Кинематика газа в массивных ядрах

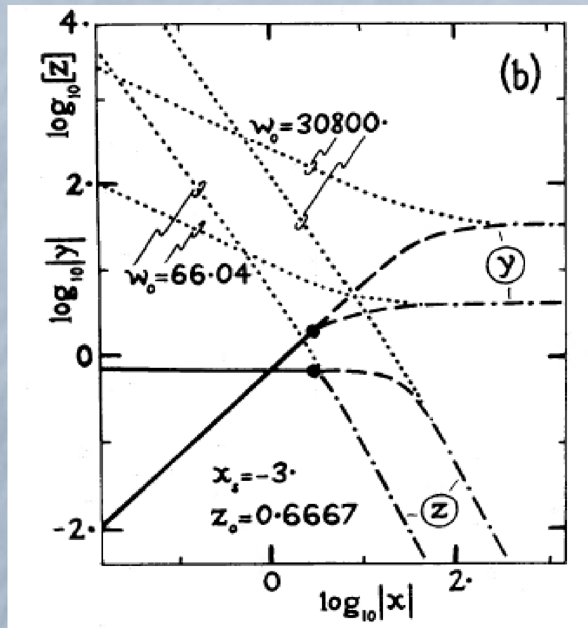
Л.Е. Пирогов,

Е.М. Домбек, П.М. Землянуха

(ИПФ РАН)

Модели протозвездных ядер

Ядро квазиравновесно (дозвездная стадия)
(Shu 1977, Hunter 1977, McKee & Tan 2003)



Whitworth & Summers
(1985)

Ядро неравновесно, V (envelope) ~ const ≠ 0
(Larson 1969, Penston 1969, Vazquez-Semadeni et al. 2019)

Стадия протозвезды: V (inner region) = √(2GM/r)

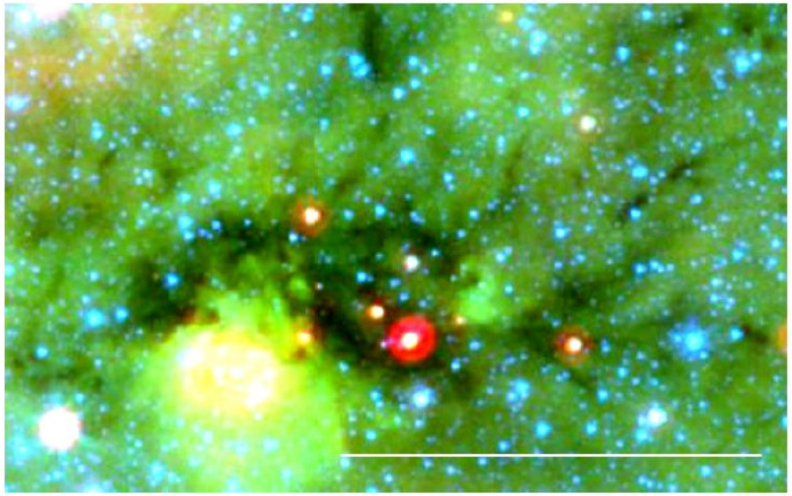


Figure 14. GLIMPSE/MIPSGAL image of G335.43–0.24, showing a candidate massive protostar and an elongated hub with six filaments radiating to the NW, one to the west, and two to the SW. The scale bar indicates 5 pc.

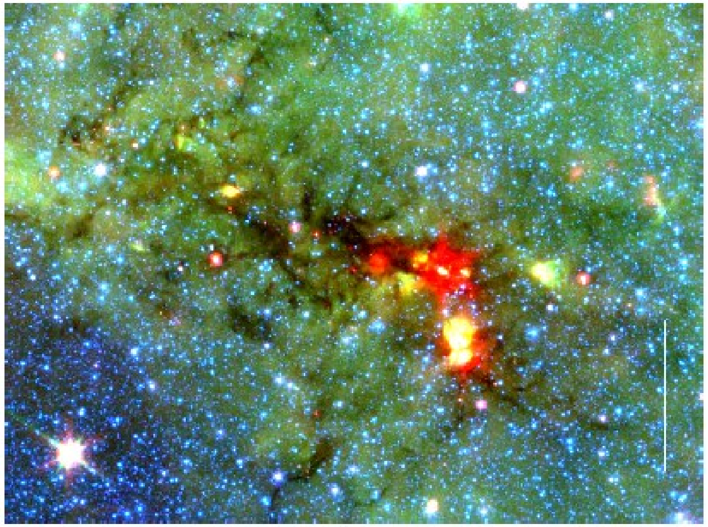


Figure 15. GLIMPSE/MIPSGAL image of G345.00–0.22, showing two candidate massive protostars and several fainter sources, in an elongated hub with seven distinct and two diffuse filaments radiating to the north and NW and additional diffuse filaments radiating to the south. The scale bar indicates 5 pc.

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FILAMENTARY STRUCTURE OF STAR-FORMING COMPLEXES

Philip C. Myers
Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA; pmyers@cfa.harvard.edu
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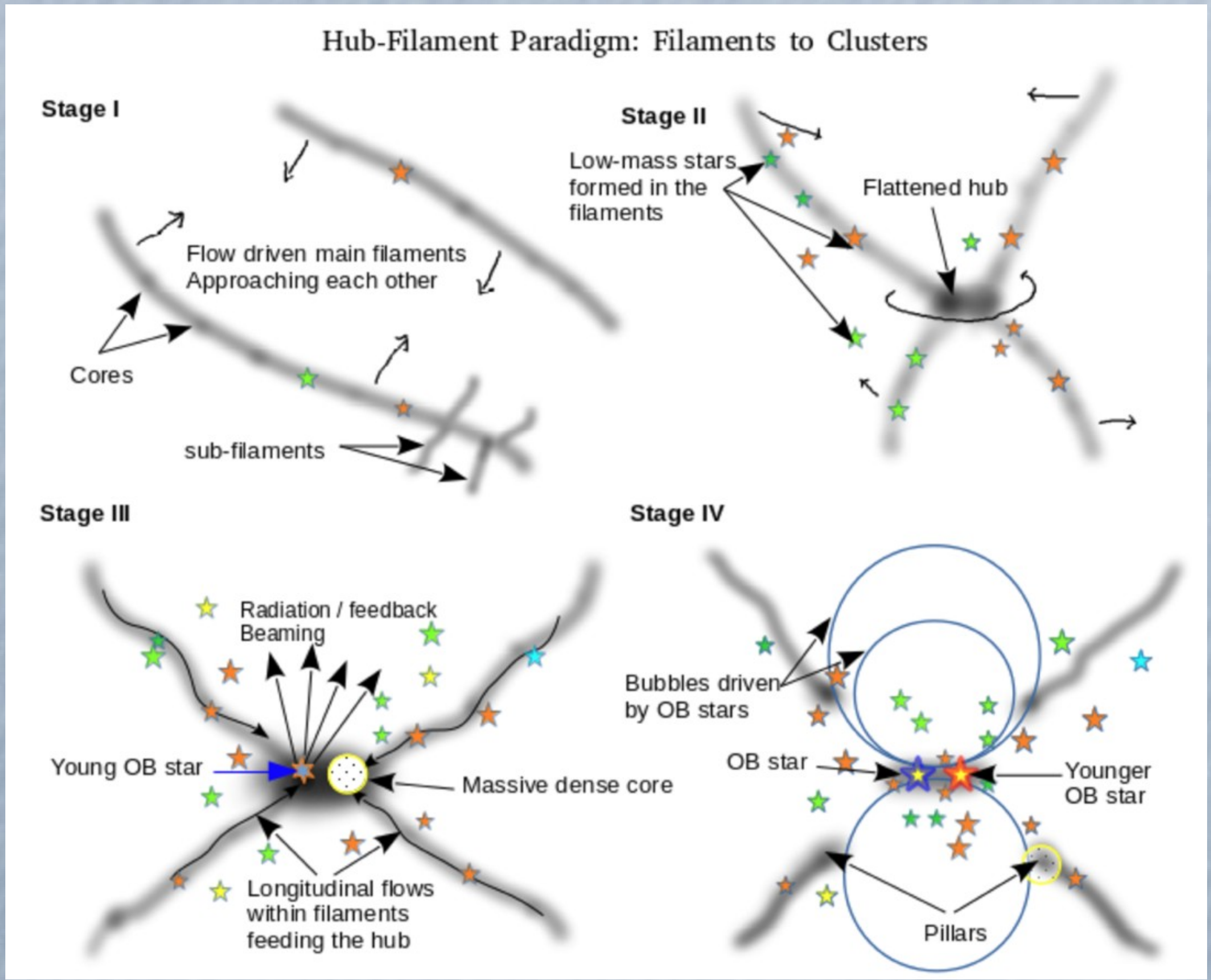


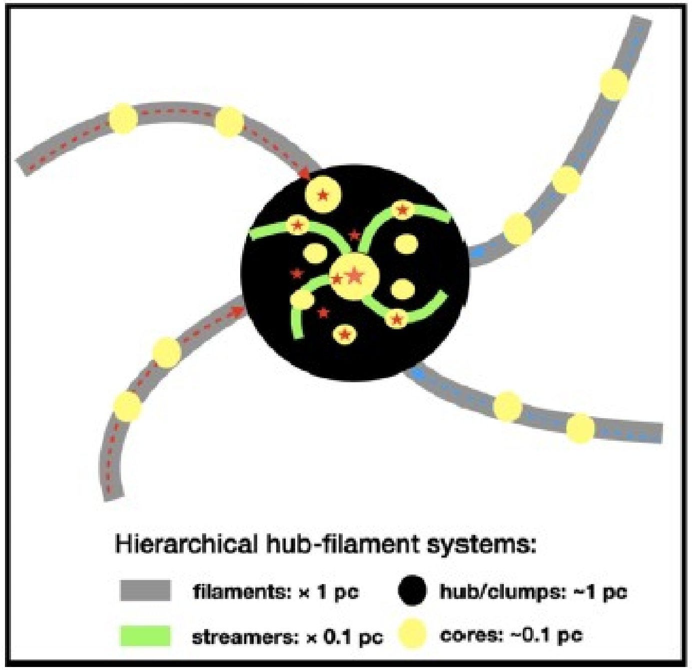
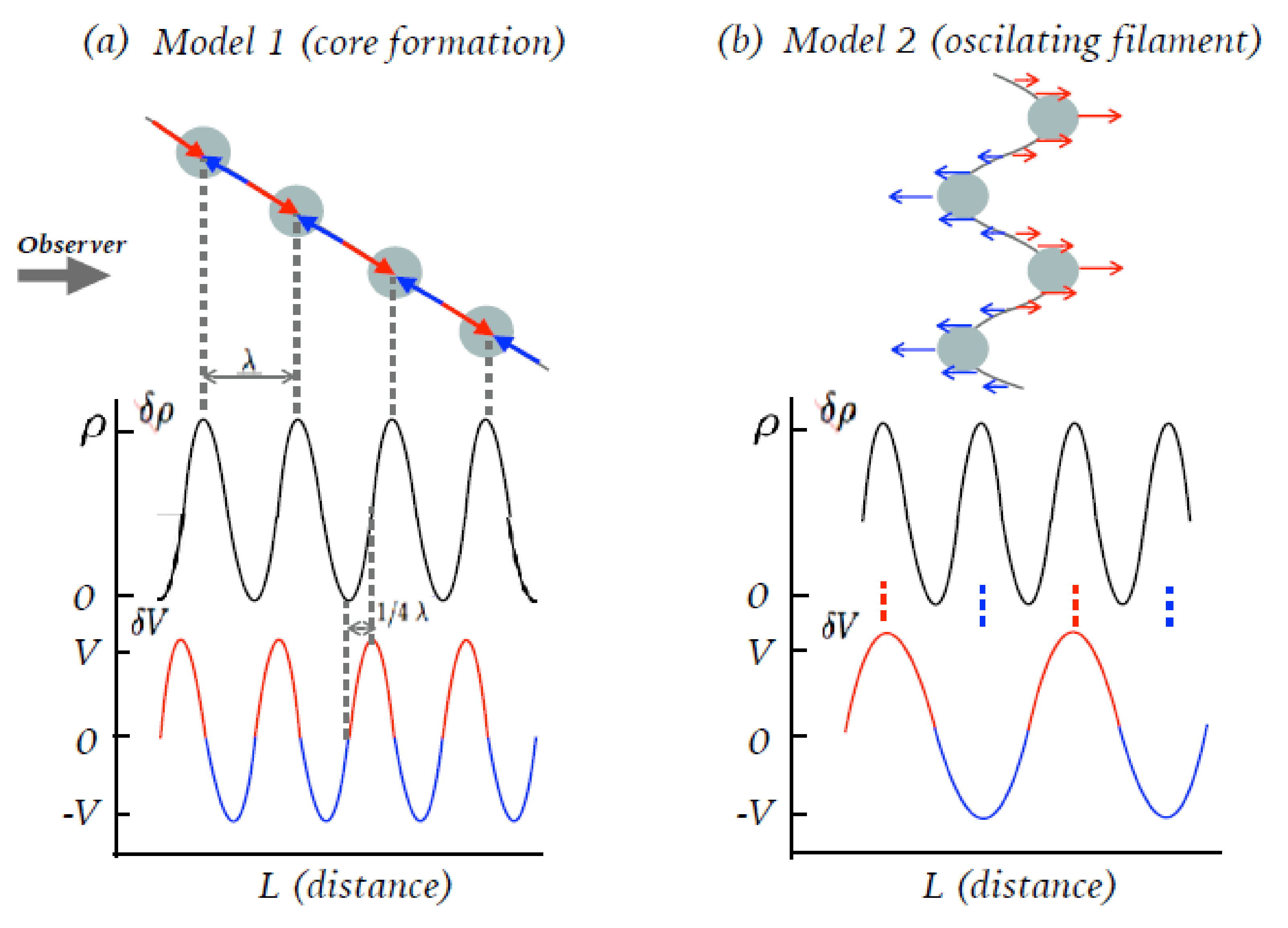


Figure 12. Schematic diagram of self-similar hierarchical HFS at different scales.

