ASTRON

Netherlands Institute for Radio Astronomy

MHONGOOSE,

MeerKAT HI Observations of Nearby Galactic Objects: Observing Southern Emitters

GBT-THINGS and a low column density view of NGC 2403

Erwin de Blok

PHISCC@ASTRON, 19 Mar 2014

Galaxy evolution in HI

The connection, over time, between between star formation, HI, dynamics and accretion.

- How do galaxies get their gas?

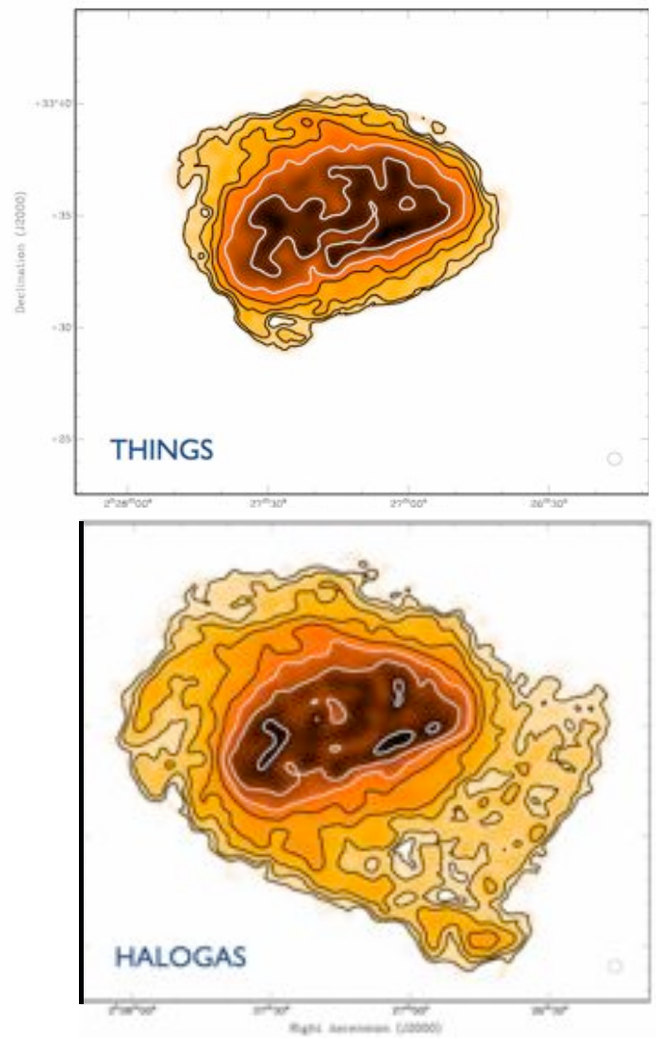
- How is star formation regulated?

- How are outer disks and cosmic web linked?

MeerKAT: 6000 hours allocated to for deep observations of 30 galaxies

Deep

- observe 25 times longer than THINGS
- 30 galaxies
- 200h per galaxy
- Accretion, cosmic web, dynamics beyond disk
- About twice as deep as HALOGAS
- $5\sigma = 1.3 \cdot 10^{19}$ cm^{-2} at 30” for 16 km s^{-1} FWHM HI line at 5 km s^{-1} channel spacing or 5.10^{17}-10^{18} cm^{-2} at 90”



Status

- Defined proto-sample
- SINGG/SUNGG (Meurer)
    - HIPASS selected
    - 90 galaxies
    - GALEX, Spitzer, WISE, ground-based all available
    - additional data with KAT7, WiFeS, …
- Selecting best sub-set of 30 in time for early science
- What to expect….

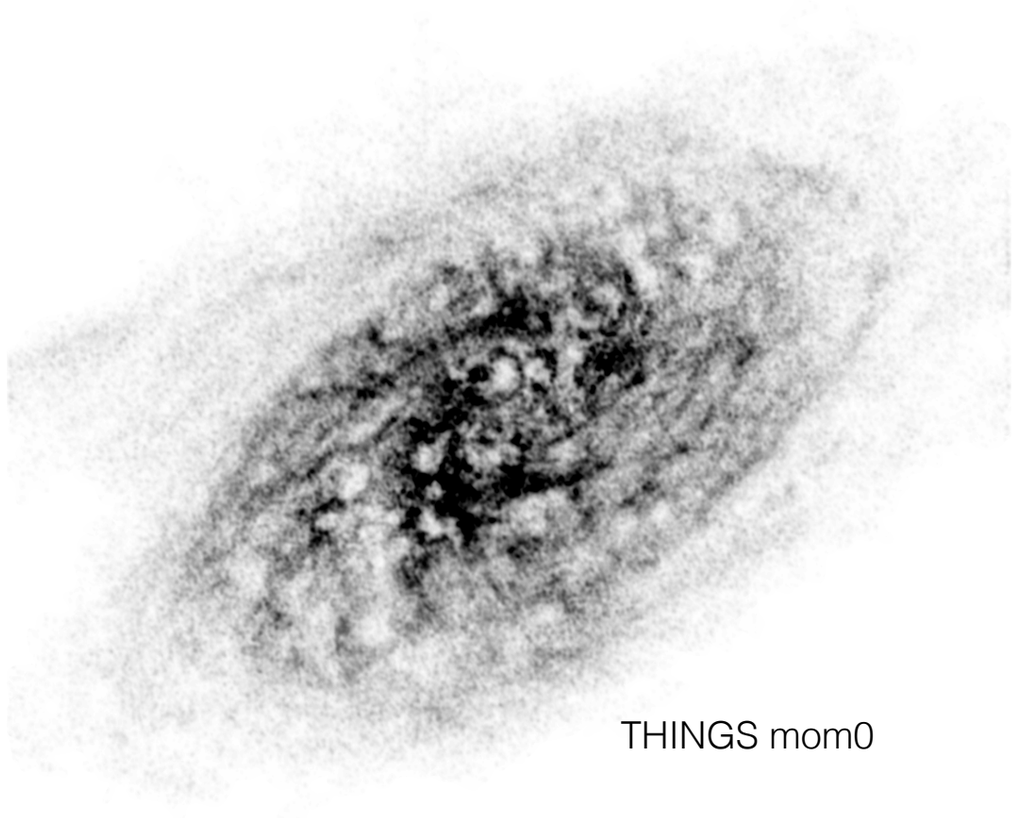
GBT-THINGS

- Observe the THINGS galaxies to low column density with the GBT

- Today: NGC 2403

- GBT THINGS: D.J. Pisano (PI), EdB, K. Keating, F. Walter, E. Brinks, F. Bigiel, A. Leroy

- NGC 2403 analysis: F. Fraternali, T. Oosterloo



THINGS mom0

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- Observe the THINGS galaxies to low column density with the GBT

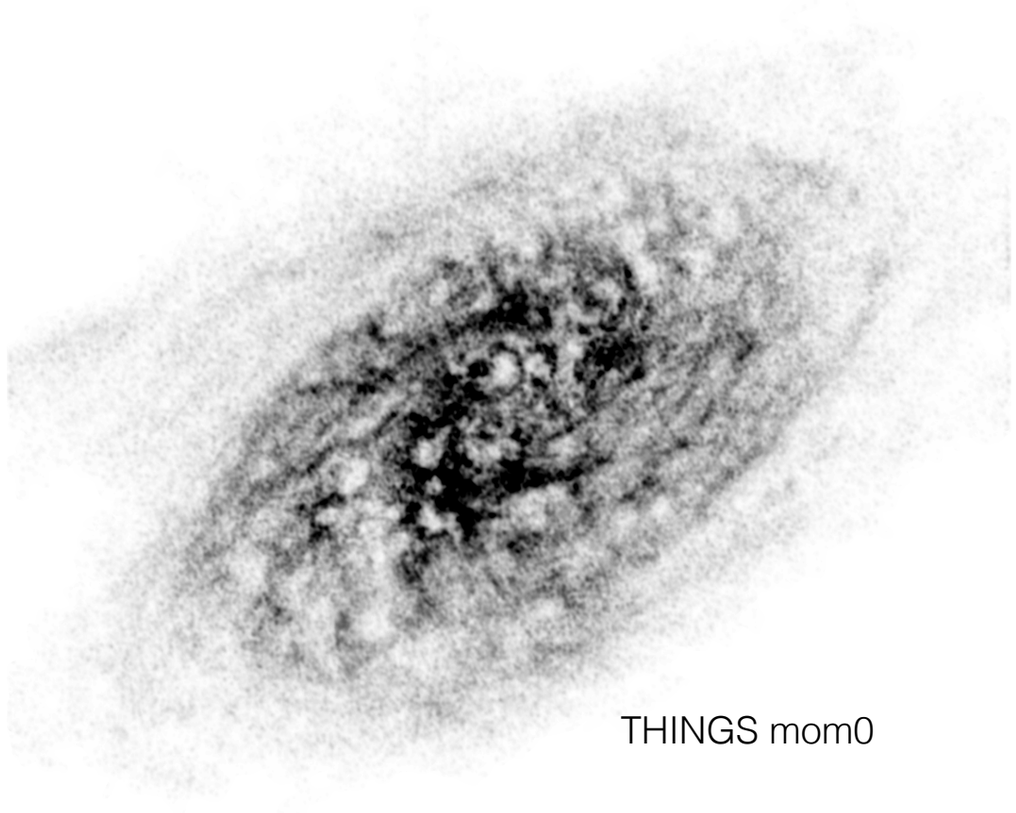
- Today: NGC 2403

- 4 by 4 degrees (0.2 x 0.2 Mpc) for 120 hours, or ~11 min/beam

- 9’ resolution (8.4 kpc), 5.2 km/s

- $-880 < v < 1750$ km s^{-1}

- 1.3 10^{17} cm^{-2} (1σ, 5.2 km/s), or 2.4 10^{18} cm^{-2} (5σ, 20 km/s)



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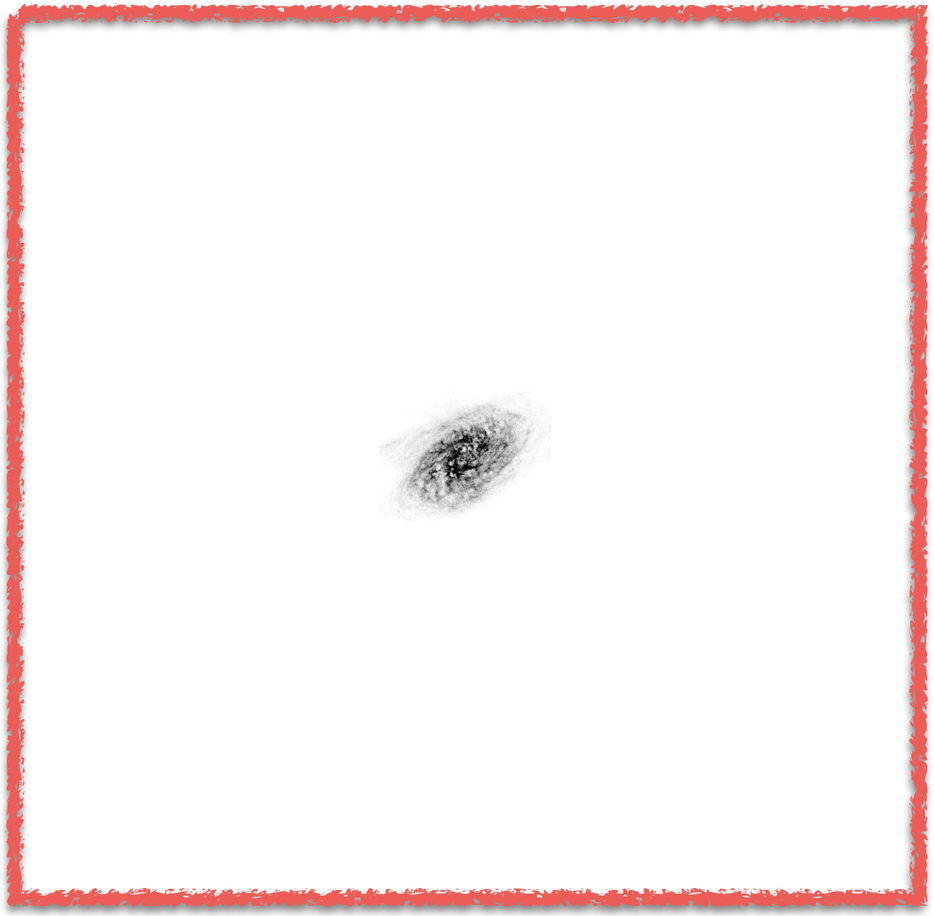


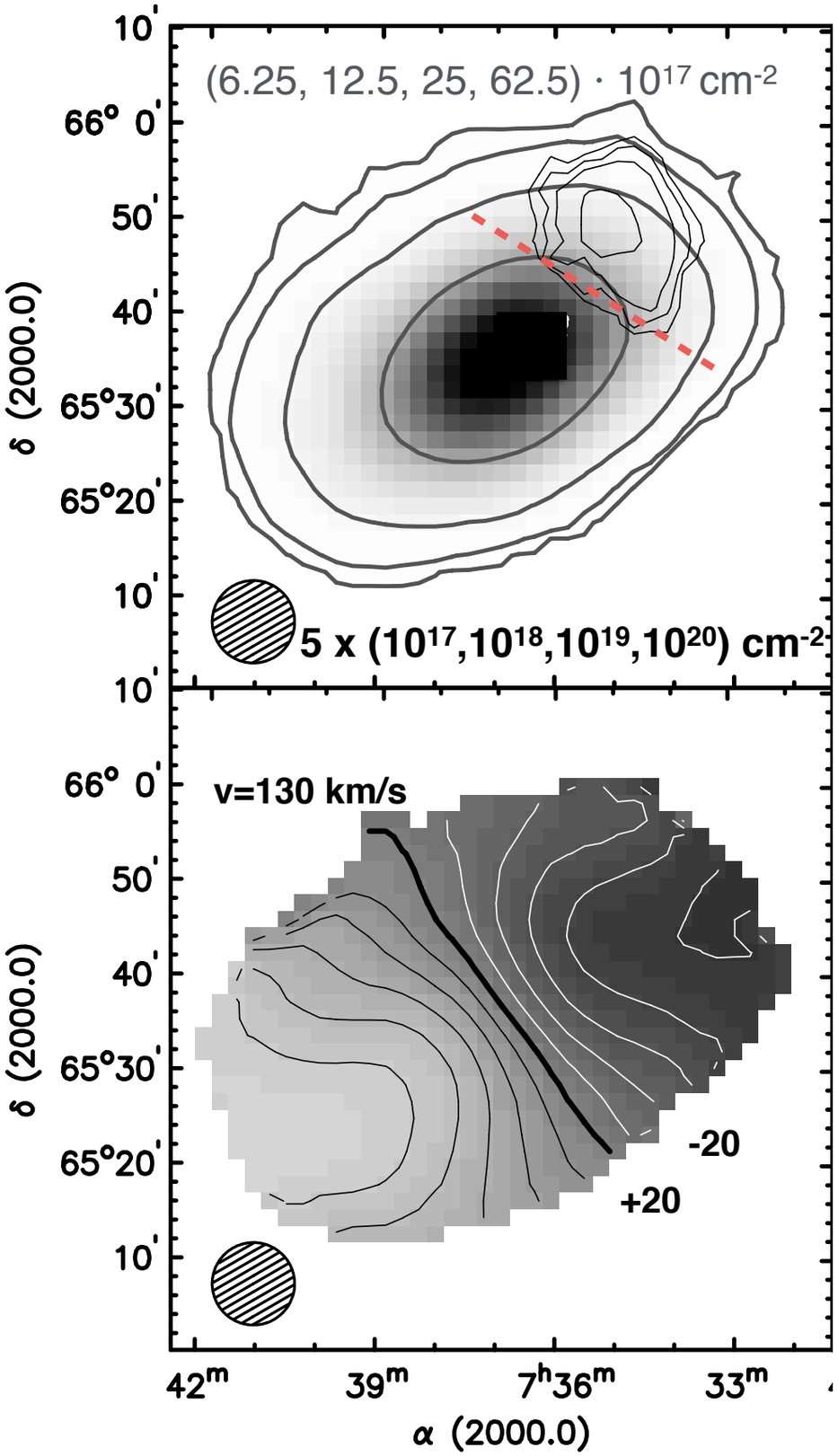
289.6 274.2 258.7 243.3 227.8
212.3 196.9 181.4 166.0 150.5
145.4 140.2 135.1 129.9 124.8
119.6 114.5 109.3 104.1 88.7
73.2 57.8 42.3 26.9 11.4

Declination (J2000.0)

Right Ascension (J2000.0)

