Star Formation Newsletter #310, 28-36

武藤恭之

No. 28

High-resolution ALMA Study of the Proto-Brown-Dwarf Candidate L328-IRS

Chang Won Lee[1,2], Gwanjeong Kim[1,2,3], Philip C. Myers[4], Masao Saito[5], Shinyoung Kim[1,2], Woojin Kwon[1,2], A-Ran Lyo[1], Archana Soam[1], and Mi-Ryang Kim[1]

arXiv:1809.10466

- Proto brown dwarf candidate の L328-IRS のALMA 観測

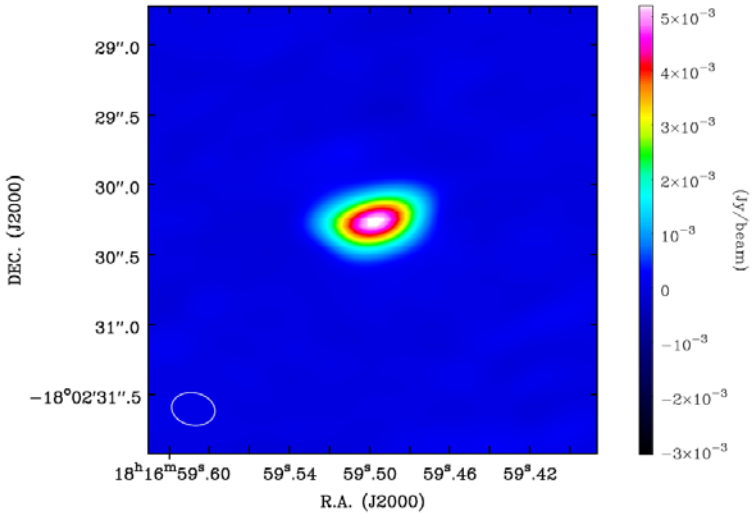
- Very Low Luminosity Object (VeLLO) としてSpitzer で発見、距離 217pc
- 小さなエンベロープ質量（0.09Msun), 低い質量降着率（10^{-7}Msun/yr）
- 中心星質量が0.05Msun と見積もられている

- Band 6、0.2 x 0.3秒角分解能、連続波＋12CO＋13CO＋C18O

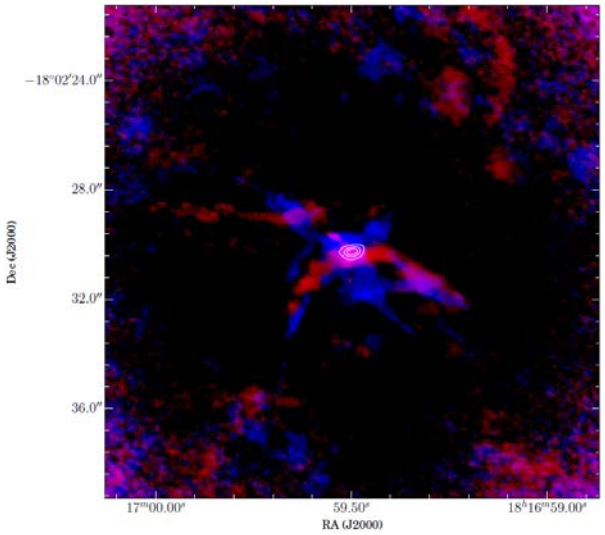
- Deconvolved size で、0.4x0.17秒角（＝87x37AU）のコンパクトなダスト放射
- CO 観測から、回転構造のような構造が見えた
  - 中心から 60-130AU の範囲で Kepler 回転で合わせると、力学的な質量が 0.3Msun と見積もられるが、60AU より内側の速度構造は Kepler 回転と合わない
- アウトフロー構造が見え、inclination の値が 66度と見積もられた
- 質量降着率の値の精度が上がり、8.9x10^{-7} Msun/yr と見積もられた

