Kinematics of Multiphase Extraplanar Gas in Spiral Galaxies

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ASTRON

3D2008

Garching

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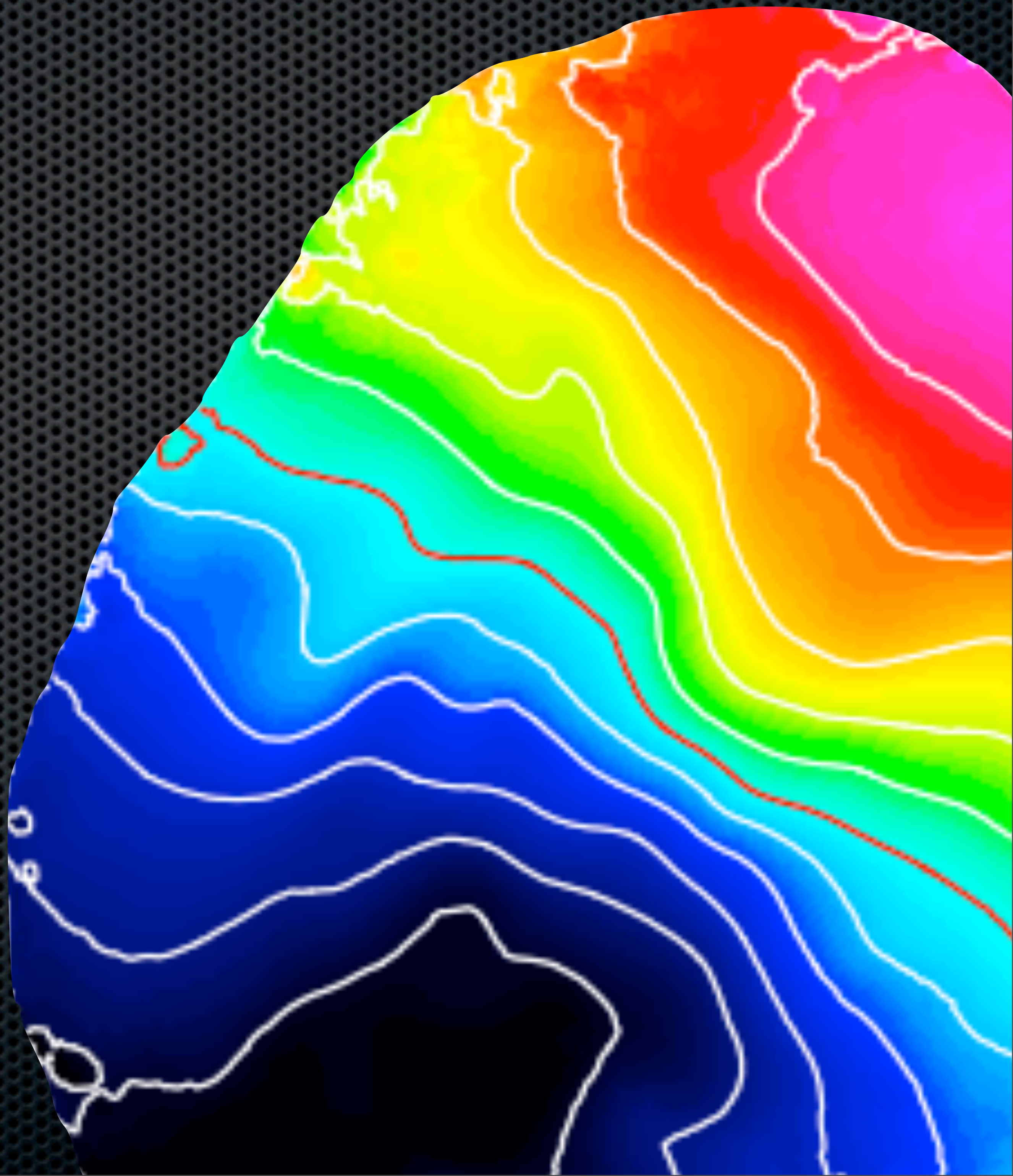
In collaboration with:
R. Rand, B. Benjamin, M. Bershady,
J. Collins, J. Bland-Hawthorn

ASTRON NWO

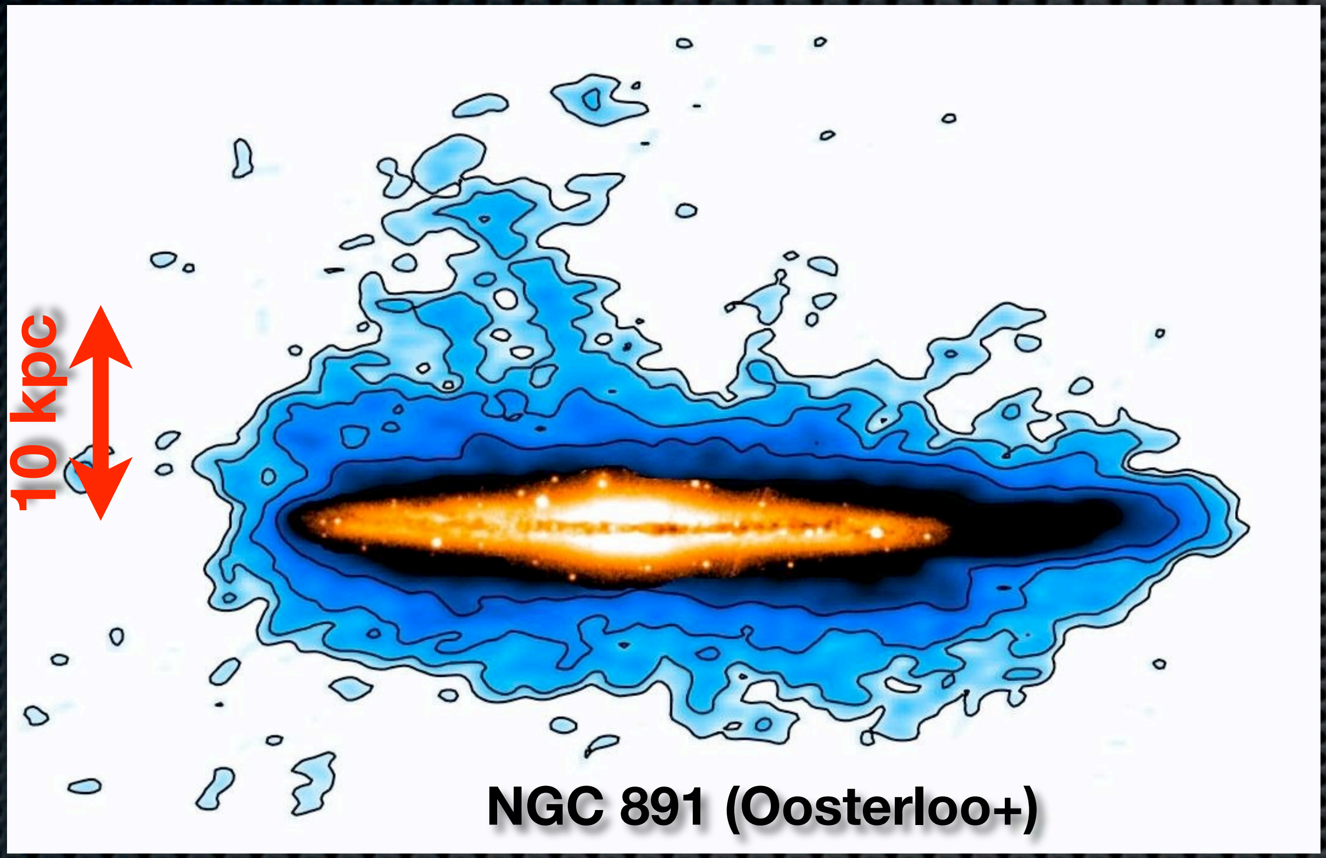


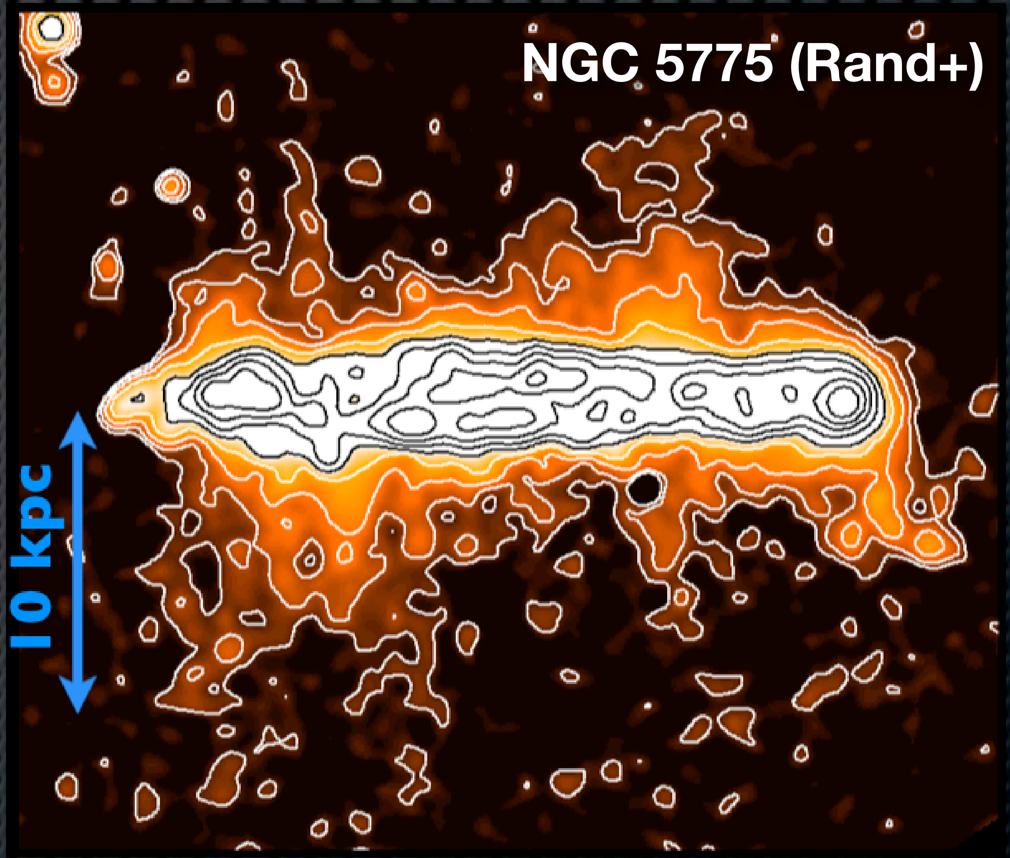
Outline

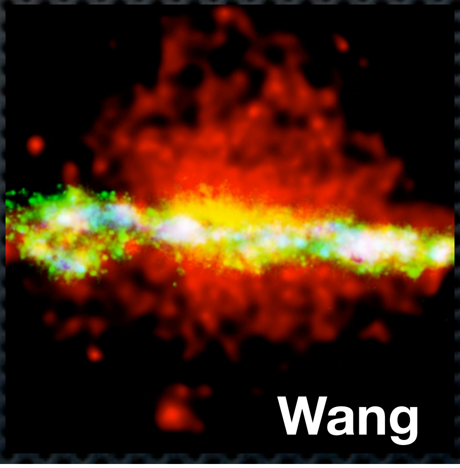
- Extraplanar gas in spiral galaxies: morphology, kinematics
- Fabry-Perot imaging spectroscopy: NGC 5775
- SparsePak IFU spectroscopy: NGC 891, NGC 4302
- WSRT HI observations: NGC 4395
- Conclusions

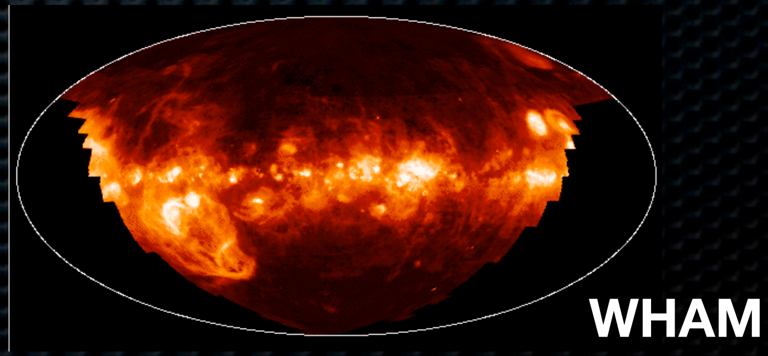
Extraplanar gas in spiral galaxies

- Deep observations of (edge-on) spirals show thick, vertically extended, ***multi-phase*** gas layers



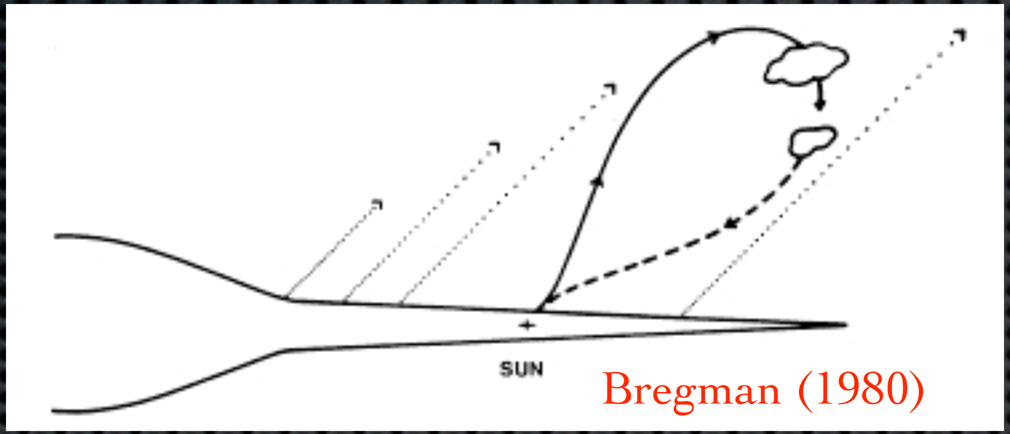






Extraplanar gas: kinematics

- What is the origin of these extraplanar gas layers?
  - Galactic fountain?



- Accretion? Cold mode expected to be important even at z=0
- Both? ***Kinematics can help determine importance of SF/accretion.***

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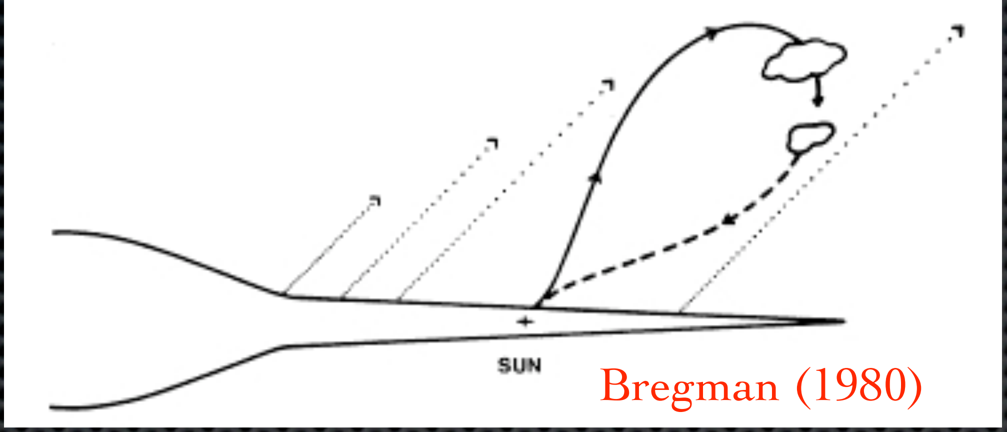

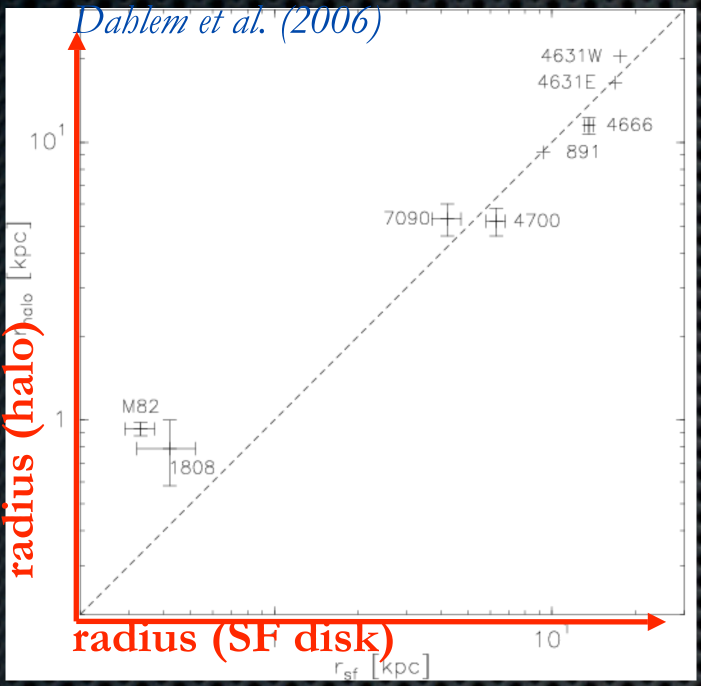

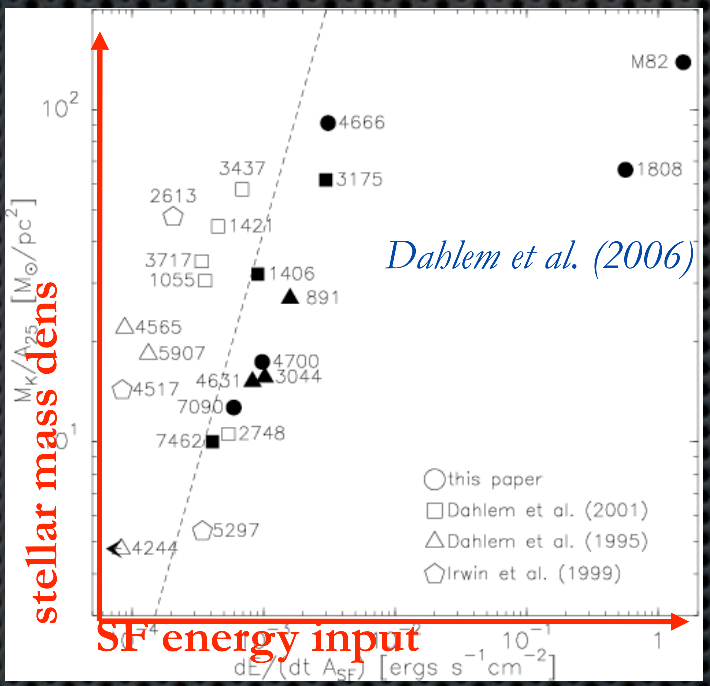

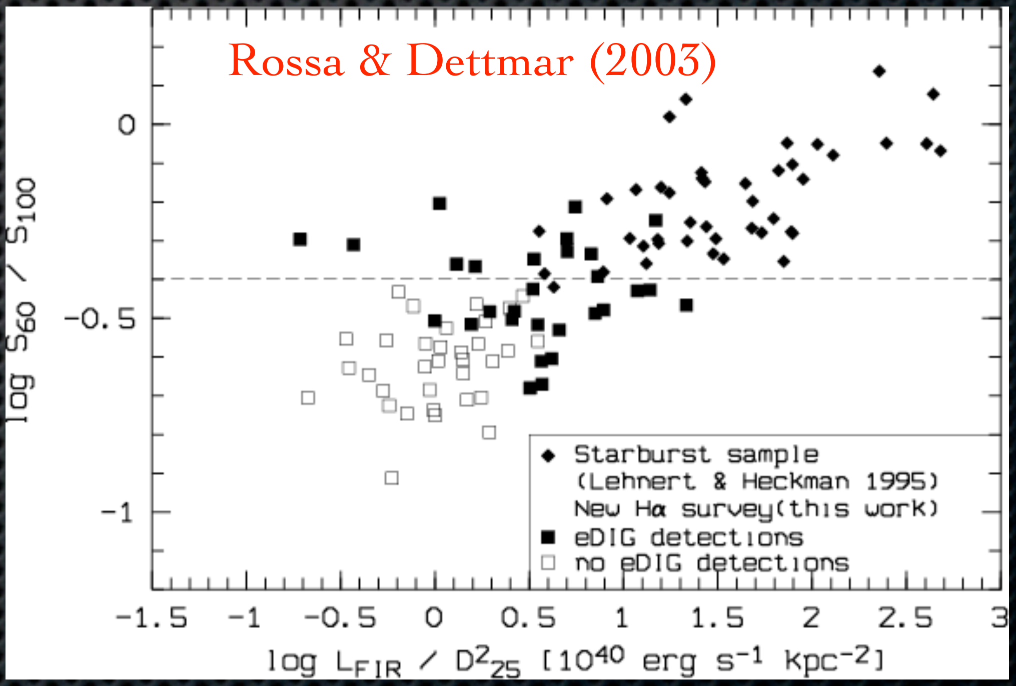

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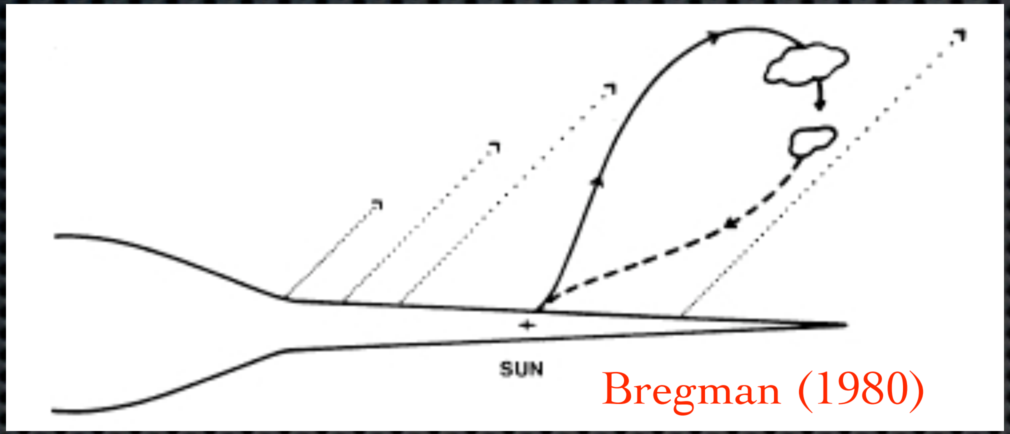

