星形成ゼミ

The Star Formation Newsletter 339

1~7

徳田一起 (大阪府立大学/NAOJ)

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33(1)

Complex structure of a proto-brown dwarf

B. Riaz,[1]★ M. N. Machida[2]
[1]*Universitäts-Sternwarte München, Ludwig-Maximilians-Universität, Scheinerstr. 1, 81679 München, Germany*
[2]*Department of Earth and Planetary Sciences, Faculty of Sciences, Kyushu University, Fukuoka, Japan*

アブストラクト

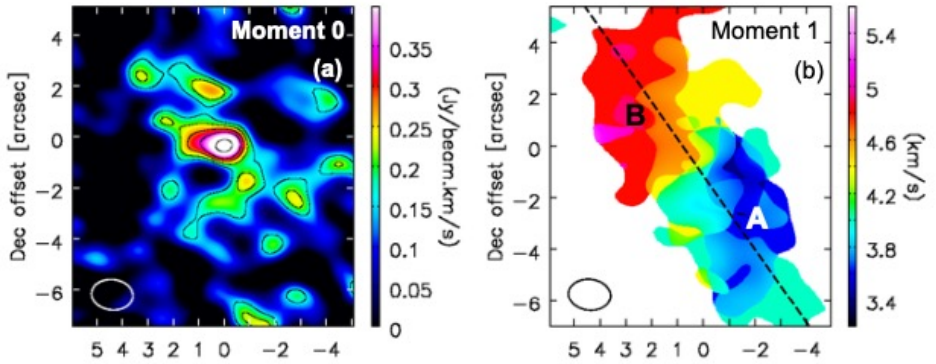
観測: ALMA 12CO, 13CO, C18O (2-1) + 連続波 分解能は大体1.”4 (= 200 au)

天体 ISO-OPH 200 (へびつかい座 距離 d~144 pc, L_bol~0.08 Lo, L_int ~0.06 Lo)

理論計算: 分子雲コア=>褐色矮星の物理/化学モデリング (Machida+09の改良版)

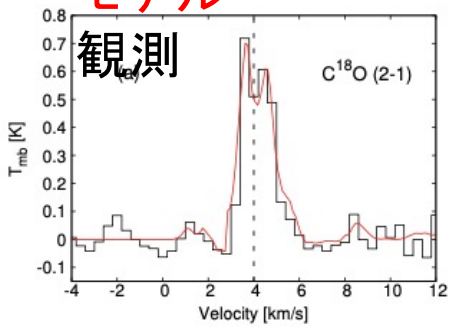
~6000 yrモデル (+inclination ~30deg)が、観測の特徴をよく再現

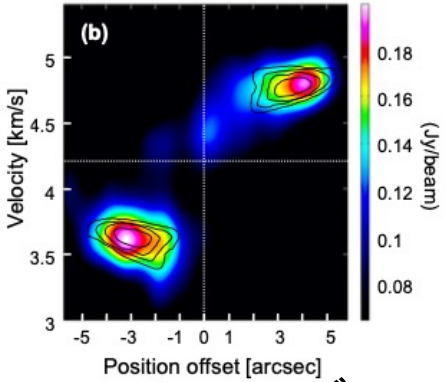
- C18O: 内側の~500 auのpseudo-disc



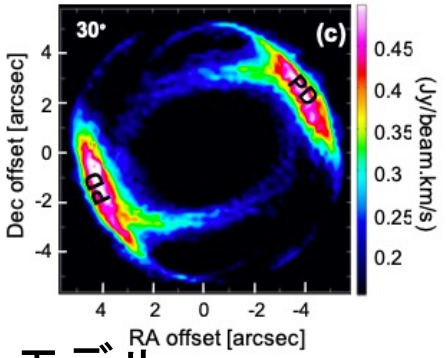
観測されたC18O Mom0とMom1

モデル





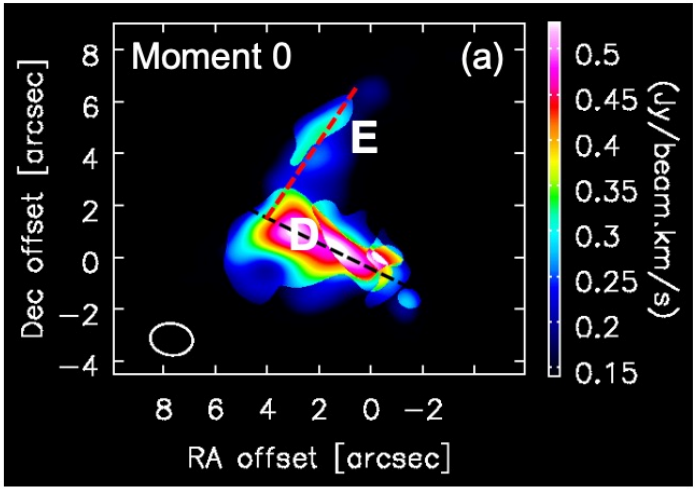
コントア;モデル



モデル

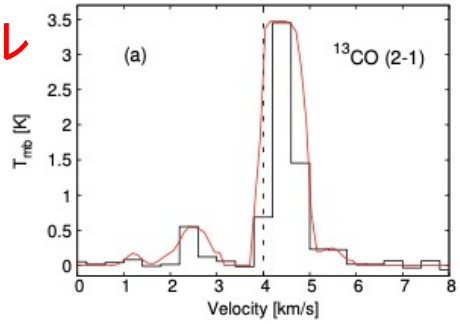
PD
=>Pseudo-disc

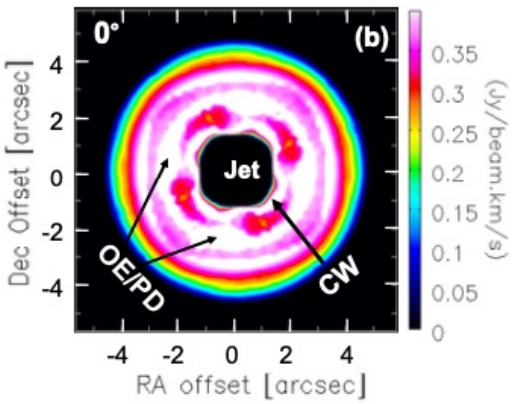
- 13CO: 外側の~1000 auのエンベロープ/pseudo-discをトレース

