星形成ゼミ
The Star Formation Newsletter 302
22~29

徳田一起 (大阪府立大学/NAOJ)

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22 (1)

The Stellar IMF from Isothermal MHD Turbulence

Troels Haugbølle[1], Paolo Padoan[2,3], and Åke Nordlund[1]

背景

- Turbulent fragmentation
- IMFを再現するには乱流だけでなく磁場/stellar feedback が重要
- Padoan+14bでは等温MHD乱流がIMFを再現できた
- 最近sink particle のモデルが新しくなった (Frimann+16b, Jensen+17)
- 本論文ではそれらを取り入れ、パラメータ依存性を調べる

初期条件

Mass: ~3000 Mo, 大きさ4pc, 乱流の線幅: 音速の10倍 (Alfvén速度の10倍)

Table 1
Numerical parameters of the large-scale runs exploring convergence and the dependence on $\alpha_{\rm vir}$

Run	Run parameters										Creation of Sinks				Accretion to Sinks				
	Root Grid	$N_{\rm AMR}$	Δx au	$L_{\rm J}$	$\rho_{\rm ref}$ / $\langle\rho\rangle$	$M_{\rm box}$ $M_\odot$	$\alpha_{\rm vir}$	$t_{\rm end}$ Myr	SFE	$N_{\rm sink}$	$L_{\rm J,s}$	$\rho_{\rm s}$ cm^{-3}	$\rho_{\rm s}$ / $\langle\rho\rangle$	$r_{\rm ex}$ / Δx	$\rho_{\rm acc}$ cm^{-3}	$\rho_{\rm acc}$ / $\langle\rho\rangle$	$\rho_{\rm th}$ / $\rho_{\rm s}$	$r_{\rm acc}$ / Δx	$\epsilon_{\rm acc}$
16	16^3	6	800	2.0	2	3000	0.83	1.6	13%	108	2	6.6×10^6	8.3×10^3	8	4227	5.3	2	4	0.5
32	32^3	6	400	2.5	5	3000	0.83	1.8	13%	169	2	2.6×10^7	3.3×10^4	8	4227	5.3	2	4	0.5
low	64^3	6	200	3.6	10	3000	0.83	2.4	13%	279	2	1.1×10^8	1.3×10^5	8	4227	5.3	2	4	0.5
med	128^3	6	100	7.2	10	3000	0.83	2.5	13%	363	2	4.2×10^8	5.3×10^5	8	4227	5.3	2	4	0.5
high	256^3	6	50	14.4	10	3000	0.83	2.5	13%	410	2	1.7×10^9	2.1×10^6	8	4227	5.3	2	4	0.5
light	256^3	6	50	14.4	20	1500	1.67	4.0	5%	86	2	1.7×10^9	4.3×10^6	8	4227	5.3	2	4	0.5
heavy	256^3	6	50	14.4	5	6000	0.42	0.7	5%	614	2	1.7×10^9	1.1×10^6	8	4227	5.3	2	4	0.5
massive	256^3	6	50	14.4	2.5	12000	0.21	0.3	3%	1223	2	1.7×10^9	5.3×10^6	8	4227	5.3	2	4	0.5

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IMFのturn over, m_peakの決まり方

$$M_{\rm BE} = 1.182 \frac{\sigma_{\rm th}^4}{G^{3/2} P_{\rm th,0}^{1/2}}.$$

$$M_{\rm BE,t} \approx \frac{1.182\, \sigma_{\rm th}^4}{G^{3/2} P_0^{1/2}} = \frac{M_{\rm BE,0}}{(1+\mathcal{M}_{\rm s}^2)^{1/2}} \approx \frac{M_{\rm BE,0}}{\mathcal{M}_{\rm s}},$$

乱流による圧力が等価的に働く

$$m_{\rm peak} \equiv \epsilon_{\rm BE}\, M_{\rm BE,t},$$

ε_BEはsink 粒子への降着効率

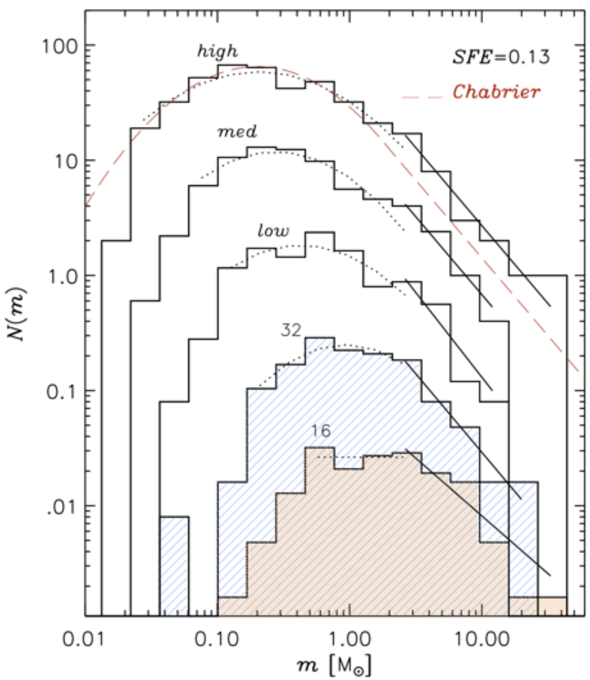


図4: resolutionを上げたらIMFのpeakが再現できた!?
(注: high以外は見やすくするためにシフトさせている)

