# 星形成セミナー

大橋聡史（国立天文台）

GAEP 0913-19 72-142

# Kinematic study of the Orion Complex: Analysing the young stellar clusters from big and small structures

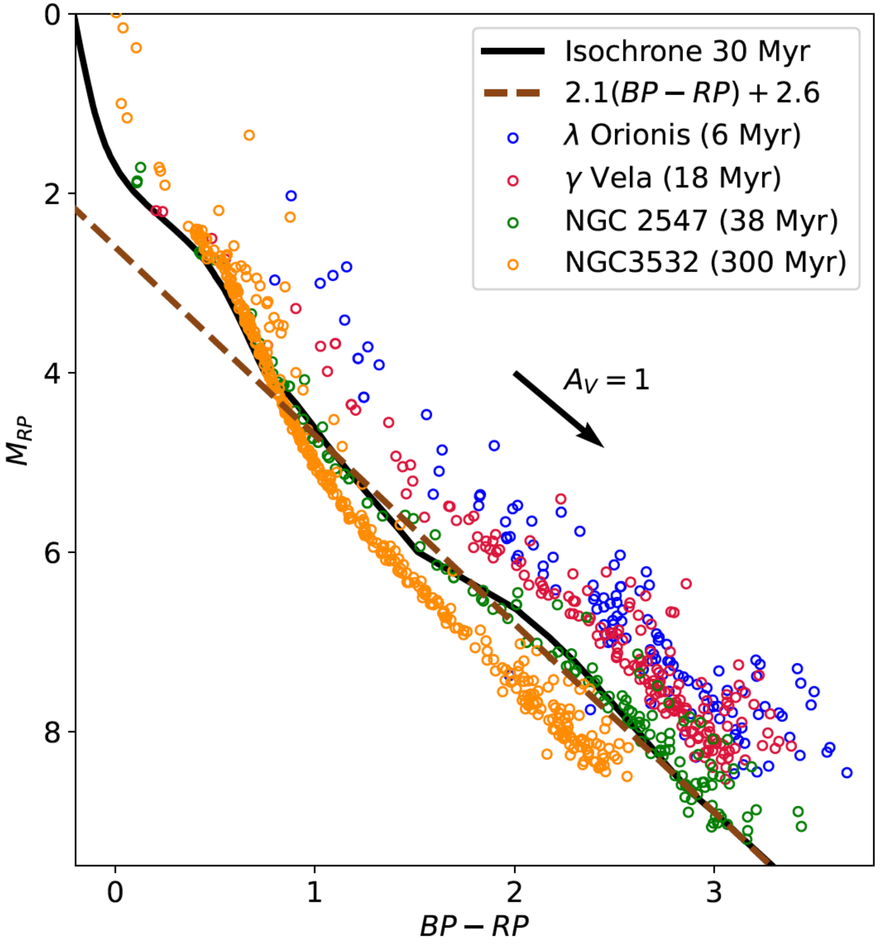
Sergio Sánchez-Sanjuán,[1★] Jesús Hernández,[1] Ángeles Pérez-Villegas,[1] Carlos Román-Zúñiga,[1]
Luis Aguilar,[1] Javier Ballesteros-Paredes,[2] Andrea Bonilla-Barroso[2]

Gaia DR3 を用いたオリオン大星雲に付随するYSOのクラスタリングとその運動を調べた

**ABSTRACT**

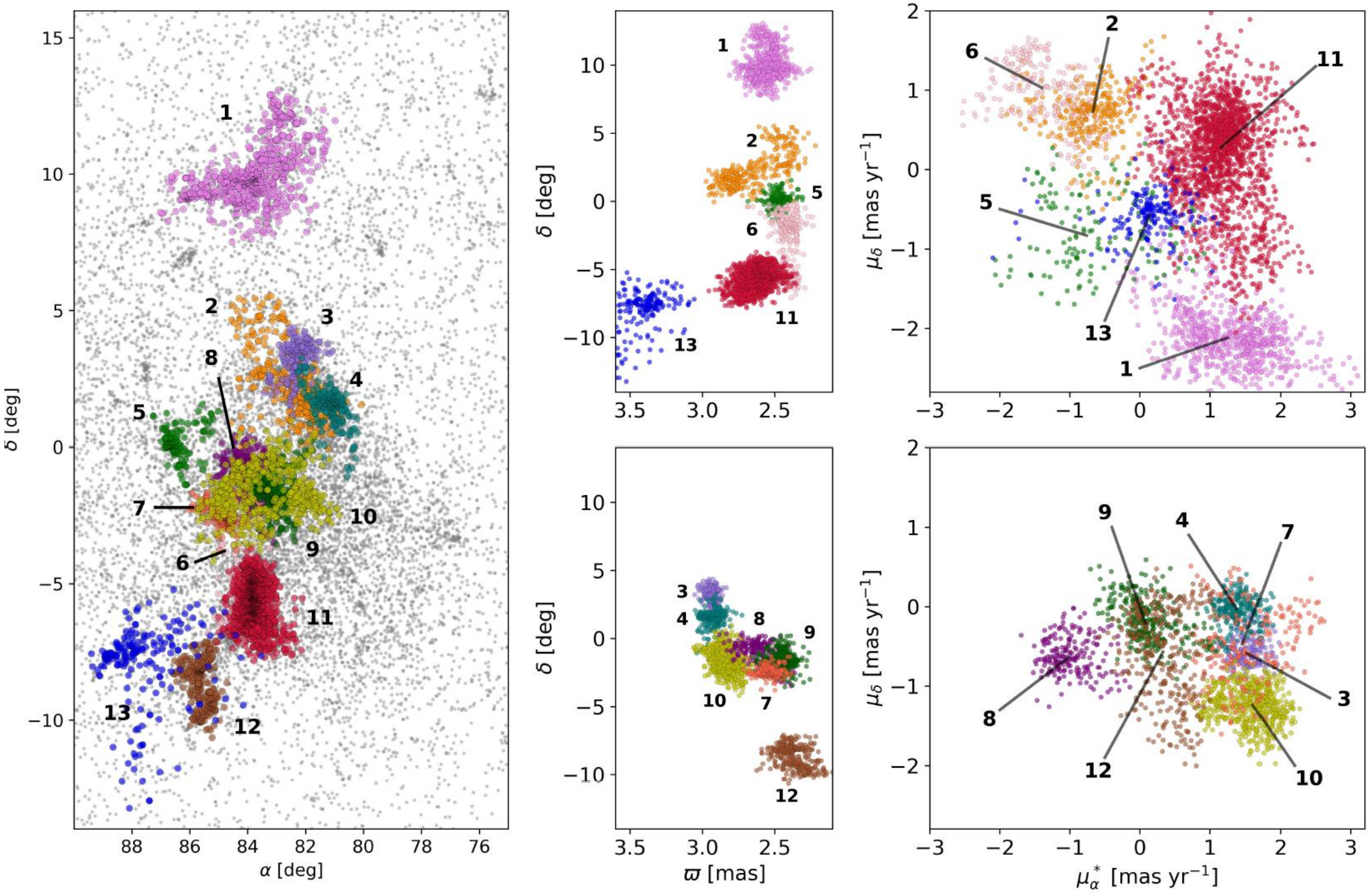
In this work, we analysed young stellar clusters with spatial and kinematic coherence in the Orion star-forming complex. For this study, we selected a sample of pre-main sequence candidates using parallaxes, proper motions and positions on the colour-magnitude diagram. After applying a hierarchical clustering algorithm in the 5D parameter space provided by *Gaia* DR3, we divided the recovered clusters into two regimes: *Big Structures* and *Small Structures*, defined by the number of detected stars per cluster. In the first regime, we found 13 stellar groups distributed along the declination axis in the regions where there is a high density of stars. In the second regime, we recovered 34 clusters classified into two types: 14 as *small groups* completely independent from the larger structures, including four candidates of new clusters, and 12 classified as *sub-structures* embedded within five larger clusters. Additionally, radial velocity data from APOGEE-2 and GALAH DR3 was included to study the phase space in some regions of the Orion complex. From the *Big Structure* regime, we found evidence of a general expansion in the Orion OB1 association over a common centre, giving a clue about the dynamical effects the region is undergoing. Likewise, in the *Small Structure* regime, the projected kinematics shows the ballistic expansion in the $\lambda$ Orionis association and the detection of likely events of clusters' close encounters in the OB1 association.