(2,4,8,16,32,64,128,256,1024) x 1.3 10^{17} cm^{-2}

GBT



- HI mass of cloud is 6.3 10^6 $M_\odot$
- Total HI mass of N2403 is 4.0 10^9 $M_\odot$
- Cloud HI mass 0.15% of galaxy HI mass
- No obvious optical counterpart
- Compare with deep VLA of Fraternali et al (2001,2002)

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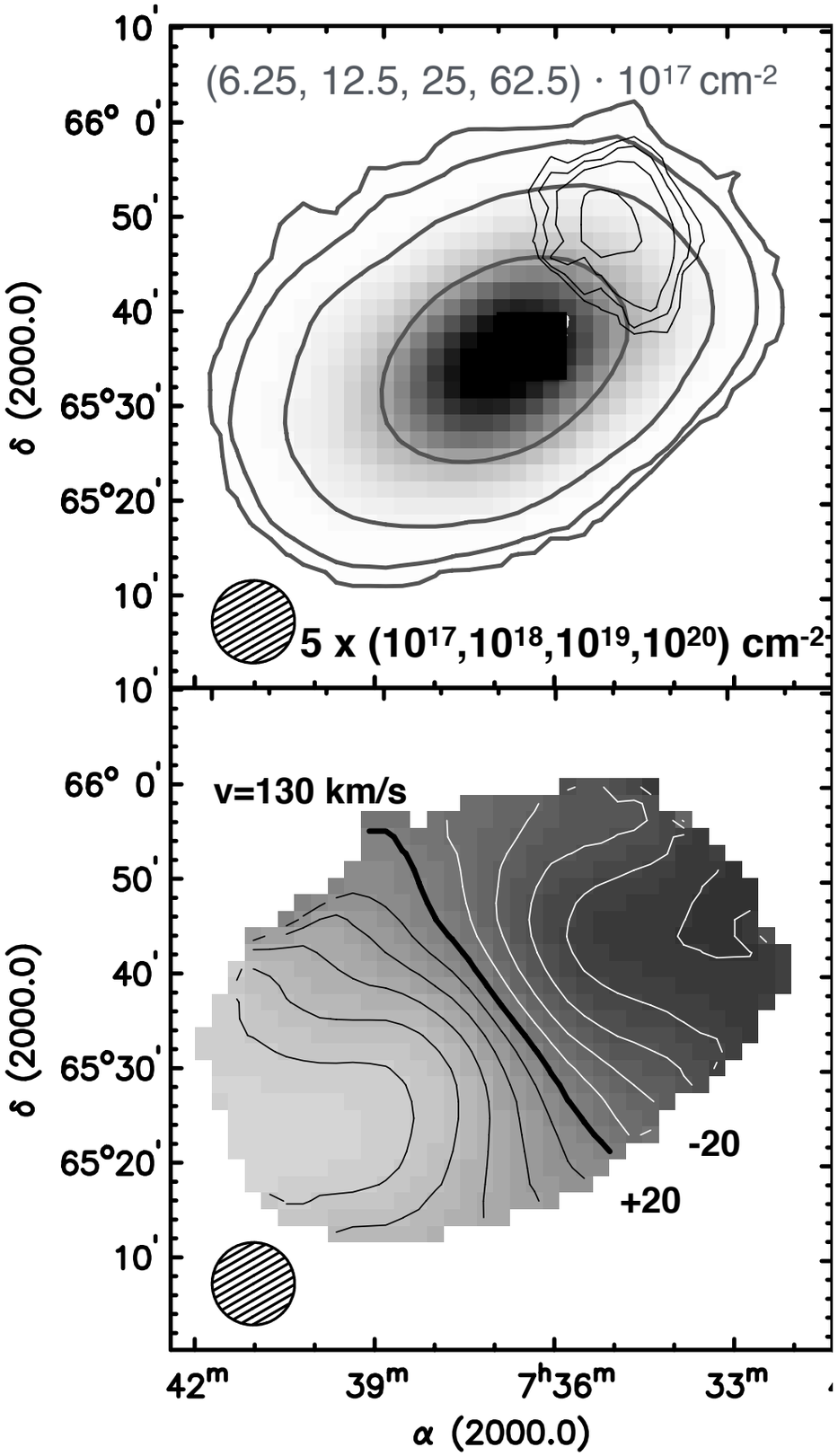

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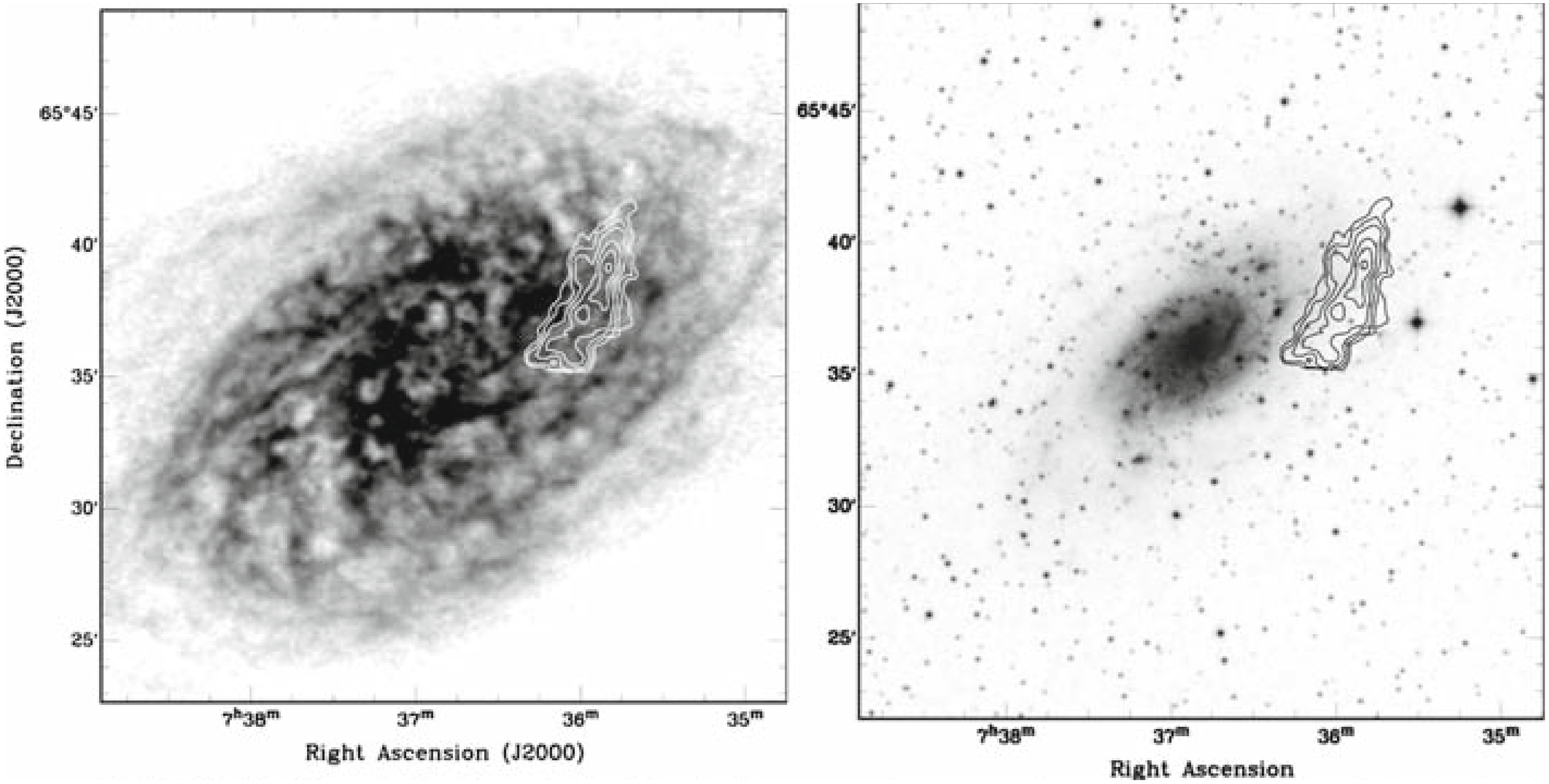
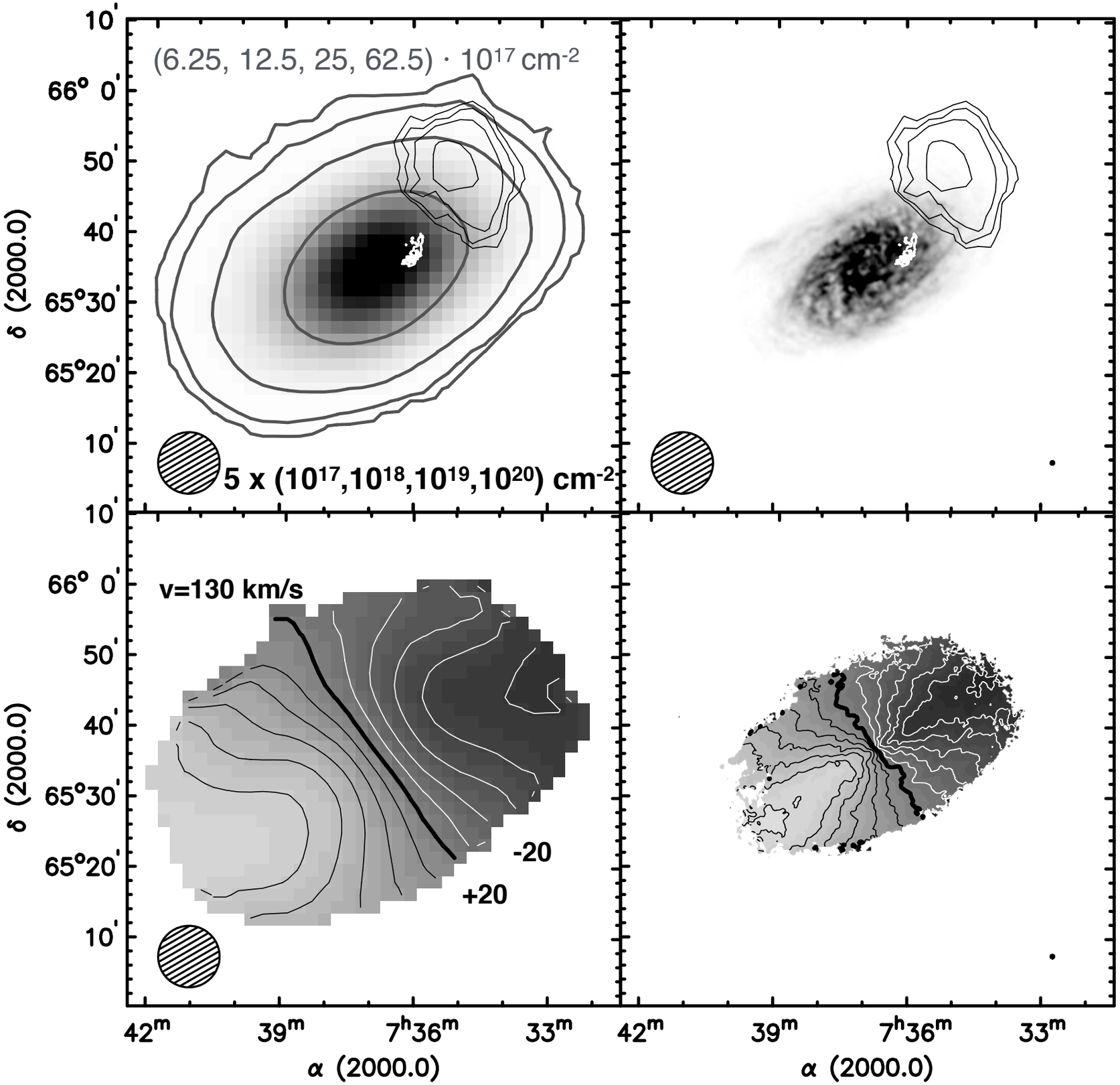
- Fraternali et al (2001/2): 40h with VLA CS array
- 30” cube, 5σ over 10 km/s is 2.0 10^{19} cm^{-2}
- Search for kinematically anomalous HI
- Largest complex is “8-kpc filament” with HI mass ~1.0 10^{7} $M_{\odot}$



Sancisi et al 2008, Fraternali et al 2001,2002

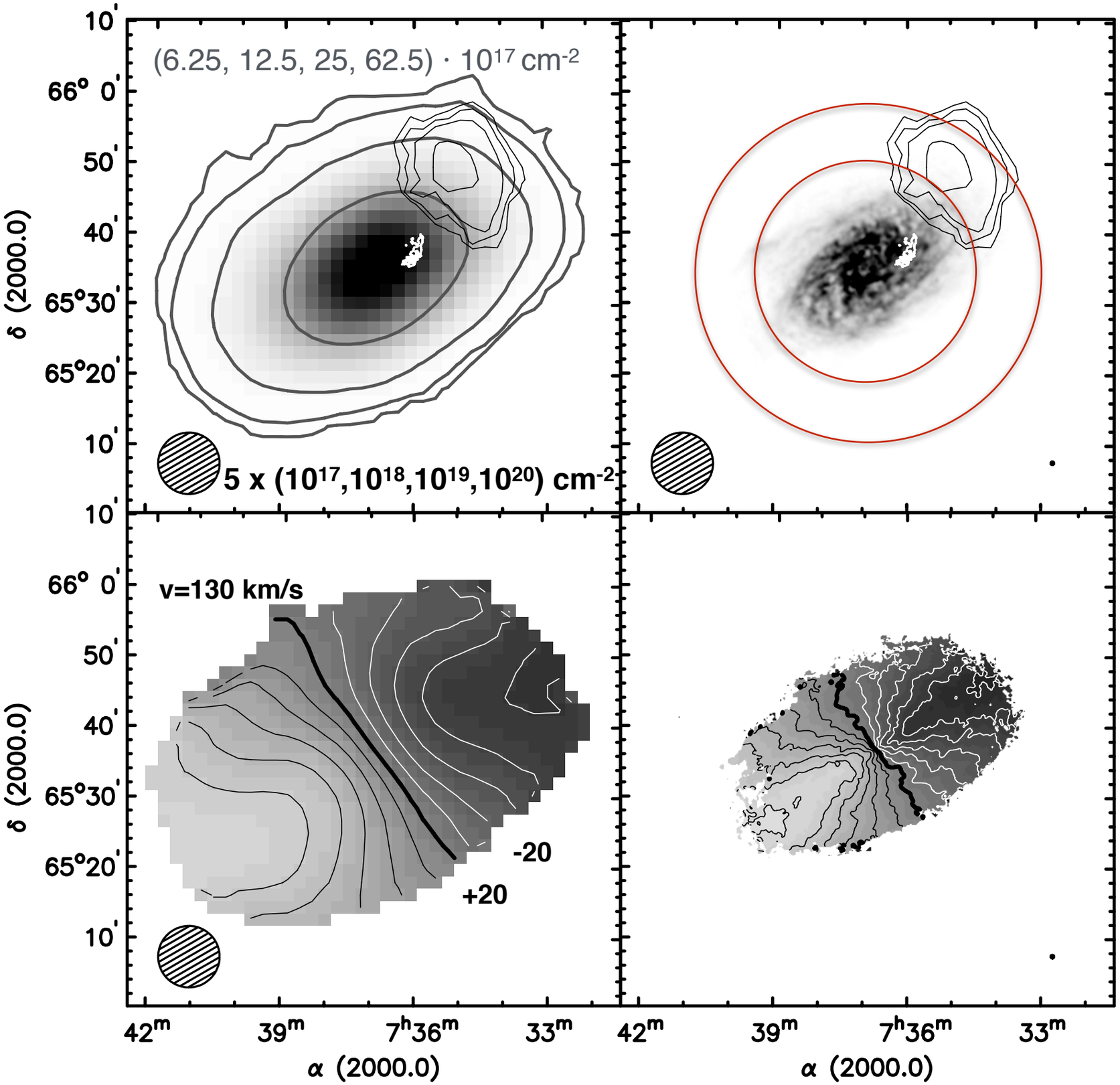
GBT

VLA


(6.25, 12.5, 25, 62.5) · 10^17 cm^-2
5 x (10^17,10^18,10^19,10^20) cm^-2
v=130 km/s
-20
+20
δ (2000.0)
α (2000.0)
10'
66° 0'
50'
40'
65°30'
65°20'
10'
42^m
39^m
7^h36^m
33^m

