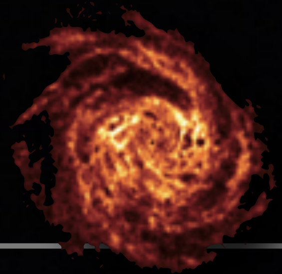
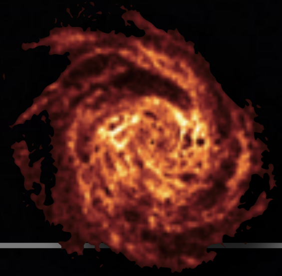


HI Morphologies and Kinematics
a concise perspective

- An overview of HI in galaxies
- Rotation curves and the TFR
- Mass distributions in galaxies
- Forthcoming HI surveys

Marc Verheijen
Kapteyn Institute



21cm spectral-line aperture synthesis imaging

Pro's

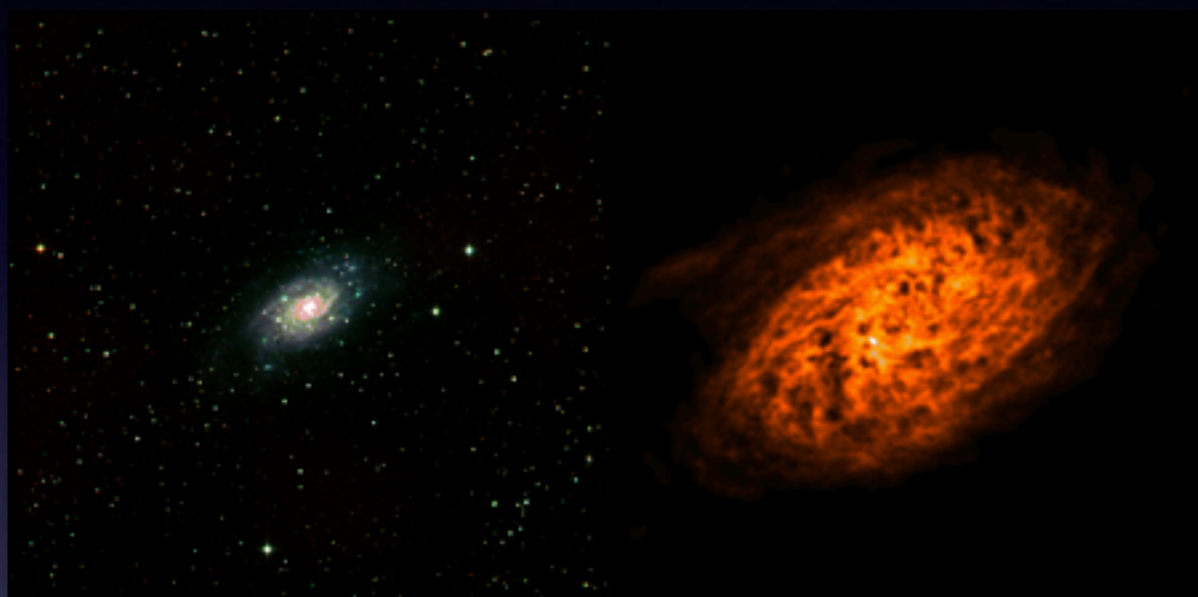
- Atomic Hydrogen is kinematically cold (5-15 km/s dispersion)
- HI disks reach far into the Dark Matter Halo
- Extended HI disks are fragile and responsive
- Observations at high spectral resolution (few km/s)

Cons

- Elaborate data acquisition/reduction/analysis process
- Observations at relatively low angular resolution (>5")
- Restricted to nearby Universe (z<0.25)
- No large-area surveys exist to date

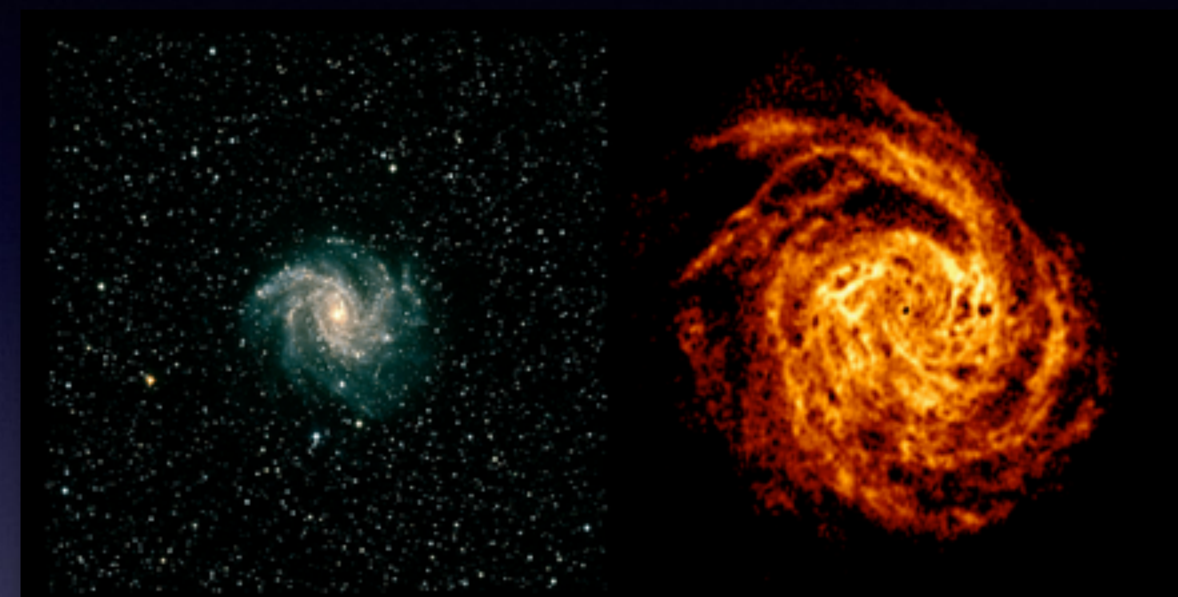
HI disks reach far into the Dark Matter halos

NGC 2403



Fraternali et al (2001)

NGC 6946



Boomsma (2007)

NGC 5055

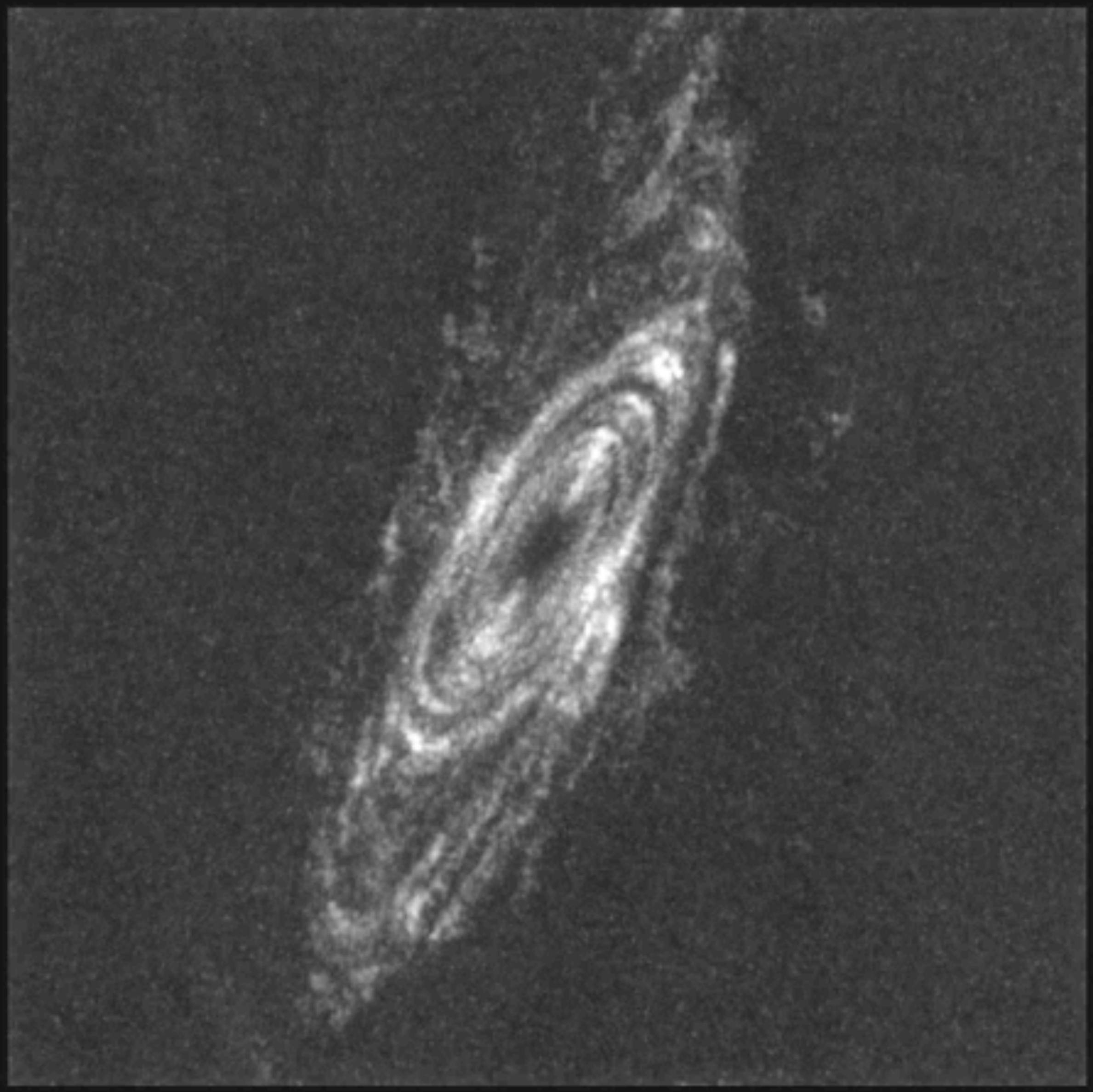
Battaglia et al (2005)

