EXPLORING THE IMF WITH N2H+: MORPHOLOGICAL ANALYSIS OF THE G327.29 PROTOCLUSTER.

Universidad de los Andes| Physics Department
COCOA- Bucaramanga| Nov 20 | 2024

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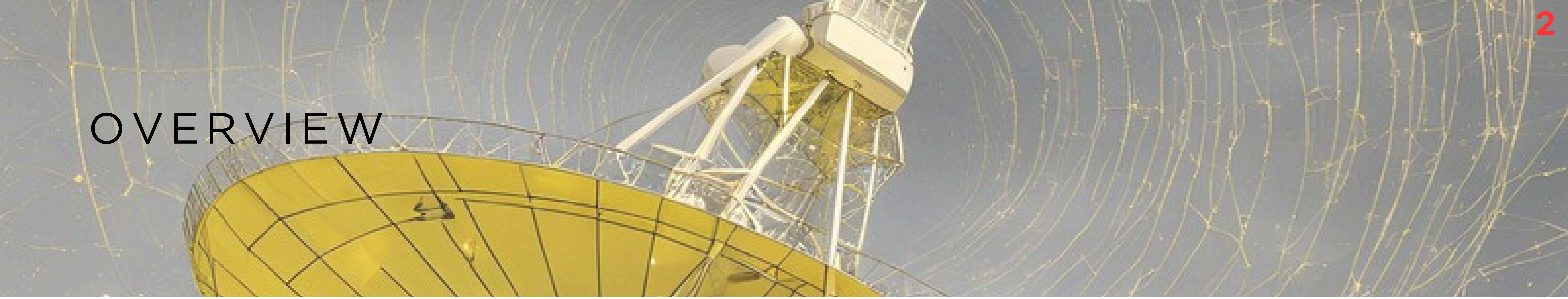
Presentation by **Fredy Orjuela**
Advisor **PhD Beatriz Sabogal**



OVERVIEW

Star-Forming Regions

LOW MASS STAR FORMATION

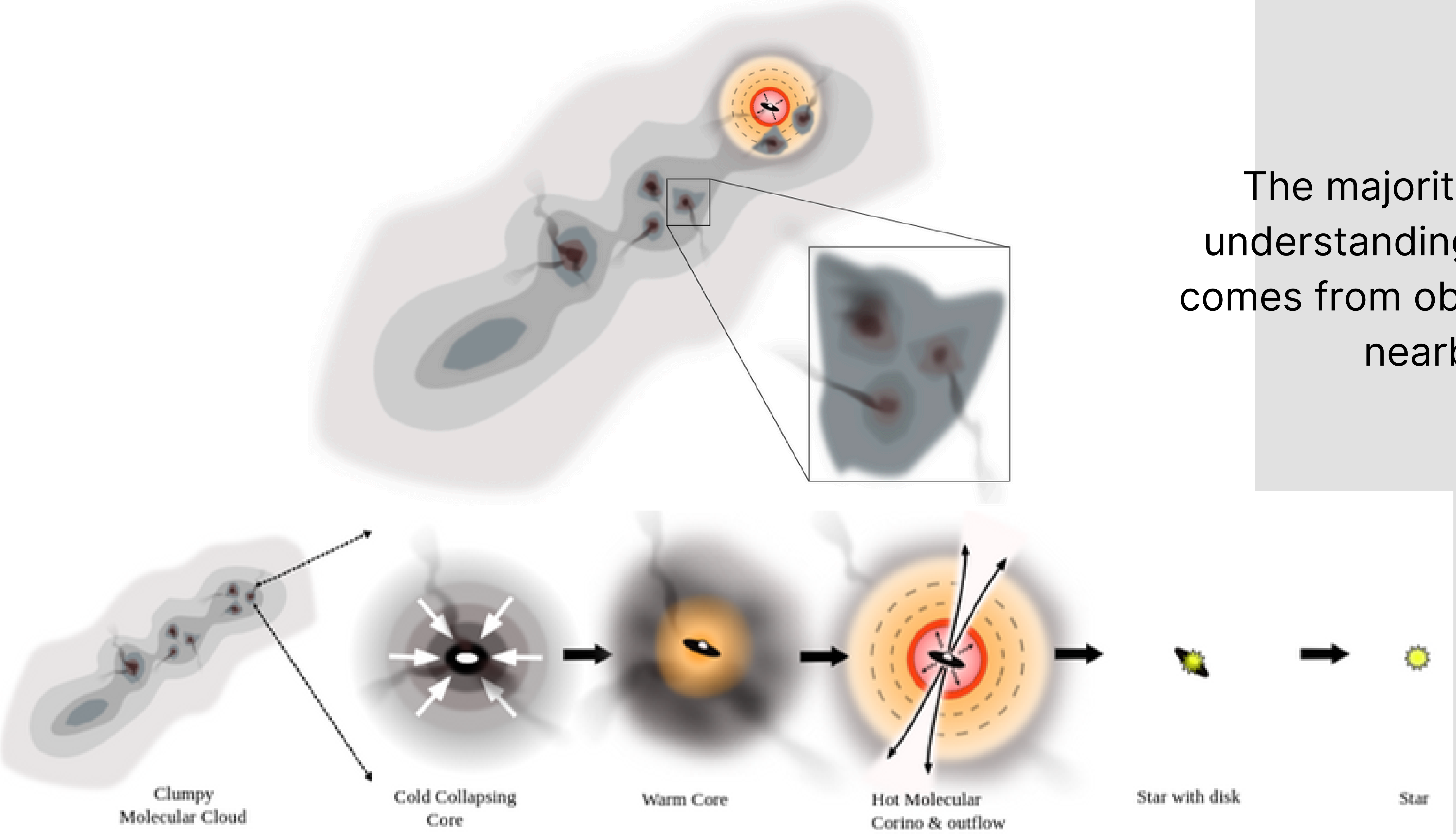


Figure 1. Ginsburg,A. (2024)

The majority of our detailed understanding of star formation comes from observations of small, nearby clouds.

HIGH MASS STAR FORMATION

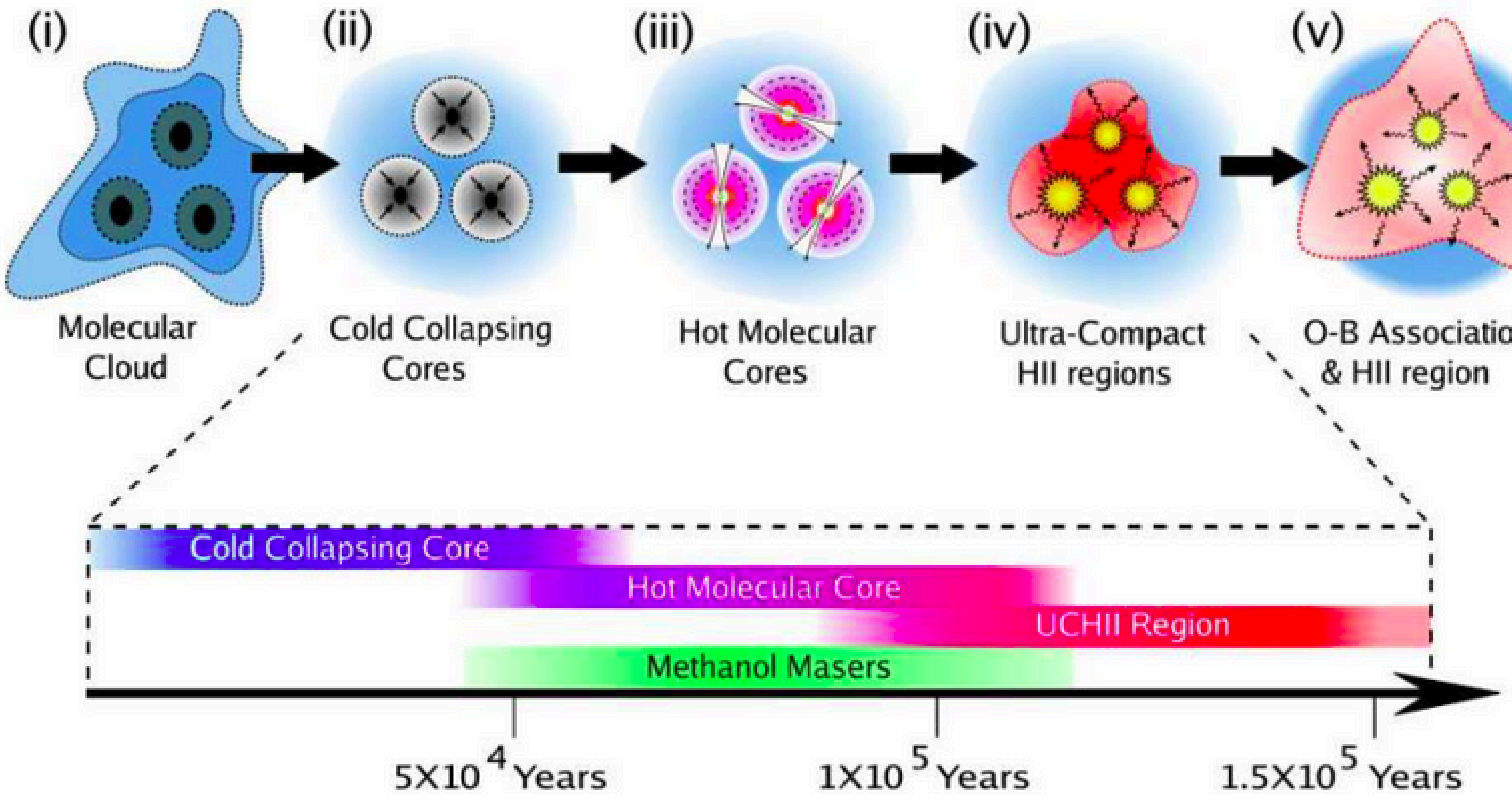
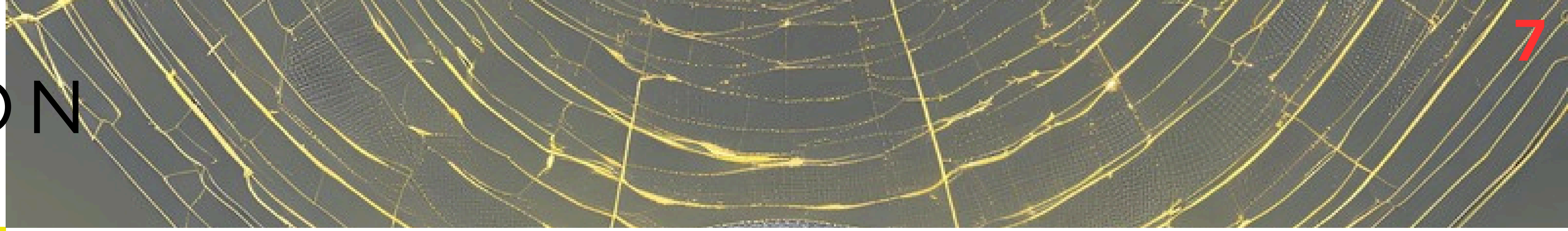


Figure 2. Purcell,C. (2006)

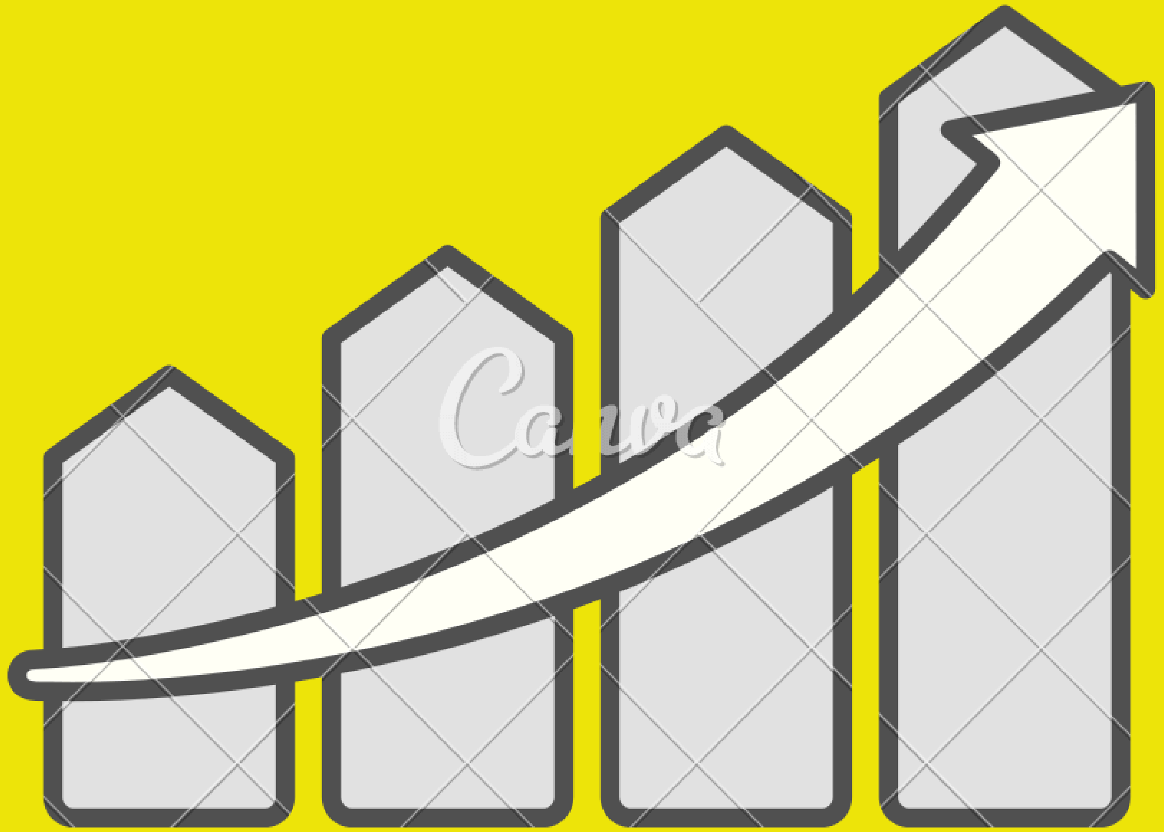
- Massive Star Formation
- Collapse and Mass Increase
- Complex Hydrocarbon Creation
- Ultra-Compact HII Regions
- Expansion of HII Region and Cluster Exposure

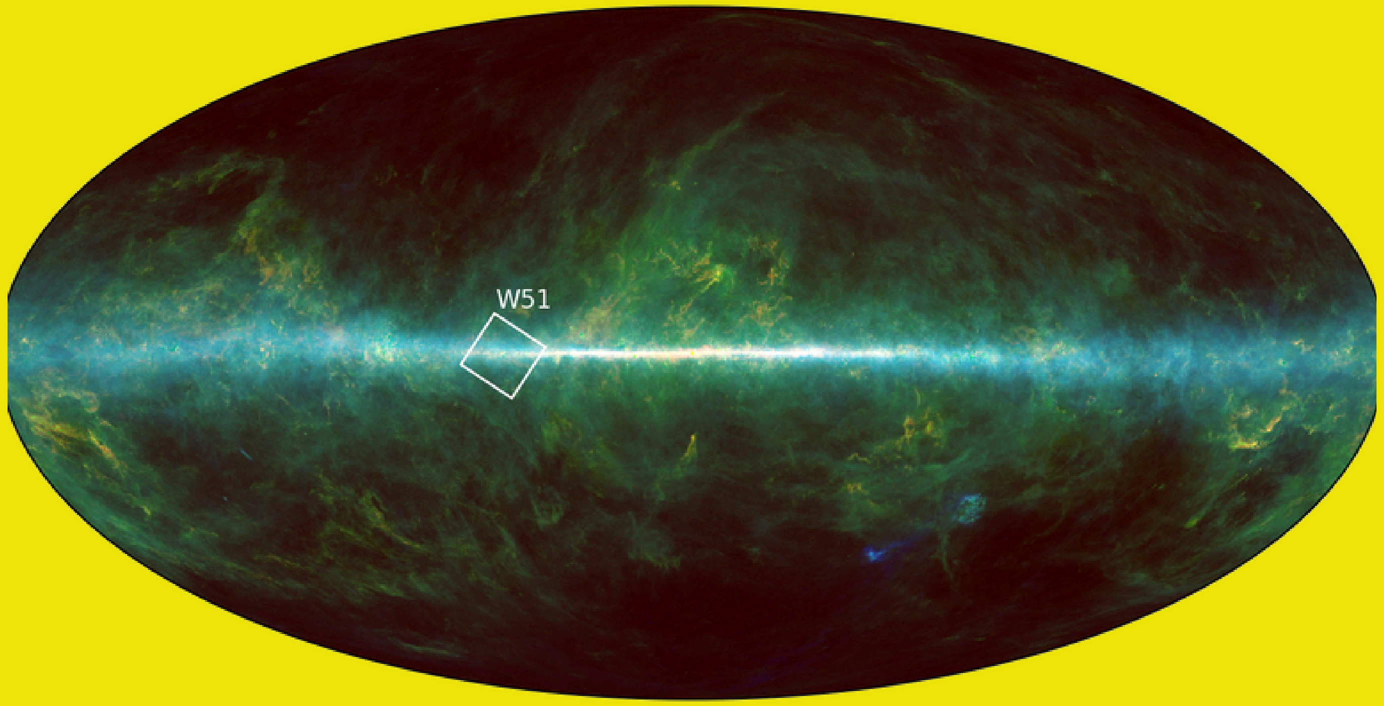
Initial Mass Function

INITIAL MASS FUNCTION



$$\phi(M)dM \simeq 0.584 M_\odot^{-1} \exp\left\{-1.54 \log^2\left[\frac{M}{0.22 M_\odot}\right]\right\}\frac{dM}{M}$$