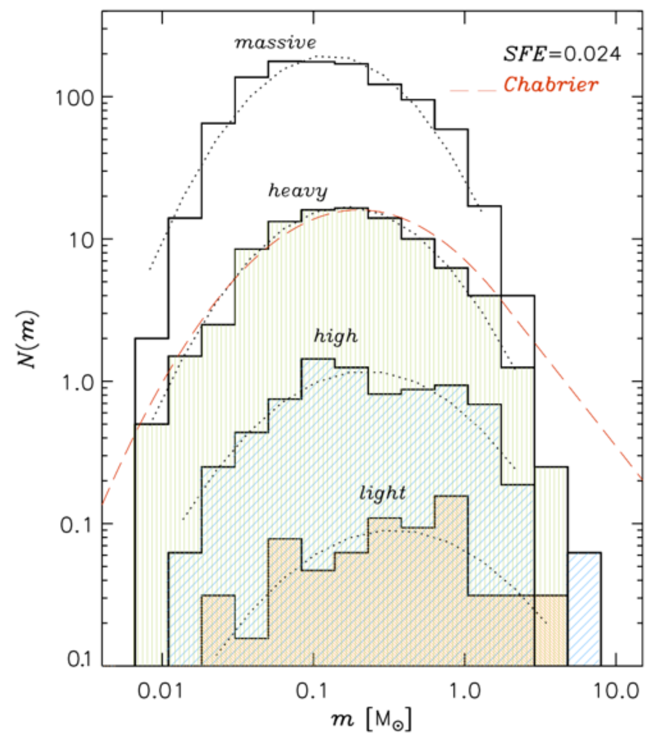
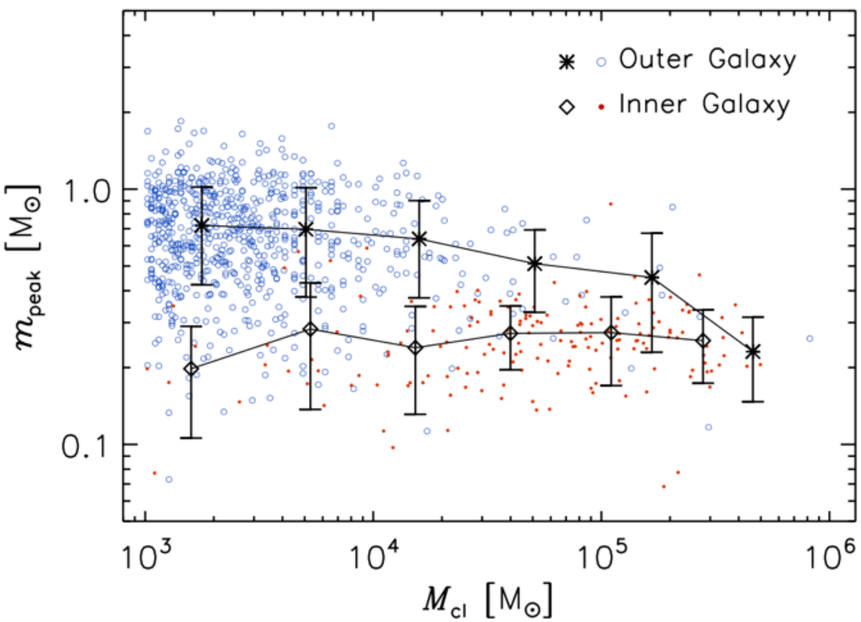


図8: 質量の大きいclump(平均密度が大きい)ほどTurn over が小さい

22 (3)

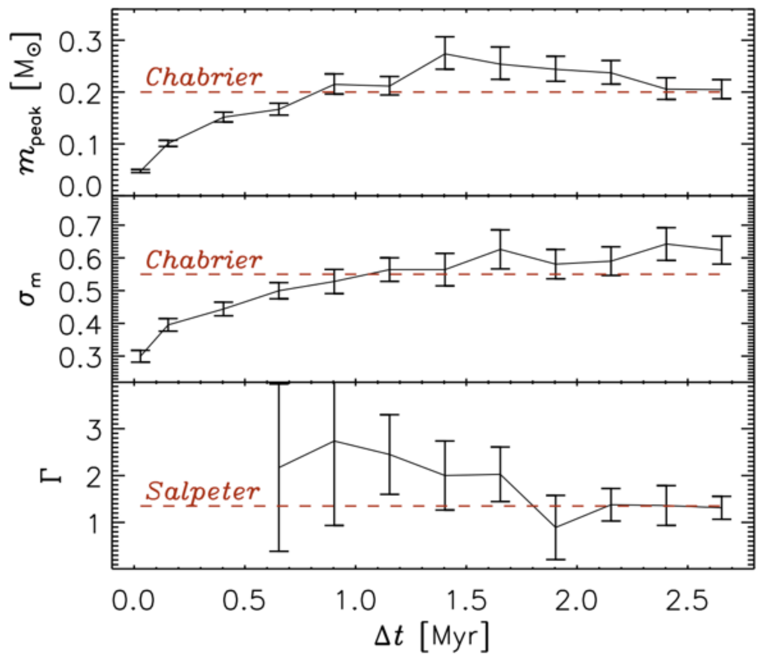
IMFの環境依存性
Molecular cloud はLarson 則に従うが、
無視できないscatter があるので、
IMFのpeakも変わりうる

$$m_{\rm peak} \approx 1.124\, M_{\rm tot}\, \mathcal{M}_{\rm s}^{-4} \alpha_{\rm vir}^{3/2},$$



銀河系の外側と内側で
どのようにIMFのpeakが変わるか観測されている分子雲のmassと速度より算出

IMFの時間依存性



・10 Moの星が95%の質量になるのには1Myr以上必要
・IMFのpeakが最終的な値になるには1Myr以上経過してから
・Salpeterのslopeを再現するには2 Myr

25 (1)