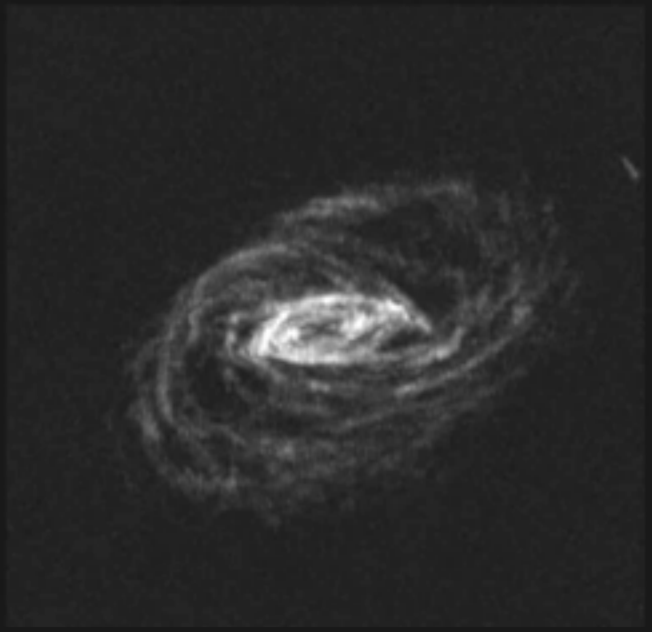
Messier 31

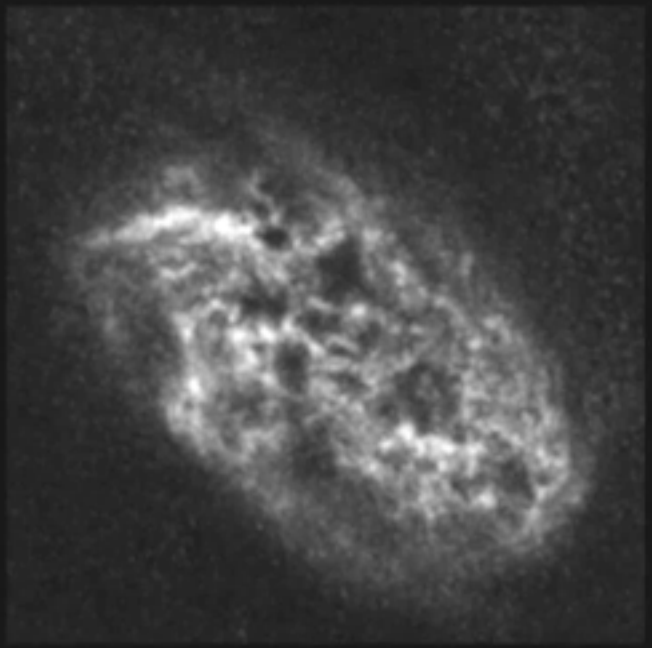
Braun et al

HI data from Westerbork

HI imaging : wide-field 'IFU' spectroscopy

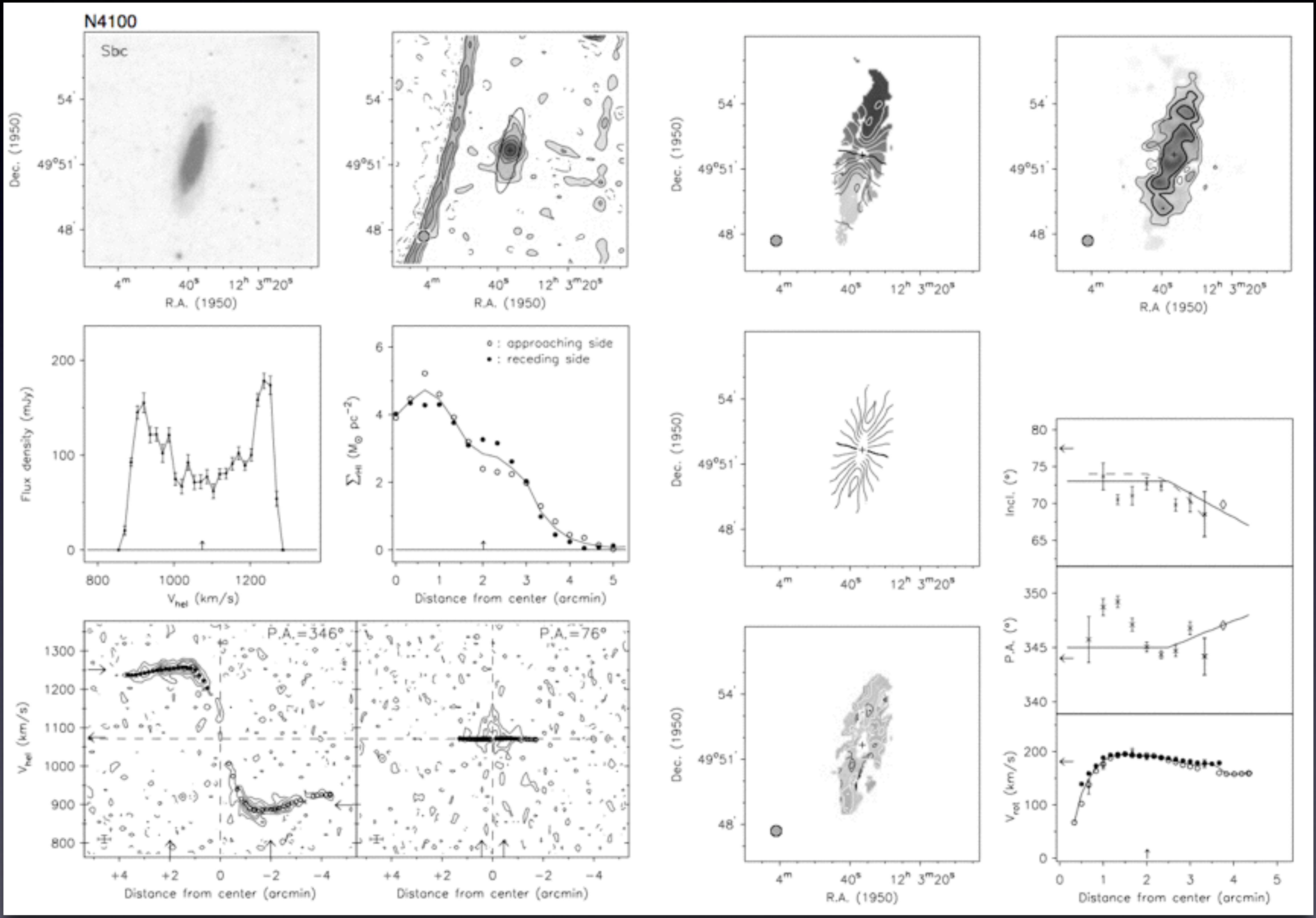






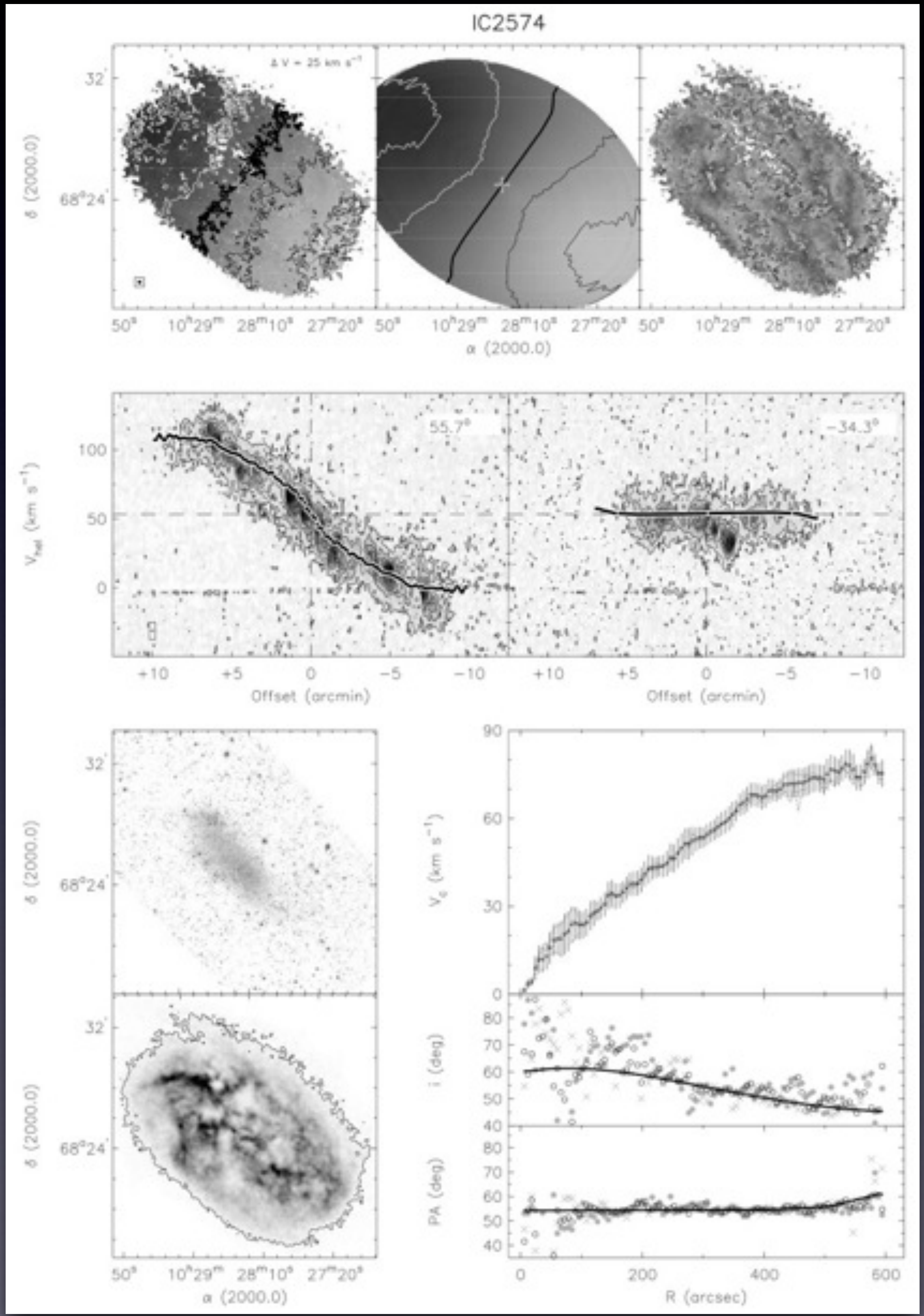
data from THINGS survey
visualization: Davide Punzo, Kapteyn Institute

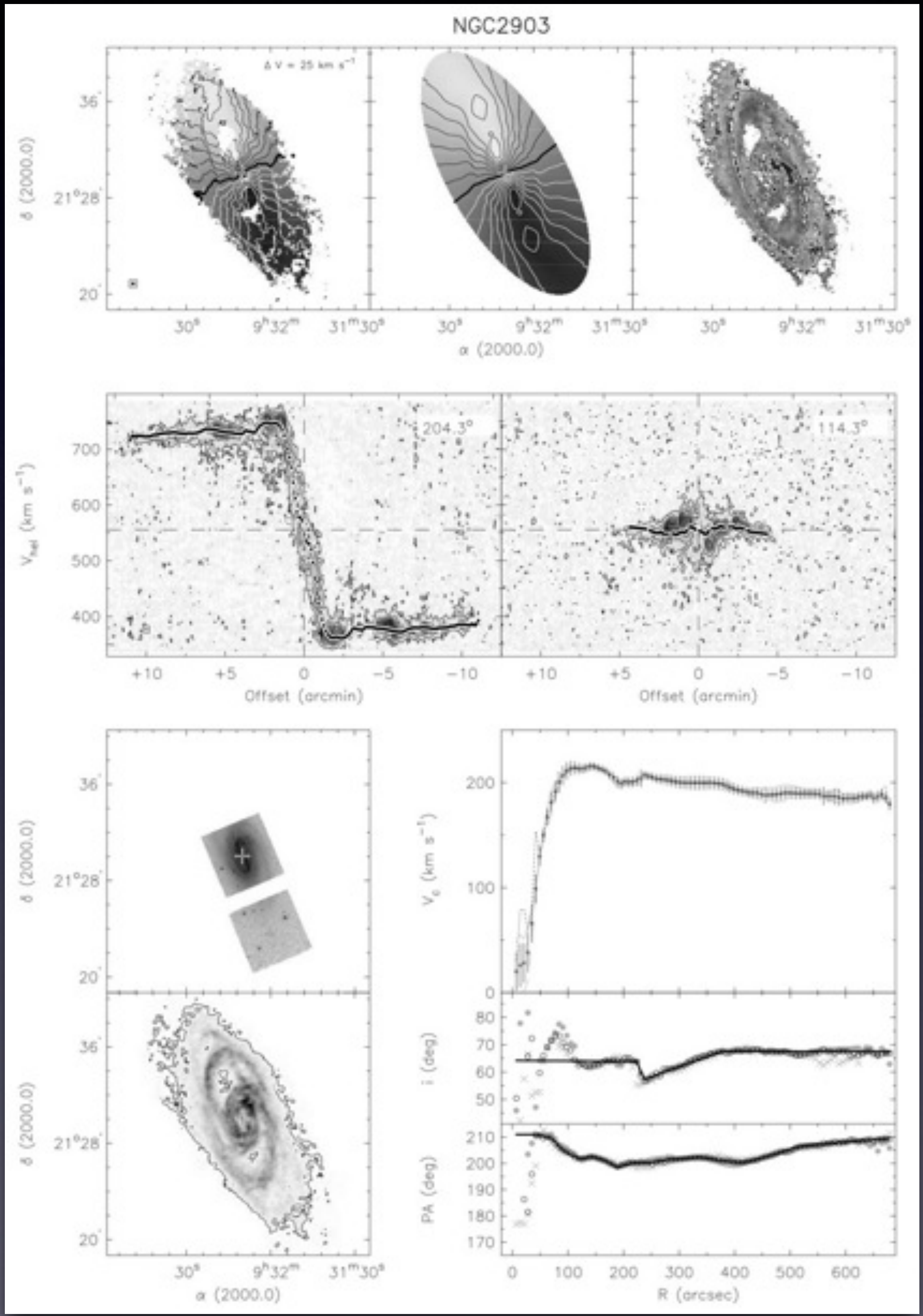
HI data products (Ursa Major - WSRT)



Verheijen & Sancisi (2001)