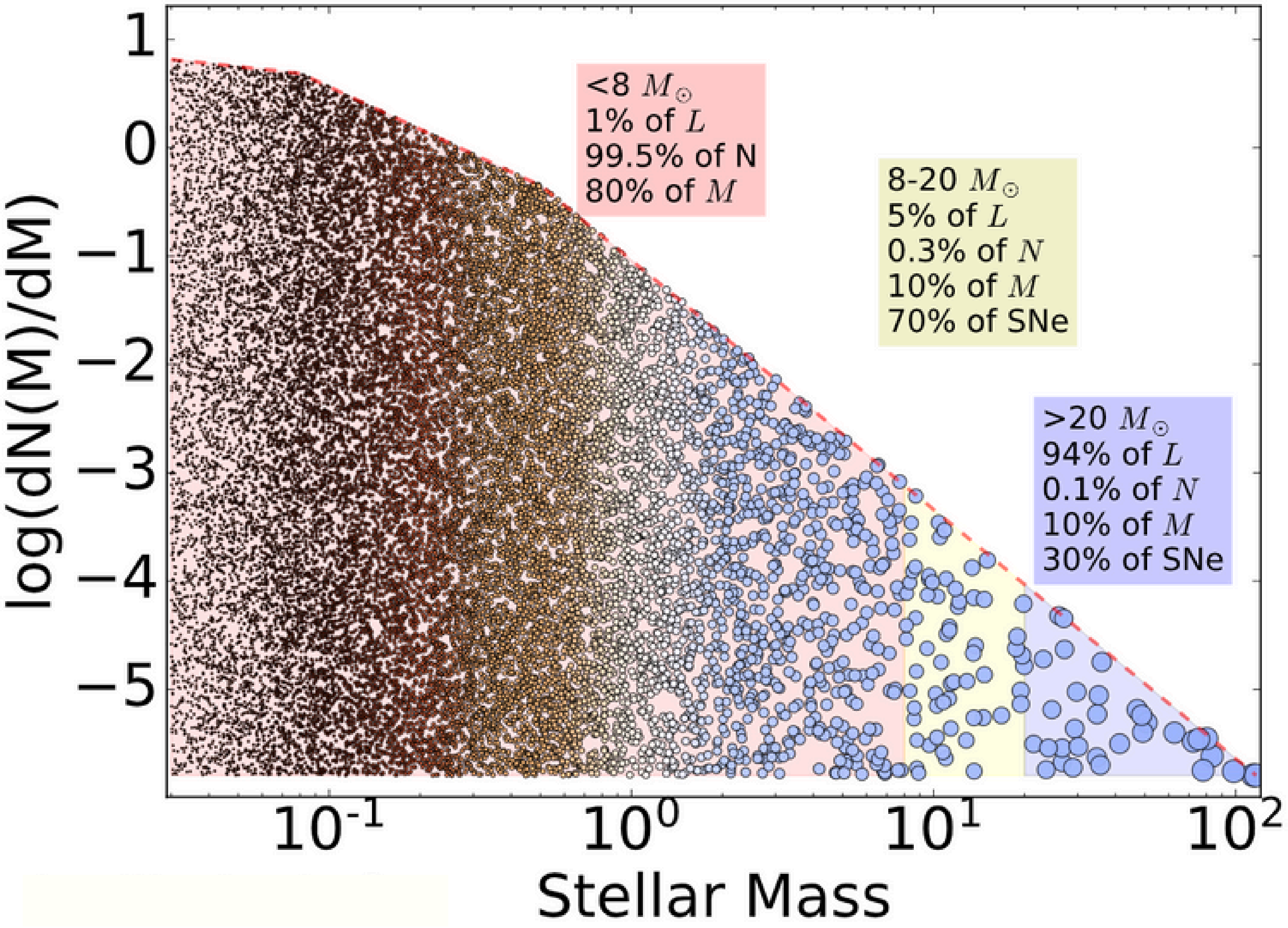


Figure 3. Ginsburg,A. (2024)

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PROPOSED/FUTURE TELESCOPES

1. How does the IMF (initial mass function) change, and what controls its changes?
2. What controls the rate of star formation in galaxies?
3. When and how do planets form?
4. How does the grouping of stars affect each of these processes?

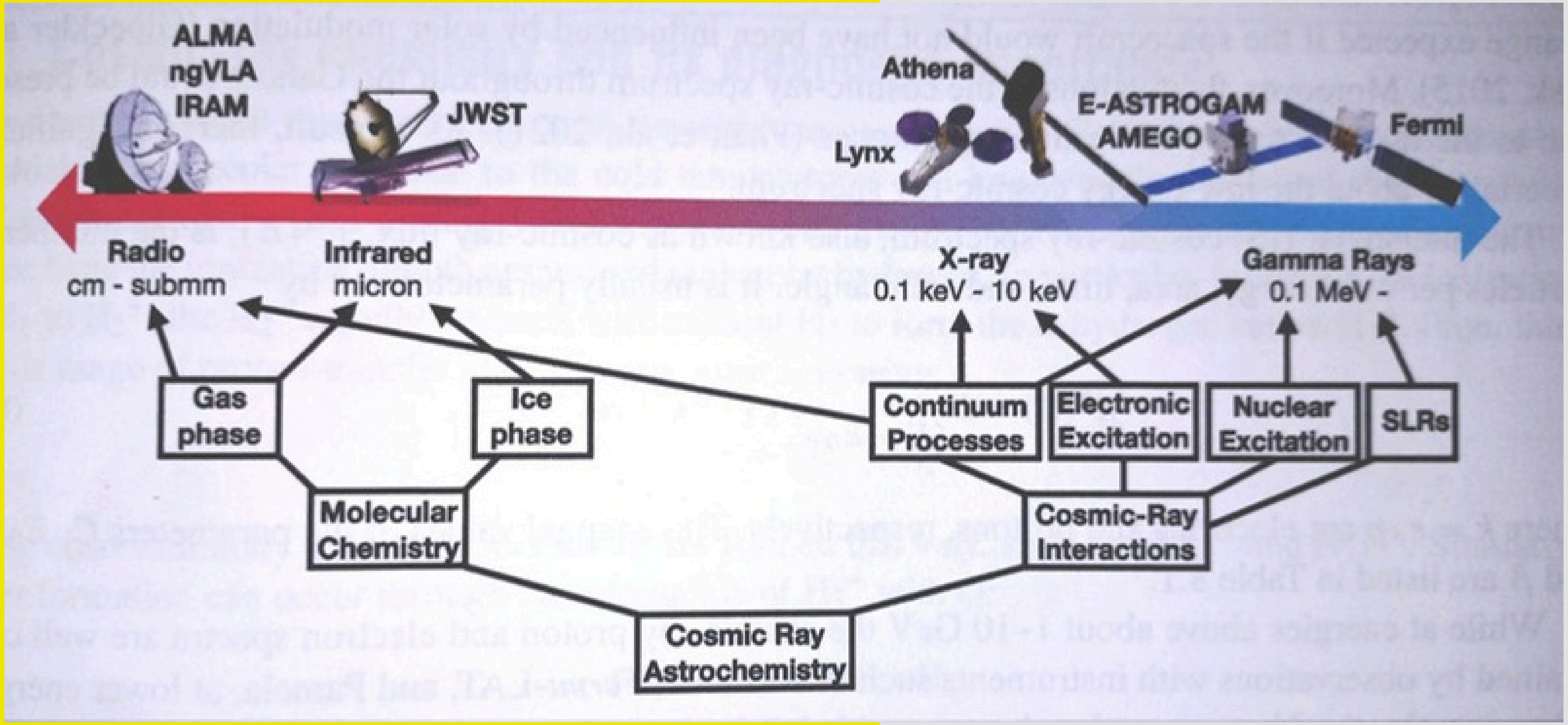

Figure 4. Bovino,S. (2024)

ALMA IMF - G327.29

ALMA IMF LARGE PROGRAM

ALMA-IMF

I. Investigating the origin of stellar masses: Introduction to the Large Program and first results

F. Motte[1], S. Bontemps[2], T. Csengeri[2], Y. Pouteau[1], F. Louvet[1,3,4], A. M. Stutz[5,6], N. Cunningham[1], A. López-Sepulcre[1,7], N. Brouillet[2], R. Galván-Madrid[8], A. Ginsburg[9], L. Maud[10], A. Men'shchikov[3], F. Nakamura[11,12,13], T. Nony[8], P. Sanhueza[11,12], R. H. Álvarez-Gutiérrez[5], M. Armante[14,15], T. Baug[16], M. Bonfand[2], G. Busquet[1,17,18], E. Chapillon[2,7], D. Díaz-González[8], M. Fernández-López[19], A. E. Guzmán[11], F. Herpin[2], H.-L. Liu[5,20], F. Olguin[21], A. P. M. Towner[9], J. Bally[22], C. Battersby[23], J. Braine[2], L. Bronfman[24], H.-R. V. Chen[21], P. Dell'Ova[14], J. Di Francesco[25], M. González[3], A. Gusdorf[14], P. Hennebelle[3], N. Izumi[11,26,27], I. Joncour[1], Y.-N. Lee[28], B. Lefloch[1], P. Lesaffre[14], X. Lu[11], K. M. Menten[29], R. Mignon-Risse[3], J. Molet[2], E. Moraux[1], L. Mundy[30], Q. Nguyễn Lương[31], N. Reyes[29,32], S. D. Reyes Reyes[5], J.-F. Robitaille[1], E. Rosolowsky[33], N. A. Sandoval-Garrido[5], F. Schuller[29,34], B. Svoboda[35], K. Tatematsu[11], B. Thomasson[1], D. Walker[36], B. Wu[11,37], A. P. Whitworth[38], and F. Wyrowski[29]

Mass Stars

How is the Formation?

Parameteres

Variety in Size and Temp

Importance in the Universe

F.Motte

A.M. Stutz

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STAR-FORMING REGIONS

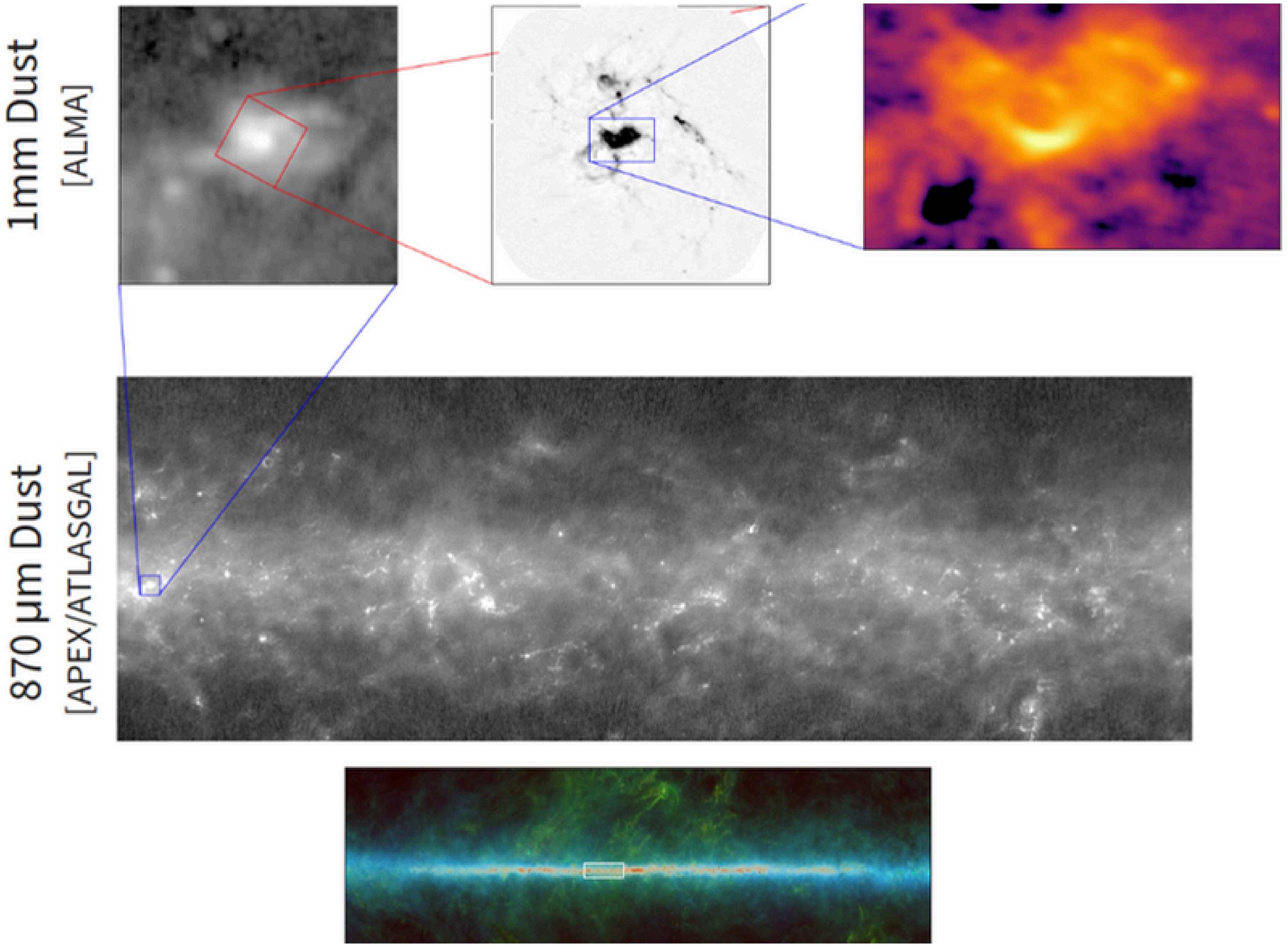
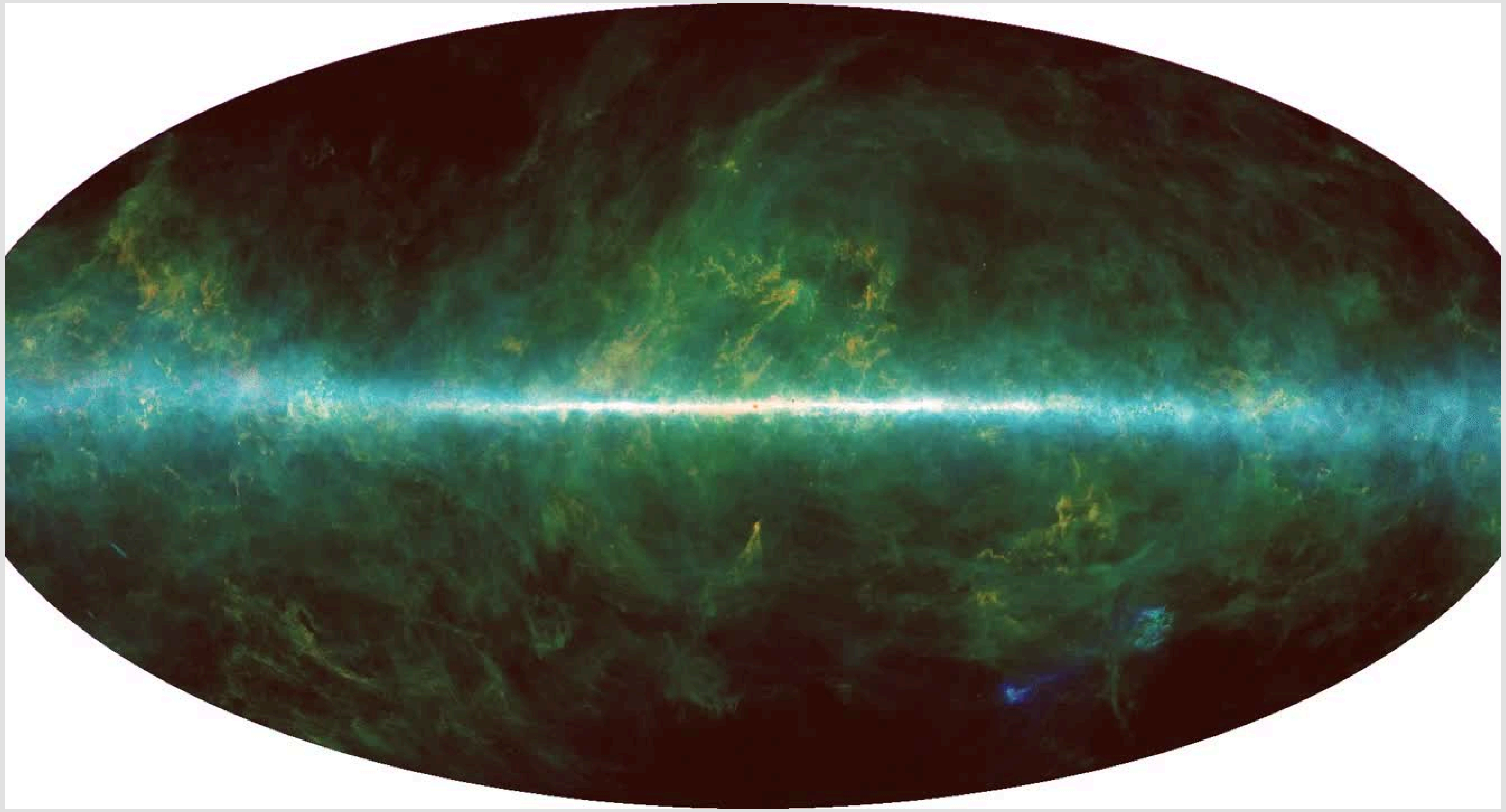


