Star Formation Newsletter #338 8-13

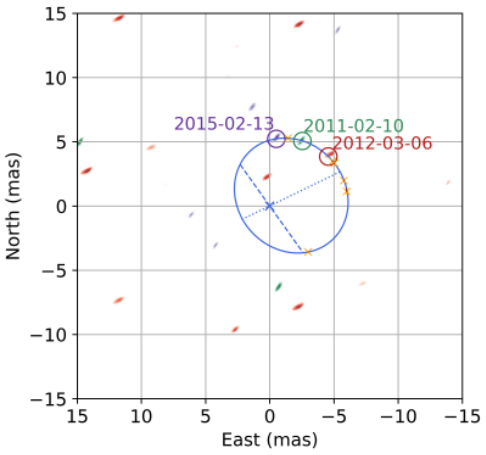
武藤恭之

No. 8

The GRAVITY young stellar object survey V. The orbit of the T Tauri binary star WW Cha

GRAVITY Collaboration, F. Eupen et al. ★ The young T Tauri star WW Cha was recently proposed to be a close binary object with strong infrared and submillimeter excess associated with circum-system emission. This makes WW Cha a very interesting source for studying the influence of dynamical effects on circumstellar as well as circumbinary material. We derive the relative astrometric positions and flux ratios of the stellar companion in WW Cha from the interferometric model fitting of observations made with the VLTI instruments AMBER, PIONIER, and GRAVITY in the near-infrared from 2011 to 2020. For two epochs, the resulting uv-coverage in spatial frequencies permits us to perform the first image reconstruction of the system in the K band. The positions of nine epochs are used to determine the orbital elements and the total mass of the system. We find the secondary star orbiting the primary with a period of T=206.55 days, a semimajor axis of a=1.01 au, and a relatively high eccentricity of e=0.45. Combining the orbital solution with distance measurements from Gaia DR2 and the analysis of evolutionary tracks, the dynamical mass of Mtot=3.20 Msol can be explained by a mass ratio between 0.5 and 1. The orbital angular momentum vector is in close alignment with the angular momentum vector of the outer disk as measured by ALMA and SPHERE. The analysis of the relative photometry suggests the presence of infrared excess surviving in the system and likely originating from truncated circumstellar disks. The flux ratio between the two components appears variable, in particular in the K band, and may hint at periods of triggered higher and lower accretion or changes in the disks' structures. The knowledge of the orbital parameters, combined with a relatively short period, makes WW Cha an ideal target for studying the interaction of a close young T Tauri binary with its surrounding material, such as time-dependent accretion phenomena.

- VLTI による原始惑星系円盤天体 WW Cha の軌道決定
- WW Cha は連星系
  - 軌道周期 206.55 日（軌道長半径 1.01 au）
  - 離心率 0.45
  - 全質量 3.20 Msun, 質量比 0.5-1
  - 連星の角運動量ベクトルは、周囲の円盤の角運動量ベクトルとほぼ一致
- SED の赤外超過は、連星によって truncate された円盤の inner edge から来ていることが示唆される



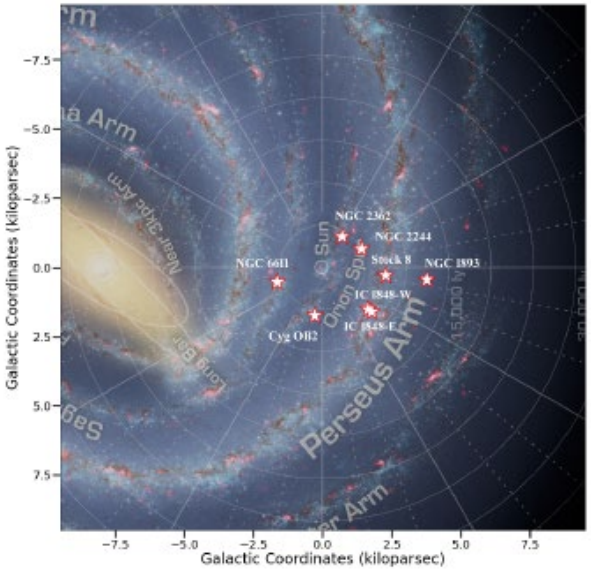
No. 9

Testing the role of environmental effects on the Initial Mass Function of low mass stars

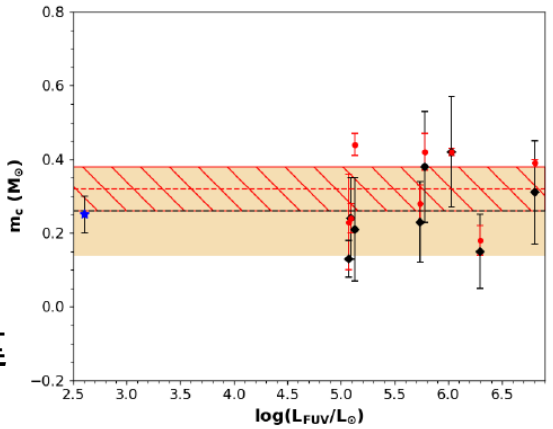
Belinda Damian, Jessy Jose, Manash R. Samal, Estelle Moraux, Swagat R. Das, Sudeshna Patra ★