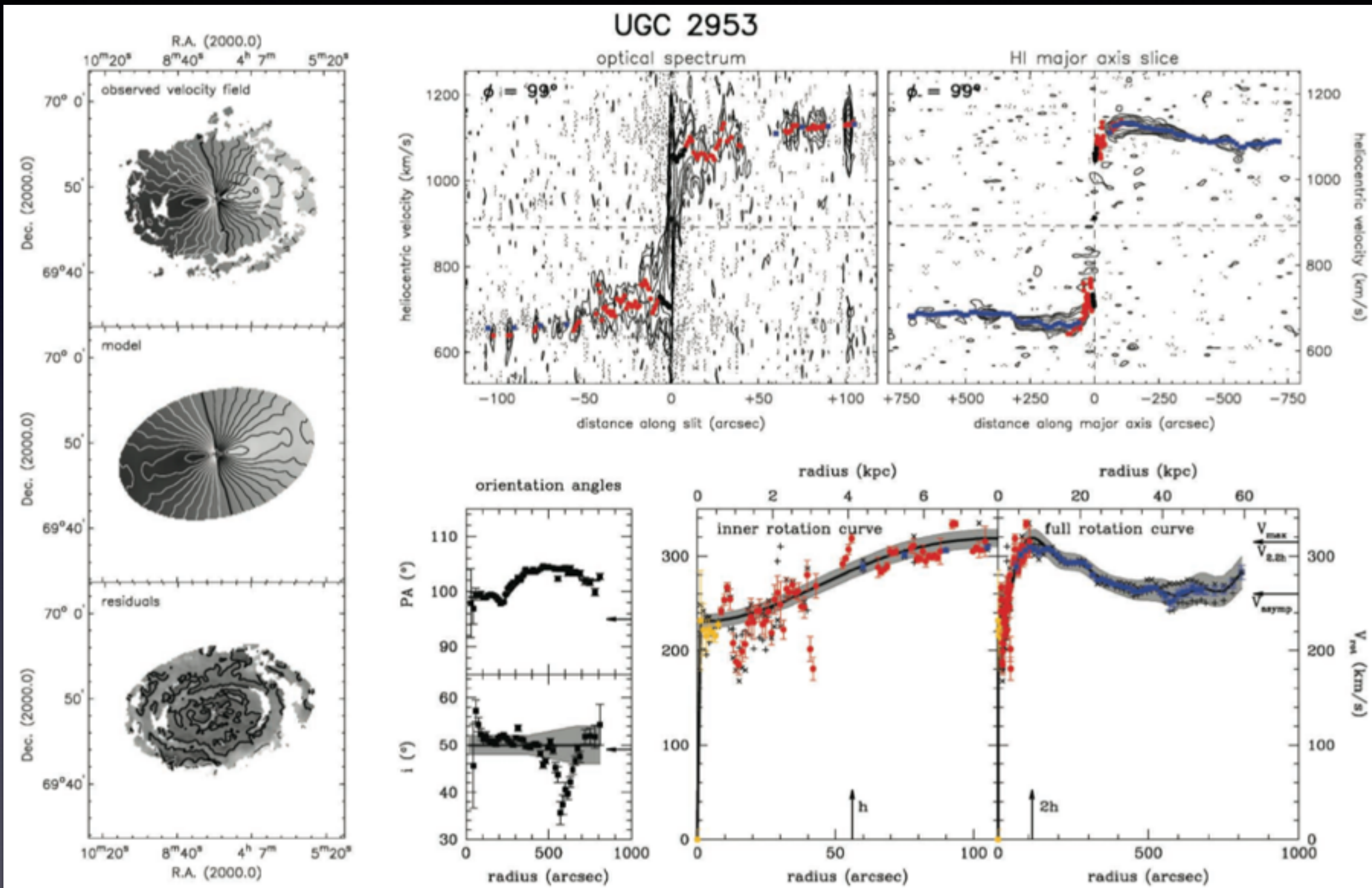
HI data products (THINGS - VLA / BCD)





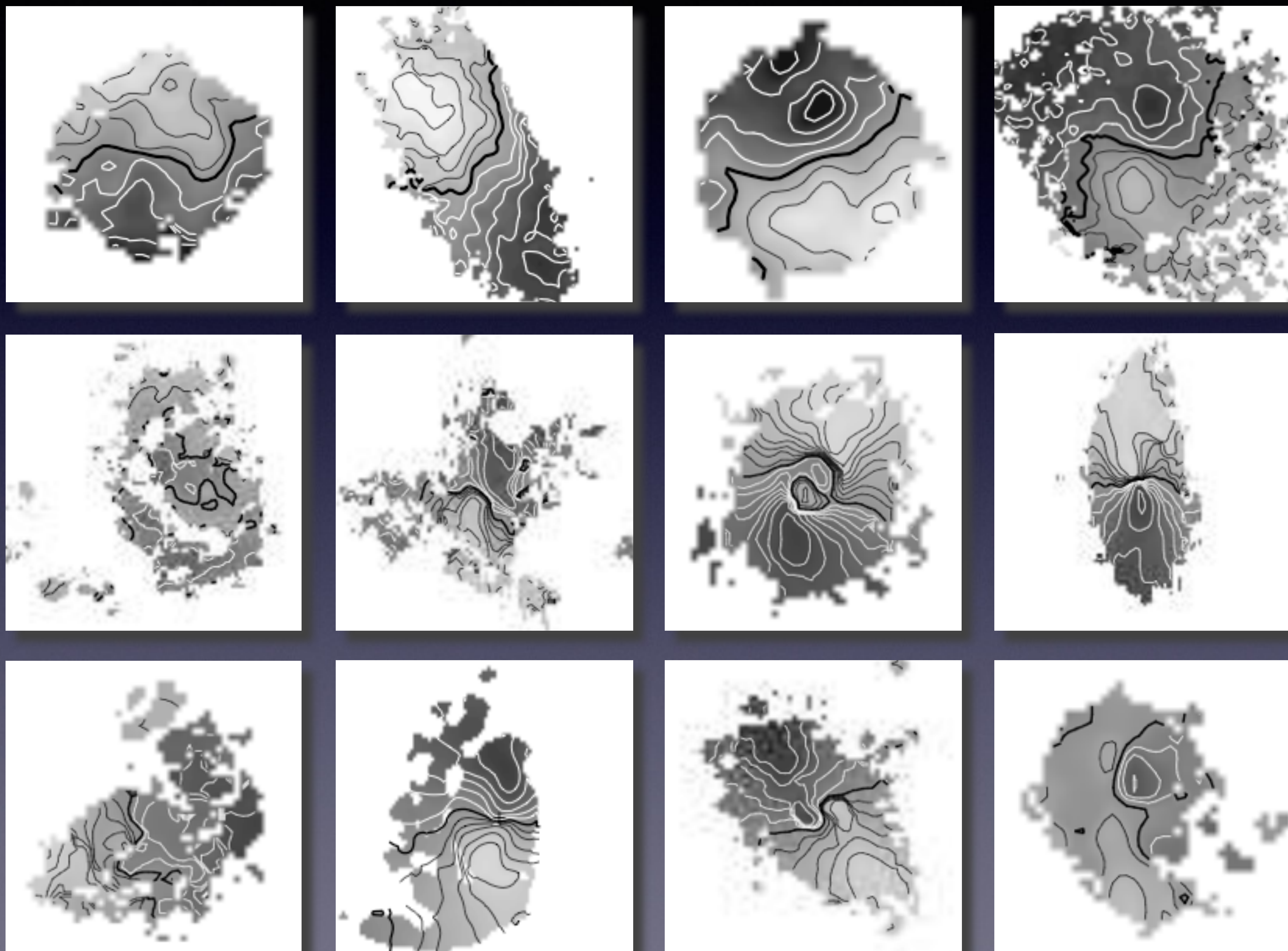
de Blok+ (2008)

HI data products (WHISP - WSRT)



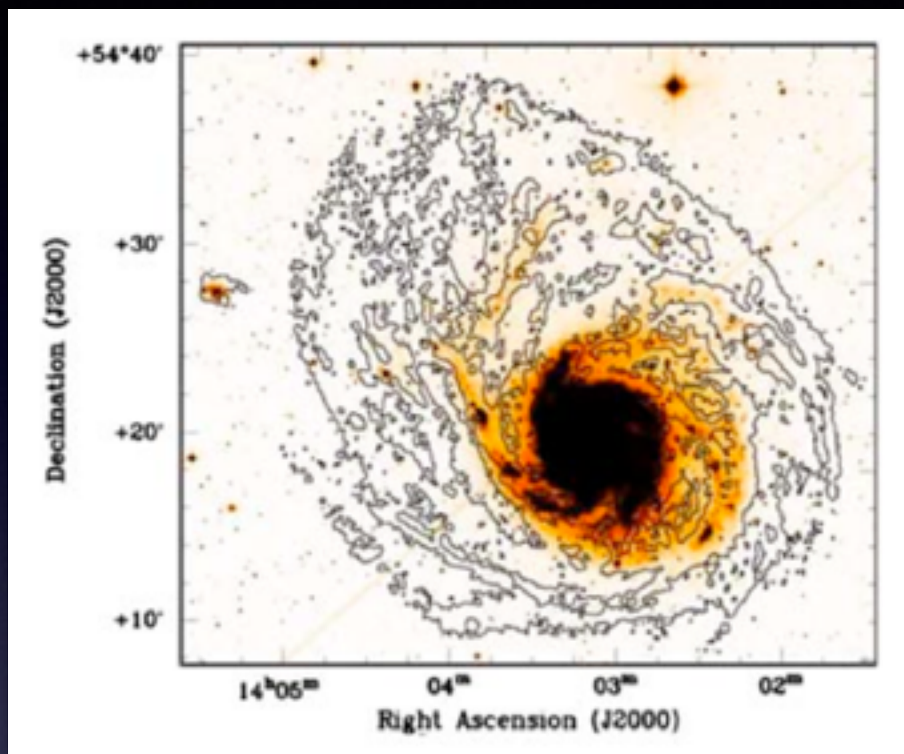
Noordermeer et al (2005)

