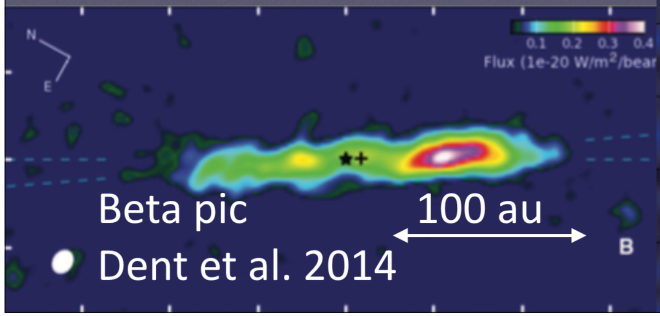
Observations

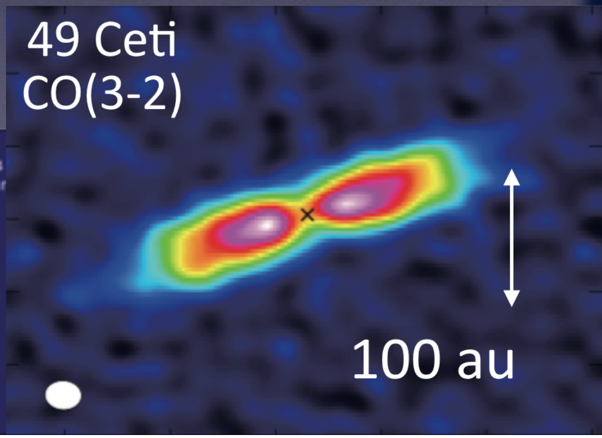
Atacama Submillimeter Telescope Experiment (ASTE)

(Oct. - Nov. 2016)

- [C I]: 492.161 GHz (Band 8 receiver)
  - dv=1.1km/s
  - rms=30mK (in T_A)
  - Integration time(on source) > 15h