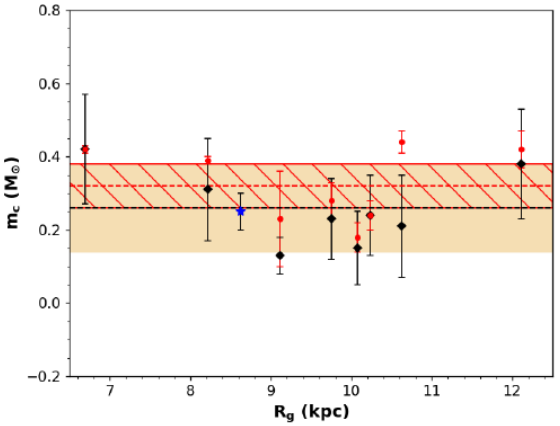
In star formation process, the vital role of environmental factors such as feedback from massive stars and stellar density on the form of the Initial Mass Function (IMF) at low-mass end is yet to be understood. Hence a systematic, high sensitive observational analysis of a sample of regions under diverse environmental conditions is essential. We analyse the IMF of eight young clusters (<5 Myr) namely IC1848-West, IC1848-East, NGC1893, NGC2244, NGC2362, NGC6611, Stock8 and Cygnus OB2 which are located at the Galactocentric distance (R_g) range ∼6-12 kpc along with nearby cluster IC348 using deep near-IR photometry and Gaia-DR2. These clusters are embedded in massive stellar environments of radiation strength $log(L_{FUV}/L_{\odot})$ ∼2.6 to 6.8, $log(L_{EUV})$ ∼42.2 to 50.85 photons/s, with stellar density in the range of ∼170 - 1220 stars/pc^2. After structural analysis and field decontamination we obtain an unbiased, uniformly sensitive sample of Pre-Main Sequence members of the clusters down to brown-dwarf regime. The log-normal fit to the IMF of nine clusters gives the mean characteristic mass (m_c) and σ of 0.32±0.02 $M_{\odot}$ and 0.47±0.02, respectively. We compare the IMF with that of low and high mass clusters across the Milky Way. We also check for any systematic variation with respect to the radiation field strength, stellar density as well with R_g. We conclude that there is no strong evidence for environmental effect in the underlying form of IMF of these clusters.

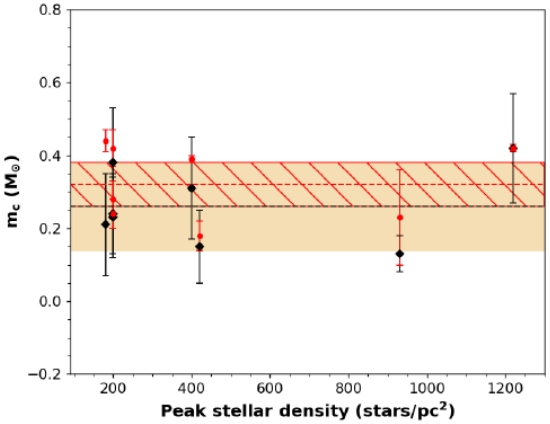
- 銀河中心から距離 6-12 kpc の範囲にある、8つの young cluster に関する初期質量関数の観測
  - 紫外線強度や星密度などの環境効果によって、初期質量関数は変わるか？
- 初期質量関数を対数正規分布でフィットすると、平均質量がおよそ 0.32 Msun 程度となった
- 銀河系内の他の cluster と比較して、大きな違いは無い

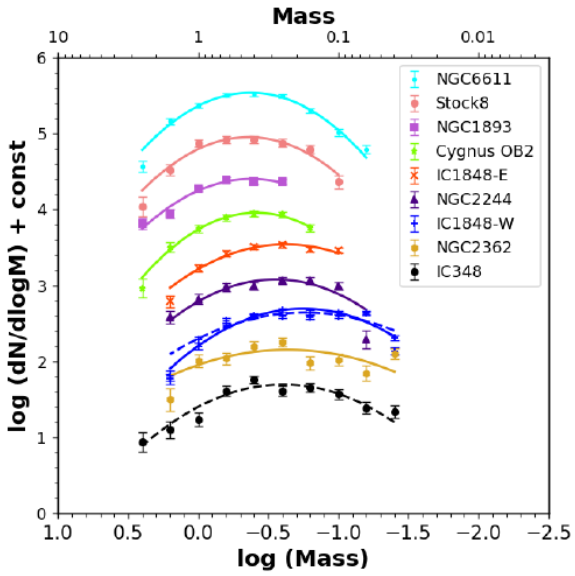


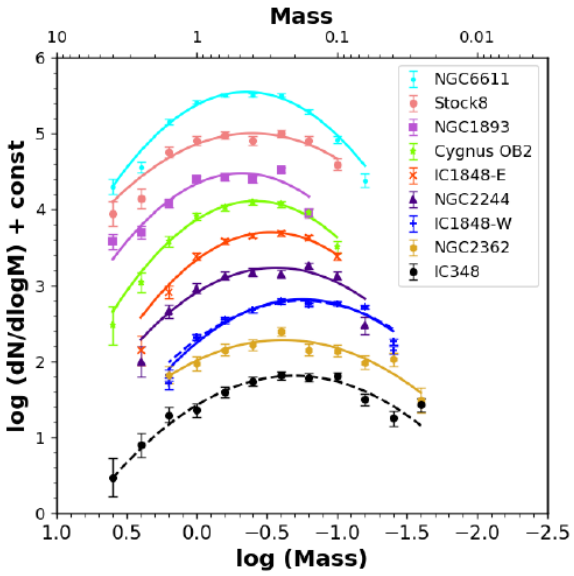
領域による IMF の違いは大きくなさそう











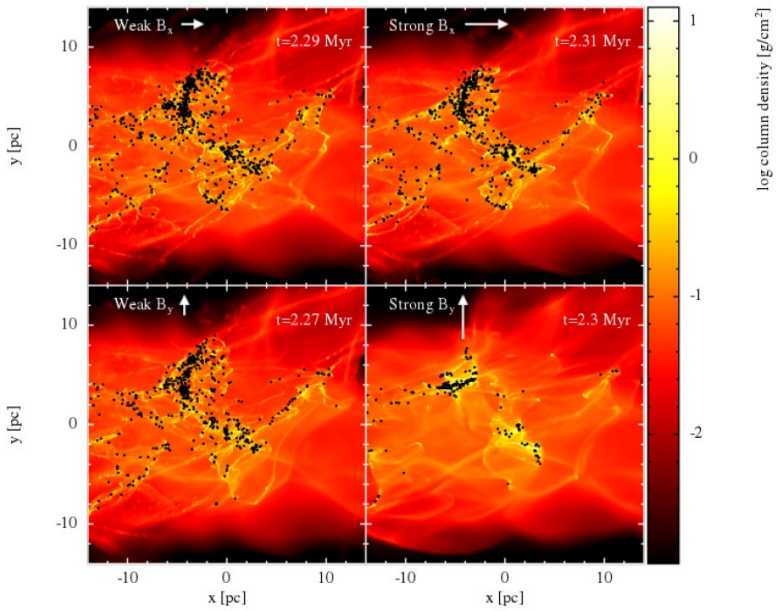
Jバンド（左）とKバンド（右）の IMF

No. 10

The properties of clusters, and the orientation of magnetic fields relative to filaments, in magnetohydrodynamic simulations of colliding clouds