- 質量降着率や明るさから見積もった質量は、0.012-0.023 Msun 程度となり、力学質量とかなり異なる

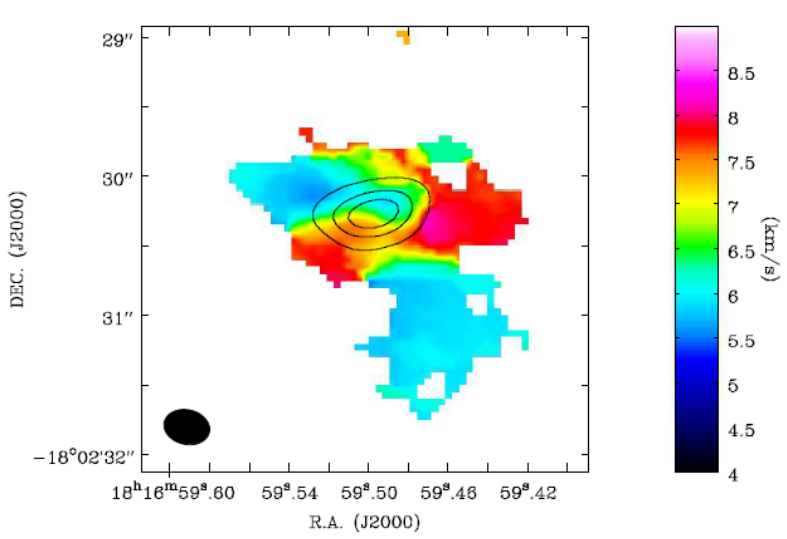
- 質量の不定性が大きく、proto Brown Dwarf とは断定できない



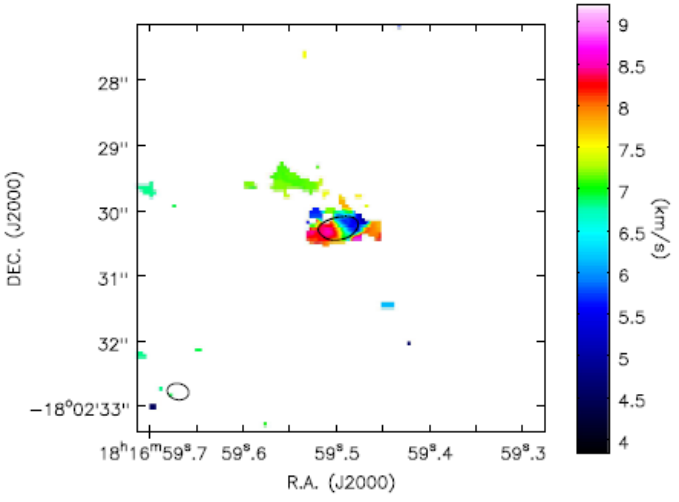
ダスト連続波放射



CO intensity map

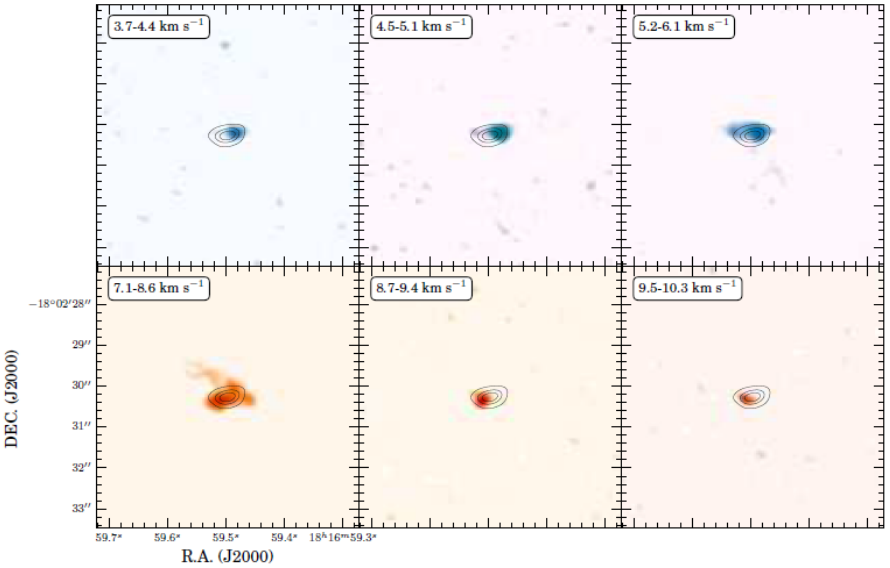


13CO moment 1 map

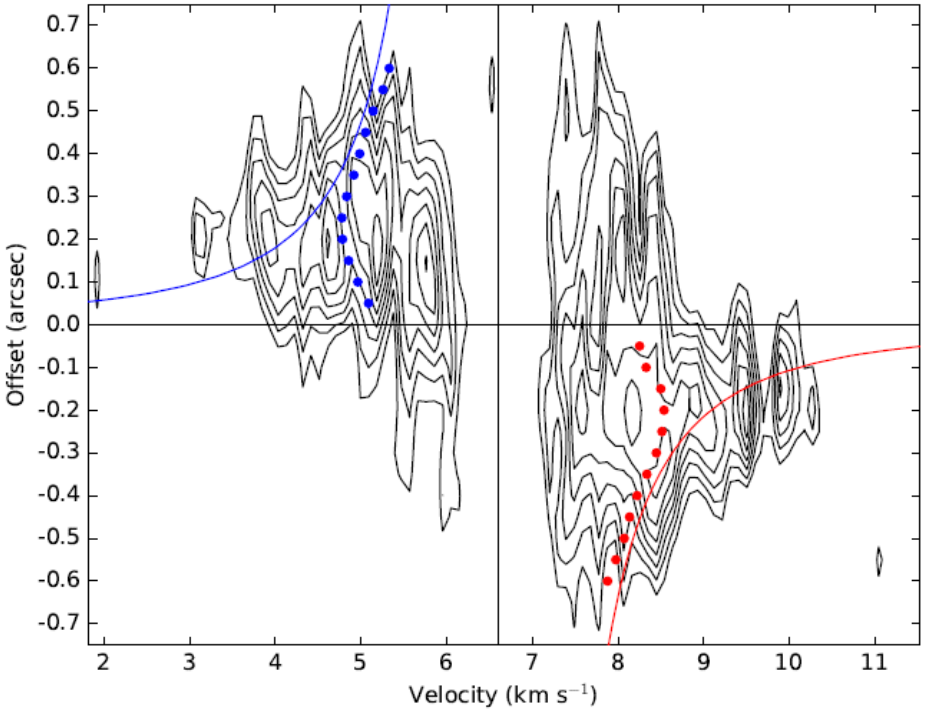


C18O moment 1 map

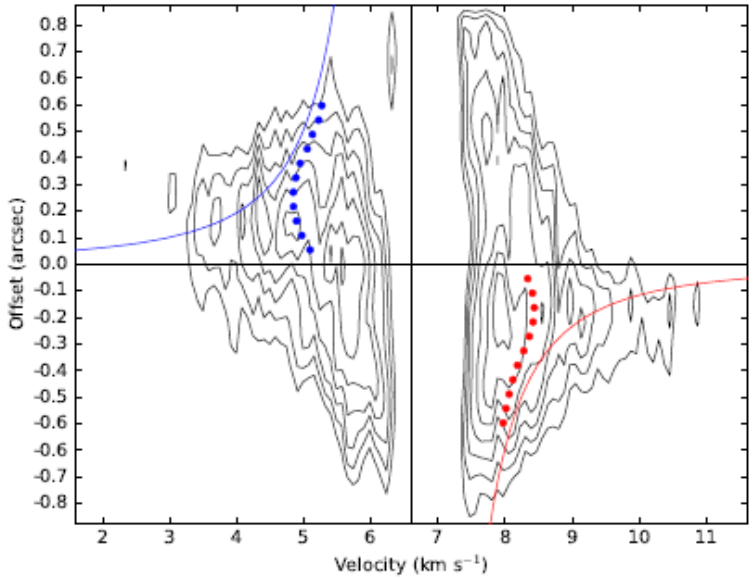
C18O channel map



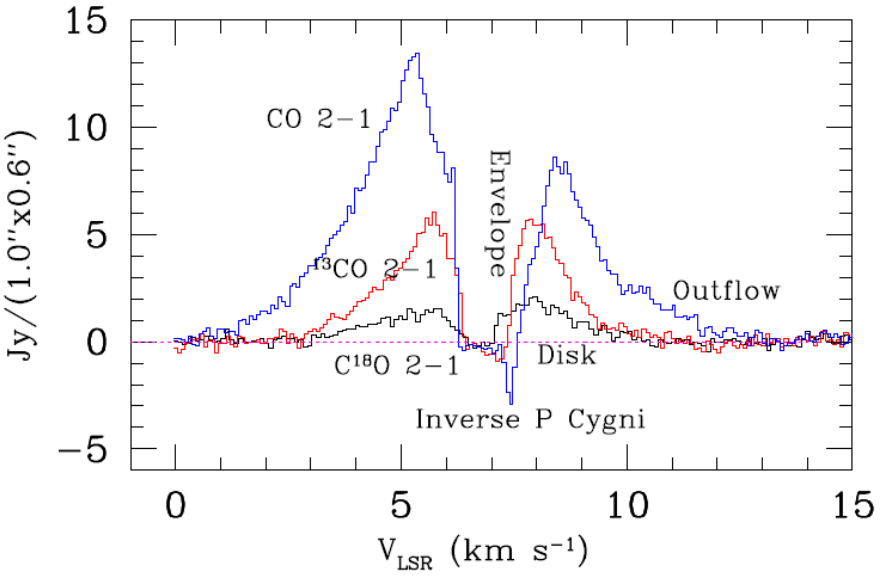
Position-Velocity diagram for C18O



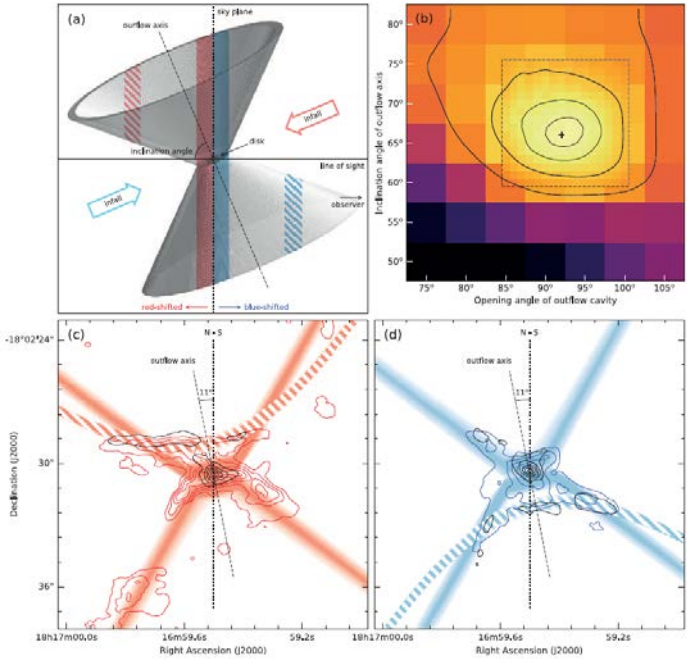
Position-Velocity diagram for 13CO