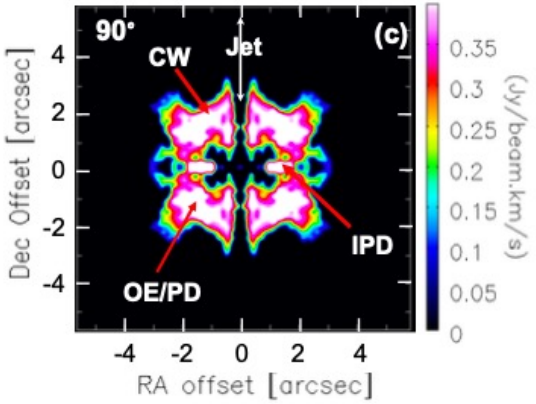


観測された13COの
Moment0マップ
(0,0)が原始星の位置

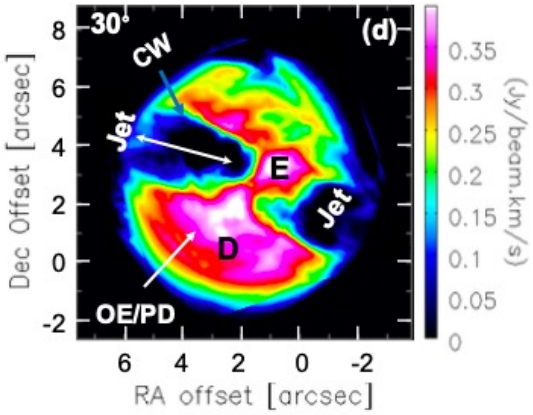
モデル
観測

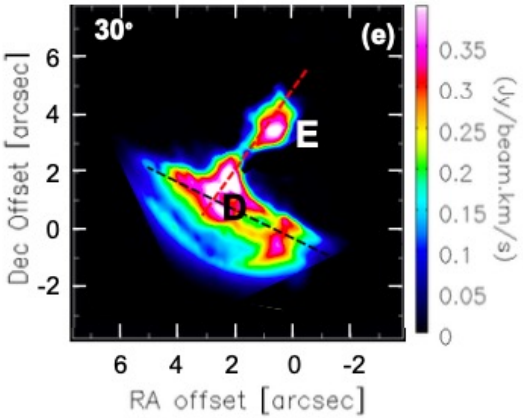






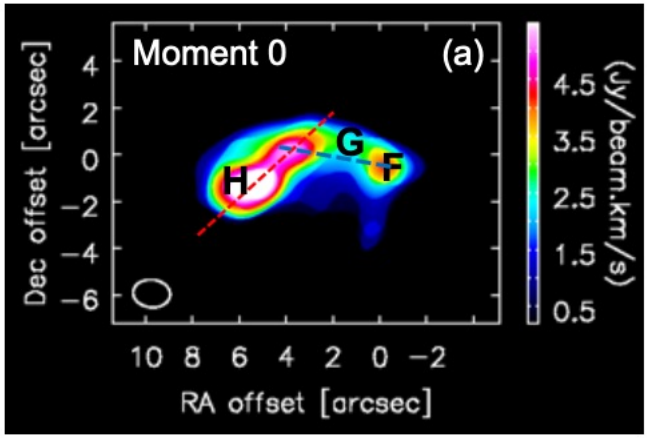
Best-fit モデル





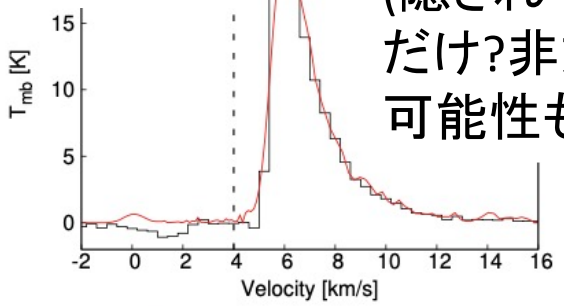
OE: outer envelope
PD: Pseudo-disc
CW: outflow cavity wall

33(3)　　- 12CO: ~1000 au程度のoutflowとshock のノット

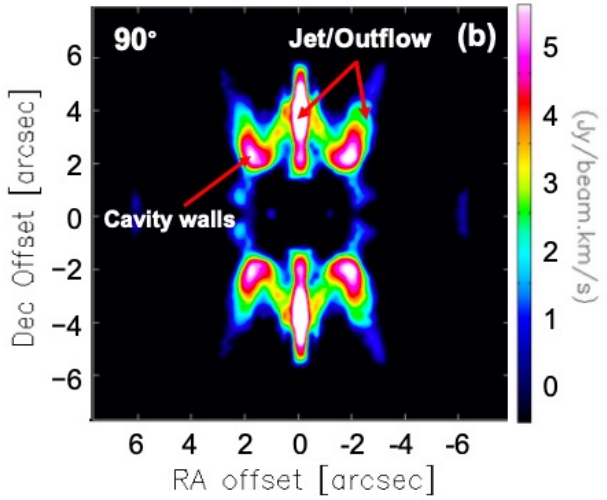


観測された12COの
Moment0マップ
(0,0)が原始星の位置

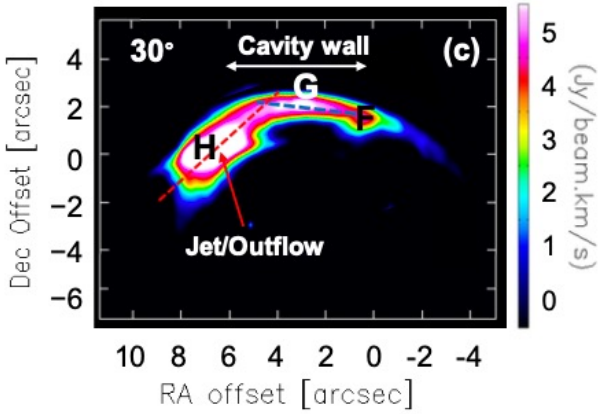
12COモデル
12CO観測



両方とも
Blue側は見えていない
(隠されて見えていない
だけ?非対称outflowの
可能性も棄却できない)