PROBING EPISODIC ACCRETION IN VERY LOW LUMINOSITY OBJECTS

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キーワード

- VeLLOs (Very Low-Luminosity Object)
- ALMA 観測
- Episodic accretion (accretion burst)

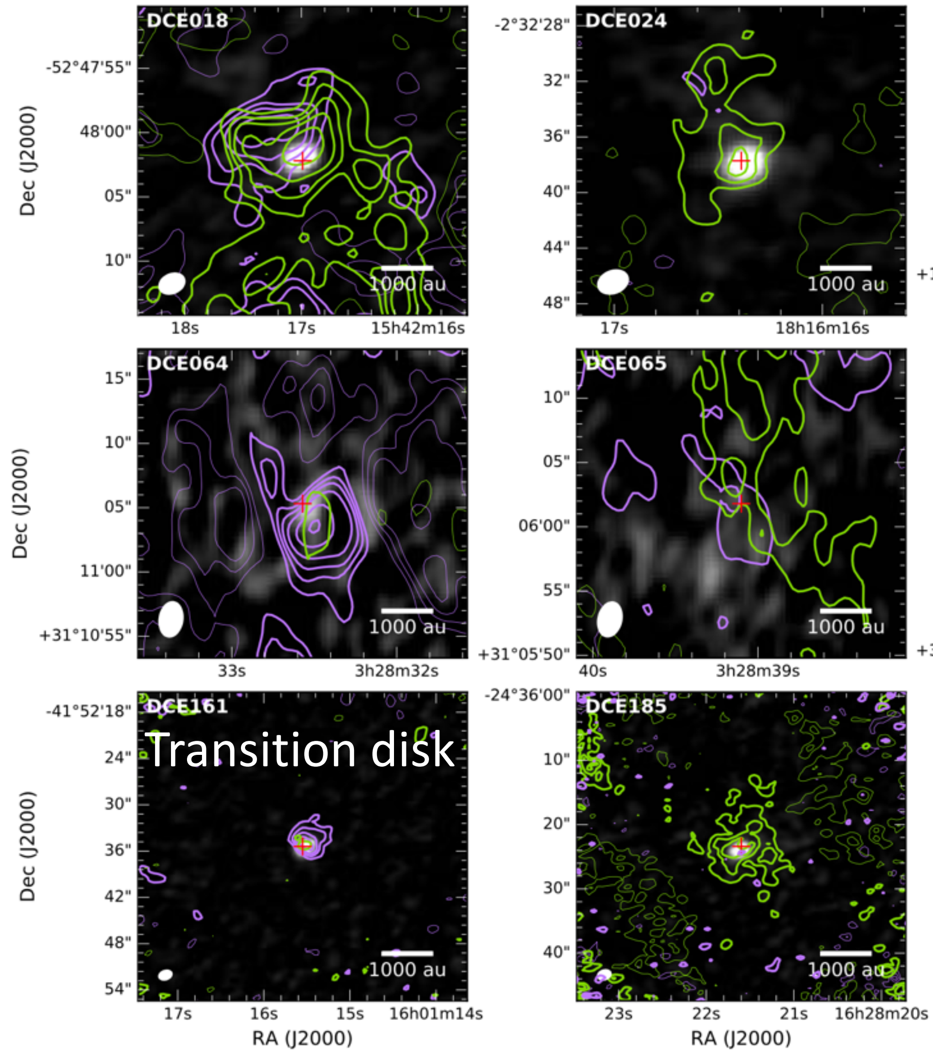
強調したい結果と示唆

CO snow lineの位置が、現在の星の輝度で予想される位置よりも遠い

70%のVeLLOがaccretion burst を経験

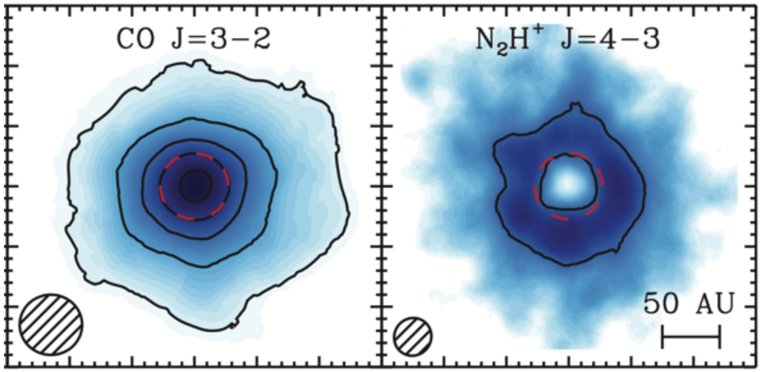
ALMAの観測

天体数	8個
Lint	0.02~0.09
距離	125~300 pc
観測輝線	N2H+, 13CO, C18O, C17O, dust cont.
空間分解能	1.2”~2.9”



グレー: 3mm dust, C18O (1-0), 13CO(1-0)

25 (2)