- 青・赤の点は観測データ
- 実線は 0.3 Msun の場合の Kepler 回転を重ねて書いている



CO 同位体の line profiles
エンベロープ・アウトフロー・円盤の構造



アウトフローのtoy model ➔ 回転する円錐面
開き角92度・inclination 66度と推定

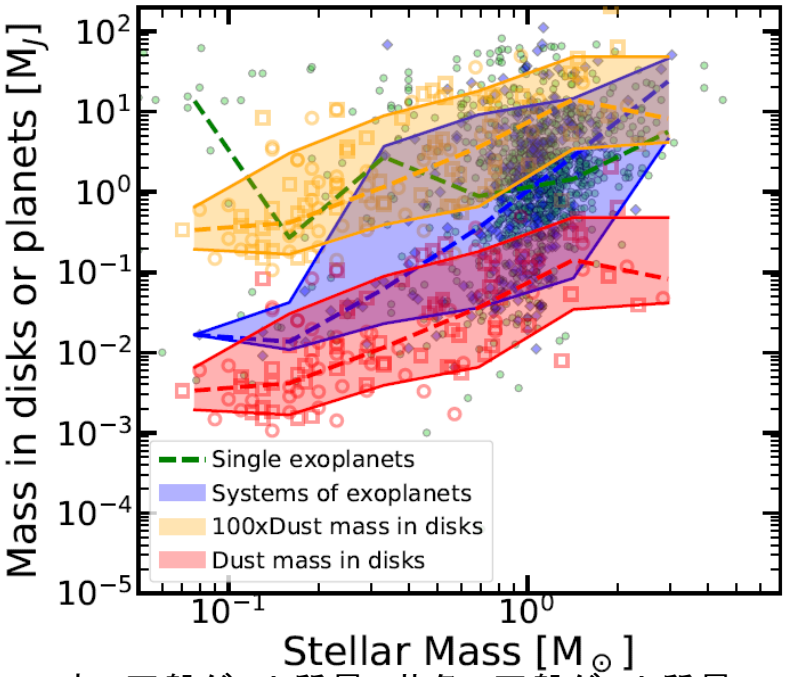
左上： モデルの概略
右上： intensity と inclination の決定精度
下： 赤側・青側のイメージを観測と比較

Why do protoplanetary disks appear not massive enough to form the known exoplanet population?

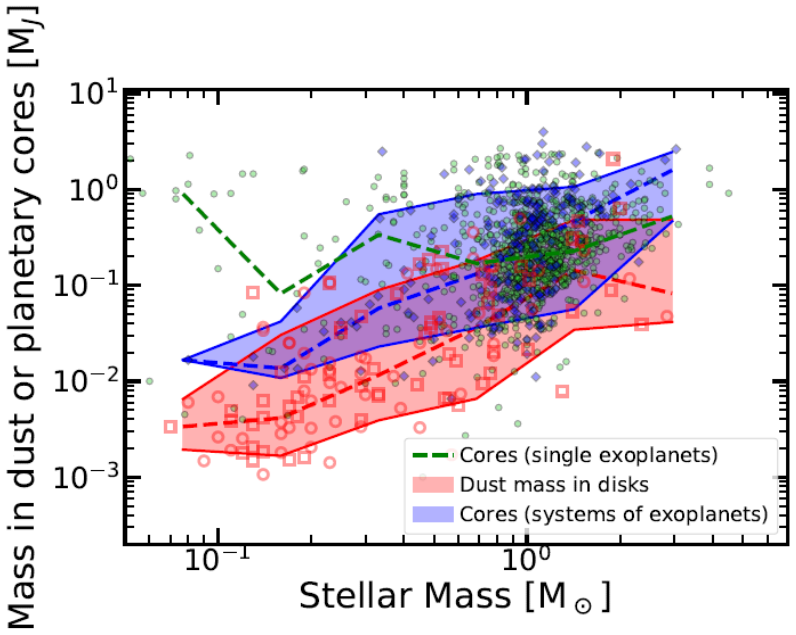
C.F. Manara[⋆1], A. Morbidelli[2], and T. Guillot[2]

arXiv:1809.07374

- 原始惑星系円盤の質量が、系外惑星の質量に足りないという問題を指摘
  - データ＋アイディア論文。詳細なモデル計算は無し
- 系外惑星のカタログからだした、惑星質量 or 惑星コアの質量分布と、ALMAで調べられた円盤質量の分布を比較
- 惑星質量 or 惑星コア質量の方が、円盤質量よりも重い傾向にある
- 二つの可能性を指摘
  - 惑星コアを早く作る
  - 星への降着物質が円盤を介して降着し、円盤に常にダストが降り注いでいる



赤：円盤ダスト質量、黄色：円盤ダスト質量×100
青：惑星系の質量分布、緑：単一惑星系の中央値



惑星質量をコア質量に焼き直した分布

- 特に、中心星の質量の小さいところで、惑星質量の中央値が円盤質量よりも大きい
- 観測バイアス ➔ 円盤サーベイも惑星サーベイも、重い方にバイアスがあるはず
- 若い段階（1Myr 以内）で、惑星を作ってしまう可能性
  - 微惑星形成の効率が良くないので、重い円盤＋効率的なガス散逸が必要
  - Class I 段階の強いアウトフローで飛ばしてしまう？
- 円盤を介したエンベロープ降着による惑星形成
  - 10^{-8} Msun/yr の降着が、1Myr 続けば、10MJ のガス ＝ 0.1MJ のダストが入ってくる

No. 31

Probing the protoplanetary disk gas surface density distribution with ^{13}CO emission