GBT

VLA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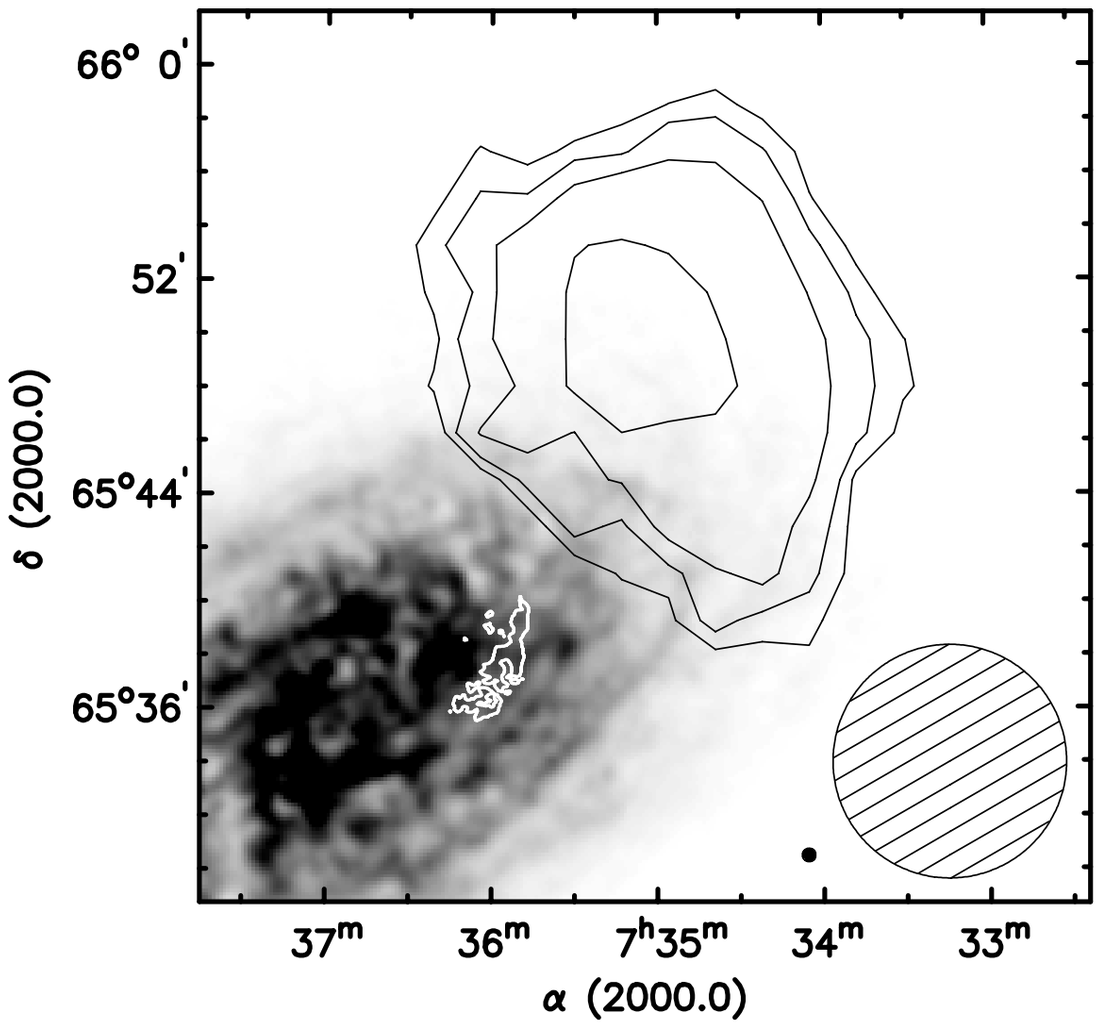
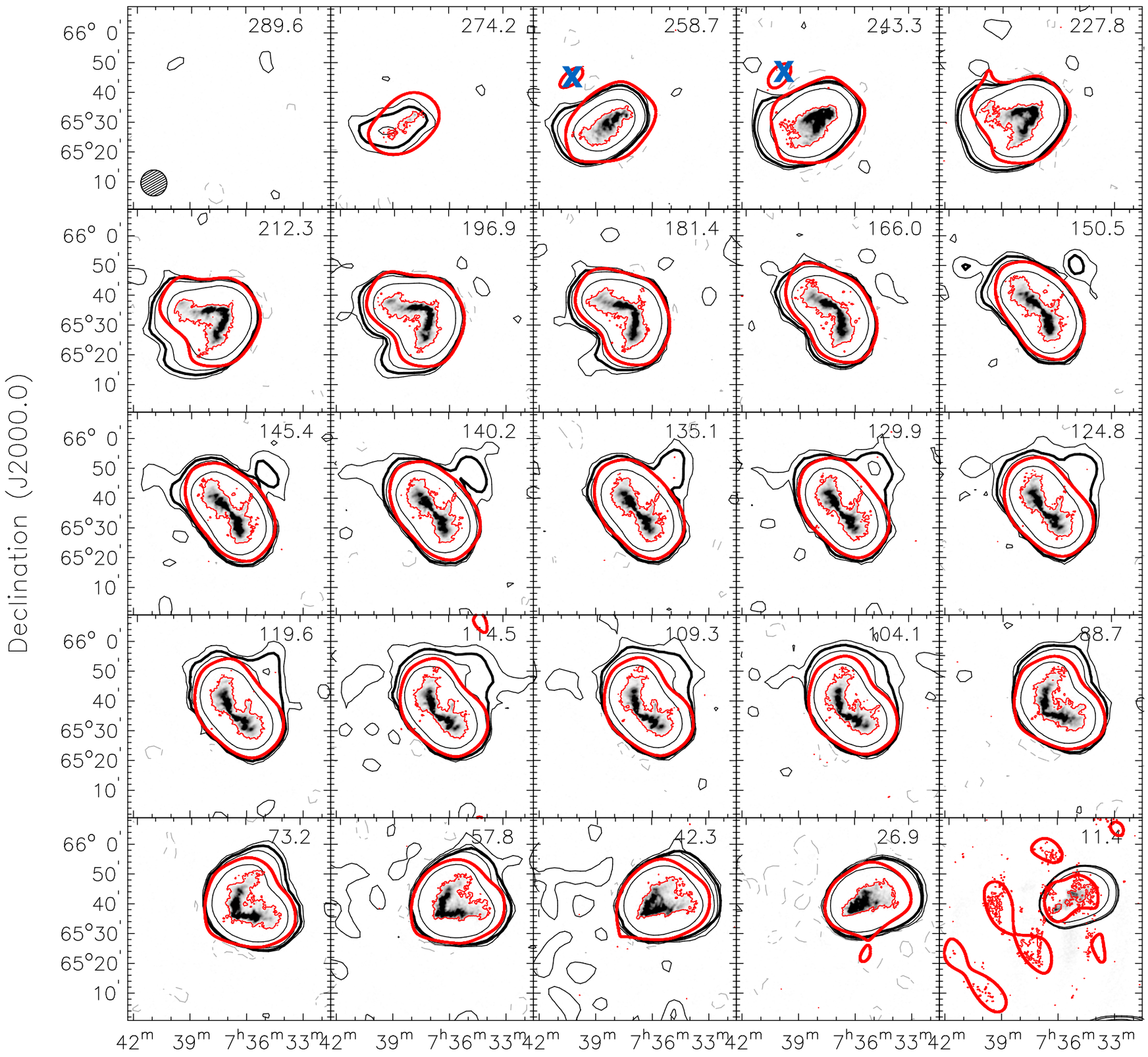
42^m
39^m
7^h36^m
33^m

Properties

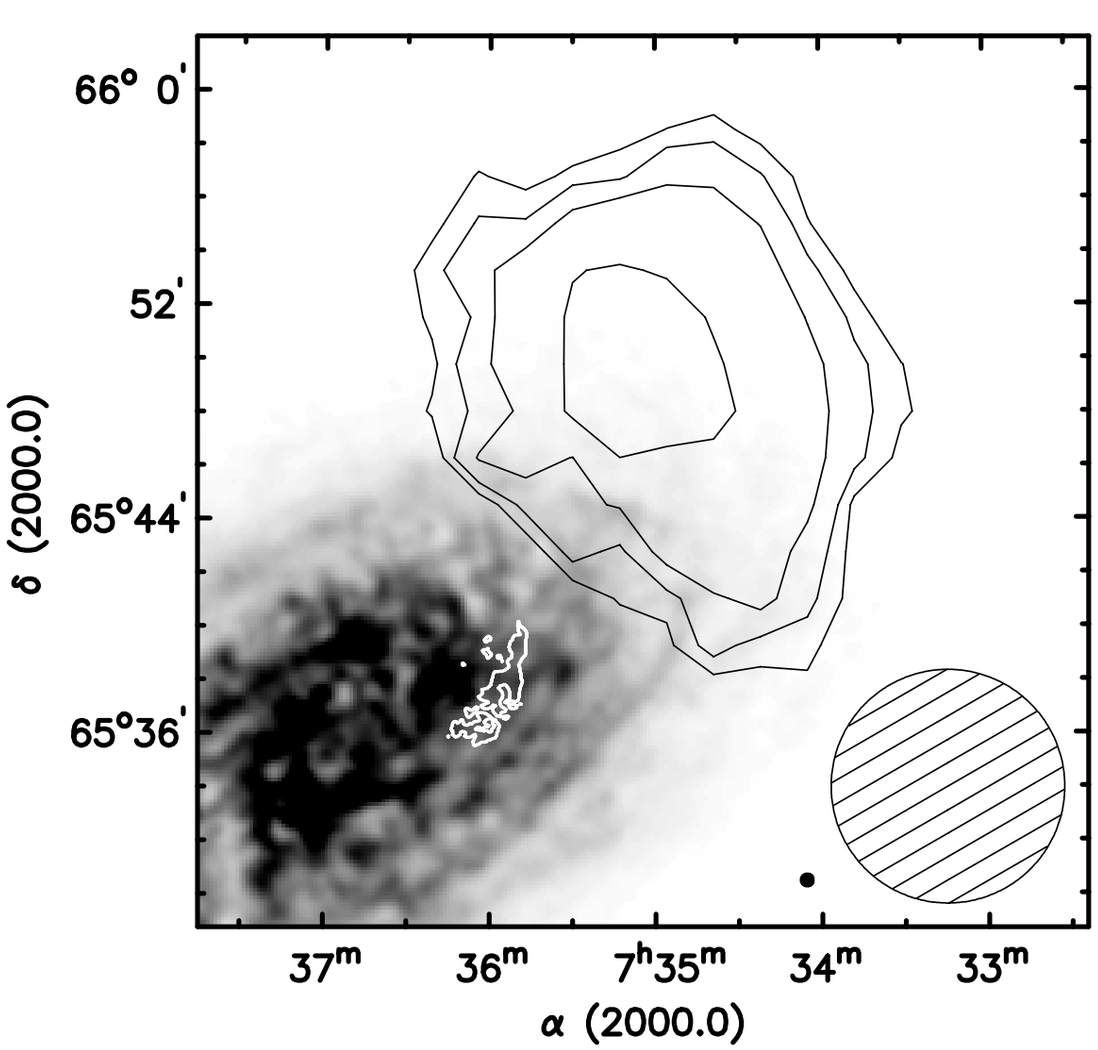
- HI mass of cloud is 6.3 10^6 $M_\odot$
- Size 16’ x 12’ (15 x 11 kpc)
- Uniform distribution within GBT cloud size: ~6 10^{18} cm^{-2}
- Same size as 8-kpc filament: ~6 10^{19} cm^{-2}
- This is comparable to actual filament
- Would show up in VLA data at 1σ

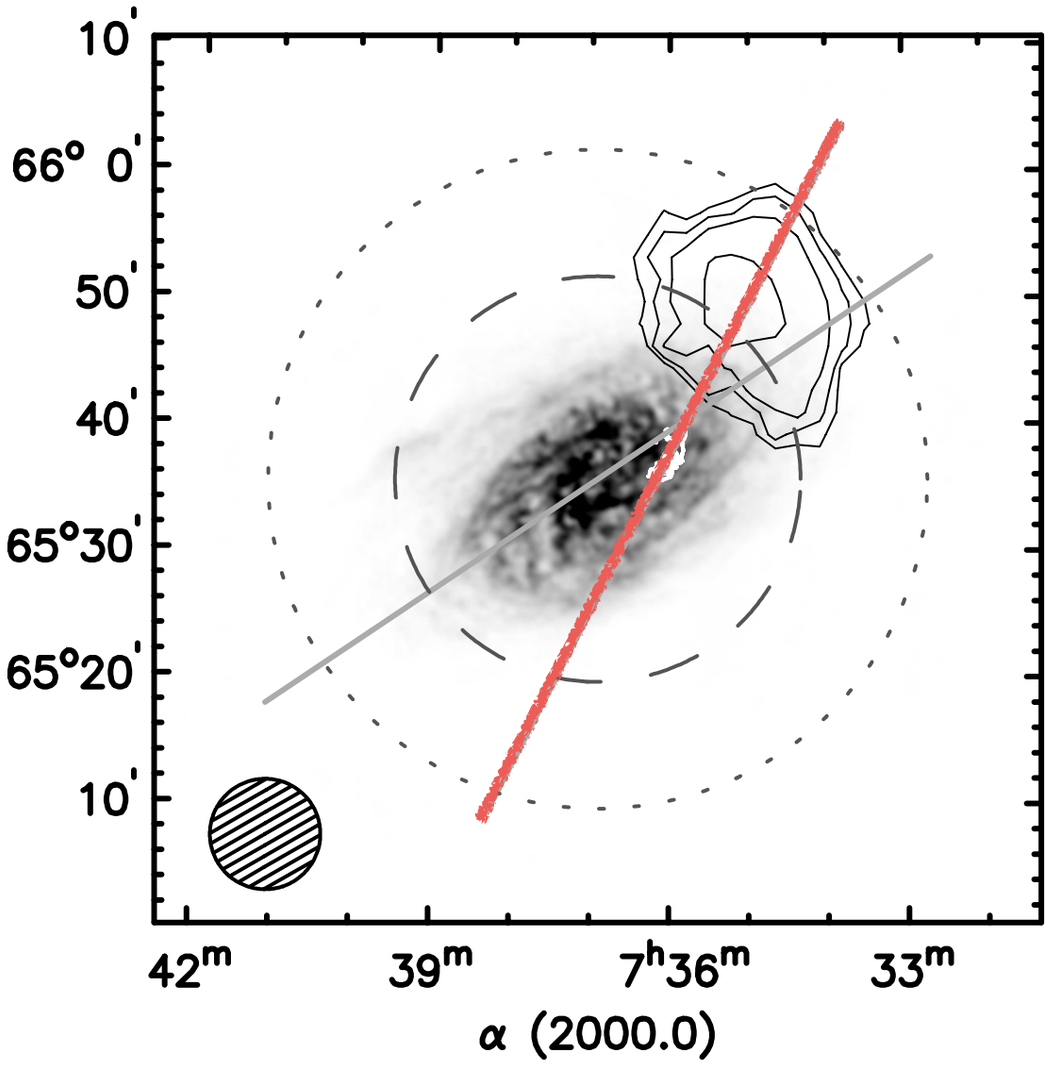
But is it real?





thick contours: 5 10^{17} cm^{-2}


66° 0'
52'
65°44'
65°36'
δ (2000.0)
37m
36m
7h35m
34m
33m
α (2000.0)