Best-fit モデル



まとめ
-モデルとの比較より: Class-Flatと思われてたが、outflowがpole-onっぽくてもっと若い
-proto-brown dwarfの観測された複雑な構造の解釈を与える (要はviewing angleのせい？)
-この天体はきっとClass 0の段階に近い, 褐色矮星矮星が分子雲コアの収縮で生まれる
メモ: 中心星の質量は求めたかったようだが無理だったようだ

New Mid-Infrared Imaging Constraints on Companions and Protoplanetary Disks around six Young Stars

D. J. M. Petit dit de la Roche, N. Oberg, M. E. van den Ancker, I. Kamp, R. van Boekel, D. Fedele, V. D. Ivanov, M. Kasper, H. U. Käufl, M. Kissler-Patig, P. A. Miles-Páez, E. Pantin, S. P. Quanz, Ch. Rab, R. Siebenmorgen, L. B. F. M. Waters ★ Mid-infrared imaging traces the sub-micron and micron sized dust grains in protoplanetary disks and it offers constraints on the geometrical properties of the disks and potential companions, particularly if those companions have circumplanetary disks. We use the VISIR instrument and its upgrade NEAR on the VLT to take new mid-infrared images of five (pre-)transition disks and one circumstellar disk with proposed planets and obtain the deepest resolved mid-infrared observations to date in order to put new constraints on the sizes of the emitting regions of the disks and the presence of possible companions. We derotate and stack the data to find the disk properties. Where available we compare the data to ProDiMo (Protoplanetary Disk Model) radiation thermo-chemical models to achieve a deeper understanding of the underlying physical processes within the disks. We apply the circularised PSF subtraction method to find upper limits on the fluxes of possible companions and model companions with circumplanetary disks. We resolve three of the six disks and calculate position angles, inclinations and (upper limits to) sizes of emission regions in the disks, improving upper limits on two of the unresolved disks. In all cases the majority of the mid-IR emission comes from small inner disks or the hot inner rims of outer disks. We refine the existing ProDiMo HD 100546 model SED fit in the mid-IR by increasing the PAH abundance relative to the ISM, adopting coronene as the representative PAH, and increase the outer cavity radius to 22.3 AU. We produce flux estimates for putative planetary-mass companions and circumplanetary disks, ruling out the presence of planetary-mass companions with $L > 0.0028 L_{\odot}$ for $a > 180$ AU in the HD 100546 system. Upper limits of 0.5 mJy-30 mJy are obtained at 8 μm-12 μm for potential companions in the different disks.

35 **Undetected Binary Stars Cause an Observed Mass Dependent Age Gradient in Upper Scorpius**

Kendall Sullivan, Adam Kraus ★ Young stellar associations represent a key site for the study of star formation, but to accurately compare observations to models of stellar evolution, the age of an association must be determined. The Upper Scorpius region is the youngest section of the Scorpius-Centaurus OB association, which is the largest collection of nearby, young, low-mass stars. The true age of Upper Scorpius is not clear, and an observed mass-dependent age gradient in Upper Scorpius, as well as in other star-forming regions, complicates age measurements. The age gradient may indicate a genuine astrophysical feature or may be an artifact of unrecognized systematic effects in stellar age measurements. We have conducted a synthetic red-optical low-resolution spectroscopic survey of a simulated analog to the Upper Scorpius star-forming region to investigate the effects of unresolved binary stars (which have mass-dependent demographics) on age measurements of a stellar population. We find that the observed mass-dependent age gradient in Upper Scorpius can be explained by a population of undetected binary stars. For a simulated population with an age of 10 (RMS = 2) Myr, we measure an age of 10.5 (RMS = 3.5) Myr for F stars, and 7.5 (RMS = 5.8) Myr for M stars. This discrepancy is caused by the mass-dependent mass ratio distribution and the variable steepness of the mass-luminosity relation. Our results support the previously suggested 10 Myr age for Upper Scorpius, with a small intrinsic age spread.

観測される星形成領域(Upper Sco)の若い星のAge gradient はリアルなのか？
分解されていない連星で説明できる

やったこと: 赤外線の擬似観測
10 (RMS = 2) 年の星の集団を観測、
F星の年齢は10.5 (RMS = 3.5) 年、M型星の年齢は7.5 (RMS = 5.8) 年となった。
今回の結果は、Upper Scoの年齢が10Myrであることを支持するものであり、固有の年齢の広がりは小さい。

35(1)

用意する星の質量分布

The Chabrier IMF has a log-normal form on its low-mass end, and follows a Salpeter (1955) power law form on the higher-mass end, and thus has the functional form

$$\xi(\log(m)) \propto \begin{cases} \exp(\frac{(\log(m)-\log(m_c)^2}{2\sigma^2}) & \text{if } m \leq M_{cutoff} \\ m^{-\alpha} & \text{if } m > M_{cutoff} \end{cases}$$

- Mean mass of lognormal distribution $m_c = 0.2M_\odot$
- Standard deviation of lognormal distribution $\sigma = 0.55$ dex
- Cutoff mass $M_{cutoff} = 1M_\odot$
- Salpeter power law slope $\alpha = -1.3$

Table 1. Summary of data used to infer mass-dependent models

Spectral type	Approx. mass [a] ($M_\odot$)	$\mu_{\log_{10}(a)}$ ($\log(AU)$)	$\sigma_{\log_{10}(a)}$ ($\log(AU)$)	Ref.	Γ[b]	Ref.	Multiplicity	Ref.
A0	2	2.59 ± 0.13	0.79 ± 0.12	(1)	$-2.3^{+1.0}_{-0.9}$	(1)	70%	(1)
G0	1	1.65 ± 0.5[c]	1 ± 0.2[c]	(2)	0 ± 0.5[c]	(2)	45%	(2)
M0	0.6	$1.69^{+1.5}_{-1.0}$	1 ± 0.1	(3,4)	$0.18^{+0.33}_{-0.30}$	(3)	45%	(5)
M4	0.2	$1^{+0.7}_{-0.33}$	0.8 ± 0.2	(3,4)	$1.02^{+0.59}_{-0.52}$	(3)	35%	(3)
M9	0.1	$0.65^{+0.16}_{-0.11}$	0.6 ± 0.1	(3)	$4^{+1.9}_{-1.6}$	(3)	25%	(3)