A. Miotello[1,2], S. Facchini[3], E. F. van Dishoeck[2,3], and S. Bruderer

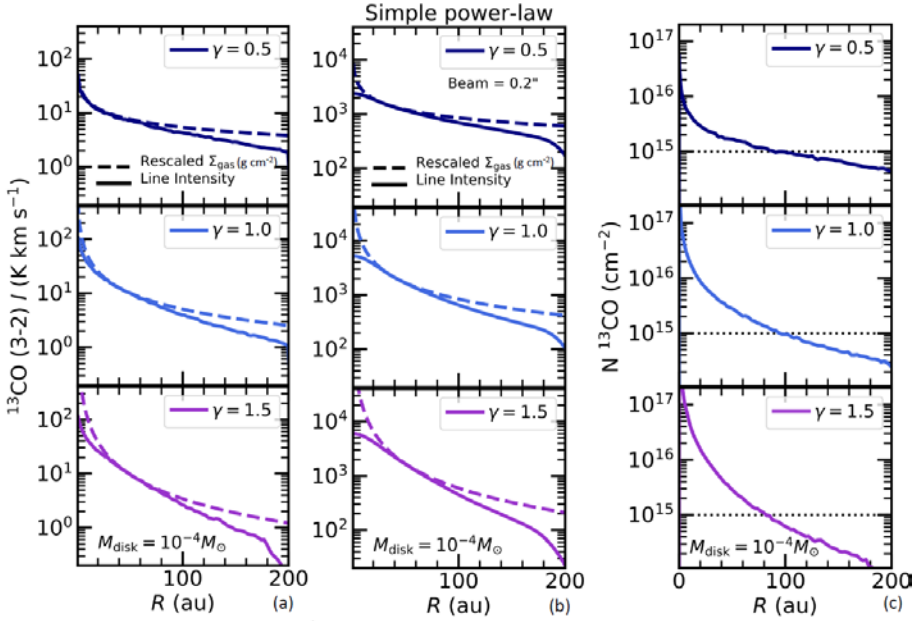
arXiv:1809.00482

- 13CO が、原始惑星系円盤のガス分布のトレーサーとなるかどうかを検証
- 円盤モデルから、輝線放射を計算。放射の分布と面密度の分布を比較
  - DALI を用いた化学反応計算＋円盤構造計算＋non-LTE の level population
  - CO freeze-out と isotope-selective photodissociation の効果が入っている
  - 円盤モデル: 異なるガス質量、power-law vs self-similar disk
  - モデル放射分布（3-10au grid） vs 0.2秒（30au @ 150pc）ビームでconvolution
- 輝線放射の積分強度が 6K km/s 程度になる場所が、13CO の光学的厚みが 1 程度になる場所であり、その付近では、ガスの面密度分布が放射の分布とほぼ一致
  - 内側では光学的に厚すぎる。外側では光学的に薄く、self-shielding が効かない。

$$\Sigma_{\rm gas} = \Sigma_c \left(\frac{R}{R_c}\right)^{-\gamma} \exp\left[-\left(\frac{R}{R_c}\right)^{2-\gamma}\right]$$

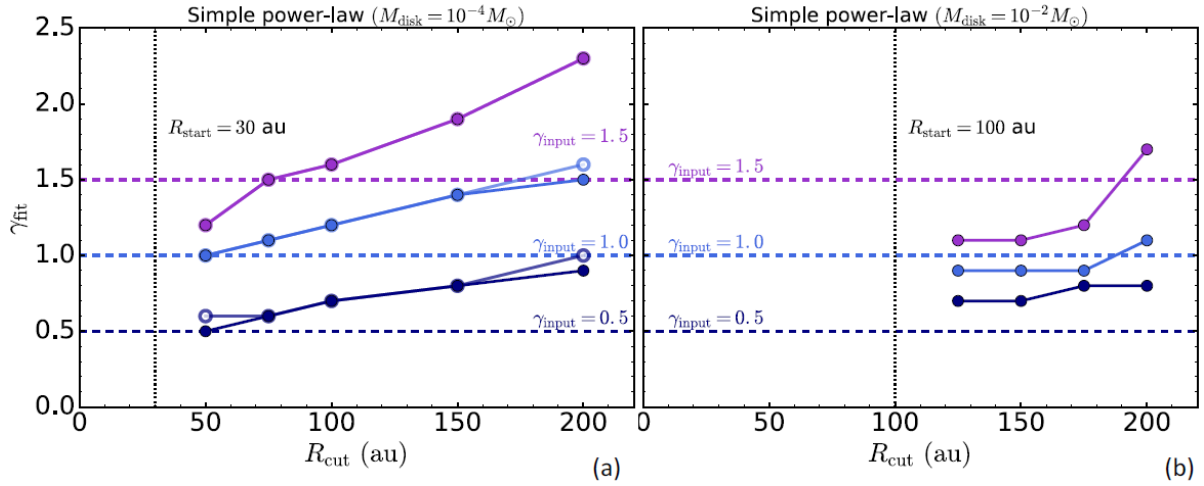
$$\Sigma_{\rm gas} = \begin{cases} \Sigma_c \left(\frac{R}{R_c}\right)^{-\gamma} & R \le R_{\rm out}, \\ 0 & R > R_{\rm out}. \end{cases}$$

Parameter	Value	
	Self similar	Power-law
γ	0.8, 1, 1.5	0.5, 1, 1.5
R_c	30, 60, 200 au	–
$R_{\rm out}$	500 au	100, 200 au
$M_{\rm gas}$	$10^{-5}, 10^{-4}, 10^{-3}, 10^{-2} M_\odot$	$10^{-5}, 10^{-4}, 10^{-3}, 10^{-2} M_\odot$