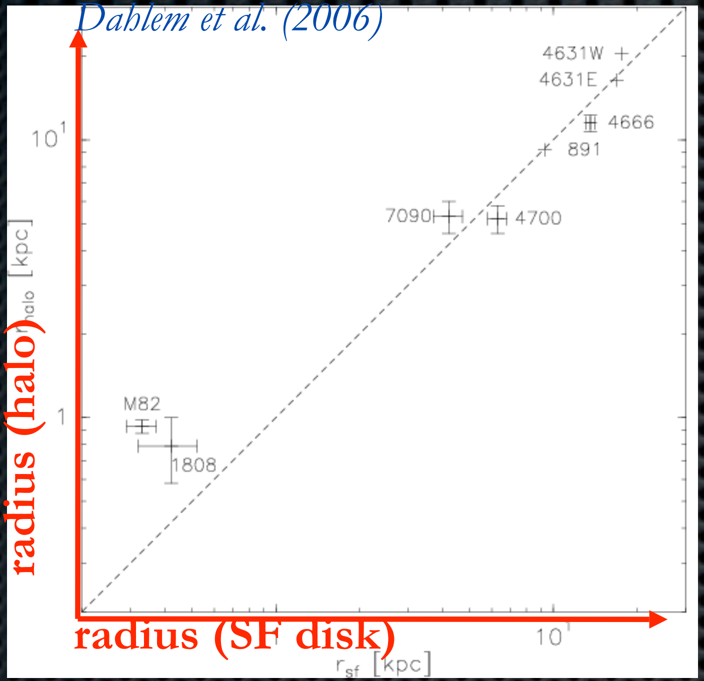

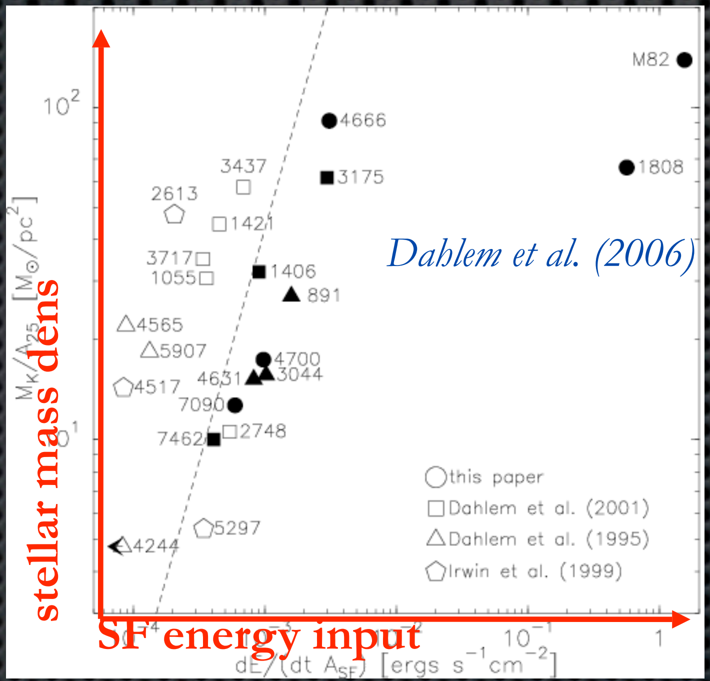

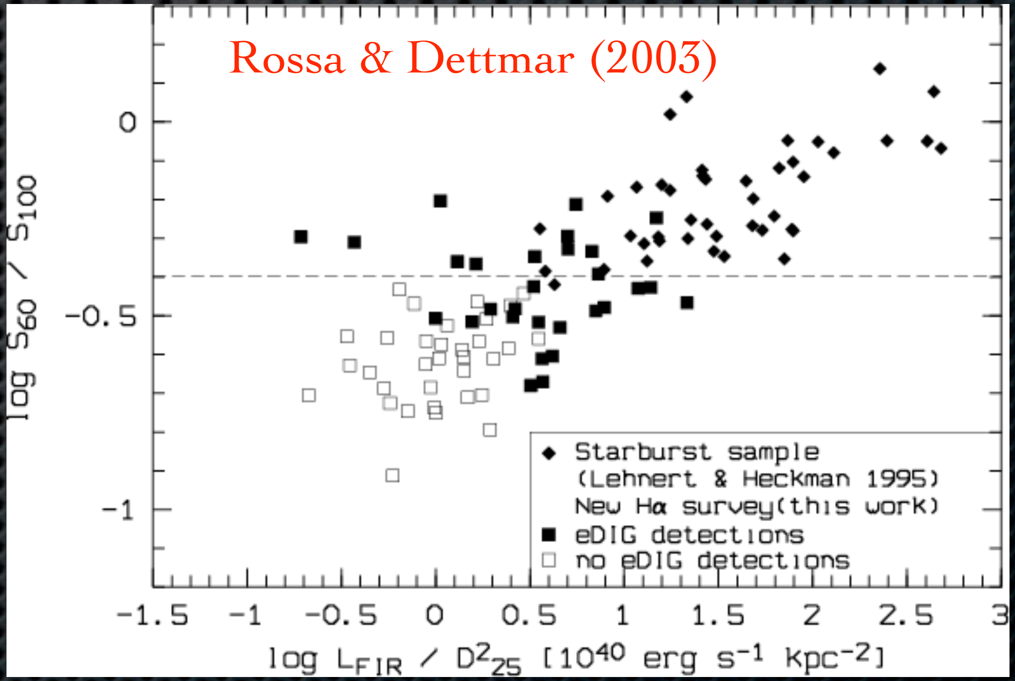

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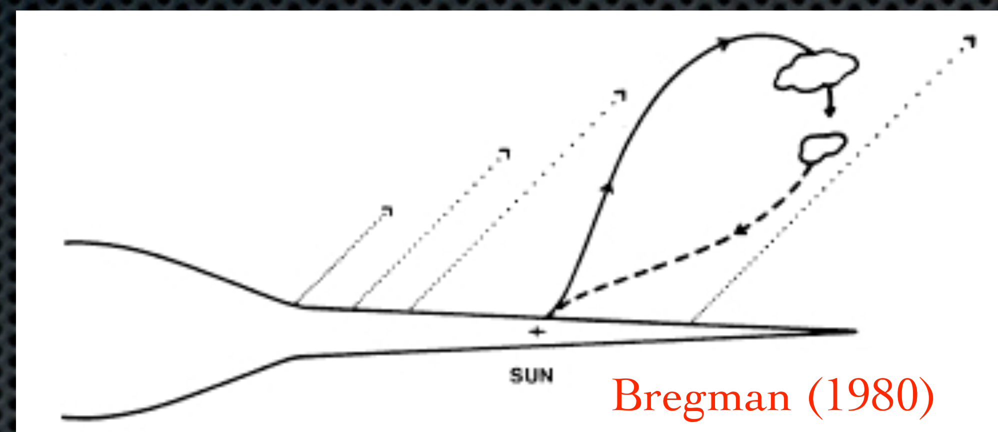

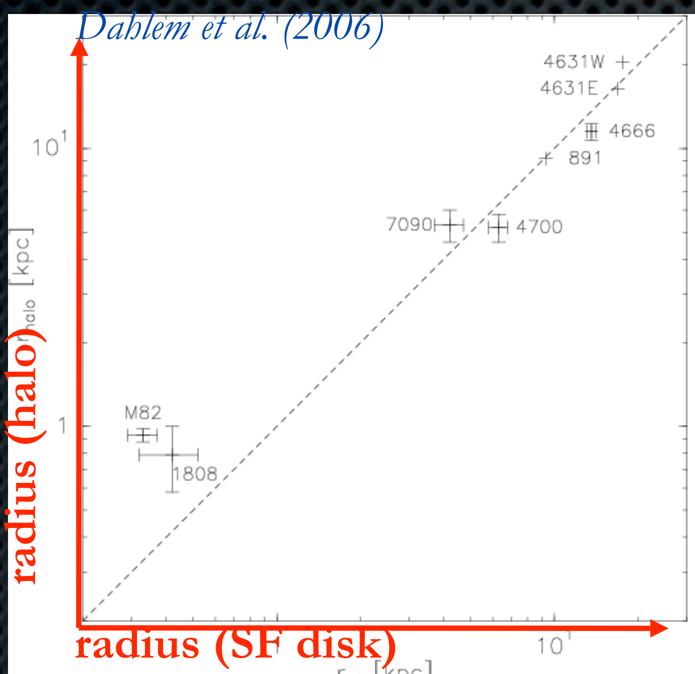

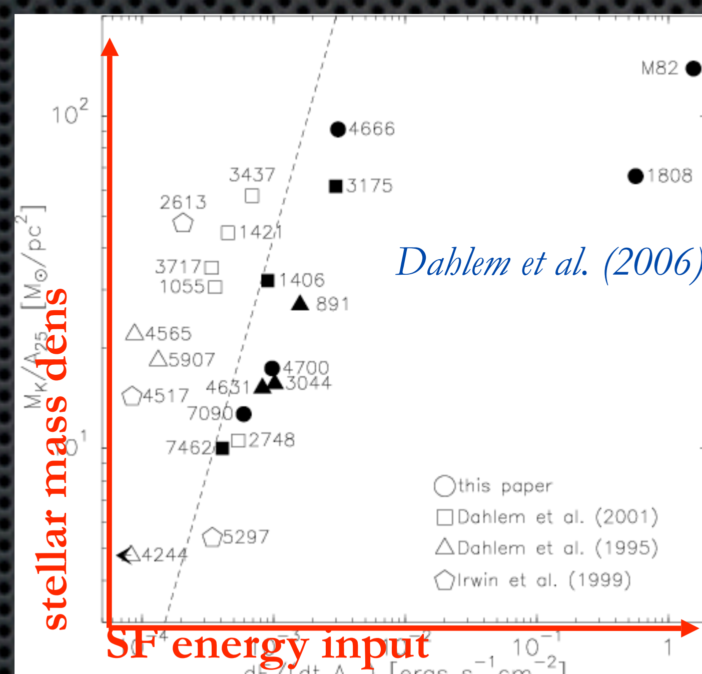

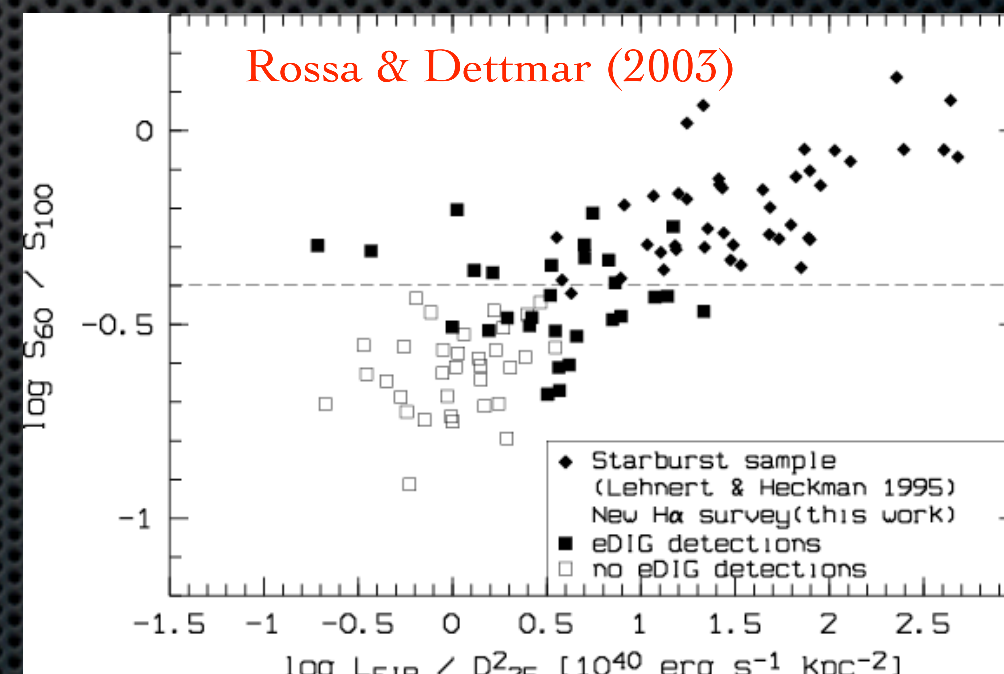

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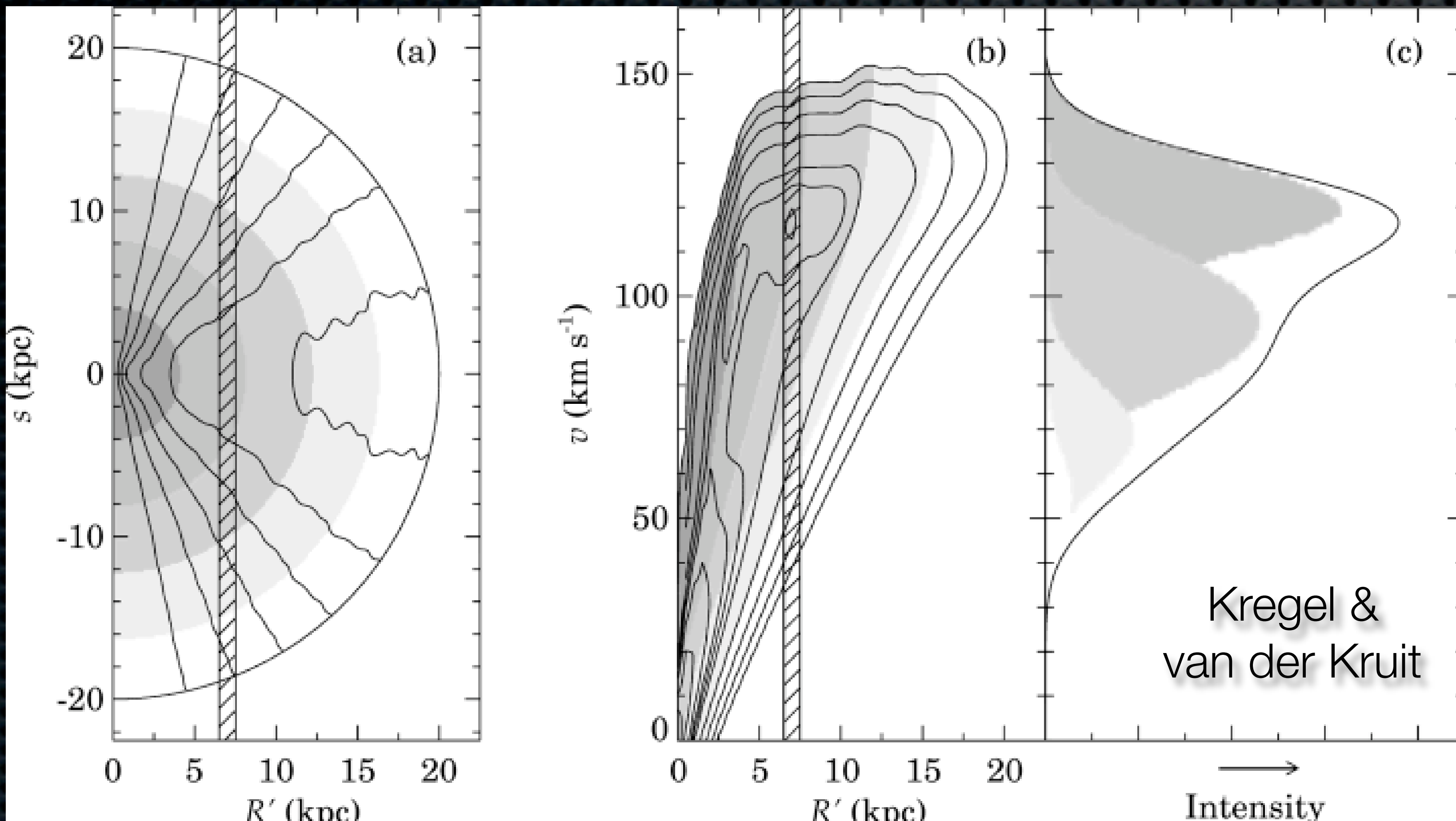
Why 3D?

- In edge-on galaxies, it is essential to understand velocity projections!