Kumar et al. 2020

Zhou et al. (2022)



Liu et al. 2019

Letter to the Editor

Gravitational collapse of the OMC-1 region★

A. Hacar[1,2], J. Alves[1], M. Tafalla[3], and J. R. Goicoechea[4]

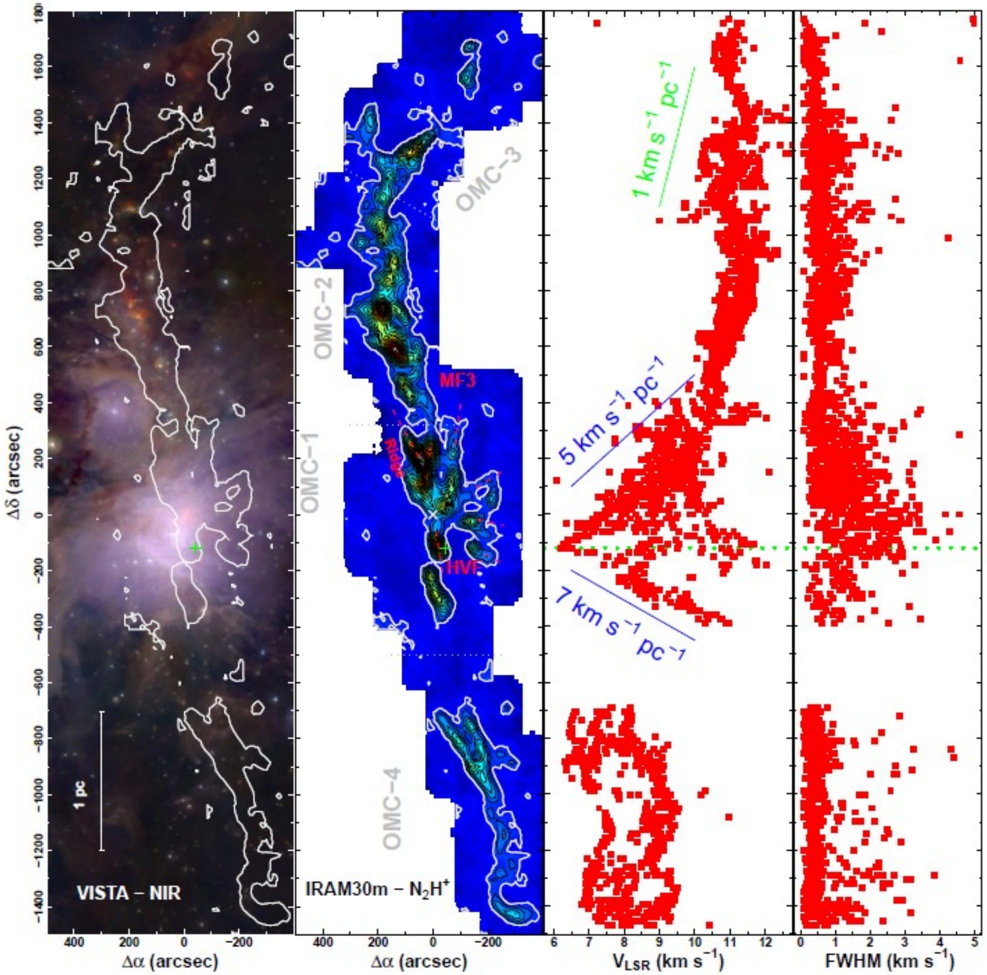
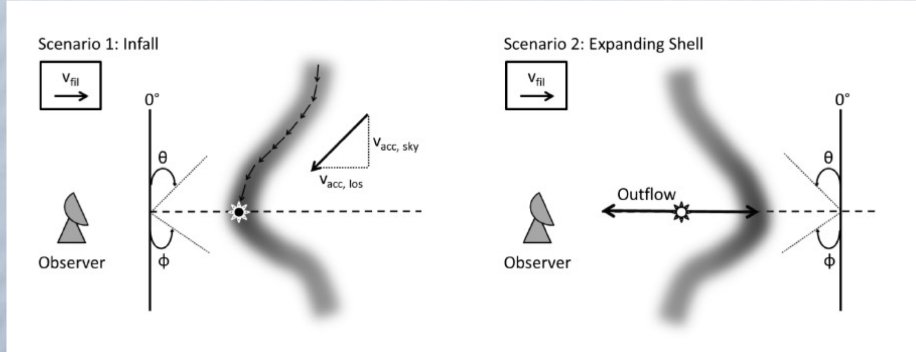
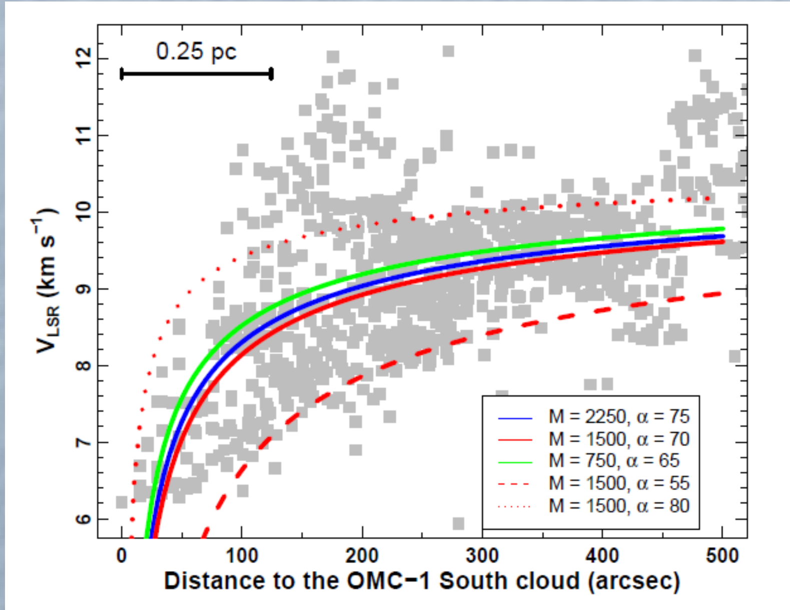


Fig. 1. From left to right: (a) VISTA-NIR image of the ISF (Meingast et al. 2016); (b) IRAM30m integrated N_2H^+ (1-0) emission; (c) N_2H^+ line velocity centroid (V_{LSR}) and (d) N_2H^+ Full-Width-Half-Maximum (FWHM) as a function of declination. Map offsets are referred, in radio projection, to the position of the Orion BN source $(\alpha,\delta)_{J2000} = (05^h35^m14^s.2, -05°22'21'')$ (white cross). N_2H^+ contours are equally spaced every 2 K km s^{-1}. For reference, the first N_2H^+ contour is superposed to the IR image. The location of the most prominent molecular fingers (e.g., the OMC-1 ridge, MF3, and HVF; Rodriguez-Franco et al. 1992) are indicated by red lines in the integrated intensity map. The magnitude of representative gradients with 1 (green) plus 5, and 7 (blue) km s^{-1} pc^{-1} are indicated in the velocity plot. The position of the OMC-1 South clump with the most blue-shifted velocity is indicated in both maps (green cross) and kinematic plots (green dashed line).

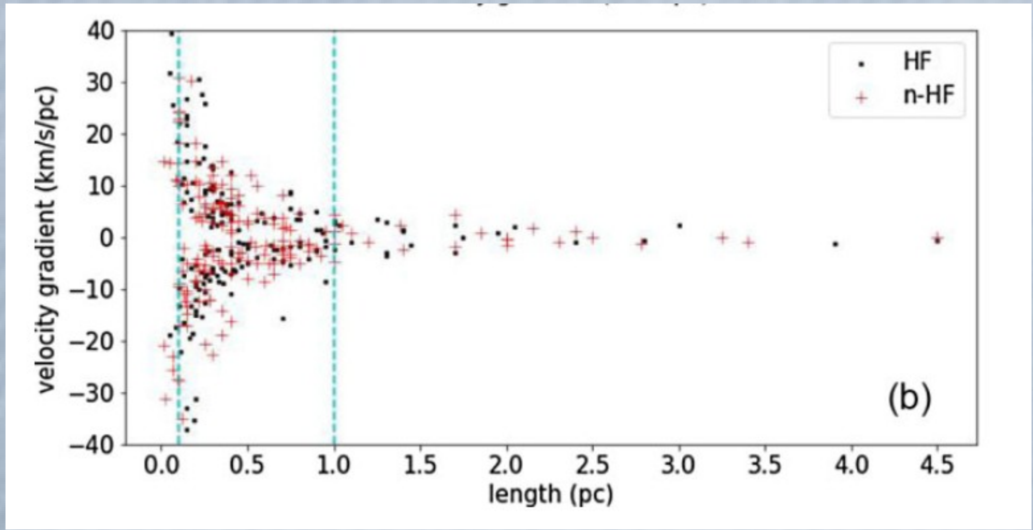


Henshaw et al. 2014

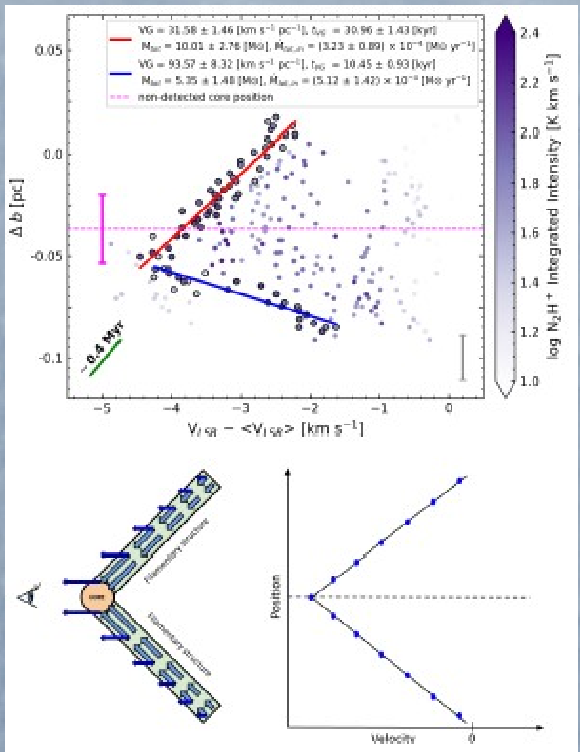


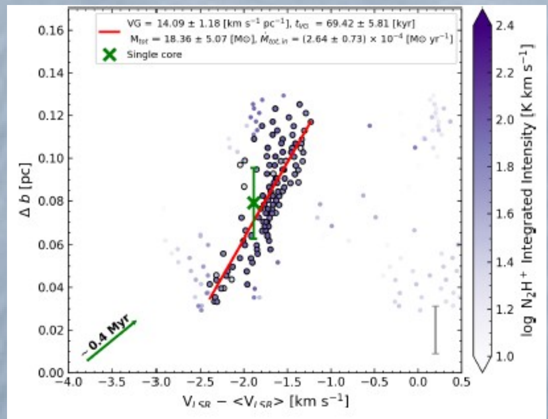
$$V_{LSR}(p) = V_{sys,0} + V_{infall}(p) \cdot cos(\alpha)$$