Perturbed HI velocity fields



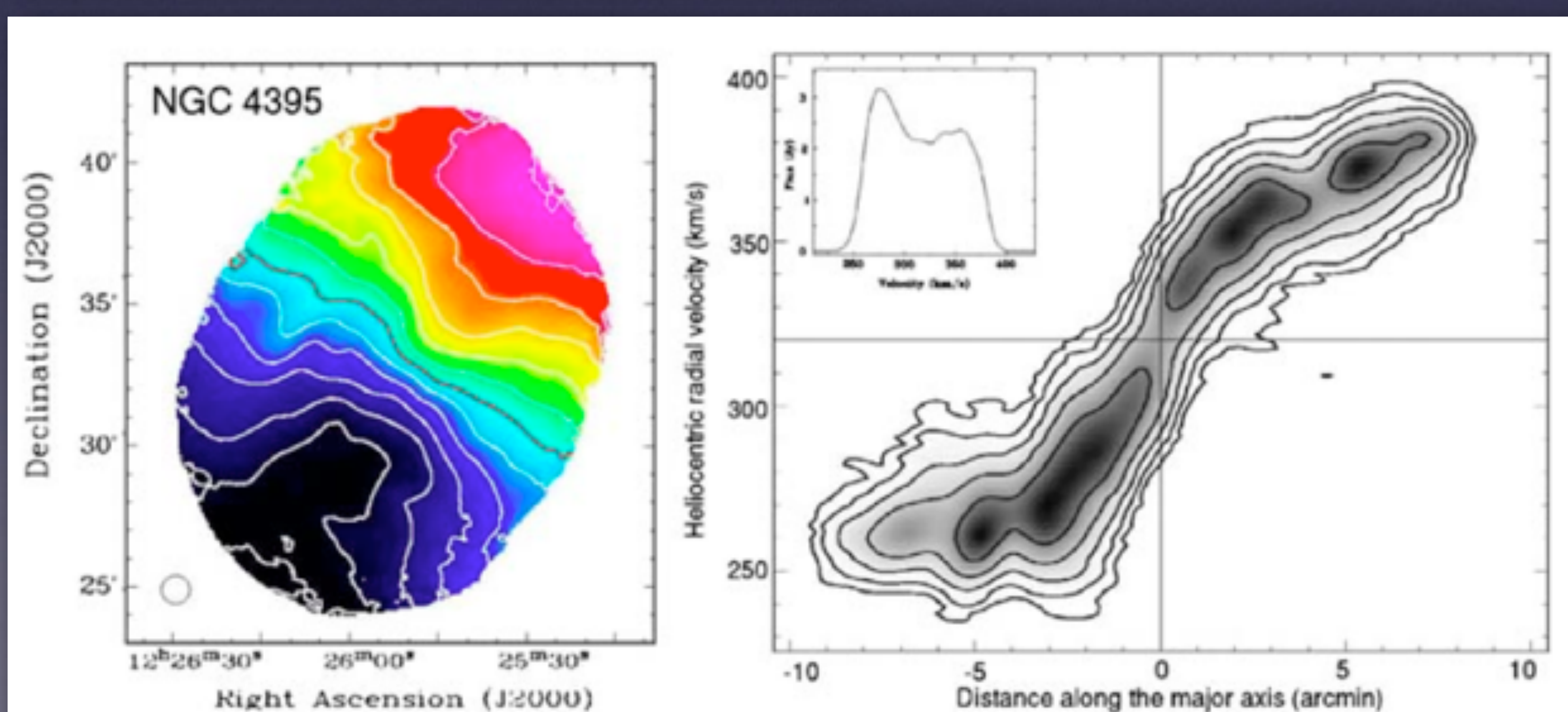
Lopsidedness

M101



Morphological lopsidedness

Kamphuis 1993



Kinematical lopsidedness

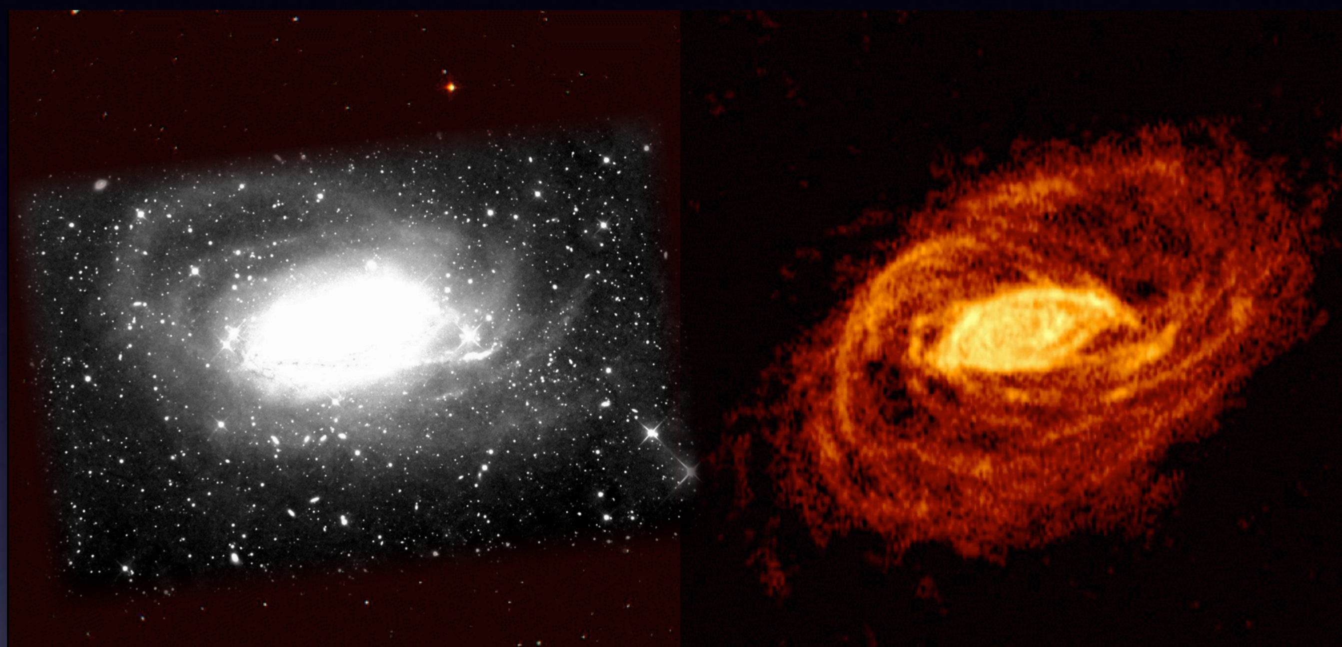
Heald & Oosterloo 2008

Warps and stellar streams

No gas associated with the streams.

NGC 5055

R. Jay GaBany



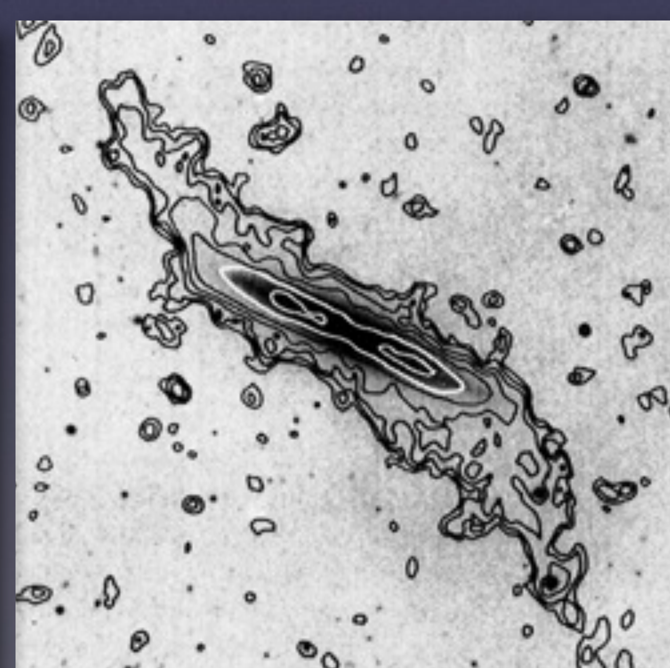
Battaglia+ 05

NGC 5907

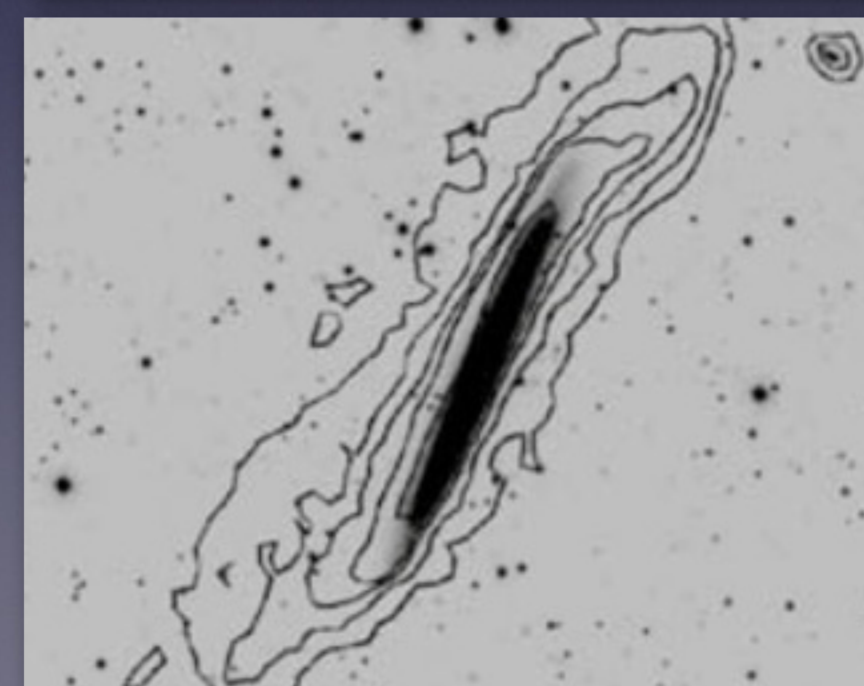
R. Jay GaBany

NGC 4013

R. Jay GaBany



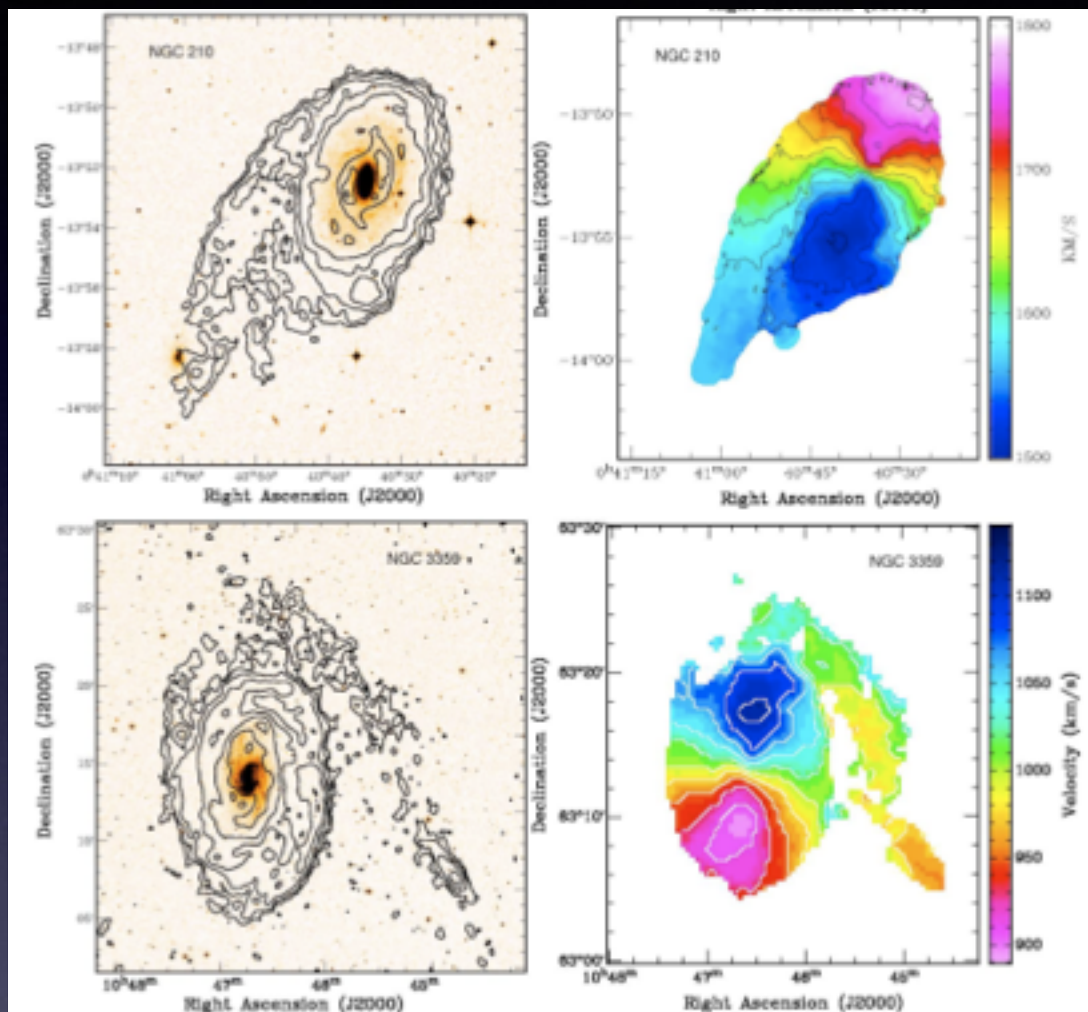
Bottema 95



Shang+ 98

Fueling the Blue Cloud

Sancisi+ 2008



sustaining star formation

-

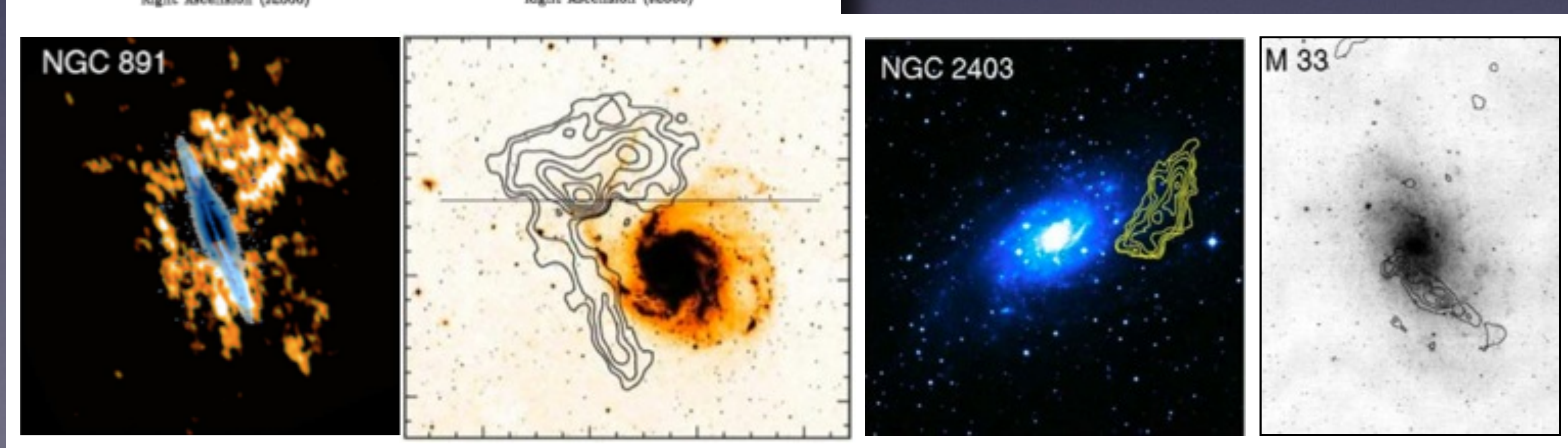
building up stellar mass

Evidence for cold accretion

or

Galactic Fountain / Fallback?