## 色等級図からYSOの年齢を推定

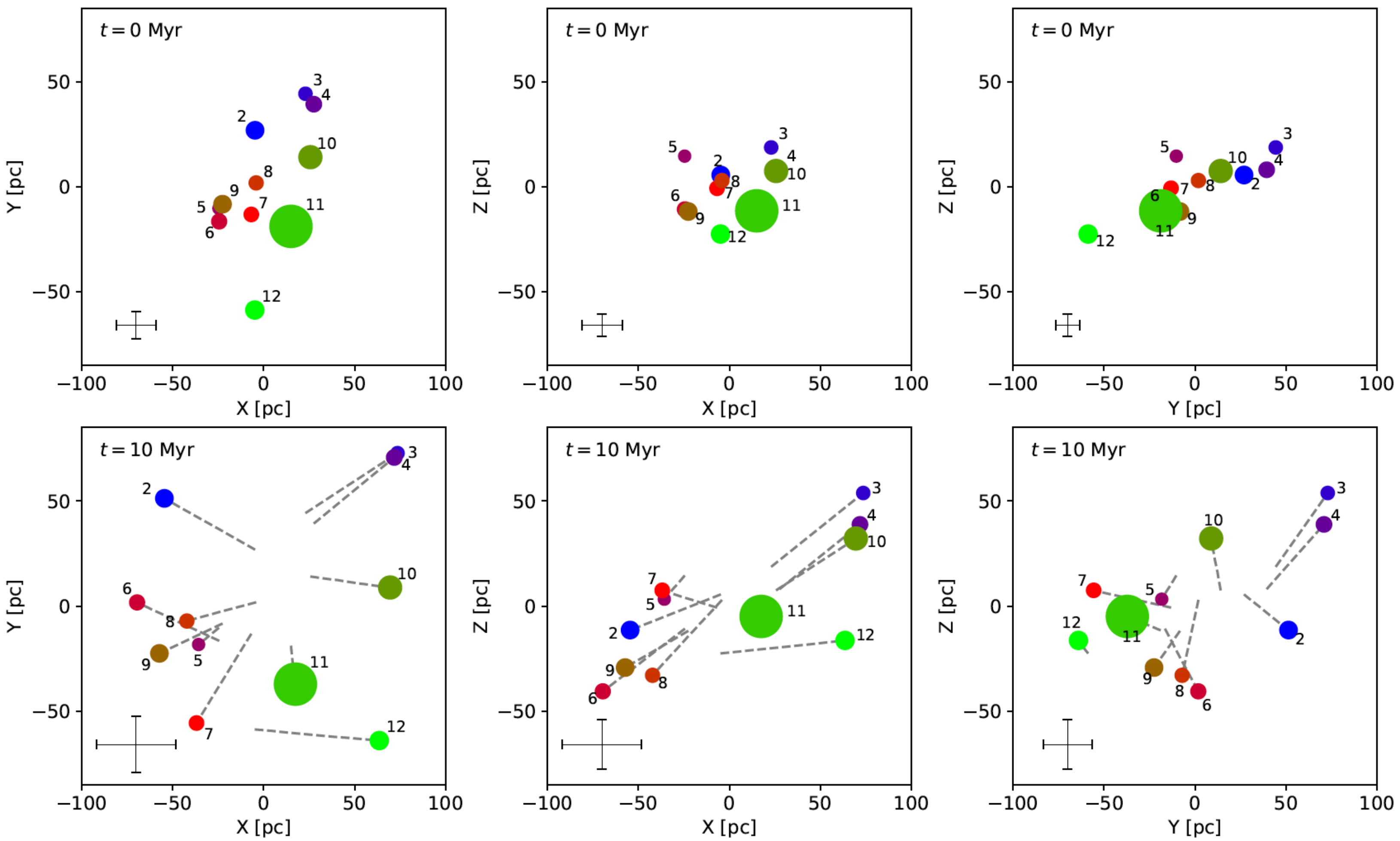


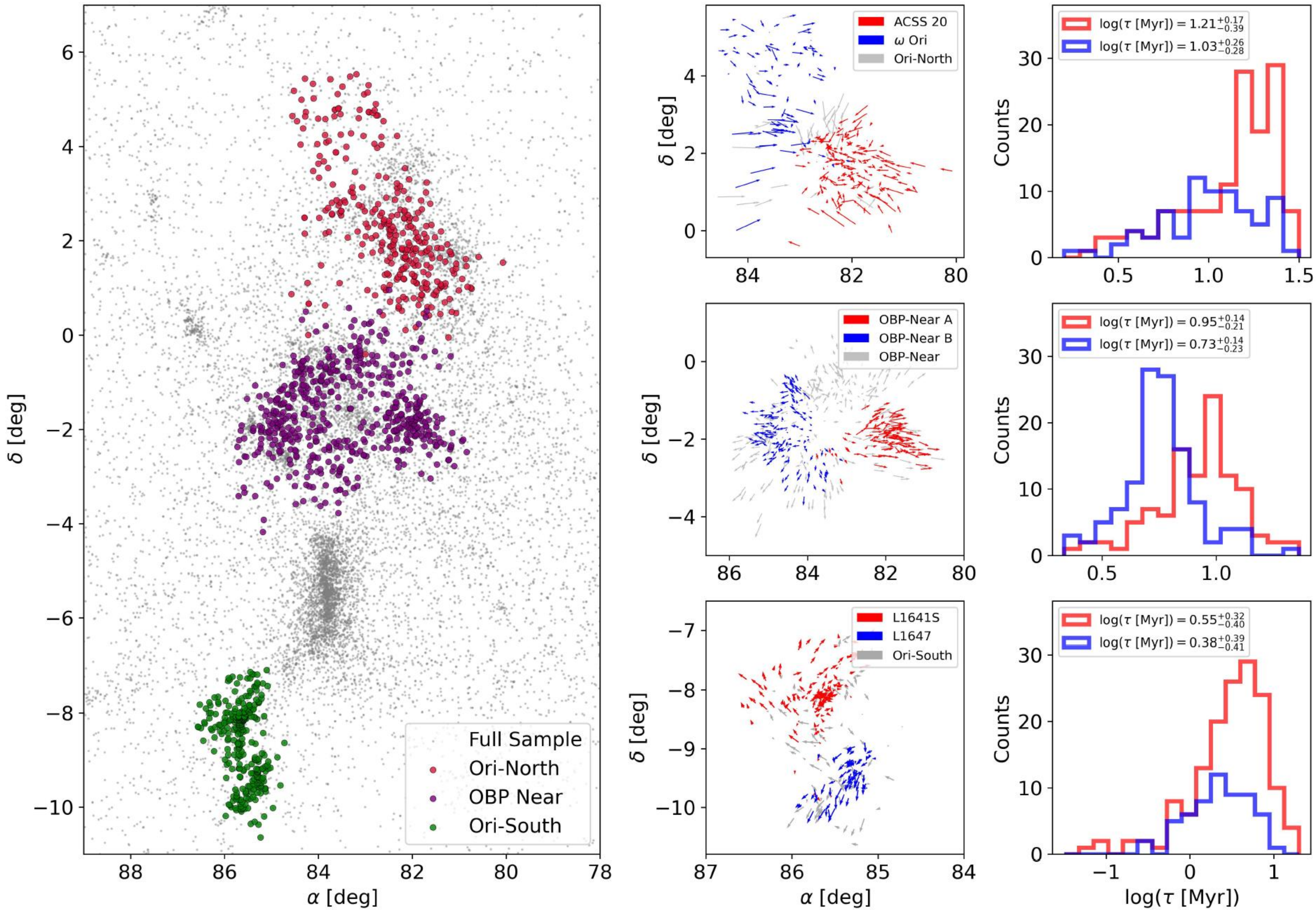

## $(\alpha, \delta, \omega, u_{\alpha}, u_{\delta})$を使ってクラスタリング解析

## 13のbig groupを同定



# 10 Myr には遠ざかる





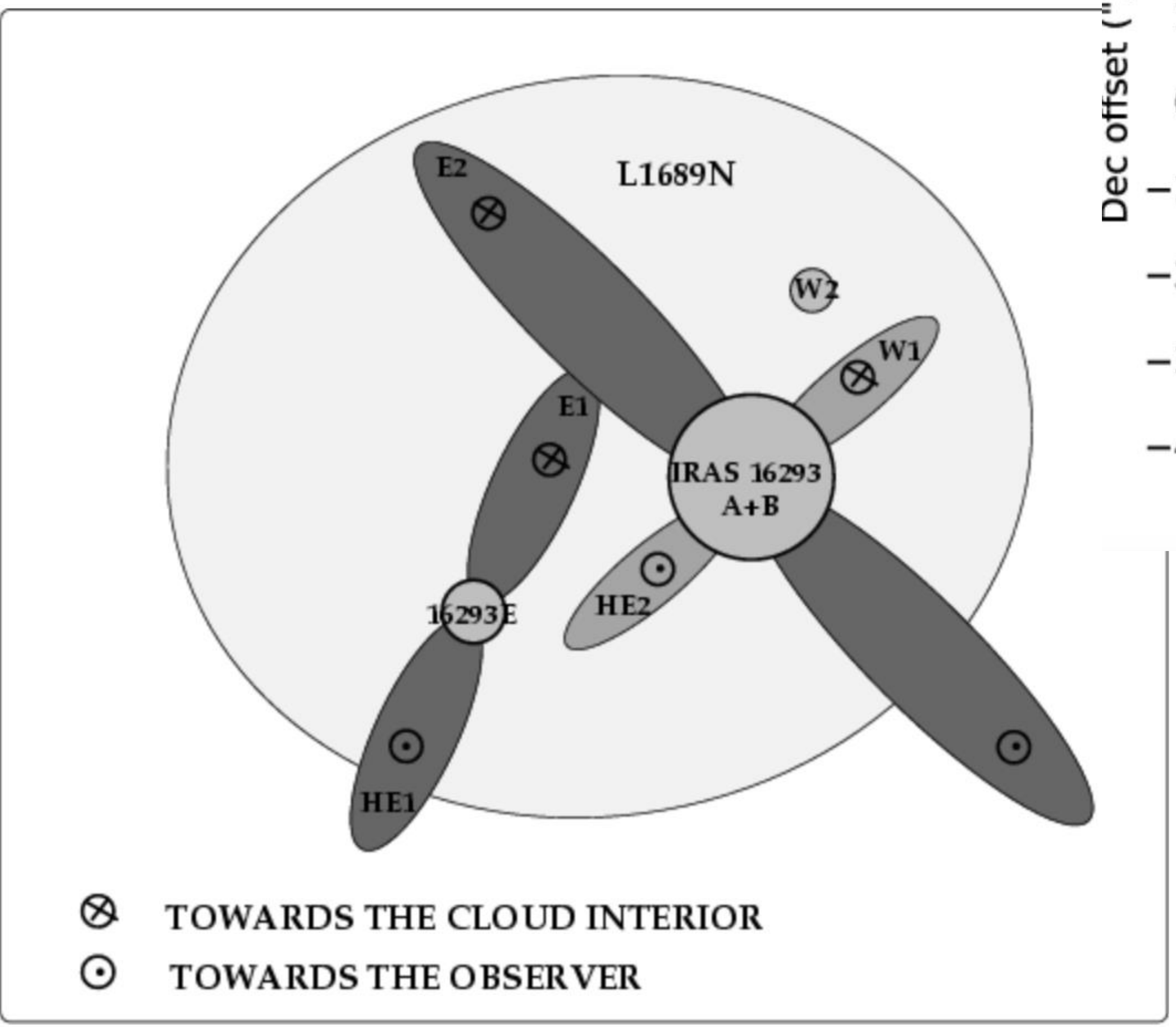
Full Sample
Ori-North
OBP Near
Ori-South
α [deg]
δ [deg]
ACSS 20
ω Ori
Ori-North
OBP-Near A
OBP-Near B
OBP-Near
L1641S
L1647
Ori-South
$\log(\tau\ [\mathrm{Myr}]) = 1.21^{+0.17}_{-0.39}$
$\log(\tau\ [\mathrm{Myr}]) = 1.03^{+0.26}_{-0.28}$
$\log(\tau\ [\mathrm{Myr}]) = 0.95^{+0.14}_{-0.21}$
$\log(\tau\ [\mathrm{Myr}]) = 0.73^{+0.14}_{-0.23}$
$\log(\tau\ [\mathrm{Myr}]) = 0.55^{+0.32}_{-0.40}$
$\log(\tau\ [\mathrm{Myr}]) = 0.38^{+0.39}_{-0.41}$
Counts
log(τ [Myr])

# First map of $D_2H^+$ emission revealing the true centre of a prestellar core: further insights into deuterium chemistry