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- Vertical gas distribution (for halo kinematics): 2D
- The velocity axis itself: **3D**

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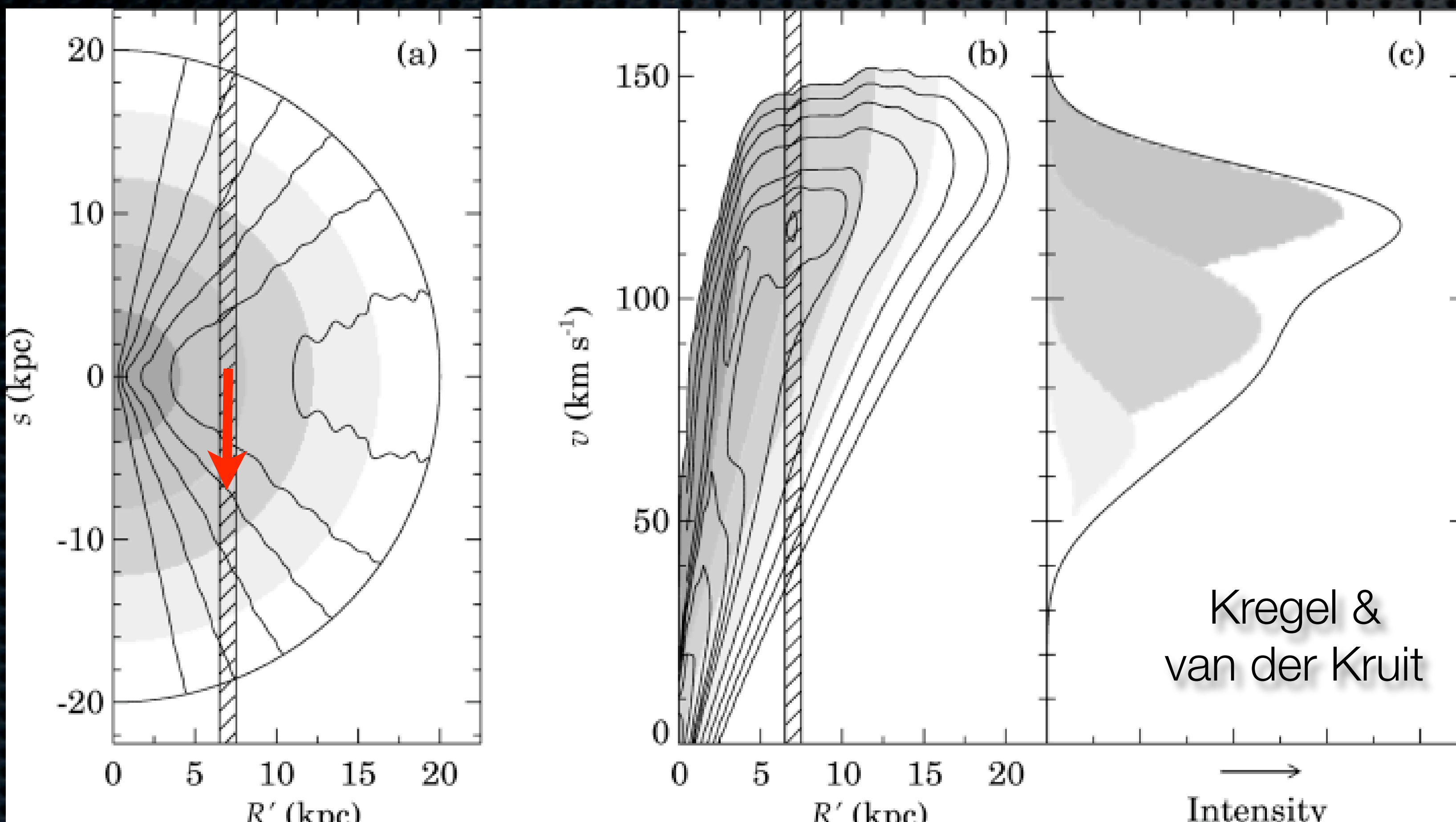

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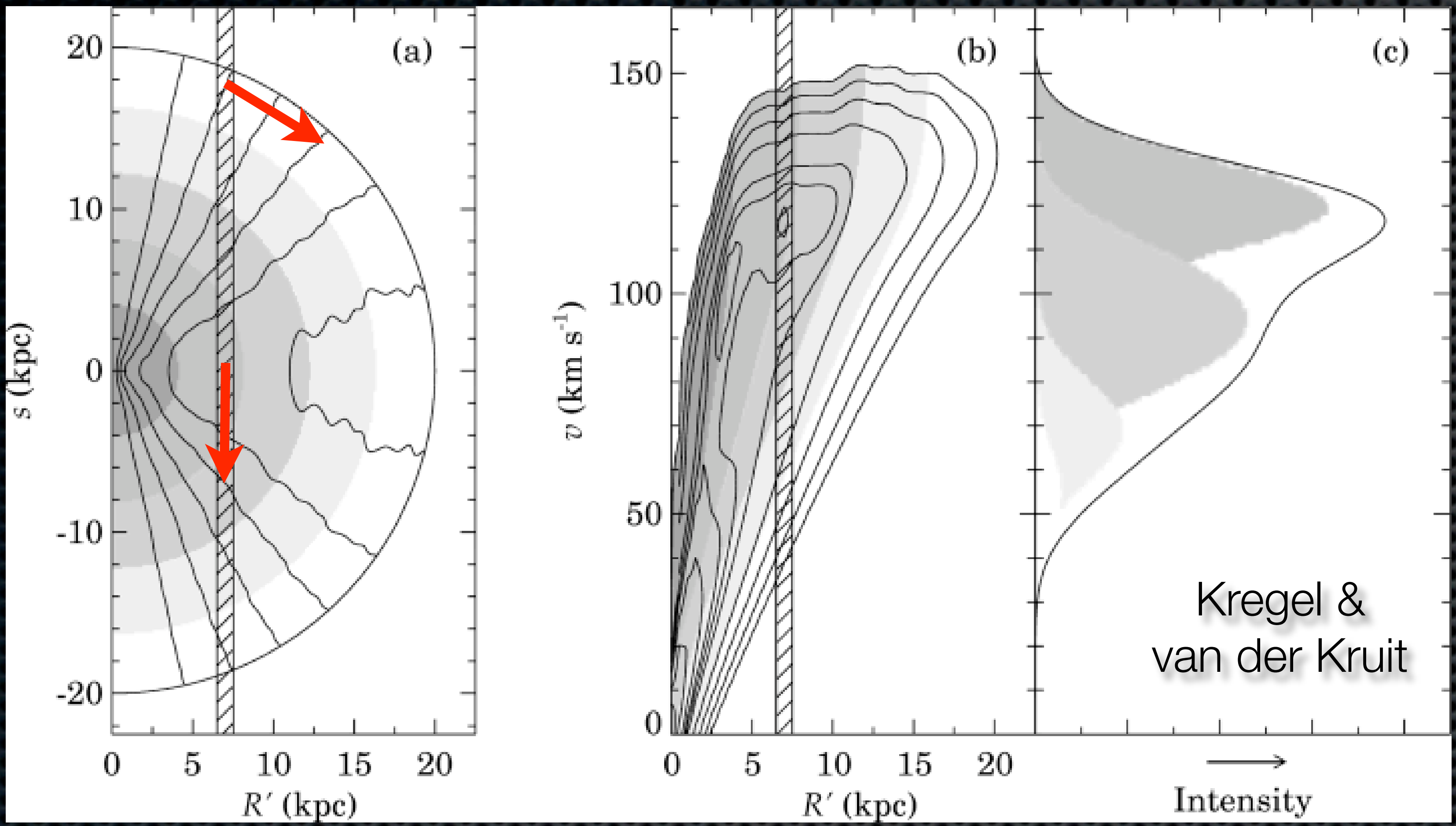

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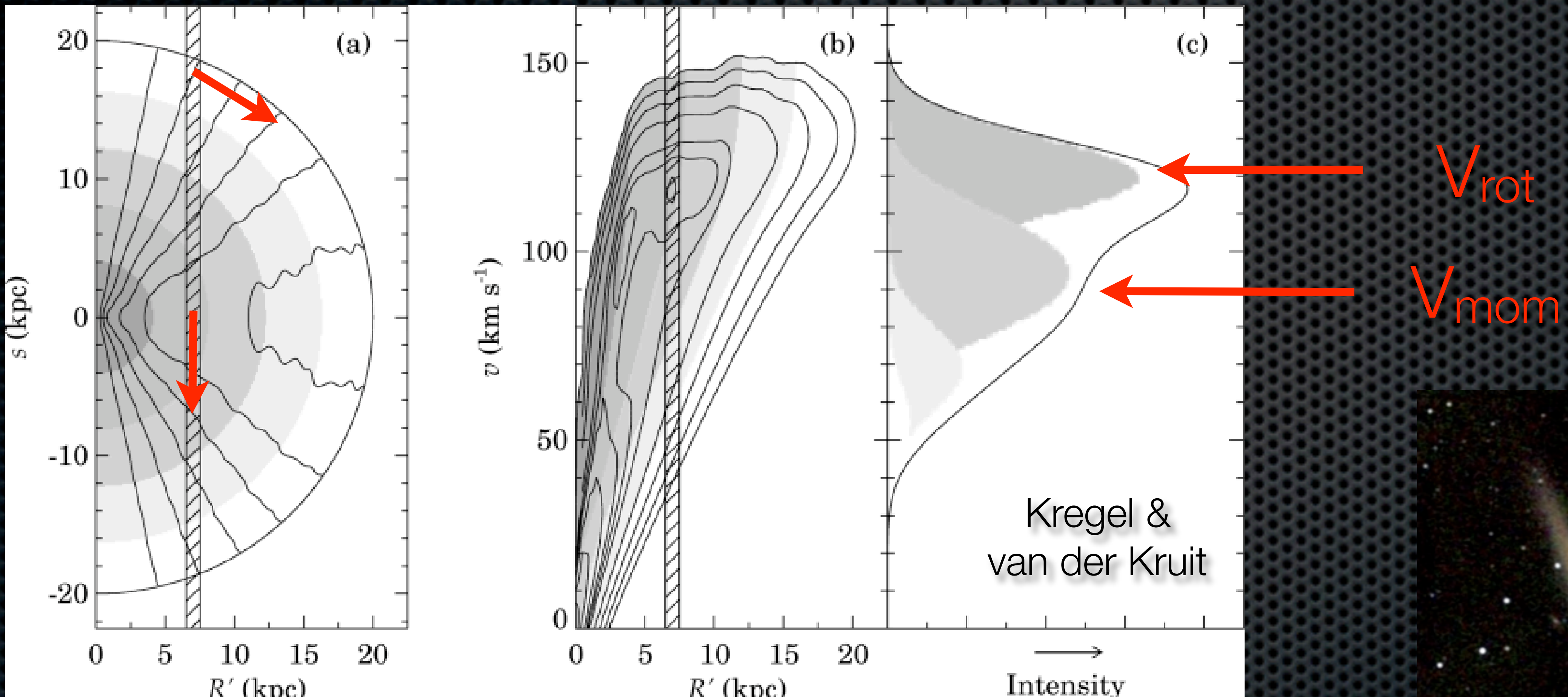

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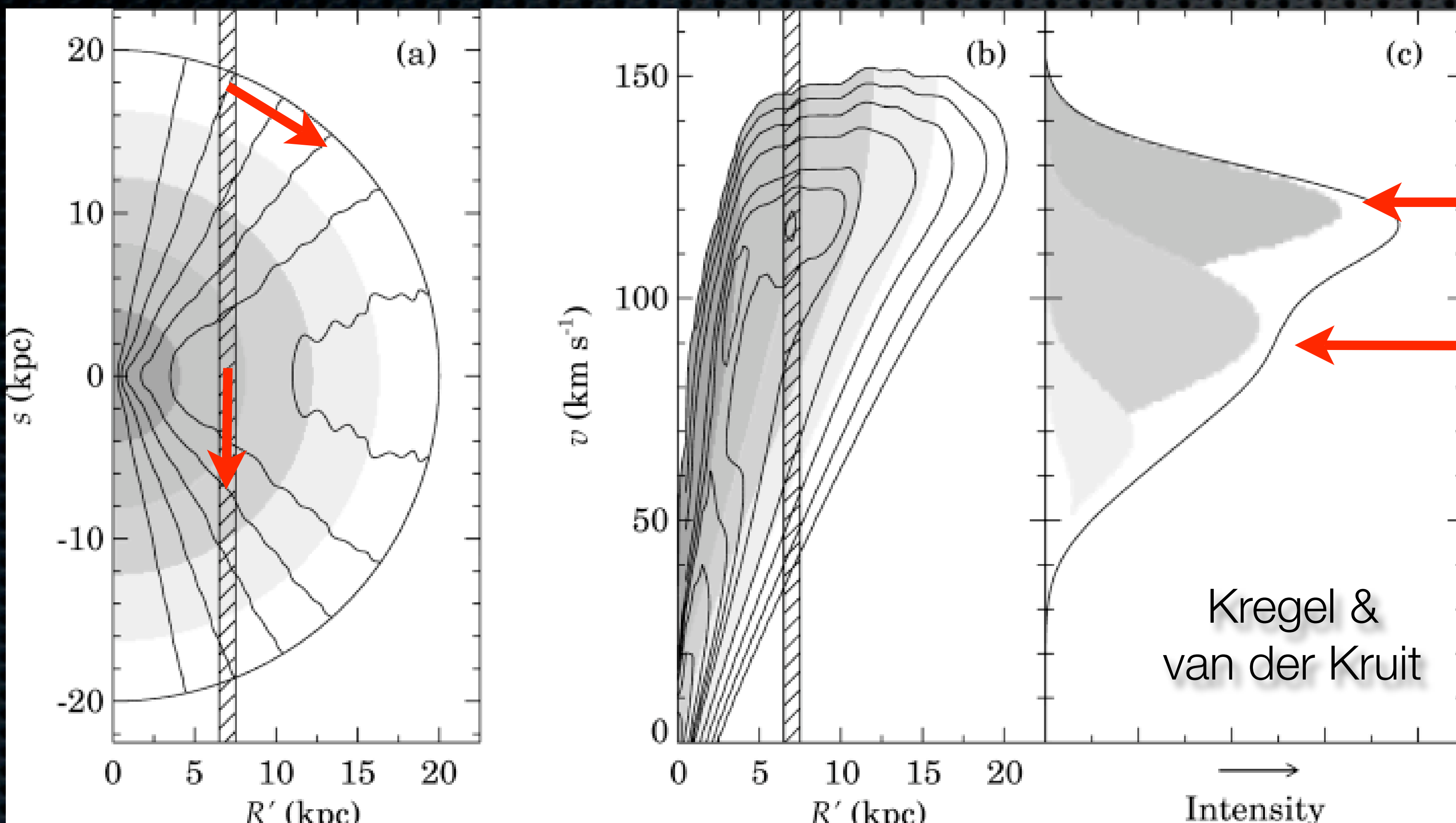

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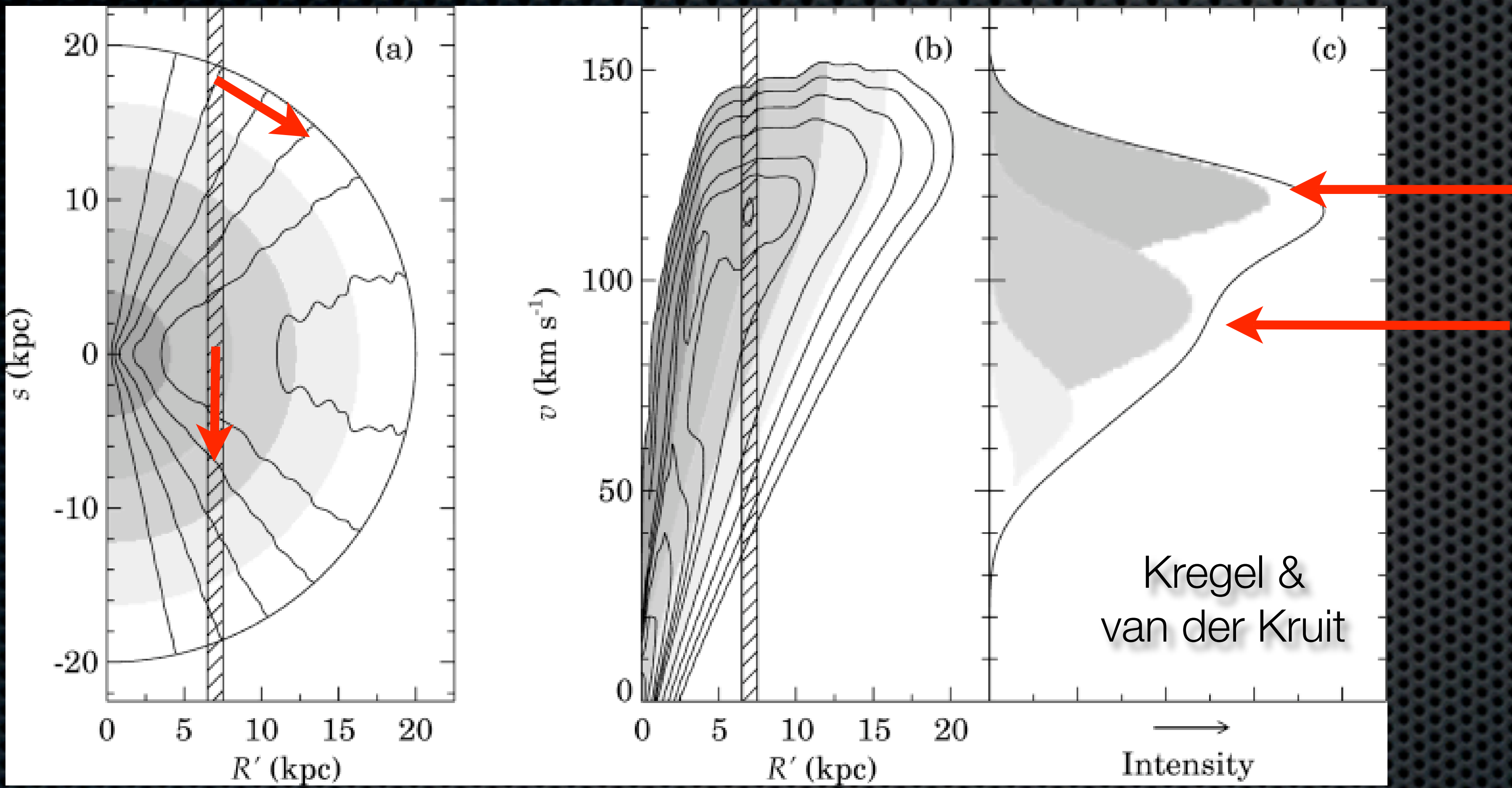

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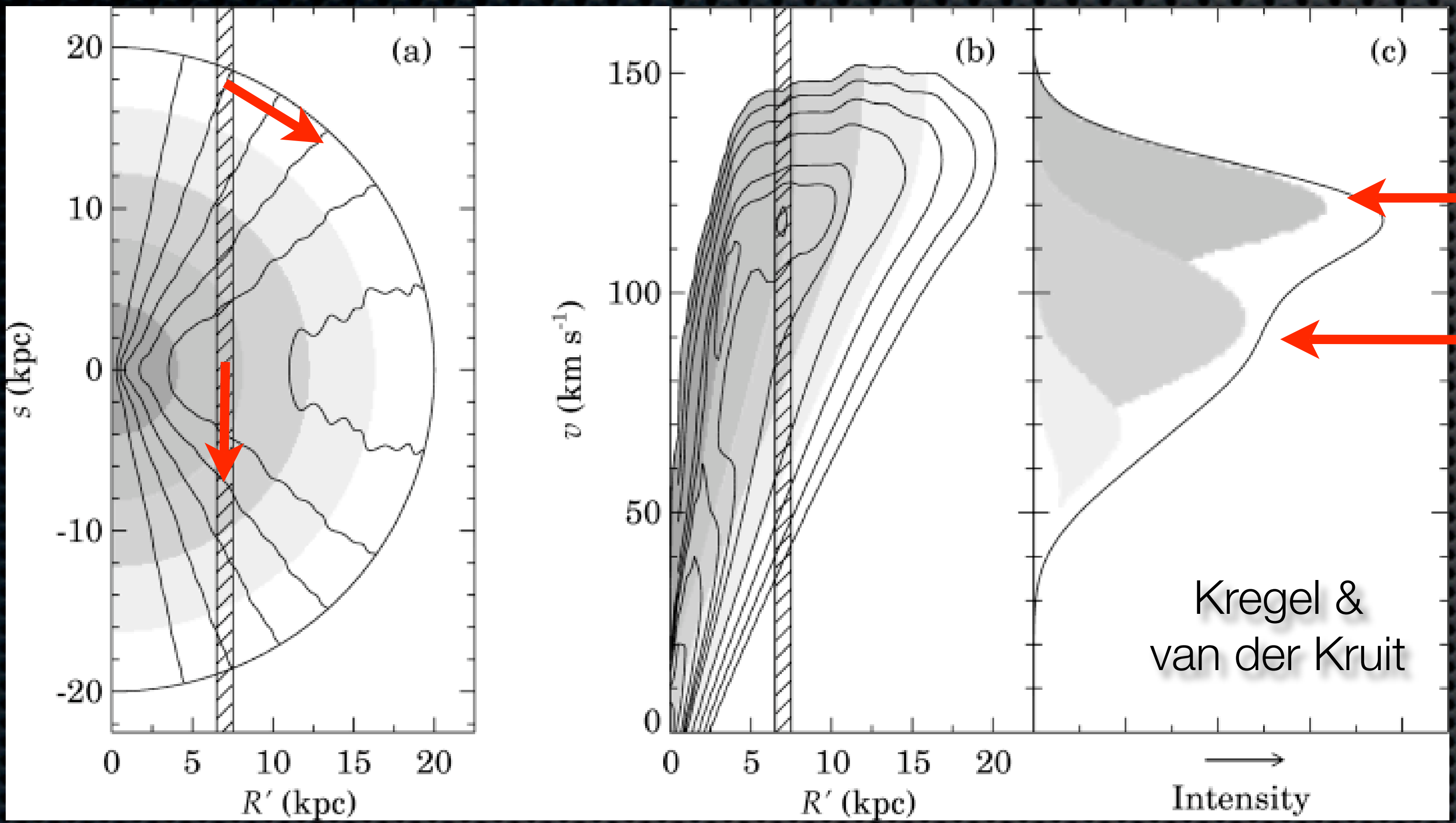