$$V_{infall}(p) = -\sqrt{\frac{2GM}{R}} = -\sqrt{\frac{2GM}{p\ /sin\alpha}}$$

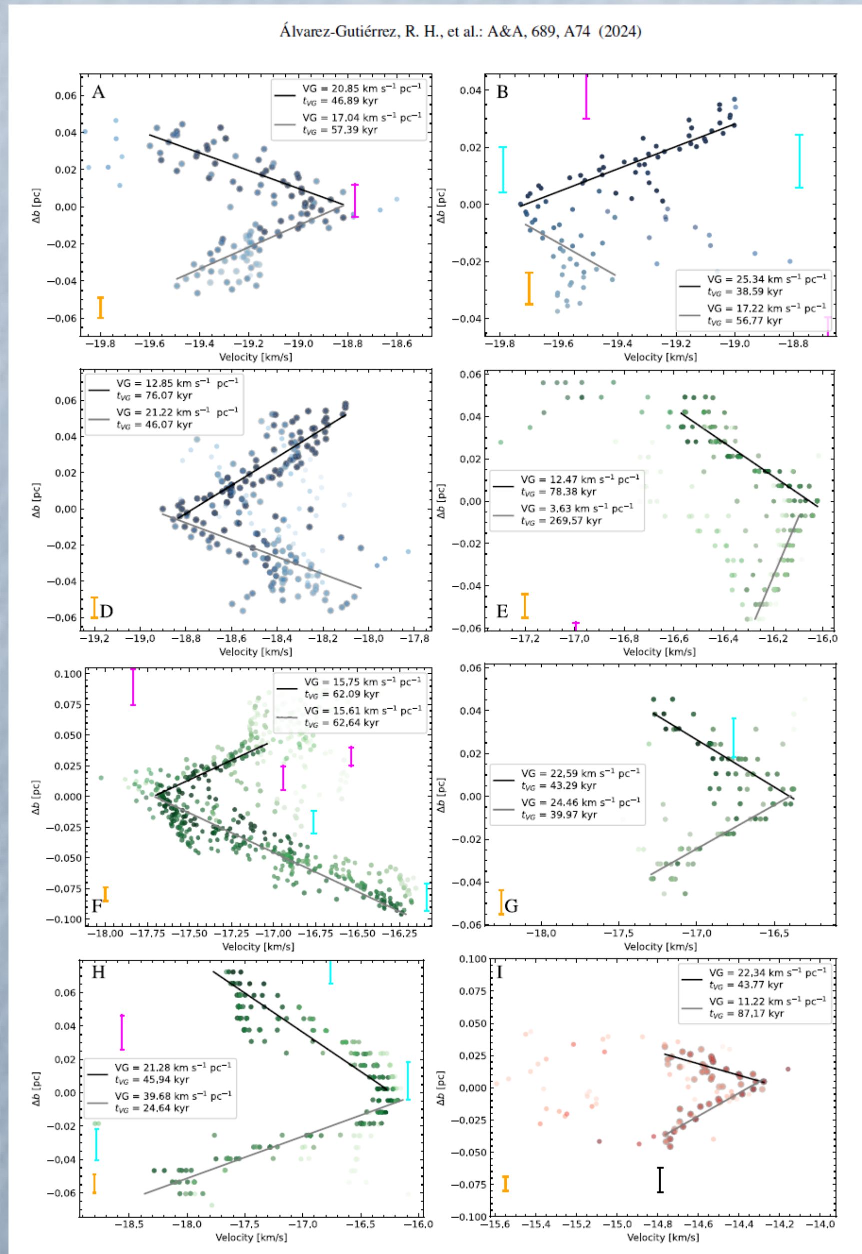


Zhou et al. 2022





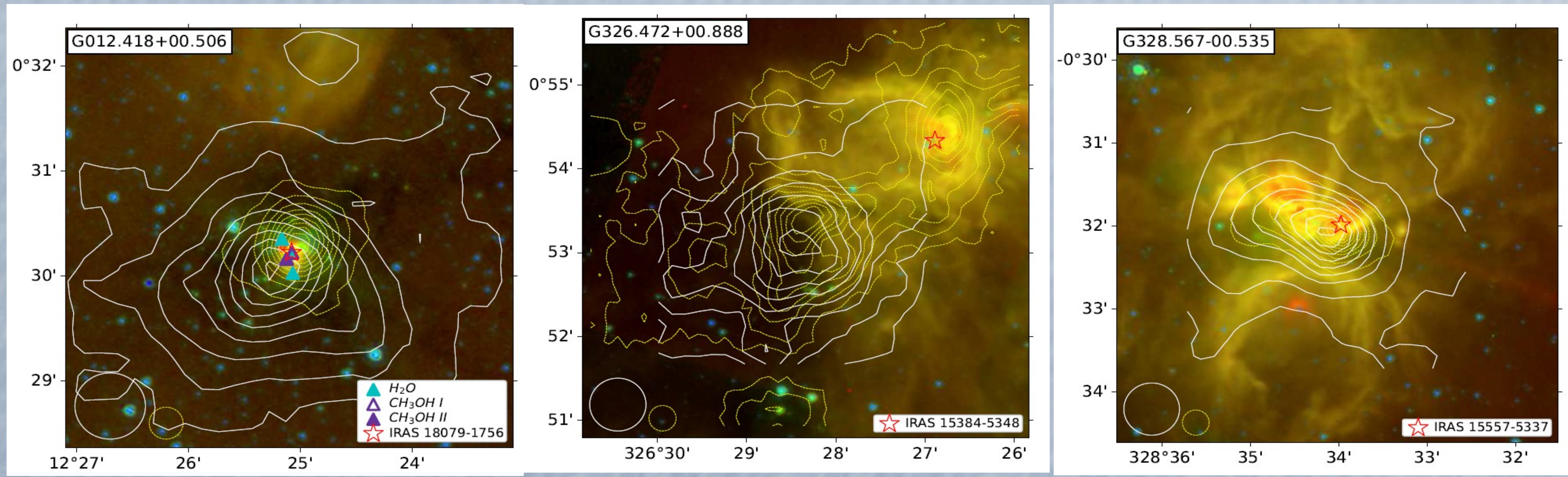
G351.77
Sandoval-Garrido et al.
(2024)

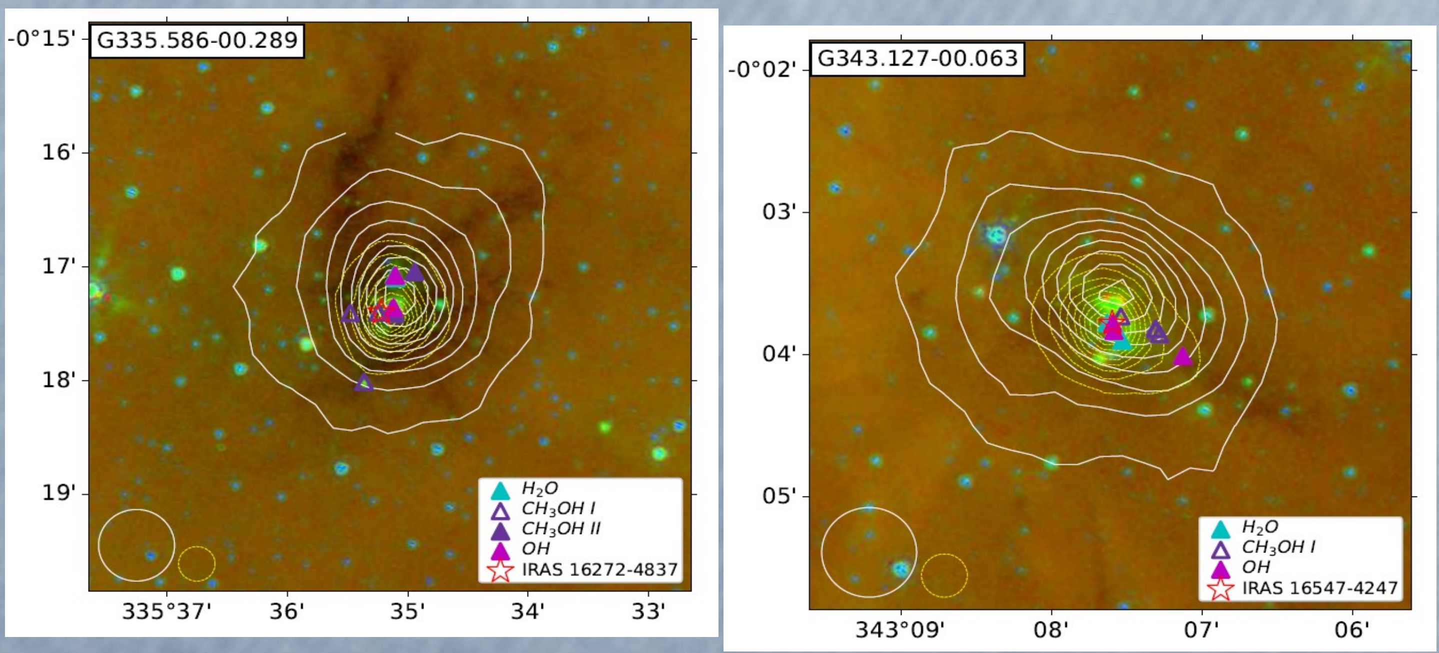


G353.41
Alvarez-Gutierrez et al. (2024)

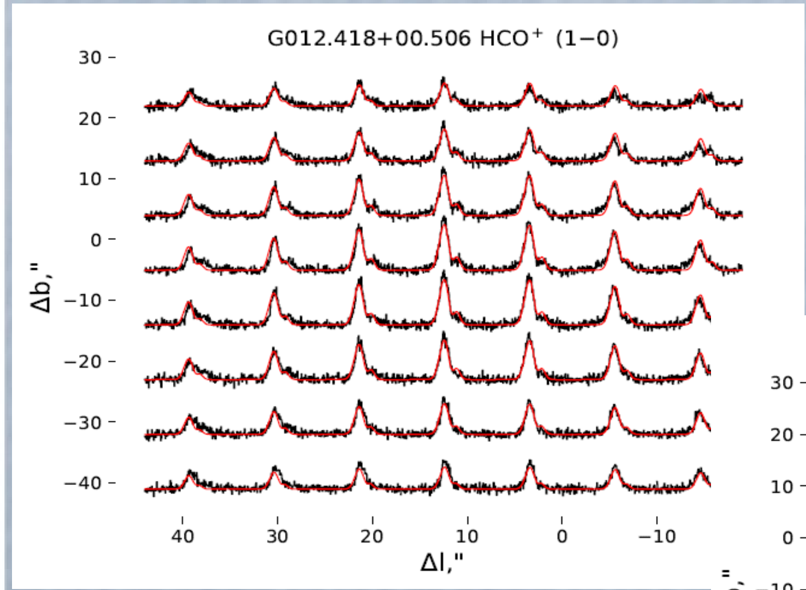
Анализ данных наблюдений массивных ядер MALT90

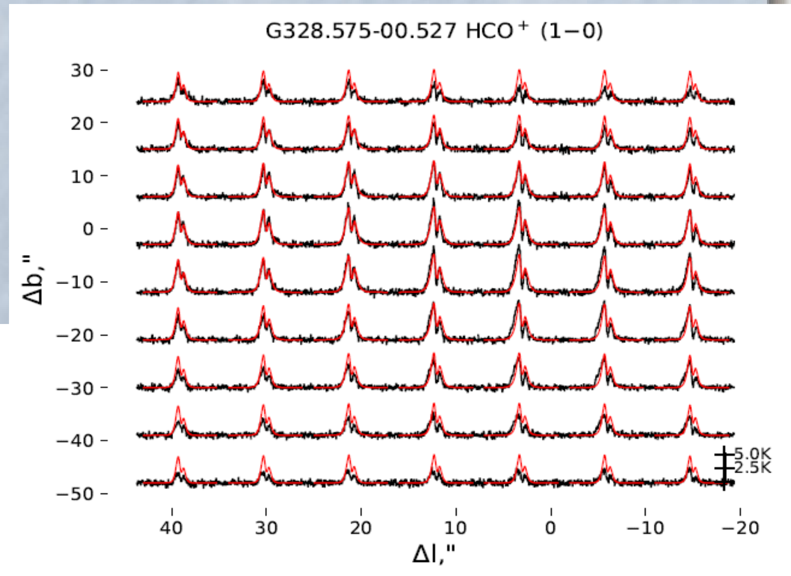
Массивные ядра с признаками сжатия
Spitzer (фон), ATLASGAL и HCO+(1-0) (MALT90) (контуры)

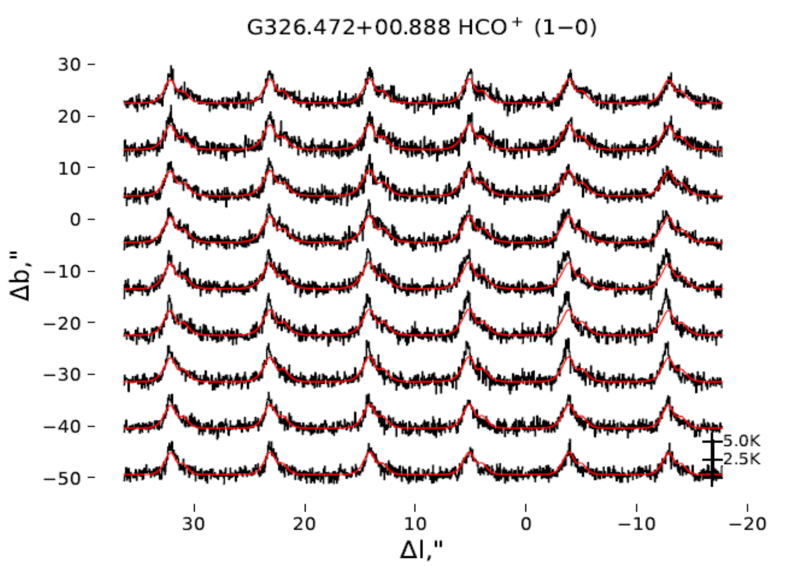


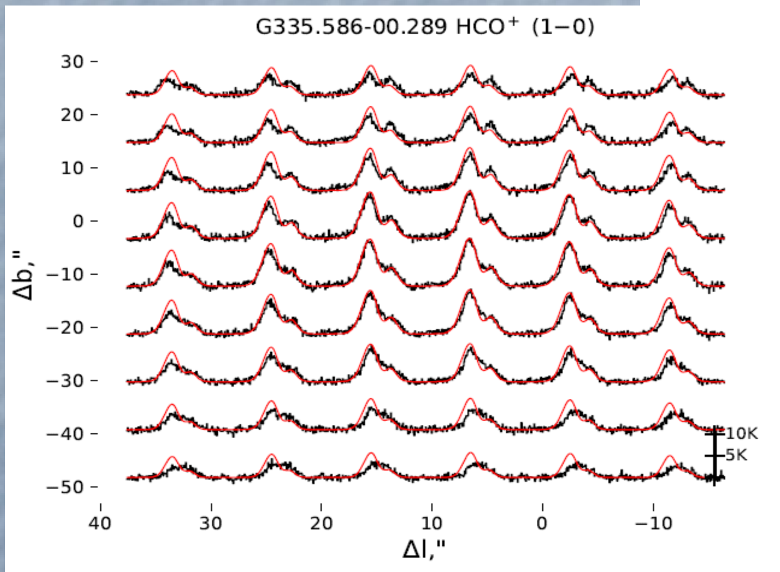


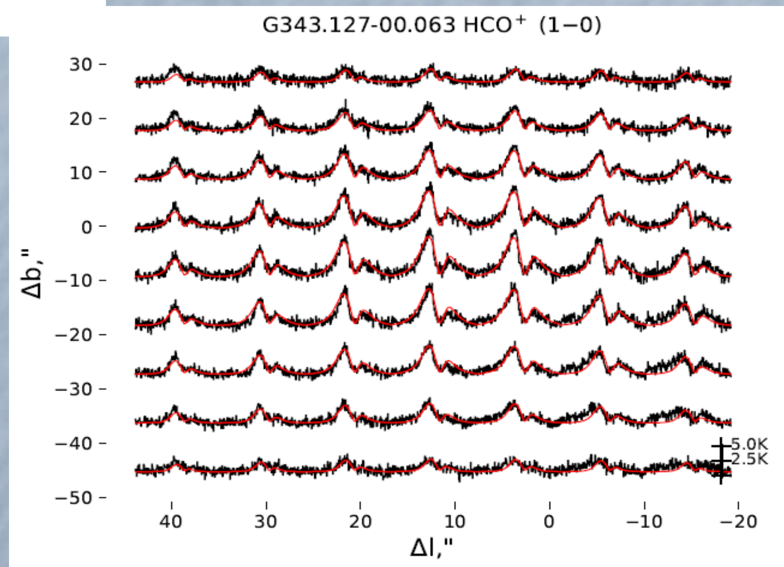
Pirogov et al. (2024)