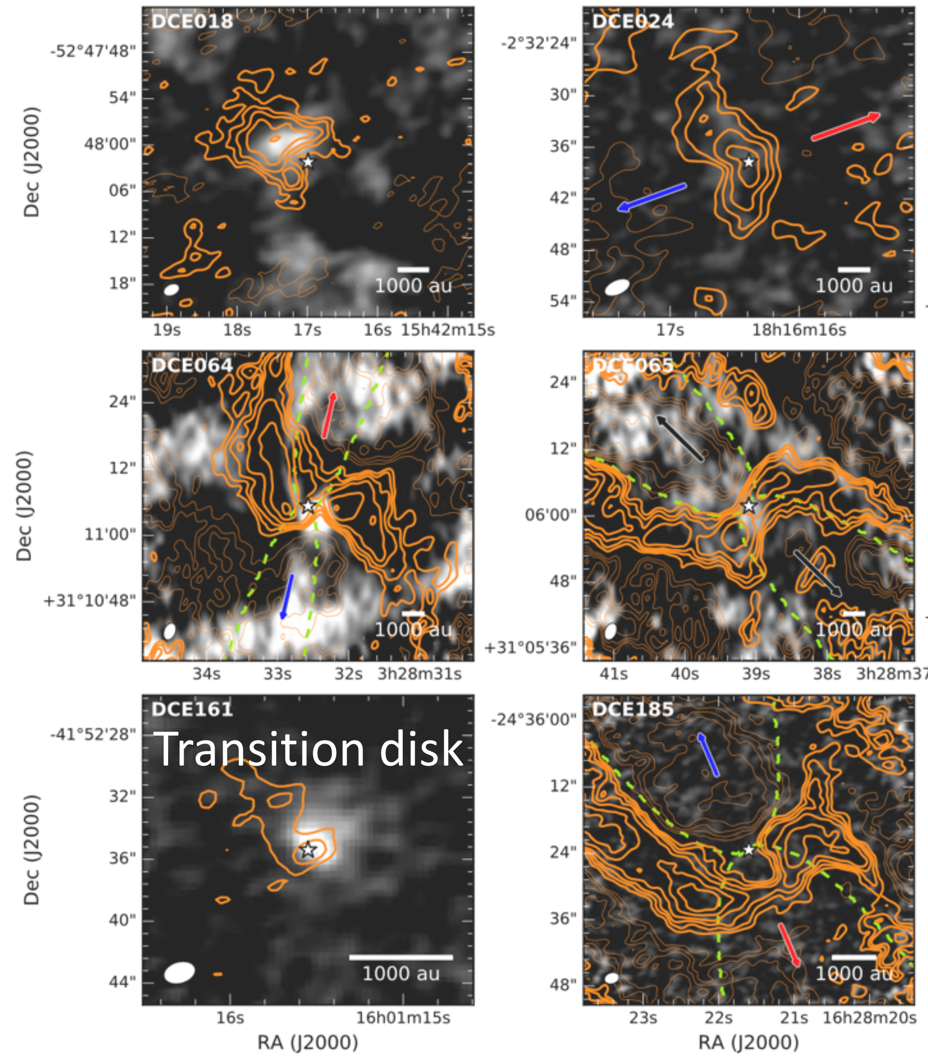


COスノーラインとN2H+の関係の図
TW Hya (Qi+2013)

Conclusions
・7個中5~6個がaccretion burst
　Class 0/I (20~50%)よりも多い
　COがfreeze outするのが1万年だとすると、1.2~1.4 万年

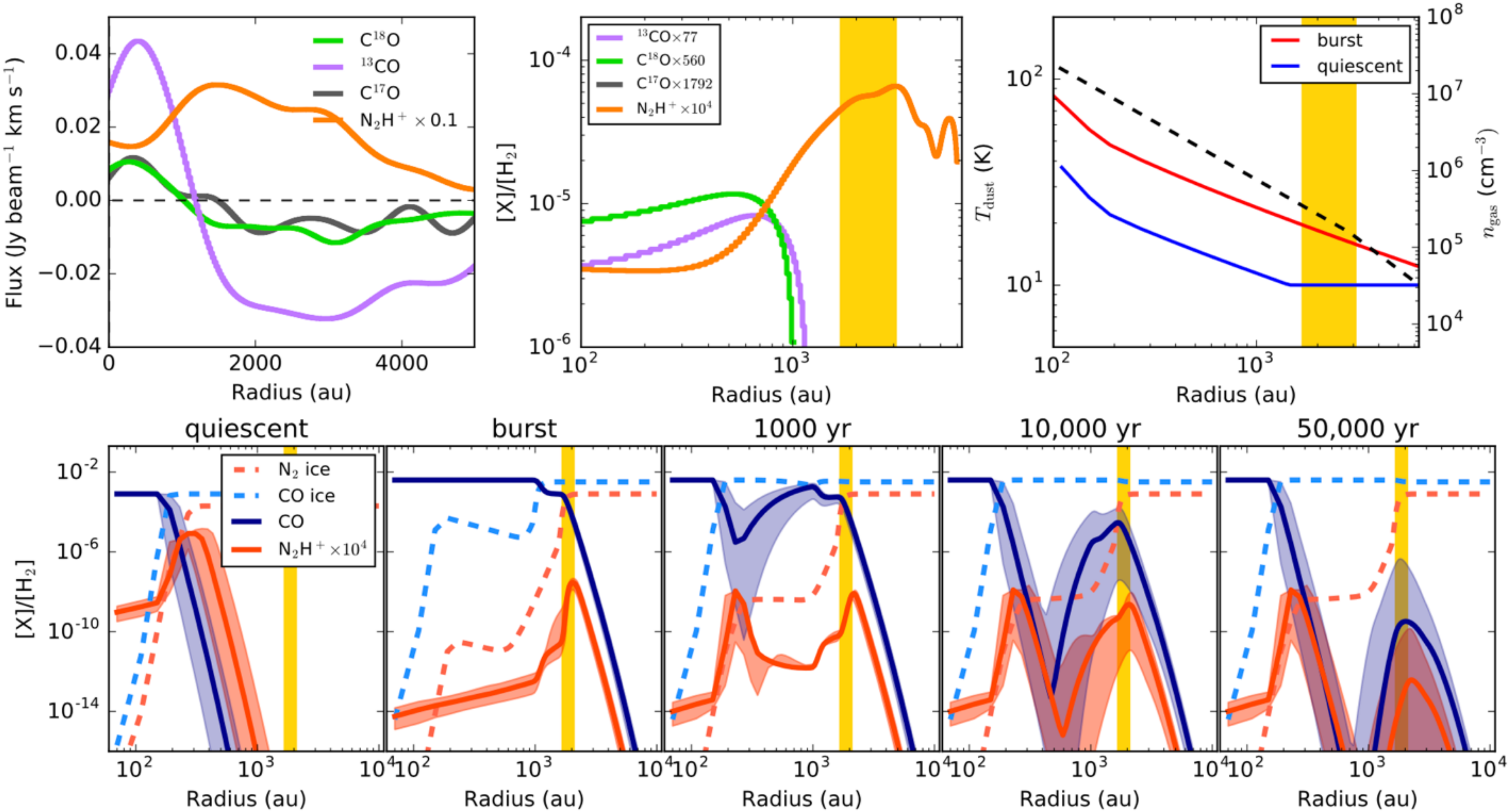
・CO snow lineはバースト後も静的なので、burst luminosity を見積もるのに使える