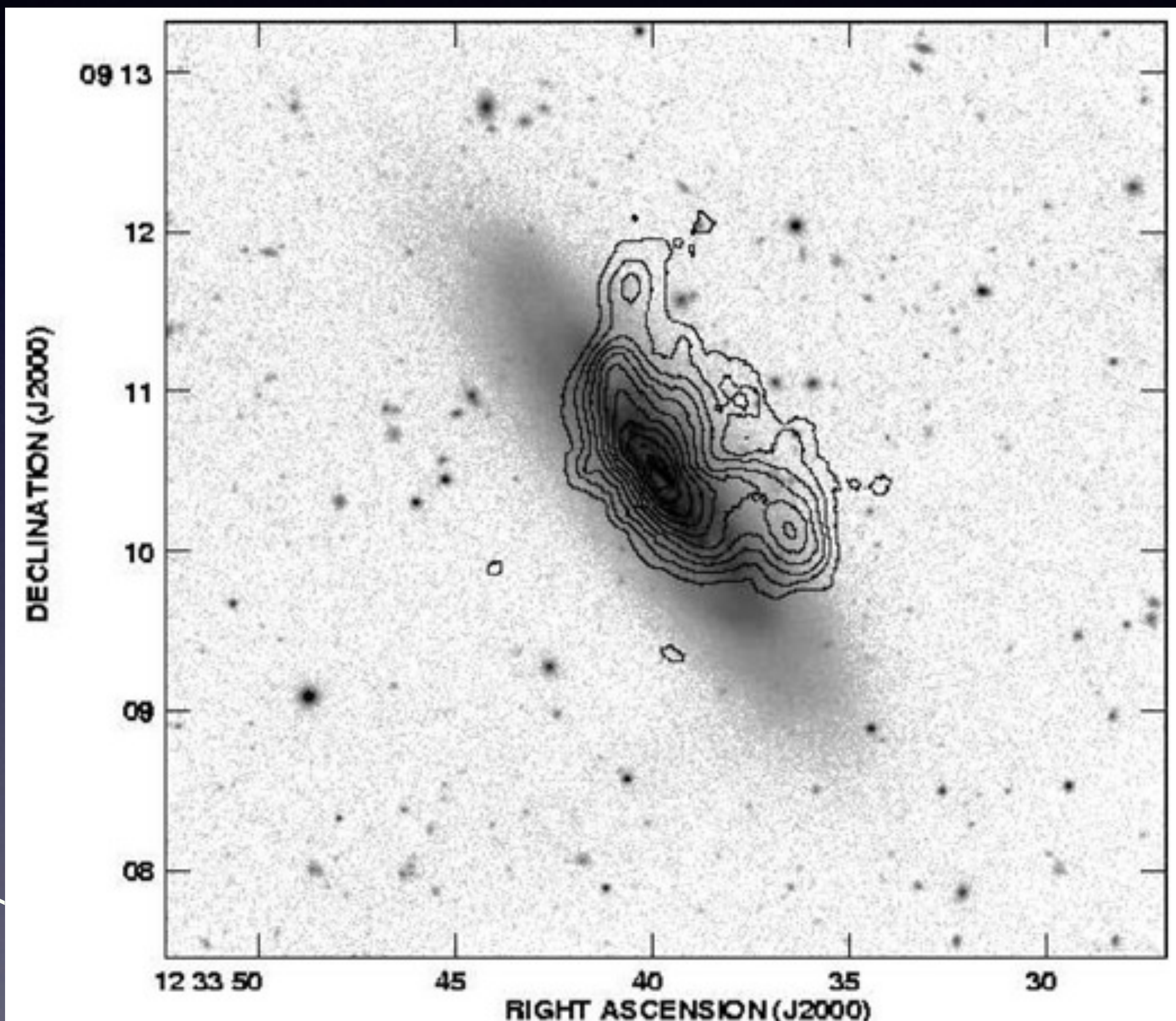
Oosterloo+ 2007



Jumping across the Green Valley

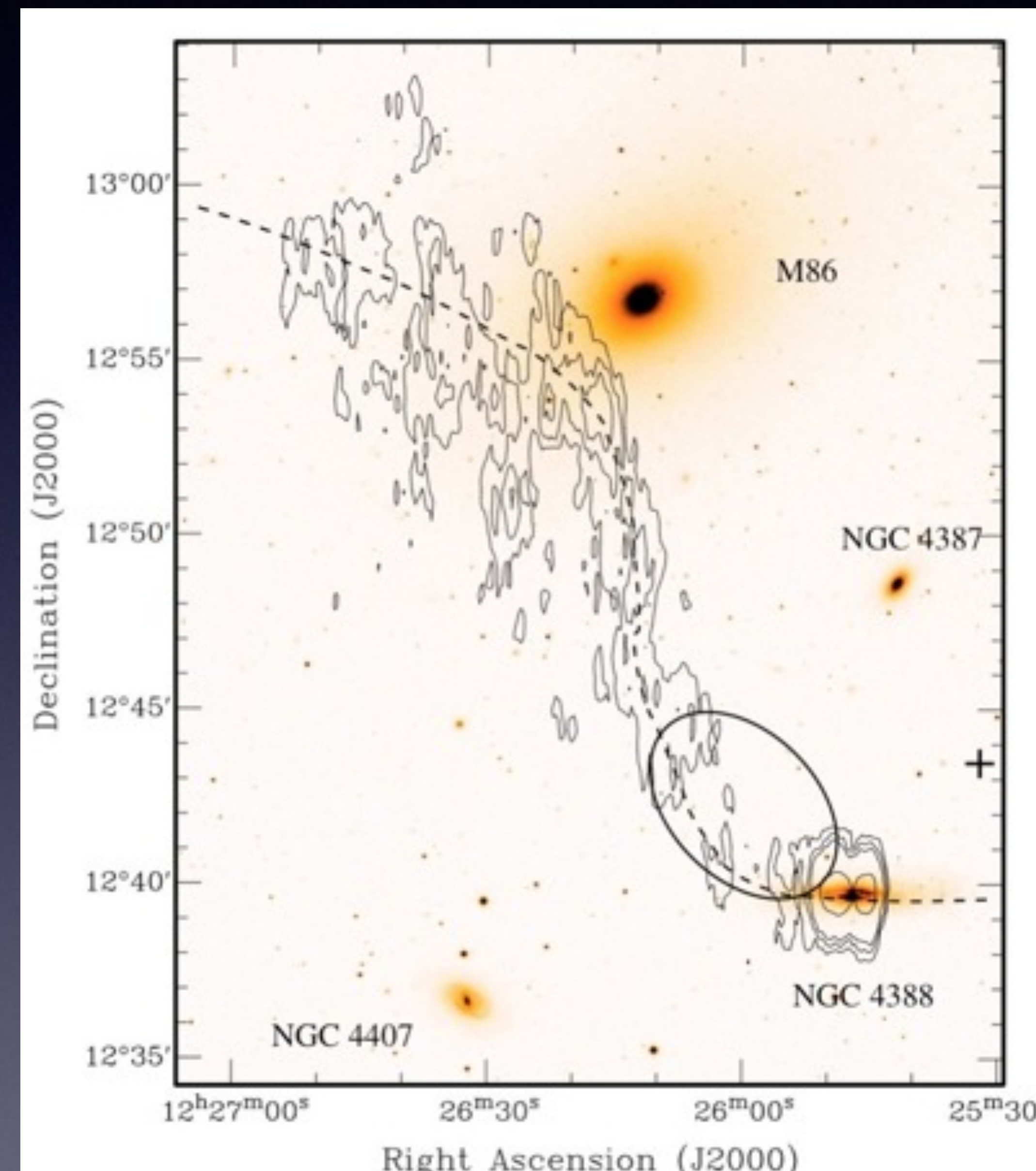
ram-pressure stripping in action

NGC 4522



Kenney+ 2004

NGC 4388

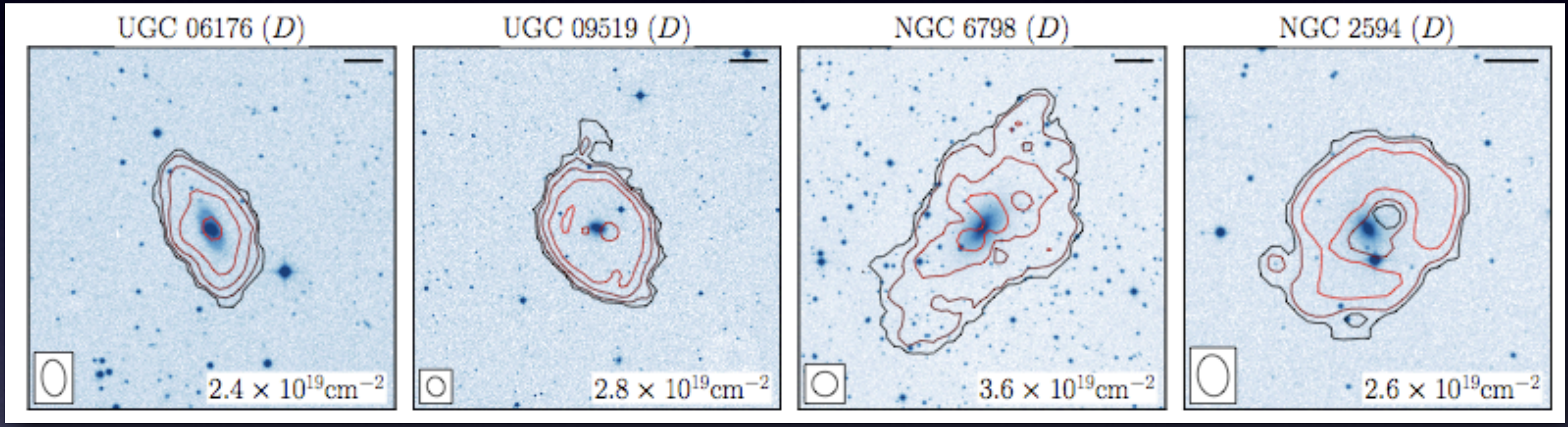


Oosterloo & van Gorkom, 2005

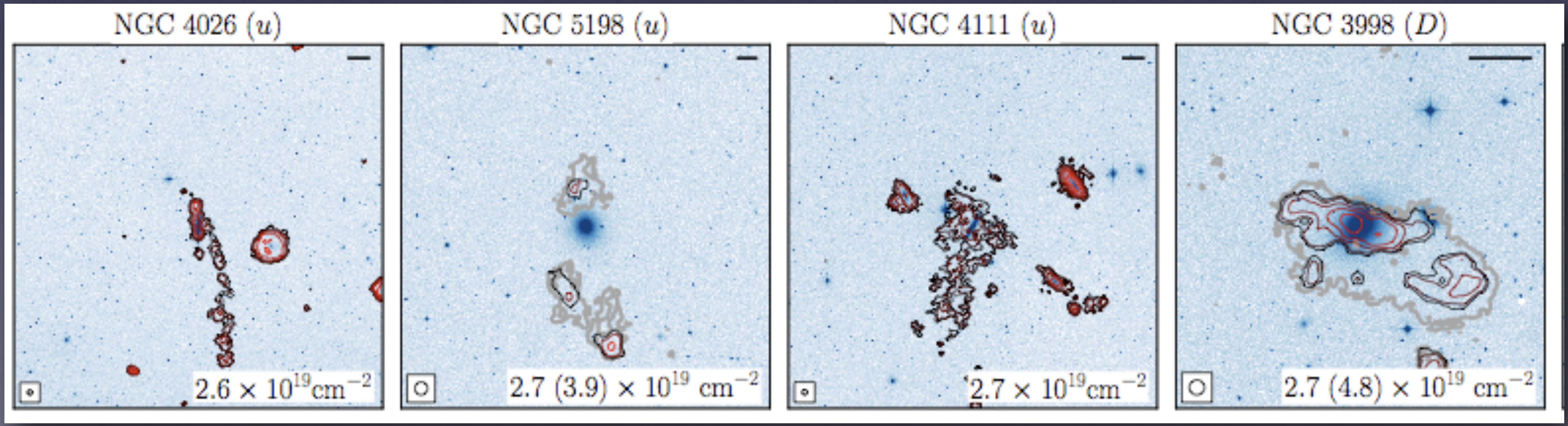
Gas in early-type galaxies

Atlas^{3D} : HI imaging of 166 early-types (1/3 detected)

