THE STAR FORMATION NEWSLETTER No. 332 (#48-54)

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23 Oct. 2020

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An APEX survey of outflow and infall toward the youngest protostars in Orion

Z. Nagy et al.

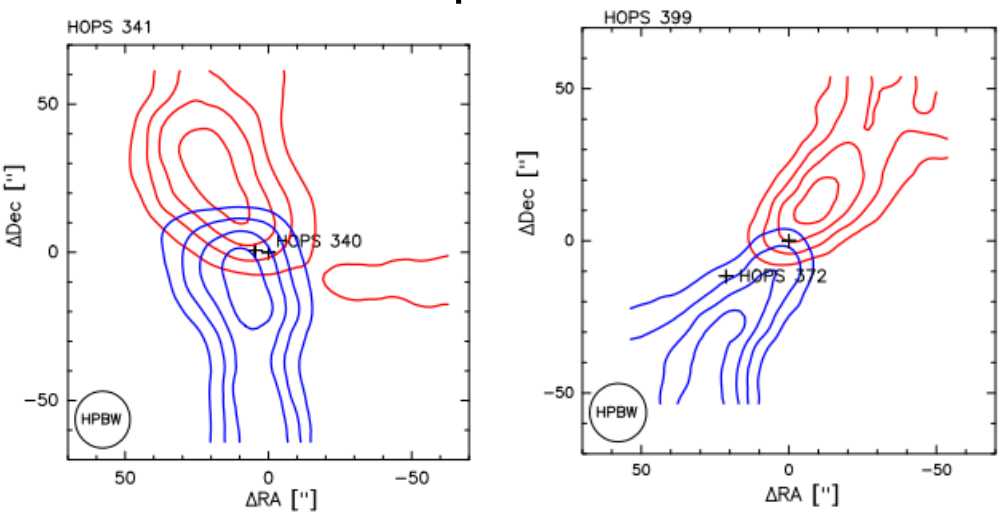
We aim to characterize the outflow properties of a sample of early Class 0 phase low-mass protostars in Orion, which were first identified by the *Herschel* Space Observatory. We also look for signatures of infall in key molecular lines. Maps of CO J=3-2 and J=4-3 toward 16 very young Class 0 protostars were obtained using the Atacama Pathfinder EXperiment (APEX) telescope. We searched the data for line wings indicative of outflows and calculated masses, velocities, and dynamical times for the outflows. We used additional HCO^+, $H^{13}CO^+$, and NH_3 lines to look for infall signatures toward the protostars. We estimate the outflow masses, forces, and mass-loss rates based on the CO J=3-2 and J=4-3 line intensities for eight sources with detected outflows. We derive upper limits for the outflow masses and forces of sources without clear outflow detections. The total outflow masses for the sources with clear outflow detections are in the range between 0.03 and 0.16 $M_\odot$ for CO J=3-2 and between 0.02 and 0.10 $M_\odot$ for CO J=4-3. The outflow forces are in the range between 1.57×10^{-4} and 1.16×10^{-3} $M_\odot$ km s^{-1} yr^{-1} for CO J=3-2 and between 1.14×10^{-4} and 6.92×10^{-4} $M_\odot$ km s^{-1} yr^{-1} for CO J=4-3. Nine protostars in our sample show asymmetric line profiles indicative of infall in HCO^+, compared to $H^{13}CO^+$ or NH_3. The outflow forces of the protostars in our sample show no correlation with the bolometric luminosity, unlike those found by some earlier studies for other Class 0 protostars. The derived outflow forces for the sources with detected outflows are similar to those found for other, more evolved, Class 0 protostars, suggesting that outflows develop quickly in the Class 0 phase.

- Orion領域で同定されたPACS Bright Red sourceに対してoutflow & infallの探査
- outflowの物理量をClass0天体と比較しClass0天体との違いを探る

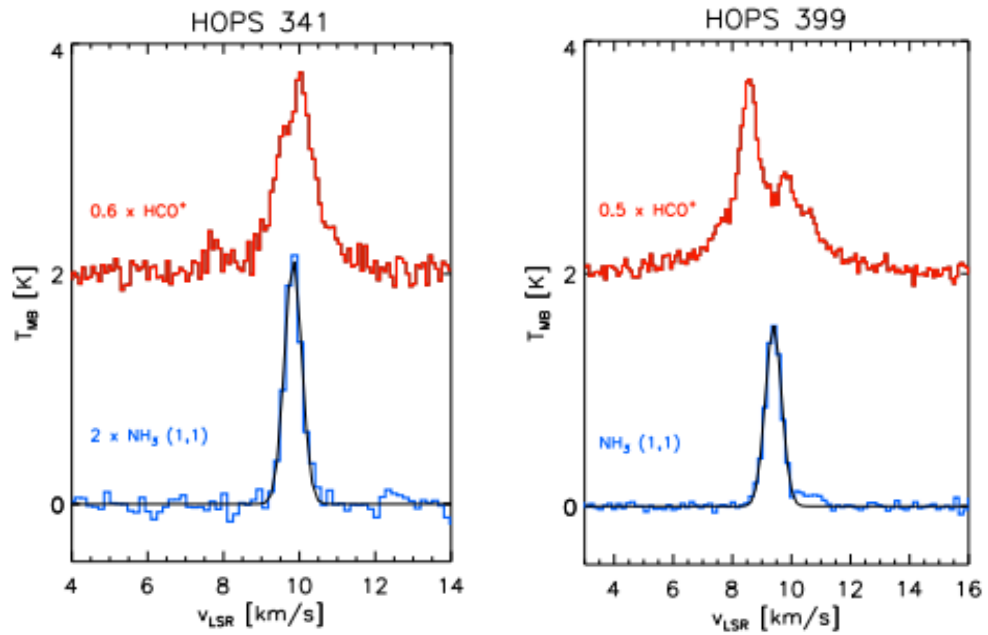
- PACS Bright Red Source (PBR)
  - 24μmで暗いが70, 160μmで明るい原始星(SpitzerでIDされにくい)
  - Class0的だが3mmのfluxが強めなのでもっと若い可能性がある
    - レアリティを考えるとt<25000yr
  - Orionでは19天体IDされている
- PBRに対するoutflow, infall signatureの系統的探査
  - APEX 12-m単一鏡 & GBT
    - CO(3-2), CO(4-3) - outflow探査
    - HCO+(3-2), $H^{13}CO^+$(3-2), NH_3(1,1) - infall motion探査
  - CARMAによる先行研究(Tobin+2016)も活用