・episodic accretion はClass I stage によく起こるというsimulation とは不整合
・Multiplicity は低い(~250 AU分解能)



グレー: 13CO(1-0), N2H+

25 (3)



Flux (Jy beam^{-1} km s^{-1})
Radius (au)
$C^{18}O$
^{13}CO
$C^{17}O$
$N_2H^+ \times 0.1$
[X]/[H_2]
$^{13}CO\times77$
$C^{18}O\times560$
$C^{17}O\times1792$
$N_2H^+\times10^4$
T_{dust} (K)
n_{gas} (cm^{-3})
burst
quiescent
quiescent
burst
1000 yr
10,000 yr
50,000 yr
N_2 ice
CO ice
CO
$N_2H^+\times10^4$

26 (1) CO AND DUST PROPERTIES IN THE TW HYA DISK FROM HIGH-RESOLUTION ALMA OBSERVATIONS

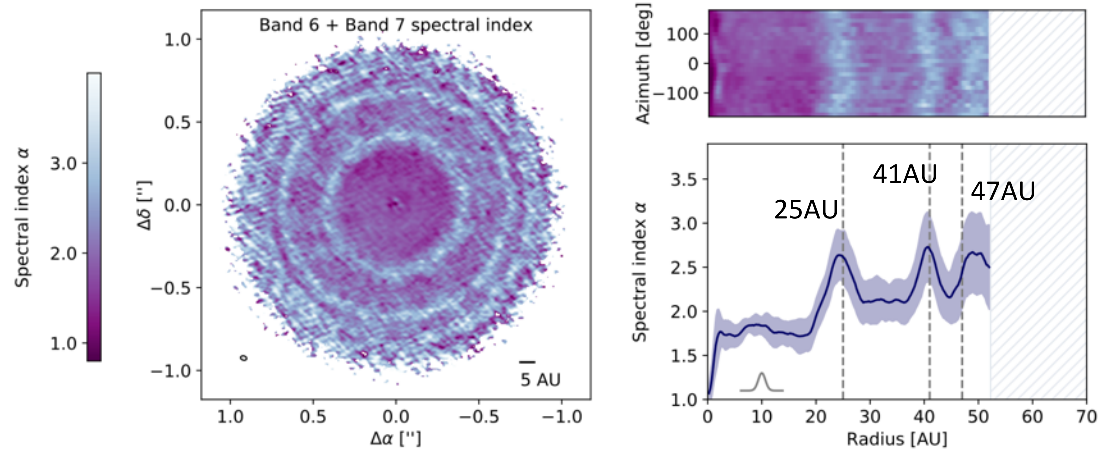
Jane Huang[1], Sean M. Andrews[1], L. Ilsedore Cleeves[1,2], Karin I. Öberg[1], David J. Wilner[1], Xuening Bai[1,3,4], Til Birnstiel[5], John Carpenter[6], A. Meredith Hughes[7], Andrea Isella[8], Laura M. Pérez[9], Luca Ricci[8], Zhaohuan Zhu[10]

TW HyaのCO, 連続波のALMA観測(アーカイブデータ)

連続波(分解能~2AU)のデータ

・25AU, 41AU, 47AUでギャップが存在し、その中のダストが数ミリ以下

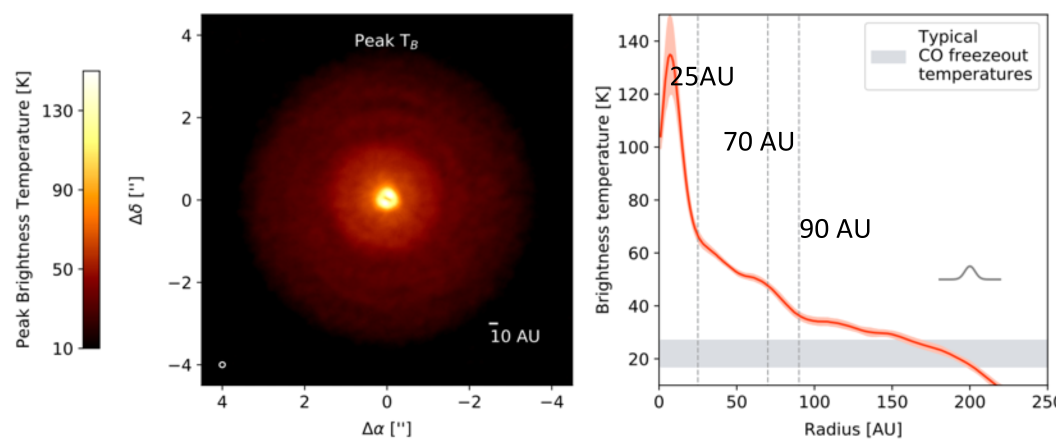
・ギャップの外ではα~2 でcmサイズのダストが存在するか、光学的に厚い



Band6と7で作ったspectral index, αのマップ

CO (分解能~8 AU)のデータ

The CO emission exhibits a bright inner core, a shoulder at r ≈ 70 AU, and a prominent break in slope at r ≈ 90 AU. Radiative transfer modeling is used to demonstrate that the emission morphology can be reasonably reproduced with a 12CO column density profile featuring a steep decrease at r ≈ 15 AU and a secondary bump peaking at r ≈ 70 AU.