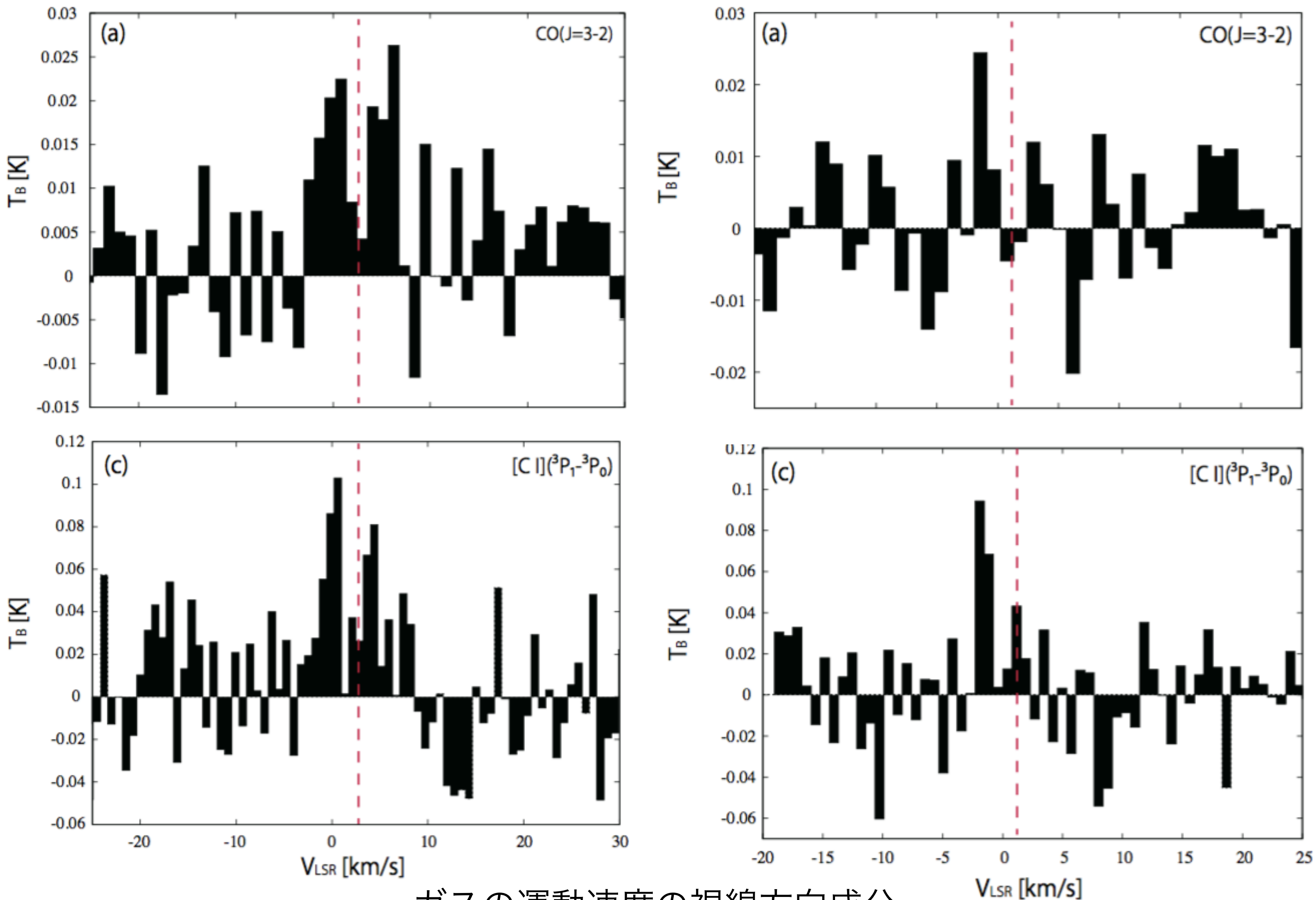
ALMA CO(3-2) images



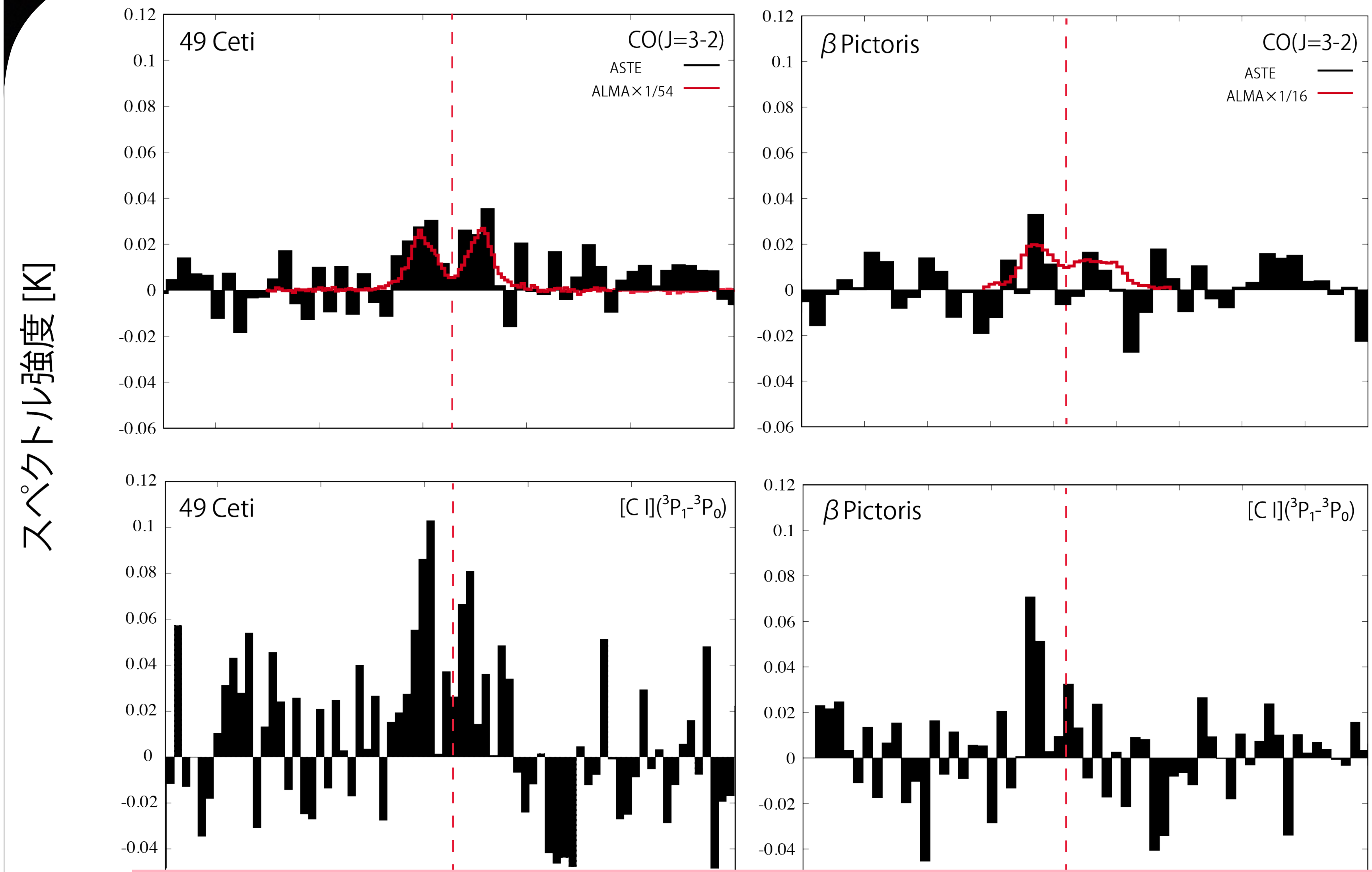


49 Ceti　　Higuchi et al. 2017　　β Pictoris

スペクトル強度[K]