HOPS[1]	PBR[2]	RA (deg) (J2000)	Dec (deg) (J2000)	L_{bol} ($L_\odot$)	T_{bol} (K)	i (deg)	Outflow detection CO J=3-2, J=4-3	CARMA CO J=1-0
340		86.7554	+0.4393	1.85	40.6		yes	
341		86.7541	+0.4395	2.07	39.4		blended	
354		88.6011	+1.7387	6.57	34.8	nearly edge-on	yes	
358		86.5301	-0.2250	24.96	41.7		yes	
359		86.8534	+0.3500	10.00	36.7		no	
372		85.3598	-2.3056	4.80	37.3		confusion	extended[3]
373	093003	86.6279	-0.0431	5.32	36.9	~50	yes	extended
394	019003	83.8497	-5.1315	6.56	45.5	~30	tentative	extended
397	061012	85.7036	-8.2696	1.66	46.1	intermediate	confusion	tentative
223		85.7019	-8.2762	19.25	247.5	intermediate	yes	extended
398	082005	85.3725	-2.3547	1.01	23.0		no	no
399	082012	85.3539	-2.3024	6.34	31.1	~50	yes	extended
400	090003	85.6885	-1.2706	2.94	35.0	~30	no	compact
401	091015	86.5319	-0.2058	0.61	26.0		tentative[4]	no
402		86.5415	-0.2047	0.55	24.2		no	no
403	093005	86.6156	-0.0149	4.14	43.9	~30	no	compact
404	097002	87.0323	+0.5641	0.95	26.1		no	no
405	119019	85.2436	-8.0934	1.60	35.0	edge-on	no	extended
407	302002	86.6177	+0.3242	0.71	26.8	~80	no	extended[5]

Outflow map例



Infall signature例

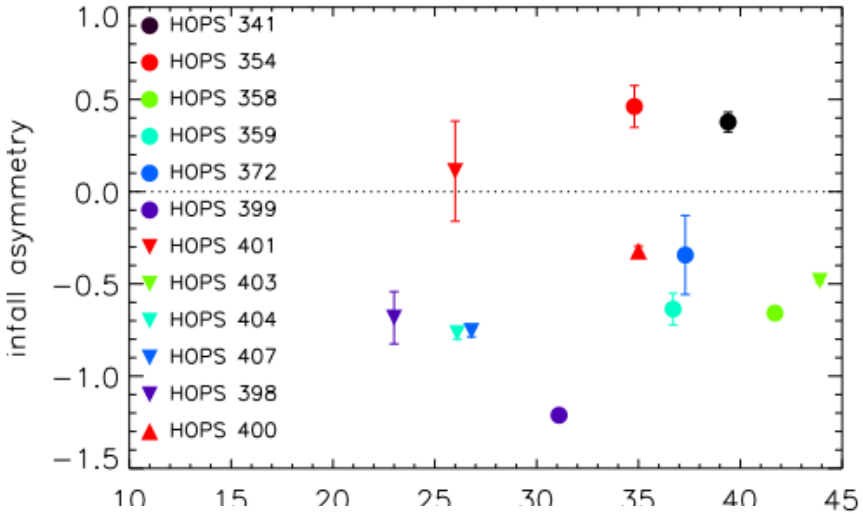


- Outflow force, kinetic luminosity, dynamical time, mass loss rateなどを導出
  - LTE assumption
  - blendedのケースなどは上限値等で対応

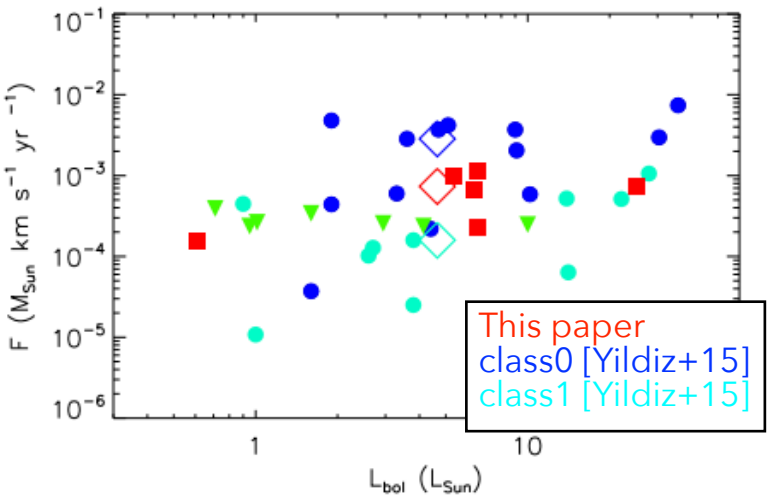
- Optically thin lineのピーク速度とoptically thick lineのピーク速度の差を評価
  - infall asymmetryの評価方法

    [Mardones+1997]

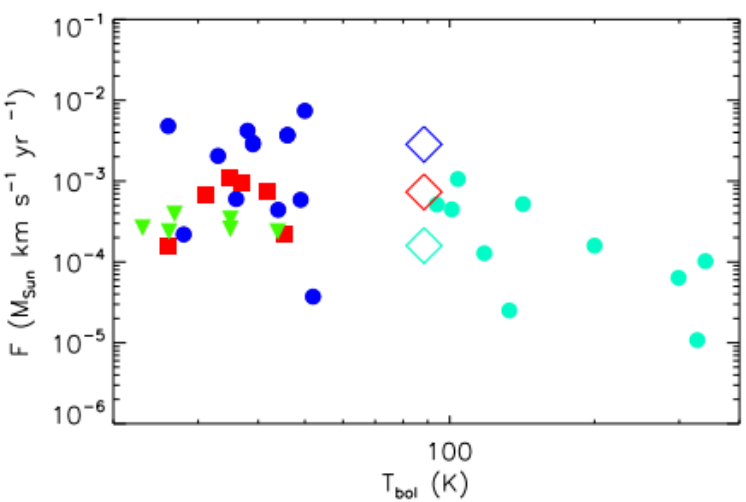
$$\delta V = (V_{\rm thick} - V_{\rm thin})/\Delta V_{\rm thin},$$



- δV < 0が多い
  - infall motionを示唆 [Mardones+97]
  - Class0天体でも見られるがClass1では見られない傾向
- PBRのinfallの兆候を捉えた初の例



- OutflowはClass0天体のものと明確な違いが見られない
- L_{bol}に対する相関も見られない
  - 過去の研究と異なるがサンプルが少ないせいかも
- PBRがClass0より若く寿命が1/6程度であることを考えると、outflowはClass0 phaseで急速に成長するのかもしれない