Lower density regions: extended & regular HI disks

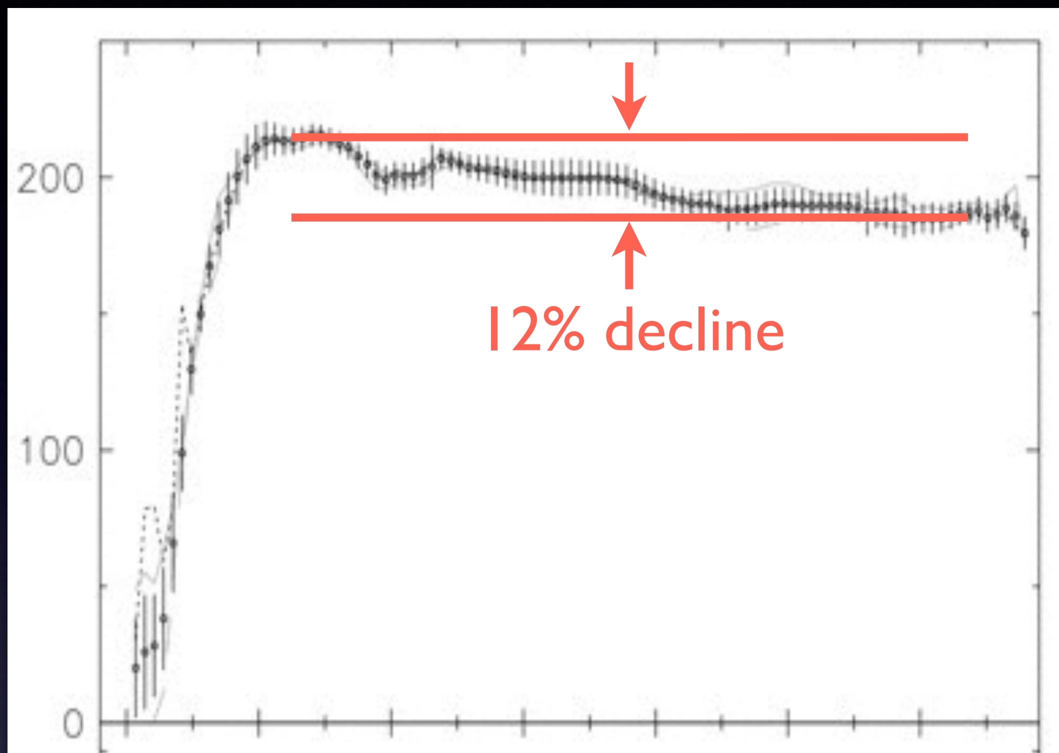


Higher density regions: clumpy & unstructured

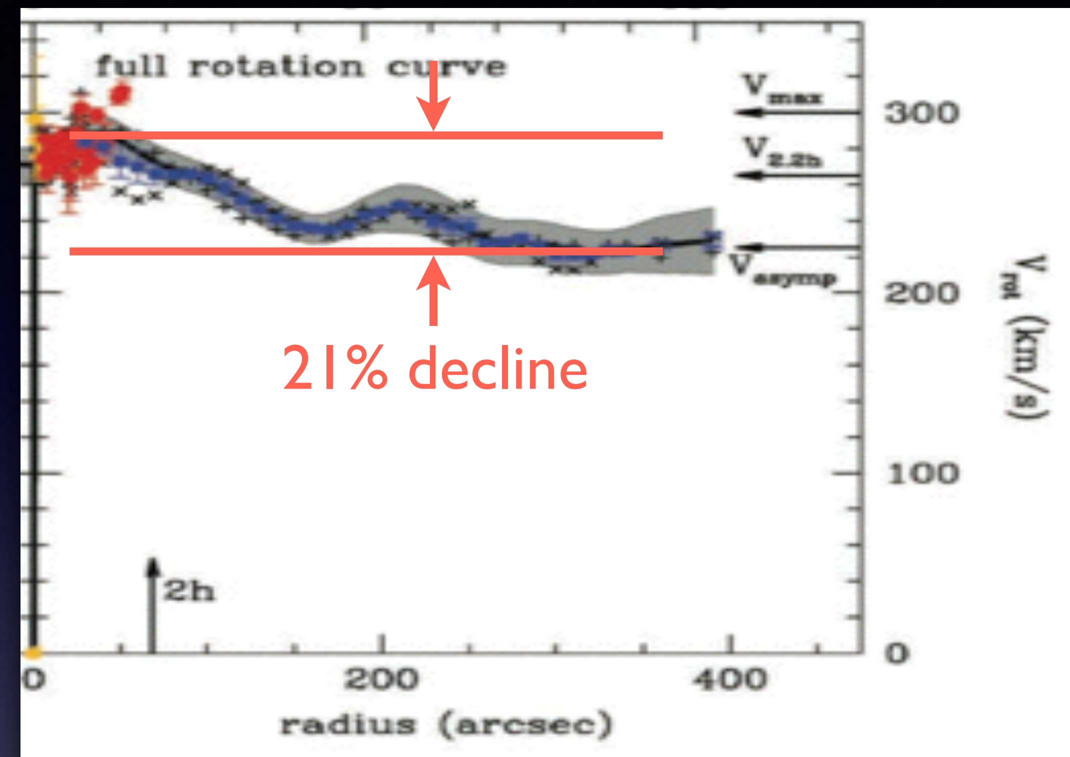


Serra+ 2011

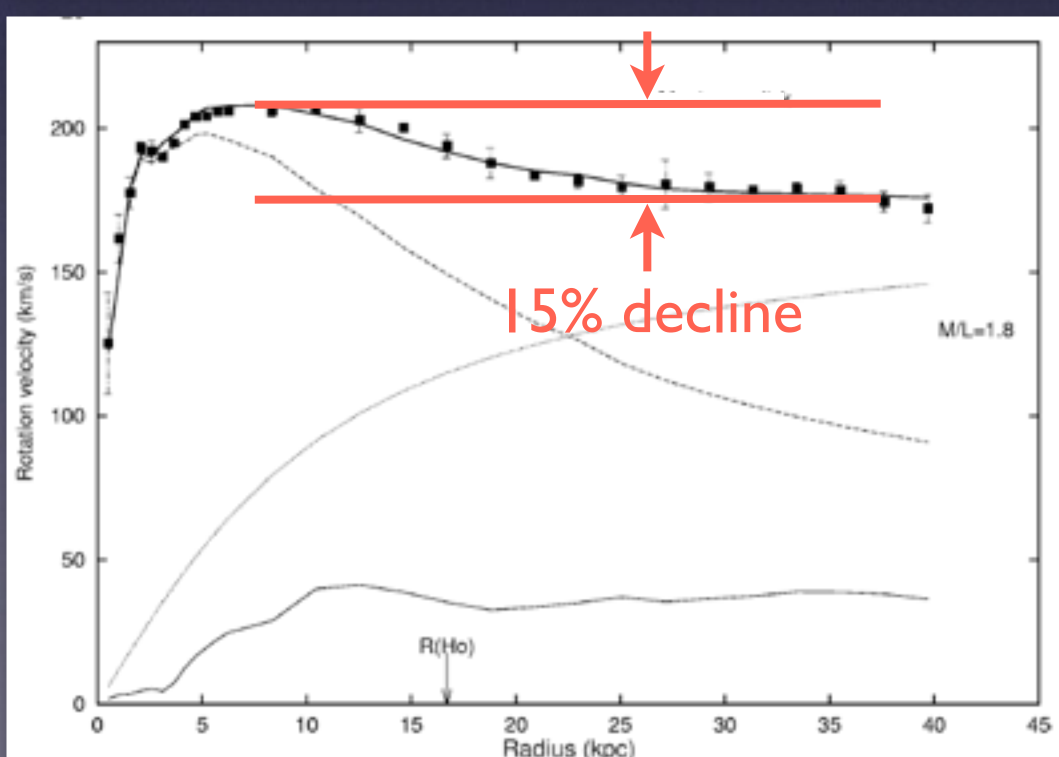
Rotation curves are *not* flat.



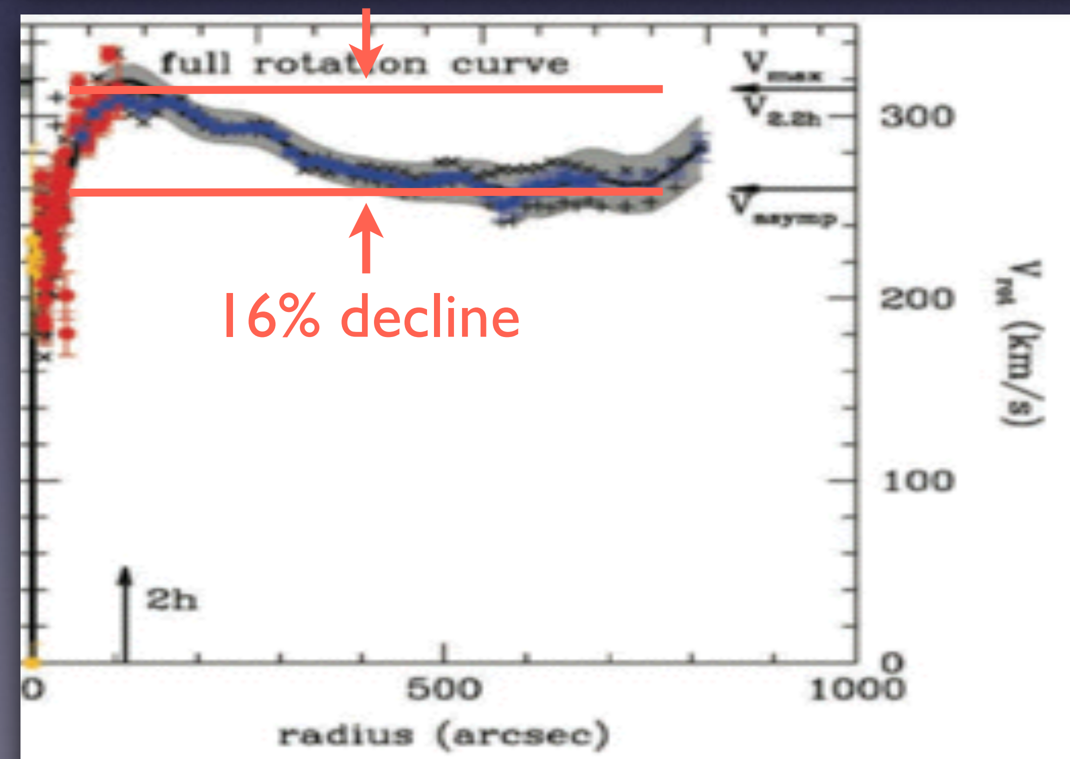
de Blok+ (2008)



Noordermeer+ (2005)