COの輝度分布とradial distribution

27 (1)

THE EXTRAORDINARY OUTBURST IN THE MASSIVE PROTOSTELLAR SYSTEM NGC6334I-MM1: EMERGENCE OF STRONG 6.7 GHZ METHANOL MASERS

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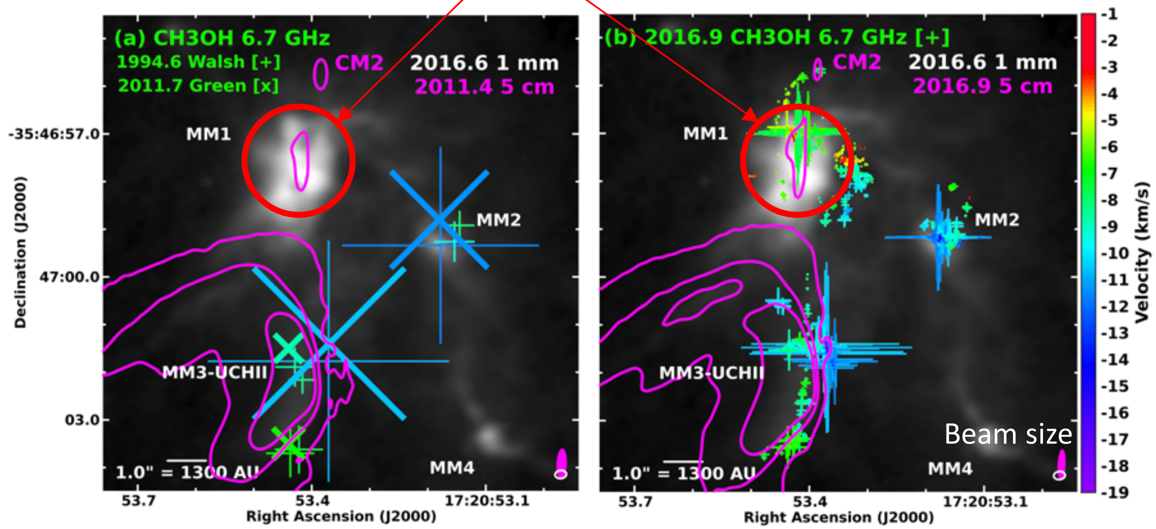
2015年に単一鏡のモニター観測(Hartebeesthoek Radio Observatory)
で強いフレア現象が見つかった(MacLeod+18)
=>JVLA を使ったフォローアップ観測 (空間分解能~500 au)
　メタノール, OHメーザーの同時観測

・NGC6334I (大質量星形成領域)
　(サブ)ミリ波源MM1で起こった
2015年のメタノールメーザーのアウトバーストを報告
　30年のメーザーの観測で初めて
・ホットコアMM2とUCHII のMM3には6.7 GHz Class II メタノールメーザーが知られていた