10'
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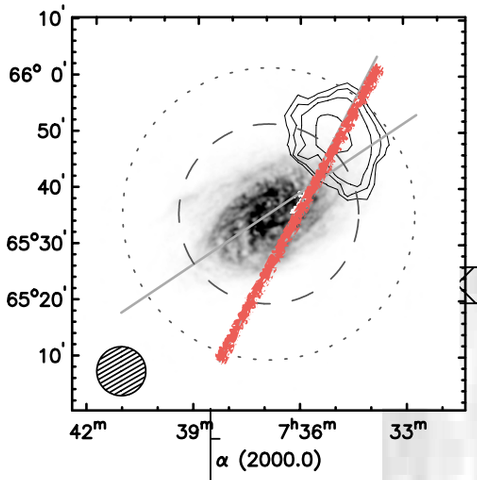
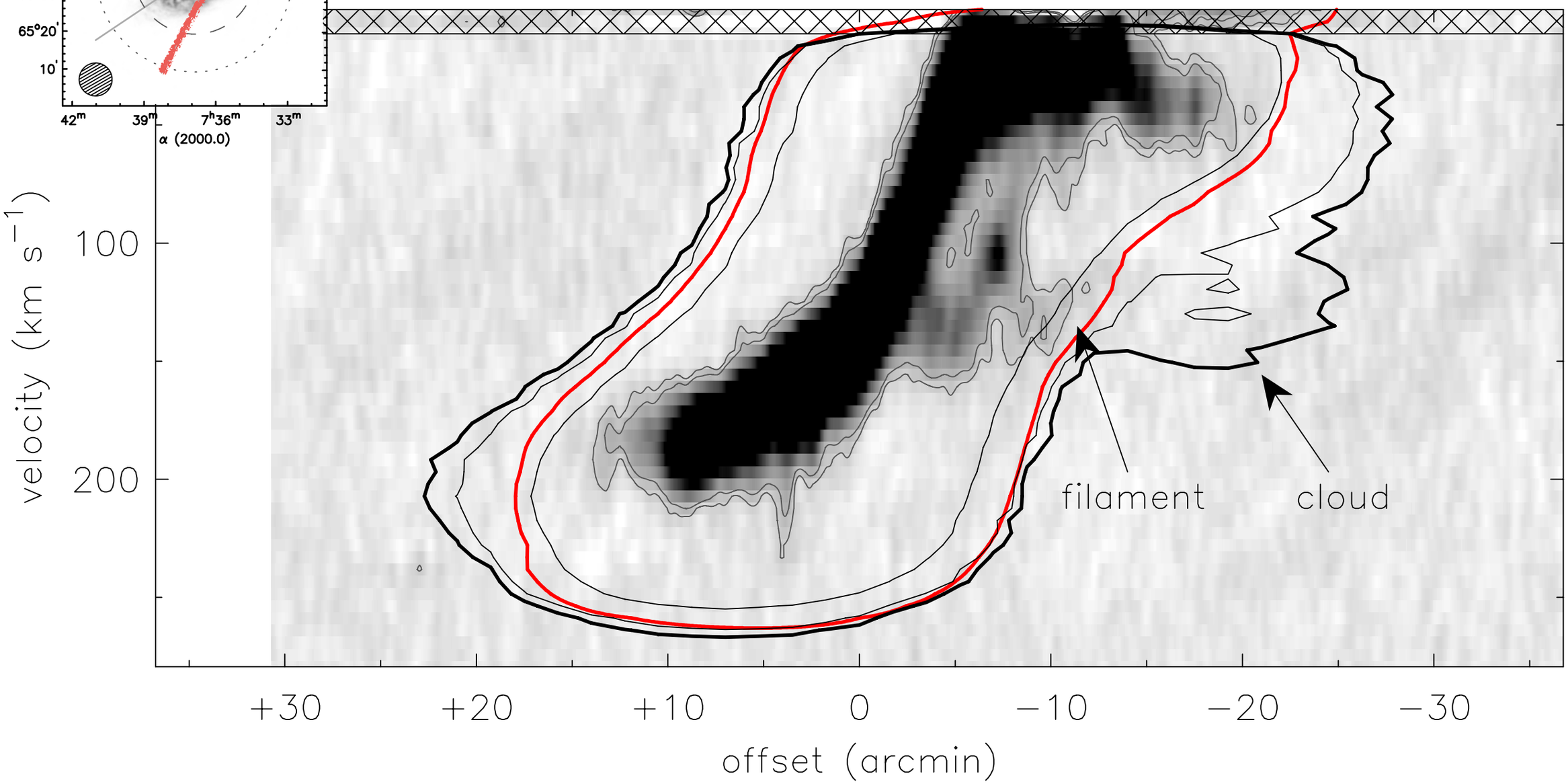
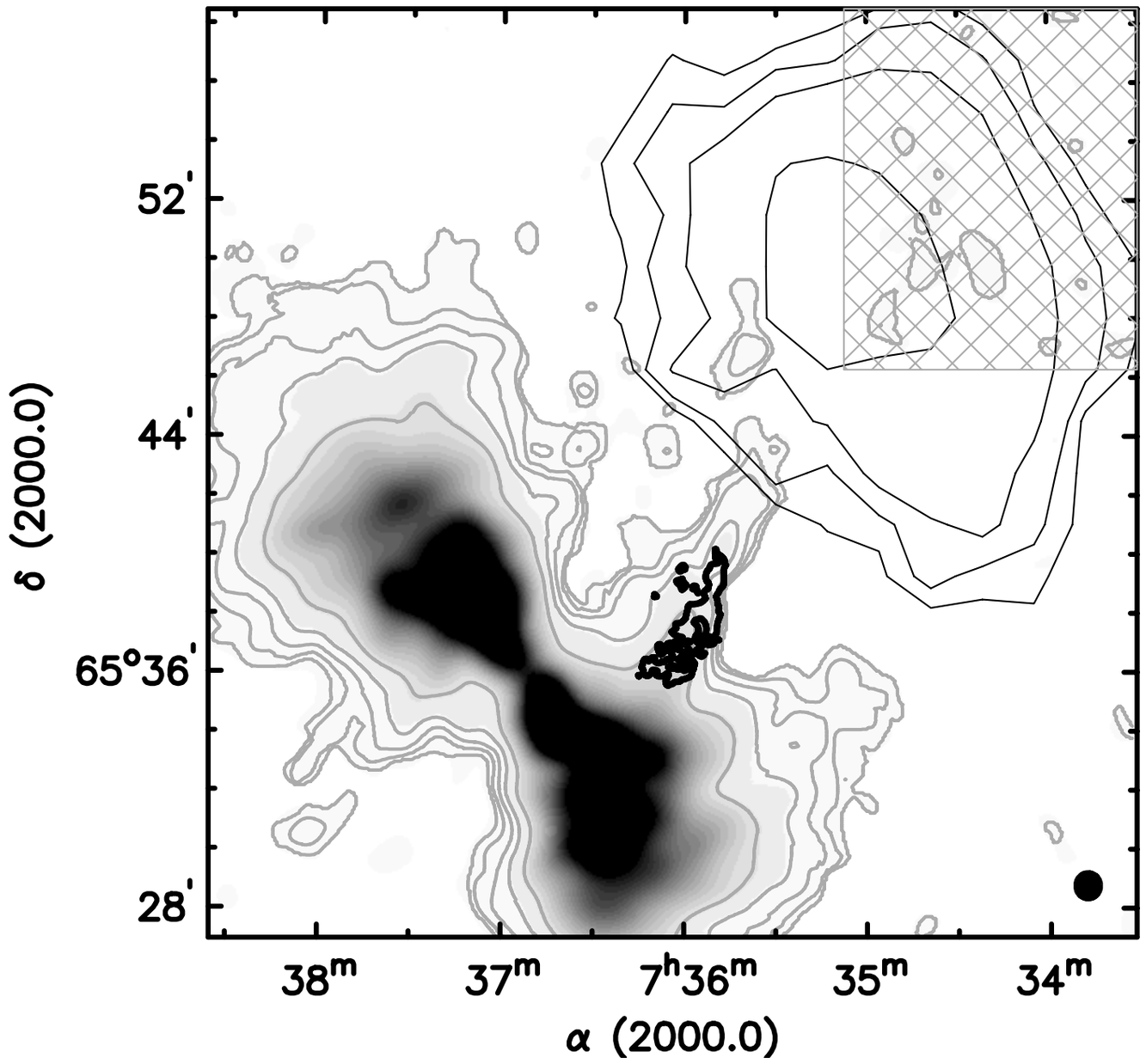




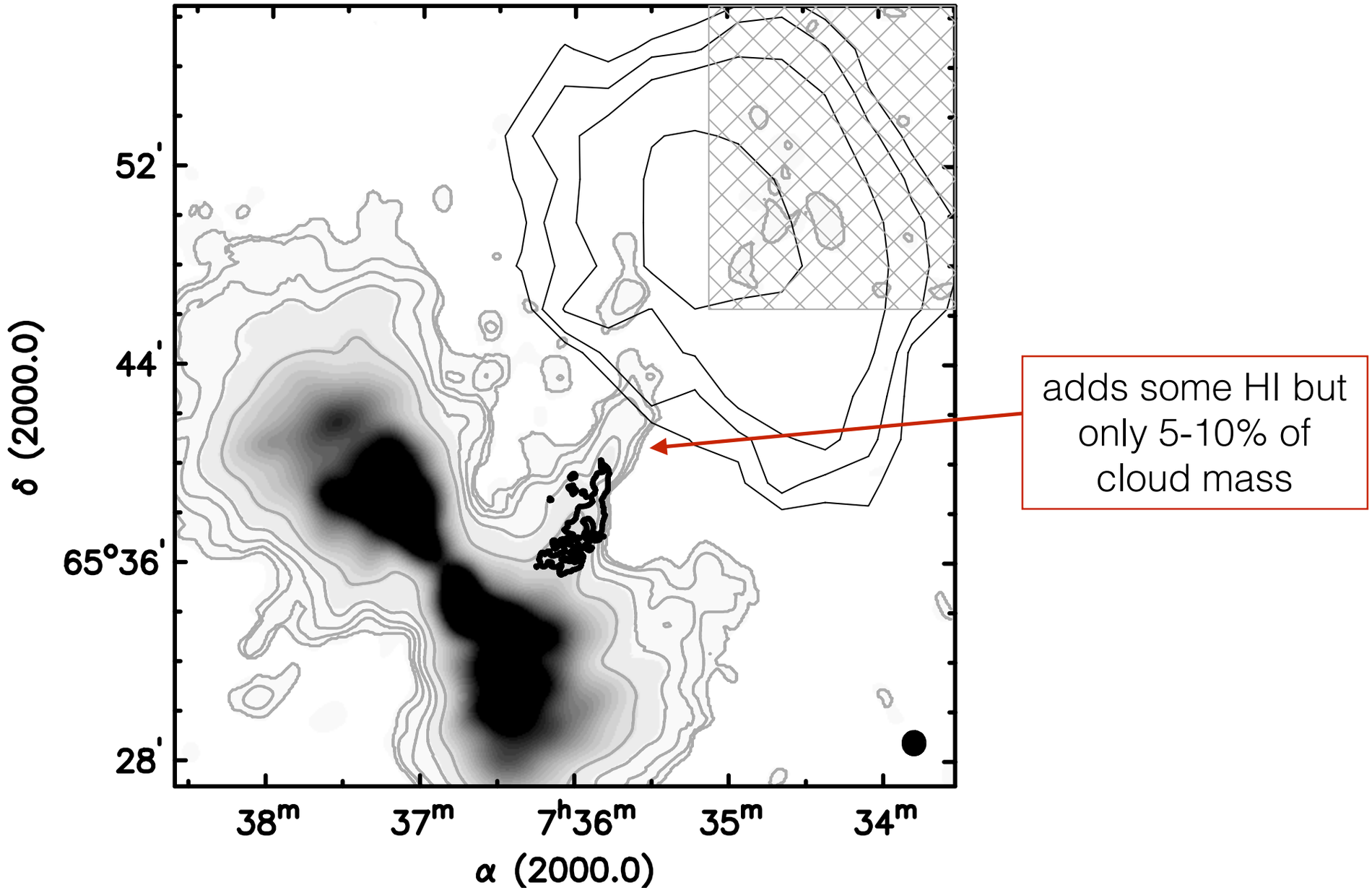
GBT: **5 10^{17},** 1 10^{18}, 5 10^{18} cm^{-2}

VLA (smoothed): **5 10^{17} cm^{-2}**



Integrated 60” HI between 119 and 150 km/s

light-gray contours (3, 7.5, 15, 30, 75) · 10^{18} cm^{-2}



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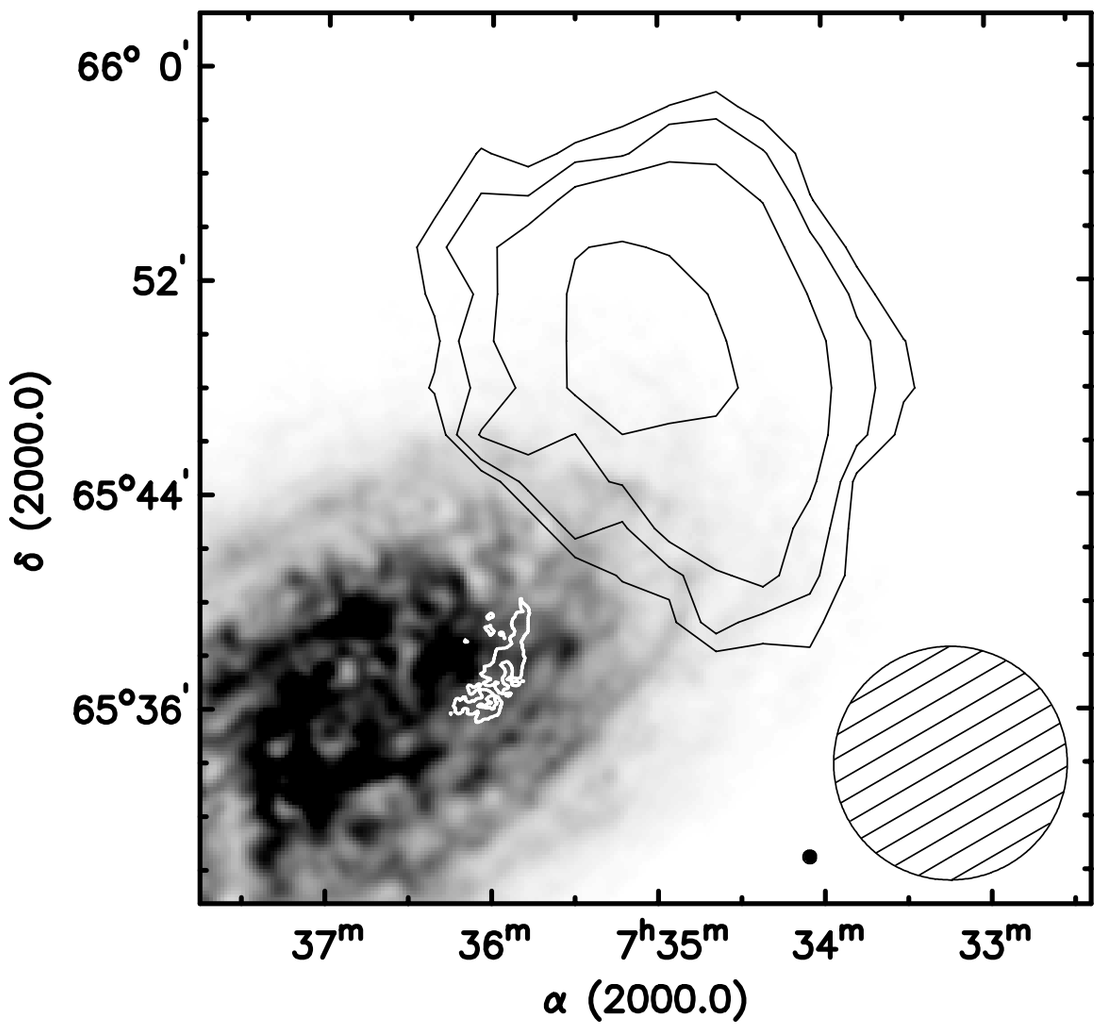
light-gray contours (3, 7.5, 15, 30, 75) · 10^{18} cm^{-2}

What process created the cloud/filament complex?