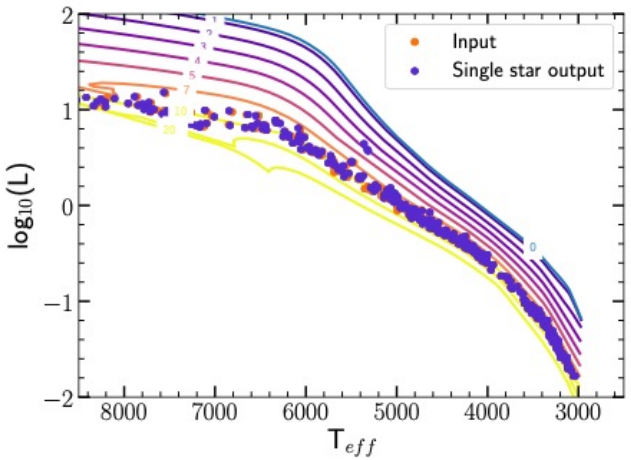
平均
連星間距離　標準偏差

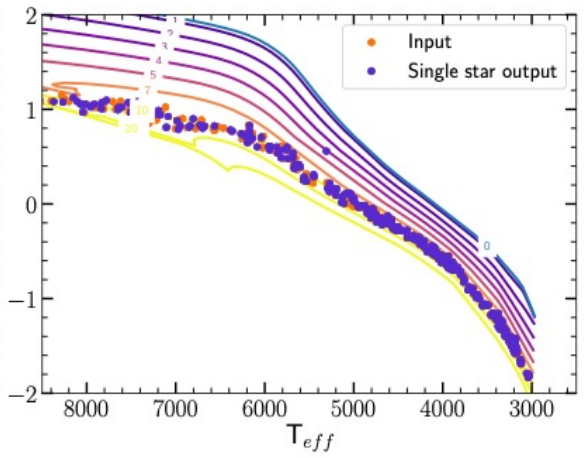
連星間の質量比
1Moで1になり、軽いほど質量比が大きい

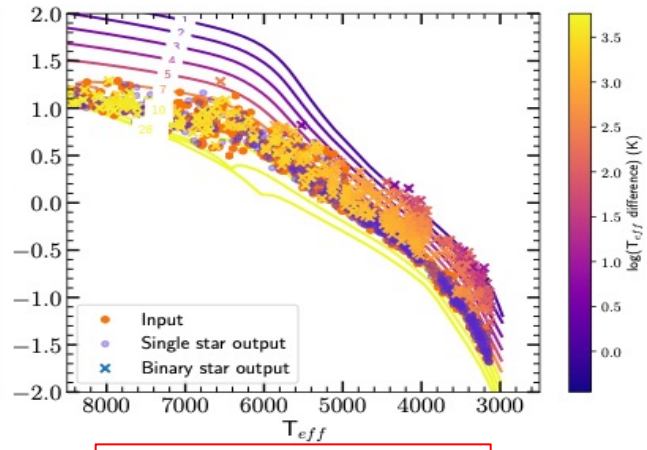
星の年齢は10Myr (平均) で分散 2 Myrをinput
PHEONIX と呼ばれる(Husser+13)というコードを用いてスペクトルを計算
これを大体>1."5 (210au at 140 pcの距離)の分解能で観測

35(2)

距離は正しくした





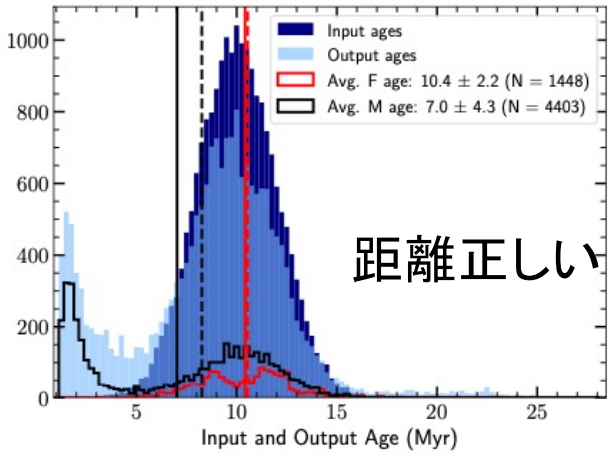


Single-star でAvなし

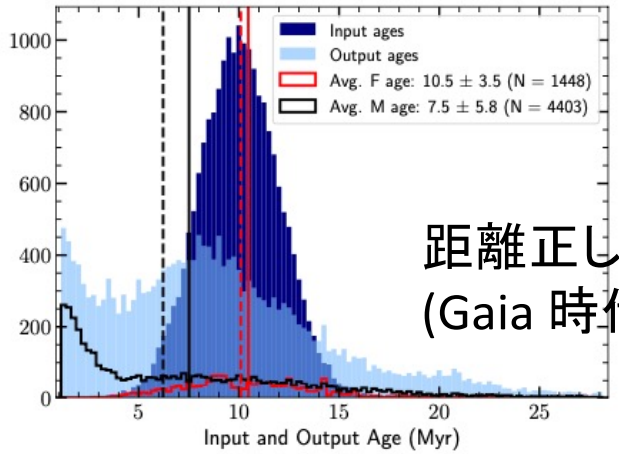
Single-star でAvあり

全部入れたの

Binaryを入れたものは明らかにAge spread がある



距離正しい



距離正しくない
(Gaia 時代以前の精度)

この研究の示唆: 年齢を5-10 Myrで精度で求めるならbinary の存在を考慮
(もちろん距離はちゃんと考慮に入れる)
この研究で考えていない物理: 星の磁場

OH mid-infrared emission as a diagnostic of H_2O UV photodissociation. I. Model and application to the HH 211 shock