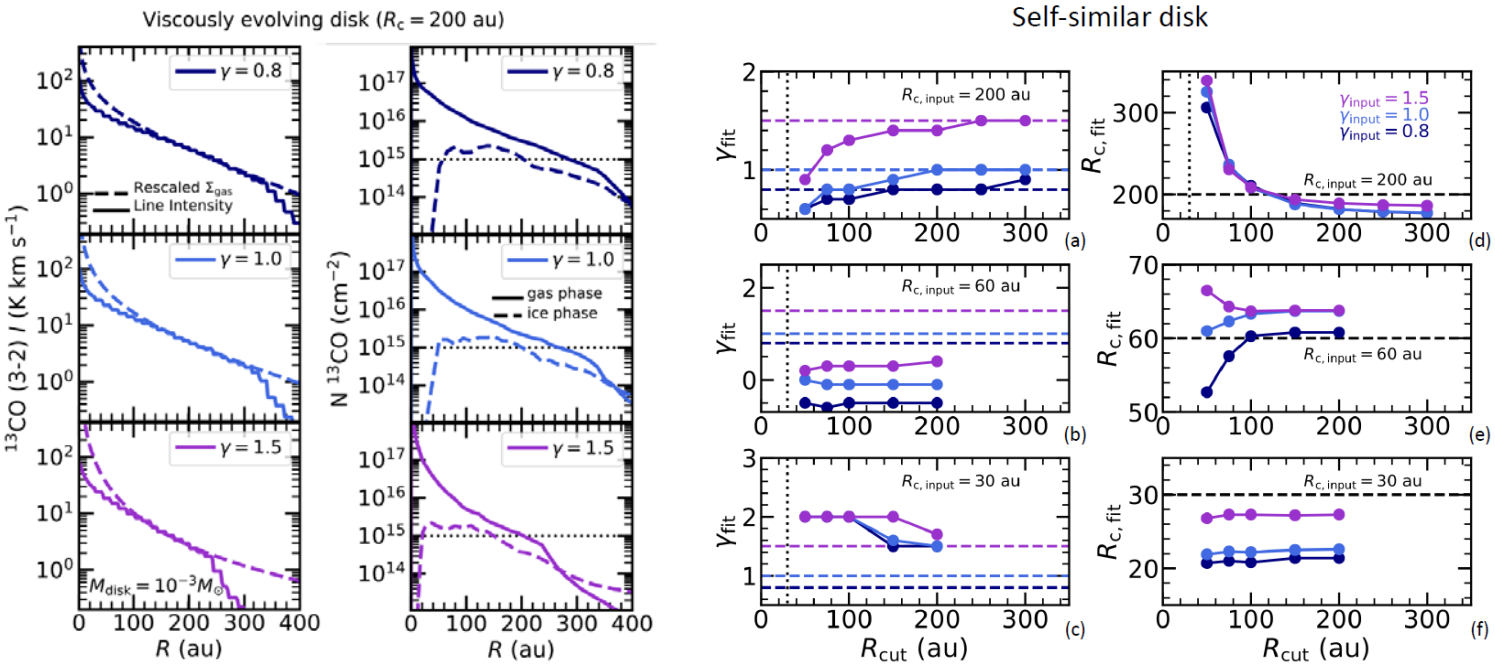
Power-law モデル

- 左：面密度プロファイル（破線）と明るさ分布（実線）の比較。convolution なし
- 中：左と同様。convolution あり。
- 13COの柱密度分布

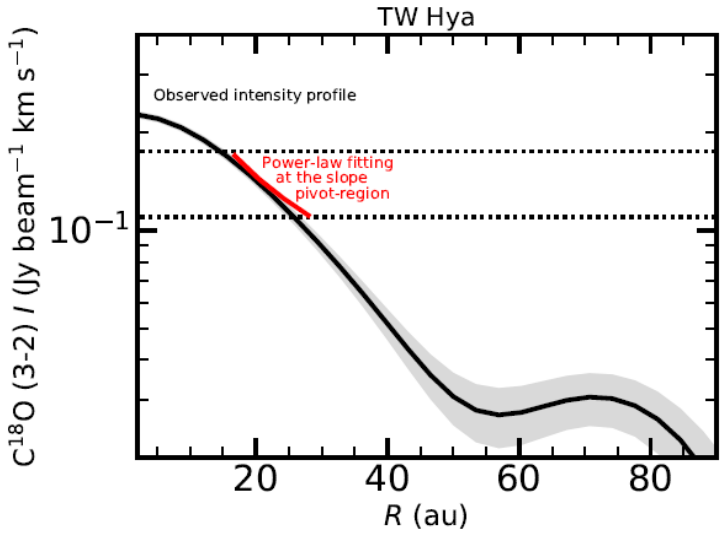


明るさ分布の fit と面密度分布のpower-law の比較

- 横軸：fit の外側半径（内側は固定）
- 縦軸：fit された power-law



粘性円盤モデルでの同様の解析



- TW Hya 観測への適用。
- 13CO が円盤全体で光学的に厚いので、C18O を使っている。
- 0.5x0.3 asec beam の観測
- 0.1-0.2 Jy/beam km/s の範囲で明るさ分布を fit
- Fit された power-law index は 0.85
- 現状の円盤のモデルでは、1 が使われることが多い
- C18O は、isotope-selective photodissociation に影響されているかもしれない