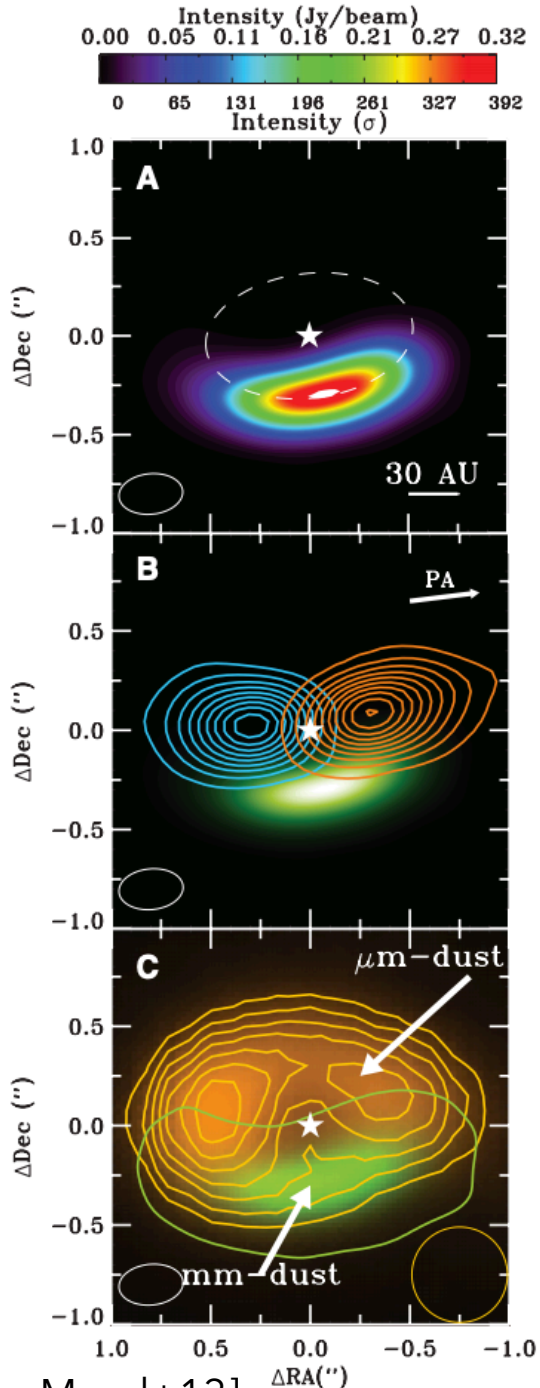
Solving grain size inconsistency between ALMA polarization and VLA continuum in the Ophiuchus IRS 48 protoplanetary disk
S. Ohashi, A. Kataoka et al.

The protoplanetary disk around Ophiuchus IRS 48 shows an azimuthally asymmetric dust distribution in (sub-)millimeter observations, which is interpreted as a vortex, where millimeter/centimeter-sized particles are trapped at the location of the continuum peak. In this paper, we present 860 μm ALMA observations of polarized dust emission of this disk. The polarized emission was detected toward a part of the disk. The polarization vectors are parallel to the disk minor axis, and the polarization fraction was derived to be 1–2%. These characteristics are consistent with models of self-scattering of submillimeter-wave emission, which indicate a maximum grain size of $\sim$100 μm. However, this is inconsistent with the previous interpretation of millimeter/centimeter dust particles being trapped by a vortex. To explain both, ALMA polarization and previous ALMA and VLA observations, we suggest that the thermal emission at 860 μm wavelength is optically thick ($\tau_{\rm abs} \sim 7.3$) at the dust trap with the maximum observable grain size of $\sim$100 μm rather than an optically thin case with $\sim$cm dust grains. We note that we cannot rule out that larger dust grains are accumulated near the midplane if the 860 μm thermal emission is optically thick.

- Oph IRS48 lopsided diskに対してALMAサブミリ波連続波の偏光観測 & VLA cm観測
- 円盤モデル&放射輸送計算で観測された偏光度と偏光角および連続波強度を再現するパラメータを探す
- 円盤はサブミリ波で光学的に厚くcmで薄い。偏光は円盤表面の100umダストで生じている。

- 原始惑星系円盤中のダストサイズ分布を観測的に調べる
  - サブミリ波スペクトル指数
    - 円盤ではα~2-3→1mmダストを示唆
  - 偏波観測でサブミリ波散乱をとらえる
    - $a_{\max} \sim \lambda/2\pi$のダストで偏光が強くなる
    - 100μmダストを示唆する観測が多い
  - 異なる場所を見ている？両方で調べることが重要
- Oph IRS 48 (d=120pc)
  - A-type star
  - ALMA(440μm)で強い非対称円盤, VLA(8.8mm)も検出

    → gas vortexによるdust trap
    - larger dust grainはより中心にtrap
- ALMA 860μm偏波観測
  - 分解能~0.49”x0.39” (=59x47au)
  - 直線偏光のみ
  - Δ(偏光度)~0.1%, Δ(偏光角)~1deg
- VLA 8.8mm & ALMA 440μmも使用