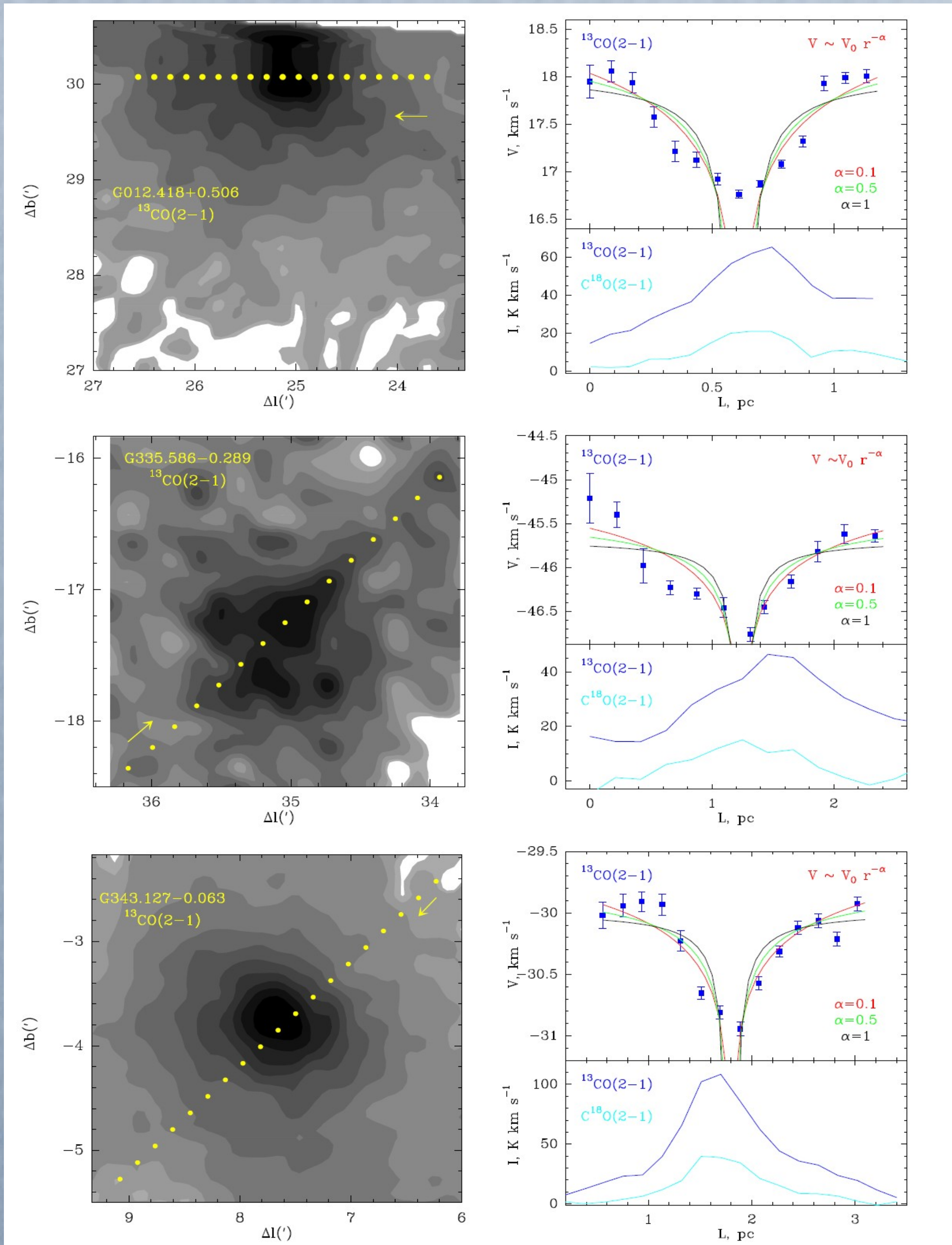

G012.418+00.506 HCO$^+$ (1−0)
Δb,"
Δl,"


G328.575-00.527 HCO$^+$ (1−0)
Δb,"
Δl,"
5.0K
2.5K


G326.472+00.888 HCO$^+$ (1−0)
Δb,"
Δl,"
5.0K
2.5K


G335.586-00.289 HCO$^+$ (1−0)
Δb,"
Δl,"
10K
5K

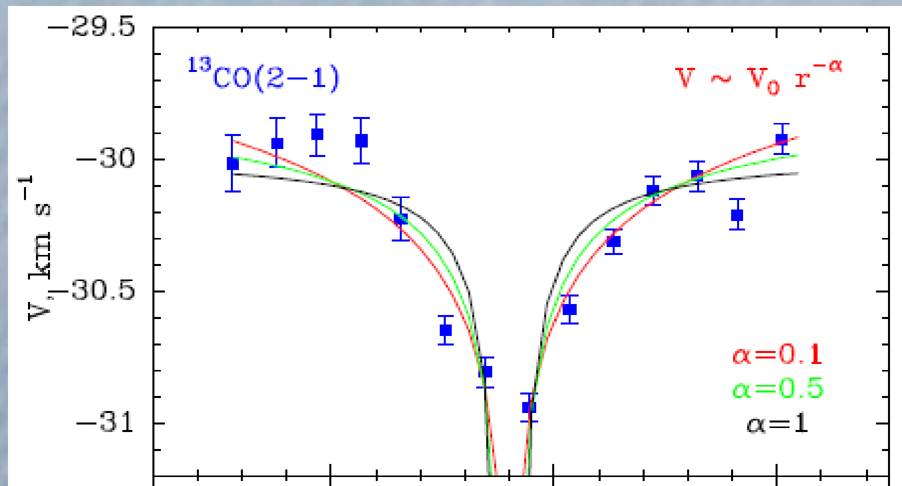

G343.127-00.063 HCO$^+$ (1−0)
Δb,"
Δl,"
5.0K
2.5K

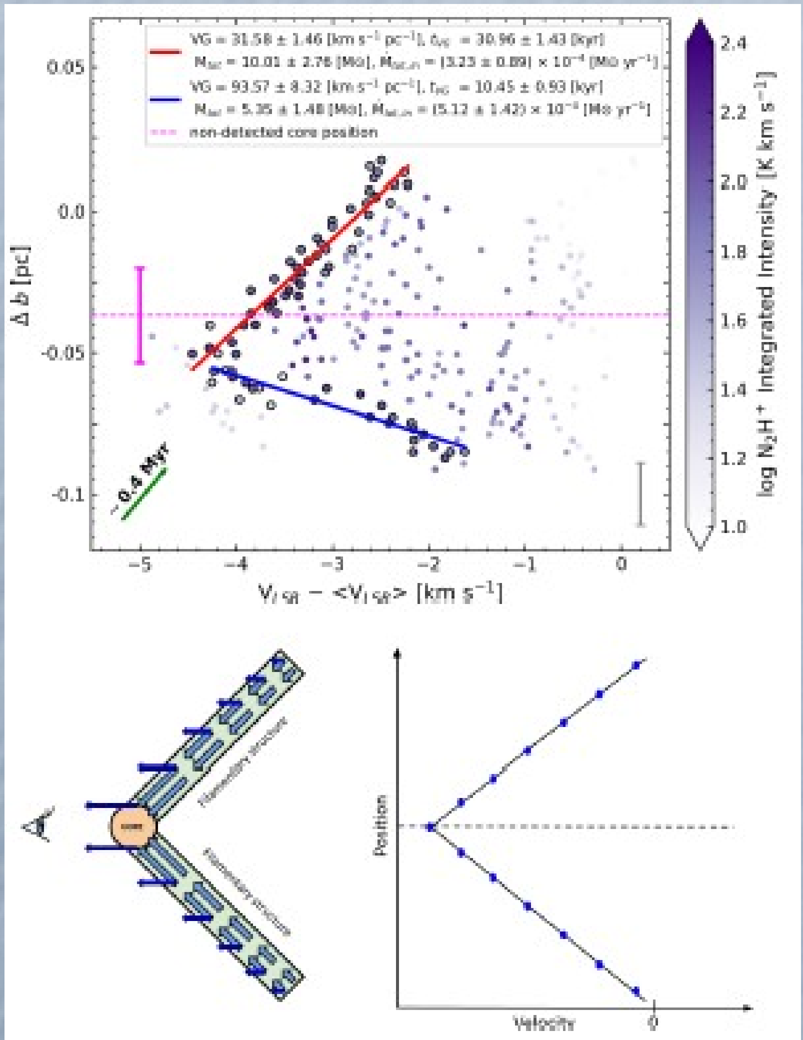


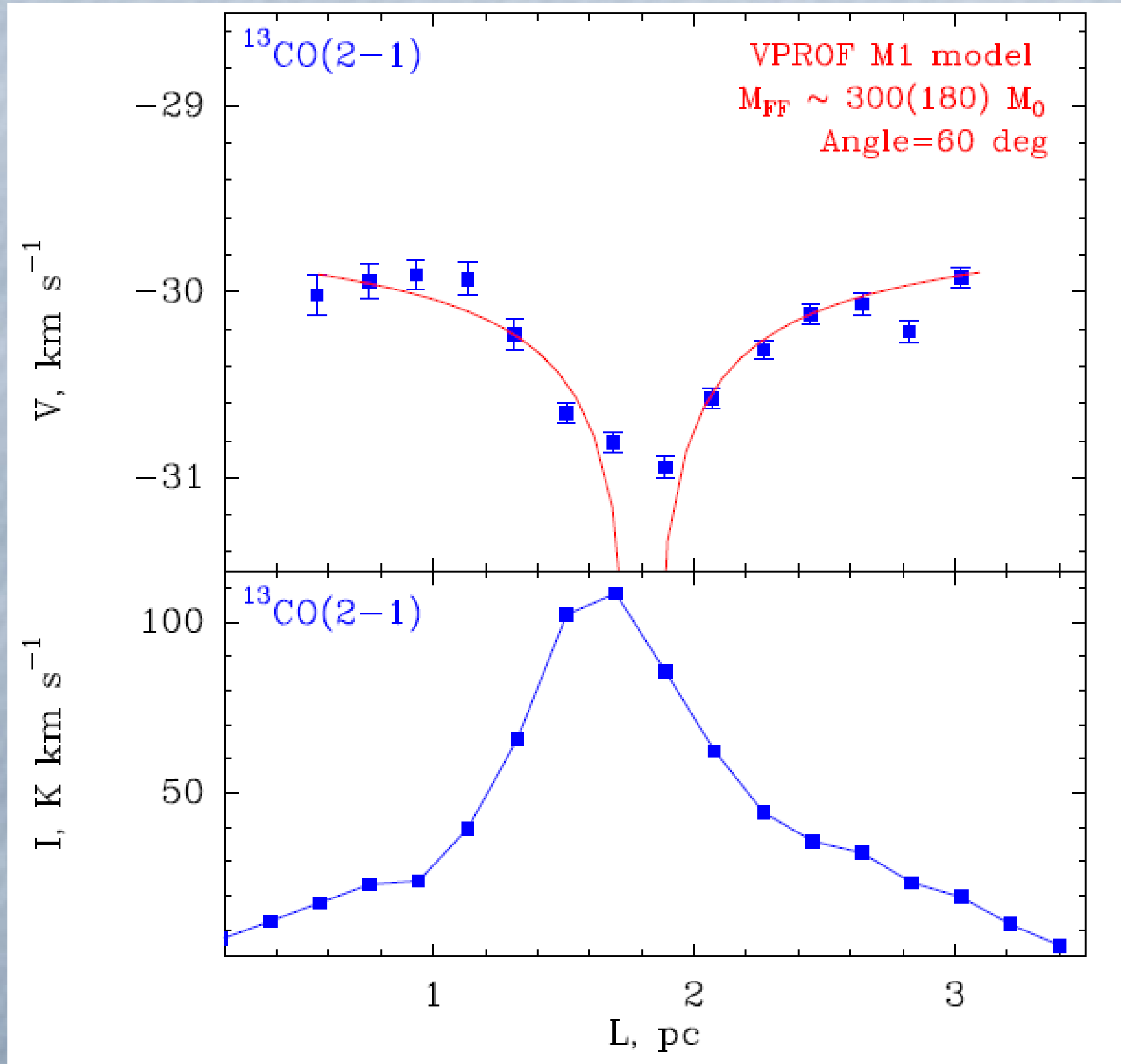
Профили скорости ^{13}CO(2-1)
(SEDIGISM, Schuller et al. 2021)