Benoît Tabone, Marc C. van Hemert, Ewine F. van Dishoeck, John H. Black ★

Water is an important molecule in interstellar and circumstellar environments. Previous observations of mid-infrared rotational lines of OH suggest that these lines may be used to probe the photodissociation of water. In this work, cross sections for the photodissociation of H_2O resolving the state of the OH fragment are collected and incorporated in a new molecular excitation code called GROSBETA, which includes radiative pumping, collisional (de)excitation, and prompt emission (i.e., following the production of OH in excited states). We find that the OH rotational line intensities in the range 9-16μm, covering rotational transitions with $N_{up} = 18$ to 45, are proportional to the column density of H_2O photodissociated per second by photons in the range 114-143nm and do not depend on other local properties. Provided an independent measurement of the column density of water is available, the strength of the local UV radiation field can be deduced with good accuracy. In contrast, the OH lines at longer far-infrared wavelengths are primarily produced by IR radiative pumping and collisions. Our model successfully reproduces the OH mid-IR lines in the $10 - 16\mu$m range observed by Spitzer toward the tip of the HH 211 bow-shock and shows that the jet shock irradiates its surroundings, exposing H_2O to a UV photon flux that is about 5×10^3 times larger than the standard interstellar radiation field. We also find that chemical pumping by the reaction $H_2 + O$ may supplement the excitation of lines in the range $16 - 30\mu$m. The mid-infrared lines of OH constitute a powerful diagnostic for inferring the photodissociation rate of water and thus the UV field water is exposed to. Future JWST-MIRI observations will be able to map the photodestruction rate of H_2O in various dense and irradiated environments and provide robust estimates of the local UV radiation field.

37

Carbon Chain Chemistry in Hot-Core Regions around Three Massive Young Stellar Objects Associated with 6.7 GHz Methanol Masers

Kotomi Taniguchi, Eric Herbst, Liton Majumdar, Paola Caselli, Jonathan C. Tan, Zhi-Yun Li, Tomomi Shimoikura, Kazuhito Dobashi, Fumitaka Nakamura, Masao Saito

★ We have carried out observations of CCH ($N = 1-0$), CH_3CN ($J = 5 - 4$), and three ^{13}C isotopologues of HC_3N ($J = 10 - 9$) toward three massive young stellar objects (MYSOs), G12.89+0.49, G16.86–2.16, and G28.28–0.36, with the Nobeyama 45-m radio telescope. Combined with previous results on HC_5N, the column density ratios of $N(CCH)/N(HC_5N)$, hereafter the CCH/HC_5N ratios, in the MYSOs are derived to be $\sim$ 15. This value is lower than that in a low-mass warm carbon chain chemistry (WCCC) source by more than one order of magnitude. We compare the observed CCH/HC_5N ratios with hot-core model calculations (Taniguchi et al. 2019). The observed ratios in the MYSOs can be best reproduced by models when the gas temperature is $\sim$ 85 K, which is higher than in L1527, a low-mass WCCC source ($\sim$ 35 K). These results suggest that carbon-chain molecules detected around the MYSOs exist at least partially in higher temperature regions than those in low-mass WCCC sources. There is no significant difference in column density among the three ^{13}C isotopologues of HC_3N in G12.89+0.49 and G16.86-2.16, while $HCC^{13}CN$ is more abundant than the others in G28.28–0.36. We discuss carbon-chain chemistry around the three MYSOs based on the CCH/HC_5N ratio and the ^{13}C isotopic fractionation of HC_3N.

野辺山45m望遠鏡による
3つの大質量星原始星の観測 G12.89+0.49, G16.86-2.16, G28.28-0.36
decli<-21deg, 距離が3kpc以内, CH3CNがそこそこ強い at Mopra
6.7 GHzのメタノールメーザーが付随している

観測輝線: CCH, CH3CN, HC3Nの13C同位体種
過去に得られていたデータ: HC5N
CCH/HC5Nの柱密度比 ~ 15 =>小質量星WCCCソースよりも1桁以上小さい
アバンダンスを説明しようとすると、85 K必要 (L1527の35 Kより高い)
大質量星原始星周りの炭素鎖分子は温度が高い領域にある

13C同位体種の差はない: G12.89+0.49, G16.86-2.16
HCC13CNはG28.28-0.36で多かった

38

Chemical modeling of the complex organic molecules in the extended region around Sagittarius B2

Yao Wang, Fujun Du, Dmitry Semenov, Hongchi Wang, Juan Li ★ The chemical differentiation of seven COMs in the extended region around Sgr B2 has been observed: CH_2OHCHO, CH_3OCHO, t-HCOOH, C_2H_5OH, and CH_3NH_2 were detected both in the extended region and near the hot cores Sgr B2(N) and Sgr B2(M), while CH_3OCH_3 and C_2H_5CN were only detected near the hot cores. The density and temperature in the extended region are relatively low. Different desorption mechanisms have been proposed to explain the observed COMs in cold regions but fail to explain the deficiency of CH_3OCH_3 and C_2H_5CN. We explored under what physical conditions the chemical simulations can fit the observations and explain the different spatial distribution of these species. We used the Monte Carlo method to perform a detailed parameter space study. We investigated how different mechanisms affect the results. All gas-grain chemical models based on static physics cannot fit the observations. The results based on evolving physical conditions can fit six COMs when $T \sim 30 - 60$ K, but the best-fit temperature is still higher than the observed dust temperature of 20 K. The best agreement at $T \sim 27$ K is achieved by considering a short-duration $\sim 10^2$ yr X-ray burst with $\zeta_{CR} = 1.3 \times 10^{-13}$ s^{-1} when the temperature is 20 K. The reactive desorption is the key mechanism for producing these COMs and inducing the low abundances of CH_3OCH_3 and C_2H_5CN. The evolution of the extended region around Sgr B2 may have begun with a cold, $T \leq 10$ K phase followed by a warm-up phase. When its temperature reached $T \sim 20$ K, an X-ray flare from Sgr A* with a short duration of no more than 100 years was acquired, affecting strongly the Sgr B2 chemistry. The observed COMs retain their observed abundances only several hundred years after such a flare, which could imply that such short-term X-ray flares occur relatively often.