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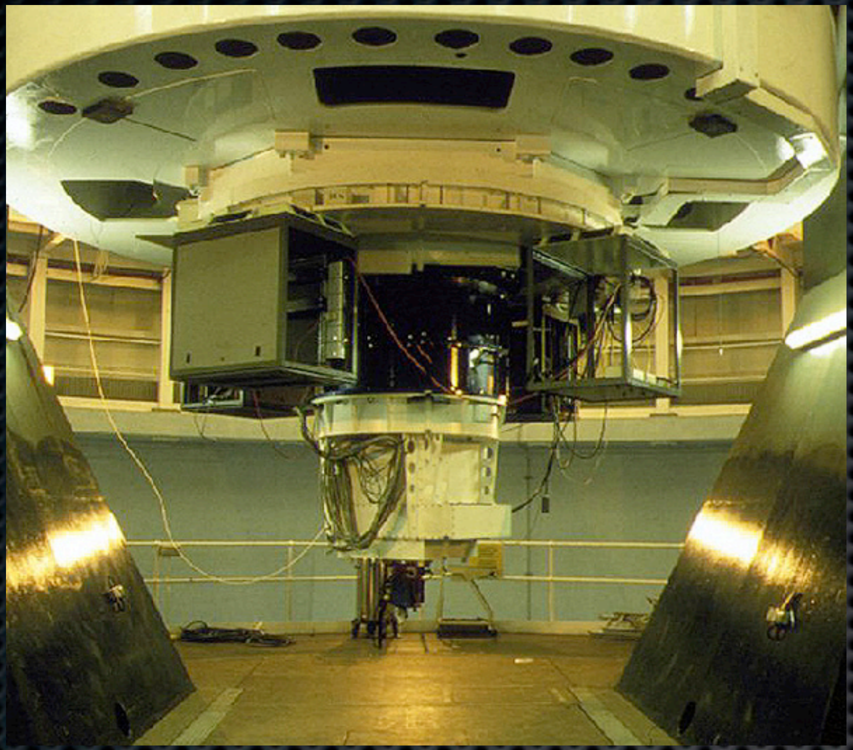
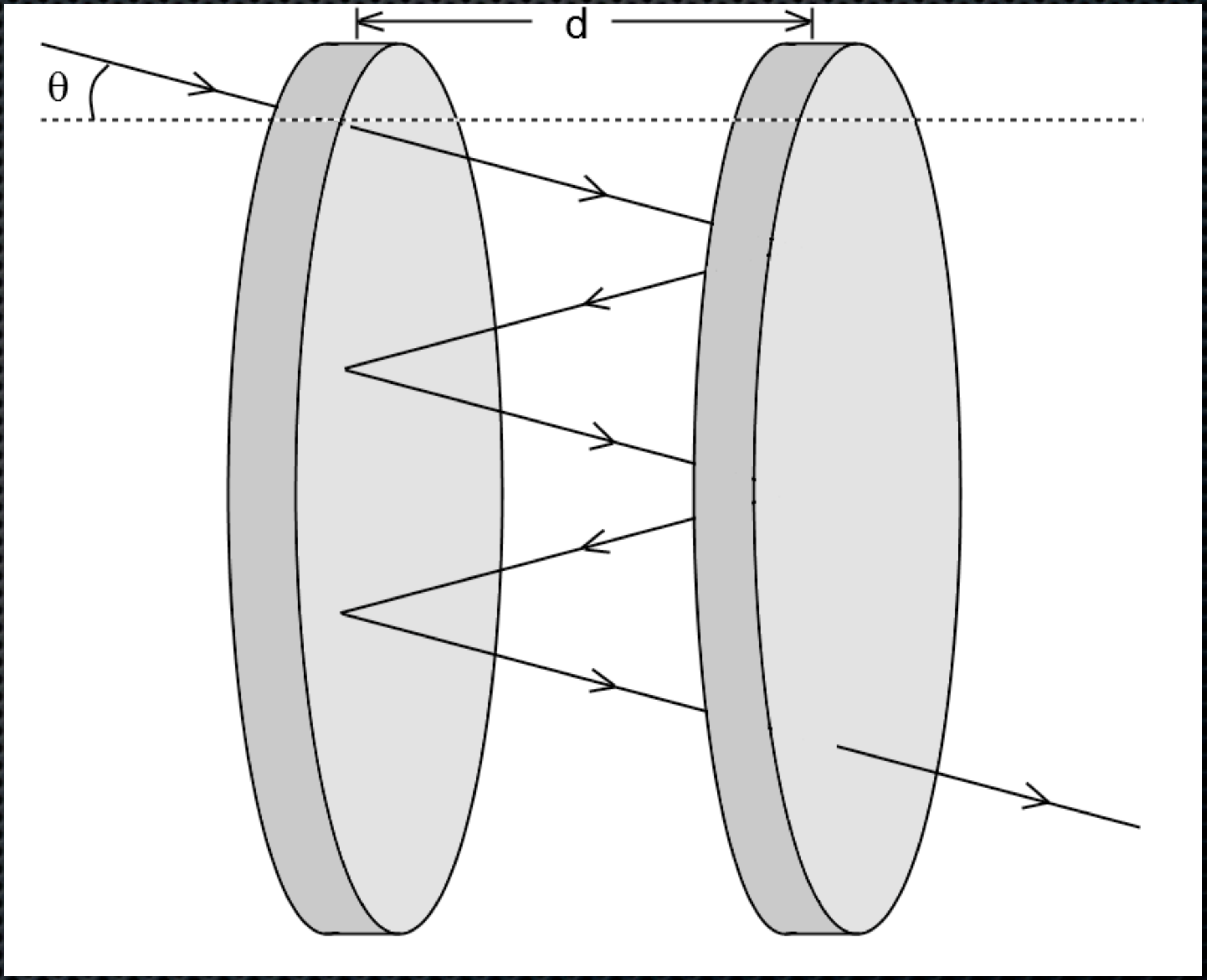
Fabry-Perot imaging spectroscopy

- TAURUS-II (AAT)





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Raw frames:
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- cosmic rays hits
- sky line rings
- stellar continuum
- Halpha emission

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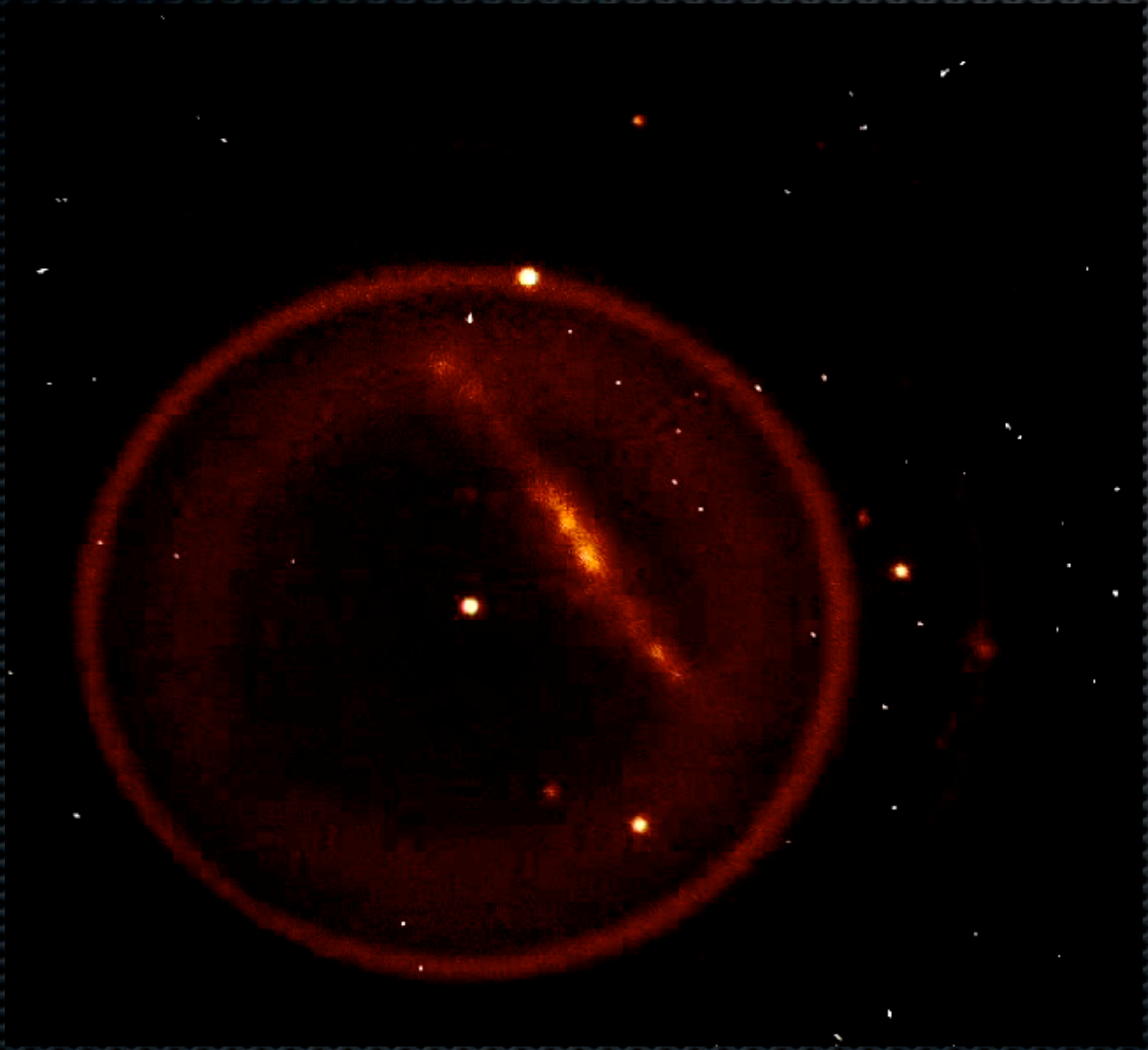

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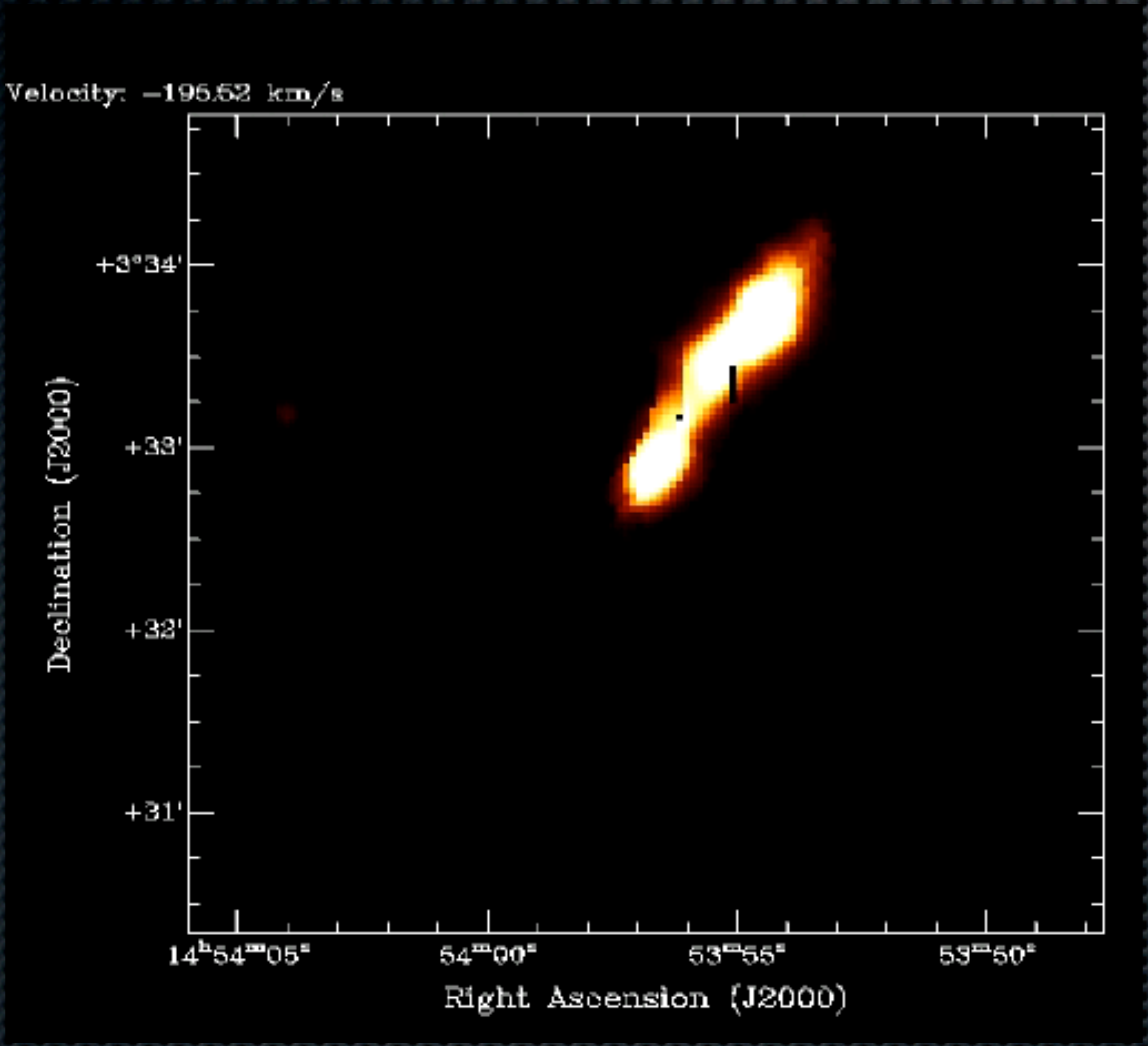

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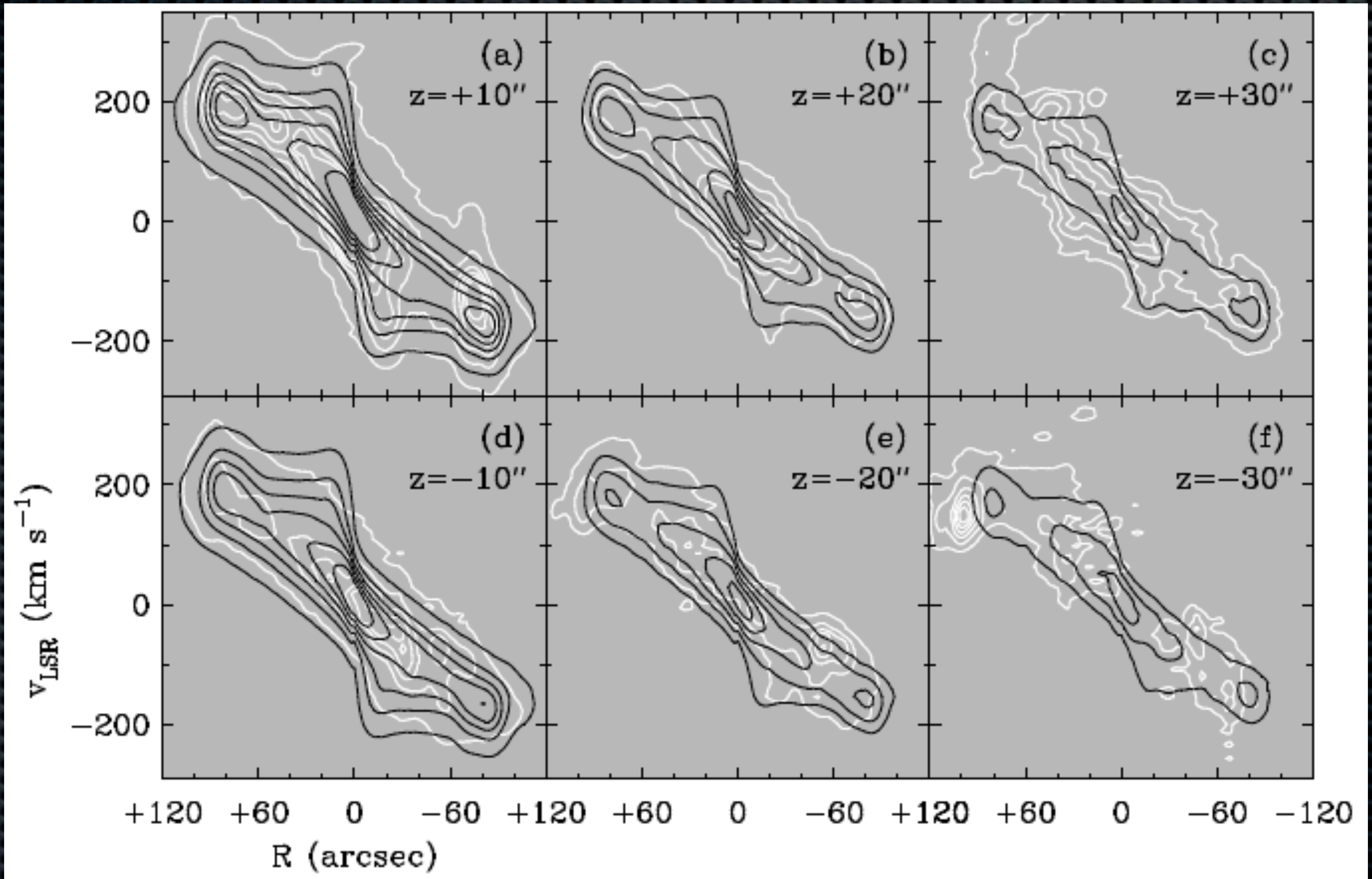
Fabry-Perot imaging spectroscopy

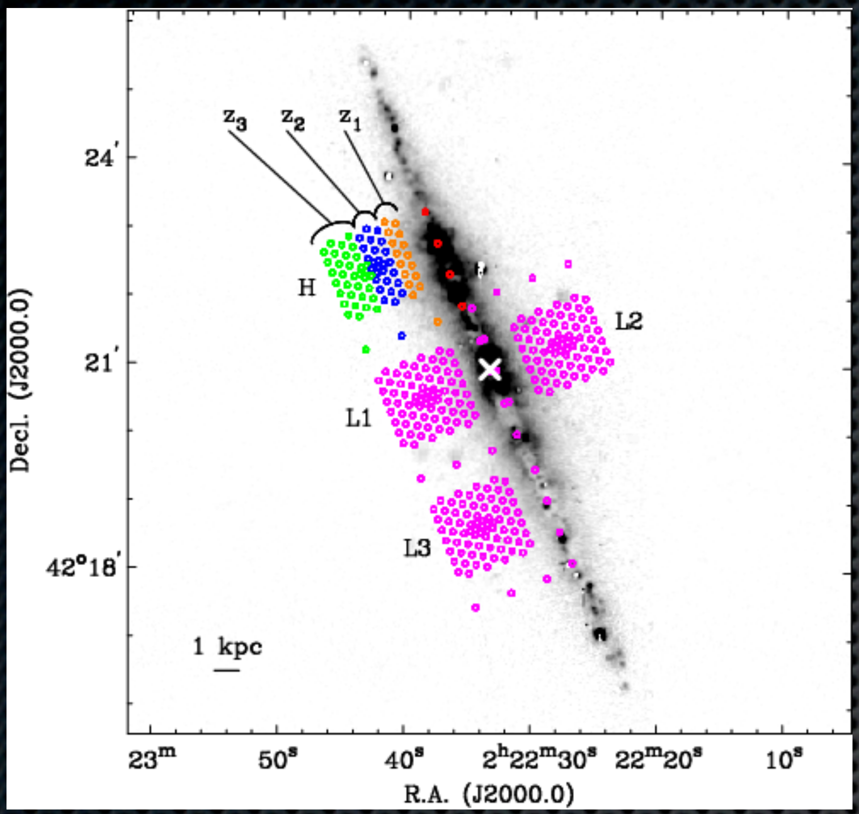
- Halo kinematics determined by performing ***geometric modeling*** and comparing simulated data with the real data