Модель

$$V = V_{LSR} + V_0\,(L/\sin A)^{-\alpha}\cos A$$







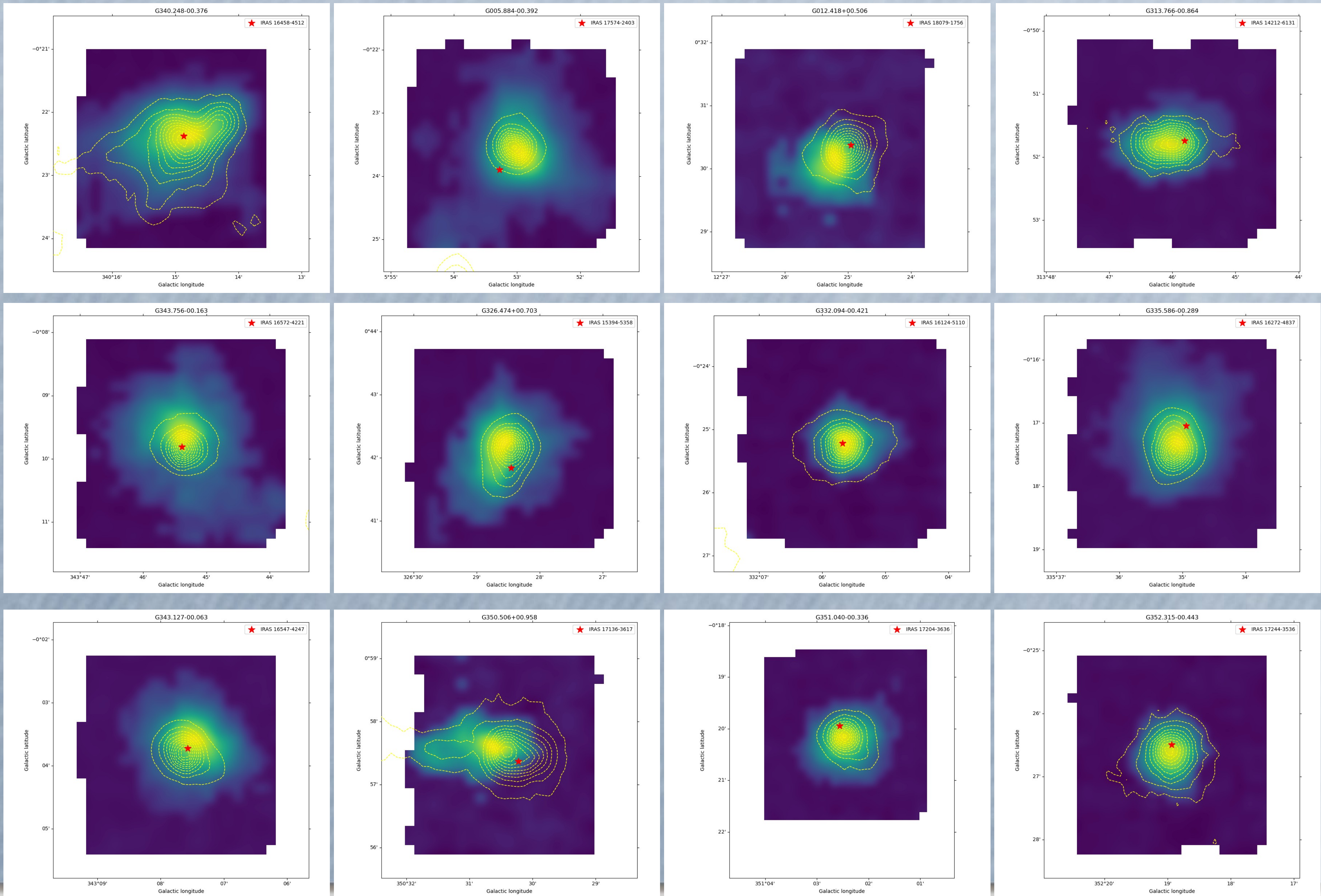
$$V_{LSR}(p) = V_{sys,0} + V_{infall}(p) \cdot cos(\alpha)$$

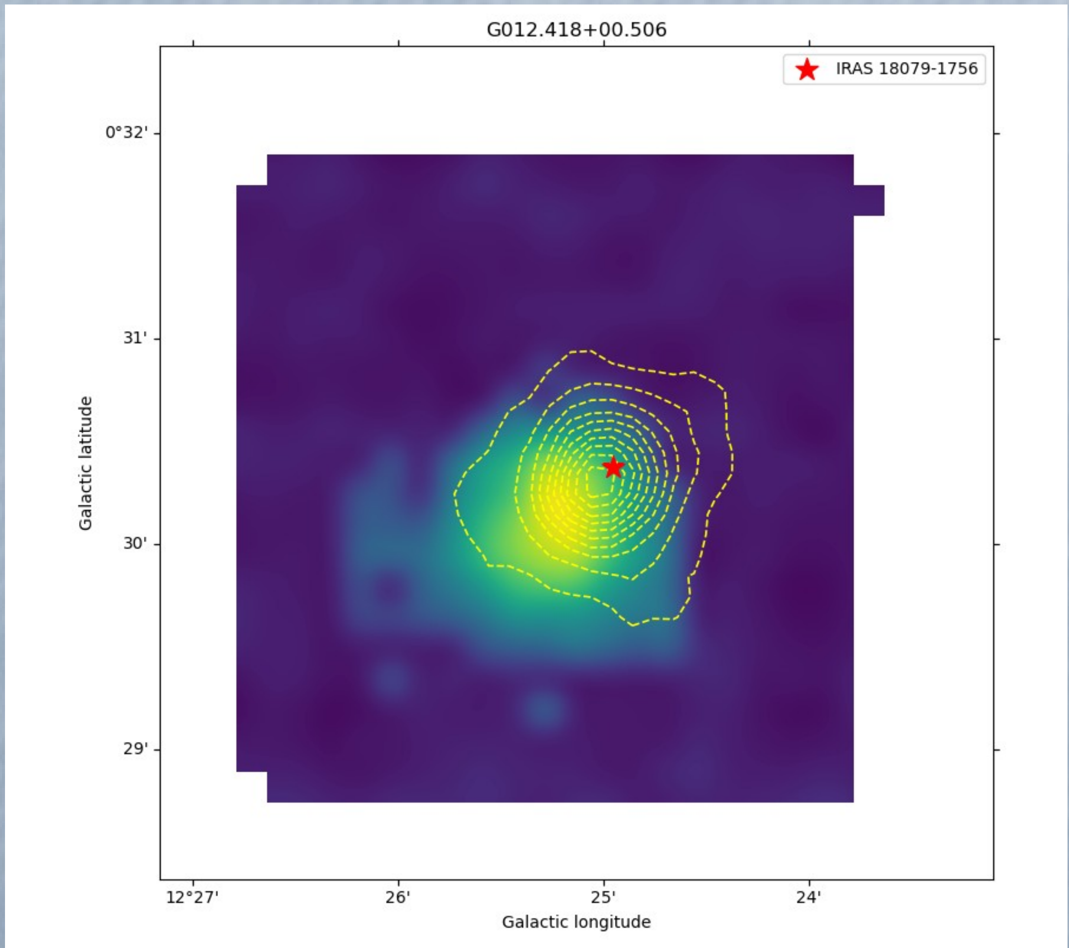
$$V_{infall}(p) = -\sqrt{\frac{2GM}{R}} = -\sqrt{\frac{2GM}{p\ /sin\alpha}}$$

Выборка ядер MALT90 (Ta* ≥ 2 K N_2H^+(1-0))

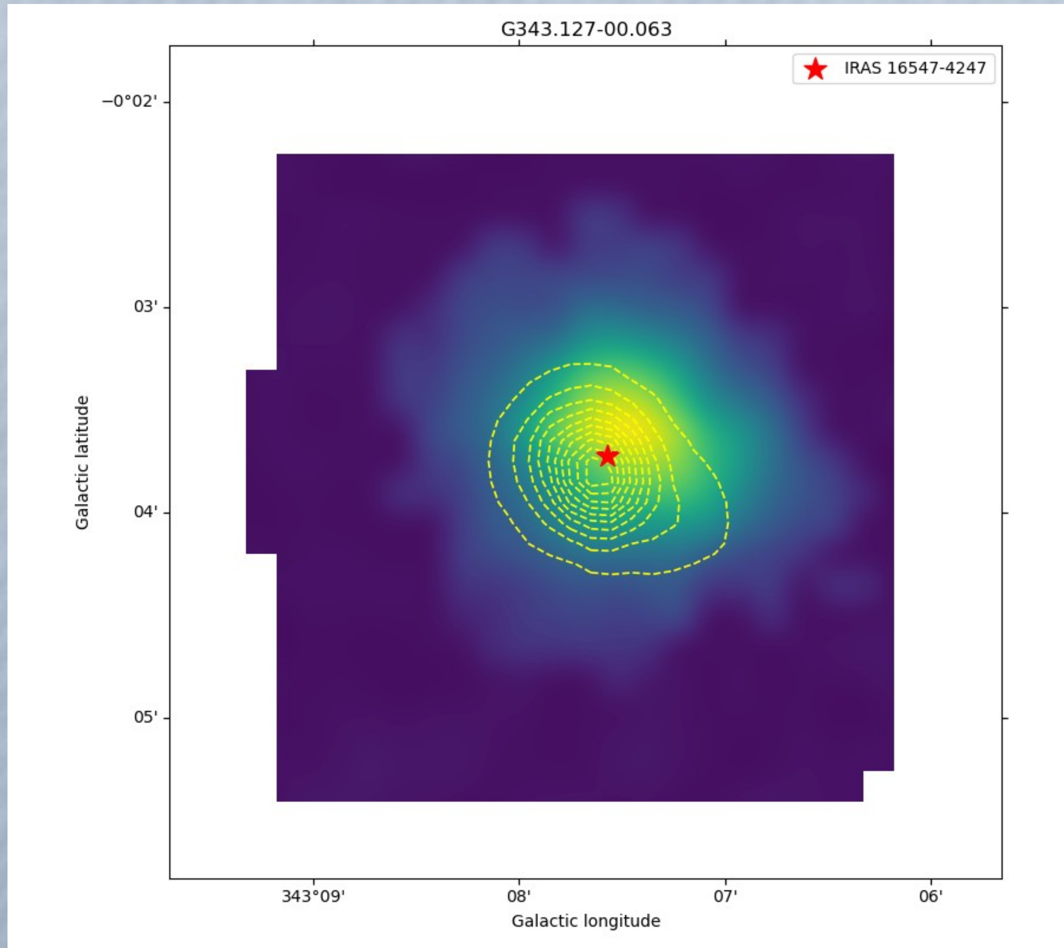
G000.090–00.664	G305.270–00.009	G335.790+00.174	G345.487+00.315
G000.320–00.200	G313.766–00.864	G336.019–00.813	G345.504+00.349
G000.547–00.855	G314.219+00.272	G337.439–00.399	G348.171+00.465
G000.594–00.872	G316.769–00.025	G337.916–00.477	G348.698–01.033
G005.884–00.392	G316.798–00.058	G337.933–00.506	G348.727–01.038
G005.898–00.444	G318.948–00.196	G337.937–00.533	G348.754–00.941
G009.877–00.748	G320.169+00.824	G338.924+00.553	G350.101+00.083
G010.225–00.207	G320.247+00.403	G338.927+00.632	G350.506+00.958
G010.286–00.125	G322.159+00.635	G339.584–00.128	G351.040–00.336
G010.342–00.142	G326.407+00.927	G340.248–00.376	G351.157+00.701
G012.418+00.506	G326.472+00.888	G340.256–00.226	G351.179+00.634
G012.777–00.210	G326.641+00.613	G340.722–00.989	G351.227+00.692
G012.790–00.197	G326.671+00.554	G340.747–01.002	G351.416+00.648
G012.808–00.198	G327.272–00.574	G340.787–01.018	G351.443+00.659
G012.831–00.209	G328.235–00.547	G340.969–01.022	G351.463+00.681
G012.853–00.226	G330.876–00.384	G341.266–00.301	G351.500+00.646
G012.879–00.287	G332.094–00.421	G343.127–00.063	G351.775–00.537
G012.894–00.281	G332.240–00.043	G343.478–00.023	G352.315–00.443
G012.908–00.258	G332.986–00.492	G343.492–00.068	G353.054+00.683
G014.194–00.194	G333.016+00.765	G343.500+00.026	G353.068+00.510
G014.331–00.644	G333.067–00.446	G343.503–00.015	G353.411-00.361
G014.631–00.575	G333.295–00.352	G343.726–00.182	G353.463+00.563
G018.876–00.489	G333.313–00.370	G343.756–00.163	G359.598–00.225
G300.969+01.145	G335.586–00.289	G345.338+01.021	

Компактные ядра из выборки. N_2H^+(1-0) (цвет), 870 мкм (контуры)



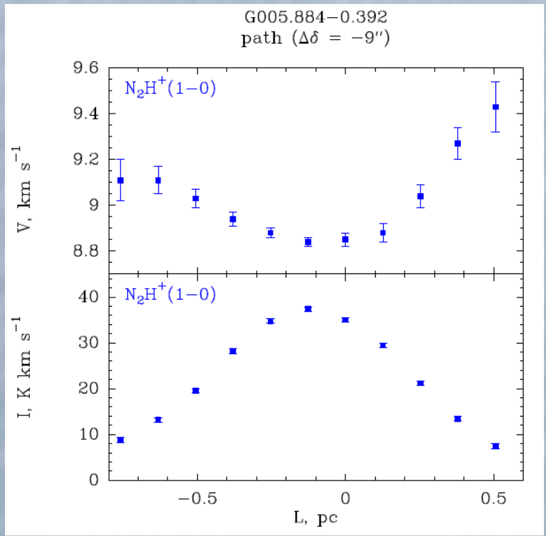


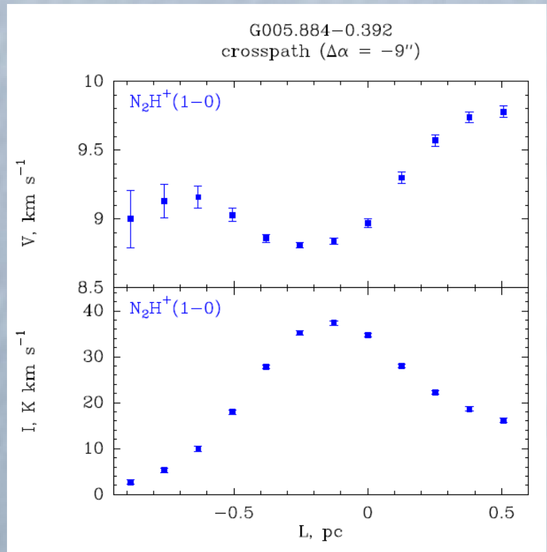
G012.418+00.506
IRAS 18079-1756
0°32'
31'
30'
29'
Galactic latitude
12°27'
26'
25'
24'
Galactic longitude