Scenarios

- Galactic fountain
- Infall of dwarf
- Tidal interactions
- Fly-by
- Accretion



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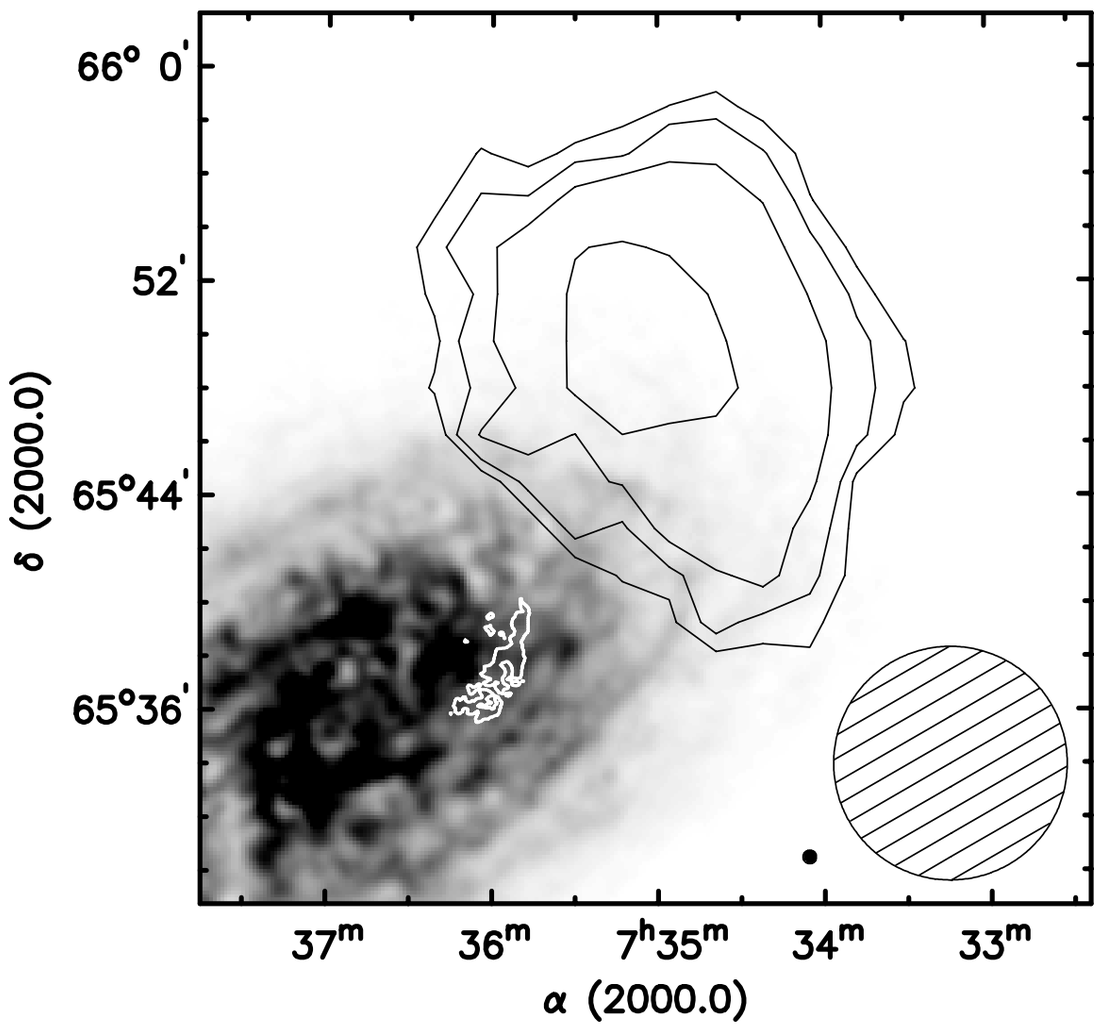

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8-kpc filament: difficult but not impossible. However, cloud increases radial distance by significant factor

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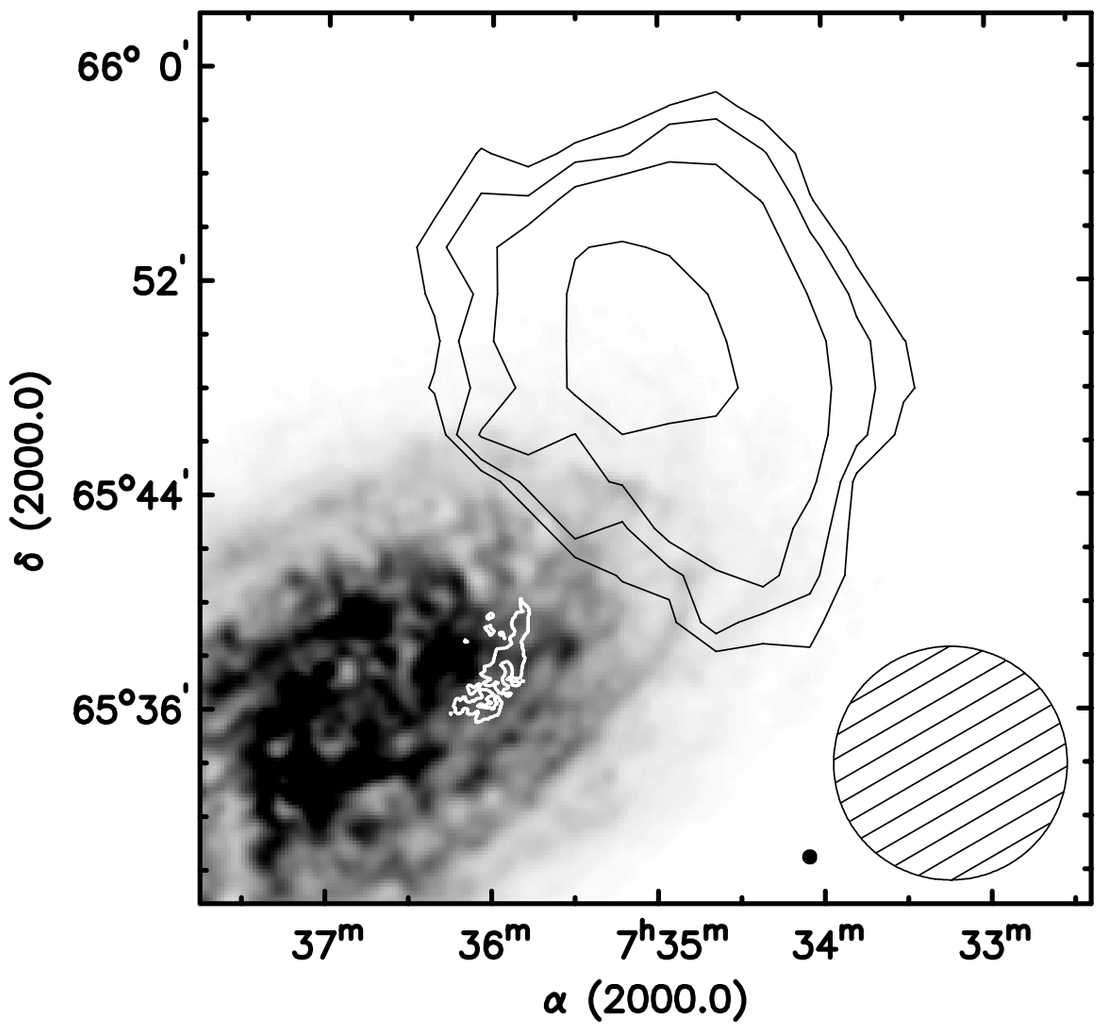

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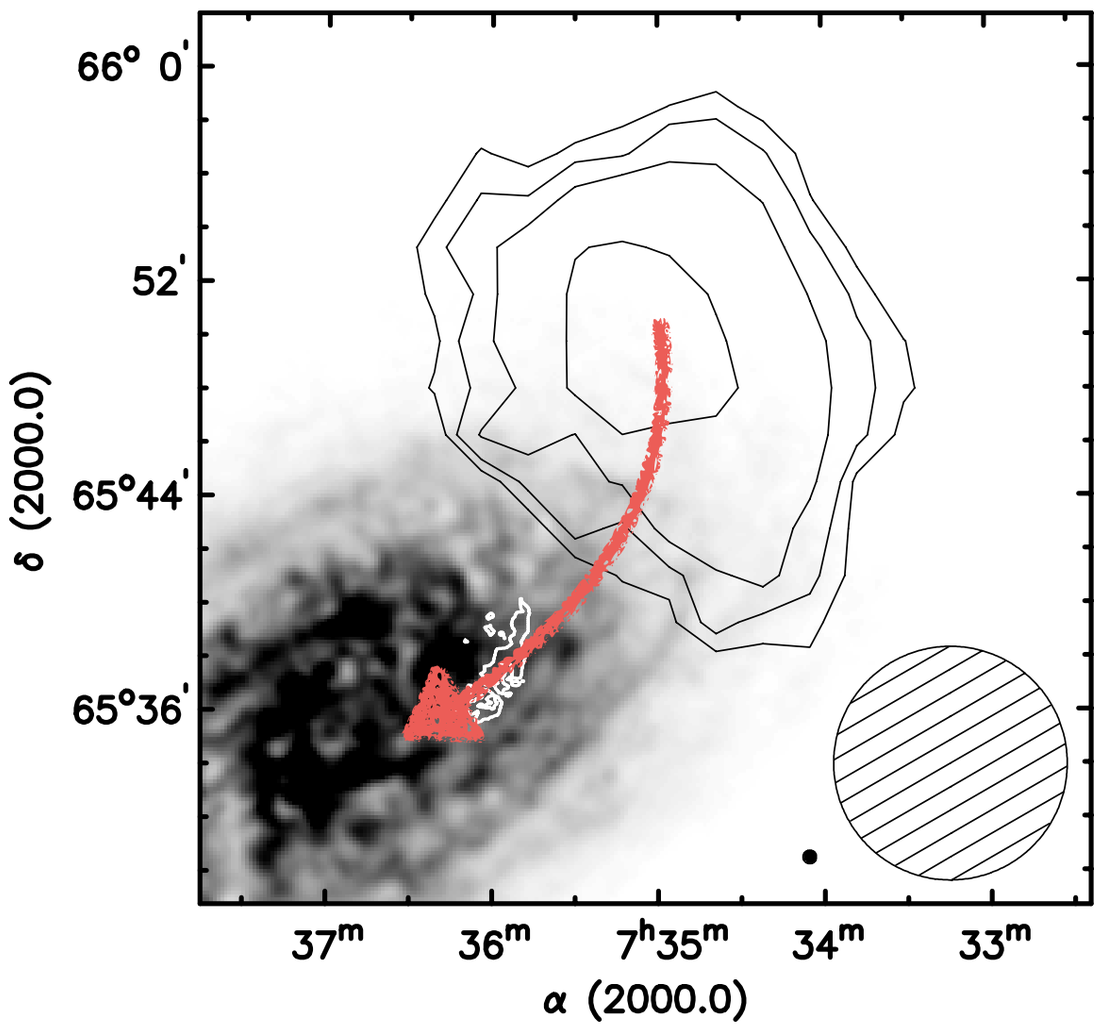

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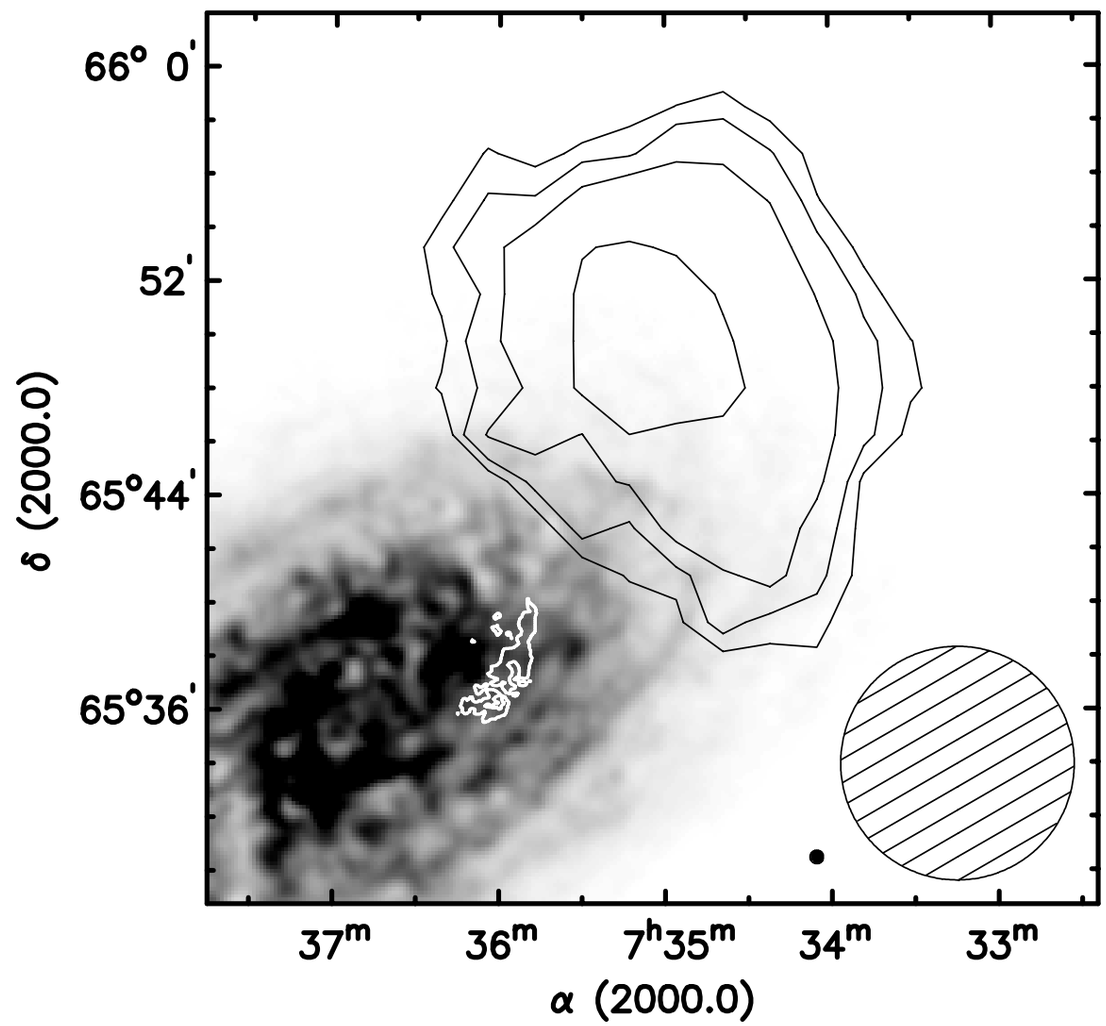

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NGC 5907
APOD 19/6/2008

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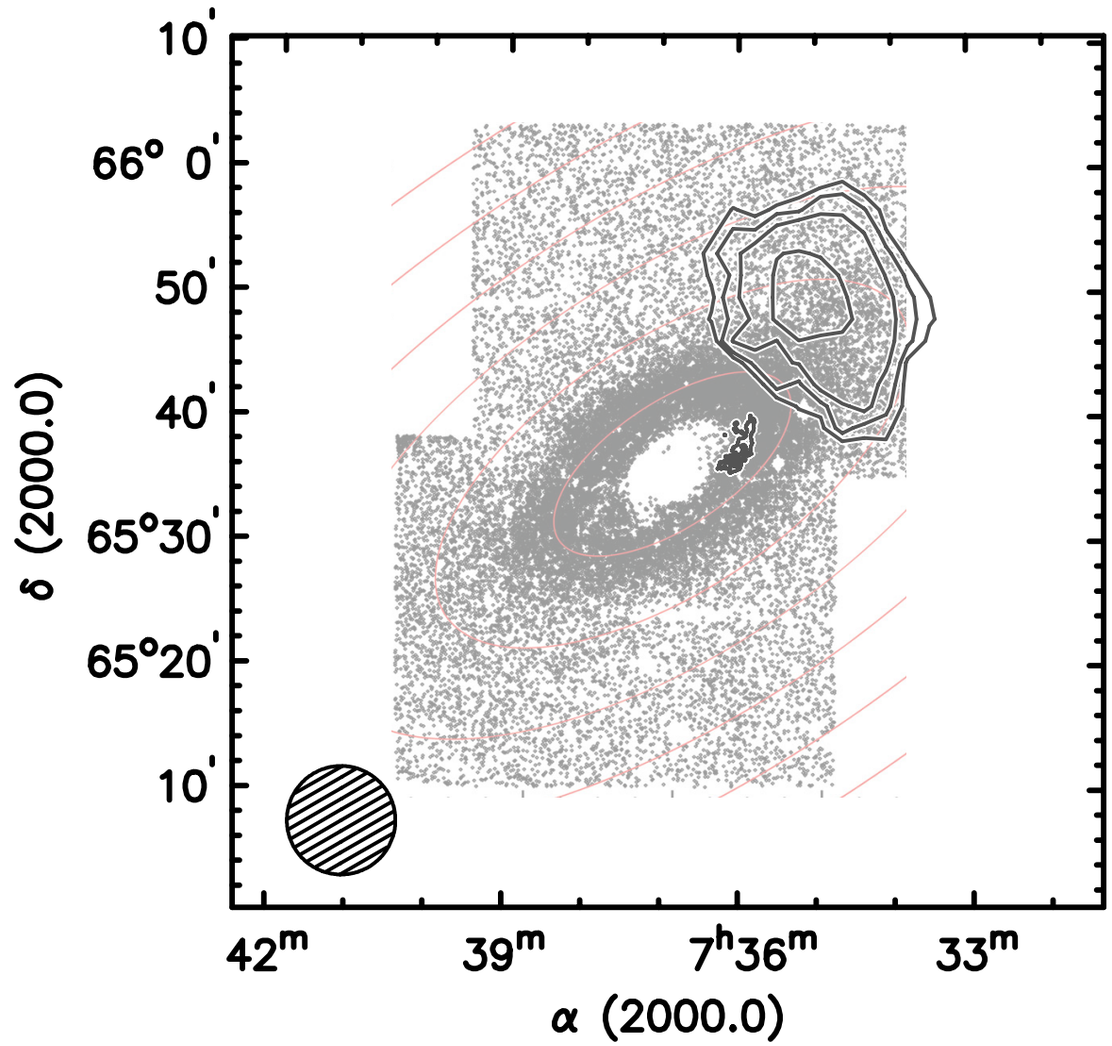