NGC 5775 (Heald+ 2006, ApJ, 636, 181)

SparsePak IFU spectroscopy

- SparsePak (WIYN) = 82 fiber IFU spectrograph



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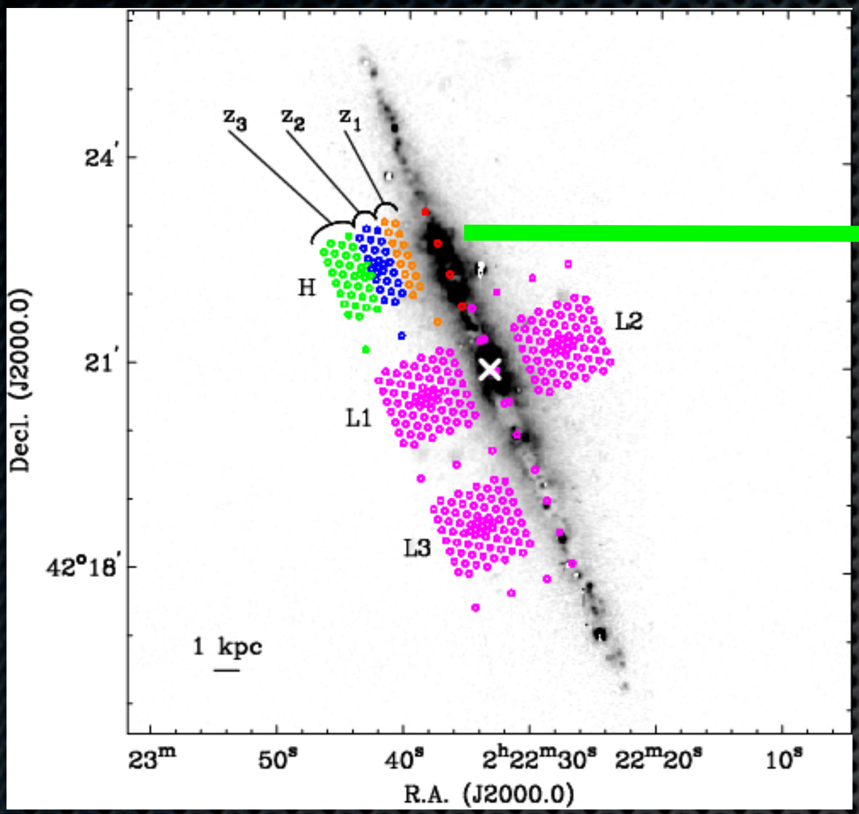

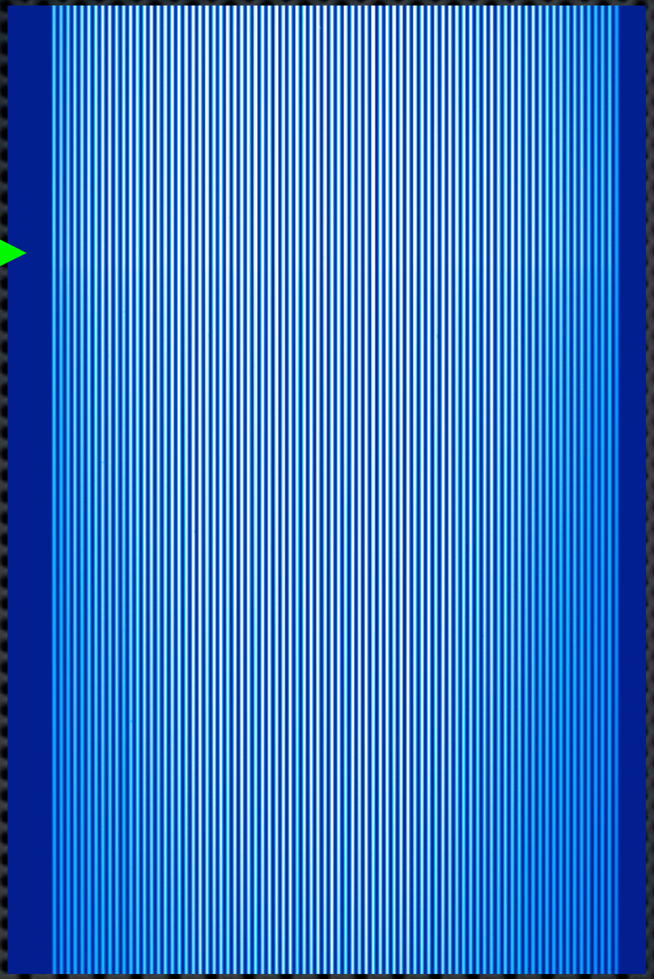

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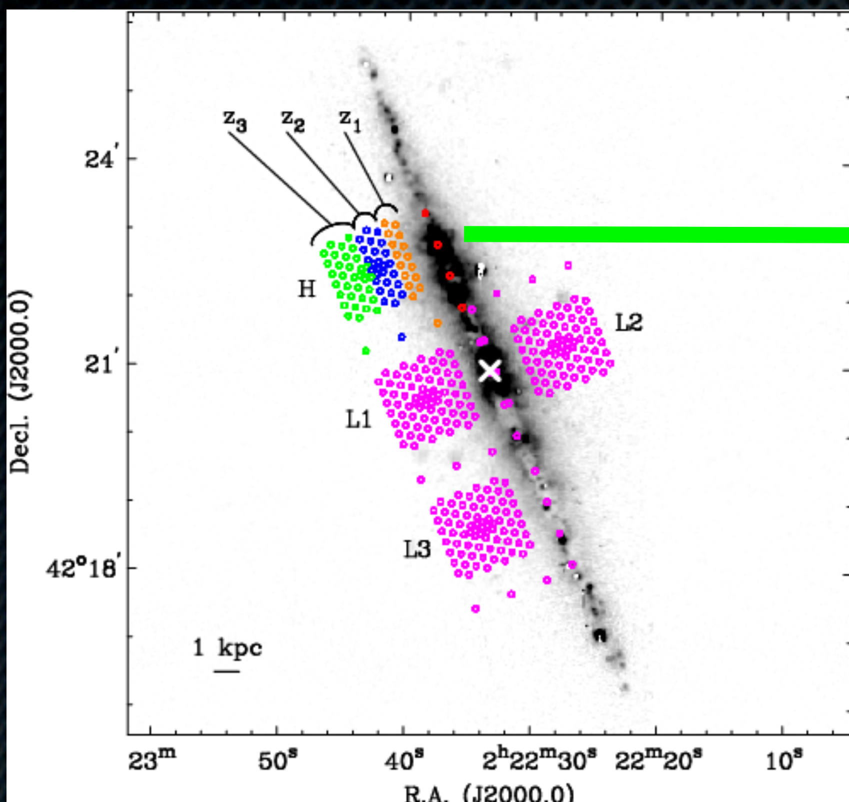

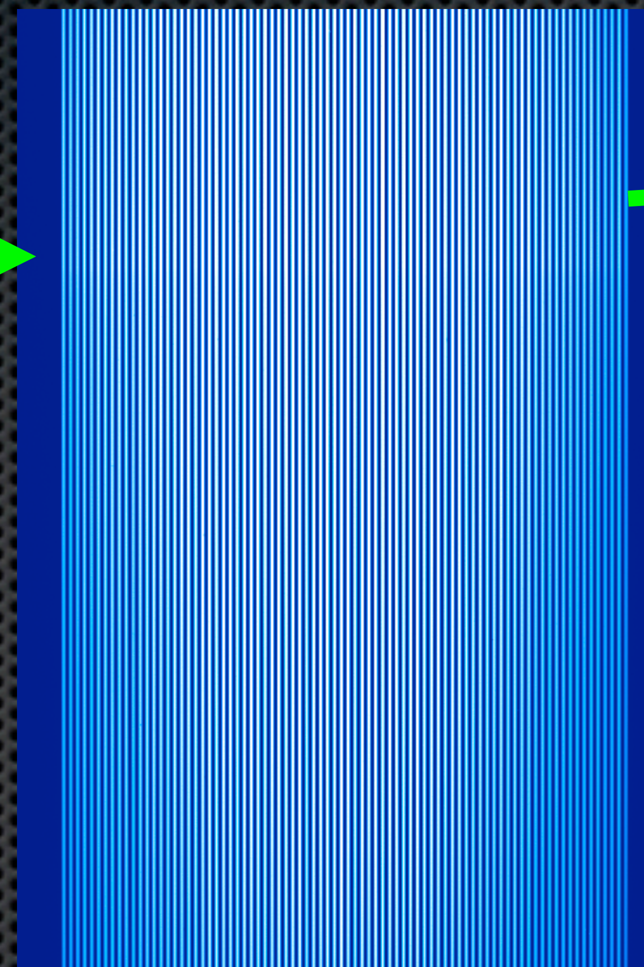

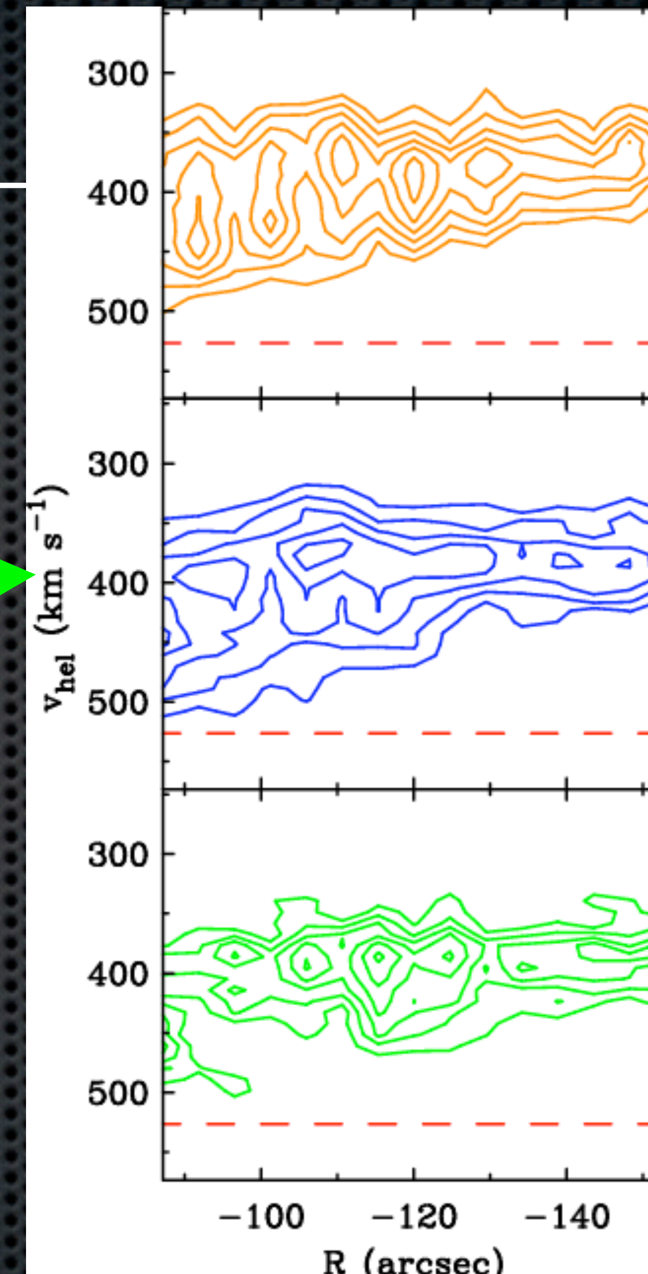

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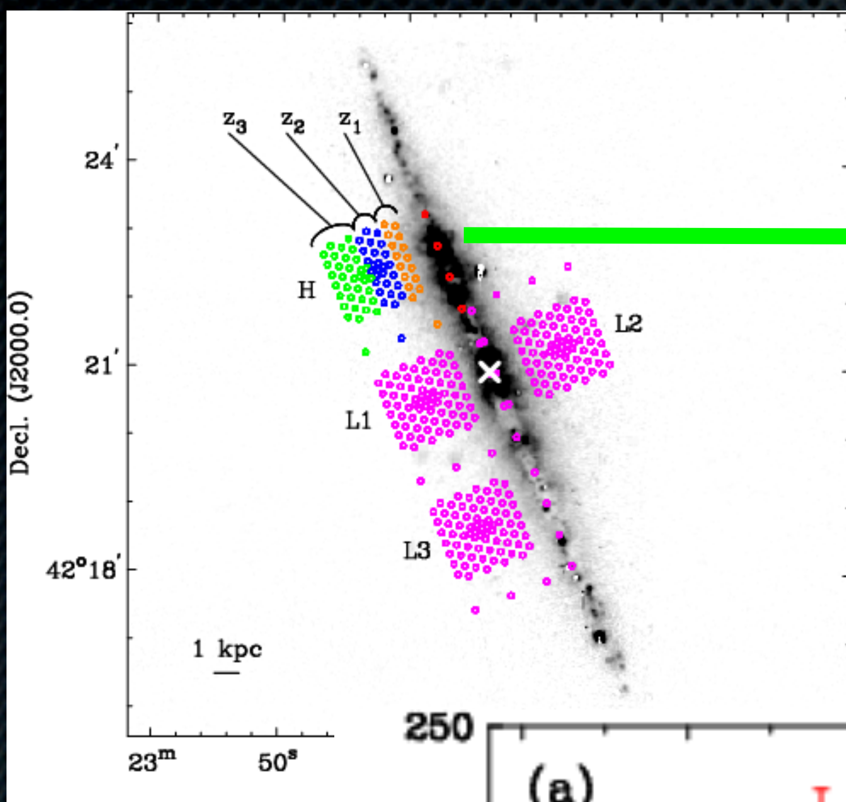