C. L. Dobbs, J. Wurster ★ We have performed Smoothed Particle Magneto-Hydrodynamics (SPMHD) calculations of colliding clouds to investigate the formation of massive stellar clusters, adopting a timestep criterion to prevent large divergence errors. We find that magnetic fields do not impede the formation of young massive clusters (YMCs), and the development of high star formation rates, although we do see a strong dependence of our results on the direction of the magnetic field. If the field is initially perpendicular to the collision, and sufficiently strong, we find that star formation is delayed, and the morphology of the resulting clusters is significantly altered. We relate this to the large amplification of the field with this initial orientation. We also see that filaments formed with this configuration are less dense. When the field is parallel to the collision, there is much less amplification of the field, dense filaments form, and the formation of clusters is similar to the purely hydrodynamical case. Our simulations reproduce the observed tendency for magnetic fields to be aligned perpendicularly to dense filaments, and parallel to low density filaments. Overall our results are in broad agreement with past work in this area using grid codes.

- SPH 法を用いた磁気流体シミュレーションによる、colliding cloud の計算
- 磁場によって星形成が阻害されることは無いが、磁場の方向によって計算結果は異なる
- 磁場が初期に衝突に対して垂直で、磁場強度が十分に強い場合、星形成は遅れ、形成される filament の密度は小さい
  - 衝突時に磁場が増幅されるため
- 磁場が初期に衝突に対して平行な場合は、磁場はあまり増幅されず、filament の密度は高い。磁場を考えない場合と似た描像になる
- 過去の grid code による計算と基本的に同じ結果になっている



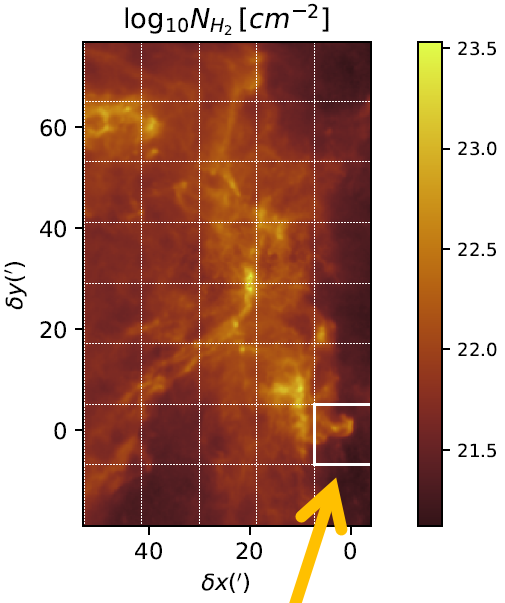
No. 11

Quantitative inference of the H_2 column densities from 3 mm molecular emission: A case study towards Orion B

Pierre Gratier, Jérôme Pety, Emeric Bron, Antoine Roueff, Jan H. Orkisz, Maryvonne Gerin, Victor de Souza Magalhaes, Mathilde Gaudel, Maxime Vono, Sébastien Bardeau, Jocelyn Chanussot, Pierre Chainais, Javier R. Goicoechea, Viviana V. Guzmán, Annie Hughes, Jouni Kainulainen, David Languignon, Jacques Le Bourlot, Franck Le Petit, François Levrier, Harvey Liszt, Nicolas Peretto, Evelyne Roueff, Albrecht Sievers ★

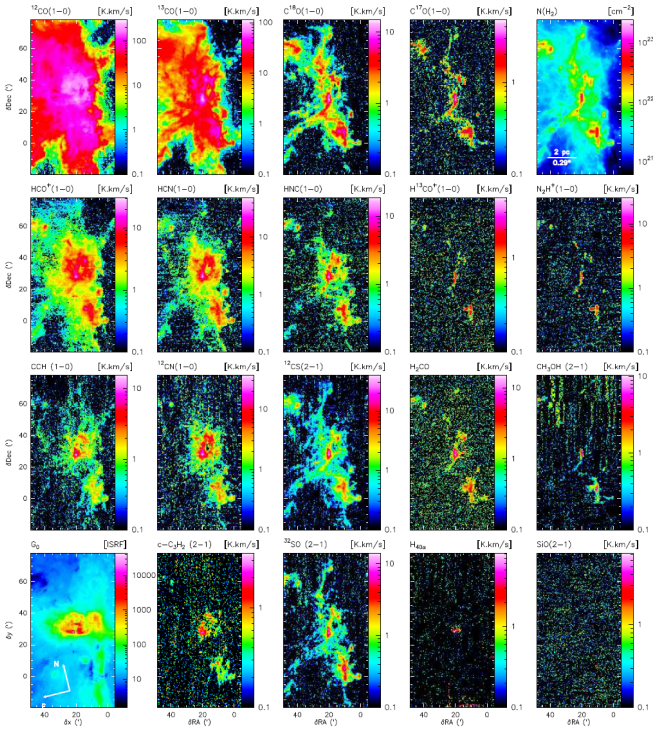
Molecular hydrogen being unobservable in cold molecular clouds, the column density measurements of molecular gas currently rely either on dust emission observation in the far-IR or on star counting. (Sub-)millimeter observations of numerous trace molecules are effective from ground based telescopes, but the relationships between the emission of one molecular line and the H2 column density (NH2) is non-linear and sensitive to excitation conditions, optical depths, abundance variations due to the underlying physico-chemistry. We aim to use multi-molecule line emission to infer NH2 from radio observations. We propose a data-driven approach to determine NH2 from radio molecular line observations. We use supervised machine learning methods (Random Forests) on wide-field hyperspectral IRAM-30m observations of the Orion B molecular cloud to train a predictor of NH2, using a limited set of molecular lines as input, and the Herschel-based dust-derived NH2 as ground truth output. For conditions similar to the Orion B molecular cloud, we obtain predictions of NH2 within a typical factor of 1.2 from the Herschel-based estimates. An analysis of the contributions of the different lines to the predictions show that the most important lines are ^{13}CO(1-0), ^{12}CO(1-0), C^{18}O(1-0), and HCO$^+$(1-0). A detailed analysis distinguishing between diffuse, translucent, filamentary, and dense core conditions show that the importance of these four lines depends on the regime, and that it is recommended to add the N_2H^+(1-0) and CH_3OH(20-10) lines for the prediction of NH2 in dense core conditions. This article opens a promising avenue to directly infer important physical parameters from the molecular line emission in the millimeter domain. The next step will be to try to infer several parameters simultaneously (e.g., NH2 and far-UV illumination field) to further test the method.