Sgr B2の有機分子をモデリングする
広がった領域+ホットコアで見える分子: CH2OHCHO, CH3OCHO, t-HCOOH, C2H5OH, and CH3NH2
ホットコア, Sgr B2(N)とSgr B2(M)のみで検出される 分子: CH3OCH3 and C2H5CN

これらのうちどちらかというと広がった領域に興味がある

結論: 10K以下のcold phase から始まり=> warm up phaseがあった。
Sgr B2の温度が約20Kに達したとき、ブラックホールSgr A*からの<100年の長さのX線フレアが発生し、Sgr B2の化学反応に強い影響を与えた。
Sgr B2で観測されたCOMsは、このフレアから数百年以下しか観測された組成を維持していることから、このような短時間のX線フレアは比較的頻繁に起きている？Sgr A*の降着活動と関連か？

39(1)

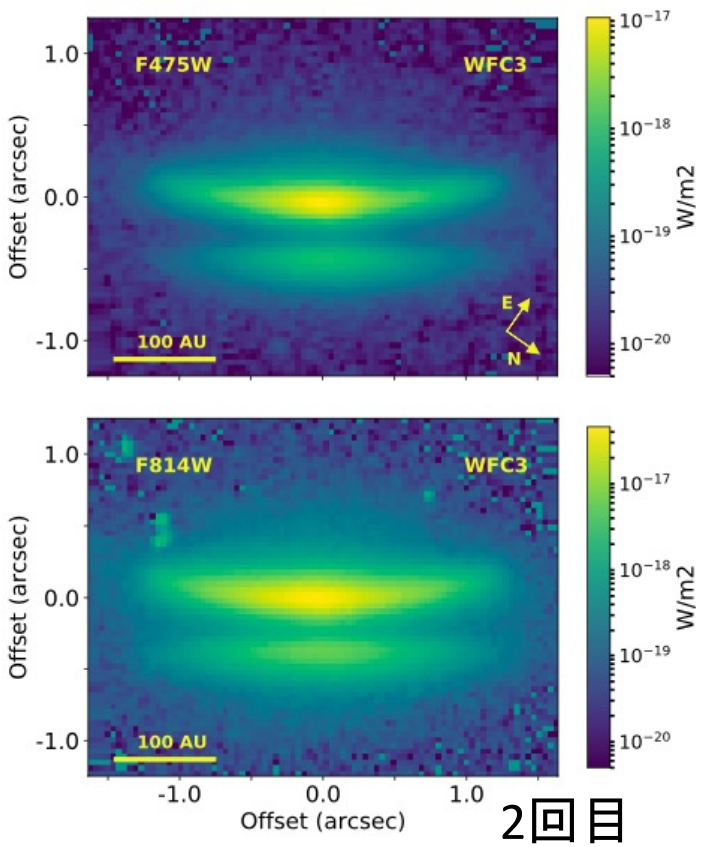
The Anatomy of an Unusual Edge-on Protoplanetary Disk I. Dust Settling in a Cold Disk

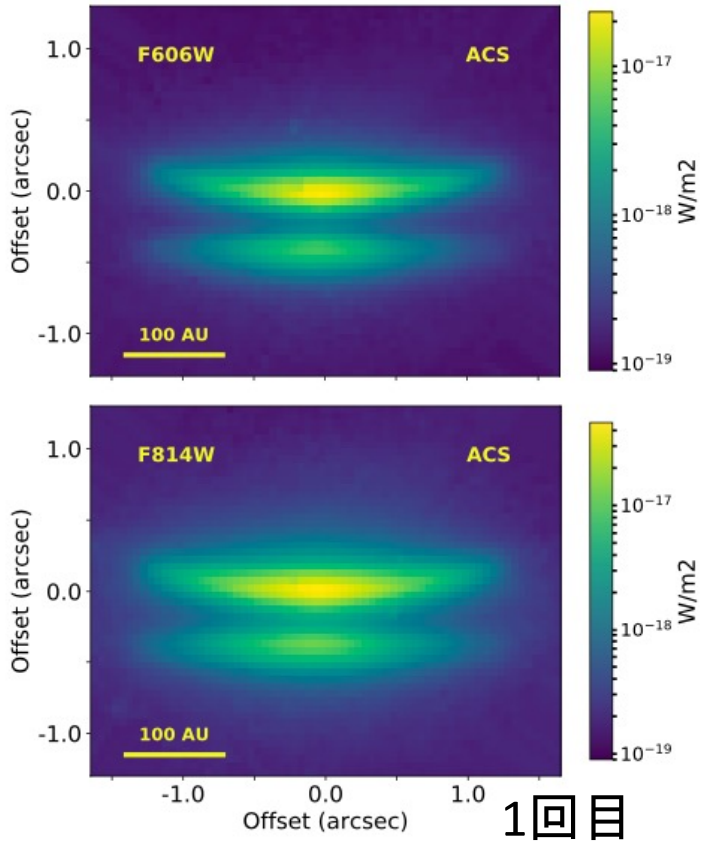
Schuyler G. Wolff,[1,2] Gaspard Duchêne,[3,4] Karl R. Stapelfeldt,[5] Francois Ménard,[4] Christian Flores,[6] Deborah Padgett,[7] Christophe Pinte,[8,9] Marion Villenave,[4] Gerrit van der Plas,[4] and Marshall D. Perrin[10]

観測天体: 2MASS J16313124-2426281 (hereafter Oph163131)
のHSTのmulti-epoch (F475W, F606W, F814W), Keck 2.2μm
+ ALMA の連続波(Band 6,7)の観測

・天体について

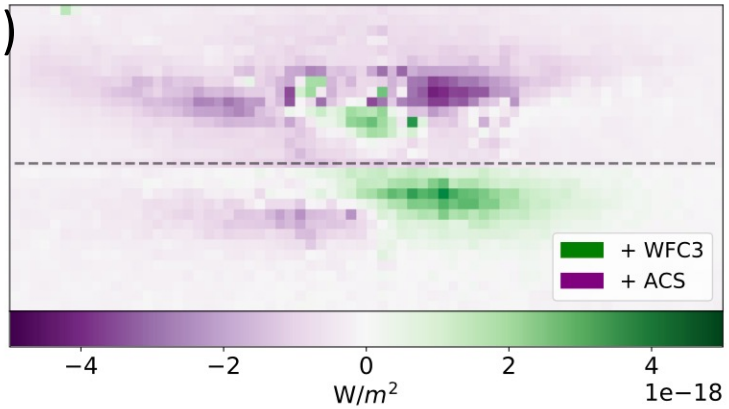
Dunham+08がρOph領域 (d~147 pc)見つけたが、高密度領域にはいない天体
Evans+09では赤外の超過を見つけたのでYSOと同定
=>赤外や可視光ですごく弱いということは、edge-onの天体である