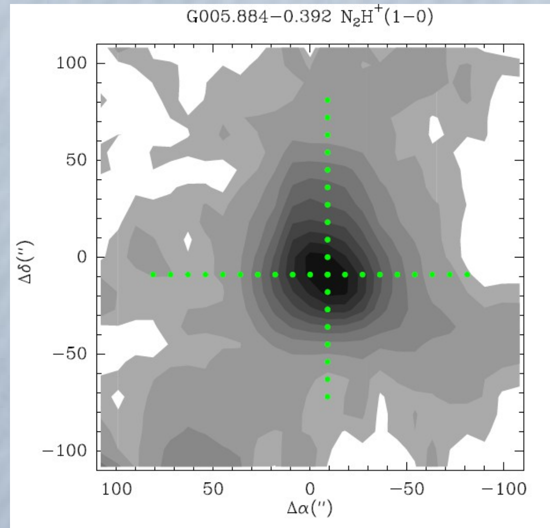


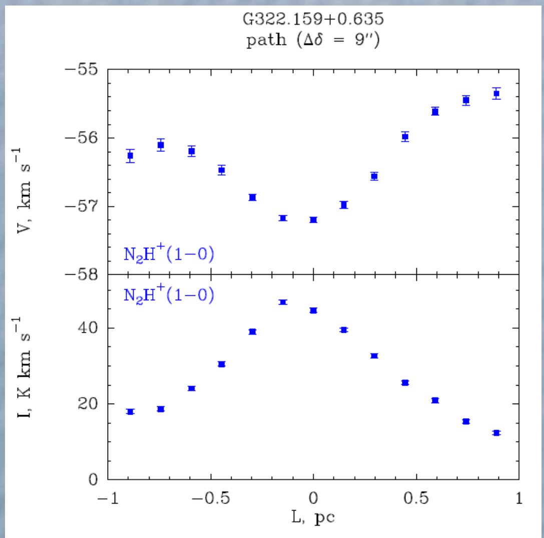
G343.127-00.063
IRAS 16547-4247
−0°02'
03'
04'
05'
Galactic latitude
343°09'
08'
07'
06'
Galactic longitude

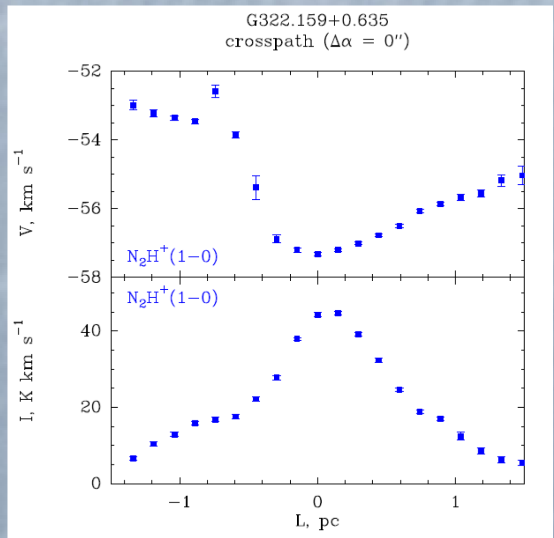
Профили скоростей V типа

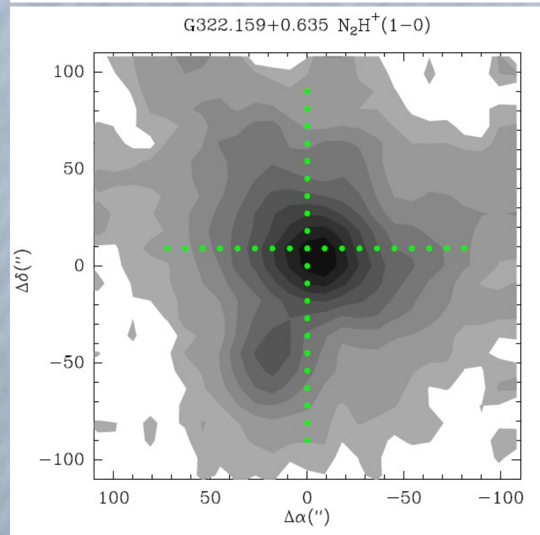




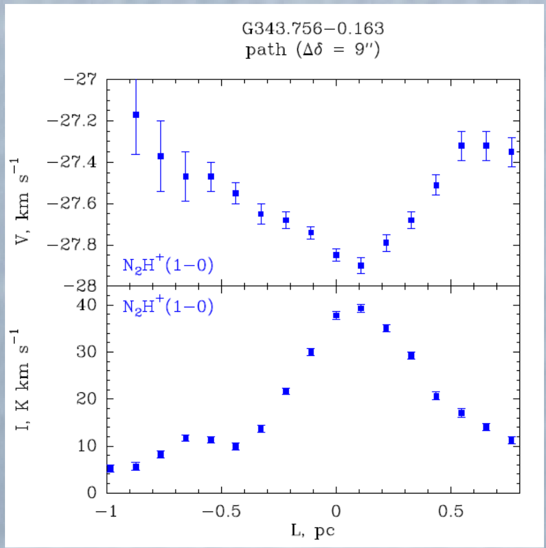


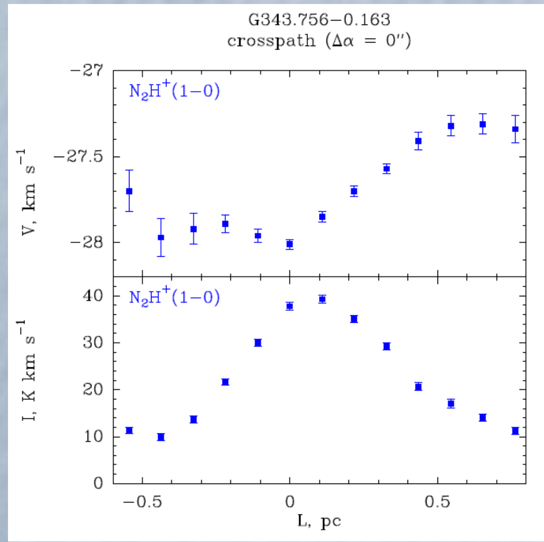


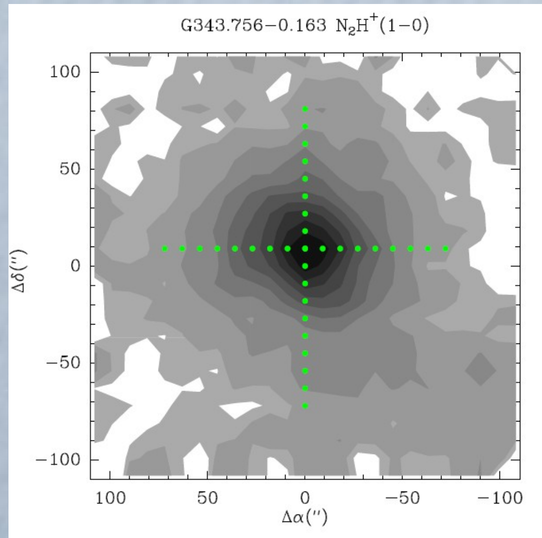


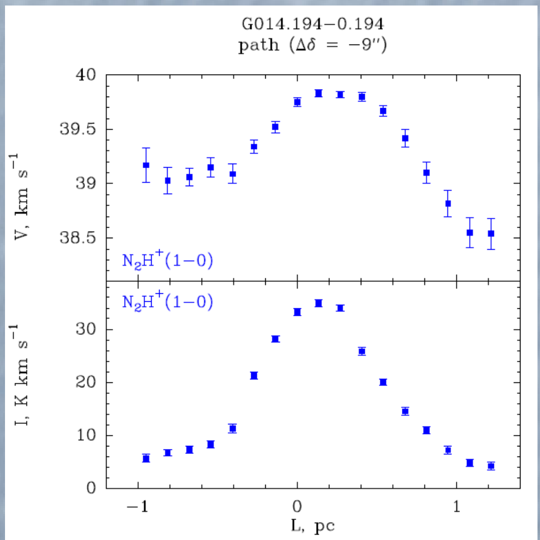


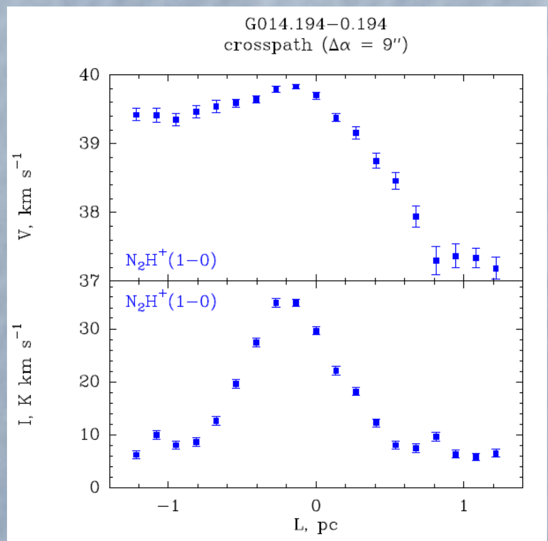
Профили скоростей \/ и /\ типов с асимметрией

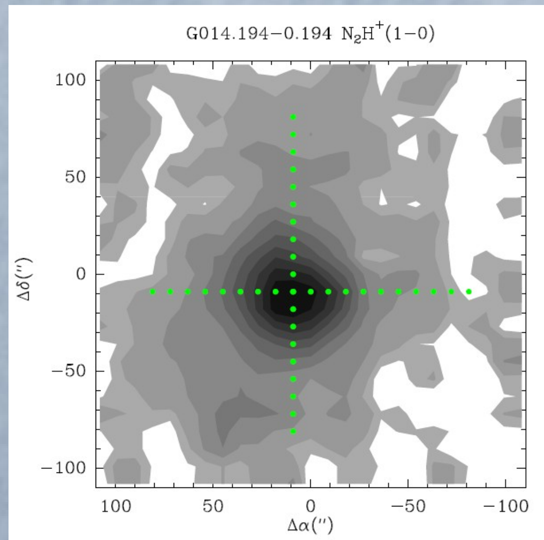




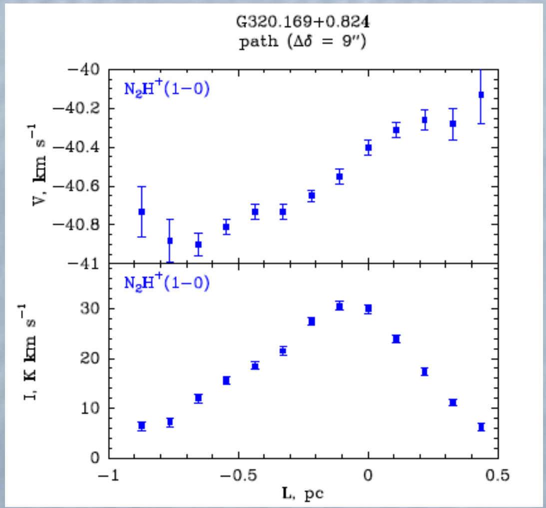


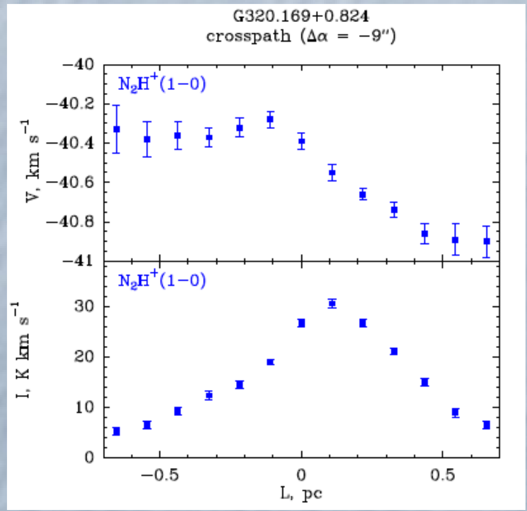


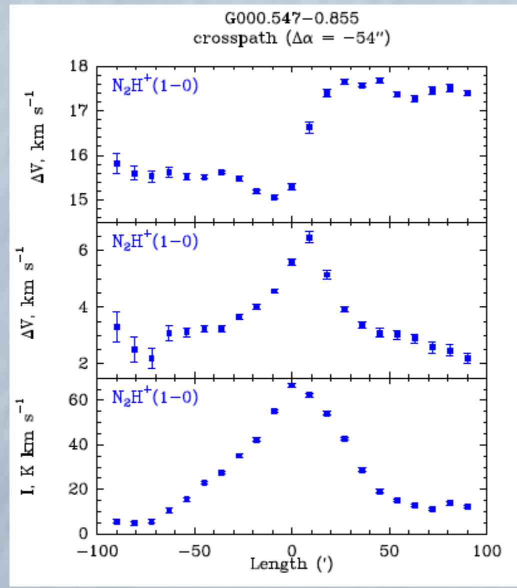




Иные типы профилей скорости

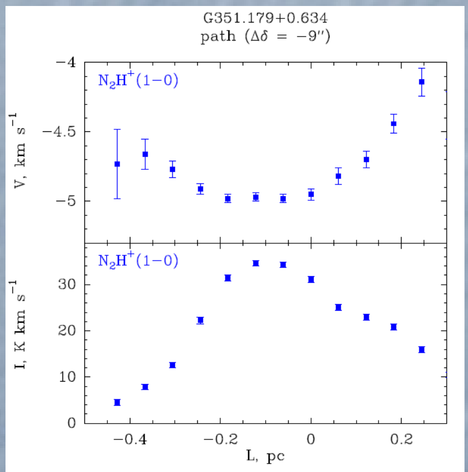


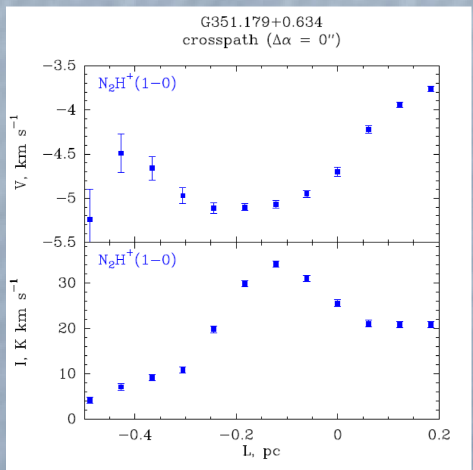


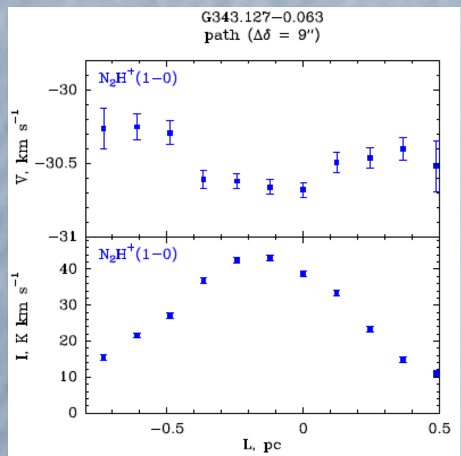


С линейными участками (I)