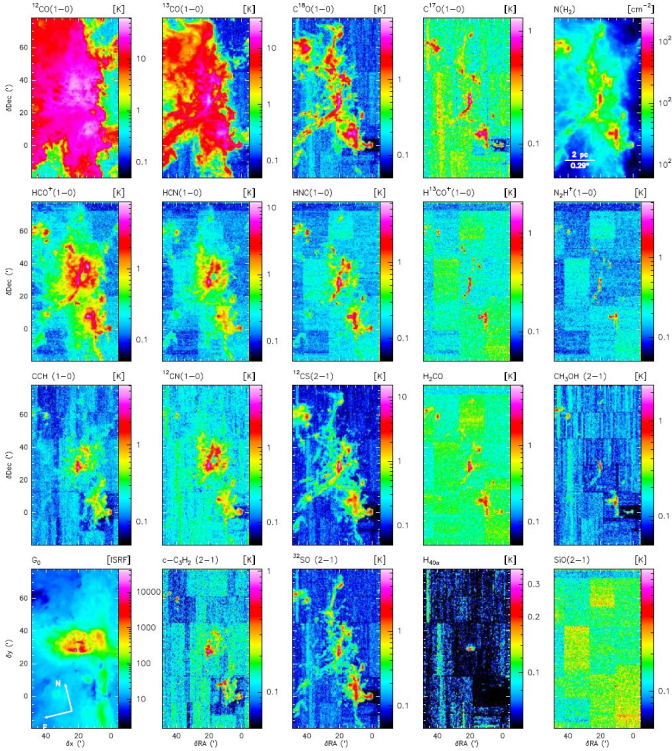
- 3mm 帯の分子輝線の観測から、H2 の量をどうやって見積もるか？
- Orion B を例に、機械学習を用いたアプローチで、水素分子の量を探るのに最適な分子輝線の組み合わせを探る
  - Herschel による dust-derived NH2 を教師データとし、分子輝線観測のデータのみを使ってこれを再現できるかどうかを調べる
- H2 の柱密度を求めるのに使える分子輝線は、13CO(1-0), 12CO(1-0), C18O(1-0), HCO+(1-0) であり、さらに dense core の領域では N2H+(1-0) と CH3OH(20-10) を加えると良い



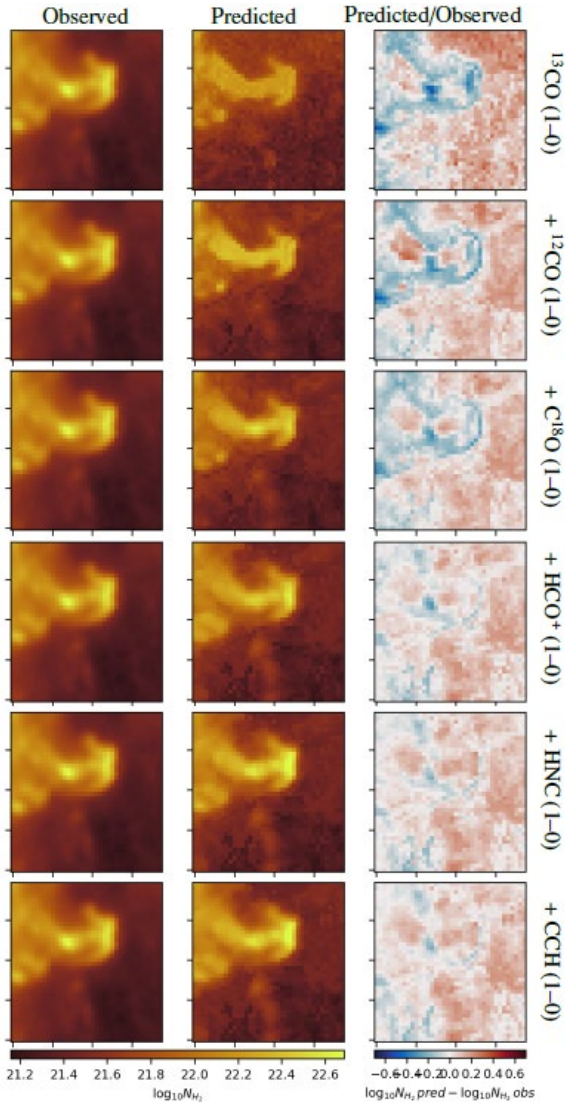
再構成したいデータ:
　Herschel Gould Belt Survey で得られたダスト分布を H2 の柱密度に焼き直したもの

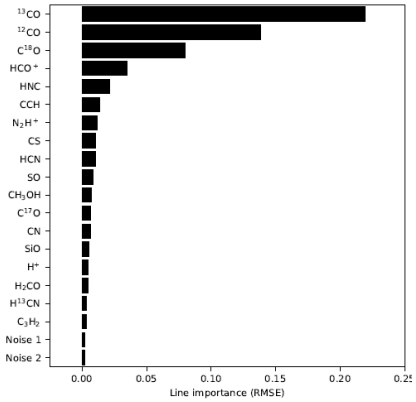
分子輝線データ: CO, HCO+, HCN など、IRAM-30m で得られた 3mm 帯の分子輝線放射の Moment 0 map と Peak temperature map