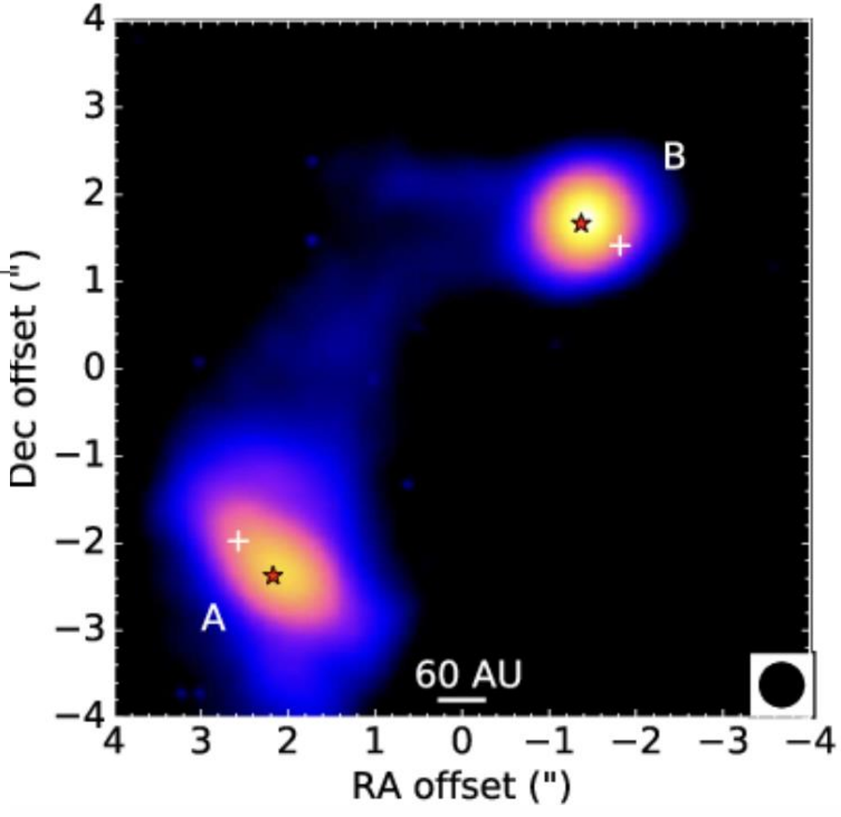
L. Pagani[1], A. Belloche[2], and B. Parise[2] *

アウトフローによって外から熱がある星なしコア IRAS 16293Eの$D_2H^+$と$H_2D^+$のマッピング
D/Hが理論値よりも高すぎる？？

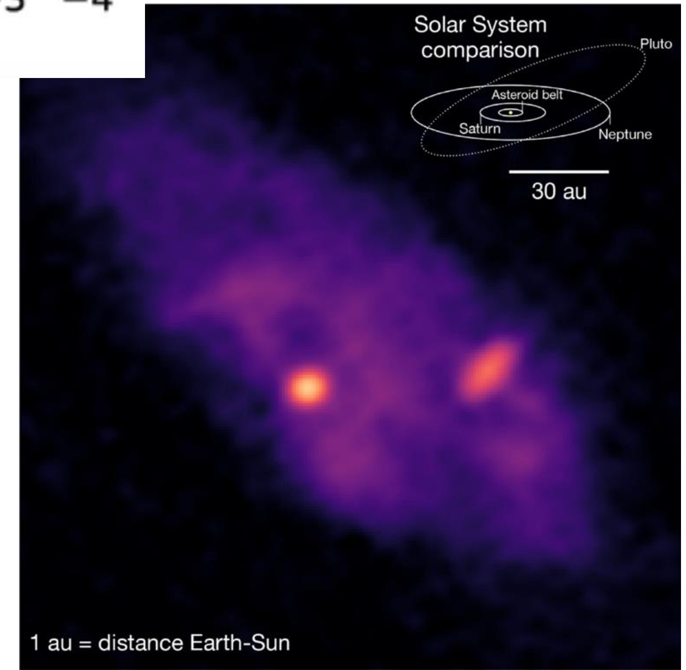
*Context.* IRAS 16293E is a rare case of a prestellar core being subjected to the effects of at least one outflow.
*Aims.* We want to disentangle the actual structure of the core from the outflow impact and evaluate the evolutionary stage of the core.
*Methods.* Prestellar cores being cold and depleted, the best tracers of their central regions are the two isotopologues of trihydrogren cation which are observable from the ground, ortho–$H_2D^+$ and para–$D_2H^+$. We used the Atacama Pathfinder EXperiment (APEX) telescope to map the para–$D_2H^+$ emission in IRAS 16293E and collected James Clerk Maxwell Telescope (JCMT) archival data of ortho–$H_2D^+$. We compare their emission to that of other tracers, including dust emission, and analyse their abundance with the help of a 1D radiative transfer tool. The ratio of the abundances of ortho–$H_2D^+$ and para–$D_2H^+$ can be used to estimate the stage of the chemical evolution of the core.
*Results.* We have obtained the first complete map of para–$D_2H^+$ emission in a prestellar core. We compare it to a map of ortho–$H_2D^+$and show their partial anti-correlation. This reveals a strongly evolved core with a para–$D_2H^+$/ortho–$H_2D^+$ abundance ratio towards the centre for which we obtain a conservative lower limit from 3.9 (at 12 K) up to 8.3 (at 8 K) while the high extinction of the core is indicative of a central temperature below 10 K. This ratio is higher than predicted by the known chemical models found in the literature. Para–$D_2H^+$ (and indirectly ortho–$H_2D^+$) is the only species that reveals the true centre of this core, while the emission of other molecular tracers and dust are biased by the temperature structure that results from the impact of the outflow.
*Conclusions.* This study invites to reconsider the analysis of previous observations of this source and possibly questions the validity of the deuteration chemical models or of the reaction and inelastic collisional rate coefficients of the $H_3^+$ isotopologue family. This could impact the deuteration clock predictions for all sources.