Barker et al 2012. Subaru observations of RGB and AGB stars

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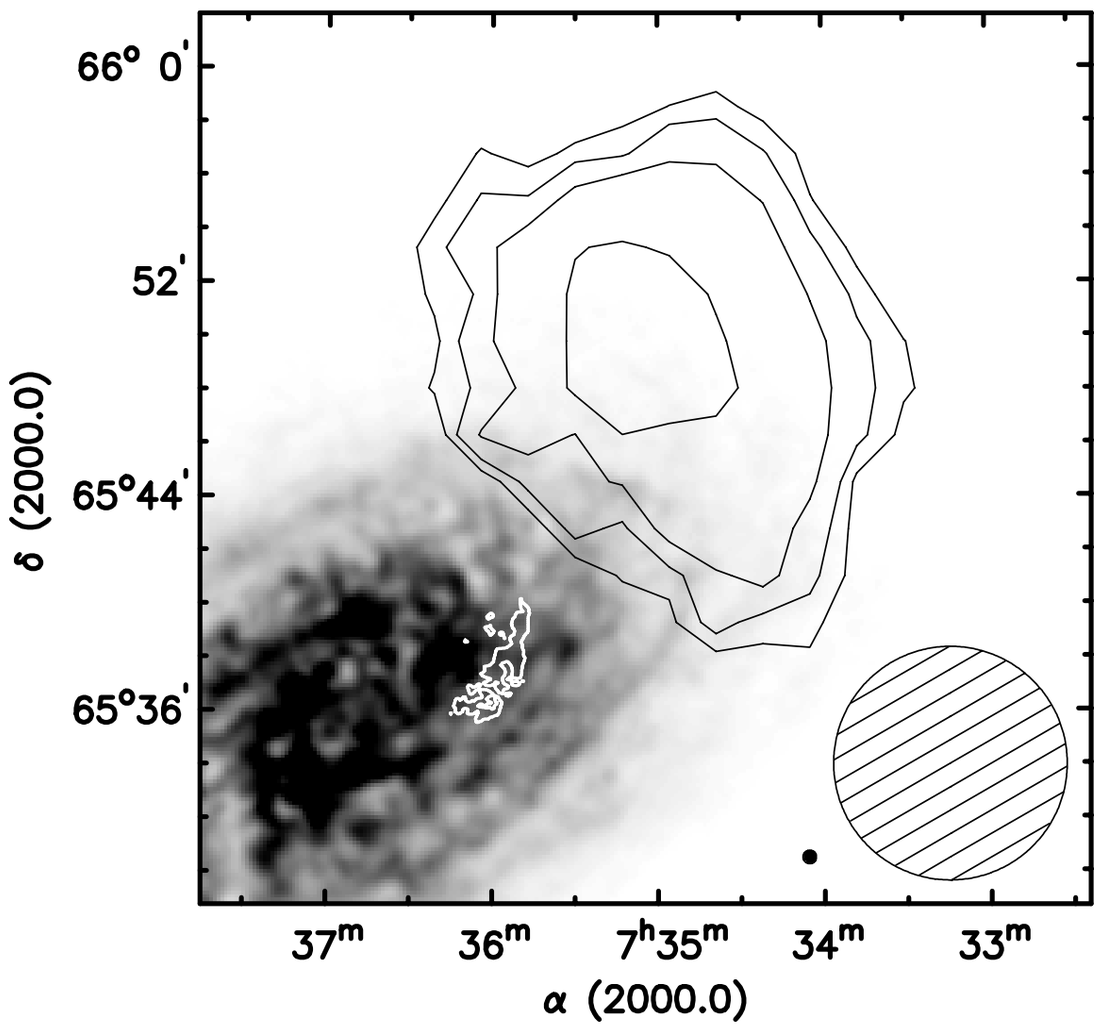
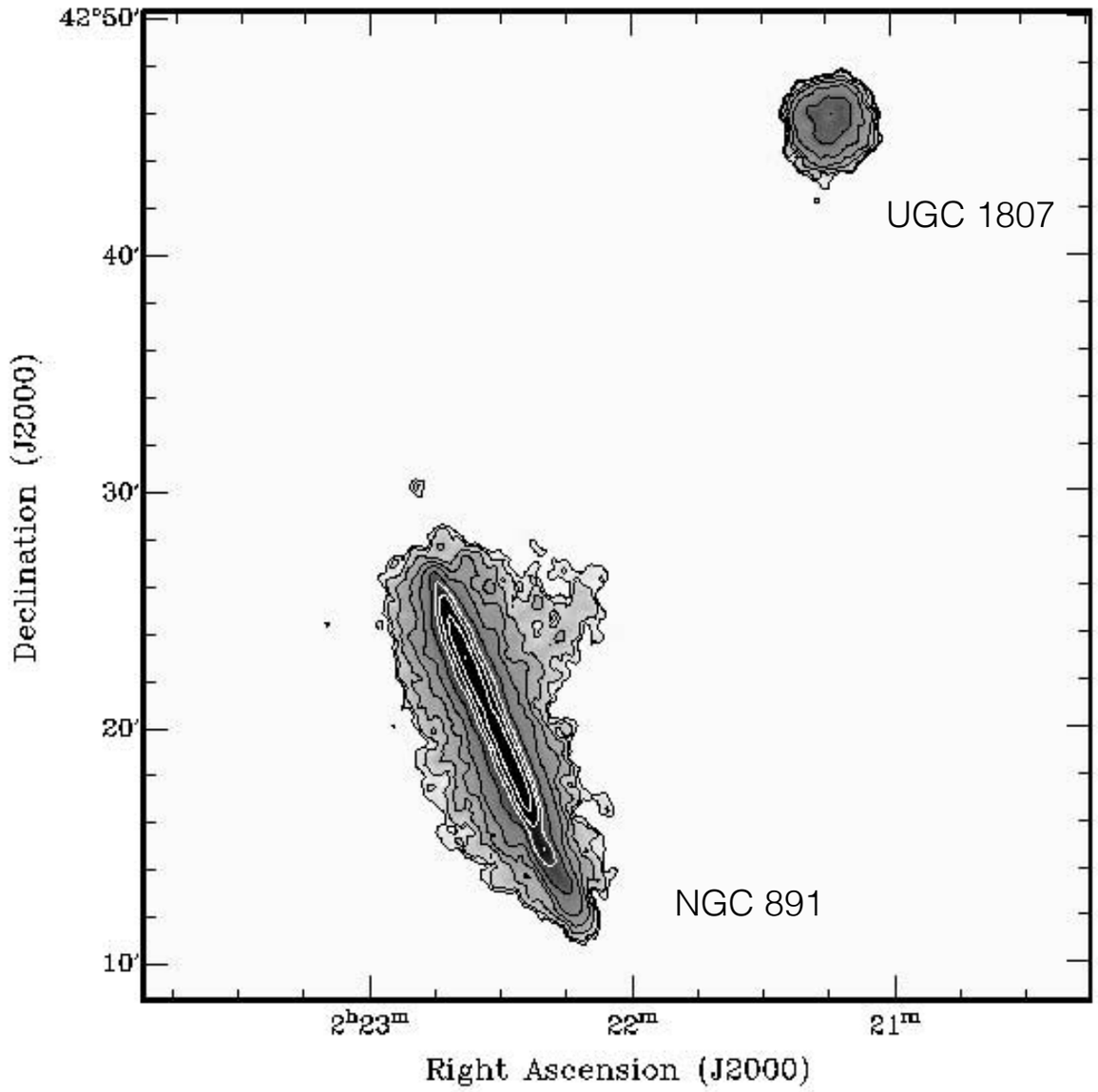
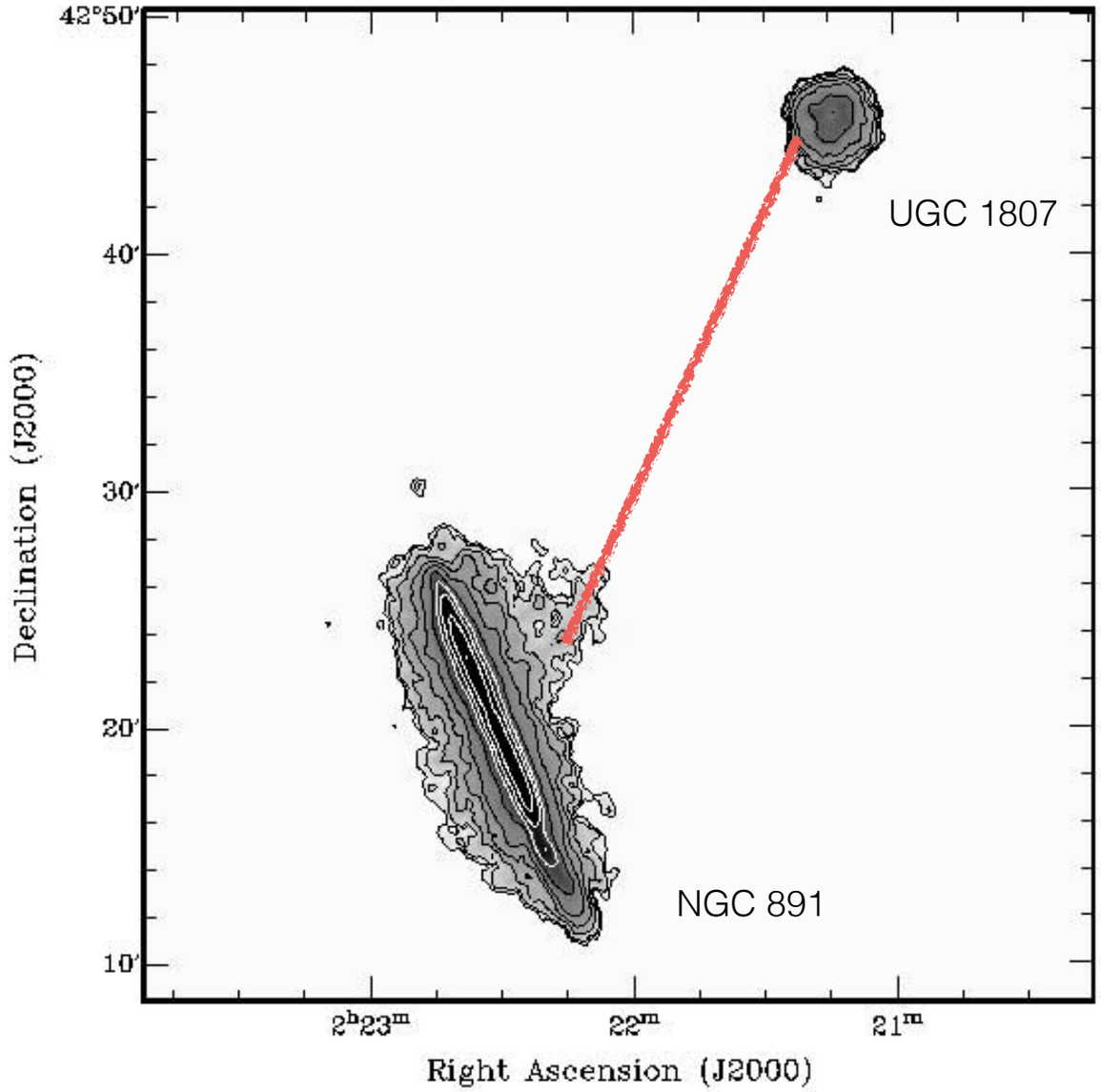




Oosterloo et al 2007



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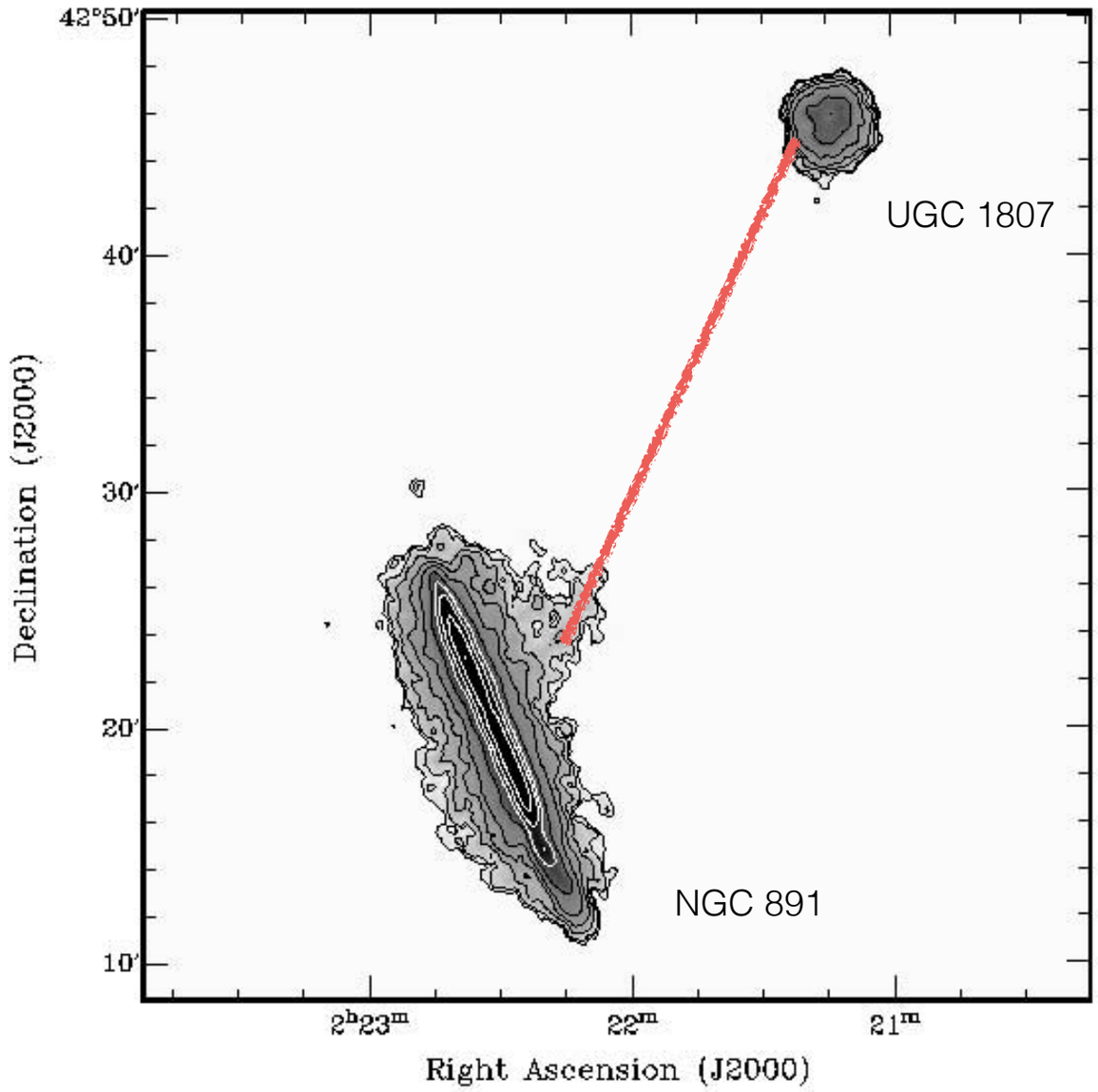