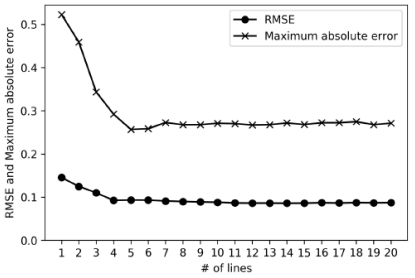




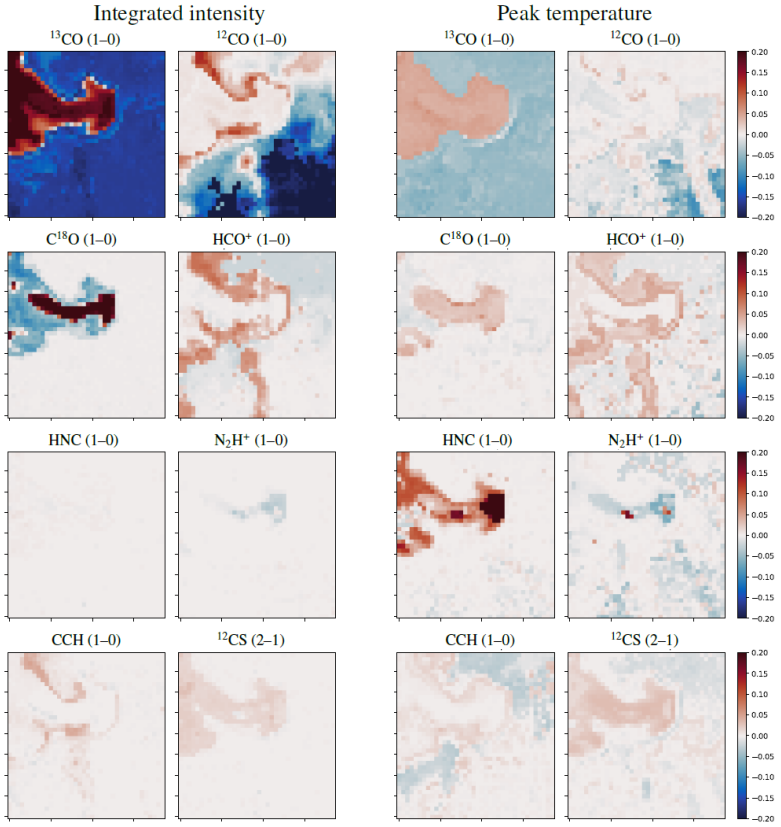
馬頭星雲の領域を training set として、分子輝線データから H2 柱密度を導くモデルを作る。



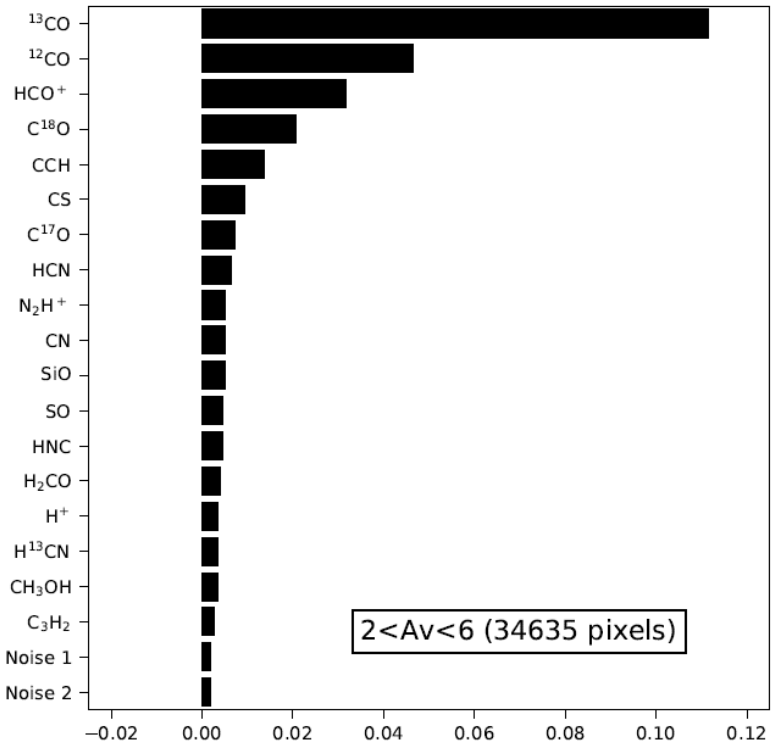


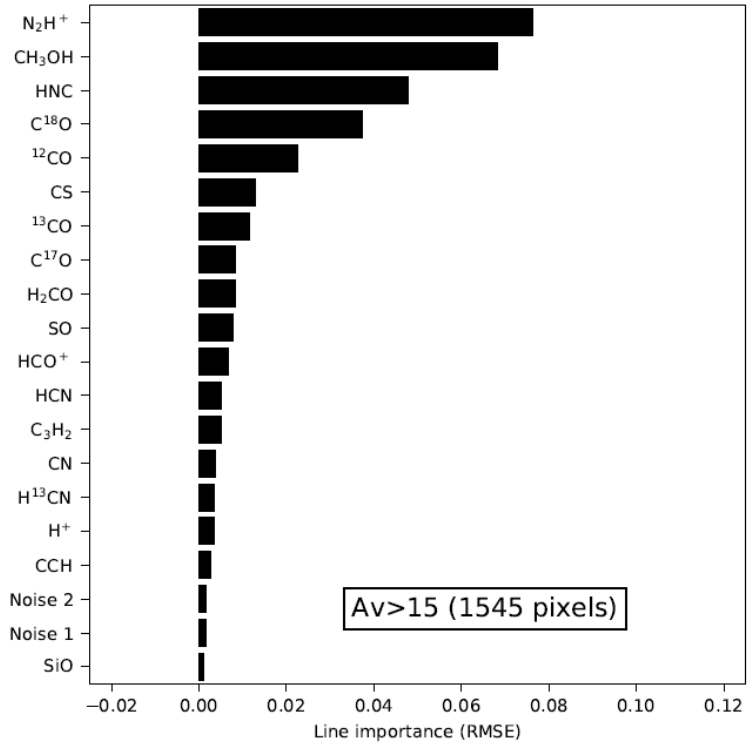


それぞれのラインの相対的な重要性。12CO, 13CO, C18O, HCO+ くらいを使うと、だいたい結果は収束



H2 の推定に使うラインを増やしていくと、
だんだんと観測とモデルが近づいてくる





Av の大きなところでは、N2H+ と CH3OH の重要性が高い

No. 12

Density profile evolution during prestellar core collapse: Collapse starts at the large scale