Figure 5. Ginsburg,A. (2024)



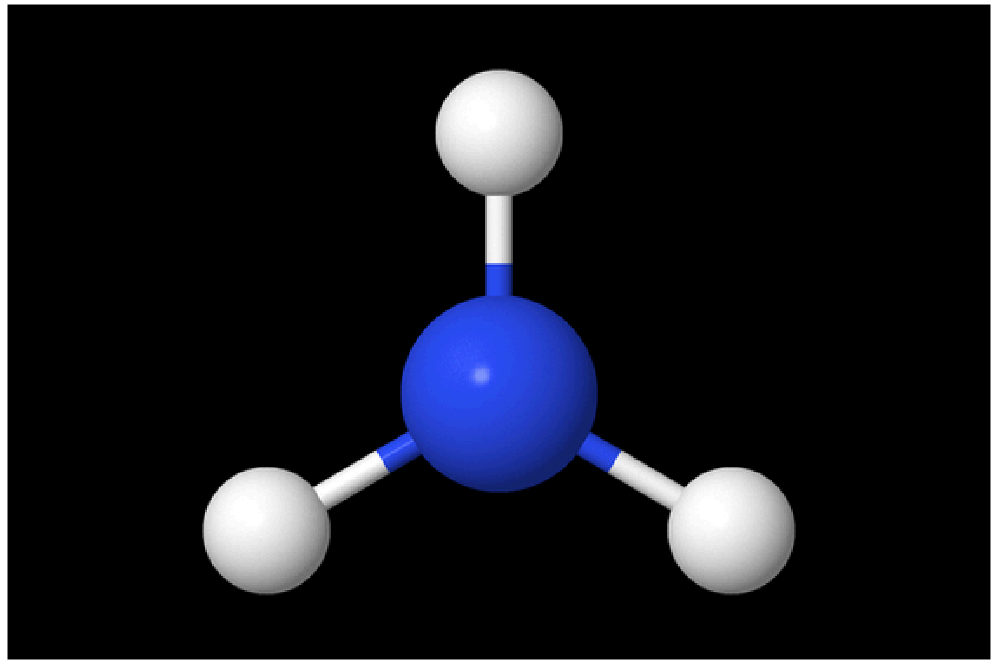
Video 1. Ginsburg,A. (2024)

MOLECULAR TRACING

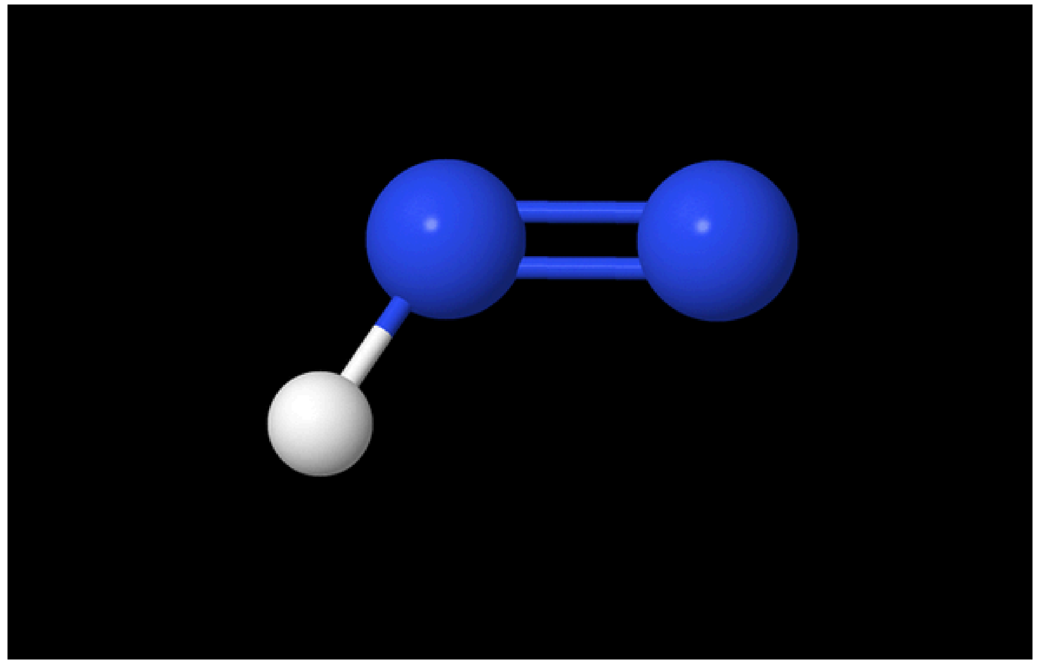
Table 1.2 Molecules found in interstellar clouds

Simple neutral molecules
H_2, CH, CN, CO, HCl, NH, NO, NS, OH, PN, SO, SiO, SiS, CS, HF, O_2, SH, CH_2, HCN, HCO, H_2O, H_2S, HNC, HNO, N_2O, OCS, SO_2, CO_2, NH_2, HO_2, NH_3, H_2CO, H_2CS, CH_3, H_2O_2, CH_4
Ionic species
(Cation)
CH^+, CO^+, SO^+, CF^+, OH^+, SH^+, HCl^+, ArH^+, HCO^+, HCS^+, HOC^+, N_2H^+, H_3^+, H_2O^+, H_2Cl^+, OH_3^+, $HCNH^+$, HCO_2^+, C_3H^+, H_2COH^+, NH_4^+, H_2NCO^+, HC_3NH^+

Table 1. Yamamoto, S. (2017)



Ammonia NH_3



Dyazenylium N_2H^+

Protocluster cloud name [(1)]	RA [(1)] [ICRS]	Dec [(1)] [ICRS]	V_{LSR} [(1)] [km s^{-1}]	d [kpc]
W51-E	19:23:44.18	+14:30:29.5	+55	5.4 ± 0.3
W43-MM1	18:47:47.00	−01:54:26.0	+97	5.5 ± 0.4
G333.60	16:22:09.36	−50:05:58.9	−47	4.2 ± 0.7
W51-IRS2	19:23:39.81	+14:31:03.5	+55	5.4 ± 0.3
G338.93	16:40:34.42	−45:41:40.6	−62	3.9 ± 1.0
G010.62	18:10:28.84	−19:55:48.3	−2	4.95 ± 0.5
W43-MM2	18:47:36.61	−02:00:51.1	+97	5.5 ± 0.4
G008.67	18:06:21.12	−21:37:16.7	+37.6	3.4 ± 0.3
G012.80	18:14:13.37	−17:55:45.2	+37	2.4 ± 0.2
G327.29	15:53:08.13	−54:37:08.6	−45	2.5 ± 0.5
W43-MM3	18:47:41.46	−02:00:27.6	+97	5.5 ± 0.4
G351.77	17:26:42.62	−36:09:20.5	−3	2.0 ± 0.7
G353.41	17:30:26.28	−34:41:49.7	−17	2.0 ± 0.7
G337.92	16:41:10.62	−47:08:02.9	−40	2.7 ± 0.7
G328.25	15:57:59.68	−53:58:00.2	−43	2.5 ± 0.5

Table 2. Motte et al. (2018)

N_2H^+ ion is key in protocluster studies, tracing dense, cold gas in star formation areas. Resistant to freezing and stellar radiation, it reveals early-stage star formation dynamics and chemistry.

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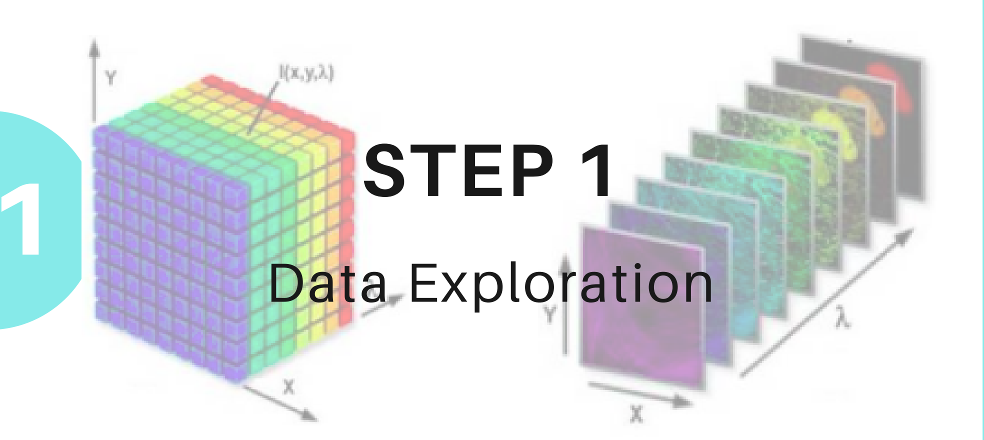
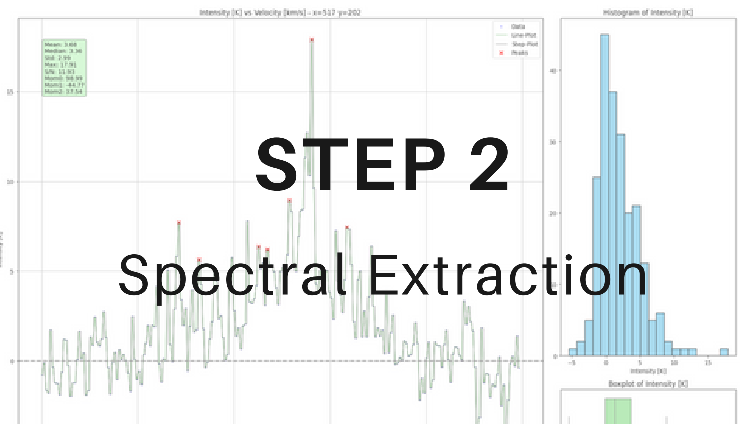
Methodology N2H+