Step-like







Плоские (F)

плоские участки в центре

Object	Distance (kpc)	Evolutionary status	T_{dust} (K)	log Mass ($M_{\odot}$)	Velocity profile type (Flat/Inclined/Λ/V/other) (gradient, km/s/pc)
G005.884-00.392	2.9	YSO	34.5	2.6	V (∼ 0.6) asym
G005.898–00.444	2.9	Complicated	28	2.7	FI V (∼ 3 – 2.5)
G009.877–00.748	3.0	HII	22.3	2.8	V (∼ 0.6) I
G010.225–00.207	3.1	YSO	17.8	2.5	I V (∼ 0.5)
G012.418+00.506	1.8	HII	25.6	2.2	II
G012.908–00.258	3.1	YSO	23.6	2.7	FI Λ (∼ 0.6)
G014.194–00.194	3.1	Protostellar	16.1	2.7	Λ (∼ 1) step
G014.331–00.644	1.9	Quiescent	10.6	2.2	I I sinus
G014.631–00.575	1.9	PDR	19.1	2.2	V (∼ 1.4) sinus
G018.876–00.489	5.0	Ambiguous	19.3	2.5	F I
G300.969+01.145	3.2	HII	44.6	2.5	V (∼ 0.6) F
G305.270–00.009	6.9	HII	25.9	3.0	I
G313.766–00.864	3.4	YSO	21.8	2.7	I F
G314.219+00.272	7.3	HII	25.4	3.1	∼ F Λ (∼ 0.3)
G318.948–00.196	2.1	HII	26.6	2.1	I I
G320.169+00.824	2.5	PDR	24.2	2.8	I I
G320.247+00.403	2.1	YSO	21.2	2.3	IF F
G322.159+00.635	3.4	Ambiduous	29.4	3.0	V (∼ 2 on average)
G326.407+00.927	2.6	YSO	21.8	2.1	I I
G326.472+00.888	2.5	PDR	22.9	2.6	F Λ (∼ 1)
G327.272–00.574	2.8	HII	27.1	2.5	V Λ (∼ 0.1 – 2)
G330.876–00.384	4.0	HII	26	2.9	V (∼ 0.1 – 2)
G332.094–00.421	3.5	HII	28.4	2.5	F F
G332.240–00.043	3.1	YSO	17	2.5	∼ F Λ weak
G332.986–00.492	3.5	YSO			Λ asym I
G335.586–00.289	3.2	YSO	23.1	2.6	IF V (∼ 1)
G335.790+00.174	3.3	Ambiguous	16.1	1.9	FI

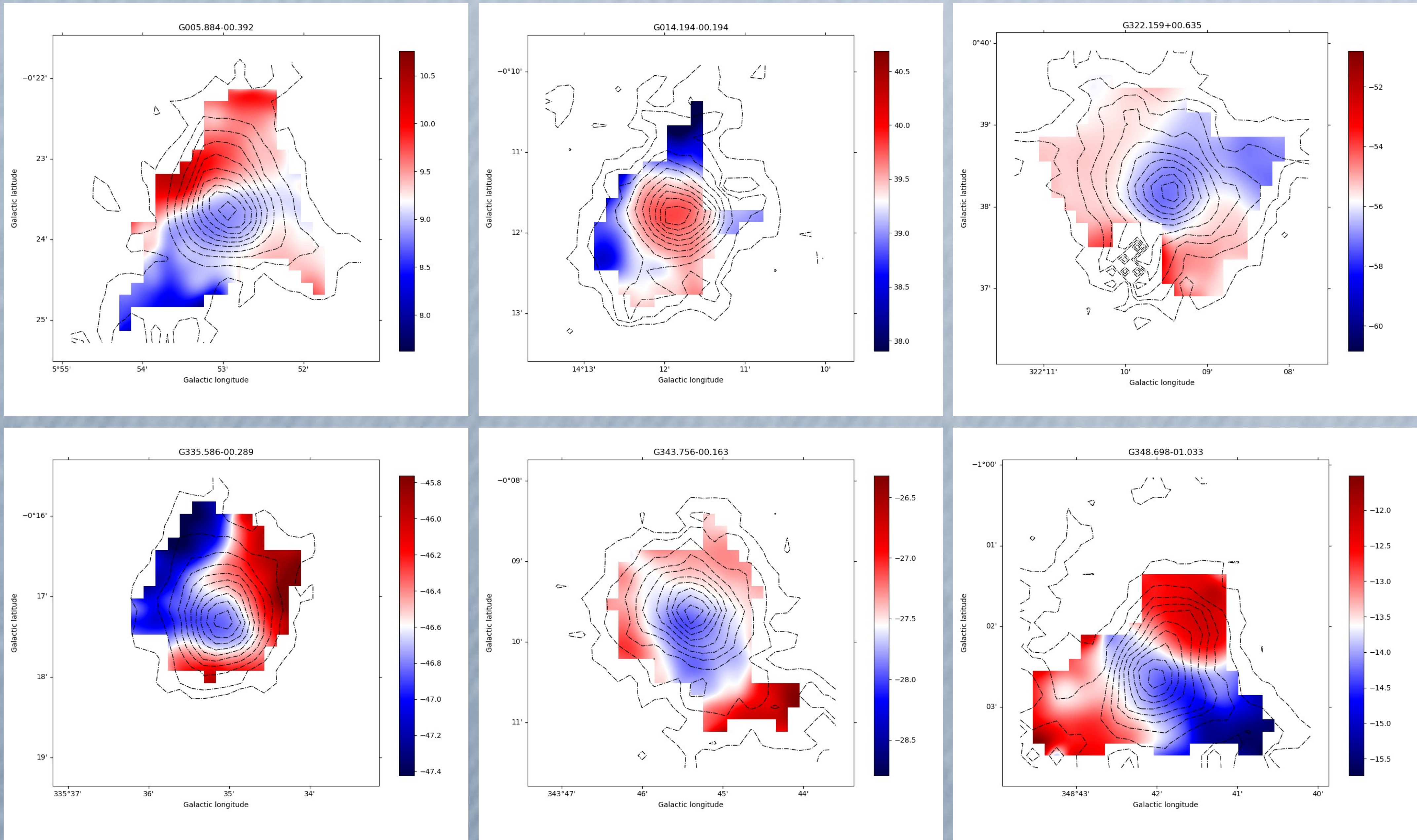
Distances, temperatures, masses from Urquhart et al. (2022)

В большинстве ядер обнаружены градиенты скоростей, указывающие на наличие асимметричных потоков газа, вероятно связанных с пересекающимися волокнами, расположенными под различными углами к наблюдателю.

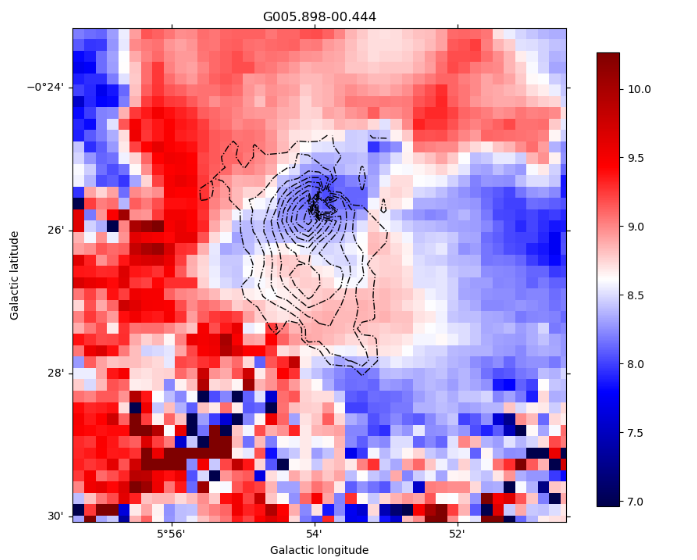
Во многих случаях наблюдаются потоки, направленные к центру ядер (\/ или /\ типов). Градиенты скоростей в большинстве из них различны по величине в различных направлениях.

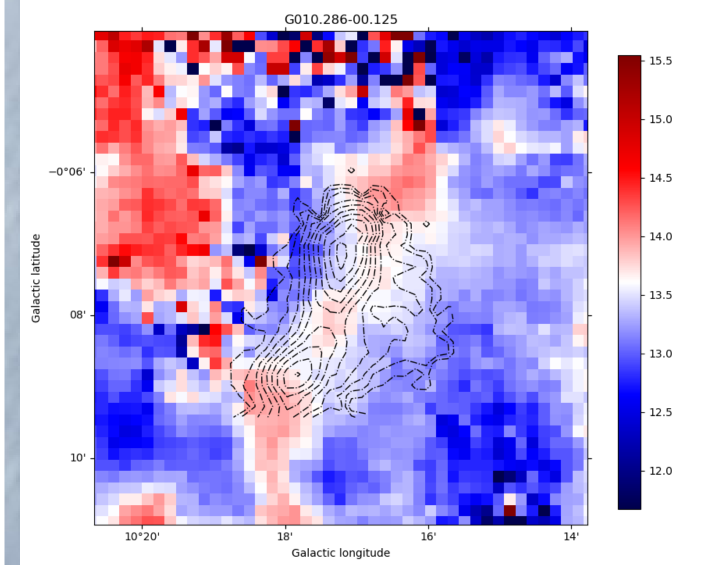
Диапазон величин градиентов скоростей для \/ или /\ типов профилей составляет: ~ 0.1 — 3 км/с/пк

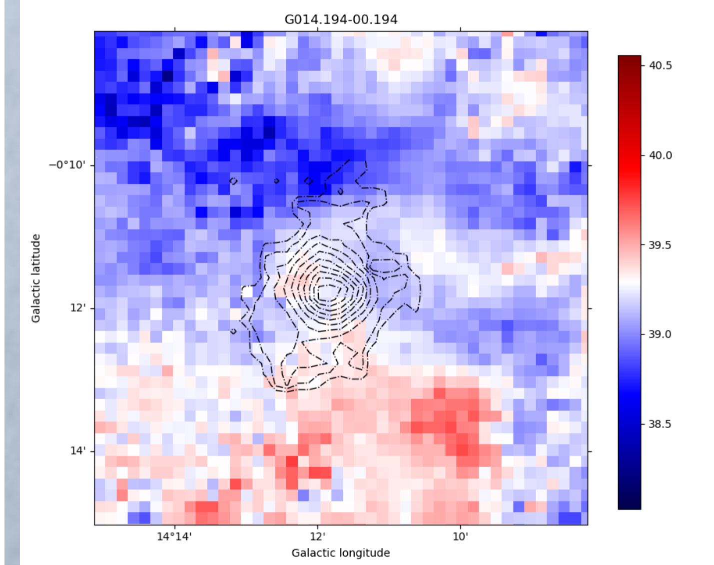
Карты скоростей N_2H^+(1-0) отдельных ядер