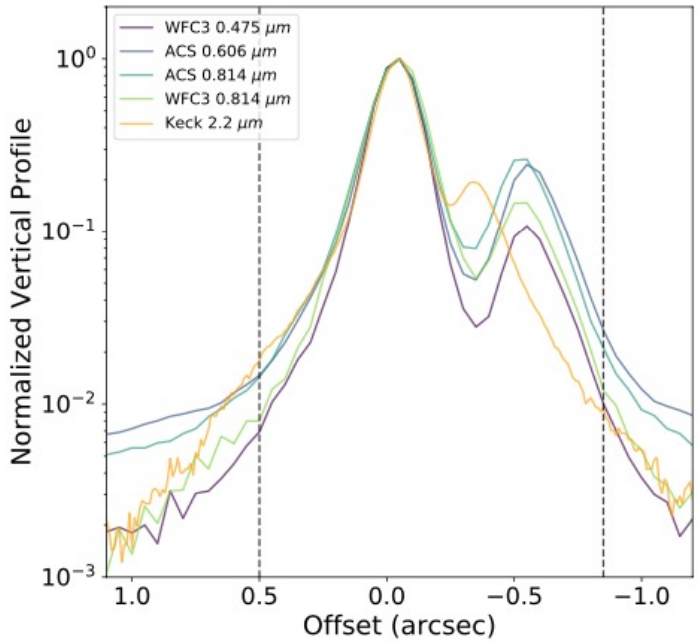


HST散乱光の図
観測
1回目:2012/3/4
ACS/F606W
ACS/F814W
2回目:2013/10/3
WFC3/F475W
WFC2/814W

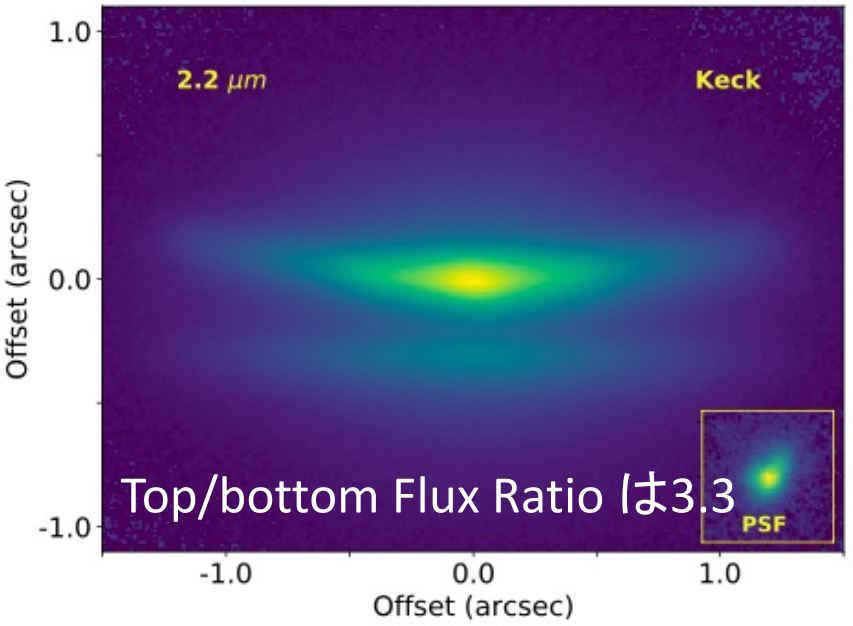
39(2)