METHODOLOGY N_2H^+

01 

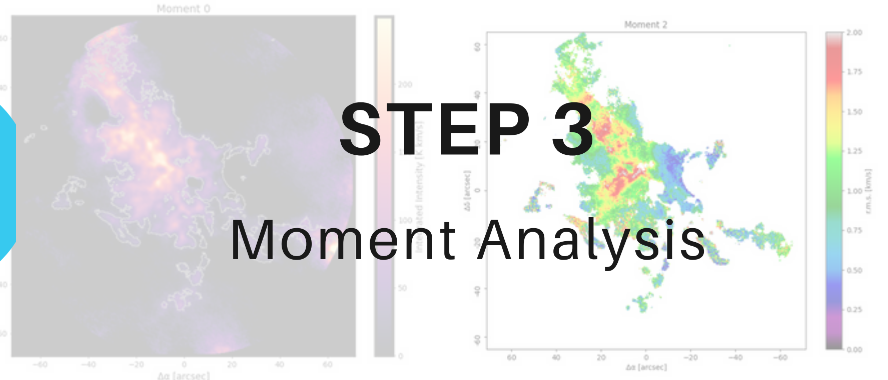
STEP 1

Data Exploration

02 

STEP 2

Spectral Extraction

03 

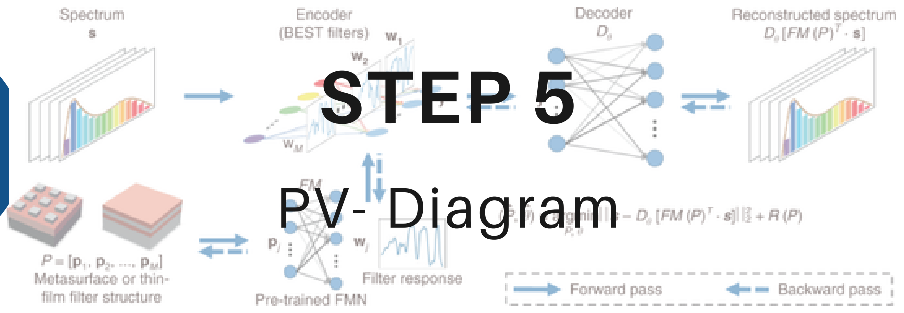
STEP 3

Moment Analysis

04 

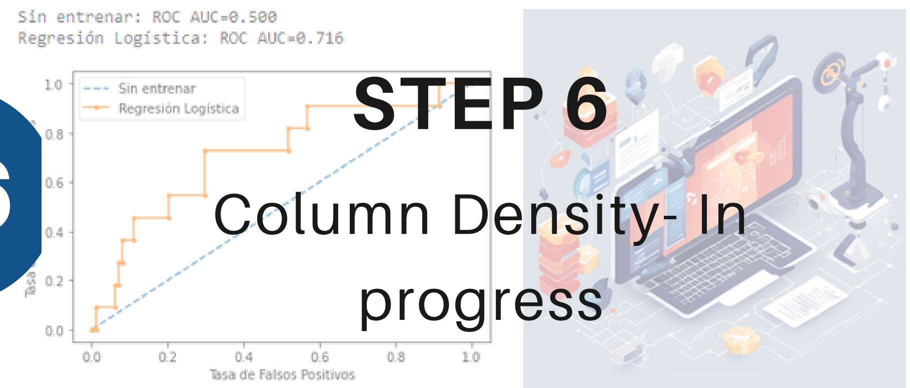
STEP 4

Spectral Fitting

05 

STEP 5

PV- Diagram

06 

STEP 6

Column Density- In progress

07 

STEP 7

Resources

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DYAZENYLIUM N_2H^+

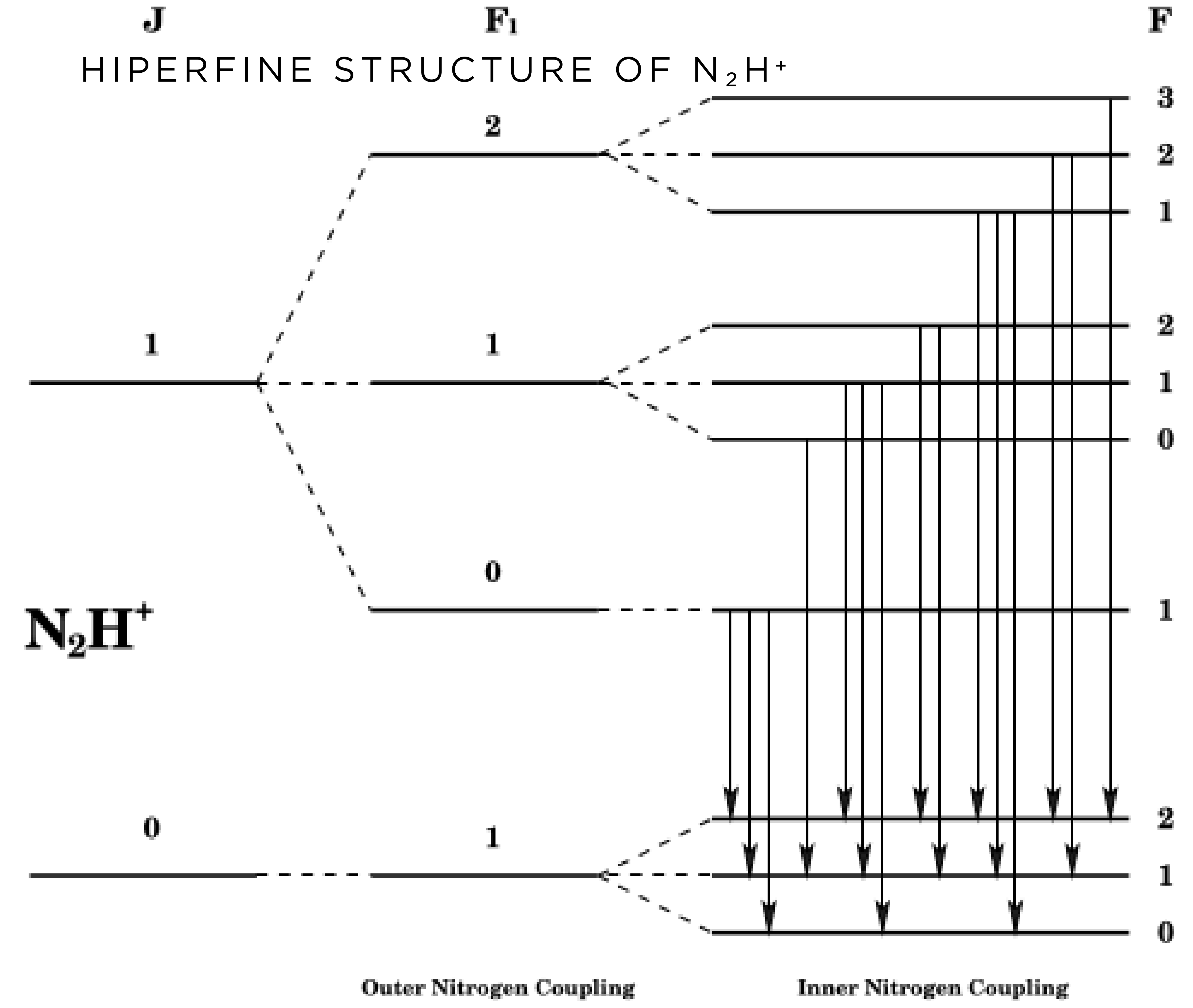


Figure 6. Caselli et al. (1995)

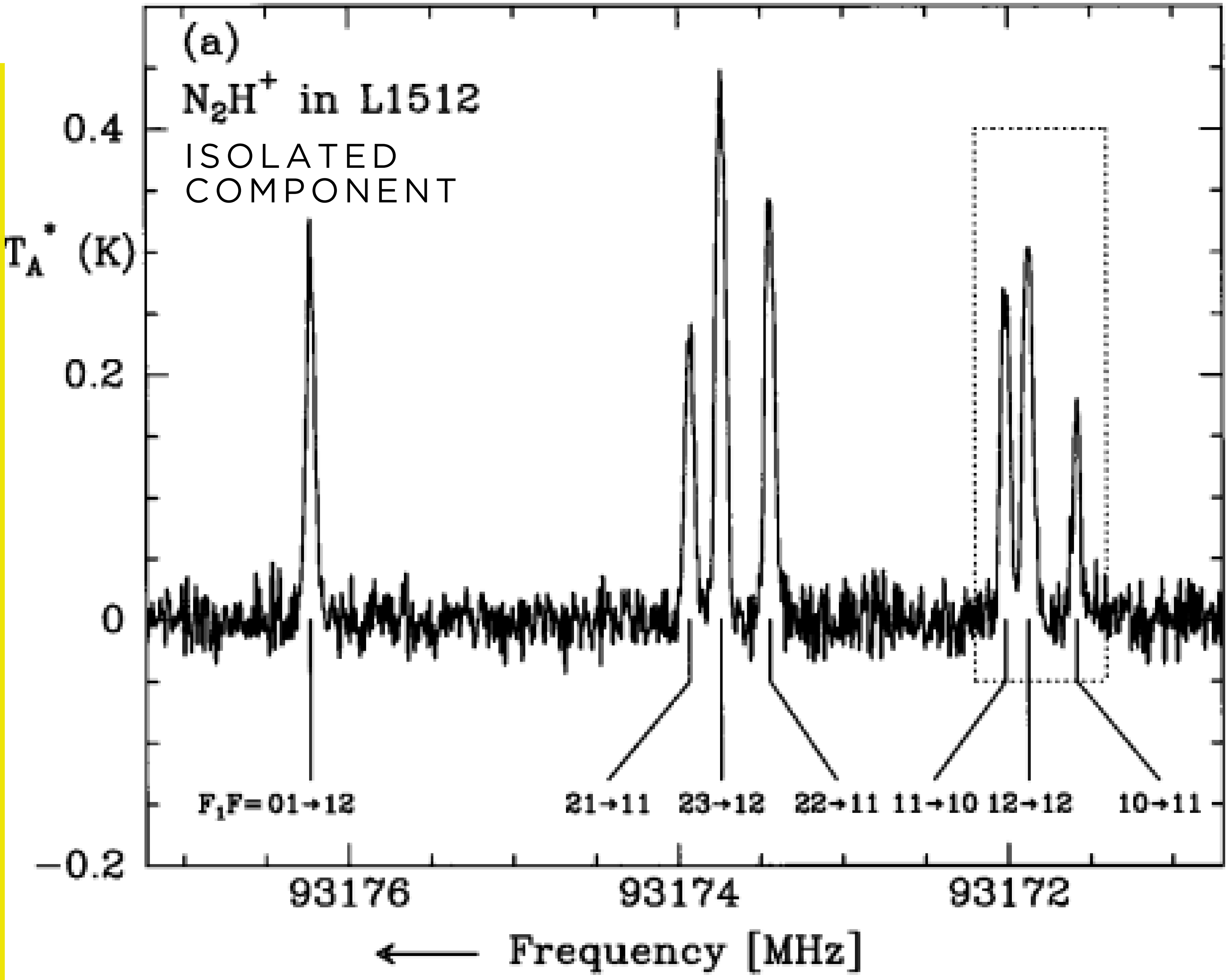


Figure 7. Caselli et al. (1995)

THE P-V DIAGRAM

Gas velocity structure of the Orion A Integral Shaped Filament

Valentina González Lobos,[1]* Amelia M. Stutz[1,2]
[1] Departmento de Astronomía, Facultad de Ciencias Físicas y Matemáticas, Universidad de Concepción, Concepción, Chile
[2] Max-Planck-Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany

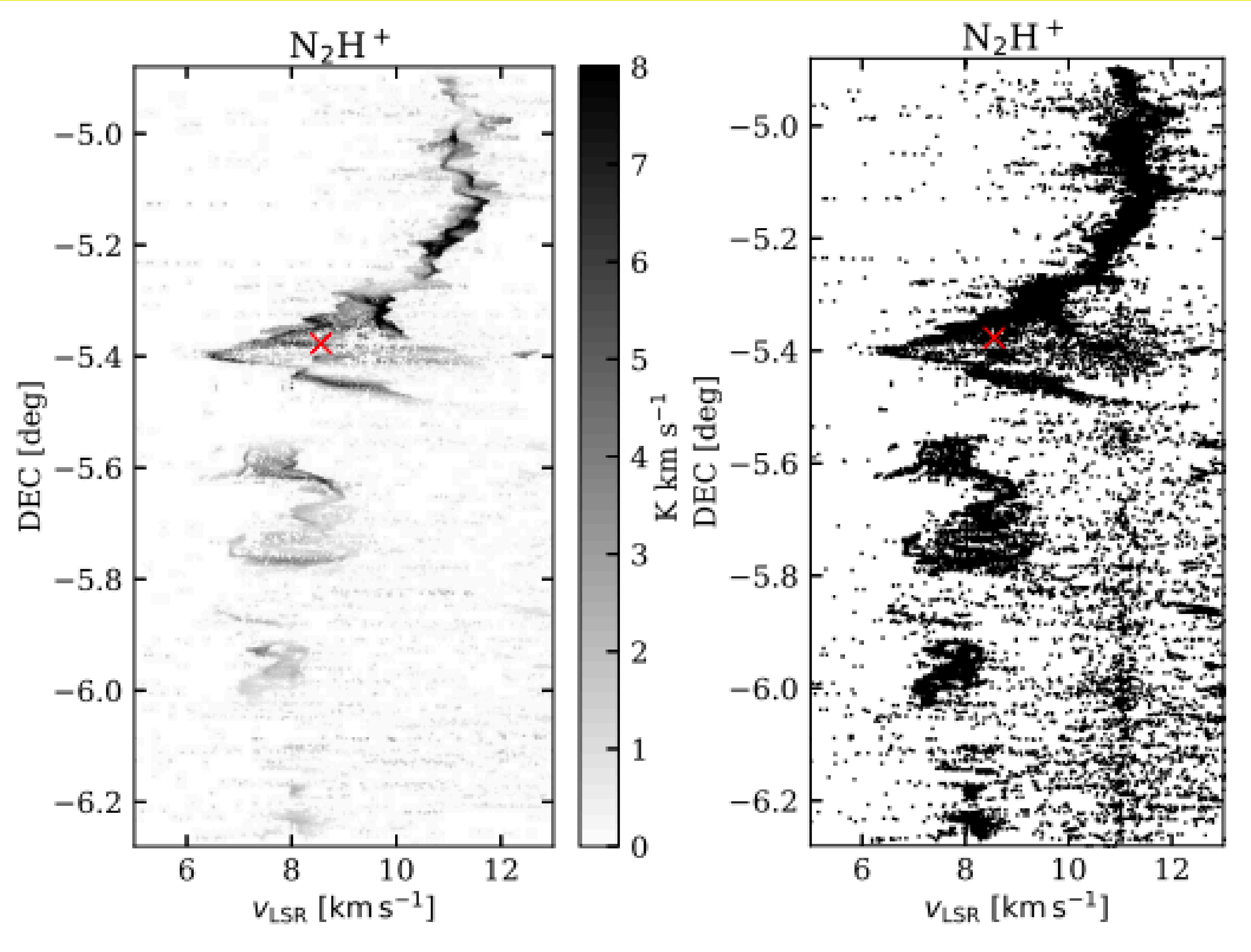


Figure 8. Lobos et al. (2019)

COLUMN DENSITY

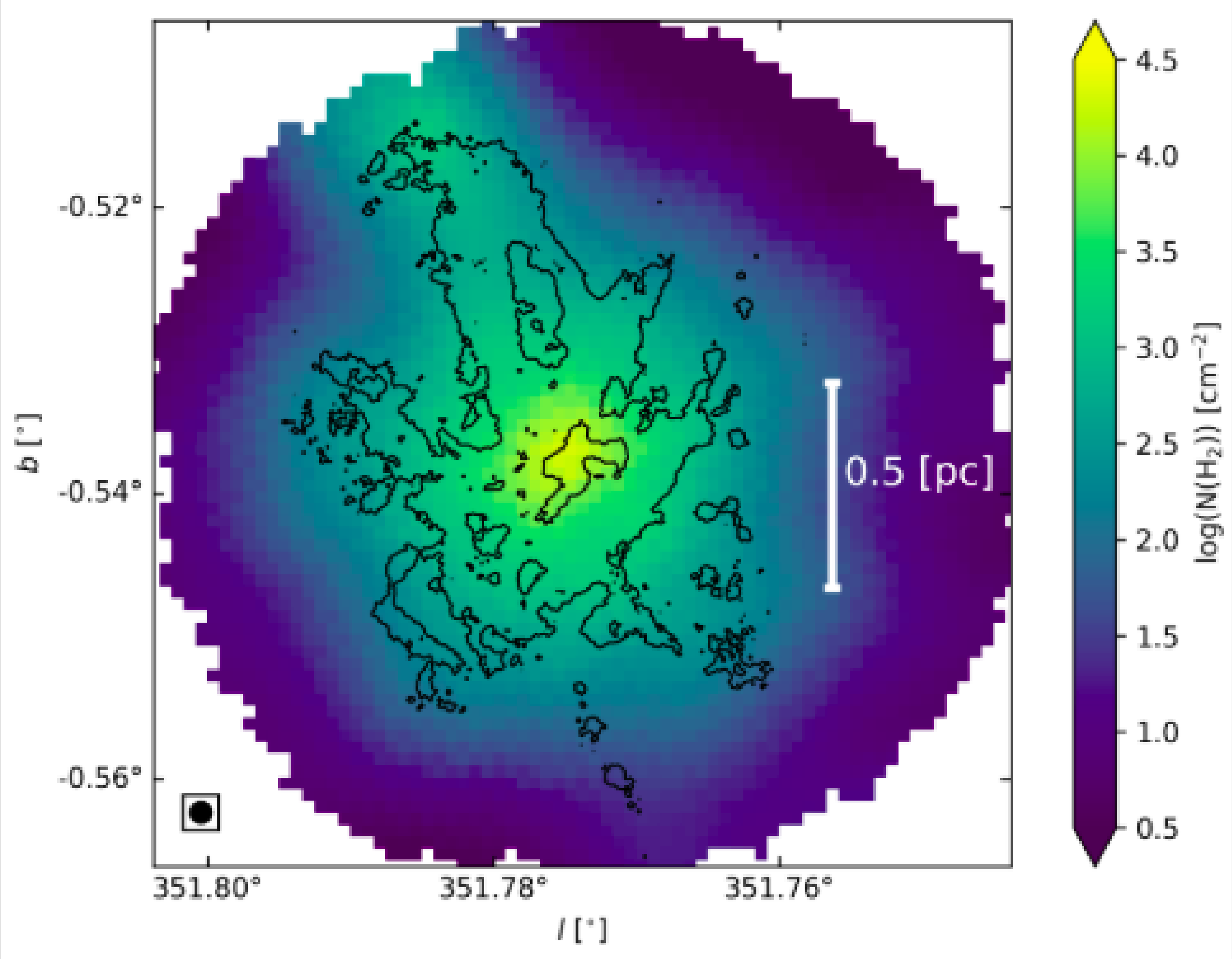


Figure 9. Garrido, N. (2024)