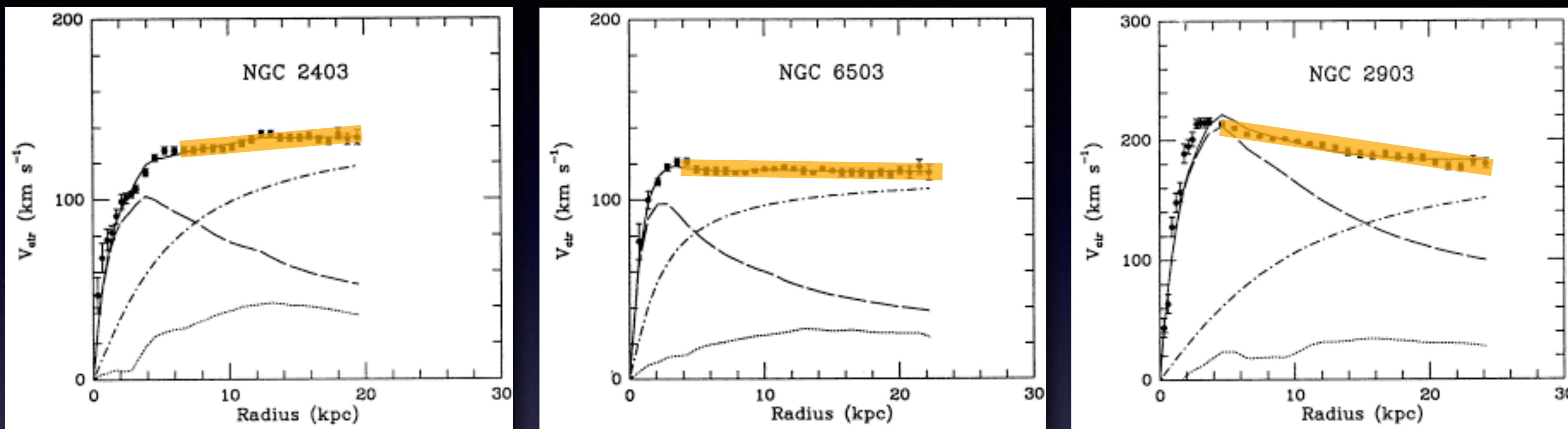
Sancisi, 2004



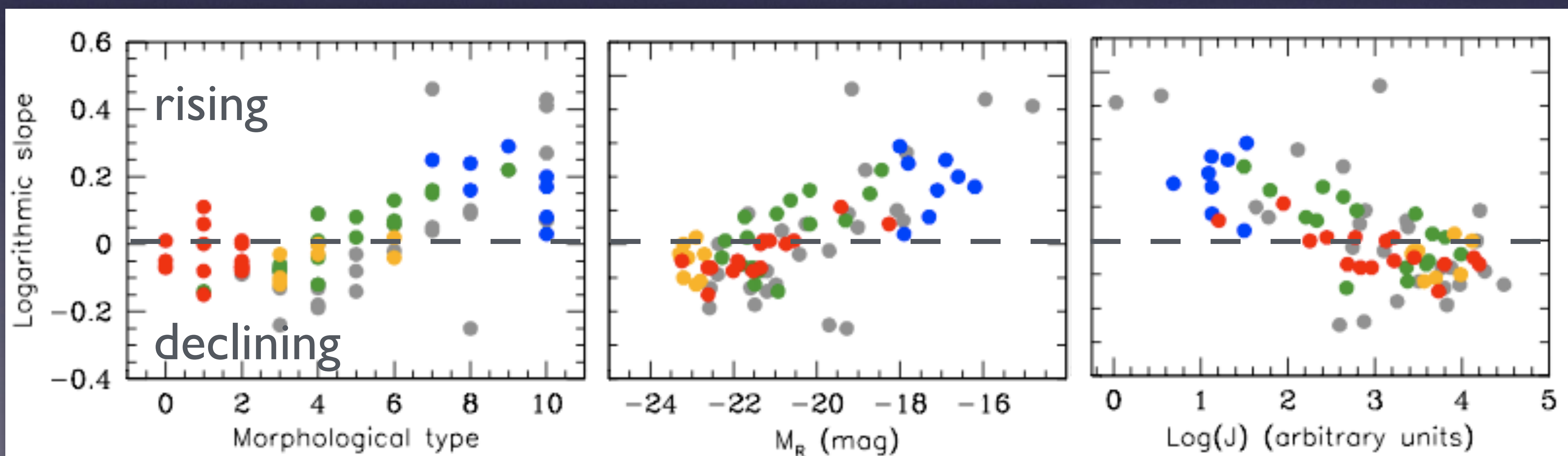
Noordermeer+ (2005)

outer slopes of extended rotation curves

S>0 : rising　　S=0 : flat　　S<0 : declining



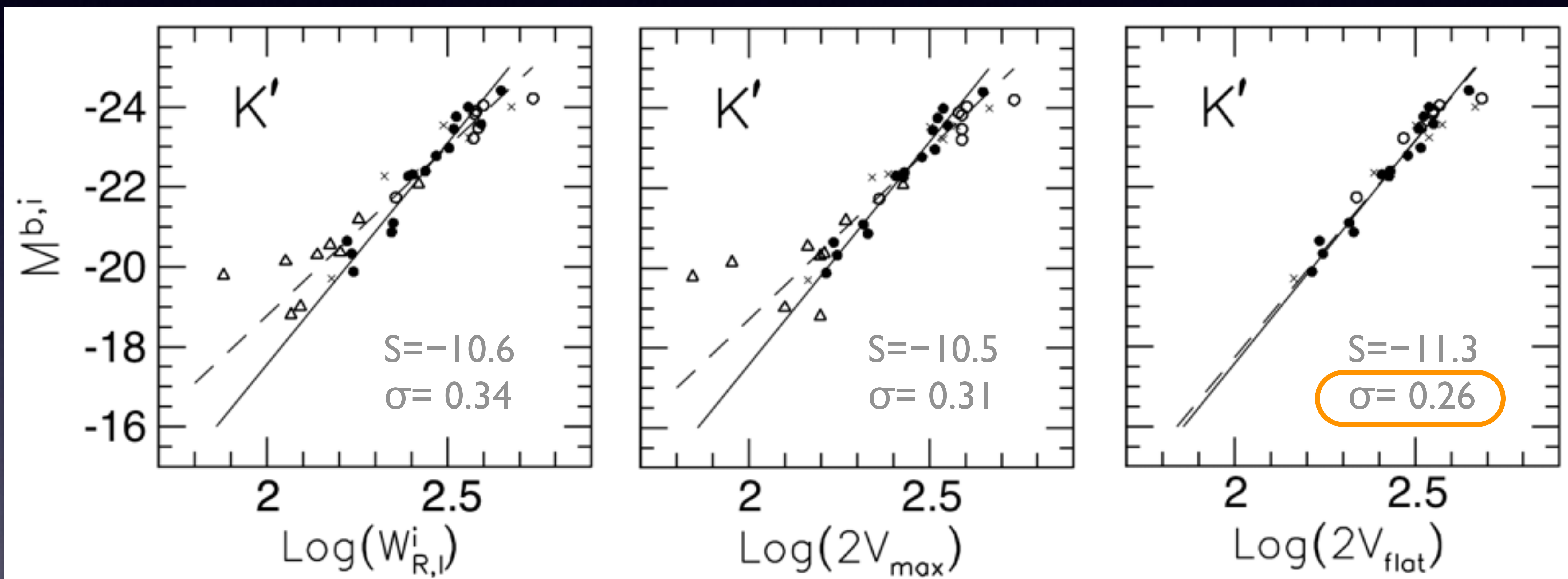
Begeman+ 1991



K-band Tully-Fisher relations

What is the relevant kinematic measure?

UMa: W_{20} V_{max} V_{flat}



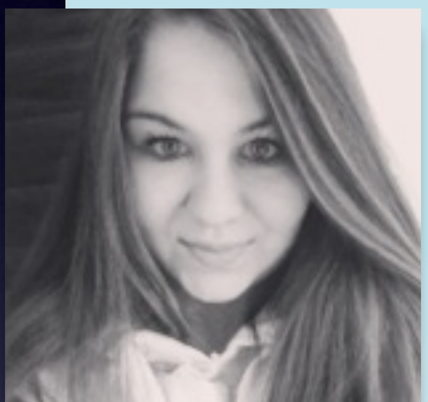
Verheijen (2001)

consistent with volume depth & measurement error
→ no intrinsic scatter?

K-band Tully-Fisher relations

What is the relevant kinematic measure?

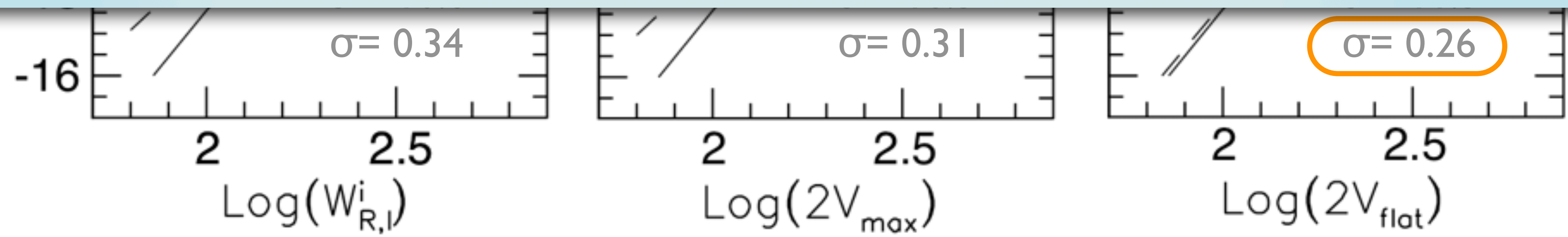
rijksuniversiteit groningen
kapteyn astronomical institute
APERTIF
APERture Tile In Focus
DAGAL



Detailed Anatomy of GALaxies:

the Tully-Fisher relation as a tool
to investigate the internal structure of galaxies

Anastasia Ponomareva, Marc Verheijen

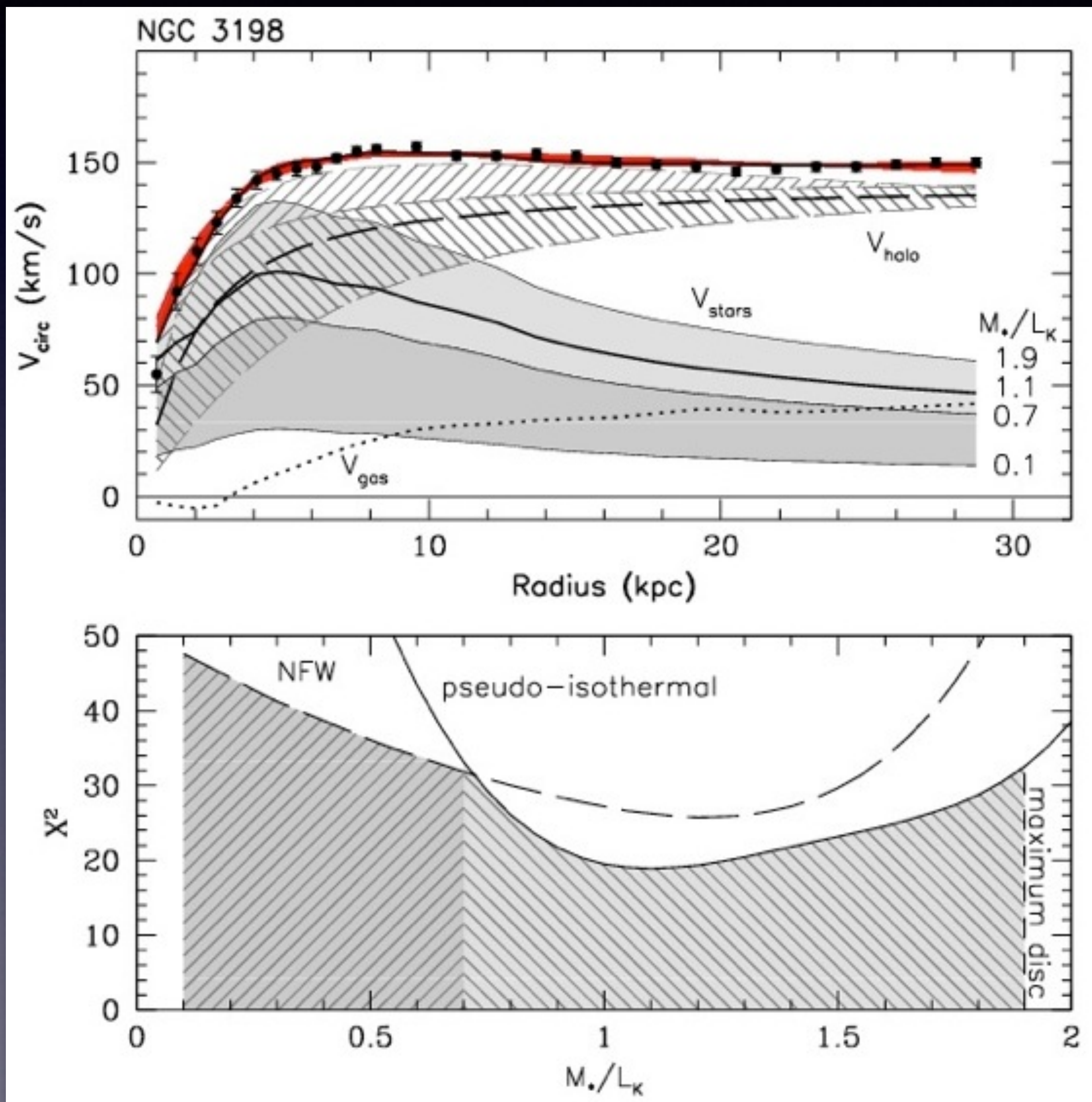


Verheijen (2001)

consistent with volume depth & measurement error
→ no intrinsic scatter?