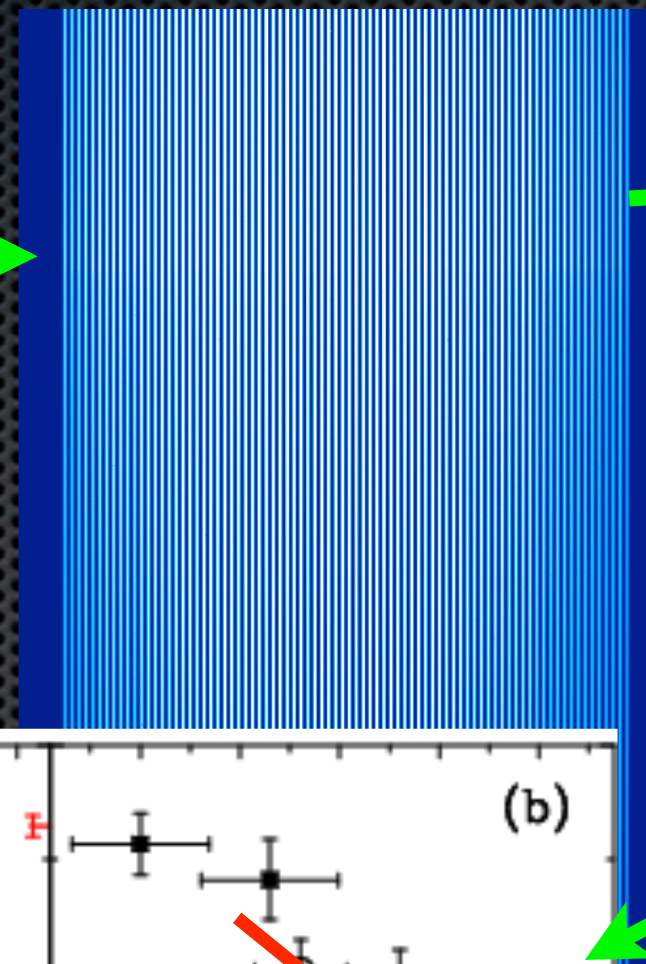

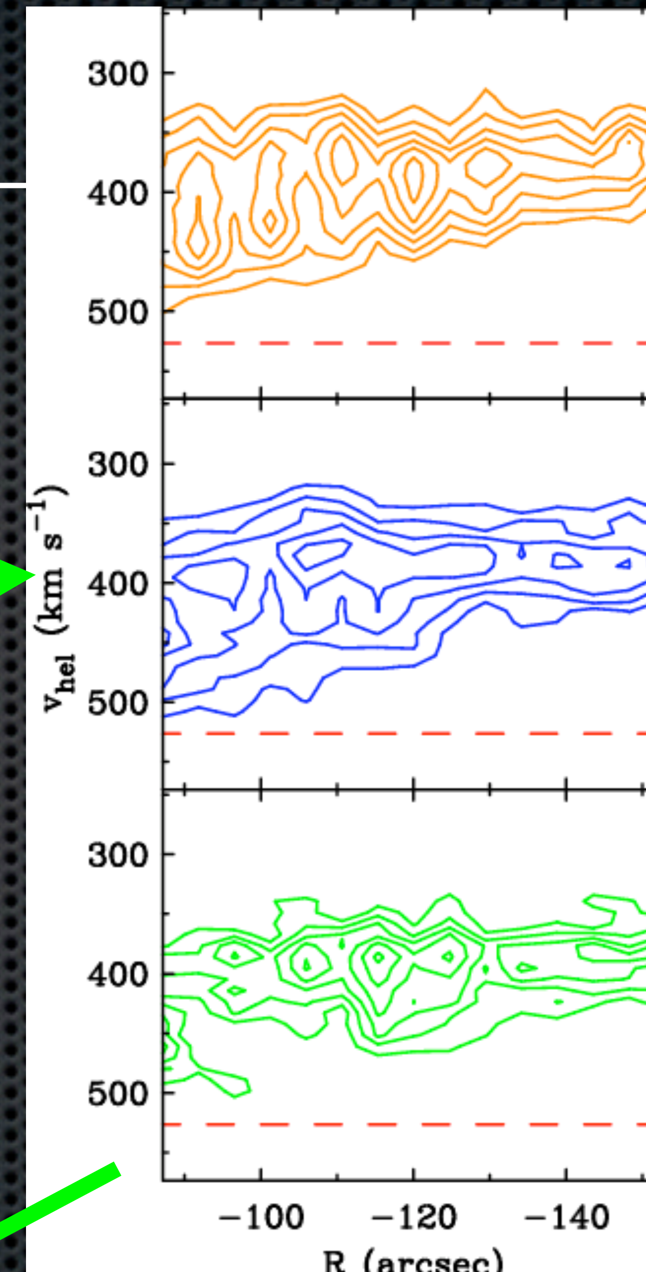

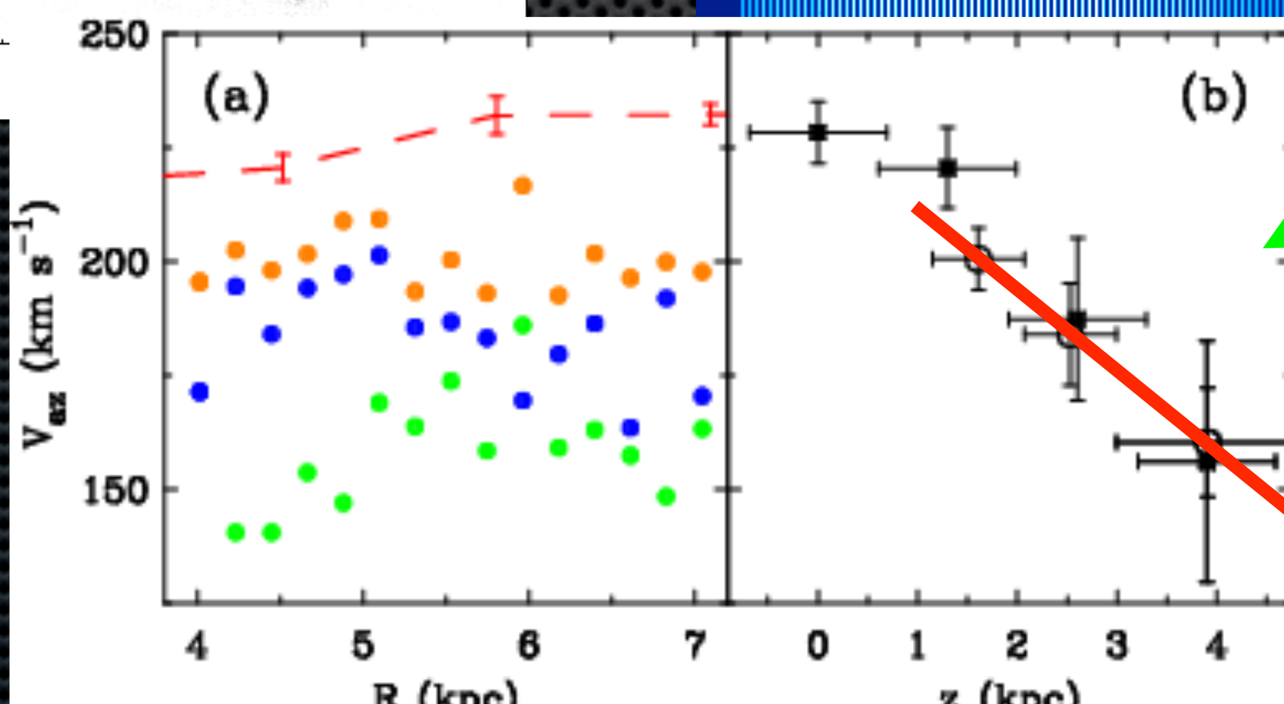

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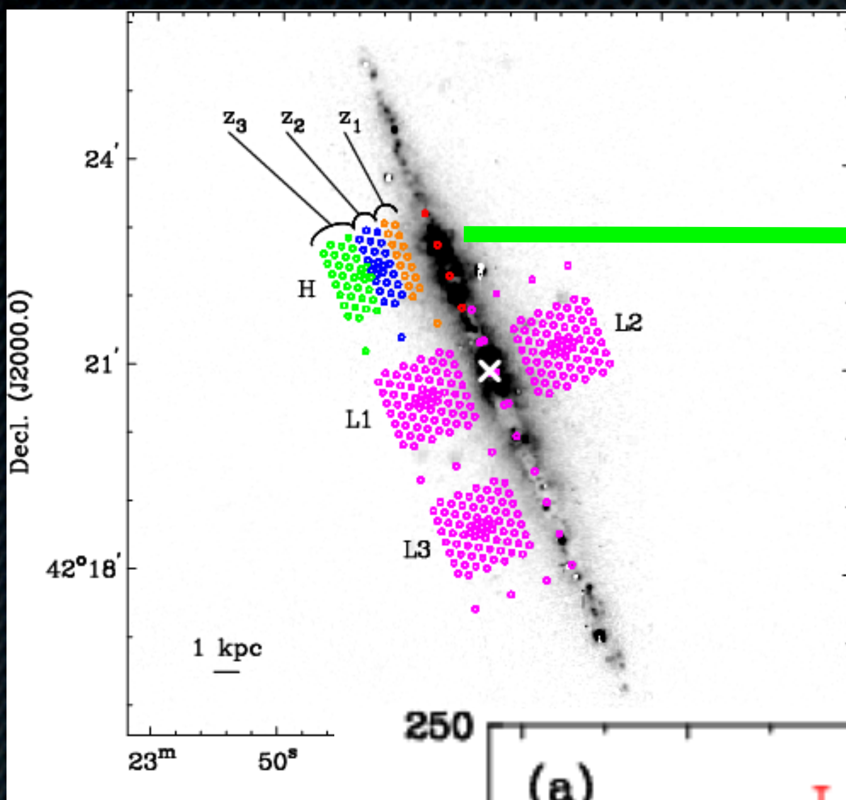
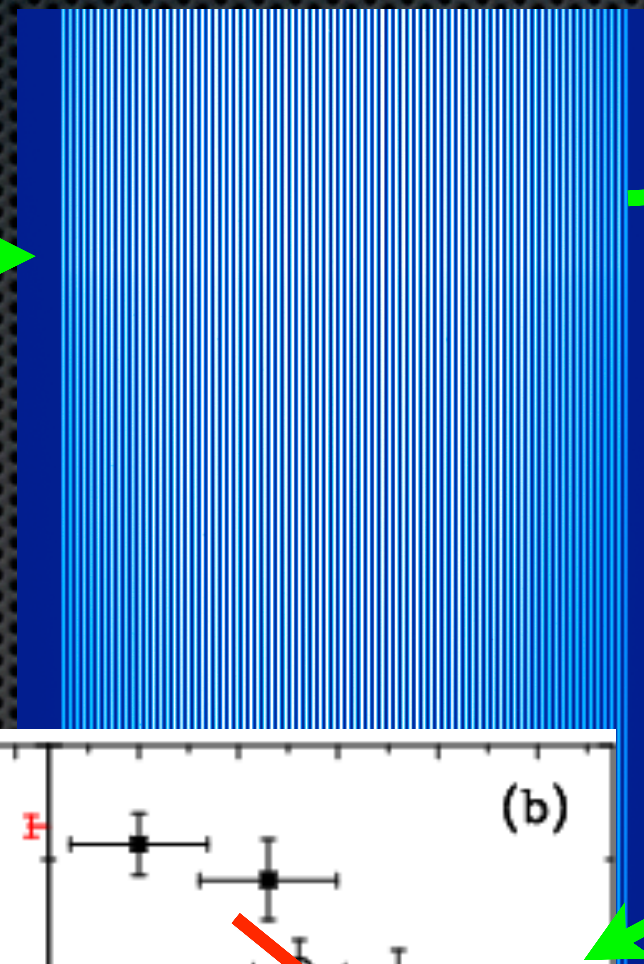
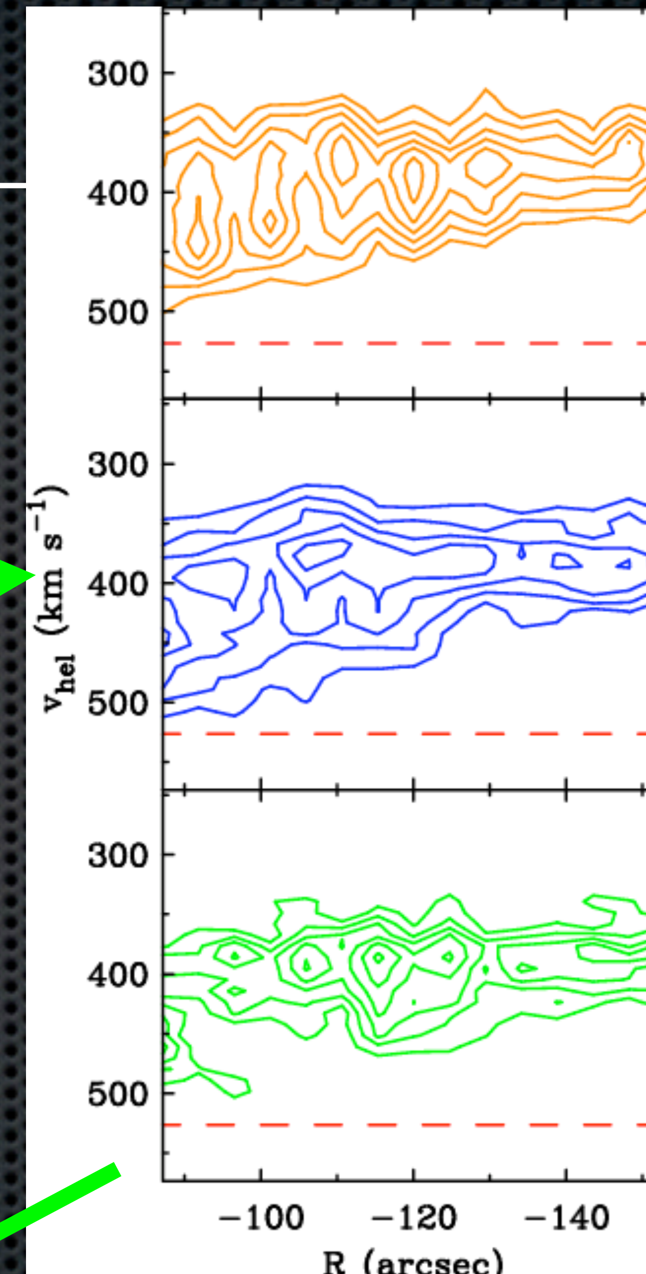
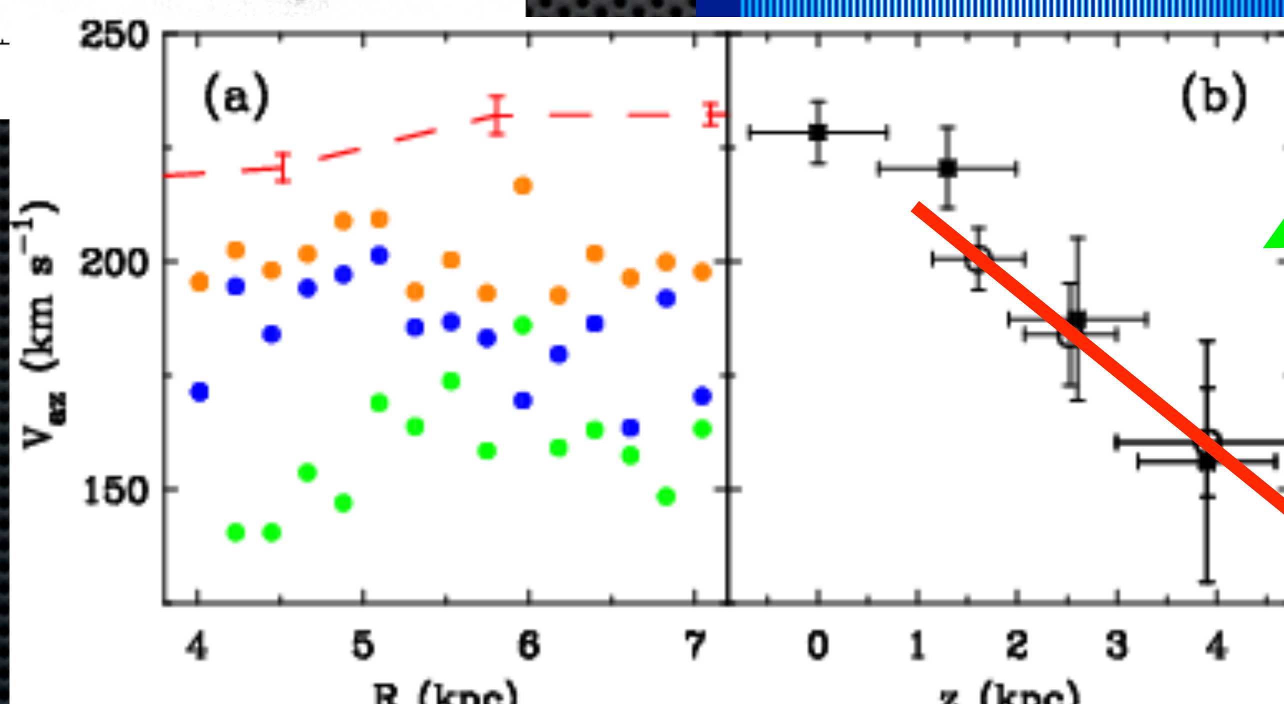




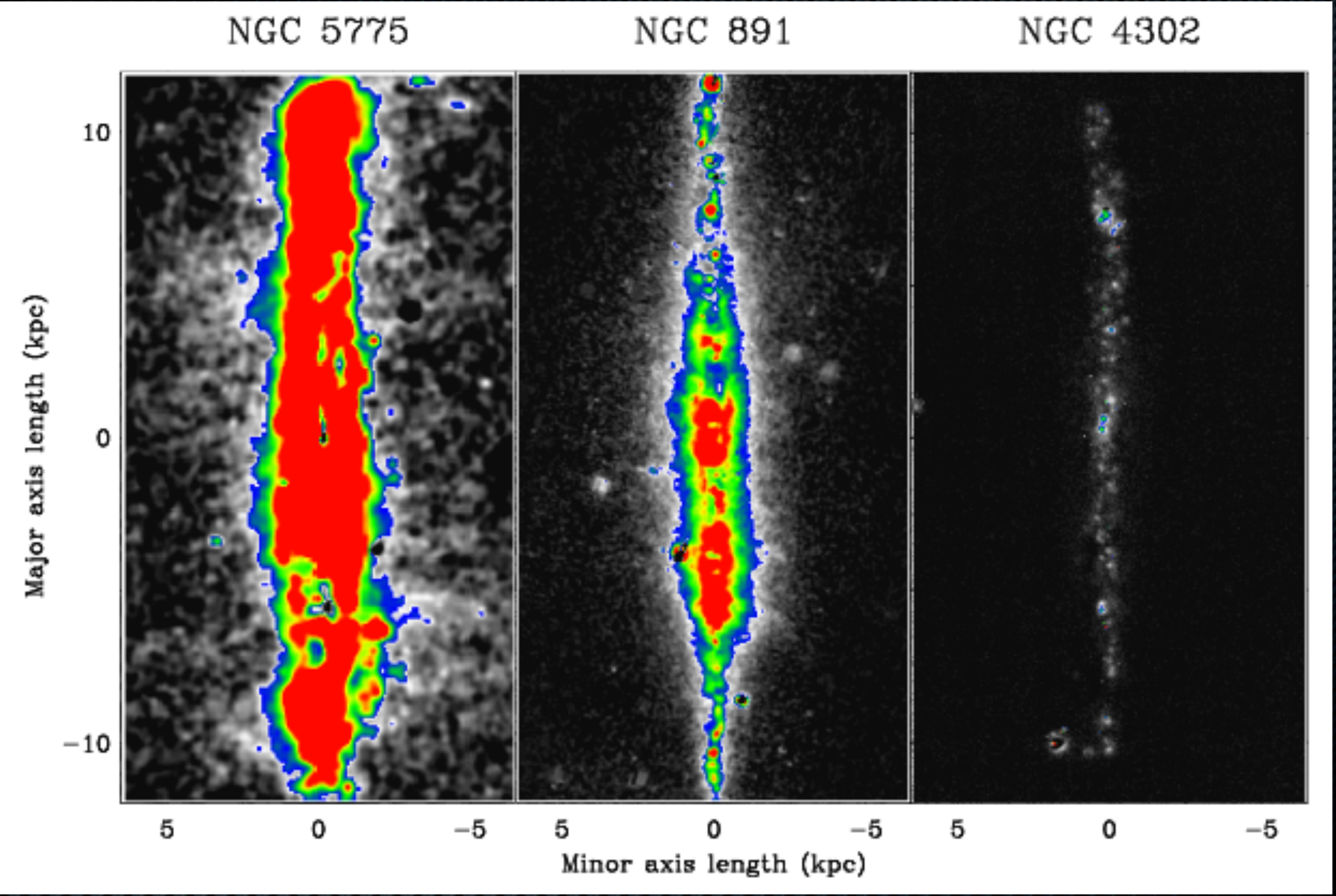




$$dV_\phi/dz \approx -15\,\mathrm{km\,s^{-1}\,kpc^{-1}}$$

NGC 891 (Heald+ 2007a, ApJ, 647, 1018)

Results of optical observations



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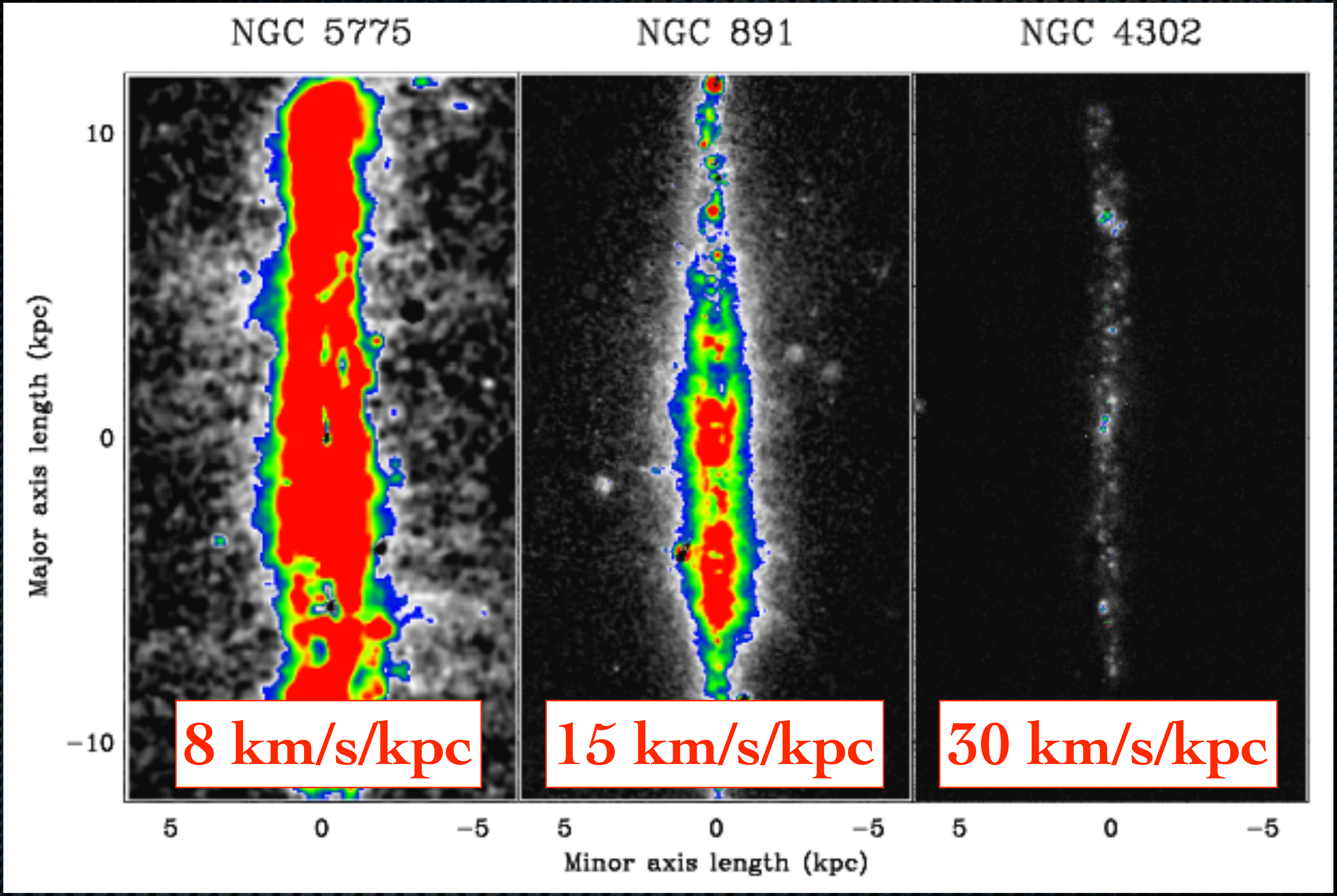

Models & Interpretation

- Rotation speed decreases as gas is higher in halo -- this seems to be a ***general trend***.