L1689N
E2
W2
W1
E1
IRAS 16293
A+B
HE2
16293E
HE1
TOWARDS THE CLOUD INTERIOR
TOWARDS THE OBSERVER

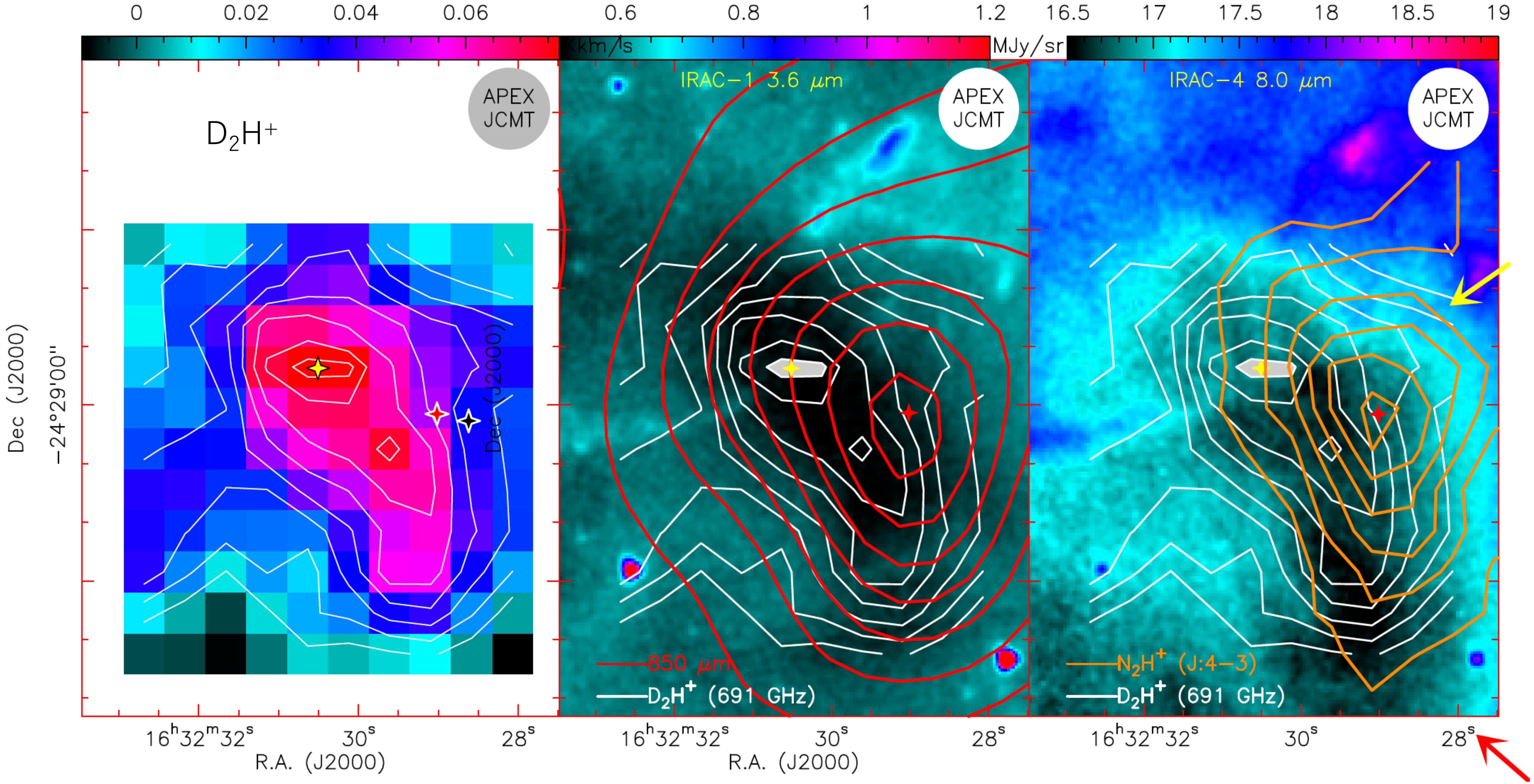



B
A
60 AU
Dec offset (")
RA offset (")
4
3
2
1
0
−1
−2
−3
−4

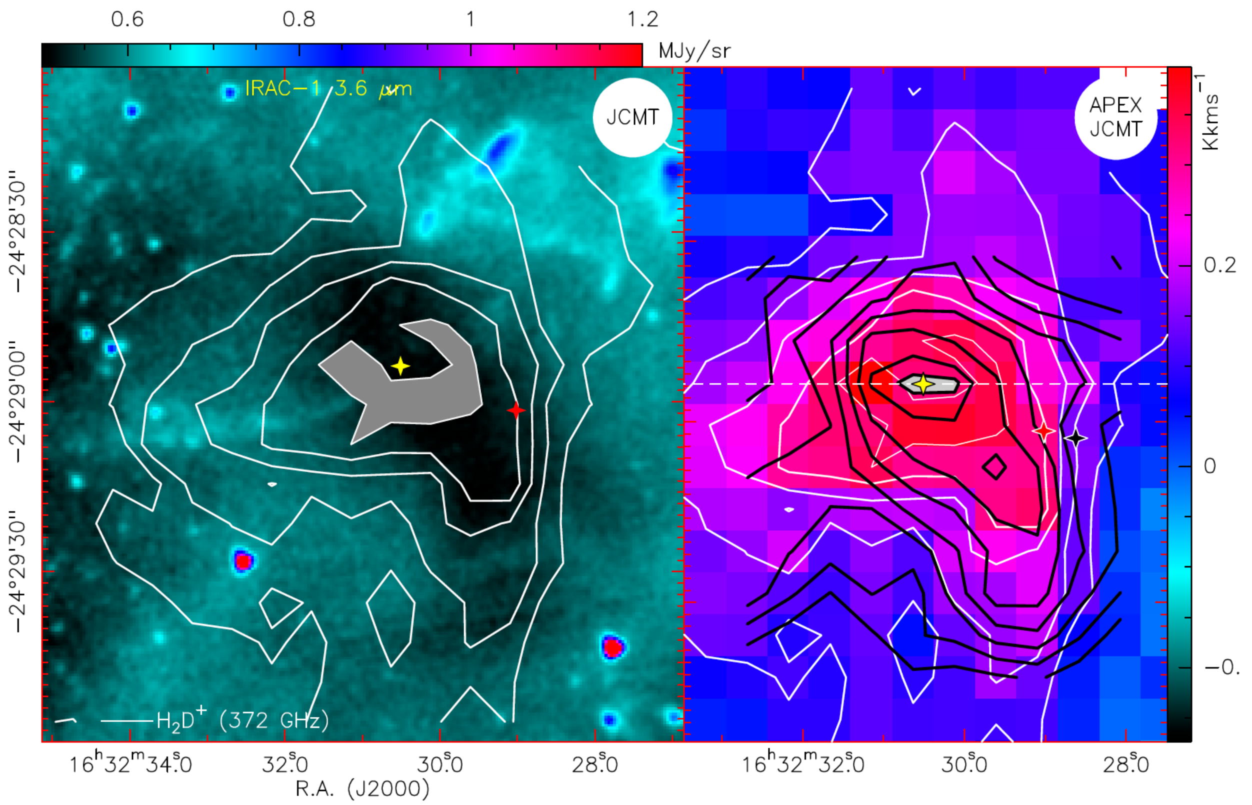



Solar System
comparison
Pluto
Asteroid belt
Saturn
Neptune
30 au
1 au = distance Earth-Sun

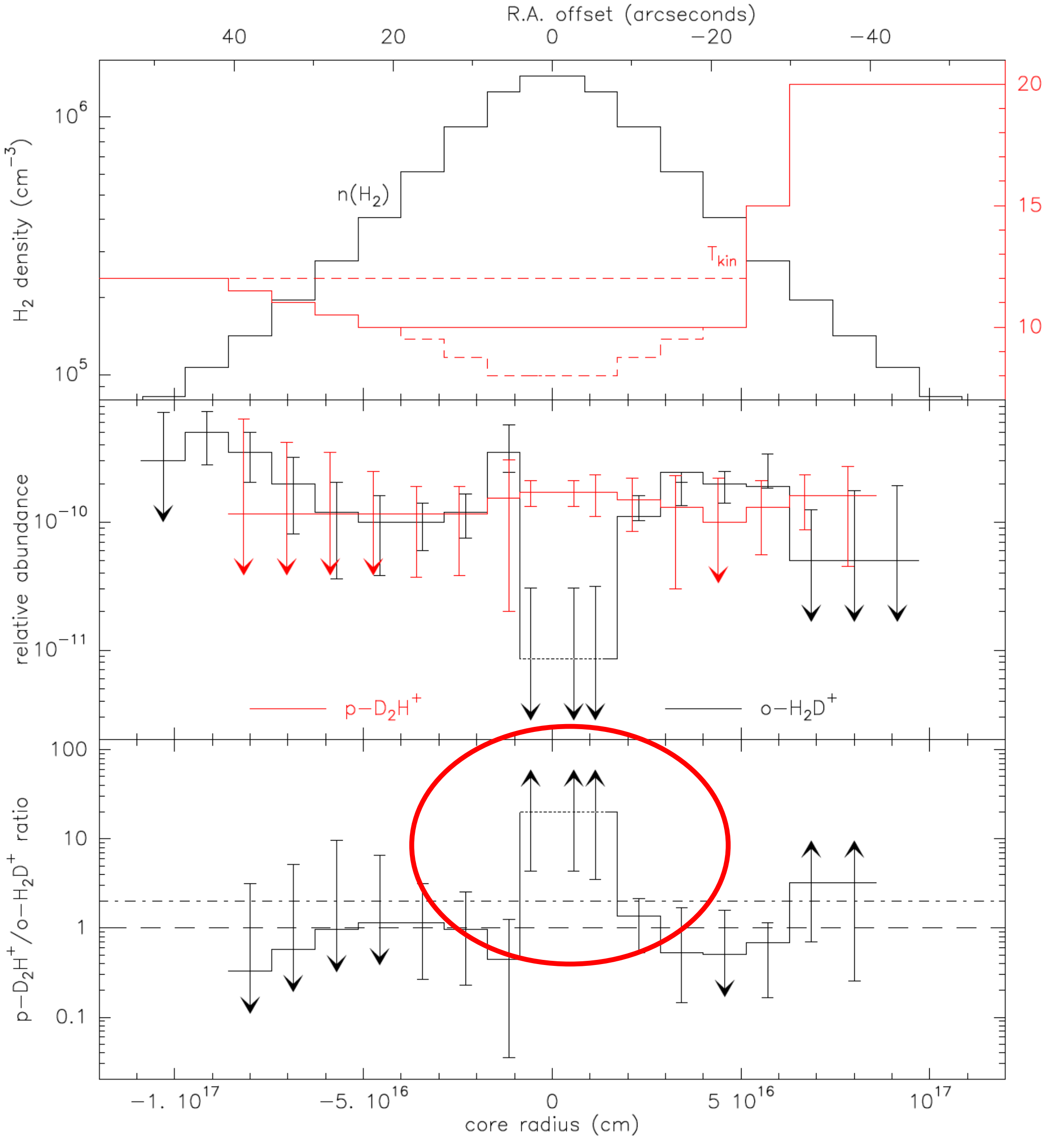
D$_2$H$^+$のピーク位置はダストやN$_2$H$^+$とずれる
→ ダストは温度の影響を受けるのでコアのピークとは限らない