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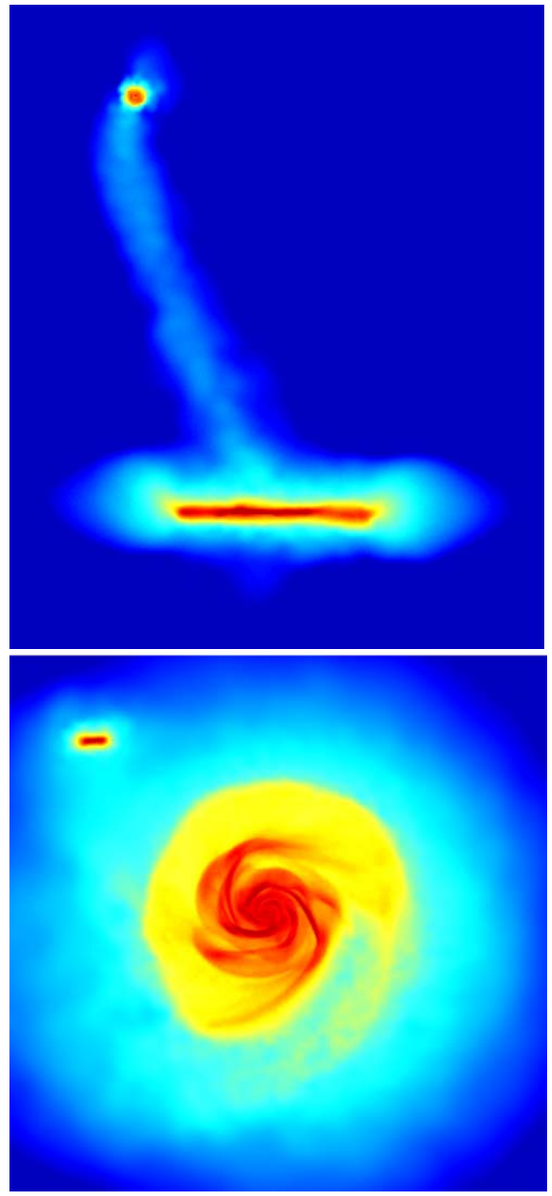
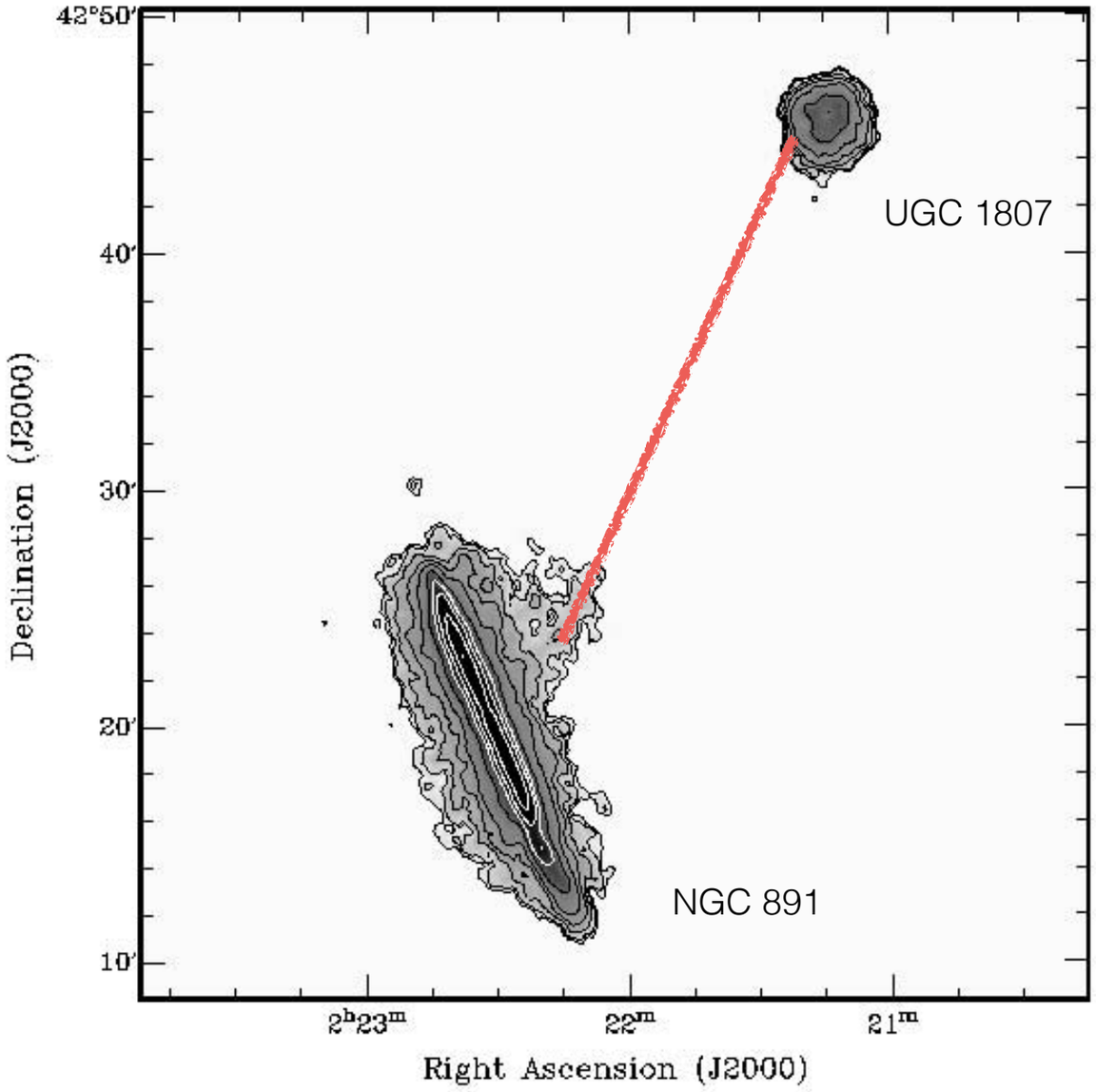
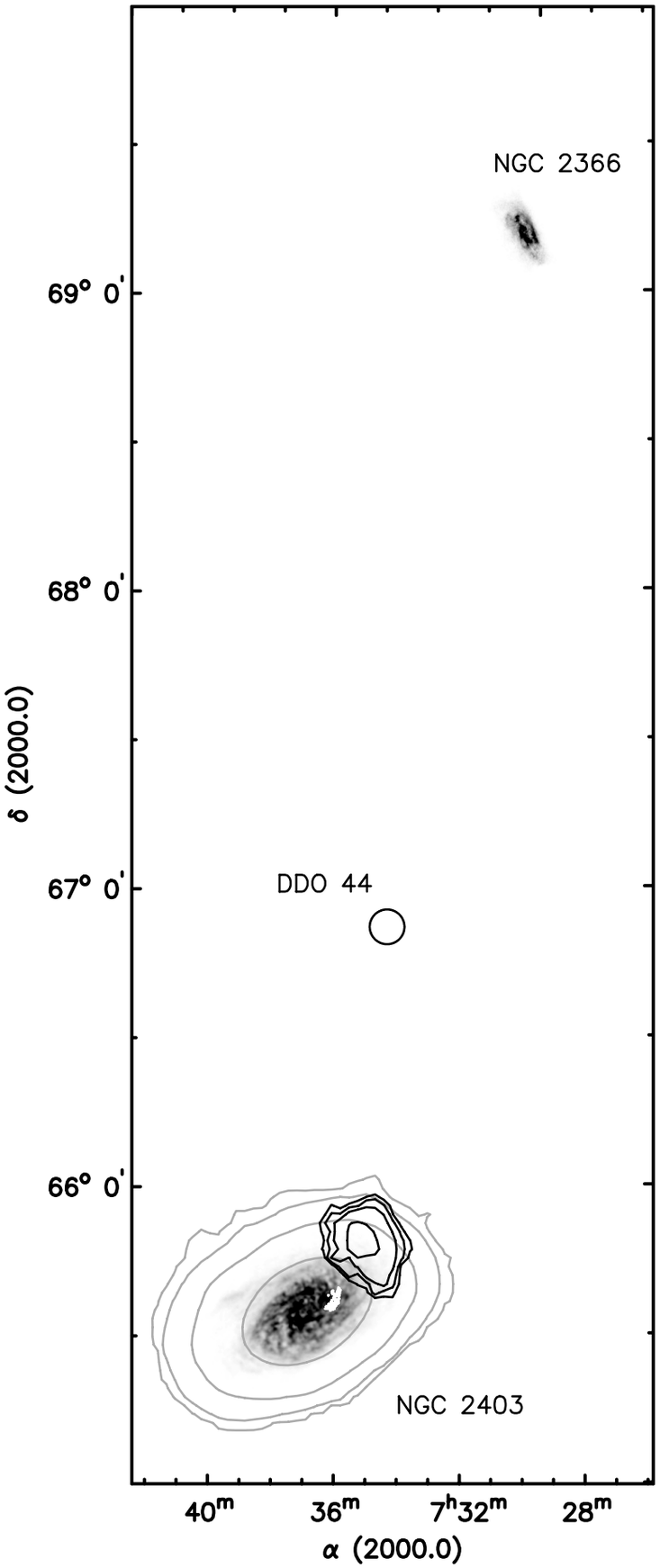


Mapelli et al 2008





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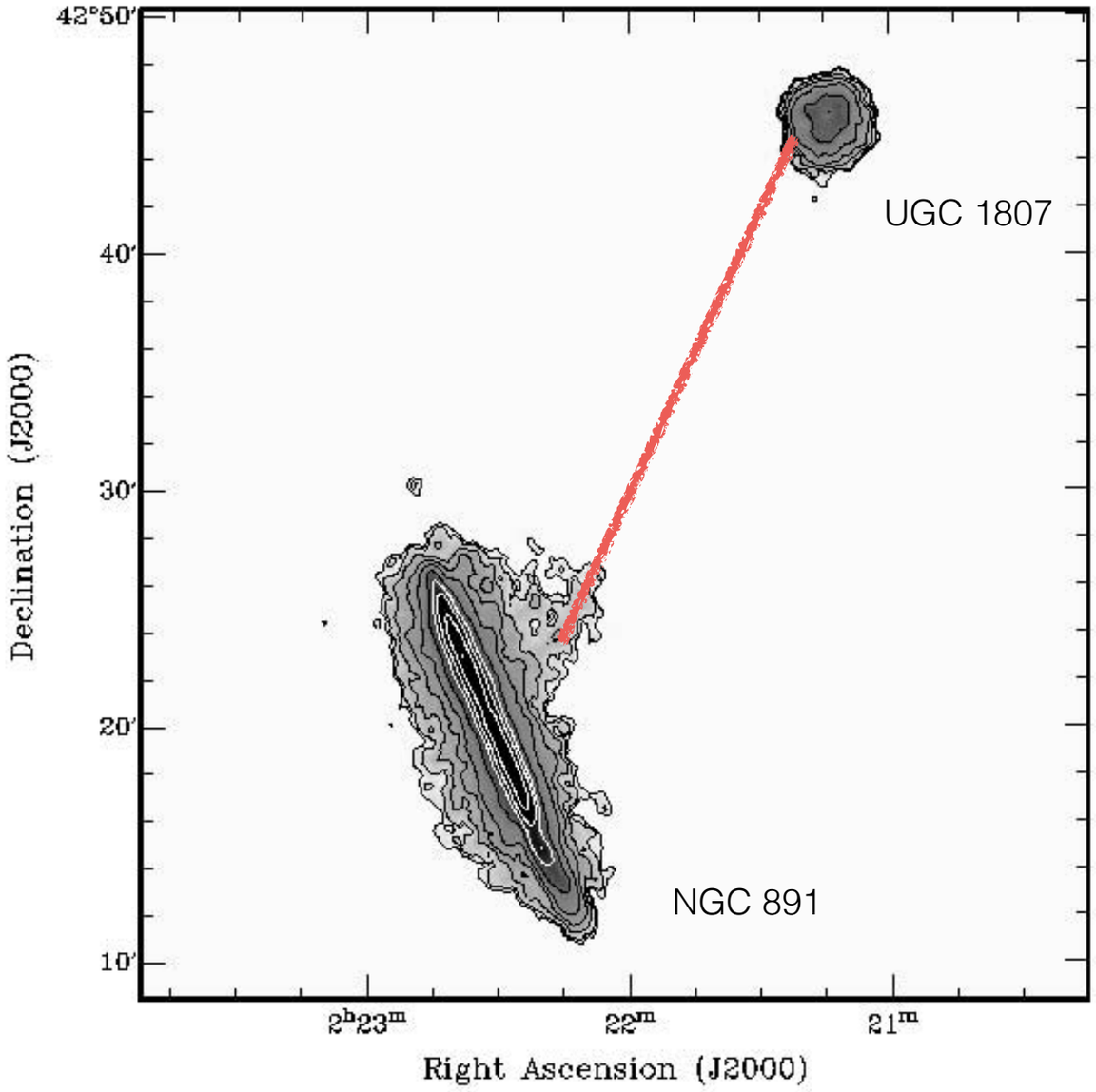