Gilberto C. Gómez, Enrique Vázquez-Semadeni, Aina Palau ★
We study the gravitationally-dominated, accretion-driven evolution of a prestellar core. In our model, as the core's density increases, it remains immersed in a constant-density environment and so it accretes from this environment, increasing its mass and reducing its Jeans length. Assuming a power-law density profile $\rho \propto r^{-p}$, we compute the rate of change of the slope p, and show that the value $p = 2$ is stationary, and furthermore, an attractor. The radial profile of the Jeans length scales as $r^{p/2}$, implying that, for $p < 2$, there is a radius below which the region is smaller than its Jeans length, thus appearing gravitationally stable and in need of pressure confinement, while, in reality, it is part of a larger-scale collapse and is undergoing compression by the infalling material. In this region, the infall speed decreases towards the center, eventually becoming subsonic, thus appearing "coherent", without the need for turbulence dissipation. We present a compilation of observational determinations of density profiles in dense cores and show that the distribution of their slopes peaks at $p \sim 1.7$–1.9, supporting the notion that the profile steepens over time. Finally, we discuss the case of magnetic support in a core in which the field scales as $B \propto \rho^{\beta}$. For the expected value of $\beta = 2/3$, this implies that the mass to magnetic flux ratio also decreases towards the central parts of the cores, making them appear magnetically supported, while in reality they may be part of larger collapsing supercritical region. We conclude that local signatures of either thermal or magnetic support are not conclusive evidence of stability, that the gravitational instability of a region must be established at the large scales, and that the prestellar stage of collapse is dynamic rather than quasistatic.

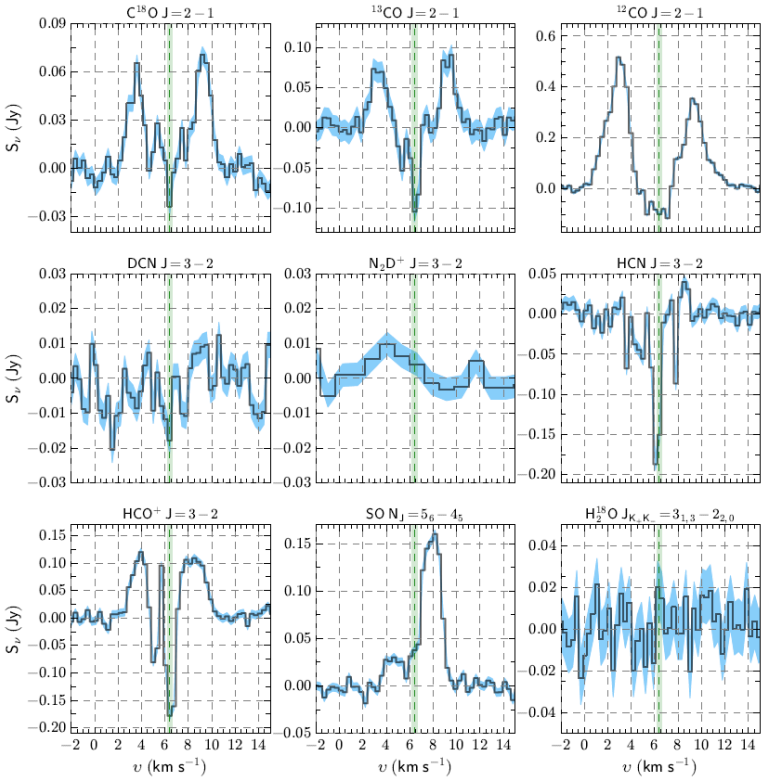
- 一様ガスの中に埋め込まれ、accretion を続ける Prestellar core の進化モデル
- 密度分布の形を ρ∝r^{-p} としたとき、p=2 が定常でアトラクターになる
  - p<2 の場合は、内側で重力的に安定になる（外側は accretion し続けている）
- 観測的には p=1.7-1.9 くらい
  - 時間が経つと、密度分布のベキが急激になっていく
- 磁場を入れた場合も、内側は磁気圧で支えられるようになる
  - 実際には、外側は不安定で accretion し続ける
- Prestellar core の重力的安定性を議論するには、large scale での運動を見ることが必要

No. 13

Resolved molecular line observations reveal an inherited molecular layer in the young disk around TMC1A