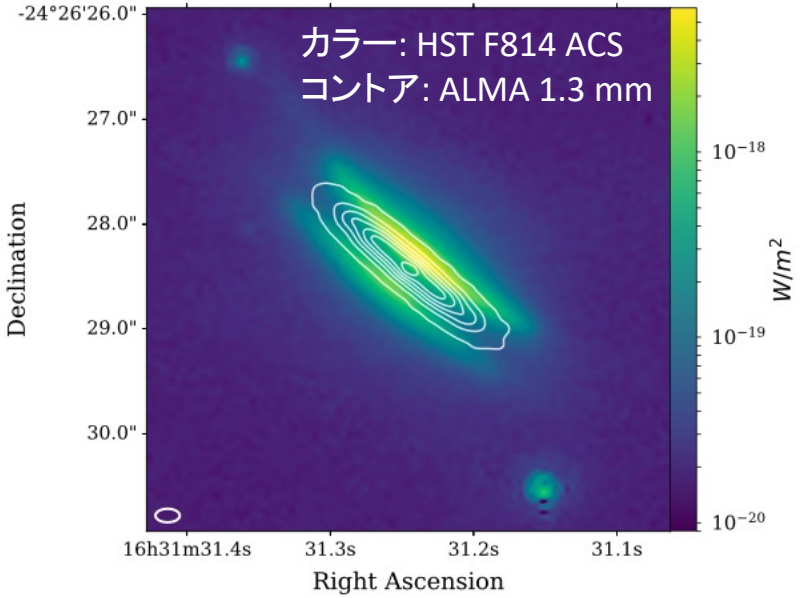


F814同士のMulti-epochでの差

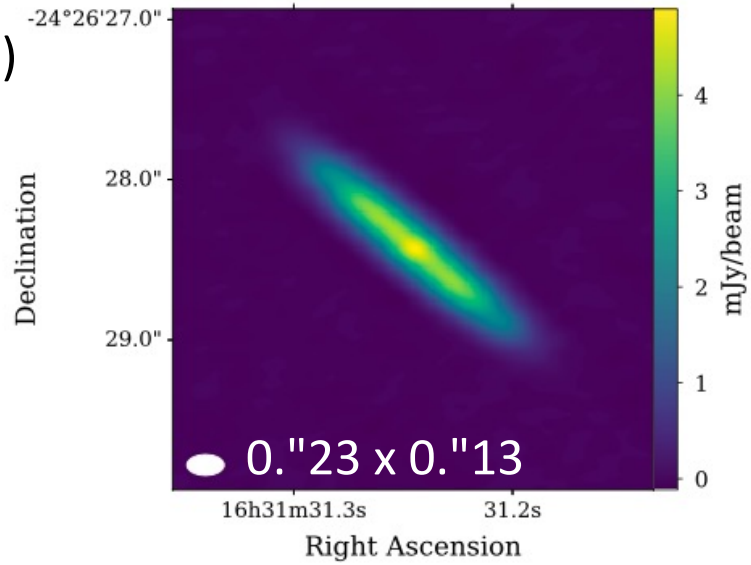


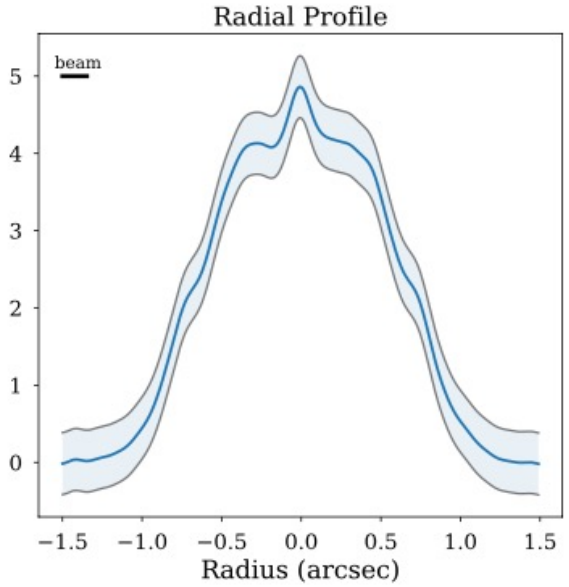
2.2μmだけプロファイルの凹み方が違う=>mid-planeに近いlarge grain を捉えている？

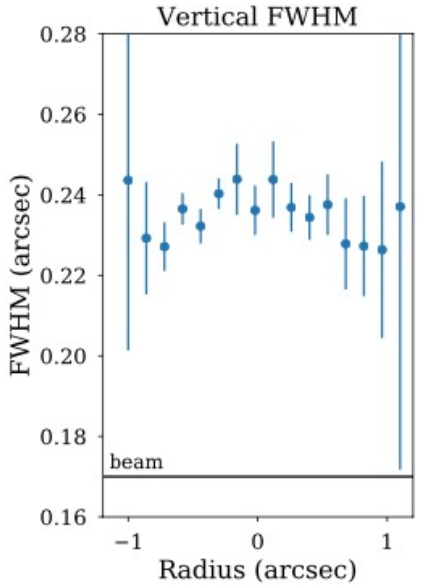




39(3)







3章以降で輻射輸送モデルを行う (詳細は飛ばします)

星のパラメータ: K3.5-K5.5 spectral type, 4500 K, 0.96 Lo, 1.7 Ro, 1.0 Mo

We chose a tapered-edge axisymmetric disk model in which the surface density Σ is described by a power law in radius (R) with an exponential taper outside of the critical radius R_c:[1]

$$\Sigma = \Sigma_c \left(\frac{R}{R_c}\right)^{-\gamma} \exp\left[\left(-\frac{R}{R_c}\right)^{2-\gamma}\right] \quad (1)$$

The disk gas scale height is also defined as a power law in radius by $H(R) = H_0(R/R_0)^{\beta}$ where β is the flaring exponent describing the curvature of the disk surface with a reference radius $R_0 = 100$ au.

Table 2. MCMC Parameter Priors

Parameter	Range
Inclination (i in degrees)	65.0 - 90.0
Scale Height (H_0 in au)	5.0 - 25.0
Dust Mass* (M in $M_\odot$)	10^{-6} - 10^{-3}
Surface Density Exponent (γ)	0.0 - 2.0
Flaring Exponent (β)	1.0 - 2.0
Grain size exponent (p)	2.5 - 4.0
Viscous Settling Param.* (α)	10^{-5} - 10^{-1}
Critical Radius (R_C in au)	25.0 - 191.0

NOTE—Parameters marked with an * use log-uniform priors. All other parameters use uniform priors.

結論

・ダストの沈殿のある比較的フラットなdisk

・ALMAと散乱光両方を合わせこんだfitはmarginal success =>より複雑なdiskの構造の存在を示唆)

Description of turbulent dynamics in the interstellar medium: multifractal/microcanonical analysis I. Application to Herschel observations of the Musca filament

H. Yahia, N. Schneider, S. Bontemps, L. Bonne, G. Attuel, S. Dib, V. Ossenkopf, A. Turiel, A. Zebadua, D. Elia, S. K. Maji, F. G. Schmitt, J. -F Robitaille ★ Observations of the interstellar medium (ISM) show a complex density and velocity structure which is in part attributed to turbulence. We here present a self-contained introduction to the multifractal formalism in a microcanonical version which allows us for the first time to compute precise turbulence characteristic parameters from a single observational map without the need for averages in a grand ensemble of statistical observables. We focus on studying the 250 mu-m Herschel map of the Musca filament and make use of MHD simulations. We find a clear signature of a multiplicative cascade in Musca with an inertial range from 0.05 to 0.65 pc. We show that the proposed microcanonical approach provides singularity spectra which are truly scale invariant as required to validate any method to analyze multifractality. The obtained, for the first time precise enough, singularity spectrum of Musca is clearly not as symmetric as usually observed in log-normal behavior. We claim that the ISM towards Musca features more a log-Poisson shape of its singularity spectrum. Since log-Poisson behavior is claimed to exist when dissipation is stronger for rare events in turbulent flows in contrast to more homogeneous (in volume and time) dissipation events, we suggest that this deviation from log-normality could trace enhanced dissipation in rare events at small scales, which may explain or is at least consistent with the dominant filamentary structure in Musca. Moreover we find that sub-regions in Musca tends to show different multifractal properties. It strongly suggests that different types of dynamics exist inside the Musca cloud. These differences between sub-regions appear only after eliminating noise features which have the tendency to "log-normalize" an observational map. Our study sets up fundamental tools which will be applied to other galactic clouds and simulations in forthcoming studies.