ここに注目

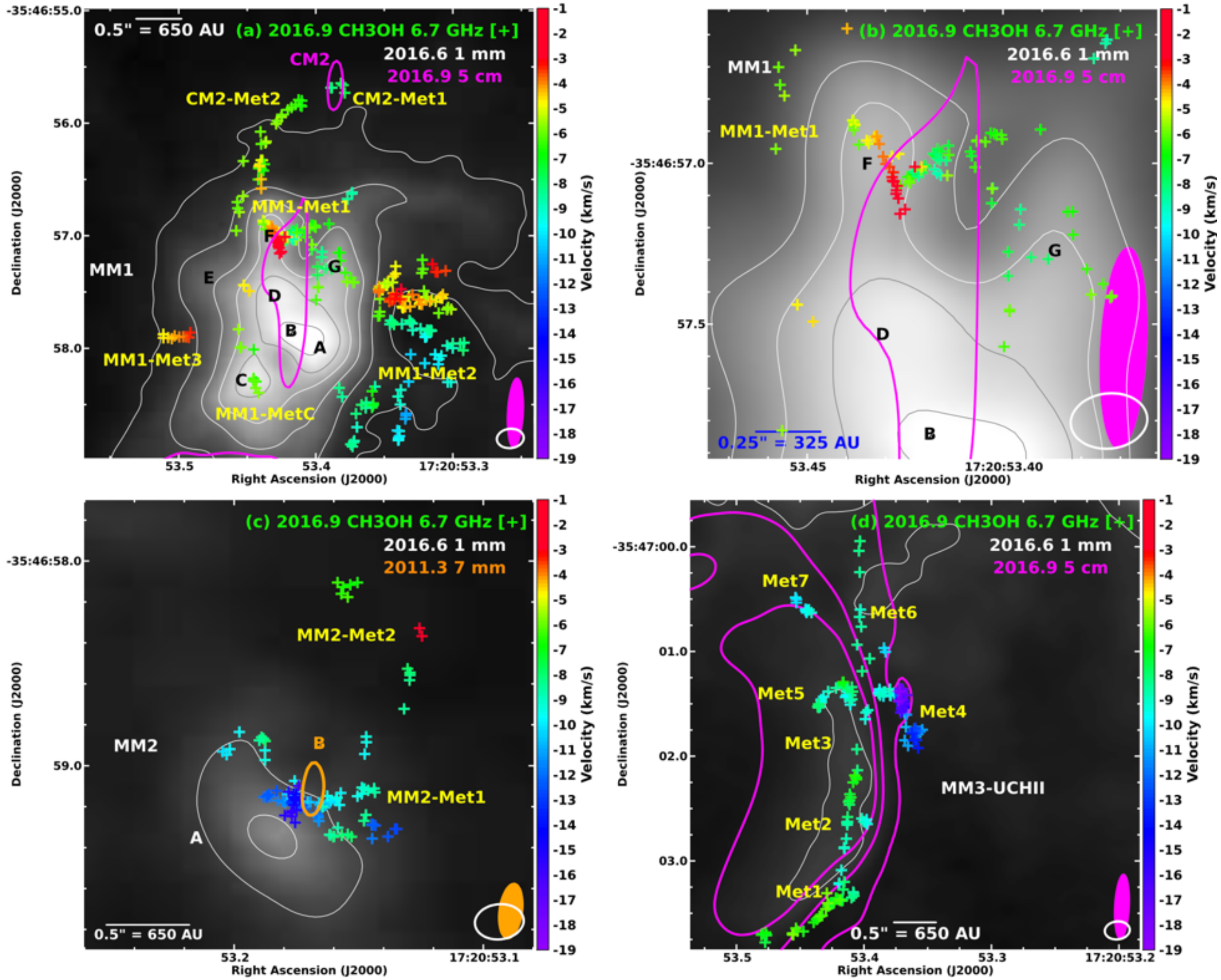


(a) +: メタノールメーザー 1998年6月, x: 2011年9月 (ATCAの観測)
(b) +: メタノールメーザー 2016年5月 (VLAの観測)
　=>マークの大きさは強さを表す

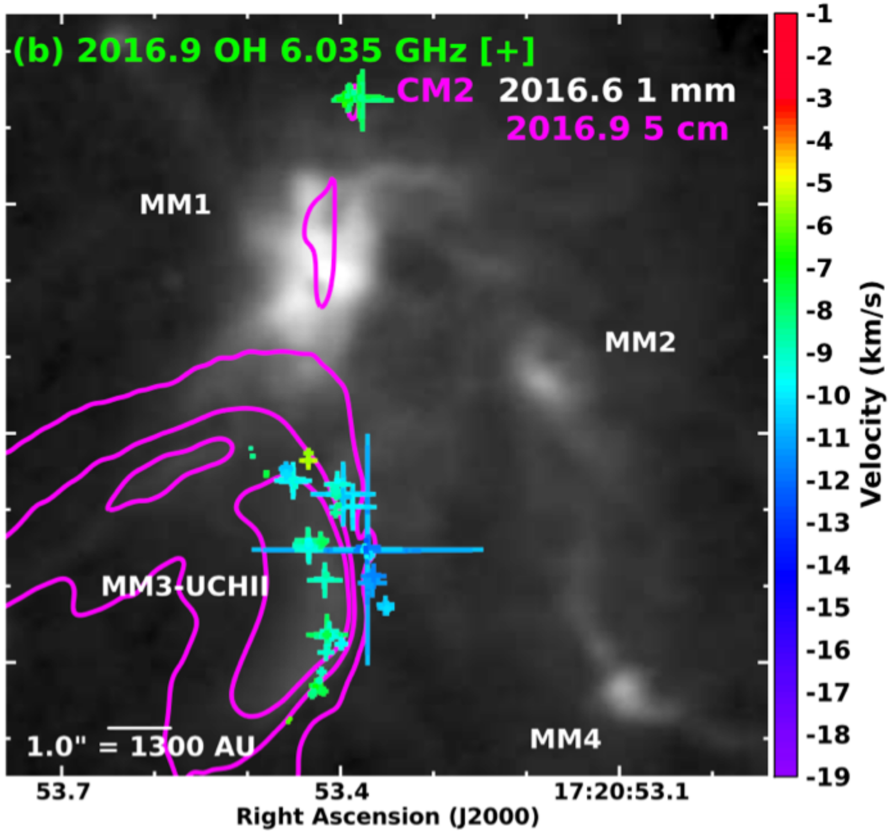
27 (2)

・MM1の最も強いメーザーはダストキャビティに存在
・dust が最も強いMM1A, 1B, 1Dにはメーザーがない

アウトバースト後のダストの温度の増加による Radiative pumping
+
Infrared photon propagation cavities の存在
+
熱的メタノール輝線の高い柱密度(ALMAの観測)



27 (3)



非熱的電波源CM2にも新しいメーザー源
6.035, 6.030 GHz のOHのライン
ゼーマン効果で磁場測定: +0.5~3.7 mG

UCHII, MM3 (OHメーザーの観測)
視線方向の磁場 :-2 ~ -3 mG => 南北で磁場が反転!?