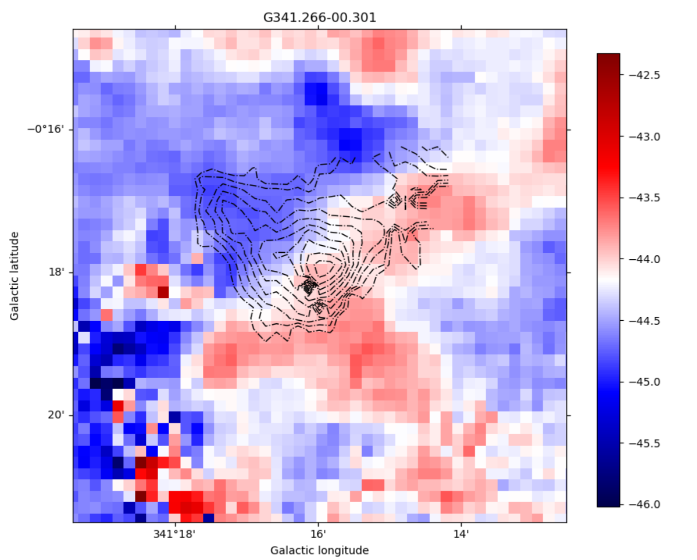


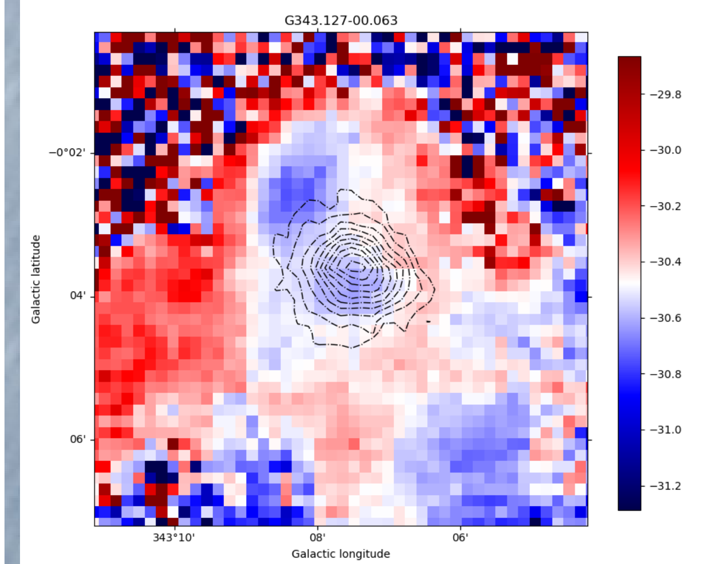
Карты скоростей в окружающем газе по данным $^{13}CO(2-1)$ (SEDIGISM)

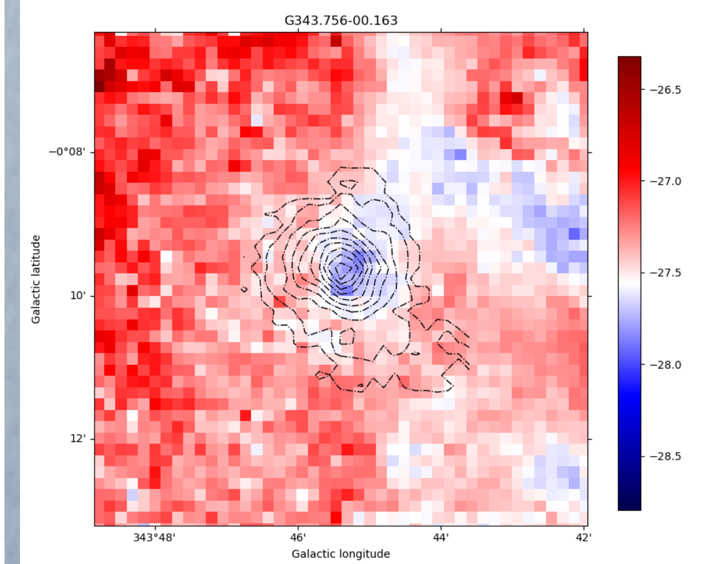




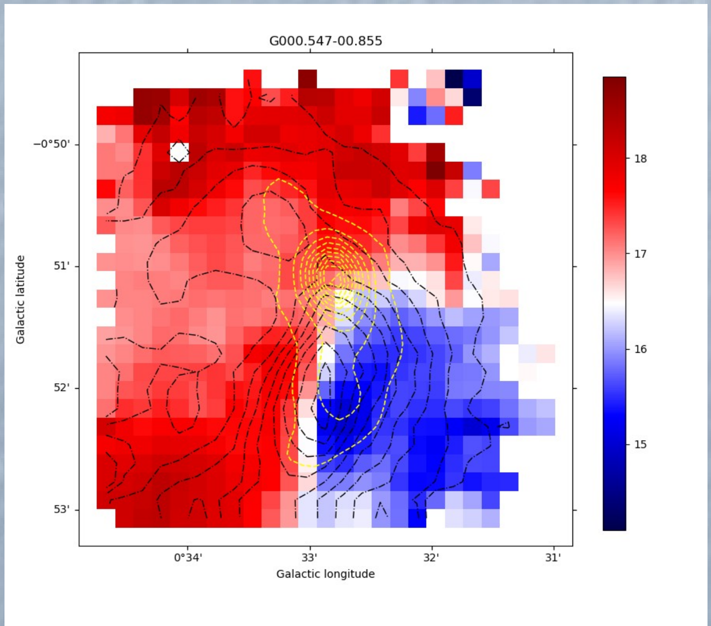


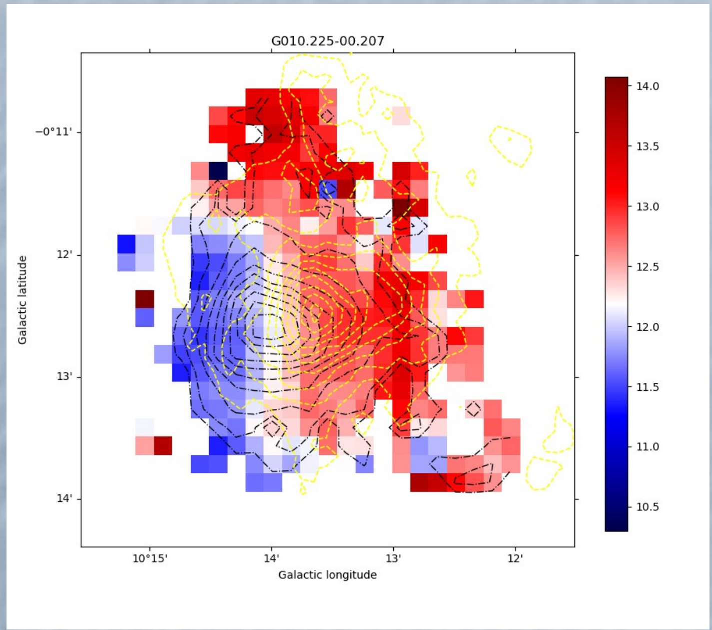


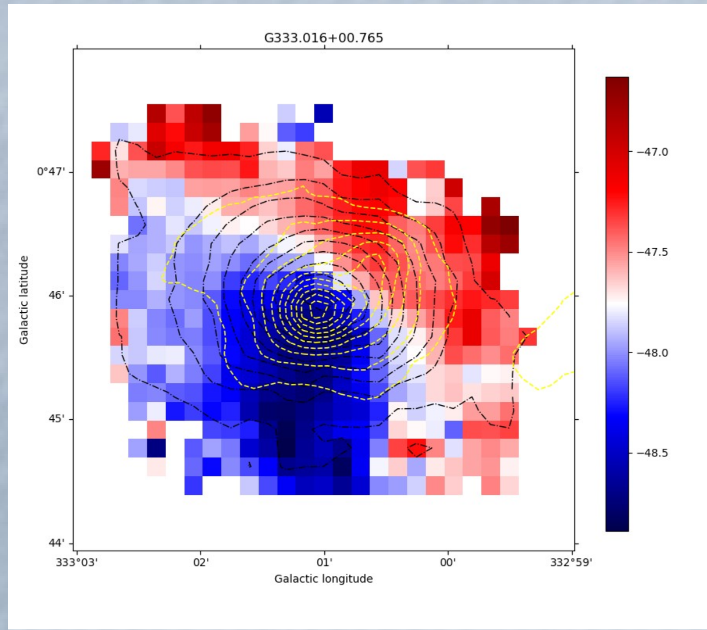




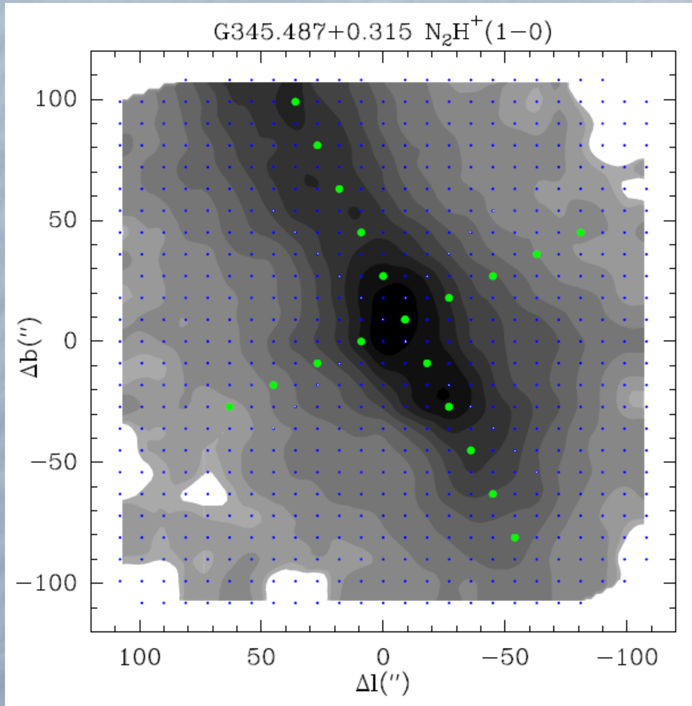
Вращение

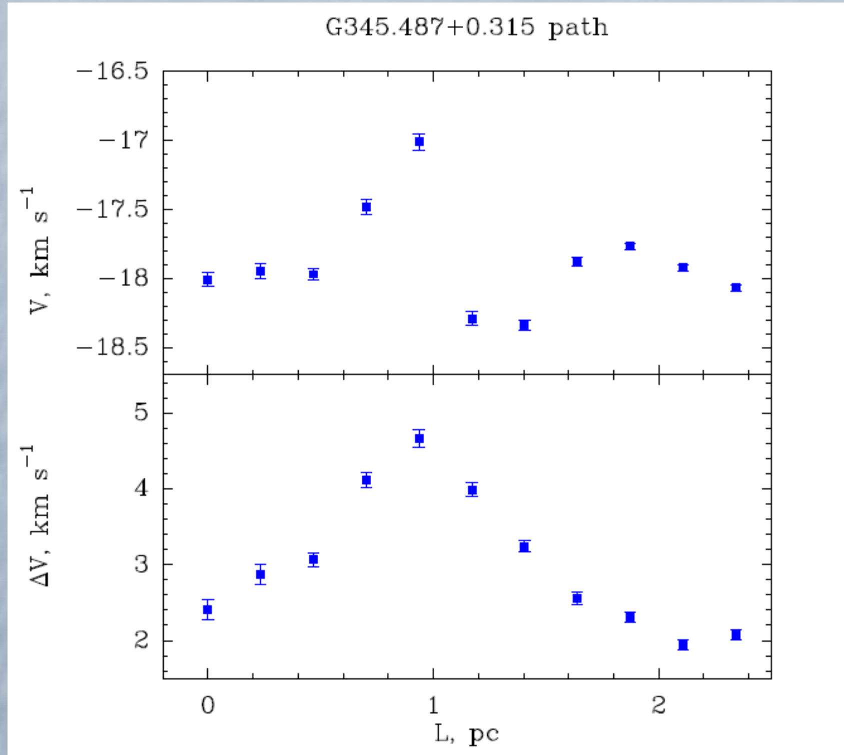

G000.547-00.855
Galactic latitude
Galactic longitude
−0°50'
51'
52'
53'
0°34'
33'
32'
31'
18
17
16
15

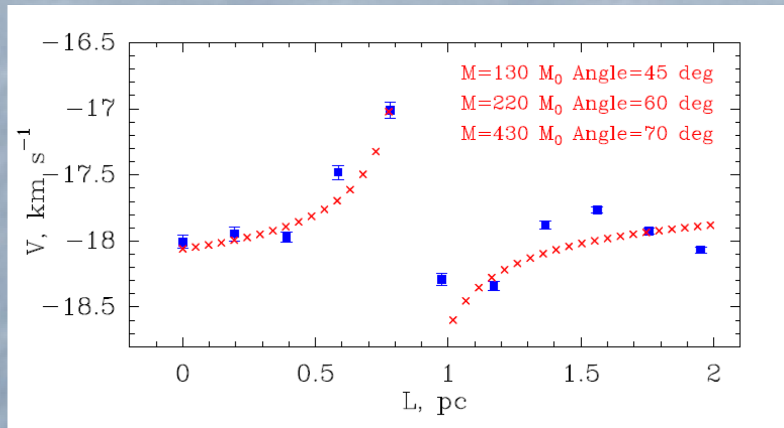

G010.225-00.207
Galactic latitude
Galactic longitude
−0°11'
12'
13'
14'
10°15'
14'
13'
12'
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5


G333.016+00.765
Galactic latitude
Galactic longitude
0°47'
46'
45'
44'
333°03'
02'
01'
00'
332°59'
−47.0
−47.5
−48.0
−48.5

G345.487 N_2H^+(1-0) — кеплеровское вращение?







Проведен анализ данных наблюдений около 100 массивных ядер из каталога MALT90 с заметным излучением в линии N_2H^+(1-0). Сделаны оценки пространственных распределений скоростей.

В большинстве случаев лучевые скорости газа изменяются вдоль профилей, проходящих через ядра. Наблюдаются профили «\/» или «/\» типов (как симметричные, так и асимметричные относительно центра ядра), линейные, плоские и ступенчатые участки, а также комбинации вышеперечисленных. Плоские участки во внутренних областях ядер могут быть признаками симметричных движений газа на луче зрения.

Наличие профилей различного вида вдоль перпендикулярных направлений, пересекающих ядра, указывает на асимметричные потоки газа, вероятно, связанные с пересекающимися волокнами, расположенными под различными углами к наблюдателю (HFS).

Планы на будущее. Анализ профилей скорости на больших масштабах по совместным данным N_2H^+(1-0) и ^{13}CO(2-1). Модельные оценки профилей скорости. Статистический анализ полученных значений параметров ядер.

Спасибо за внимание!

при поддержке гранта РНФ 24-12-00153