No. 30

ALMA observations of the young protostellar system Barnard 1b: signatures of an incipient hot corino in B1b-S

N. Marcelino[1], M. Gerin[2], J. Cernicharo[1], A. Fuente[3], H. A. Wootten[4], E. Chapillon[5,6], J. Pety[5,2], D. C. Lis[2], E. Roueff[2], B. Commerçon[7], and A. Ciardi[2]

arXiv:1809.08014

The Barnard 1b core shows signatures of being at the earliest stages of low-mass star formation, with two extremely young and deeply embedded protostellar objects. Hence, this core is an ideal target to study the structure and chemistry of the first objects formed in the collapse of prestellar cores. We present ALMA Band 6 spectral line observations at ~0.6″ of angular resolution towards Barnard 1b. We have extracted the spectra towards both protostars, and used a Local Thermodynamic Equilibrium (LTE) model to reproduce the observed line profiles. B1b-S shows rich and complex spectra, with emission from high energy transitions of complex molecules, such as CH_3OCOH and CH_3CHO, including vibrational level transitions. We have tentatively detected for the first time in this source emission from NH_2CN, NH_2CHO, CH_3CH_2OH, CH_2OHCHO, CH_3CH_2OCOH and both *aGg′* and *gGg′* conformers of $(CH_2OH)_2$. This is the first detection of ethyl formate (CH_3CH_2OCOH) towards a low-mass star forming region. On the other hand, the spectra of the FHSC candidate B1b-N are free of COMs emission. In order to fit the observed line profiles in B1b-S, we used a source model with two components: an inner hot and compact component (200 K, 0.35″) and an outer and colder one (60 K, 0.6″). The resulting COM abundances in B1b-S range from 10^{-13} for NH_2CN and NH_2CHO, up to 10^{-9} for CH_3OCOH. Our ALMA Band 6 observations reveal the presence of a compact and hot component in B1b-S, with moderate abundances of complex organics. These results indicate that a hot corino is being formed in this very young Class 0 source.

Complex molecules を、Barnard 1b に見つけている

No. 32

Chemical Signatures of the FU Ori Outbursts

Tamara Molyarova,[1] Vitaly Akimkin,[1] Dmitry Semenov,[2,3] Péter Ábrahám,[4] Thomas Henning,[3] Ágnes Kóspál,[4,3] Eduard Vorobyov,[5,6] and Dmitri Wiebe[1]

arXiv:1809.01925

The FU Ori-type young stellar objects are characterized by a sudden increase in luminosity by 1–2 orders of magnitude, followed by slow return to the pre-outburst state on timescales of ∼10–100 yr. The outburst strongly affects the entire disk, changing its thermal structure and radiation field. In this paper, using a detailed physical-chemical model we study the impact of the FU Ori outburst on the disk chemical inventory. Our main goal is to identify gas-phase molecular tracers of the outburst activity that could be observed after the outburst with modern telescopes such as ALMA and NOEMA. We find that the majority of molecules experience a considerable increase in the total disk gas-phase abundances due to the outburst, mainly due to the sublimation of their ices. Their return to the pre-outburst chemical state takes different amounts of time, from nearly instantaneous to very long. Among the former ones we identify CO, NH_3, C_2H_6, C_3H_4, etc. Their abundance evolution tightly follows the luminosity curve. For CO the abundance increase does not exceed an order of magnitude, while for other tracers the abundances increase by 2–5 orders of magnitude. Other molecules like H_2CO and NH_2OH have longer retention timescales, remaining in the gas phase for $\sim 10-10^3$ yr after the end of the outburst. Thus H_2CO could be used as an indicator of the previous outbursts in the post-outburst FU Ori systems. We investigate the corresponding time-dependent chemistry in detail and present the most favorable transitions and ALMA configurations for future observations.

FU Ori outburst における化学計算＋ALMA観測モデル

No. 33

ORIGIN OF 1I/'OUMUAMUA. I. AN EJECTED PROTOPLANETARY DISK OBJECT?

AMAYA MORO-MARTÍN[1]

arXiv:1810.02148

1I/'Oumuamua is the first interstellar interloper to have been detected. Because planetesimal formation and ejection of predominantly icy objects are common by-products of the star and planet formation processes, in this study we address whether 1I/'Oumuamua could be representative of this background population of ejected objects. The purpose of the study of its origin is that it could provide information about the building blocks of planets in a size range that remains elusive to observations, helping to constrain planet formation models. We compare the mass density of interstellar objects inferred from its detection to that expected from planetesimal disks under two scenarios: circumstellar disks around single stars and wide binaries, and circumbinary disks around tight binaries. Our study makes use of a detailed study of the PanSTARRS survey volume; takes into account that the contribution from each star to the population of interstellar planetesimals depends on stellar mass, binarity, and planet presence; and explores a wide range of possible size distributions for the ejected planetesimals, based on solar system models and observations of its small-body population. We find that 1I/'Oumuamua is unlikely to be representative of a population of isotropically distributed objects, favoring the scenario that it originated from the planetesimal disk of a young nearby star whose remnants are highly anisotropic. Finally, we compare the fluxes of meteorites and micrometeorites observed on Earth to those inferred from this population of interstellar objects, concluding that it is unlikely that one of these objects is already part of the collected meteorite samples.