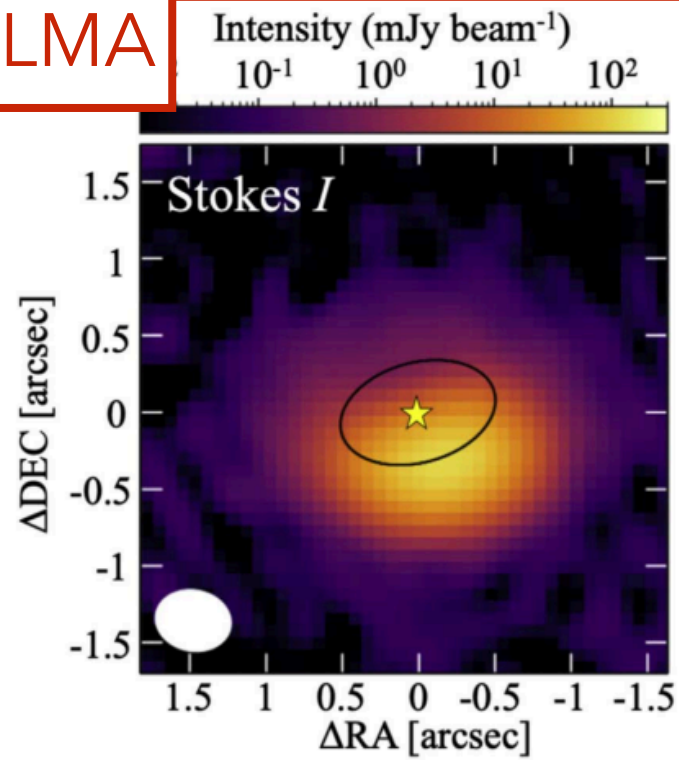


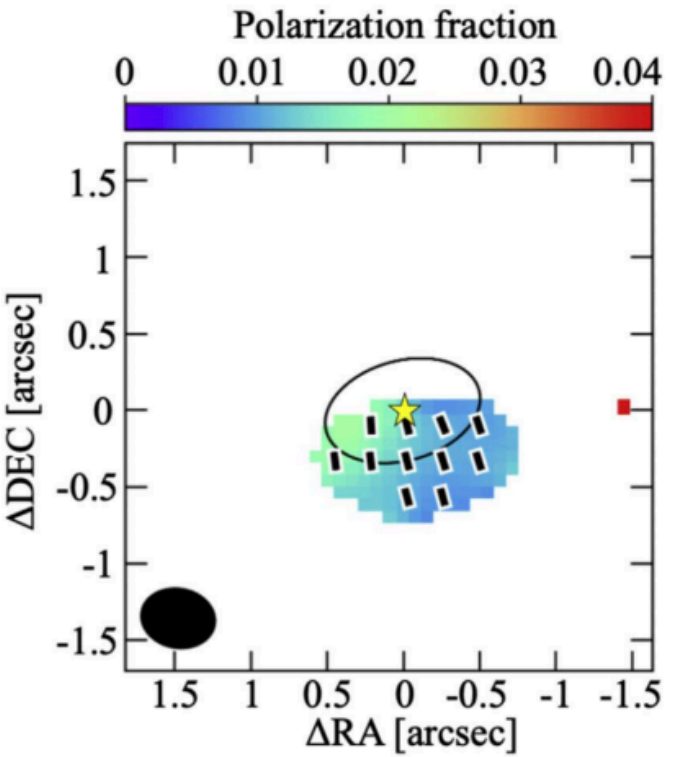
[van der Marel+13]

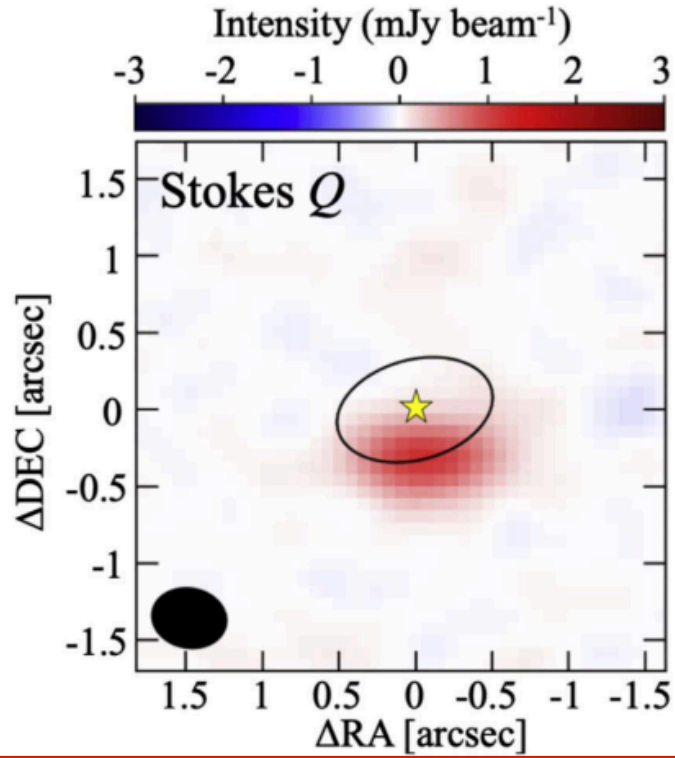
- 動径方向の偏波ベクトル(~10deg)

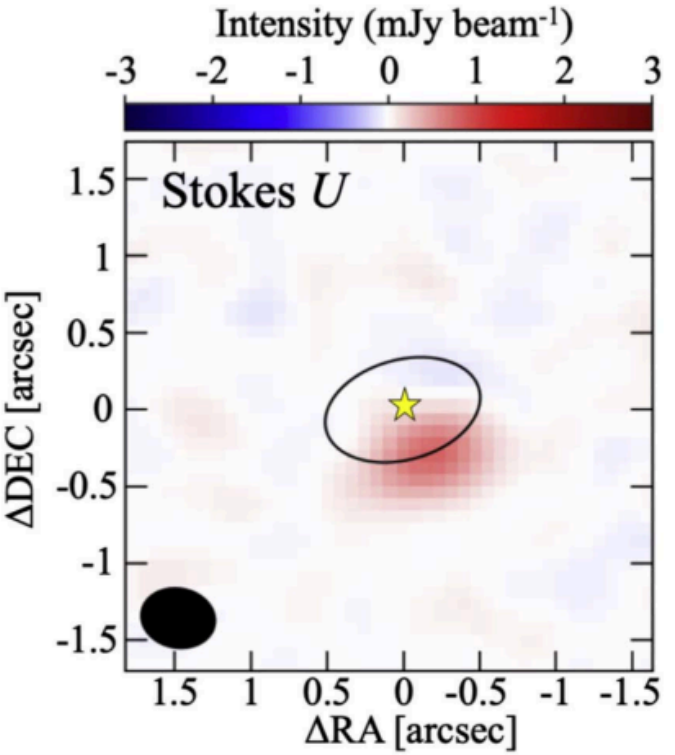
  →円盤minor axis
- 偏光度は~1–2%
- VLA8.8mmはよりコンパクト