$D_2H^+$のピークで$H_2D^+$は若干depressしてる




1次元のnon LTE radiative transfer




D/Hは理論的には ~ 2くらいが限界
10までD/Hがいくのは D濃縮の理論が何か違う？

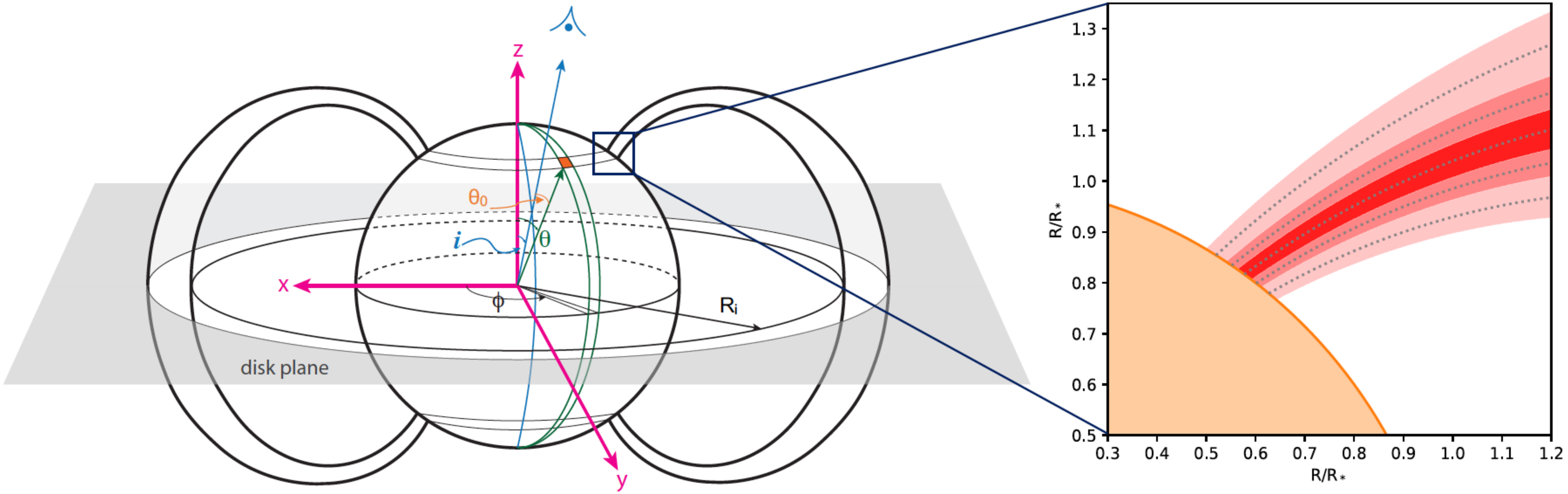
# A Model of the C IV $\lambda\lambda$ 1548, 1550 Doublet Line in T Tauri Stars

Thanawuth Thanathibodee,[1] Connor Robinson,[2] Nuria Calvet,[3] Catherine Espaillat,[1] Caeley Pittman,[1] Nicole Arulanantham,[4] Kevin France,[5] Hans Moritz Günther,[6] Seok-Jun Chang,[7] and P. Christian Schneider[8]

The C IV doublet in the UV has long been associated with accretion in T Tauri stars. However, it is still unclear where and how the lines are formed. Here, we present a new C IV line model based on the currently available accretion shock and accretion flow models. We assume axisymmetric, dipolar accretion flows with different energy fluxes and calculate the properties of the accretion shock. We use Cloudy to obtain the carbon level populations and calculate the emerging line profiles assuming a plane-parallel geometry near the shock. Our model generally reproduces the intensities and shapes of the C IV emission lines observed from T Tauri stars. We find that the narrow component is optically thin and originates in the postshock, while the broad component is optically thick and emerges from the preshock. We apply our model to seven T Tauri stars from the Hubble Ultraviolet Legacy Library of Young Stars as Essential Standards Director's Discretionary program (ULLYSES), for which consistently determined accretion shock properties are available. We can reproduce the observations of four stars, finding that the accretion flows are carbon-depleted. We also find that the chromospheric emission accounts for less than 10 percent of the observed C IV line flux in accreting T Tauri stars. This work paves the way toward a better understanding of hot line formation and provides a potential probe of abundances in the inner disk.