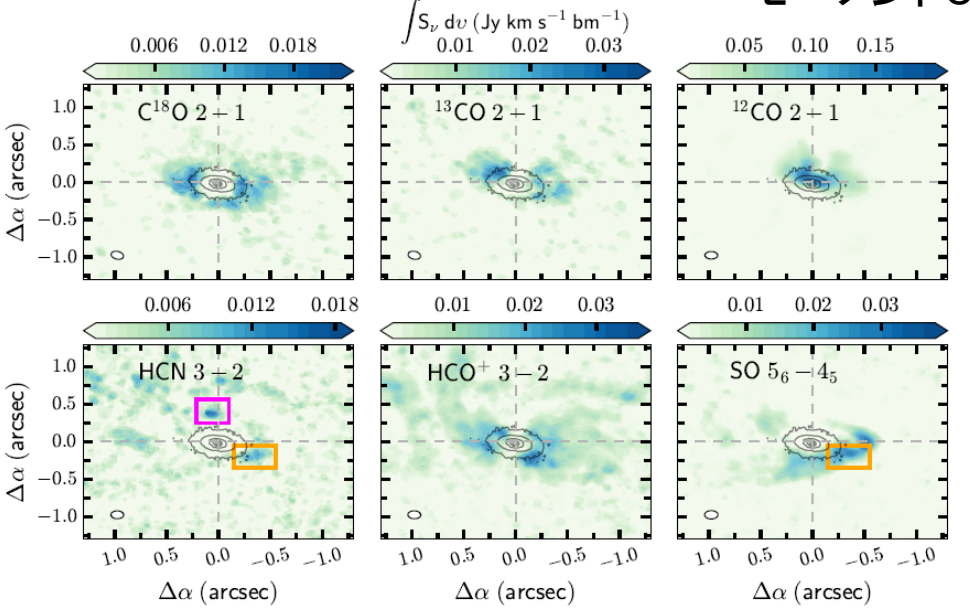
Daniel Harsono, Matthijs van der Wiel, Per Bjerkeli, Jon Ramsey, Hannah Calcutt, Lars Kristensen, Jes Jørgensen ★
Physical processes that govern the star and planet formation sequence influence the chemical composition and evolution of protoplanetary disks. To understand the chemical composition of protoplanets, we need to constrain the composition and structure of the disks from whence they are formed. We aim to determine the molecular abundance structure of the young disk around the TMC1A protostar on au scales in order to understand its chemical structure and any possible implications for disk formation. We present spatially resolved Atacama Large Millimeter/submillimeter Array observations of CO, HCO^+, HCN, DCN, and SO line emission, as well as dust continuum emission, in the vicinity of TMC1A. Molecular column densities are estimated both under the assumption of optically thin emission from molecules in LTE as well as through more detailed non-LTE radiative transfer calculations. Resolved dust continuum emission from the disk is detected between 220 and 260 GHz. Rotational transitions from HCO^+, HCN, and SO are also detected from the inner 100 au region. From the derived HCO^+ abundance, we estimate the ionization fraction of the disk surface and find values that imply that the accretion process is not driven by the magneto-rotational instability. The molecular abundances averaged over the TMC1A disk are similar to its protostellar envelope and other, older Class II disks. We meanwhile find a discrepancy between the young disk's molecular abundances relative to Solar System objects. Abundance comparisons between the disk and its surrounding envelope for several molecular species reveal that the bulk of planet-forming material enters the disk unaltered. Differences in HCN and H_2O molecular abundances between the disk around TMC1A, Class II disks, and Solar System objects trace the chemical evolution during disk and planet formation.

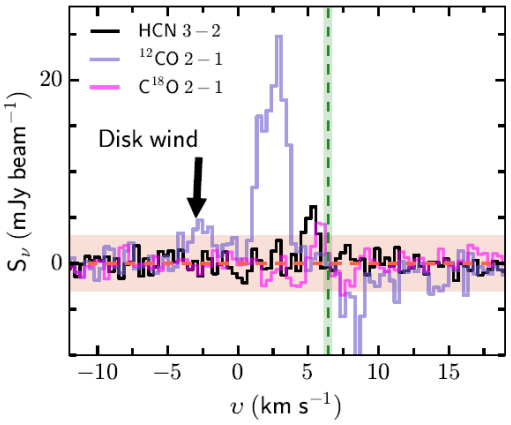
- 原始星 TMC-1A の周囲の円盤の化学組成の空間分布を ALMA で調べた
  - CO, HCO+, HCN, DCN, SO を空間分解
  - HCO+, HCN, SO を、中心星から 100au 以内の領域で検出
- HCO+ のアバンダンスから円盤のイオン化率を求め、MRI による質量降着が起きていないことが示唆された
- 様々な分子の存在量・存在比を、Class II 天体や太陽系天体と比較して、円盤や惑星形成の化学進化を探る