ALMA

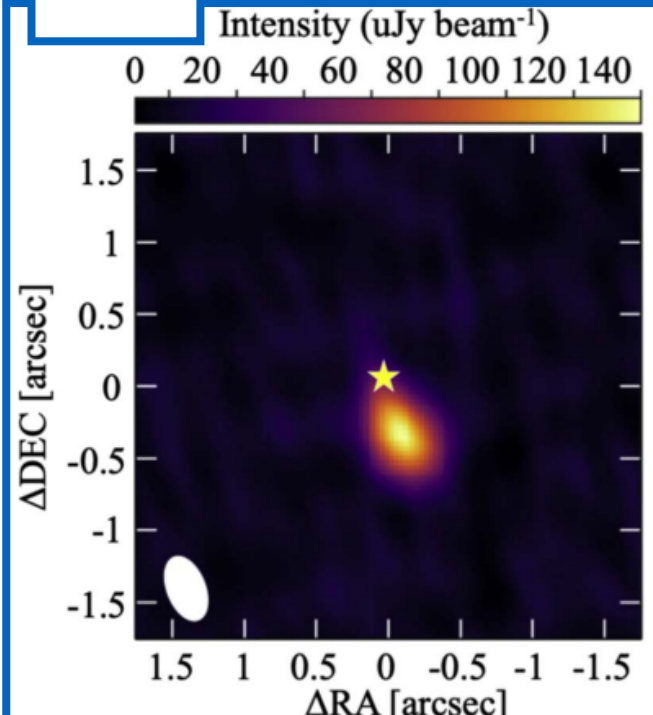








VLA

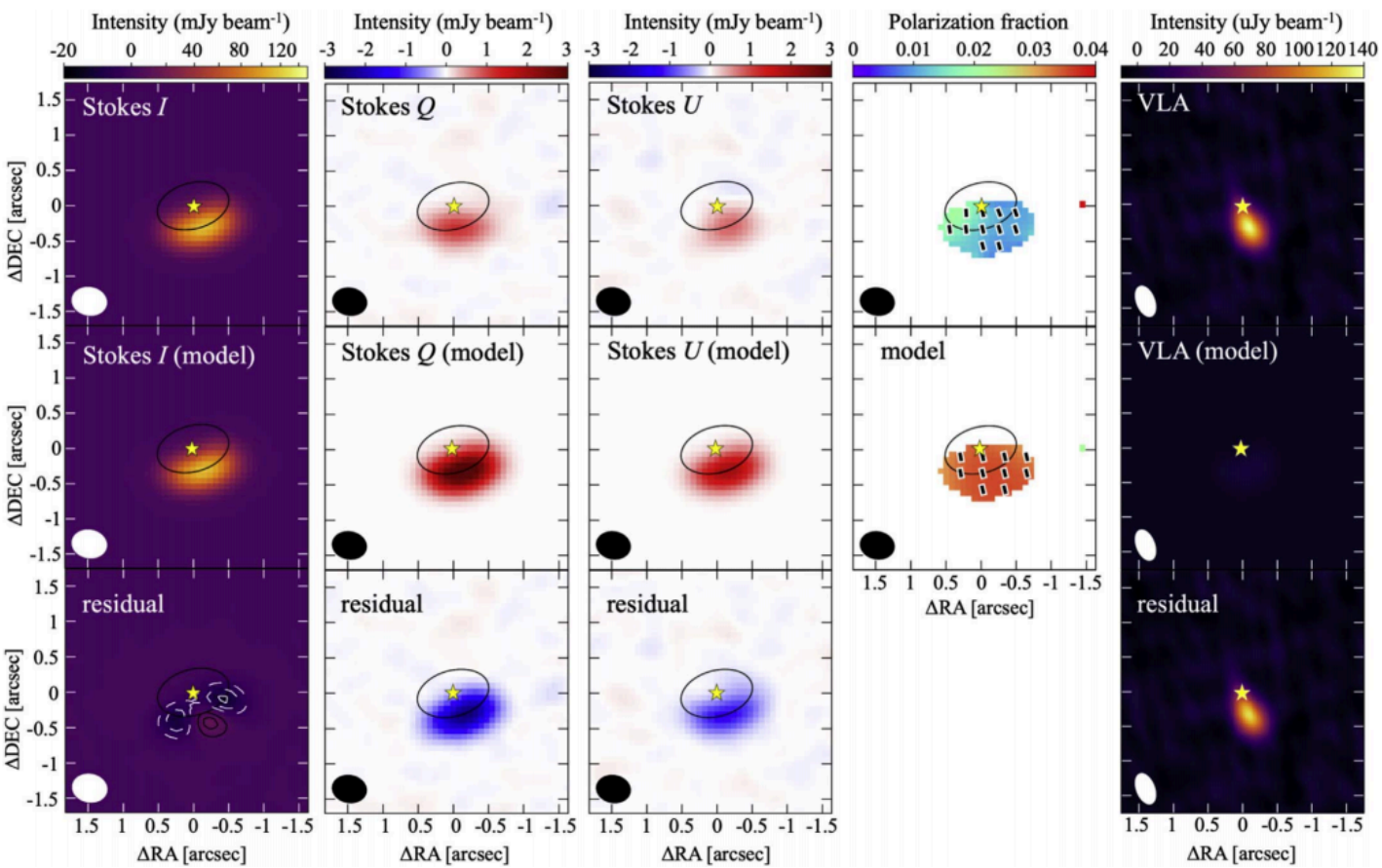


- 円盤モデル+放射輸送計算(RADMC3D)で全観測を再現する
  - 動径&方位角方向にガウシアンの密度分布
  - $h_d = h_g/10$
  - 3つの円盤+ダストサイズcondition
  - T_d=60K at 60au
  - 観測分解能でsmoothing

Table 1
Models of Possible Dust Distributions for Radiative Transfer Calculations

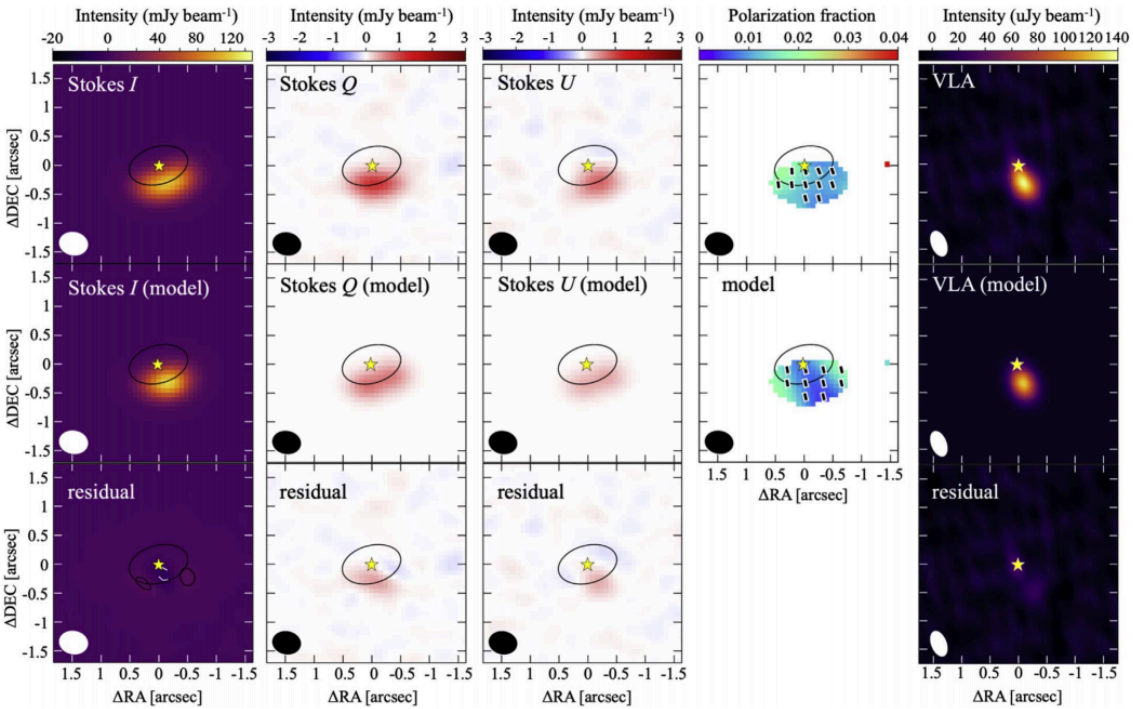
Optically thin model
1. Optically thin with $a_{max} \sim 100\ \mu$m 2. Optically thin with $a_{max} \sim 100\ \mu$m and ~1 cm
Optically thick model
3. Optically thick with $a_{max} \sim 100\ \mu$m