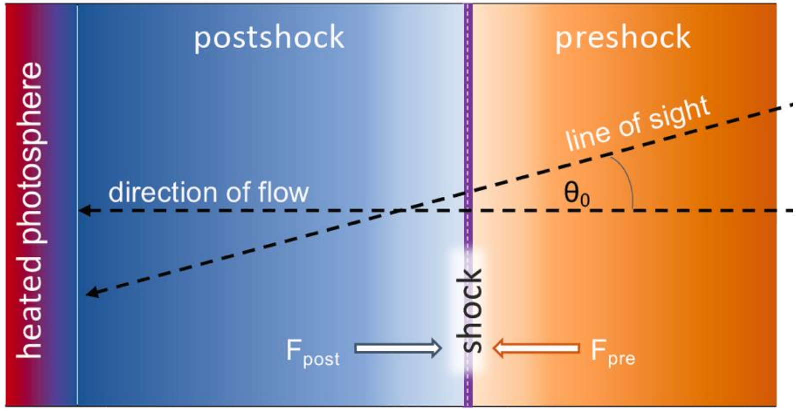
イントロ
UVで観測されるC IVなどのaccretion shockに起因すると思われるラインがあるが、そのメカニズムはよくわかっていない。特に輝線はbroad とnarrowの二つがあって複雑な様子？
Accretion luminosityや中心星質量などとの相関が見られないのも不思議

モデル: 内側円盤から軸対象にdipole flowで降着. Accretionのエネルギフラックスも3つ（小中大）



ショックモデルからClaudyを使って
アバンダンスを計算

ショックモデル




ショック通過後と通過前での２
成分を考慮して輻射輸送
特にショック前領域が観測者の
手前にくることが大事

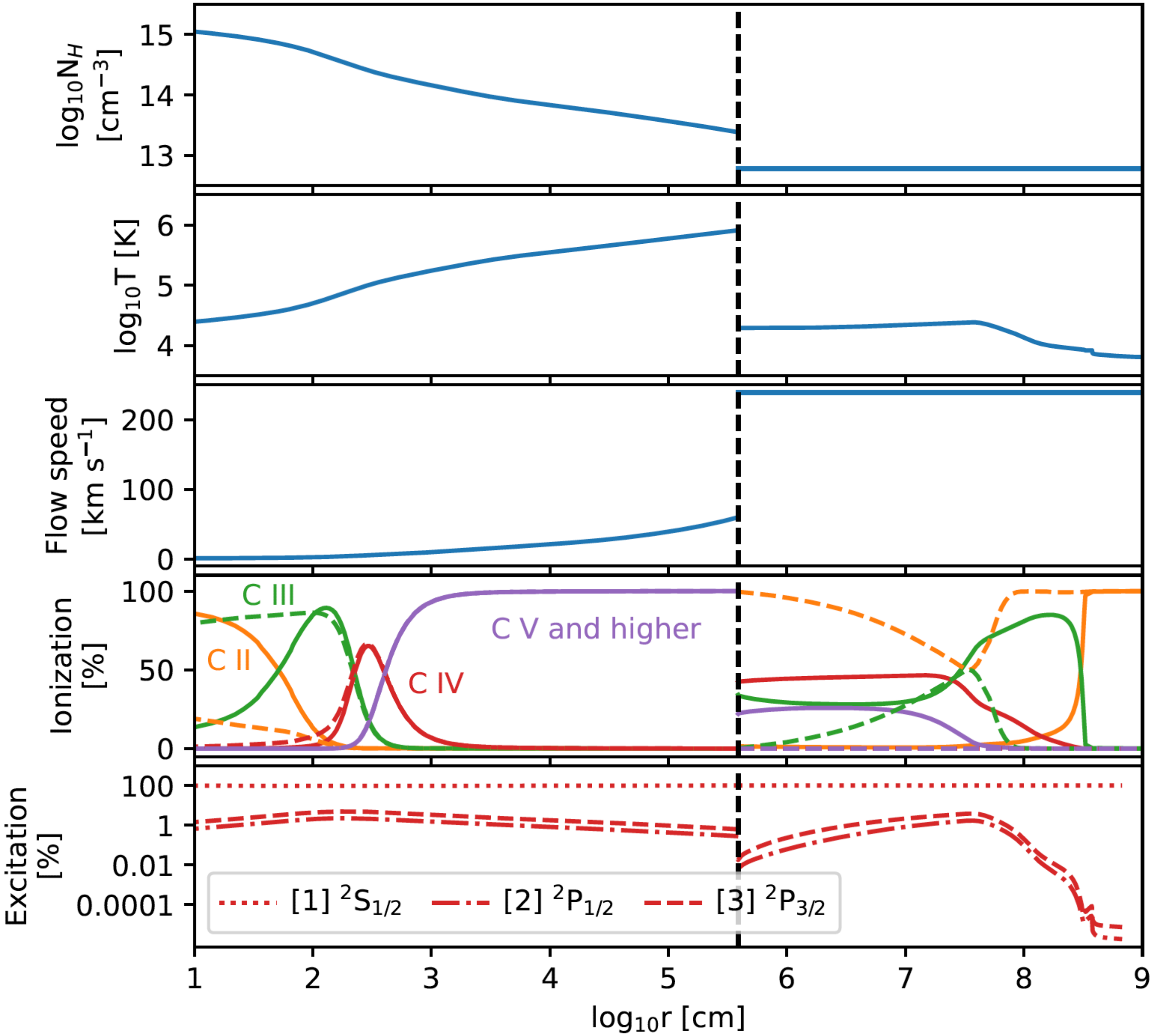
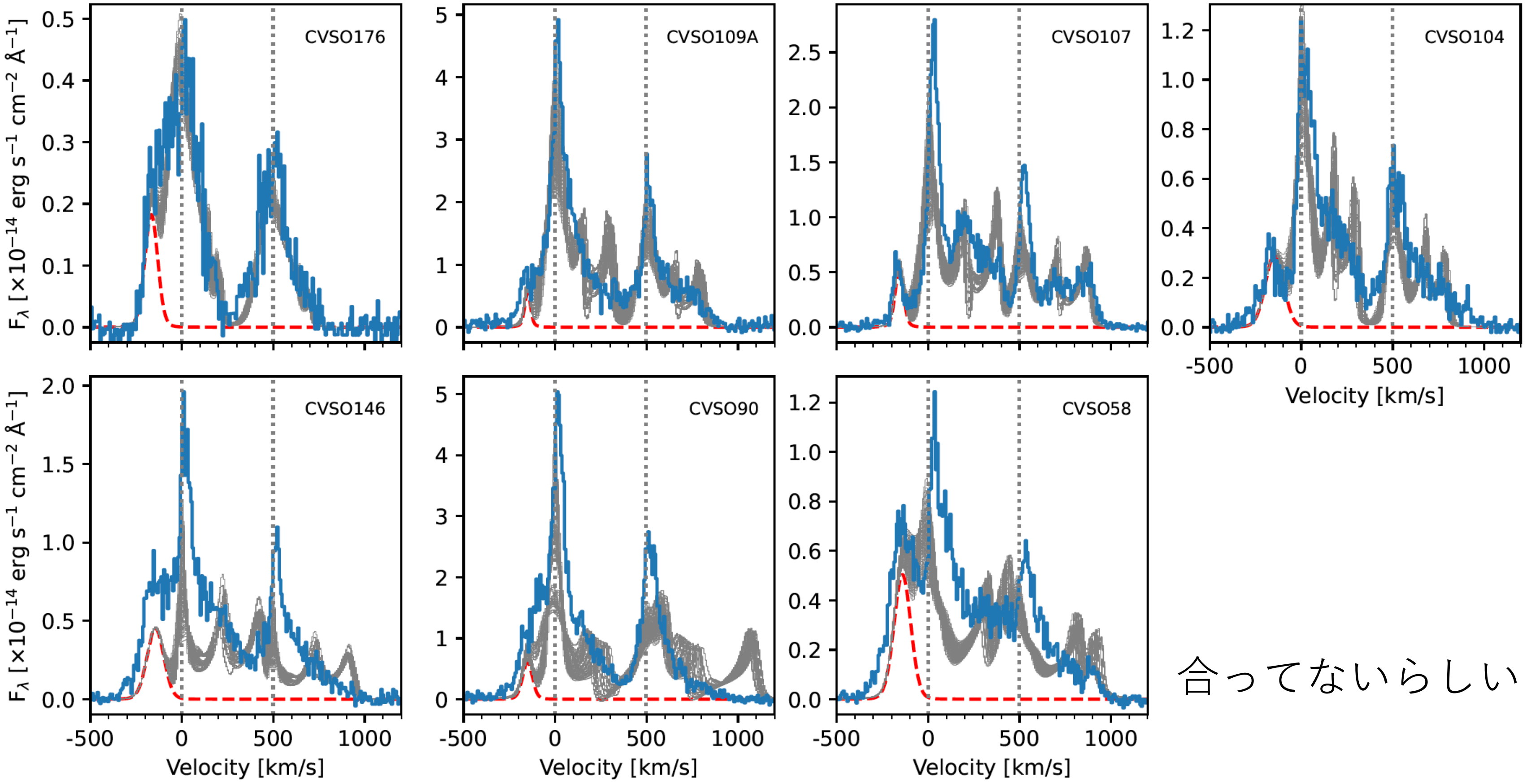