Filament Rotation in the California L1482 Cloud

Álvarez-Gutiérrez[1], A. M. Stutz[1,2], C. Y. Law[3,4], S. Reissl[5], R. S. Klessen[5,6], N. W. C. Leigh[1,
H.-L. Liu[1,3,8], and R. A. Reeves[1]

ONE COMPONENT SPECTRUM

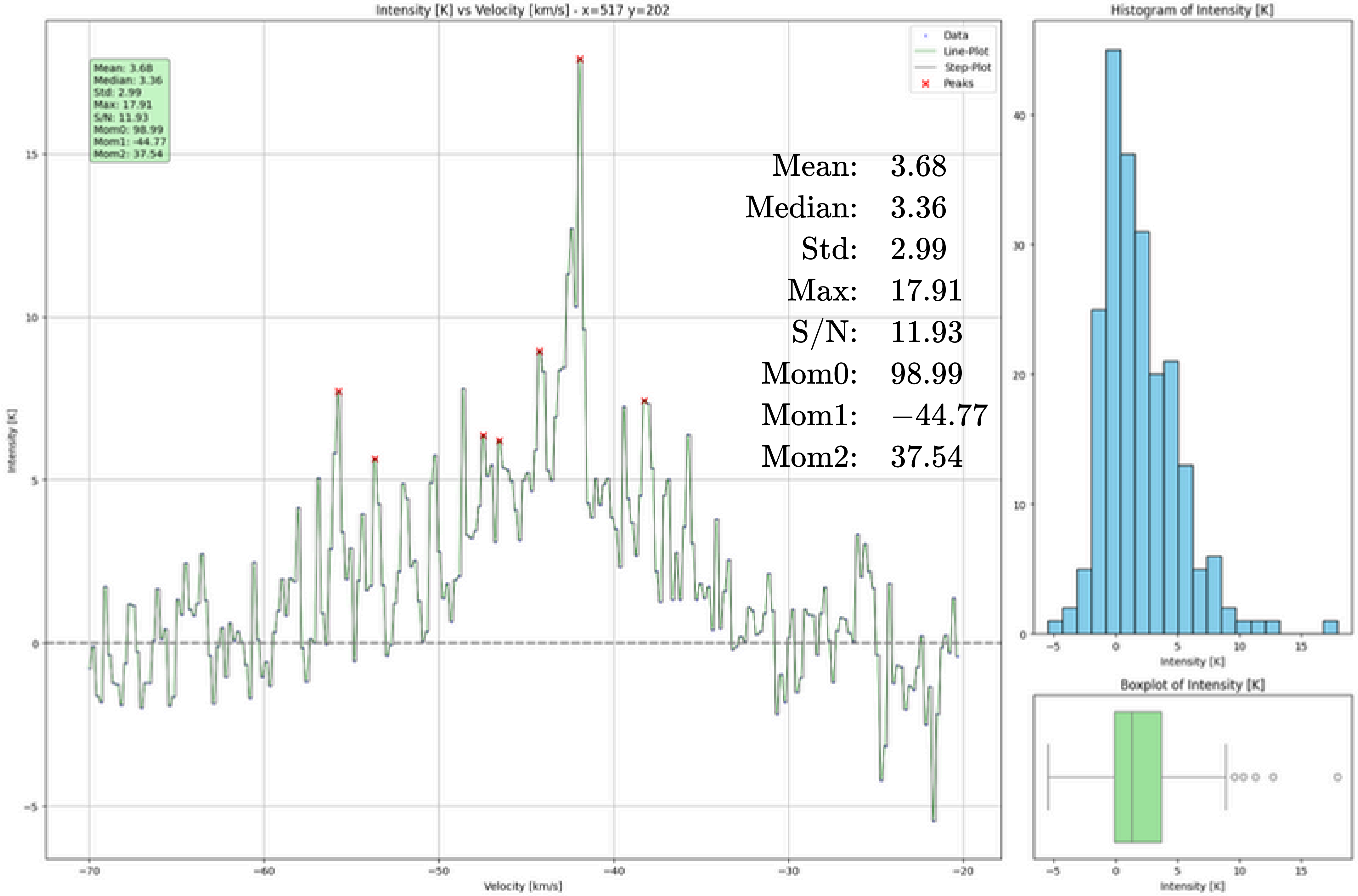
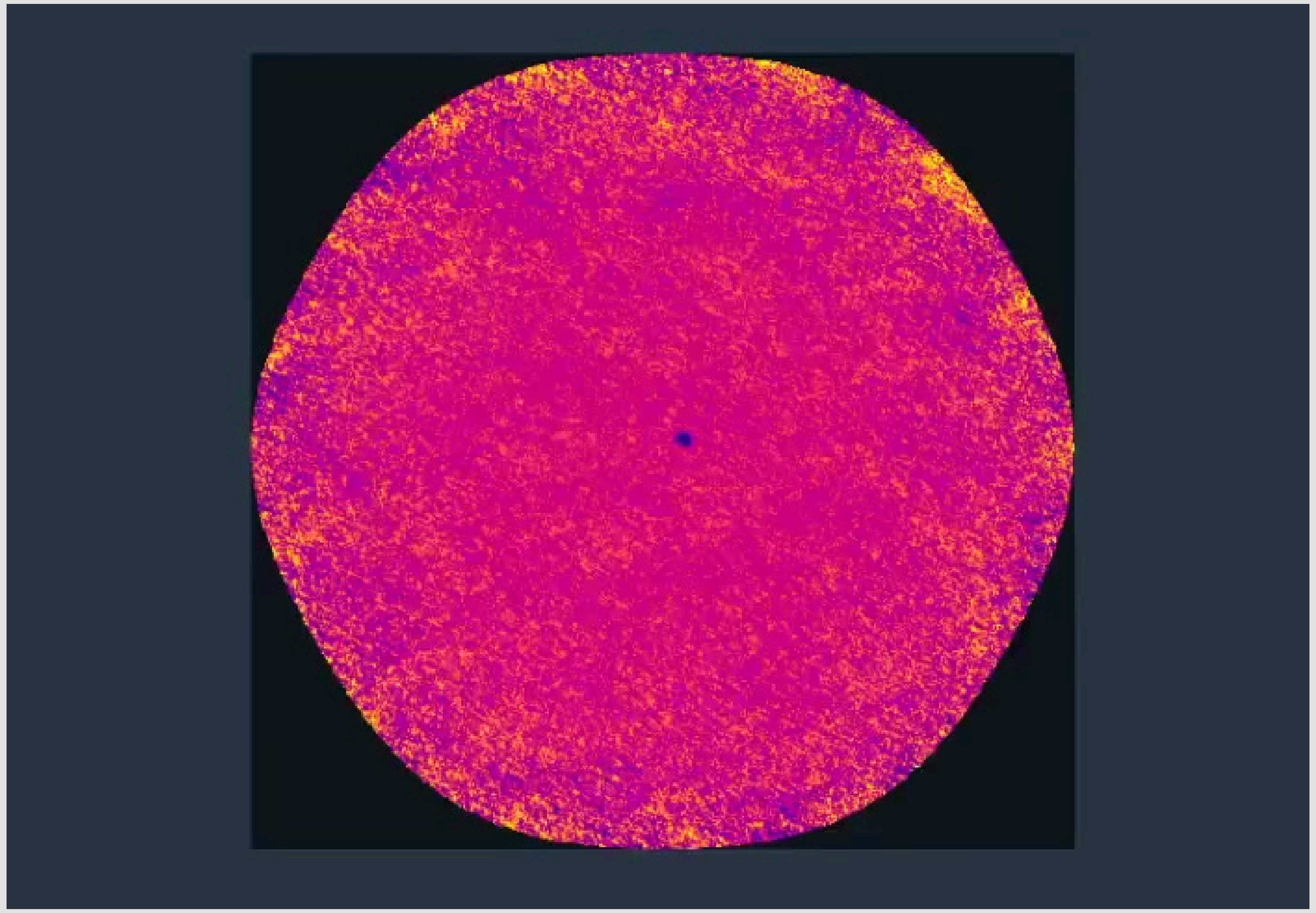
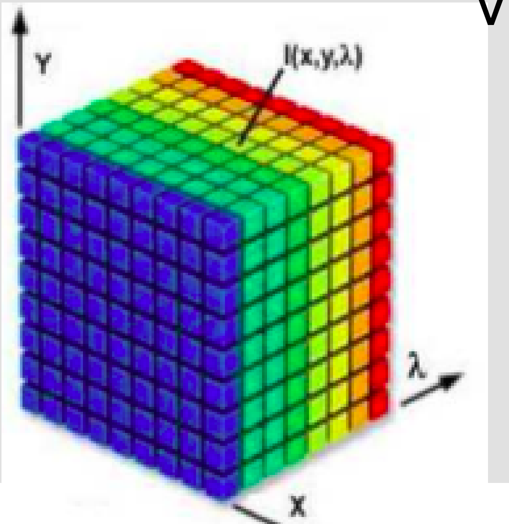


Figure 10. Spectrum for one component



Video 3. Spectral Axis



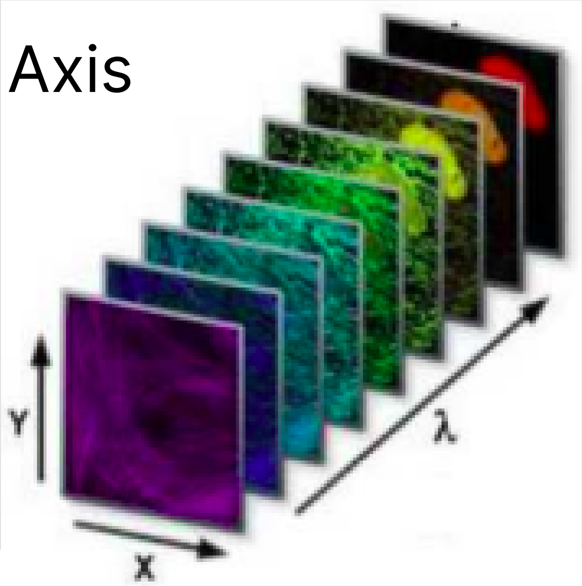
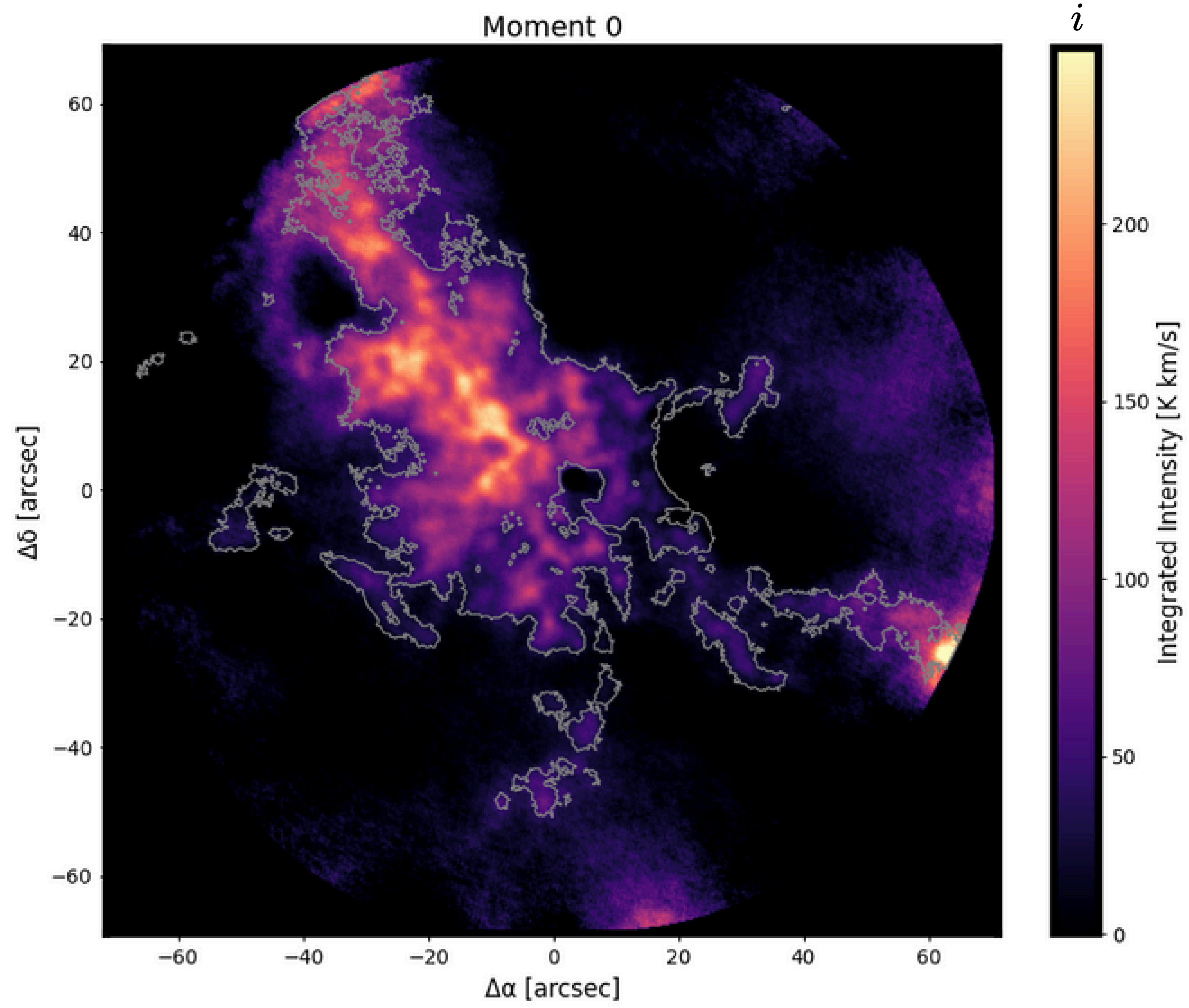


Figure 11. Data Cube. Ibraheem , I. (2015).