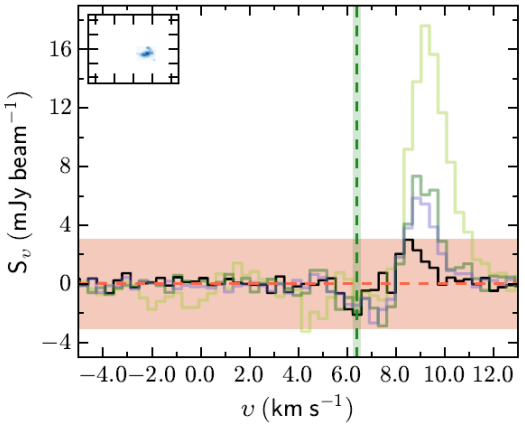
観測された分子のスペクトル

モーメント0



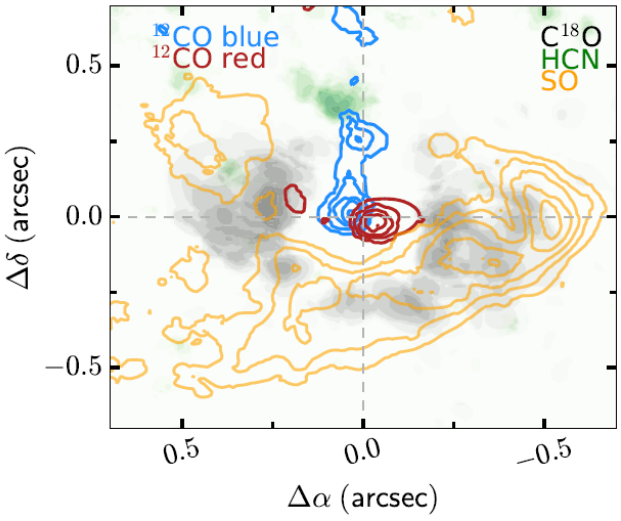


北側のスペクトル

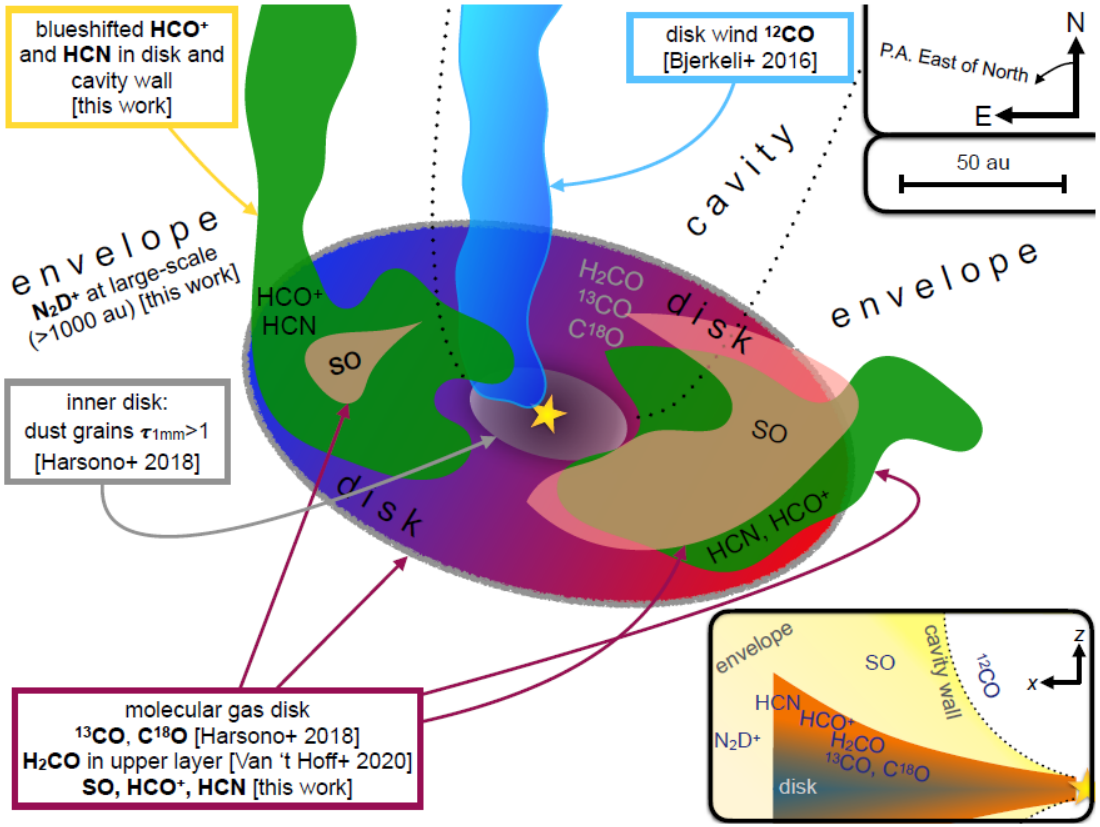


西側のスペクトル

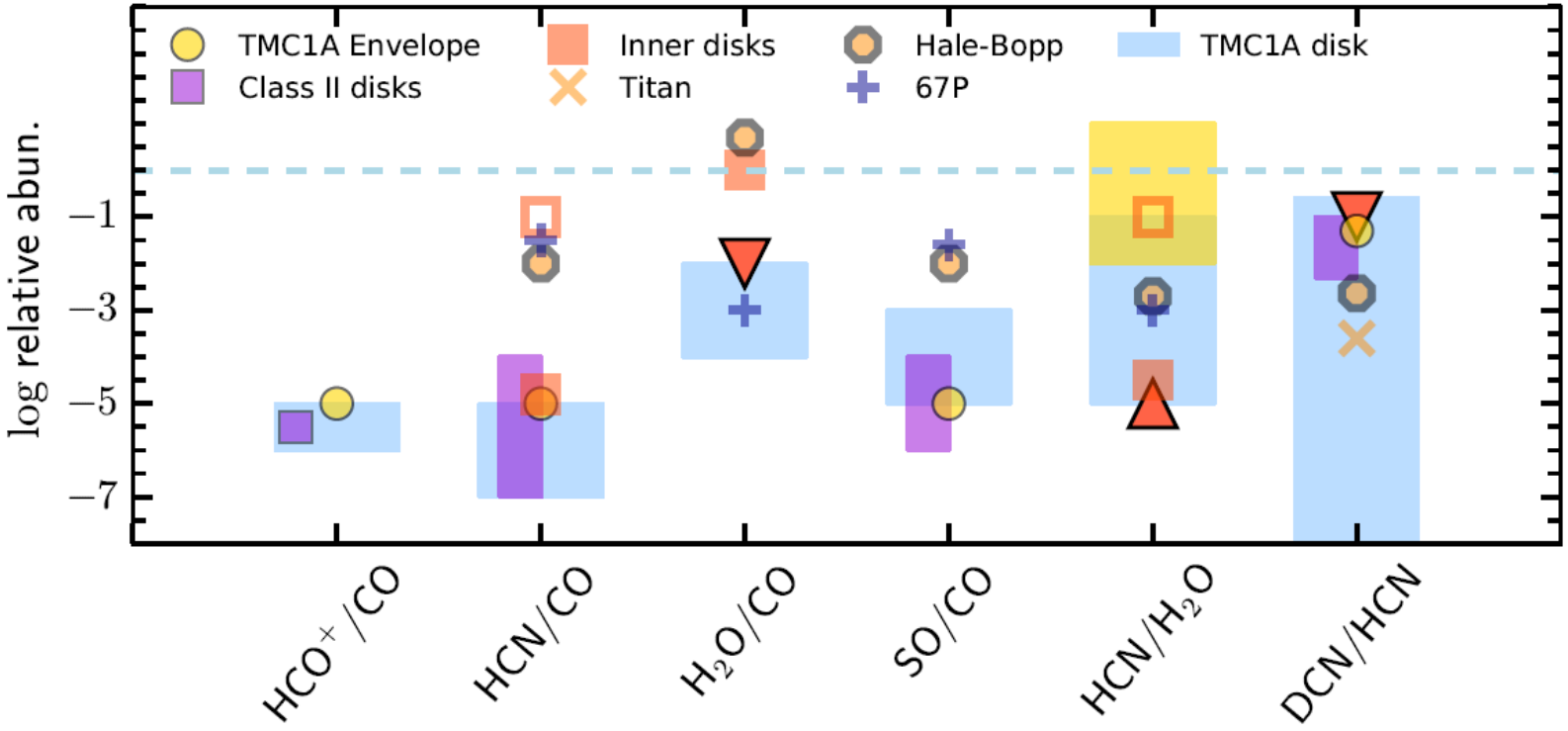
HCN, HCO+, SO, C18O



様々な分子の emission
が見えている場所



TMC-1A の全体像



太陽系や Class II との、分子存在比の比較

- TMC-1A の円盤とエンベロープで、分子の存在比はほぼ同じであり、エンベロープからの円盤形成はスムーズに起こる
- HCO+/CO, HCN/CO, SO/CO は、TMC-1A と Class II 円盤でほぼ同じであり、一部の分子については円盤形成の段階で、その量がある程度決まっている
- 太陽系天体との違い： HCN/H2O 比