NGC 4302 (Heald+ 2007b, ApJ, 663, 933)

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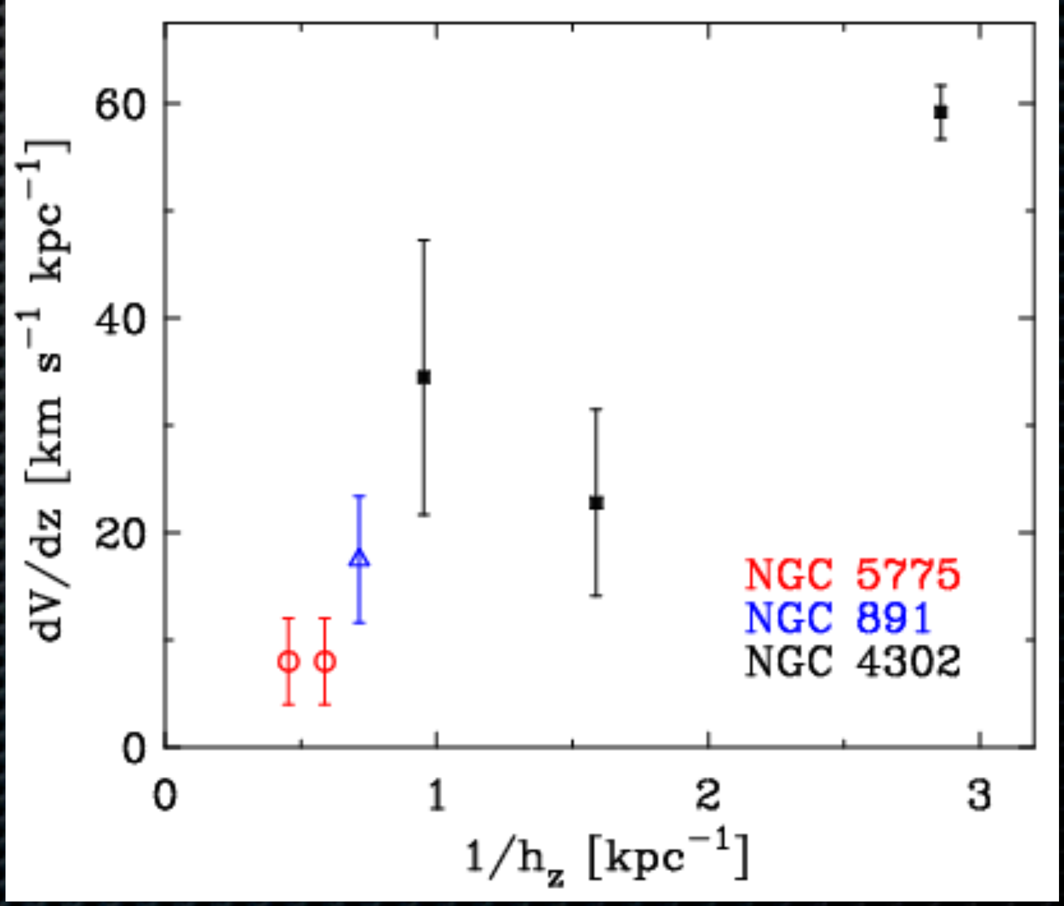

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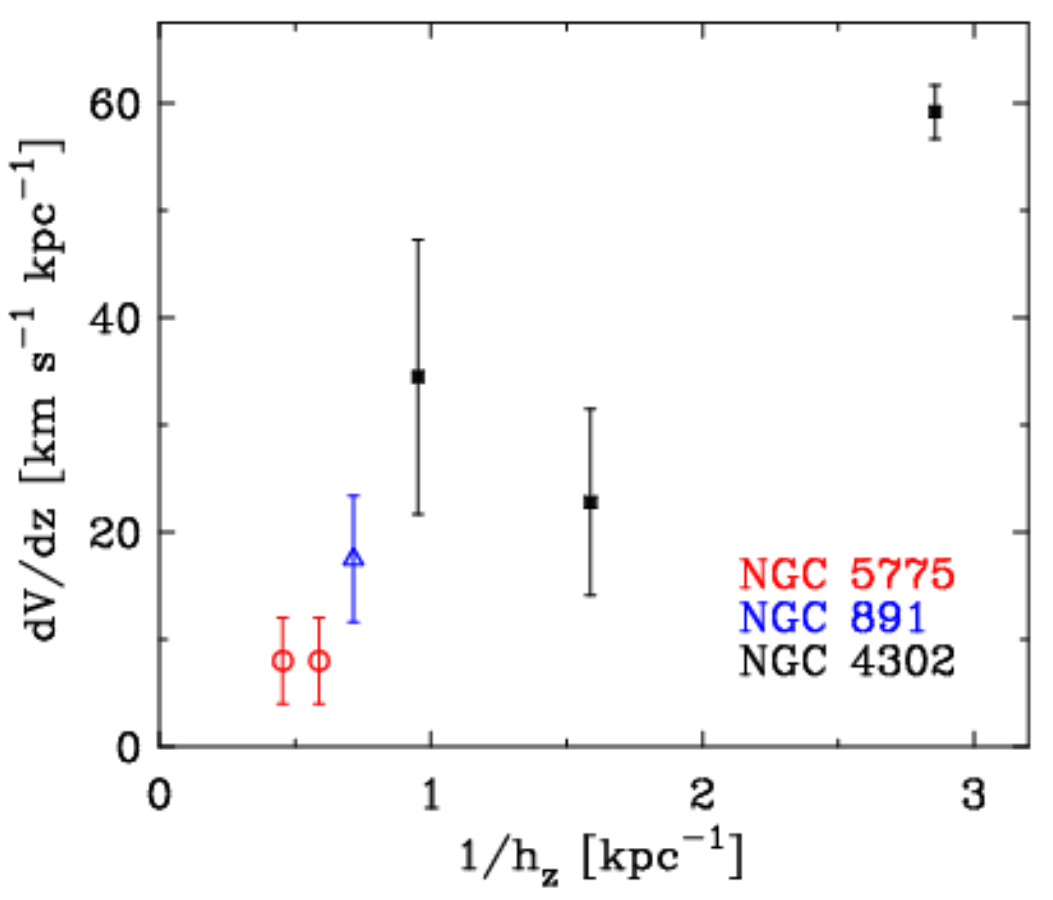
- Need face-on galaxies to compare w/ SFR



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Kinematics in not-edge-on galaxies

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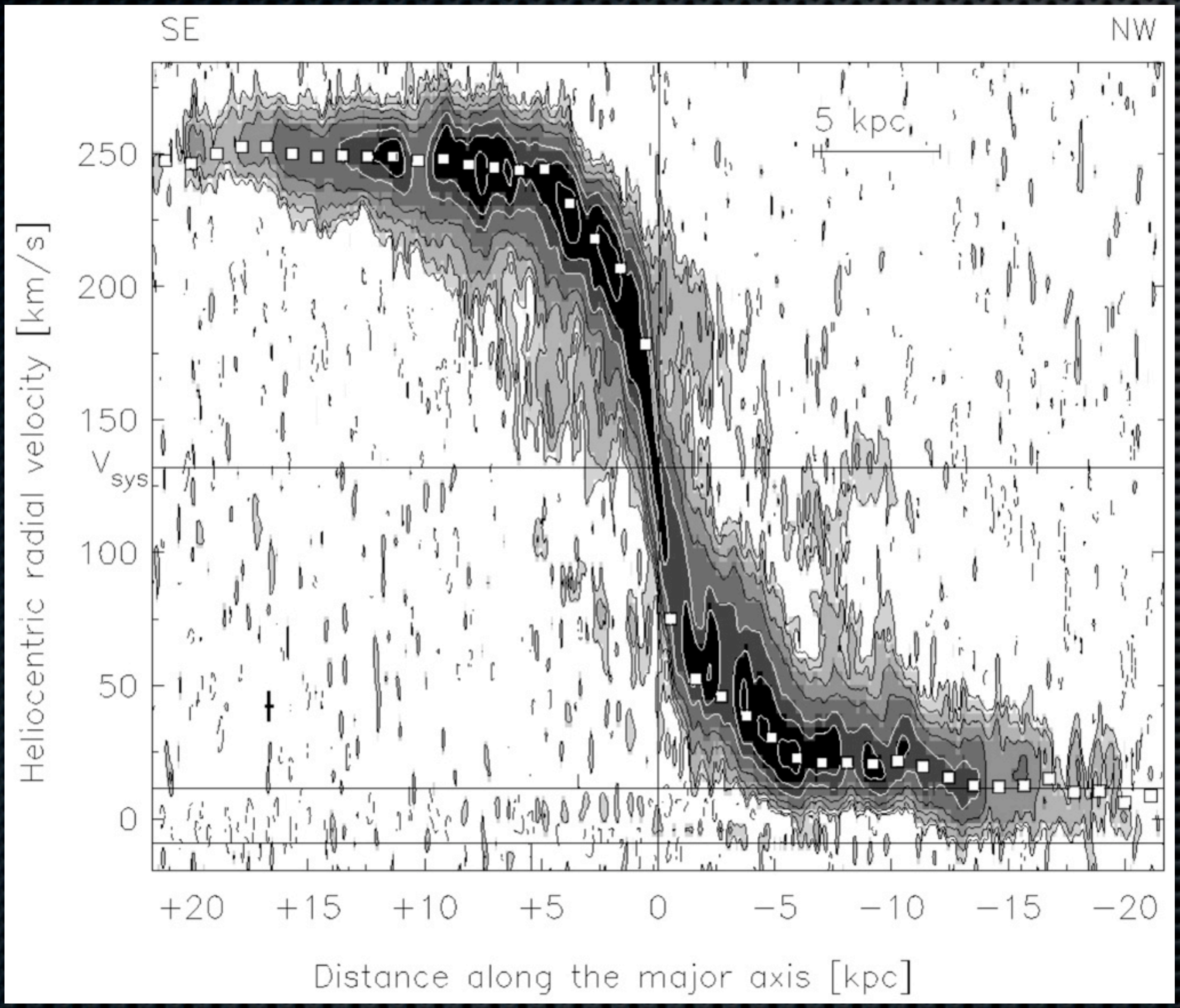

NGC 2403 (Fraternali+ 2001)

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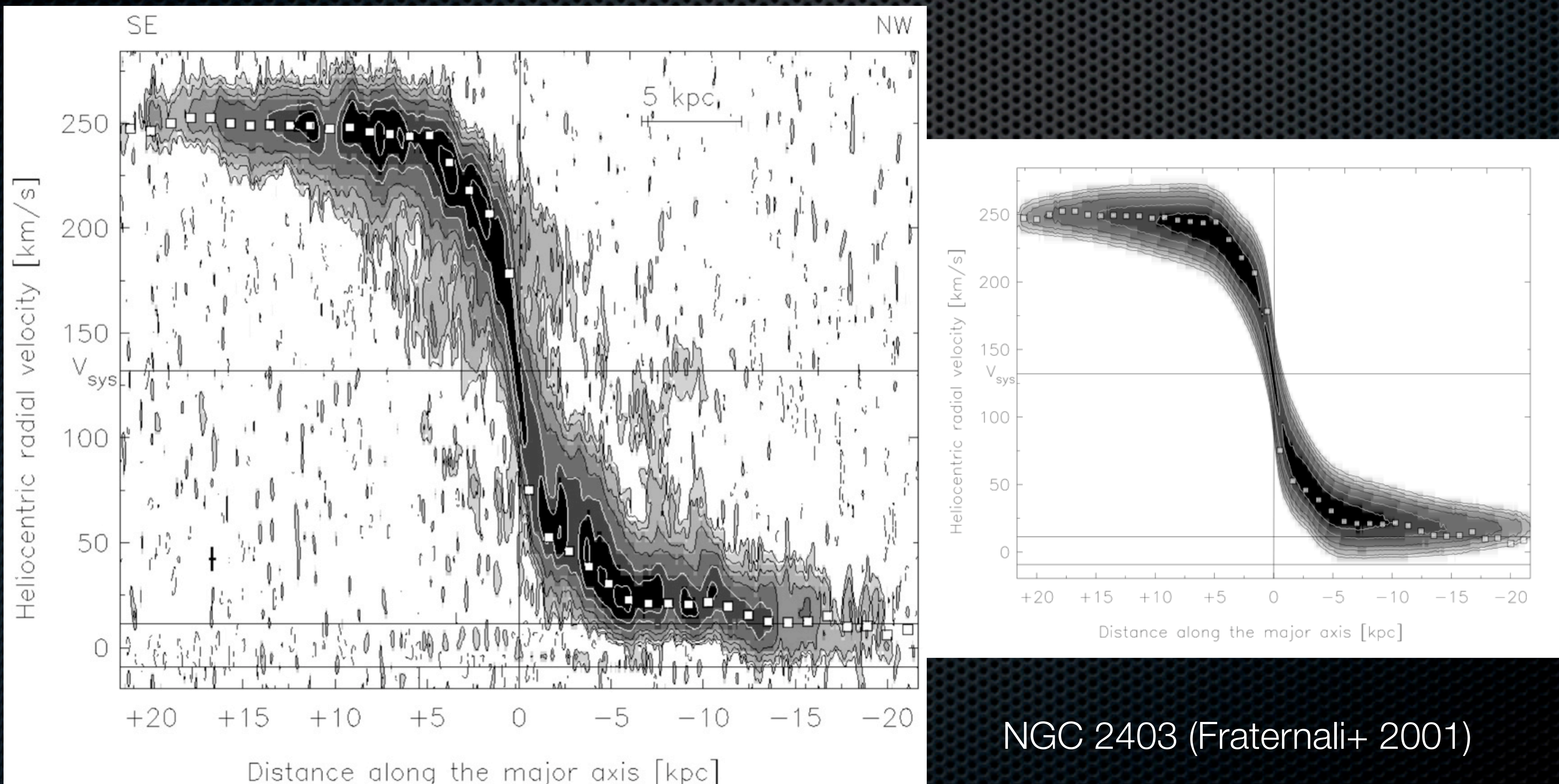

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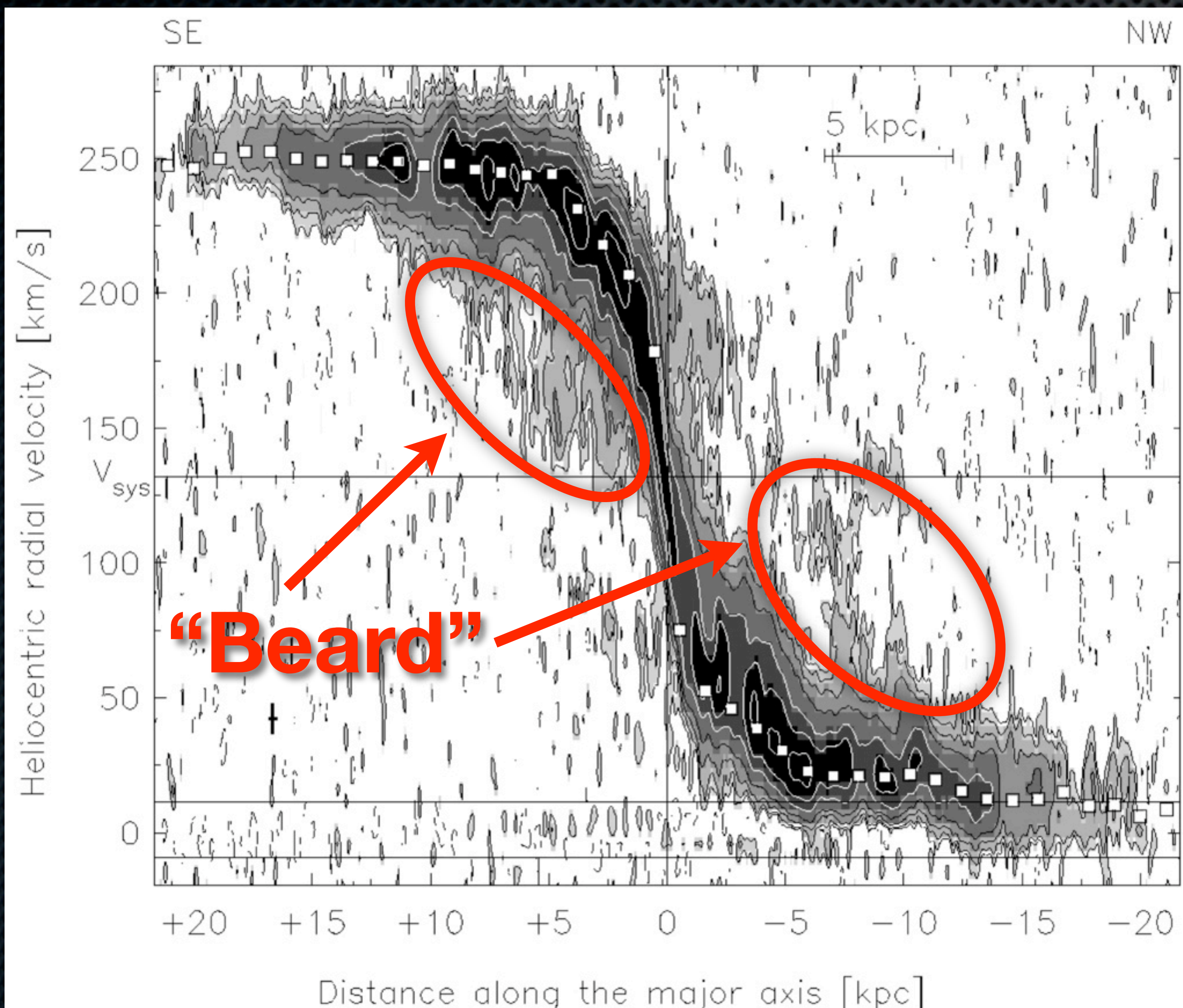
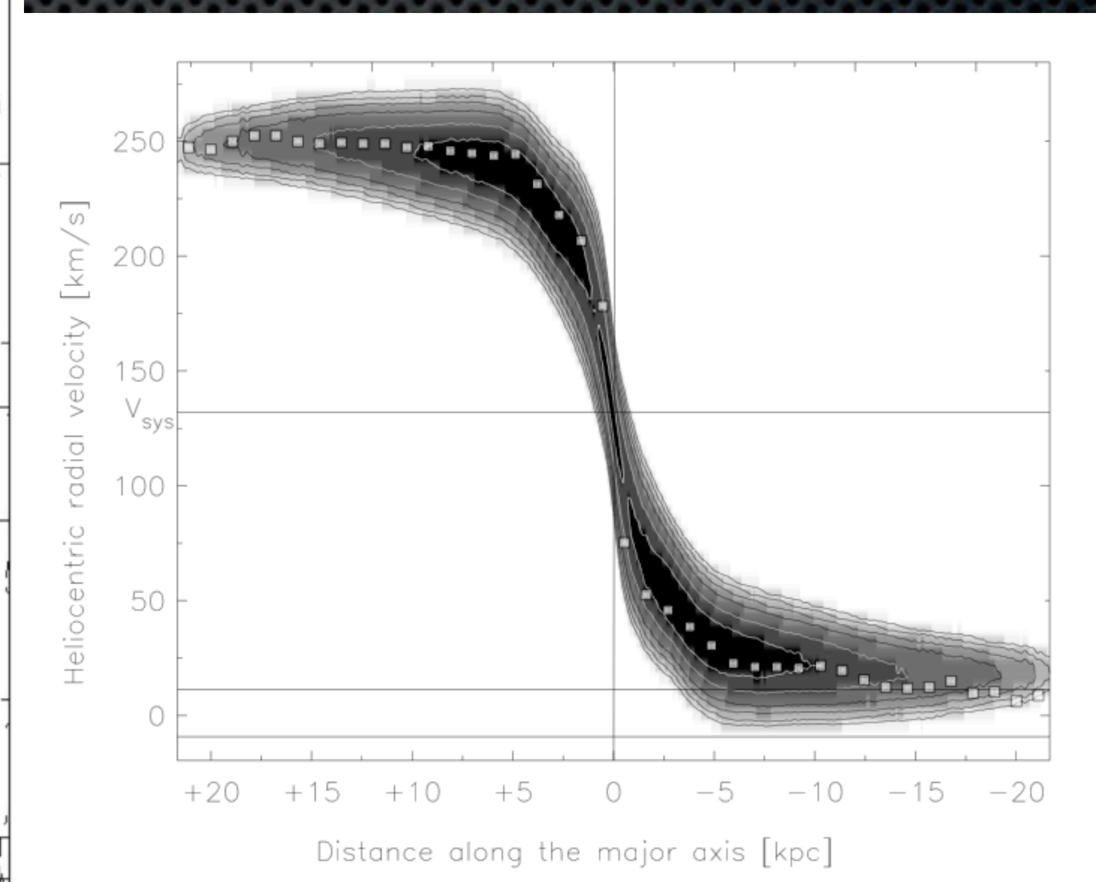
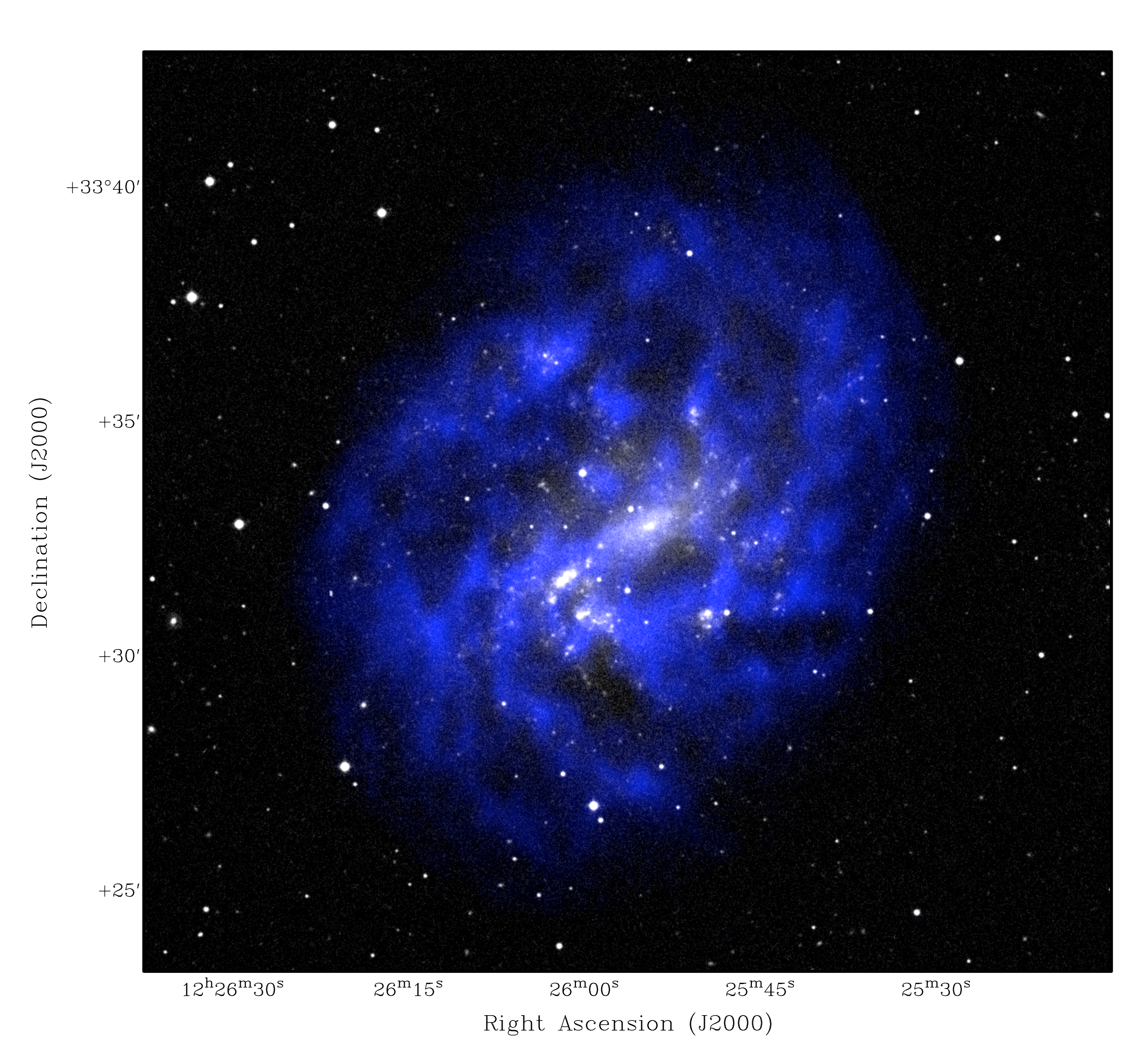