MOMENTUM ANALYSIS

$$M_0 = \sum_i T_B^*(v_i)\Delta v$$



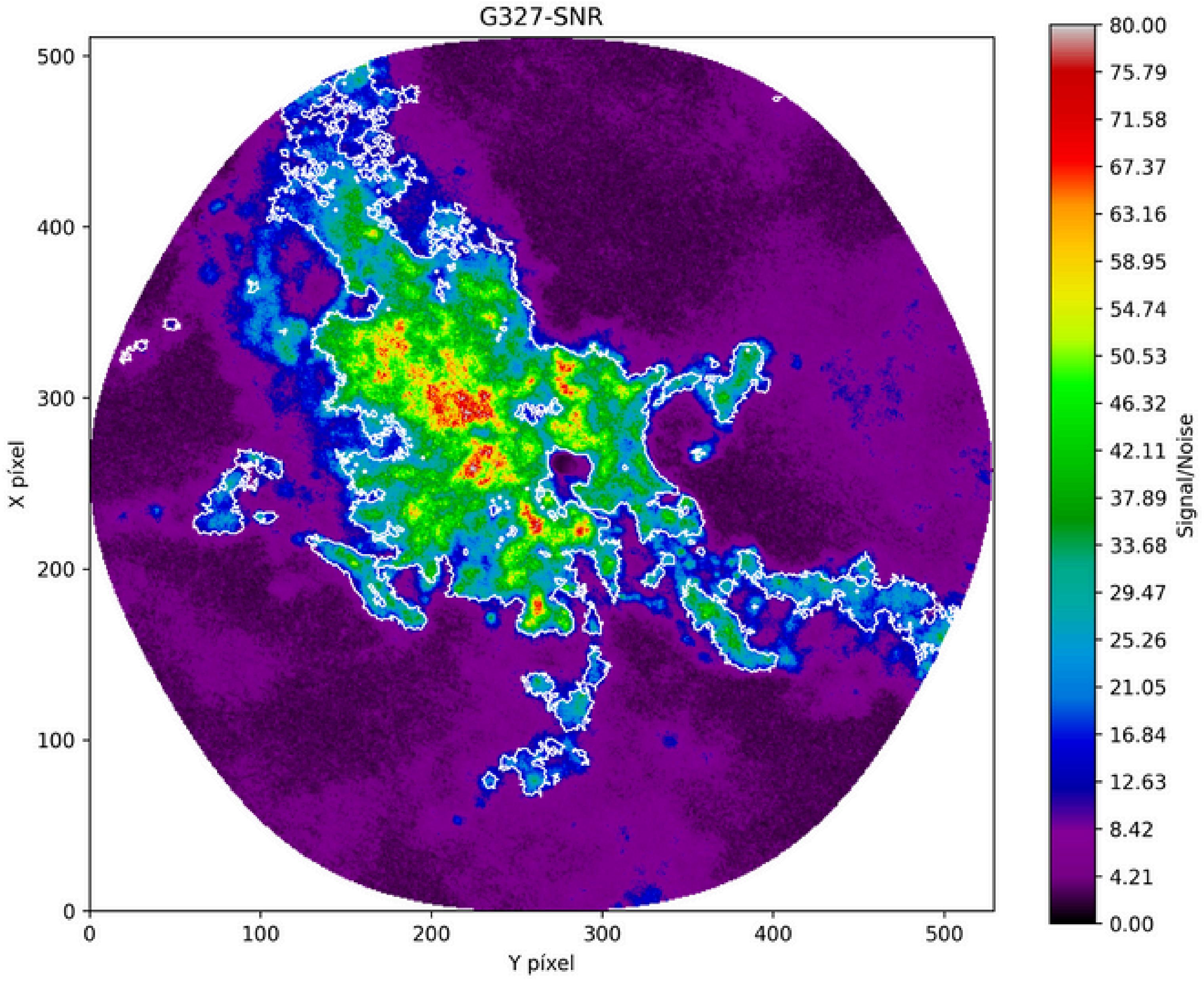


Figure 12. Moment Zero

Figure 13. Signal to Noise

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MOMENTUM ANALYSISII

$$M_1 = \frac{\sum_i T_B^*(v_i) v_i \Delta v}{\sum_i T_B^*(v_i) \Delta v}$$

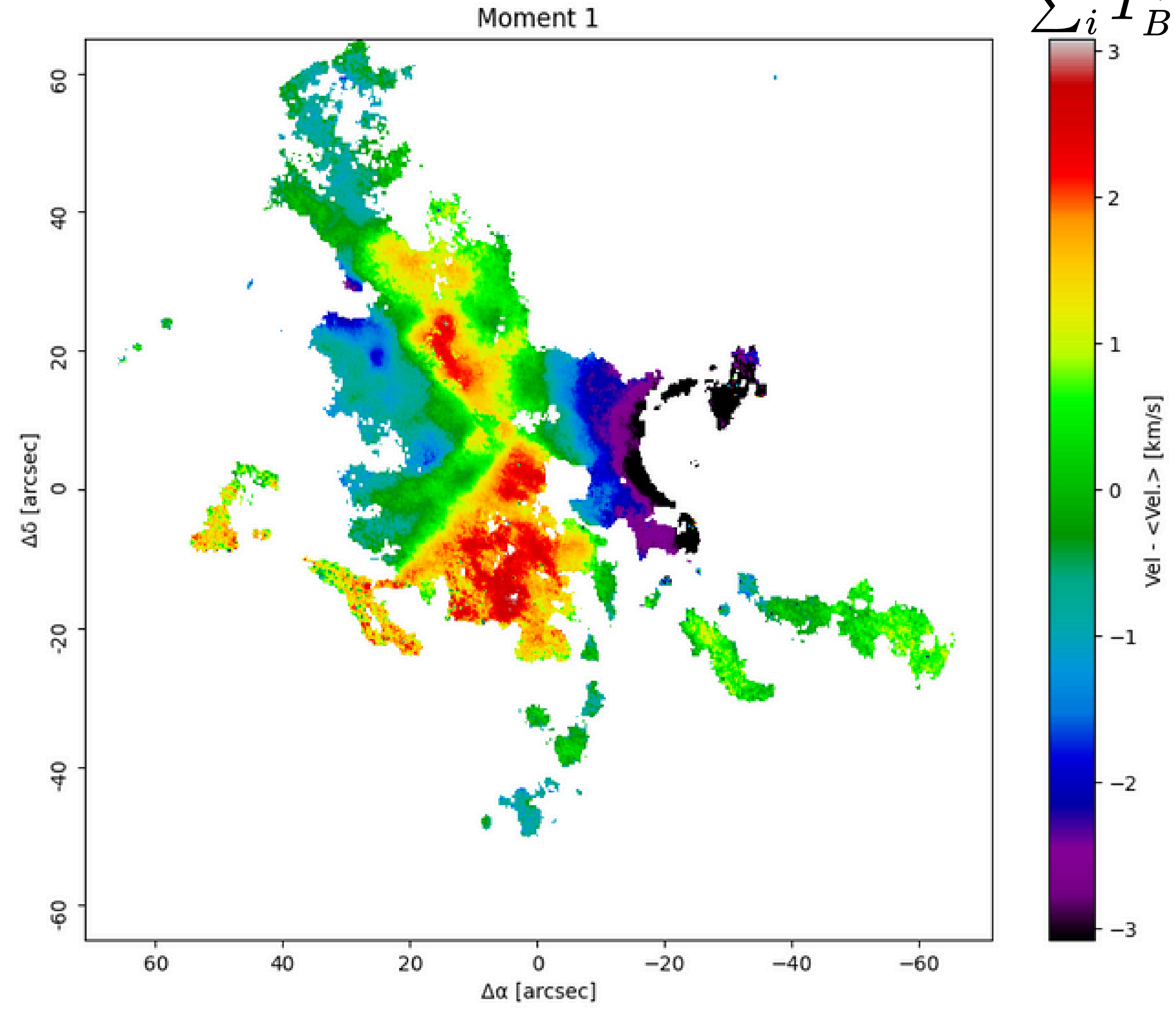

Figure 14. Moment One

$$M_2 = \sqrt{\frac{\sum_i T_B^*(v_i)(v_i - M_1)^2 \Delta v}{\sum_i T_B^*(v_i) \Delta v}}$$

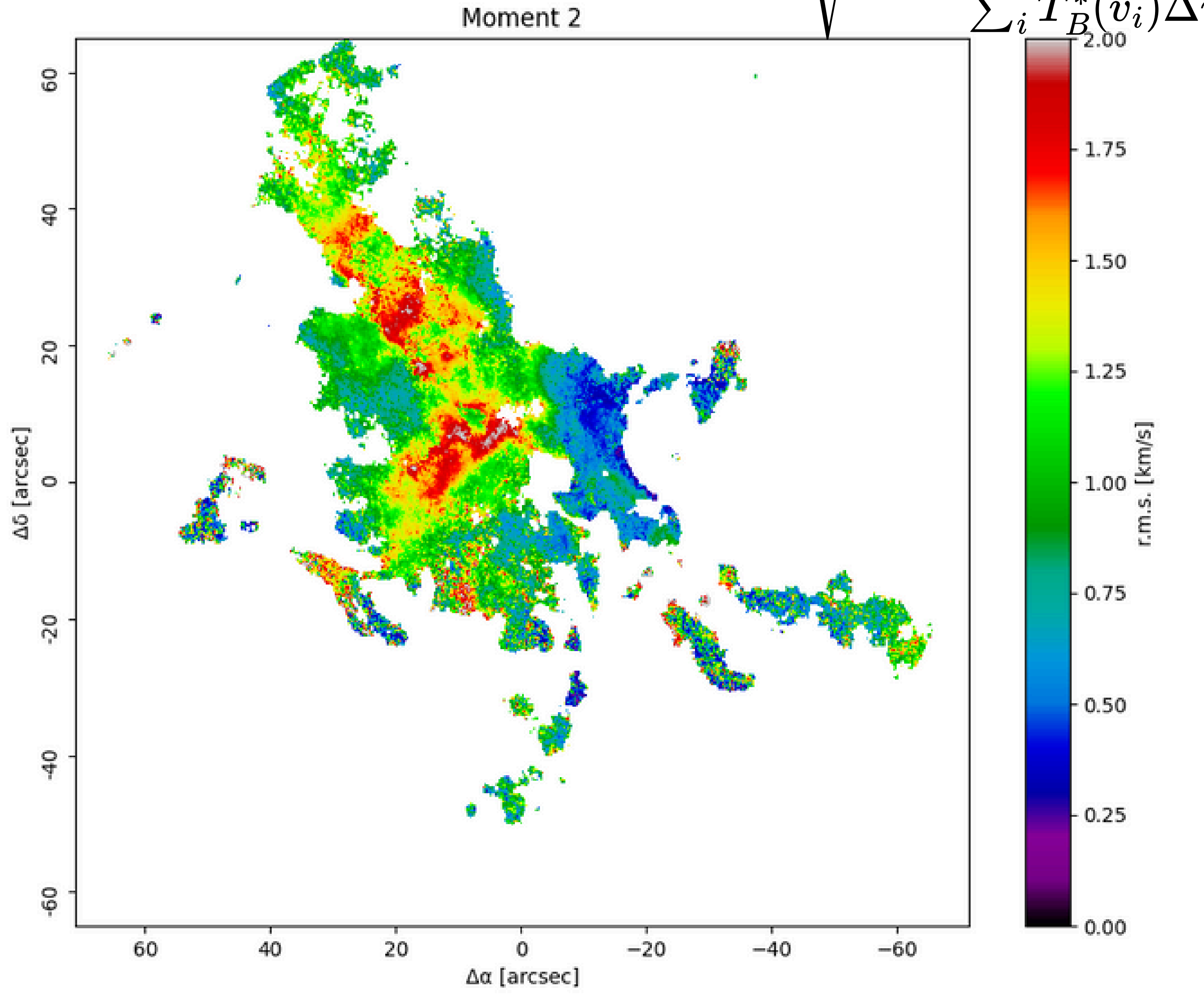

Figure 15. Moment Two

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FIT ONE COMPONENT

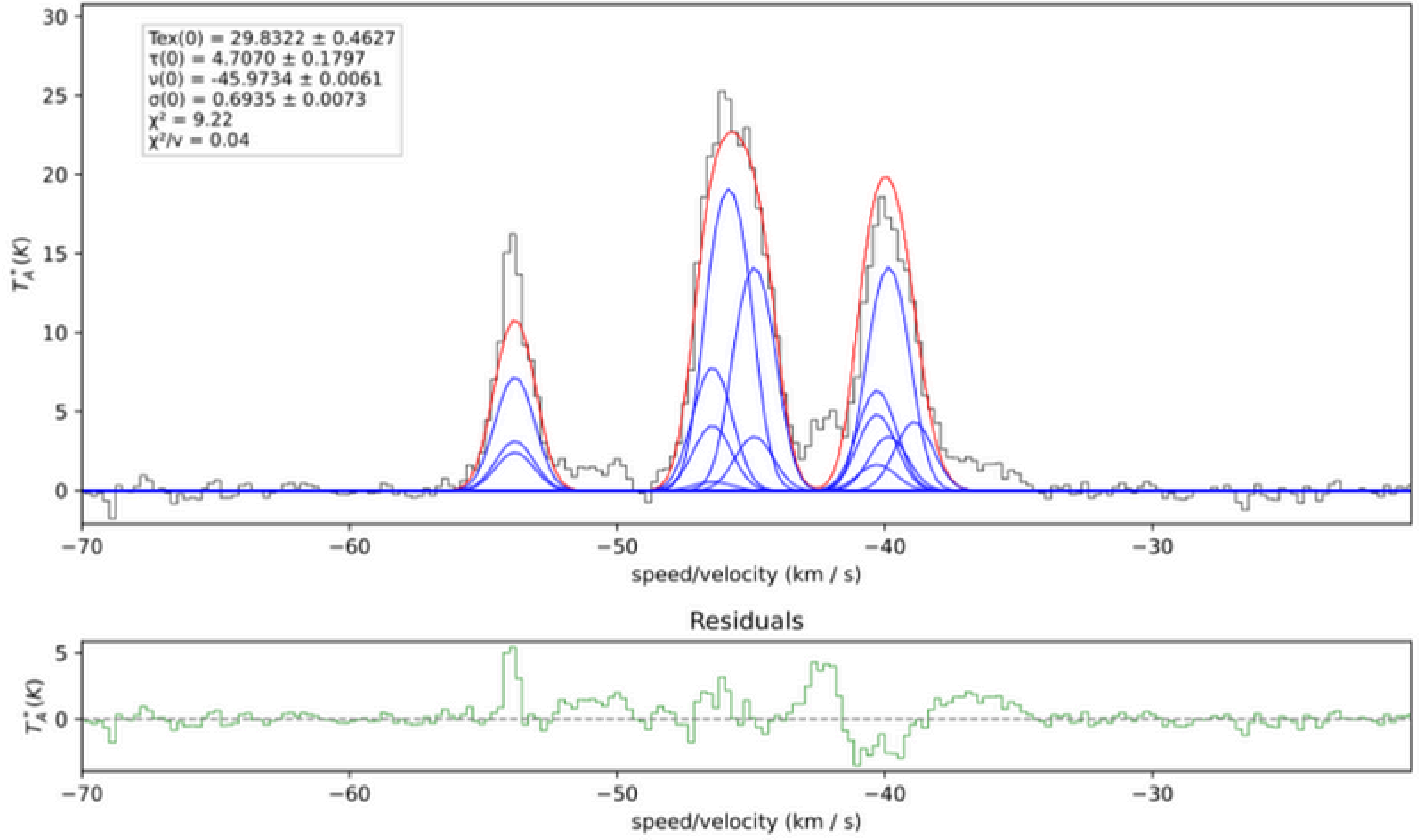

Figure 16. Fit Spectrum

$$T_{\text{ex}}(0) = 29.8322 \pm 0.4627$$
$$\tau(0) = 4.7070 \pm 0.1797$$
$$v_{lrsm}(0) = -45.9734 \pm 0.0061$$
$$\sigma(0) = 0.6935 \pm 0.0073$$
$$\chi^2 = 9.22$$
$$\chi^2/\nu = 0.04$$