Optically thin & a_{max}~100μm



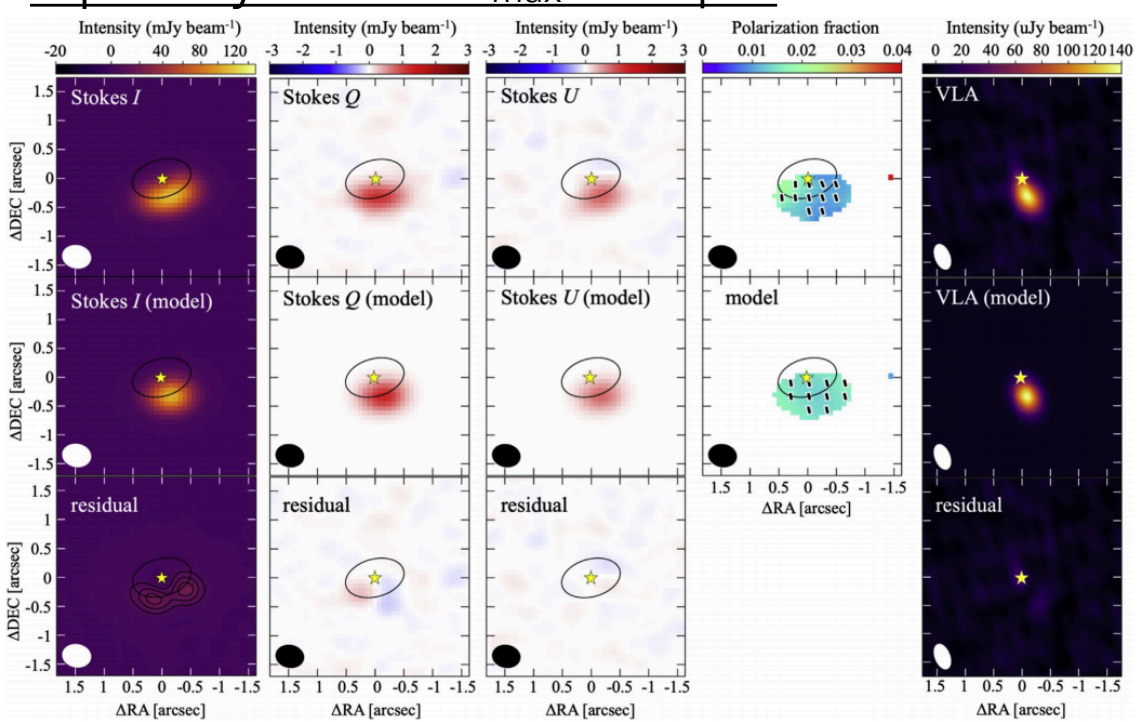
- 観測と合わない
  - 偏光度が高すぎる
  - VLAの強度が足りない

Optically thin & a_{max}~100μm+1cm



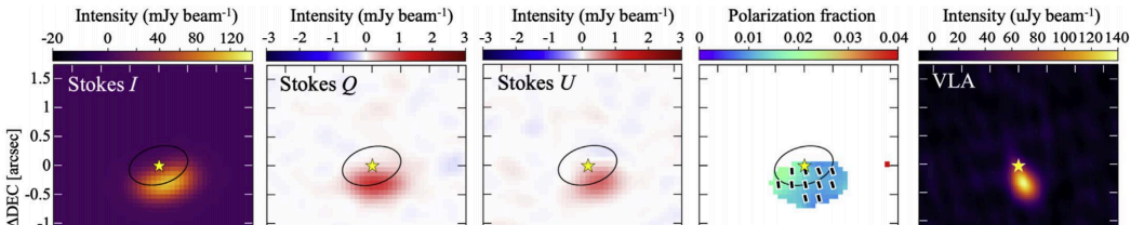
- 中心に1cmダストを追加
- VLA放射を再現
- 偏光度も合う
  - 1cmダストのせいで変更度が下がる
- 現実的なa_{max}の空間分布を考えると、偏光度はもっと小さくなり観測と合わないかも