23 Where can a Trappist-1 planetary system be produced?

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We study the evolution of protoplanetary discs that would have been precursors of a Trappist-1 like system under the action of accretion and external photoevaporation in different radiation environments. Dust grains swiftly grow above the critical size below which they are entrained in the photoevaporative wind, so although gas is continually depleted, dust is resilient to photoevaporation after only a short time. This means that the ratio of the mass in solids (dust plus planetary) to the mass in gas rises steadily over time. Dust is still stripped early on, and the initial disc mass required to produce the observed 4 $M_\oplus$ of Trappist-1 planets is high. For example, assuming a Fatuzzo & Adams (2008) distribution of UV fields, typical initial disc masses have to be >30per cent the stellar (which are still Toomre Q stable) for the majority of similar mass M dwarfs to be viable hosts of the Trappist-1 planets. Even in the case of the lowest UV environments observed, there is a strong loss of dust due to photoevaporation at early times from the weakly bound outer regions of the disc. This minimum level of dust loss is a factor two higher than that which would be lost by accretion onto the star during 10 Myr of evolution. Consequently even in these least irradiated environments, discs that are viable Trappist-1 precursors need to be initially massive (>10per cent of the stellar mass).

Accepted by MNRAS

http://arxiv.org/pdf/1801.05822

Trappist-1: 木星質量程度の赤色矮星 (惑星が確認されている)
質量降着中であり、異なった外部輻射場の環境におけるdiskの進化を調査
=>Trappist-1 systemの前駆体となるdiskは最初の質量は大きい必要がある
(星の質量の10 %以上)

24 Evolution of Magnetic Fields in Collapsing Star-forming Clouds under Different Environments

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In nearby star-forming clouds, amplification and dissipation of the magnetic field are known to play crucial roles in the star-formation process. The star-forming environment varies from place to place and era to era in galaxies. In the present study, amplification and dissipation of magnetic fields in star-forming clouds are investigated under different environments using magnetohydrodynamics (MHD) simulations. We consider various star-forming environments in combination with the metallicity and the ionization strength, and prepare prestellar clouds having two different mass-to-flux ratios. We calculate the cloud collapse until protostar formation using ideal and non-ideal (inclusion and exclusion of Ohmic dissipation and ambipolar diffusion) MHD calculations to investigate the evolution of the magnetic field. We perform 288 runs in total and show the diversity of the density range within which the magnetic field effectively dissipates, depending on the environment. In addition, the dominant dissipation process (Ohmic dissipation or ambipolar diffusion) is shown to strongly depend on the star-forming environment. Especially, for the the primordial case, magnetic field rarely dissipates without ionization source, while it efficiently dissipates when very weak ionization sources exist in the surrounding environment. The results of the present study help to clarify star formation in various environments.

- 星形成クラウドの磁場の増幅と散逸を様々な環境でMHD simulationで計算
- 用意した環境: 異なった金属量+電離度，２つの異なったmass-to-flux ratioのprestellar core
- 原始星が誕生するまで計算: 理想, 非理想MHD(オーム散逸, ambipolar diffusion)の両方
  合計で288 runs, オーム散逸/ ambipolar diffusionは環境依存が強い
  磁場は電離源がなければなかなか散逸しない
  周囲に弱くても電離源があれば効率よく散逸する

28 V2492 Cygni: Optical BVRI variability during the period 2010-2017

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Results from BVRI photometric observations of the young stellar object V2492 Cyg collected during the period from August 2010 to December 2017 are presented. The star is located in the field of the Pelican Nebula and it was discovered in 2010 due to its remarkable increase in the brightness by more than 5 mag in R-band. According to the first hypothesis of the variability V2492 Cyg is an FUor candidate. During subsequent observations it was reported that the star shows the characteristics inherent to EXor- and UXor-type variables. The optical data show that during the whole time of observations the star exhibits multiple large amplitude increases and drops in the brightness. In the beginning of 2017 we registered a significant increase in the optical brightness of V2492 Cyg, which seriously exceeds the maximal magnitudes registered after 2010.

Accepted by Publications of the Astronomical Society of Australia (PASA)

https://arxiv.org/pdf/1801.05482

原始星 V2492 Cygni (パイプ星雲に存在)の2011年8月~2017年12月までのvariability の観測
2010年にR-bandで急に明るくなって(>5mag)発見された
FUor candidateとされていた。EXor, Uxor-type の変動を持つと報告されていた
本論文の結果
・全期間の強度の調べると、複数の大きな強度の減少が見られた
・2017年の最初に今まで報告されていたよりも明るくなった

29 Dust Coagulation Regulated by Turbulent Clustering in Protoplanetary Disks

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The coagulation of dust particles is a key process in planetesimal formation. However, the radial drift and bouncing barriers are not completely resolved, especially for silicate dust. Since the collision velocities of dust particles are regulated by turbulence in a protoplanetary disk, the turbulent clustering should be properly treated. To that end, direct numerical simulations (DNSs) of the Navier Stokes equations are requisite. In a series of papers, Pan & Padoan used a DNS with the Reynolds number $Re \sim 1000$. Here, we perform DNSs with up to $Re = 16100$, which allow us to track the motion of particles with Stokes numbers of $0.01 < St < 0.2$ in the inertial range. By the DNSs, we confirm that the rms relative velocity of particle pairs is smaller by more than a factor of two, compared to those by Ormel & Cuzzi (2007). The distributions of the radial relative velocities are highly non-Gaussian. The results are almost consistent with those by Pan & Padoan or Pan et al. at low-Re. Also, we find that the sticking rates for equal-sized particles are much higher than those for different-sized particles. Even in the strong-turbulence case with α-viscosity of 10^{-2}, the sticking rates are as high as $\gtrsim$50% and the bouncing probabilities are as low as $\sim$10% for equal-sized particles of $St \lesssim 0.01$. Thus, the turbulent clustering plays a significant role for the growth of cm-sized compact aggregates (pebbles) and also enhances the solid abundance, which may lead to the streaming instability in a disk.

Accepted by ApJ

http://arxiv.org/pdf/1801.08805