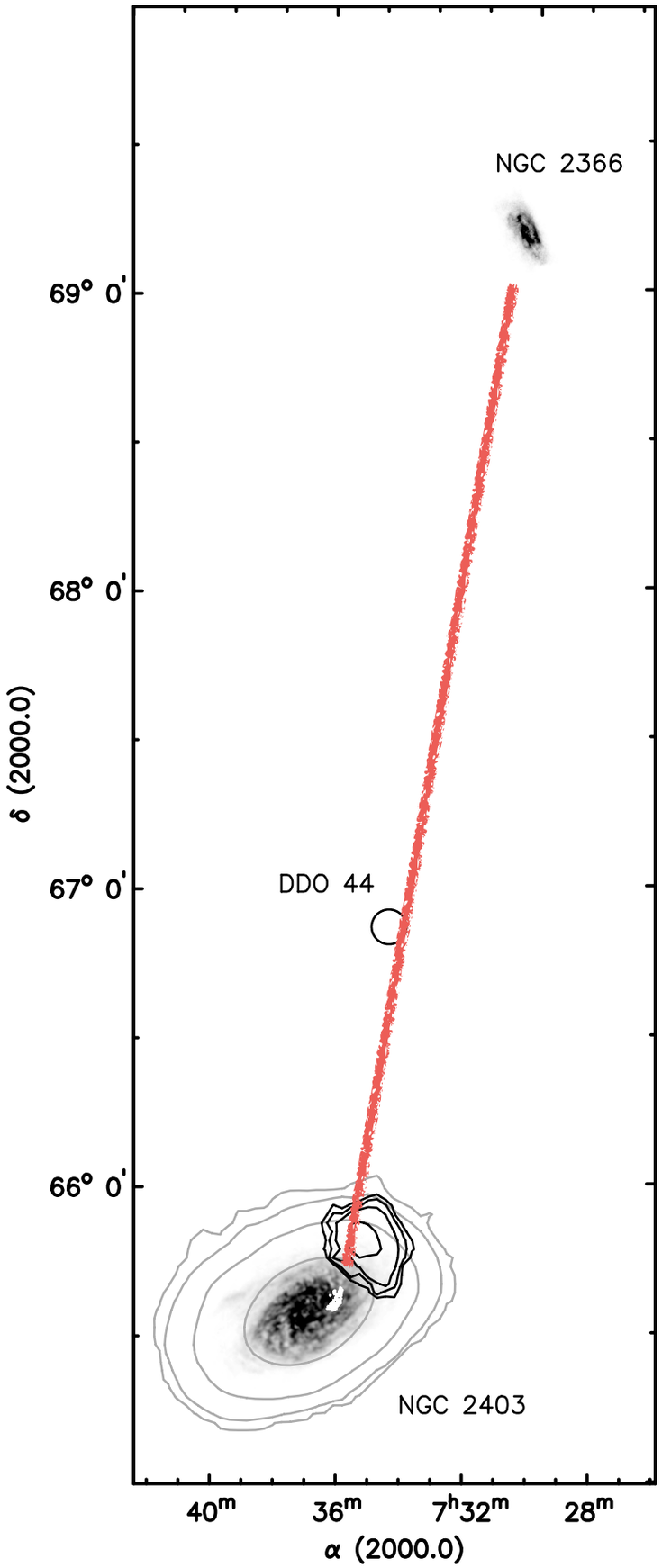

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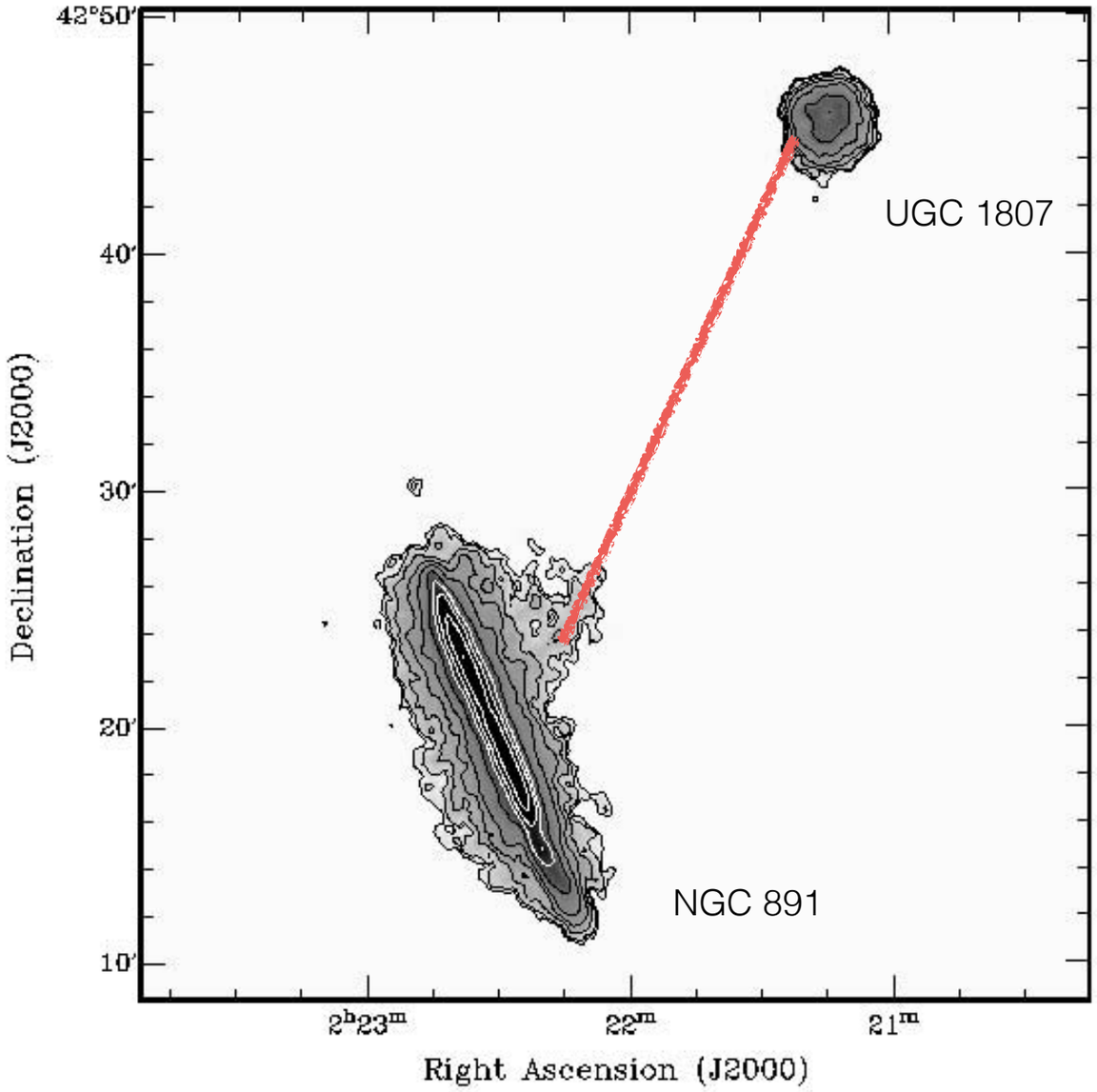
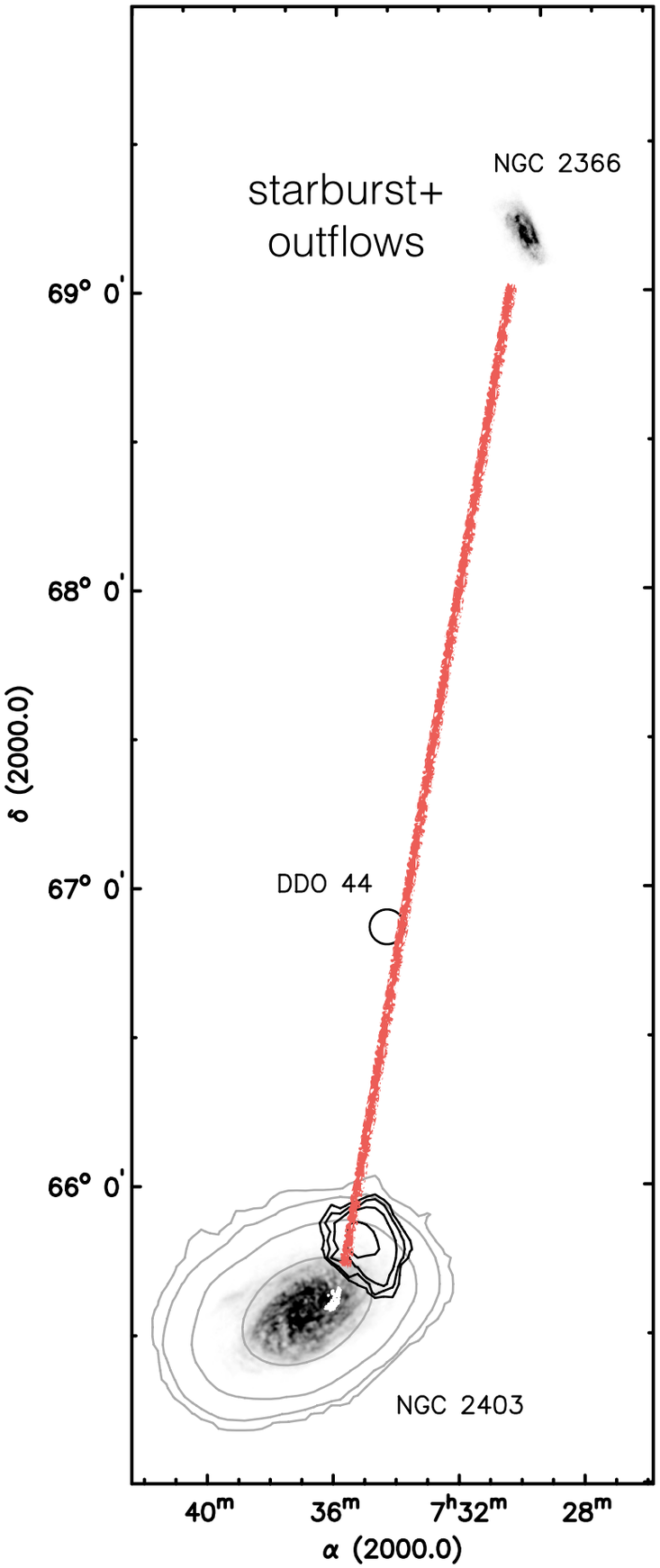
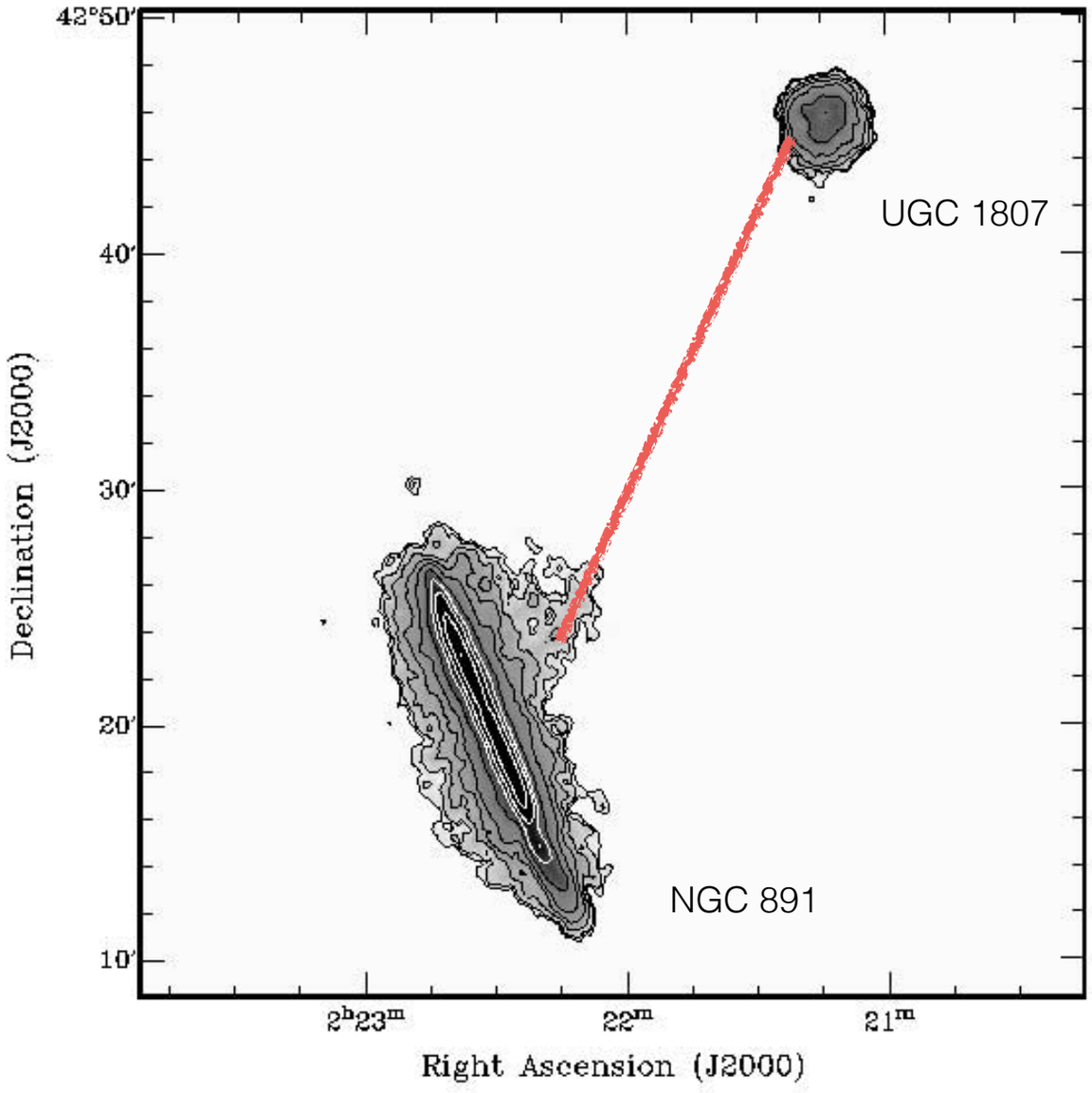
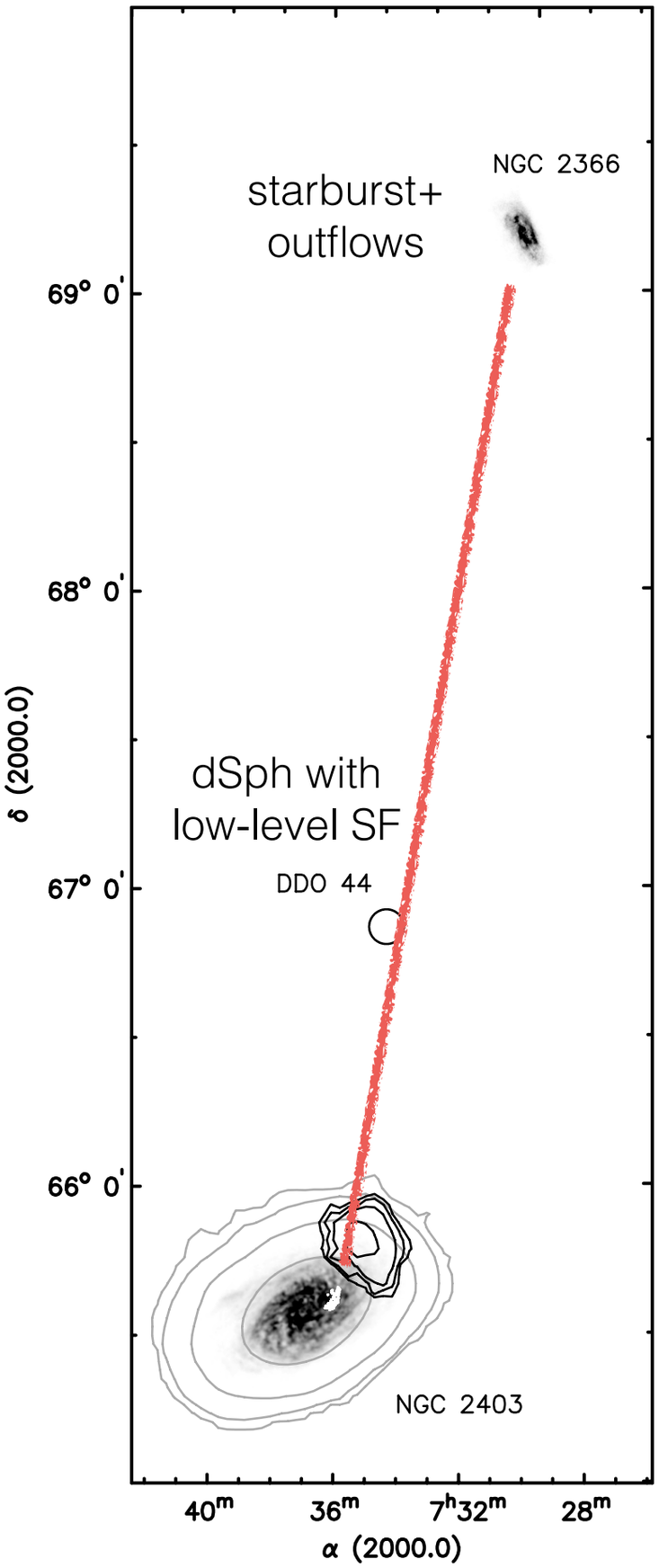




Oosterloo et al 2007





Oosterloo et al 2007

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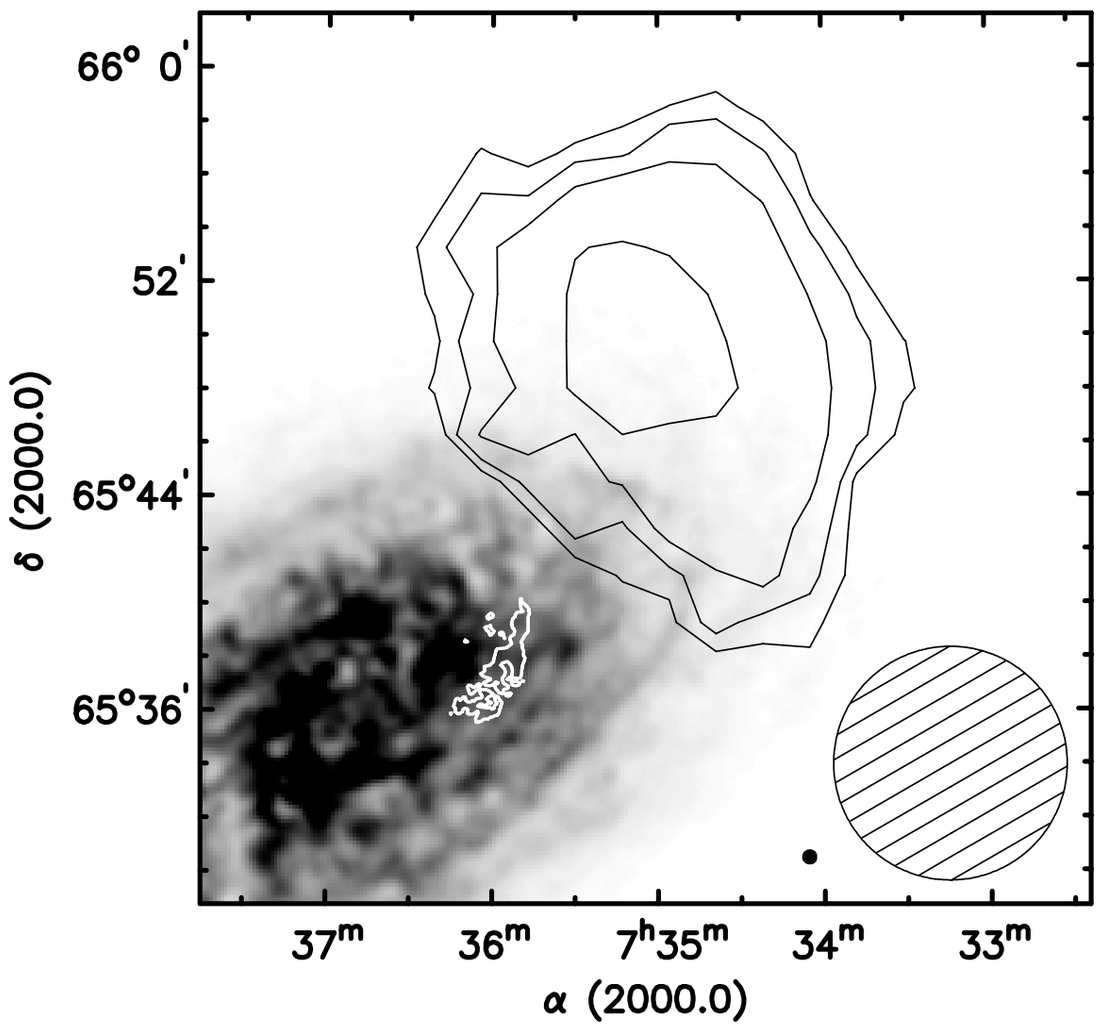

Summary

- NGC 2403 mapped by GBT to ~10^{18} cm^{-2}
- ~10^7 $M_\odot$ HI cloud, connected with 8-kpc filament
- Possibly accretion or fly-by
- Further analysis of sample to constrain importance and nature of features

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- ~10^7 $M_\odot$ HI cloud, connected with 8-kpc filament
- Possibly accretion or fly-by
- Further analysis of sample to constrain importance and nature of features
- At 3σ level (~5 10^{17} cm^{-2}) no other features in cube