**Table 2.** Results of the Accretion Flow and Shock Models

| Star | $\dot{M}_{flow}$ ($10^{-8}$ M$_\odot$ yr$^{-1}$) | R$_i$ (R$_\star$) | W$_r$ (R$_\star$) | T$_{max}$ ($10^3$ K) | $i$ (deg) | $\dot{M}_{shock}$ ($10^{-8}$ M$_\odot$ yr$^{-1}$) | $f_{1E10}$ (fraction of stellar surface) | $f_{1E11}$ | $f_{1E12}$ | Av[a] (mag) |
|---|---|---|---|---|---|---|---|---|---|---|
| CVSO 58 | $2.6 \pm 0.1$ | $2.6 \pm 0.5$ | $0.2 \pm 0.0$ | $7.8 \pm 0.4$ | $61 \pm 3$ | $2.10^{+0.12}_{-0.11}$ | 0.069 | 0.00033 | 0.0116 | $1.70^{+0.04}_{-0.04}$ |
| CVSO 90 | $2.5 \pm 0.3$ | $4.8 \pm 0.1$ | $0.2 \pm 0.0$ | $8.4 \pm 0.1$ | $41 \pm 1$ | $2.00^{+0.04}_{-0.05}$ | ··· | 0.00026 | 0.0290 | $1.05^{+0.01}_{-0.01}$ |
| CVSO 104 | $1.6 \pm 0.6$ | $2.8 \pm 0.6$ | $0.3 \pm 0.2$ | $9.1 \pm 0.8$ | $57 \pm 11$ | $1.13^{+0.01}_{-0.01}$ | 0.0479 | 0.00454 | 0.000316 | $0.01^{+0.00}_{-0.00}$ |
| CVSO 107 | $2.2 \pm 0.1$ | $2.7 \pm 0.4$ | $0.3 \pm 0.3$ | $7.2 \pm 0.2$ | $54 \pm 4$ | $2.59^{+0.11}_{-0.11}$ | 0.0008 | 0.0156 | 0.0049 | $1.02^{+0.03}_{-0.03}$ |
| CVSO 109A[b] | $2.6 \pm 1.3$ | $2.2 \pm 0.2$ | $0.2 \pm 0.0$ | $7.2 \pm 0.0$ | $37 \pm 8$ | $4.01^{+0.13}_{-0.23}$ | 0.0008 | 0.0217 | 0.00167 | $0.21^{+0.02}_{-0.05}$ |
| CVSO 146 | $0.5 \pm 0.0$ | $2.9 \pm 0.3$ | $0.3 \pm 0.1$ | $9.3 \pm 0.2$ | $65 \pm 5$ | $2.20^{+0.08}_{-0.07}$ | 0.149 | 0.0094 | 0.00142 | $0.91^{+0.03}_{-0.03}$ |
| CVSO 176 | $2.9 \pm 0.1$ | $2.5 \pm 0.5$ | $0.2 \pm 0.0$ | $8.2 \pm 1.1$ | $54 \pm 7$ | $0.911^{+0.016}_{-0.016}$ | 0.0373 | 0.0006 | 0.000046 | $0.49^{+0.02}_{-0.02}$ |

[a]The extinction used in the shock model assumes the Whittet et al. (2004) law.

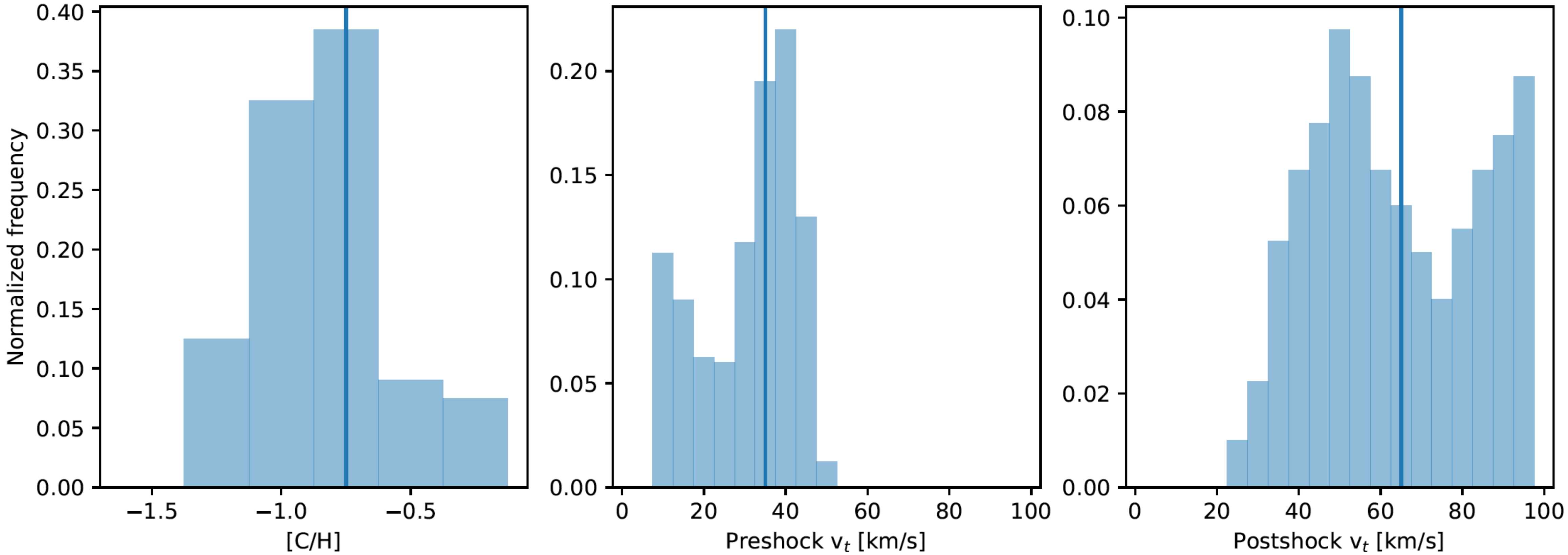
YSOのaccretion parameterを使って
Inclination,
C/H ratio,
乱流(pre shock, post shock)
をフィッティング




合ってるらしい

合ってないらしい

# ベストフィットのヒストグラム




C/Hは太陽標準値より低い→ 炭素の枯渇
乱流強度は衝撃波通過後でも結構ある(20%以上)、物理的な機構があるのか、フィットの問題なのか