NGC 2403 (Fraternali+ 2001)

WSRT HI data: NGC 4395

- NGC 4395 (~face-on spiral w/ low SFR) observed 8x12hr with WSRT



WSRT HI data: NGC 4395

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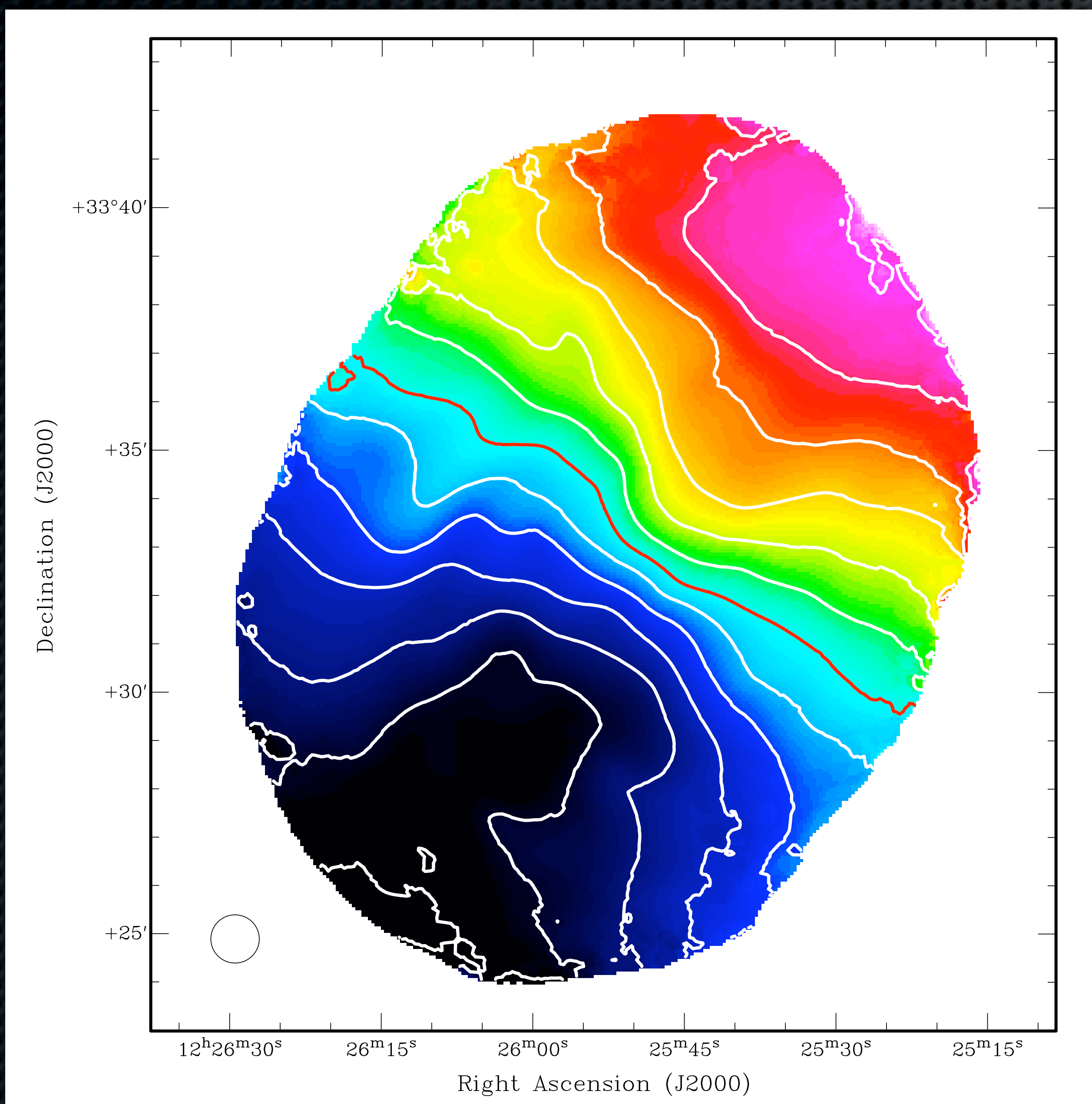
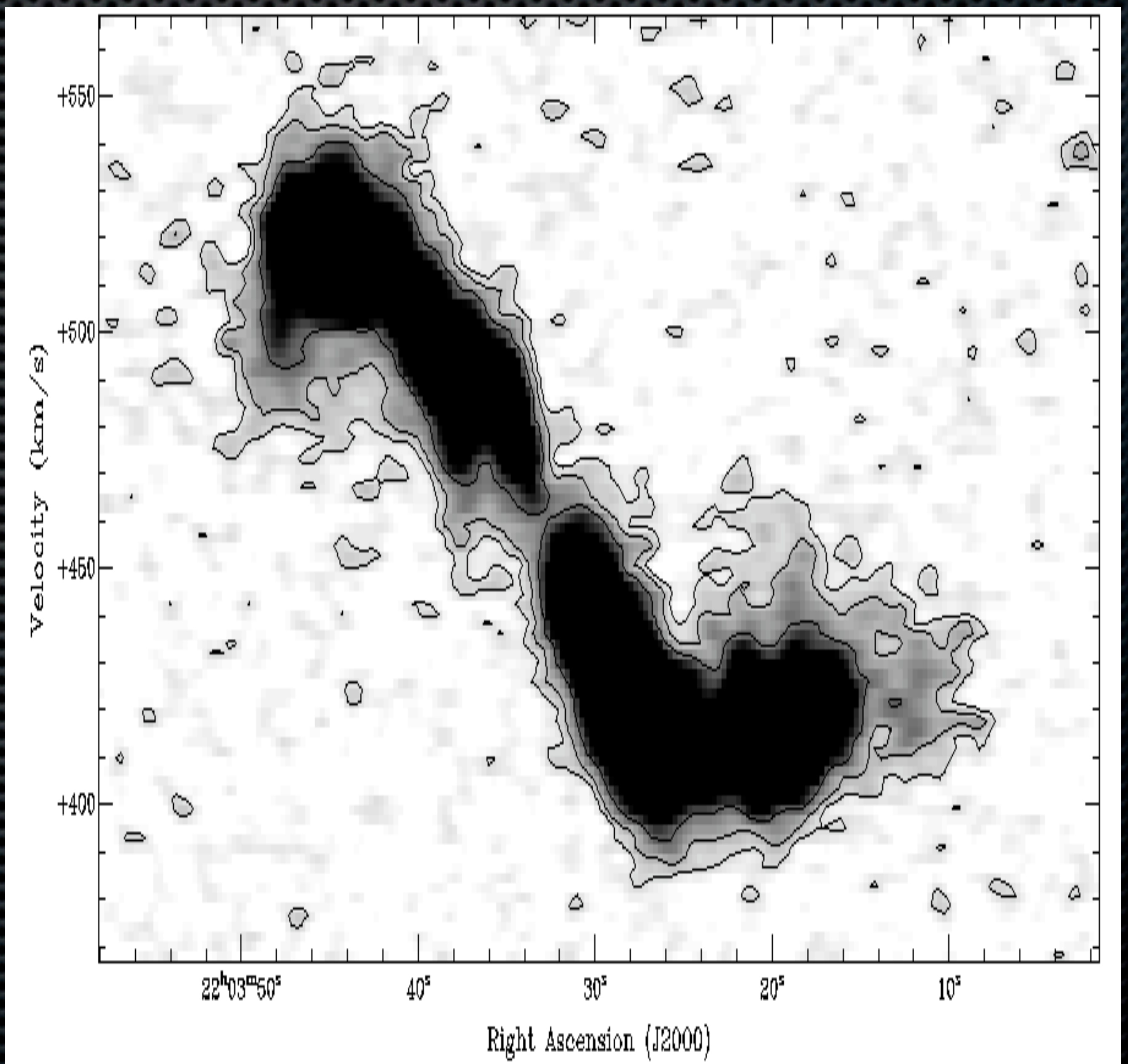
- (Lopsided!) rotation curve determined





WSRT HI data: NGC 4395

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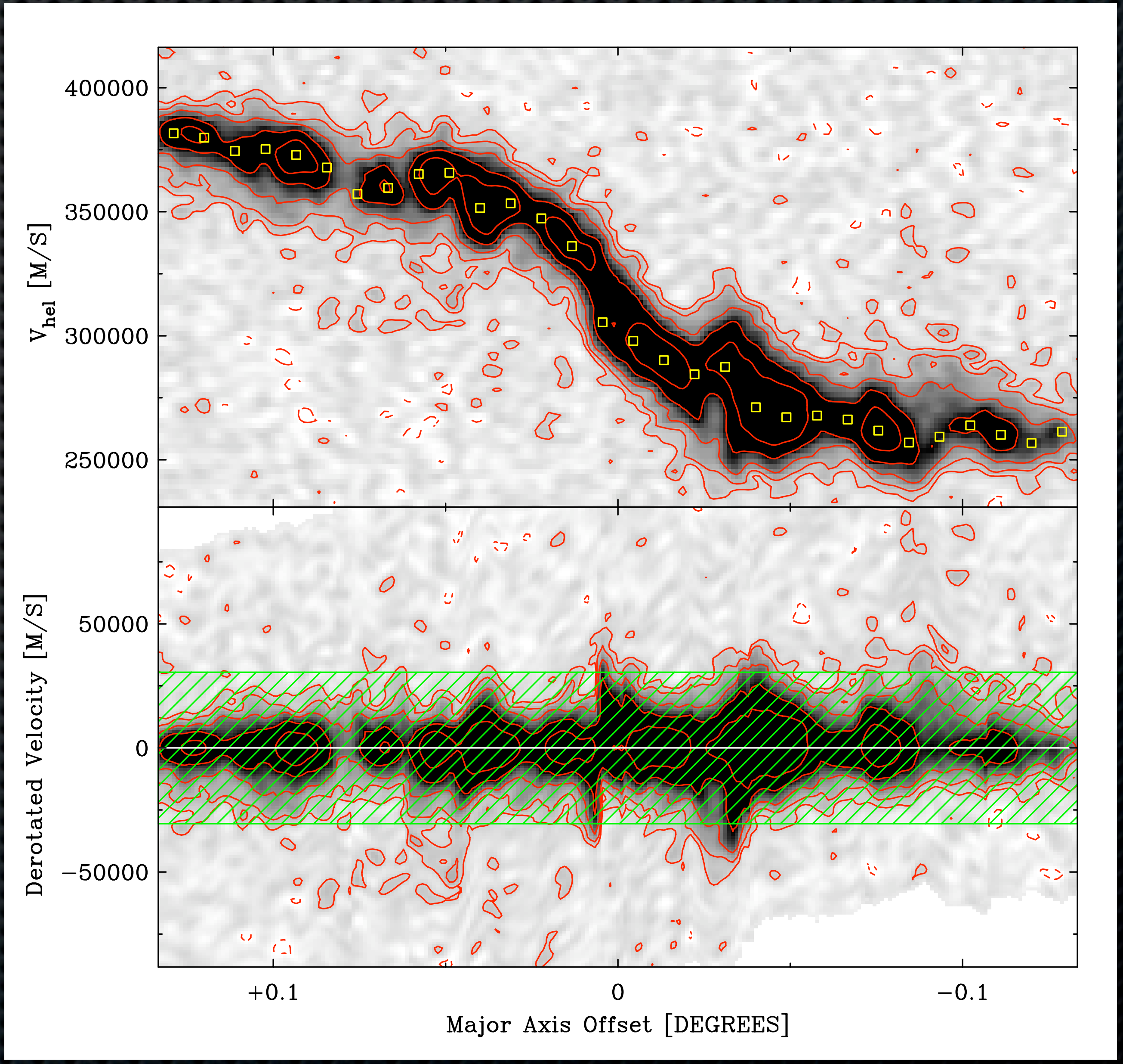
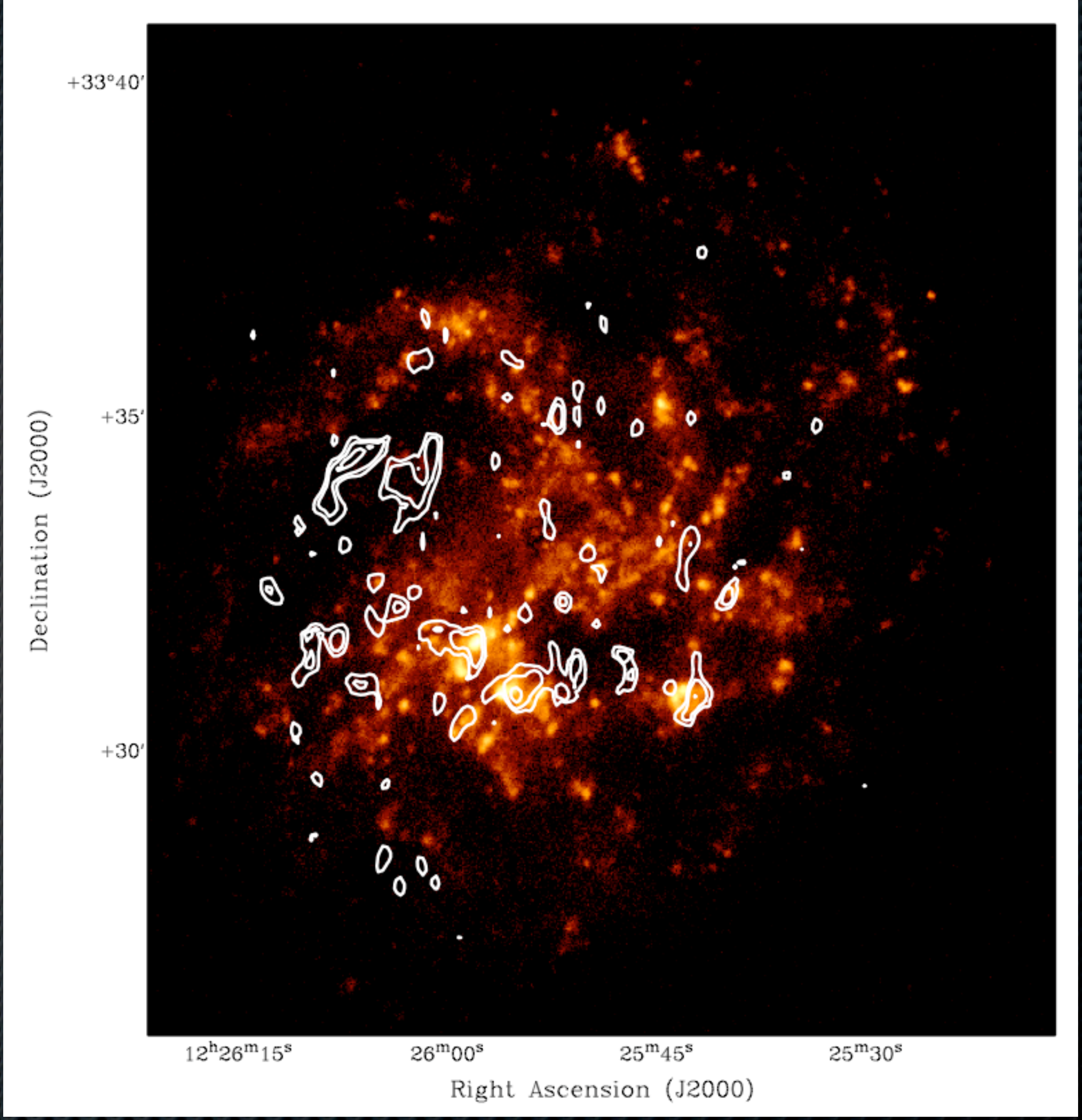
- (Lopsided!) rotation curve determined
- "Shuffled" the data cube
- Extracted emission with more than 30 km/s deviation from rotation



WSRT HI data: NGC 4395

- Most "anomalous" gas corresponds to locations of star formation
- Large cloud complex (~10^7 $M_\odot$) unassociated with SF, may be accreting



Heald & Oosterloo (2008)

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- 3D data analysis techniques essential for this type of study!