FIT DATA CUBE

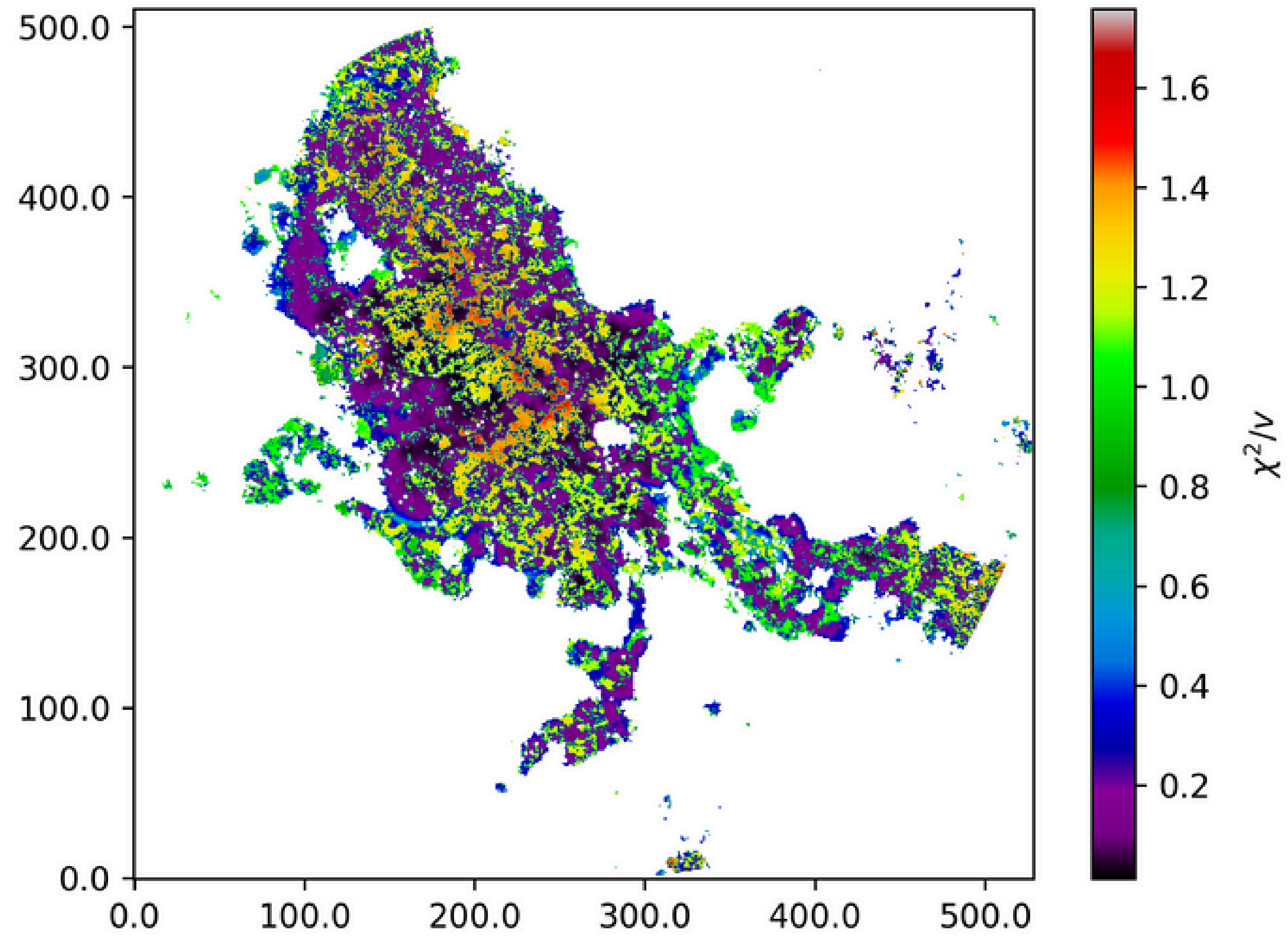

Figure 17. Chi Square

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MWYDYN

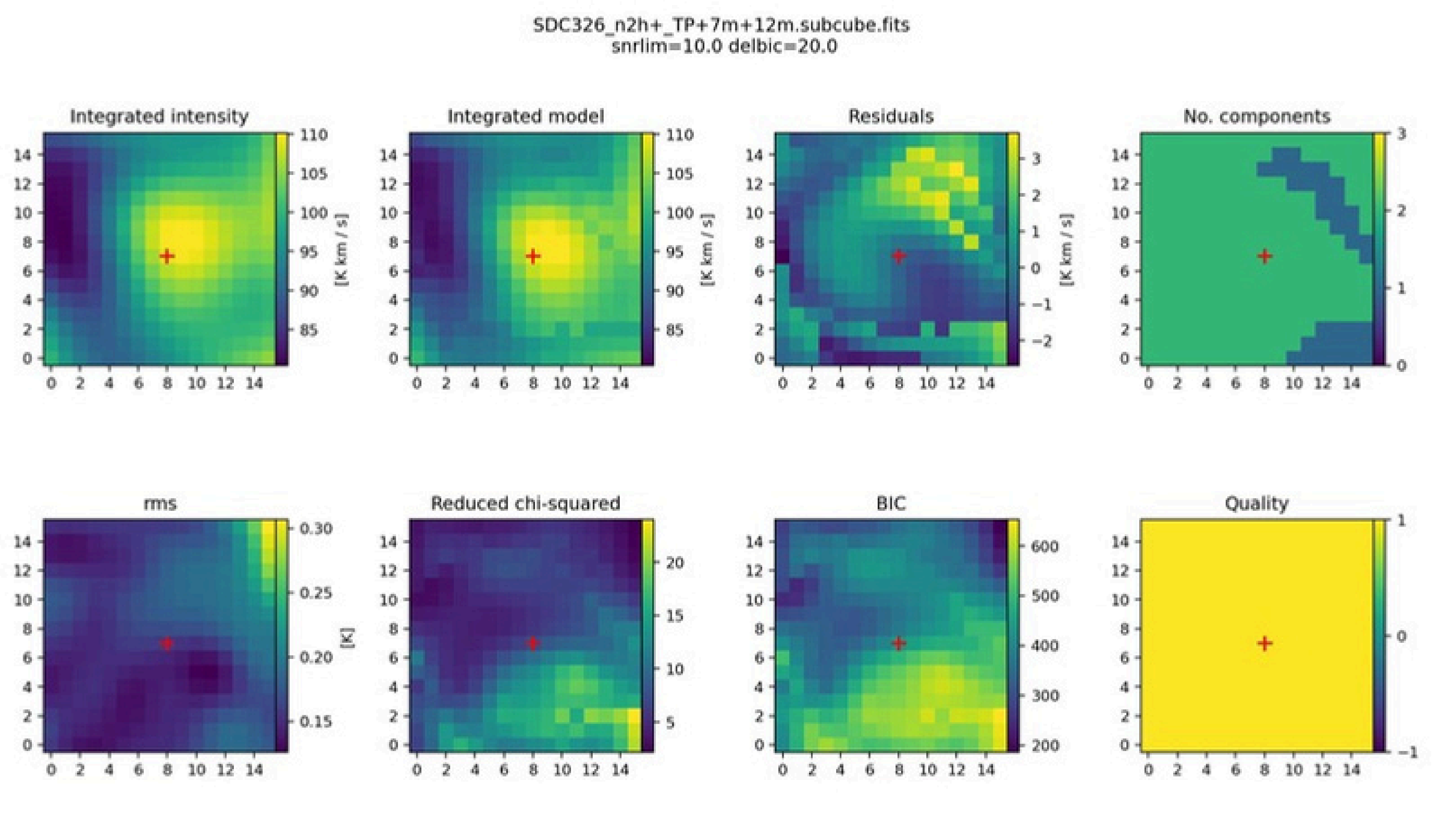

Figure 18. Summary of MWYDYN

The Bayesian Information Criterion (BIC) is a metric used for model selection in statistics and machine learning that balances model fit quality with model complexity.