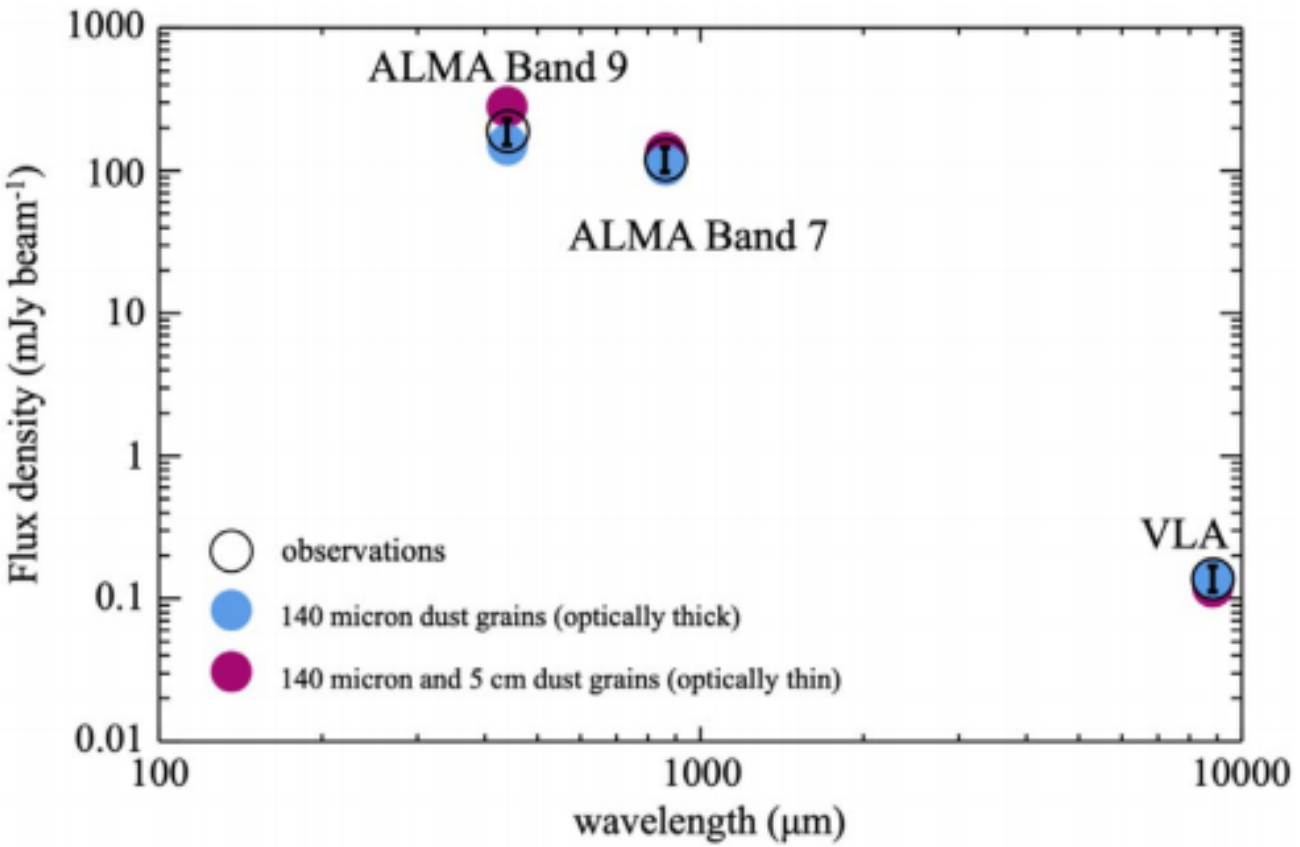
Optically thick & a_{max}~100μm

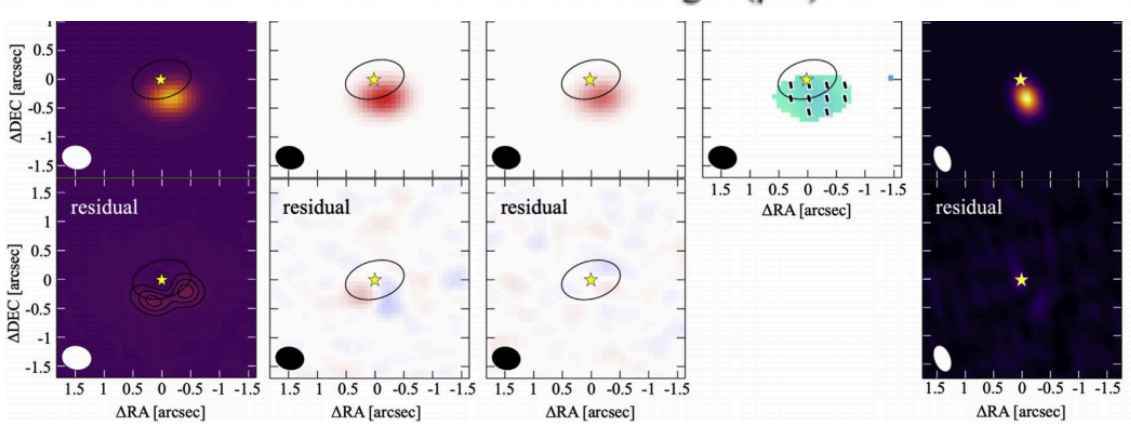


- 従来のモデルより柱密度を大きくする (0.15→8.2 g/cm^2)
  - 860μmでoptically thick, 8.8mmでthin
- 観測と整合
  - 860μmの残差に対応する希薄なダストを加える必要があるかも
- 偏光は円盤表面の100μmダスト起源。赤道面に成長したダストがあっても良い。

Optically thin & a_{max}~100μm+1cm







- 中心に1cmダストを追加
- VLA放射を再現
- 偏光度も合う

cmダストのせいで変更度が下がる

的なa_{max}の空間分布を考える

偏光度はもっと小さくなり観

合わないかも

のモデルより柱密度を大きくする

5→8.2 g/cm^2)

60μmでoptically thick, 8.8mmでthin

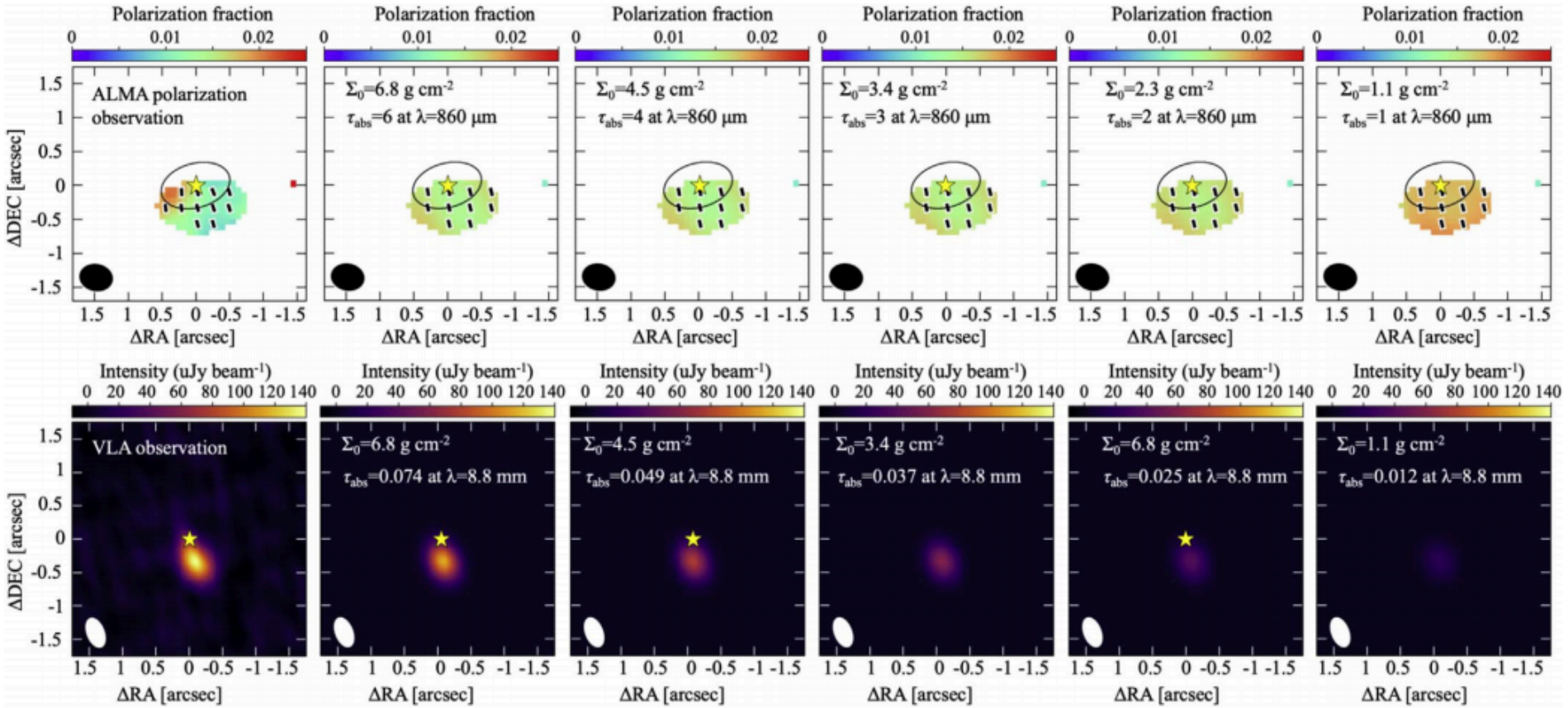
と整合

60μmの残差に対応する希薄なダストを加える必要があるかも

- 偏光は円盤表面の100μmダスト起源。赤道面に成長したダストがあっても良い。

440μm強度まで考えるとthickケースの方が良さそう

- $\Sigma_d = 8.2\ \mathrm{g\ cm^{-2}}$; 重力安定であるためにはg2d<10が必要
  - van der Marel+16のガス質量の見積もりとconsistent
  - $\Sigma_d < 8.2\ \mathrm{g\ cm^{-2}}$だと偏光度は再現するがVLAのflux densityが足りない