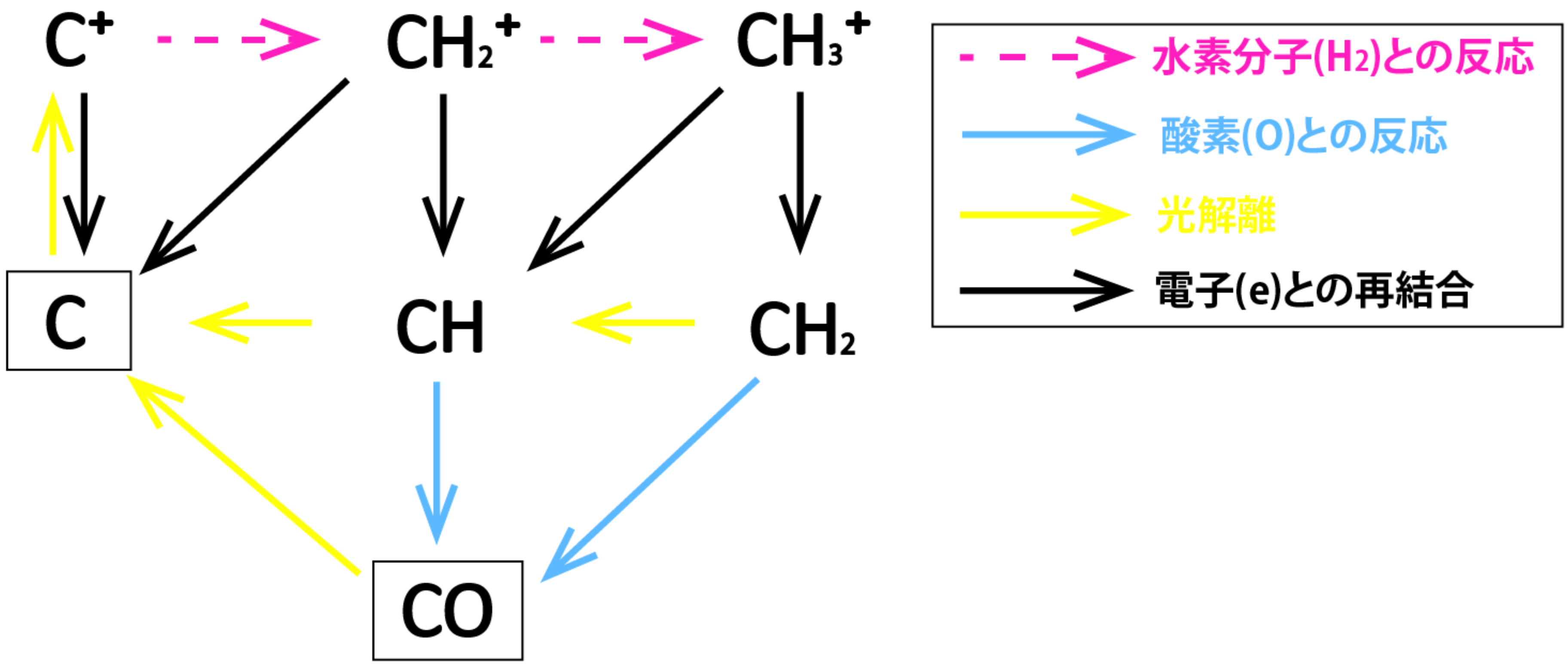
ガスの運動速度の視線方向成分



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.

Chemical reaction of 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.

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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) observed with the same telescope and the ALMA.
    - 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 unusually high ratios of C to CO are likely attributed to a lack of H_2 molecules needed to reproduce CO molecules efficiently from C.
  - 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.

Future work

- (Higuchi) ALMA observation with the high resolution and sensitivity to understand the spatial and velocity distribution of [C I] emission.
  - Understanding the spatial distribution of [C I] emission with ALMA
  - Derivation of C/CO and Gas to Dust (G/D) ratio
- (Sato) ASTE observation for increasing the number of [C I] detection sources.
- (Iwasaki/Kobayashi) Modeling of the photodissociation and chemical reactions in debris disks (PDR calculation) for giving a constraint on the amount of hydrogen molecule in debris disks