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FIT TWO COMPONENT

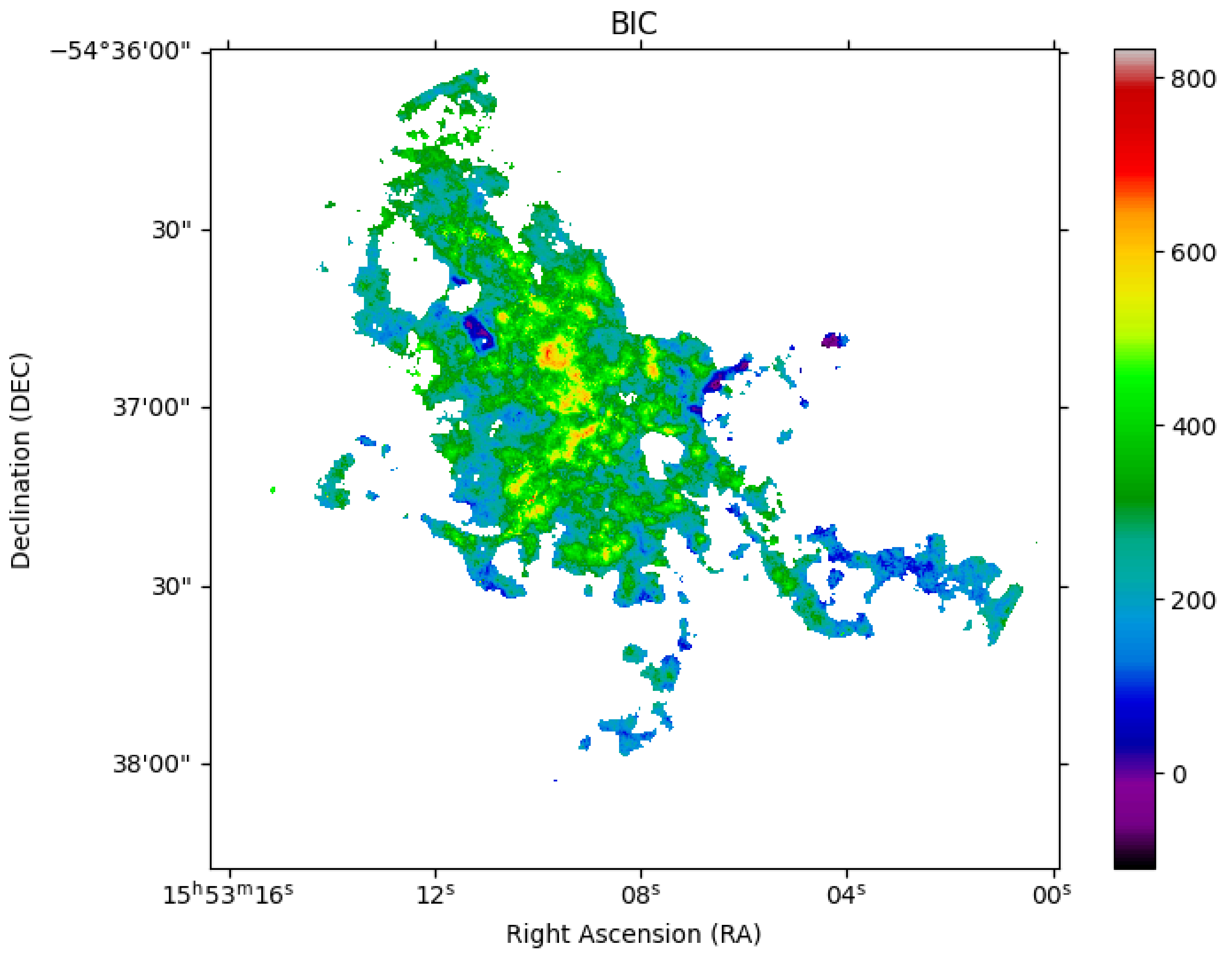

Figure 19. BIC

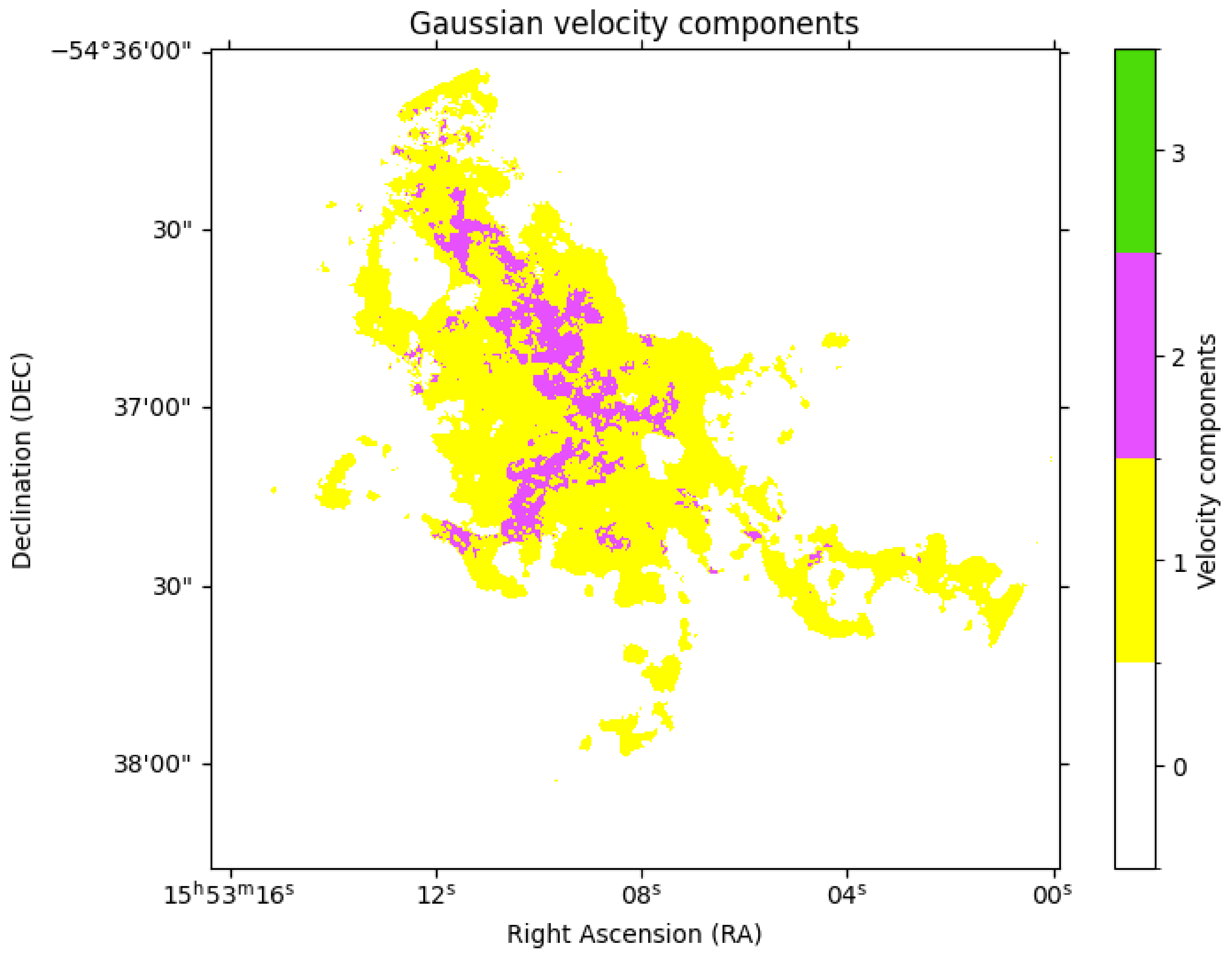

Figure 20. Two Velocity Components

P-V DIAGRAM

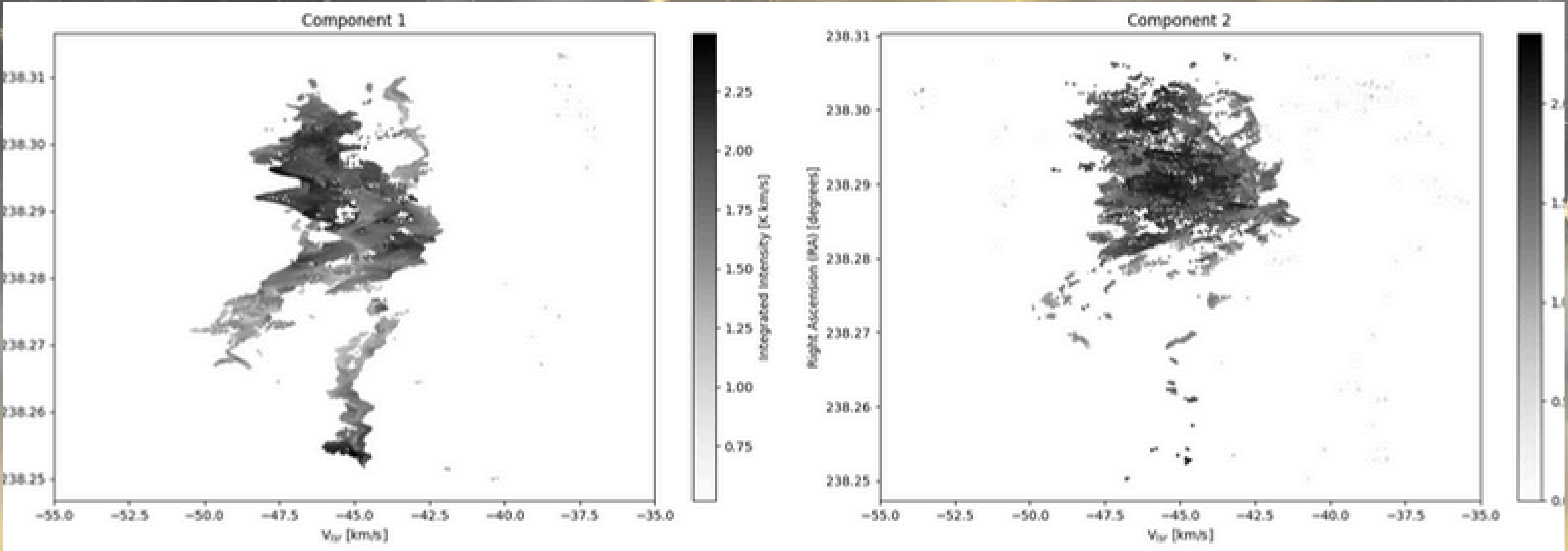

Figure 21. P-V Diagram one and two components of N_2H^+

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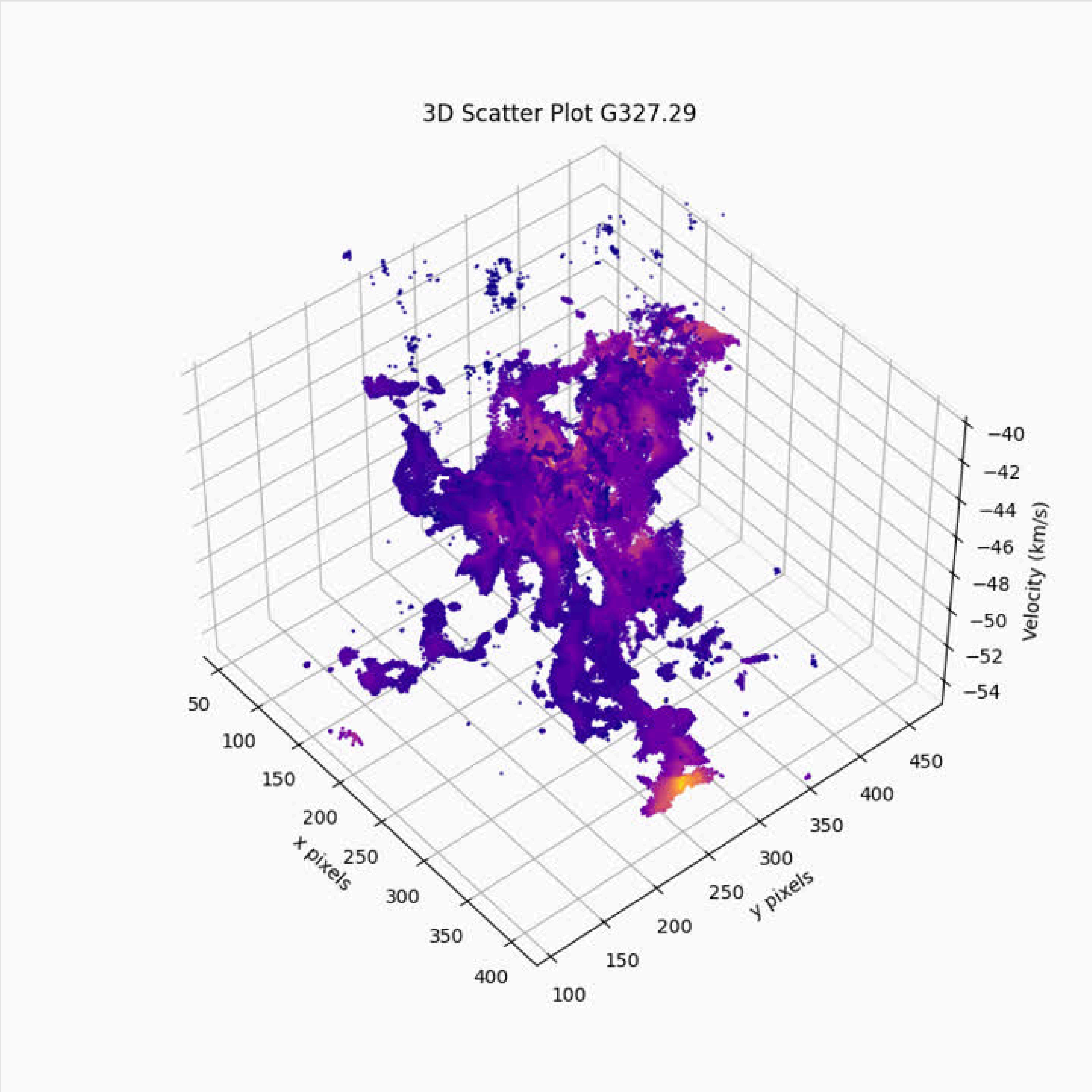
VELOCITY DISTRIBUTION



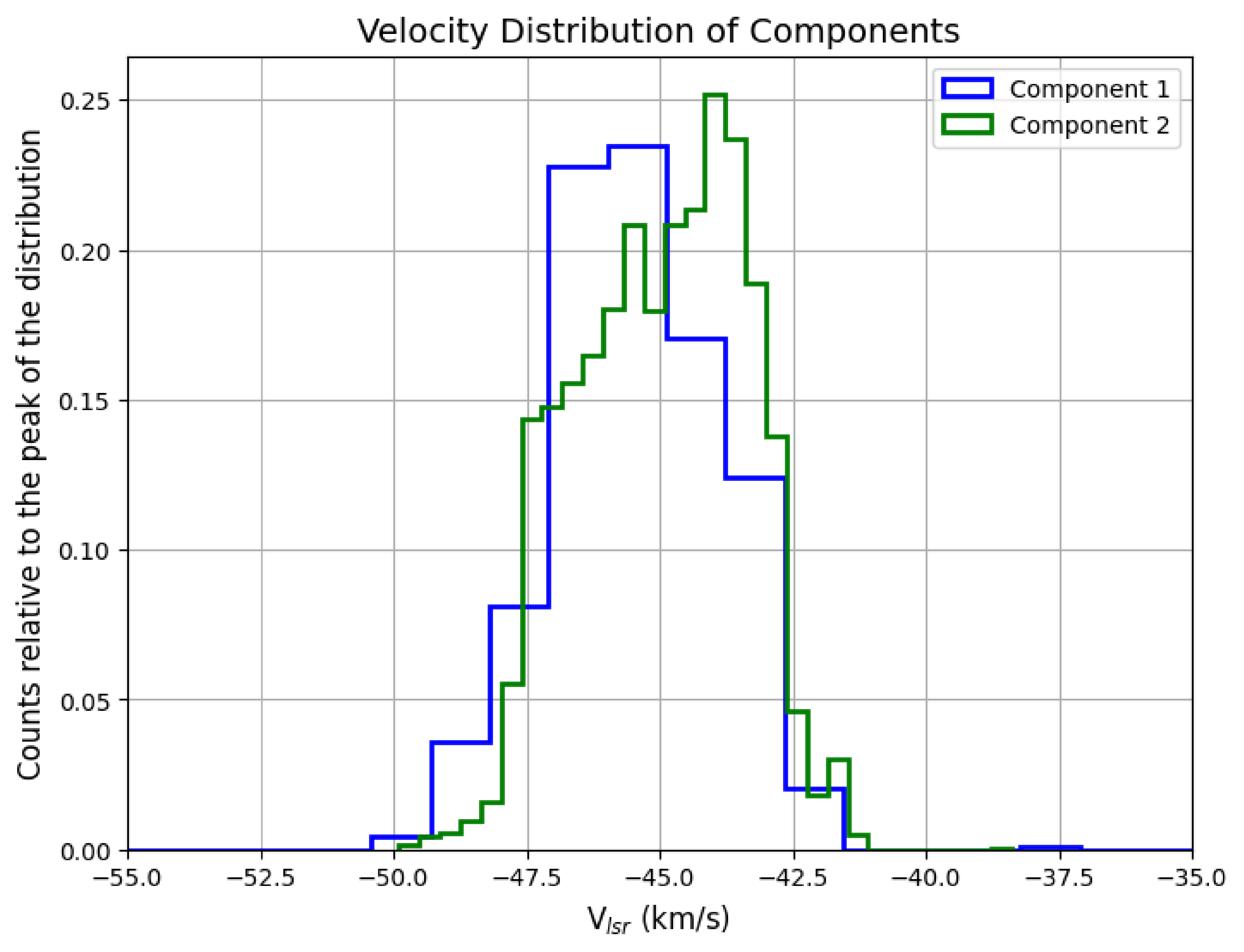


Figure 22. Distributions of components of N_2H^+

Conclusions

WORK IN PROGRESS

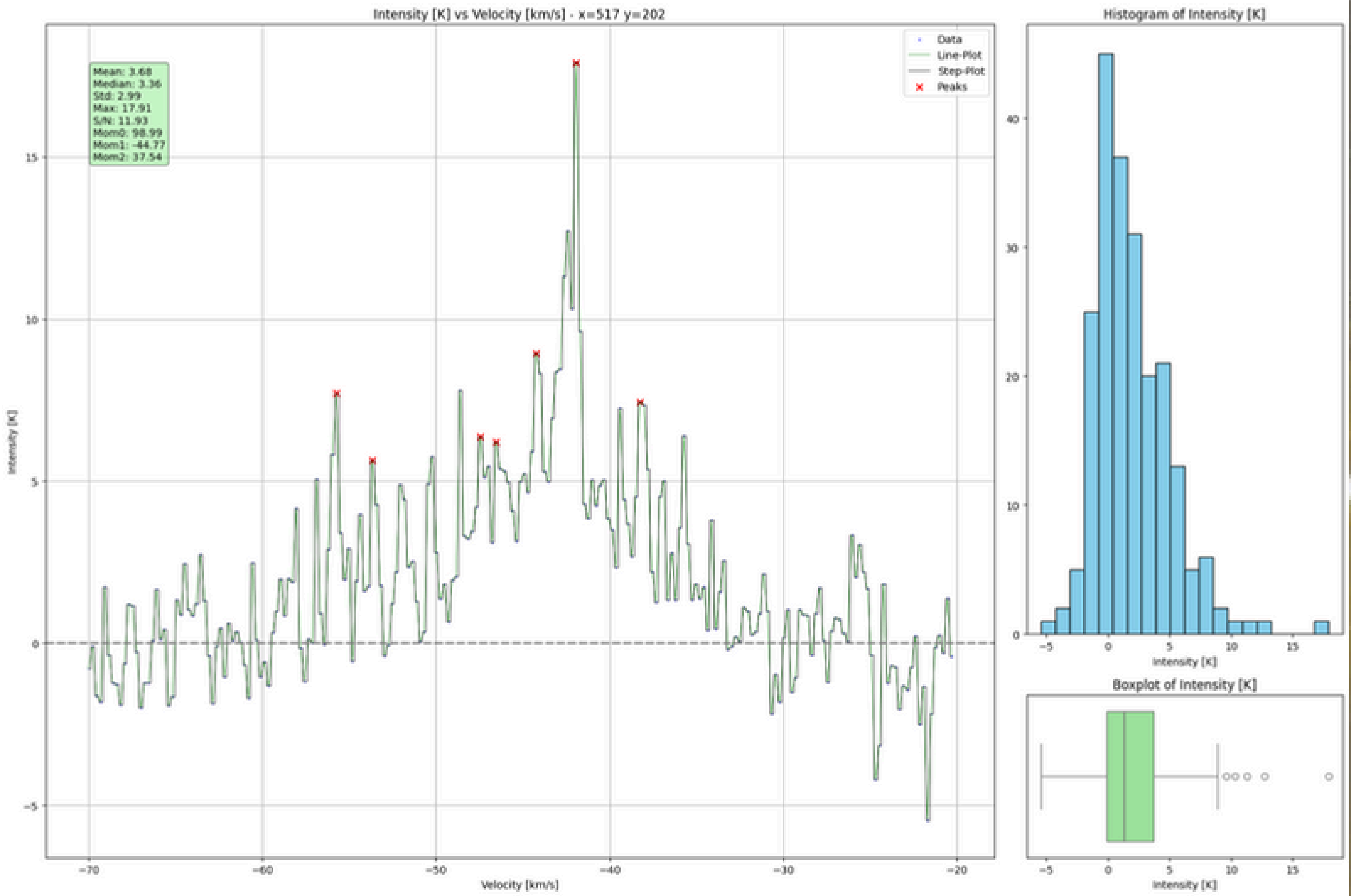
Conclusions

01

The gas in G327.29 is concentrated in dense structures, traced effectively using N_2H^+, ideal for early star formation studies.

Velocity analysis shows multiple components, indicating dynamic interactions like gravitational collapse and accretion flows.

Bayesian models helped identify key gas motions, such as turbulence, shaping massive star formation.



Use an autoencoder to extract the physical parameters of the cloud, enabling a more efficient and detailed analysis of the data.

Compare N_2H^+ observations with other molecular tracers, such as NH_3 or CO, to validate and complement the findings.

Complete a comprehensive morphological analysis of N_2H^+ to better understand its role in early star formation.

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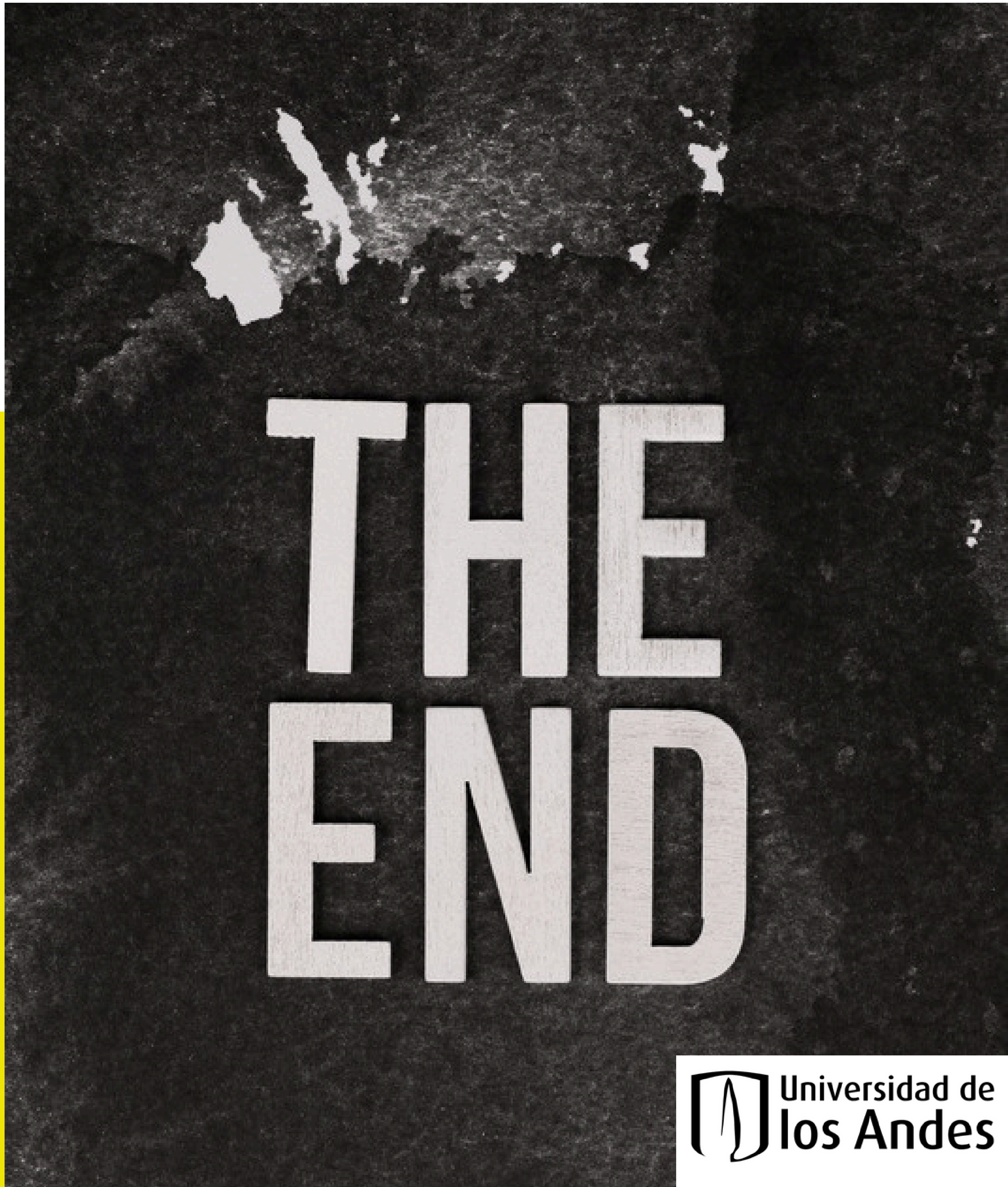
THANK YOU SO MUCH!



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