- h_d=h_gの場合、偏光度が小さくなり観測と不整合

  →ダストは沈殿している方が合いそう
  - 少なくともh_d=h_g/2, より正確に出すには高分解能観測が必要

Searching for debris discs in the 30 Myr open cluster IC 4665

N. Miret-Roig et al.

Context. Debris discs orbiting young stars are key to understand dust evolution and the planetary formation process. We take advantage of a recent membership analysis of the 30 Myr nearby open cluster IC 4665 based on the Gaia and DANCe surveys to revisit the disc population of this cluster.
Aims. We aim to study the disc population of IC 4665 using Spitzer (MIPS and IRAC) and WISE photometry.
Methods. We use several colour-colour diagrams with empirical photospheric sequences to detect the sources with an infrared excess. Independently, we also fit the spectral energy distribution (SED) of our debris disc candidates with the Virtual Observatory SED analyser (VOSA) which is capable of automatically detecting infrared excesses and provides effective temperature estimates.
Results. We find six candidates debris disc host-stars (five with MIPS and one with WISE) and two of them are new candidates. We estimate a disc fraction of 24±10% for the B–A stars, where our sample is expected to be complete. This is similar to what has been reported in other clusters of similar ages (Upper Centaurus Lupus, Lower Centaurus Crux, the β Pictoris moving group, and the Pleiades). For solar type stars we find a disk fraction of 9±9%, lower than that observed in regions with comparable ages.
Conclusions. Our candidates debris disc host-stars are excellent targets to be studied with ALMA or the future James Webb Space Telescope (JWST).

- 既存データを用いたOpen cluster IC 4665でのデブリ円盤探査
- 6つのデブリ円盤候補天体を検出, 2つは新検出
- ALMAやJWSTの観測候補

Dynamical traceback age of the β Pictoris moving group

N. Miret-Roig et al.

Context. The β Pictoris moving group is one of the most well-known young associations in the solar neighbourhood and several members are known to host circumstellar discs, planets, and comets. Measuring its age with precision is basic to study several astrophysical processes such as planet formation and disc evolution which are strongly age dependent.
Aims. We aim to determine a precise and accurate dynamical traceback age for the β Pictoris moving group.
Methods. Our sample combines the extremely precise *Gaia* DR2 astrometry with ground-based radial velocities measured in an homogeneous manner. We use an updated version of our algorithm to determine dynamical ages. The new approach takes into account a robust estimate of the spatial and kinematic covariance matrices of the association to improve the sample selection process and to perform the traceback analysis.
Results. We estimate a dynamical age of $18.5^{+2.0}_{-2.4}$ Myr for the β Pictoris moving group. We investigated the spatial substructure of the association at birth time and we propose the existence of a core of stars more concentrated. We also provide precise radial velocity measurements for 81 members of β Pic, including ten stars with the first determination of their radial velocities.
Conclusions. Our dynamical traceback age is three times more precise than previous traceback age estimates and, more important, for the first time, reconciles the traceback age with the most recent estimates of other dynamical, lithium depletion boundary, and isochronal ages. This has been possible thanks to the excellent astrometric and spectroscopic precisions, the homogeneity of our sample, and the detailed analysis of binaries and membership.

- GAIAやradial velocityデータを使った、新しいアルゴリズムを用いて、beta pic. moving groupのdynamical ageを詳細に決める
- 従来の3倍近い精度で年齢を決めれた
- 従来の他の見積もり方法による値が正確であることを確認したことも重要

Unified simulations of planetary formation and atmospheric evolution II: Rapid disk clearing by photoevaporation yields low-mass super-Earth atmospheres

M. Ogihara et al.

Super-Earths possess low-mass H_2/He atmospheres (typically less than 10% by mass). However, the origins of super-Earth atmospheres have not yet been ascertained. We investigate the role of rapid disk clearing by photoevaporation during the formation of super-Earths and their atmospheres. We perform unified simulations of super-Earth formation and atmospheric evolution in evolving disks that consider both photoevaporative winds and magnetically driven disk winds. For the growth mode of planetary cores, we consider two cases in which planetary embryos grow with and without pebble accretion. Our main findings are summarized as follows. (i) The time span of atmospheric accretion is shortened by rapid disk dissipation due to photoevaporation, which prevents super-Earth cores from accreting massive atmospheres. (ii) Even if planetary cores grow rapidly by embryo accretion in the case without pebble accretion, the onset of runaway gas accretion is delayed because the isolation mass for embryo accretion is small. Together with rapid disk clearing, the accretion of massive atmospheres can be avoided. (iii) After rapid disk clearing, a number of high-eccentricity embryos can remain in outer orbits. Thereafter, such embryos may collide with the super-Earths, leading to efficient impact erosion of accreted atmospheres. We, therefore, find that super-Earths with low-mass H_2/He atmospheres are naturally produced by N-body simulations that consider realistic disk evolution.

- super Earthの大気を再現するため、惑星形成期における原始惑星系円盤のphotoevaporationによるclearingの影響を調べた
- PEの円盤散逸により大気形成時間が短くなり、low-massのH2/He大気を再現する
- 円盤散逸が早いためeccentricityの大きいembryoが外側に残る

The Origin of Massive Stars: The Inertial–Inflow Model

P. Padoan et al.

We address the problem of the origin of massive stars, namely the origin, path and timescale of the mass flows that create them. Based on extensive numerical simulations, we propose a scenario where massive stars are assembled by large-scale, converging, inertial flows that naturally occur in supersonic turbulence. We refer to this scenario of massive-star formation as the *Inertial-Inflow Model*. This model stems directly from the idea that the mass distribution of stars is primarily the result of *turbulent fragmentation*. Under this hypothesis, the statistical properties of the turbulence determine the formation timescale and mass of prestellar cores, posing definite constraints on the formation mechanism of massive stars. We quantify such constraints by the analysis of a simulation of supernova-driven turbulence in a 250-pc region of the interstellar medium, describing the formation of hundreds of massive stars over a time of approximately 30 Myr. Due to the large size of our statistical sample, we can say with full confidence that *massive stars in general do not form from the collapse of massive cores, nor from competitive accretion*, as both models are incompatible with the numerical results. We also compute synthetic continuum observables in Herschel and ALMA bands. We find that, depending on the distance of the observed regions, estimates of core mass based on commonly-used methods may exceed the actual core masses by up to two orders of magnitude, and that there is essentially no correlation between estimated and real core masses.

- 大質量星形成のextensive numerical simulation
- Inertial-Inflow Modelの提唱
  - “Large-scale, converging, inertial flow”による大質量形成
- *“we can say with full confidence that massive stars in general do not form from the collapse of massive cores, nor from competitive accretion”*