オウムアムアの起源が近くの原始惑星系円盤だとすると、オウムアムア は、typical な形状などをしているか？結論；typical ではない。

No. 34

Gap Formation in Planetesimal Disks Via Divergently Migrating Planets

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arXiv:1809.10209

While many observed debris disks are thought to have gaps suggestive of the presence of planets, direct imaging surveys do not find many high mass planets in these systems. We investigate if divergent migration is a viable mechanism for forming gaps in young debris disks with planets of low enough mass to currently elude detection. We perform numerical integrations of planet pairs embedded in planetesimal disks to assess the conditions for which divergent, planetesimal-driven migration occurs and gaps form within the disk. Gap widths and the migration rate of planets within a pair depend on both disk mass and the degree to which the planets share disk material. We find that planet pairs with planets more massive than Neptune can produce gaps with widths similar to their orbit distance within 10 Myr at orbit separations probed by direct imaging campaigns. Pairs of migrating super-Earths likely cannot form observable gaps on the same time and distance scales, however. Inferring the responsible planet masses from these gaps while neglecting migration could overestimate the mass of planets by more than an order of magnitude.

デブリ円盤で、重い惑星が見つかっていないのに、gap 構造があることの起源を議論。
N体計算。複数の軽い惑星でギャップをあける

No. 35

The role of environment and gas temperature in the formation of multiple protostellar systems: molecular tracers

N. M. Murillo[1], E. F. van Dishoeck[1,2], J. J. Tobin[3], J. C. Mottram[4], and A. Karska[5]

arXiv:1809.05003

Context. Simulations suggest that gas heating due to radiative feedback is a key factor in whether or not multiple protostellar systems will form. Chemistry is a good tracer of the physical structure of a protostellar system, since it depends on the temperature structure.
Aims. To study the relationship between envelope gas temperature and protostellar multiplicity.
Methods. Single dish observations of various molecules that trace the cold, warm and UV-irradiated gas are used to probe the temperature structure of multiple and single protostellar systems on 7000 AU scales.
Results. Single, close binary and wide multiples present similar current envelope gas temperatures, as estimated from H_2CO and DCO^+ line ratios. The temperature of the outflow cavity, traced by $c-C_3H_2$, on the other hand, shows a relation with bolometric luminosity and an anti-correlation with envelope mass. Although the envelope gas temperatures are similar for all objects surveyed, wide multiples tend to exhibit a more massive reservoir of cold gas compared to close binary and single protostars.
Conclusions. Although the sample of protostellar systems is small, the results suggest that gas temperature may not have a strong impact on fragmentation. We propose that mass, and density, may instead be key factors in fragmentation.

星が単独星として生まれるか binary になるかの違いが、周囲のガスの温度と関係するかを、単一鏡の分子のデータを使って調べる。
周囲の温度はあまり関係無さそう。

No. 36

RADIATION HYDRODYNAMICS SIMULATIONS OF PHOTOEVAPORATION OF PROTOPLANETARY DISKS II: METALLICITY DEPENDENCE OF UV AND X-RAY PHOTOEVAPORATION

Riouhei Nakatani[1], Takashi Hosokawa[2], Naoki Yoshida[1,3,4], Hideko Nomura[5], and Rolf Kuiper[6]

arXiv:1809.07992

We perform a suite of radiation hydrodynamics simulations of photoevaporating disks with varying the metallicity in a wide range of $10^{-3}\ Z_\odot \leq Z \leq 10^{0.5}\ Z_\odot$. We follow the disk evolution for over ~ 5000 years by solving hydrodynamics, radiative transfer, and non-equilibrium chemistry. Our chemistry model is updated from the first paper of this series by adding X-ray ionization and heating. We study the metallicity dependence of the disk photoevaporation rate and examine the importance of X-ray radiation. In the fiducial case with solar metallicity, including the X-ray effects does not significantly increase the photoevaporation rate when compared to the case with ultra-violet (UV) radiation only. At sub-solar metallicities in the range of $Z \gtrsim 10^{-1.5}\ Z_\odot$, the photoevaporation rate increases as metallicity decreases owing to the reduced opacity of the disk medium. The result is consistent with the observational trend that disk lifetimes are shorter in low metallicity environments. Contrastingly, the photoevaporation rate decreases at even lower metallicities of $Z \lesssim 10^{-1.5}\ Z_\odot$, because dust-gas collisional cooling remains efficient compared to far UV photoelectric heating whose efficiency depends on metallicity. The net cooling in the interior of the disk suppresses the photoevaporation. However, adding X-ray radiation significantly increases the photoevaporation rate, especially at $Z \sim 10^{-2}\ Z_\odot$. Although the X-ray radiation itself does not drive strong photoevaporative flows, X-rays penetrate deep into the neutral region in the disk, increase the ionization degree there, and reduce positive charges of grains. Consequently, the effect of photoelectric heating by far UV radiation is strengthened by the X-rays and enhances the disk photoevaporation.

光蒸発の輻射流体計算。Metalicity の依存性や、X線・UV の影響を議論。
光蒸発は、太陽近傍の分子量に比べて 30倍程度小さいときが最も強い。