Rotation curve decompositions

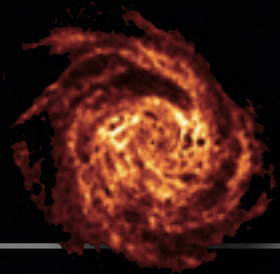
disk-halo degeneracy



no constraints on DM halo density profile without knowledge of baryonic mass or M/L

→ maximum-disk hypothesis

supported by kinematic features in rotation curves and velocity fields

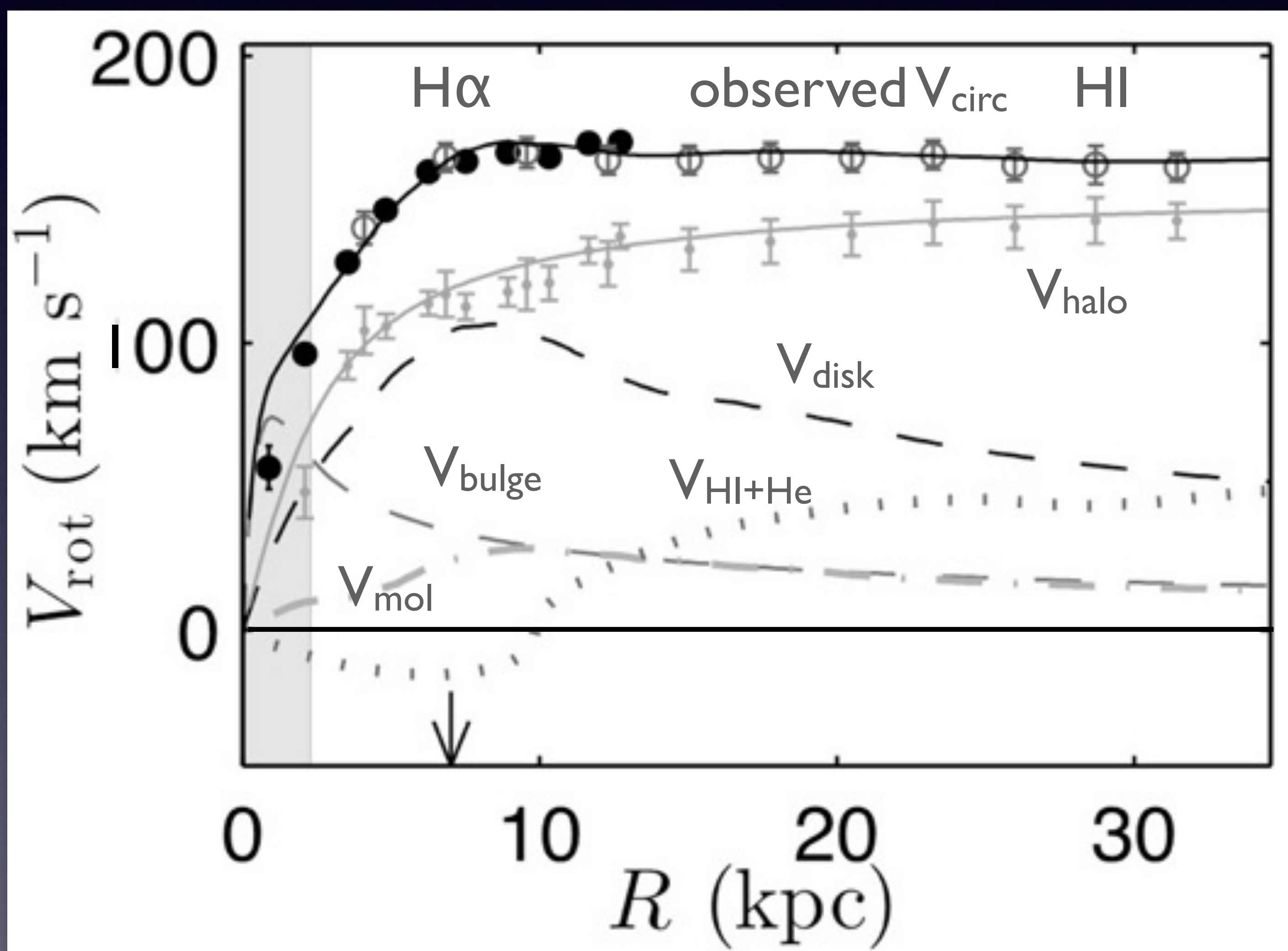


Breaking the disk-halo degeneracy

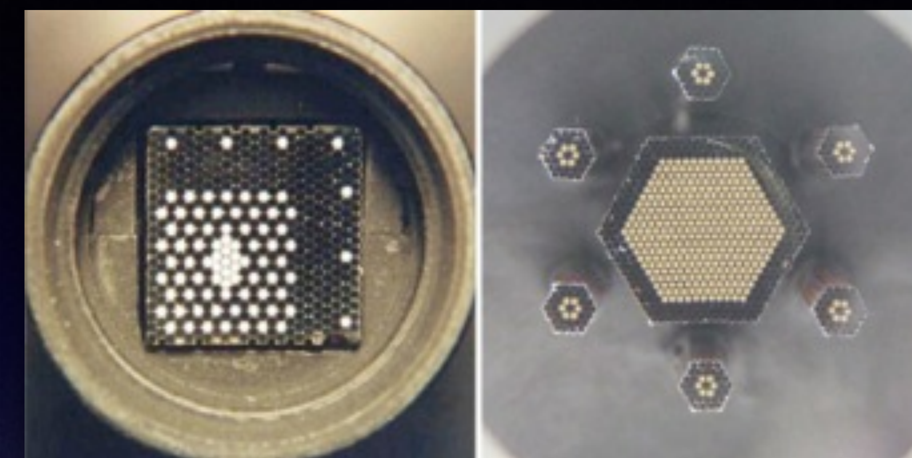
DiskMass Survey : (Bershady+ 2010)

→ use IFU-measured stellar kinematics

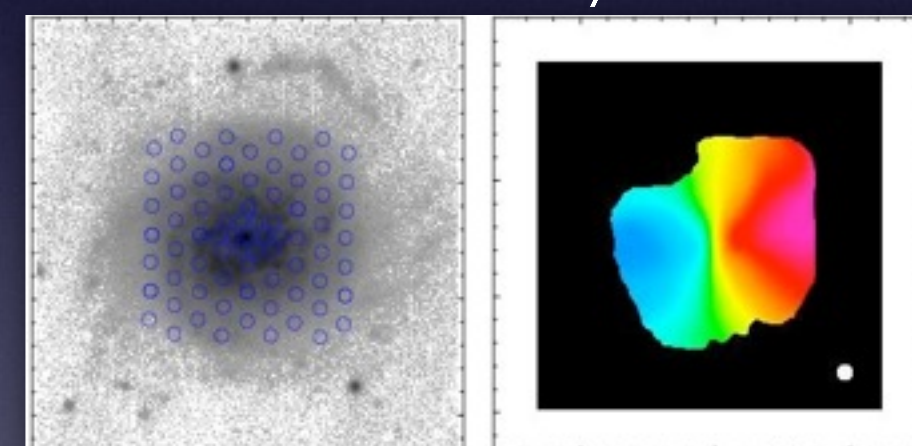
→ stellar mass surface densities and M/L.



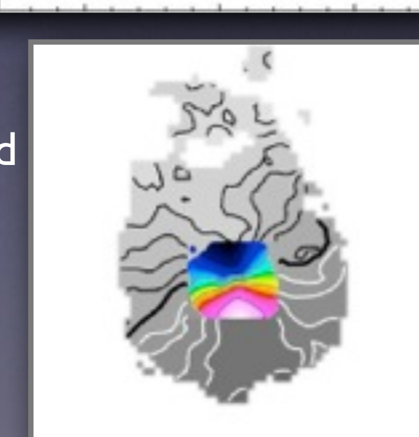
SparsePak/WIYN PPak/Calar Alto



UGC 6918 Hα velocity field



Hα + HI velocity field

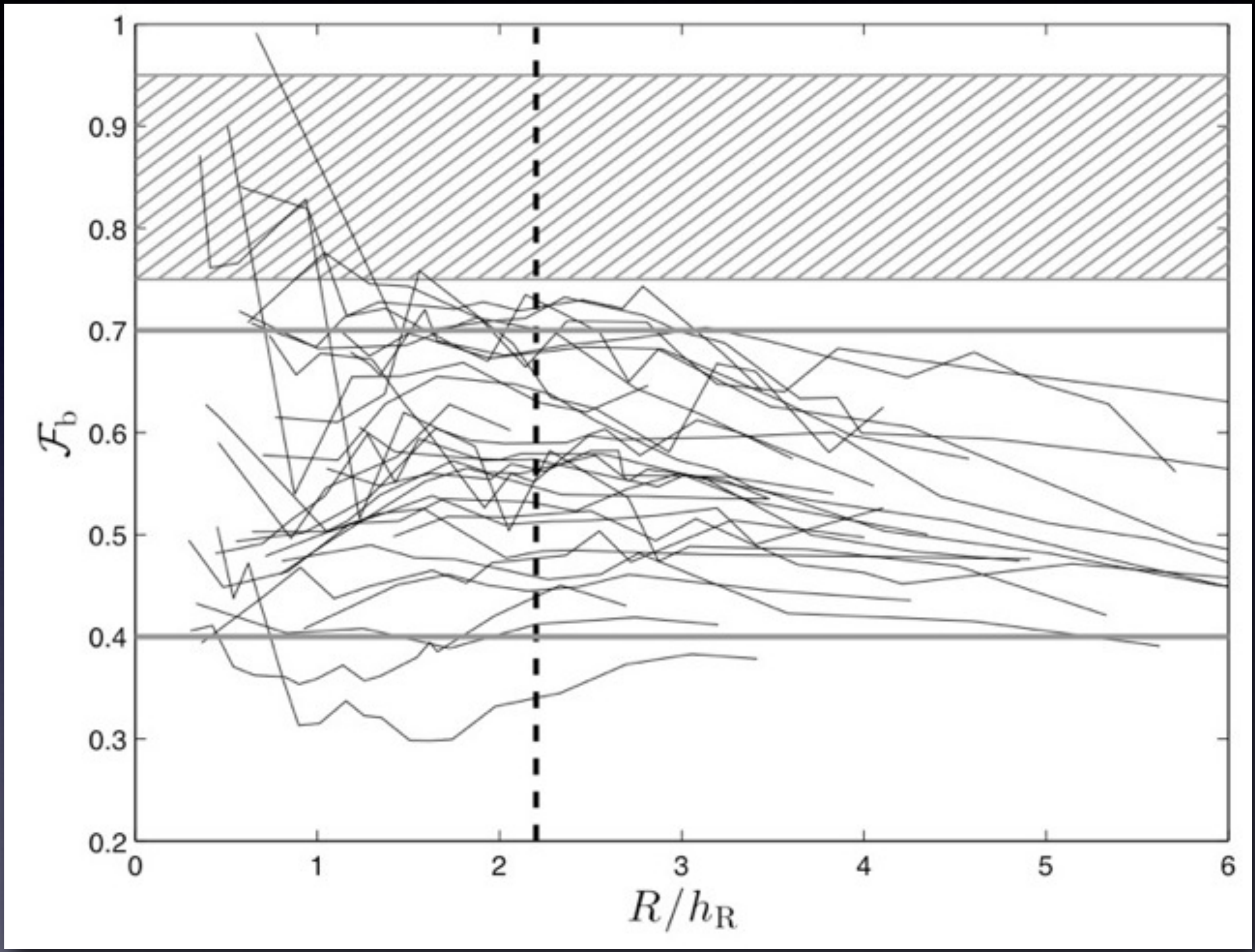


With known M/L, calculate rotation curves of all baryonic components.

$$V_{halo} = \sqrt{V_{obs}^2 - V_{bary}^2}$$

Baryonic contribution to rotation curves

$F_{bary} = V_{bary} / V_c$



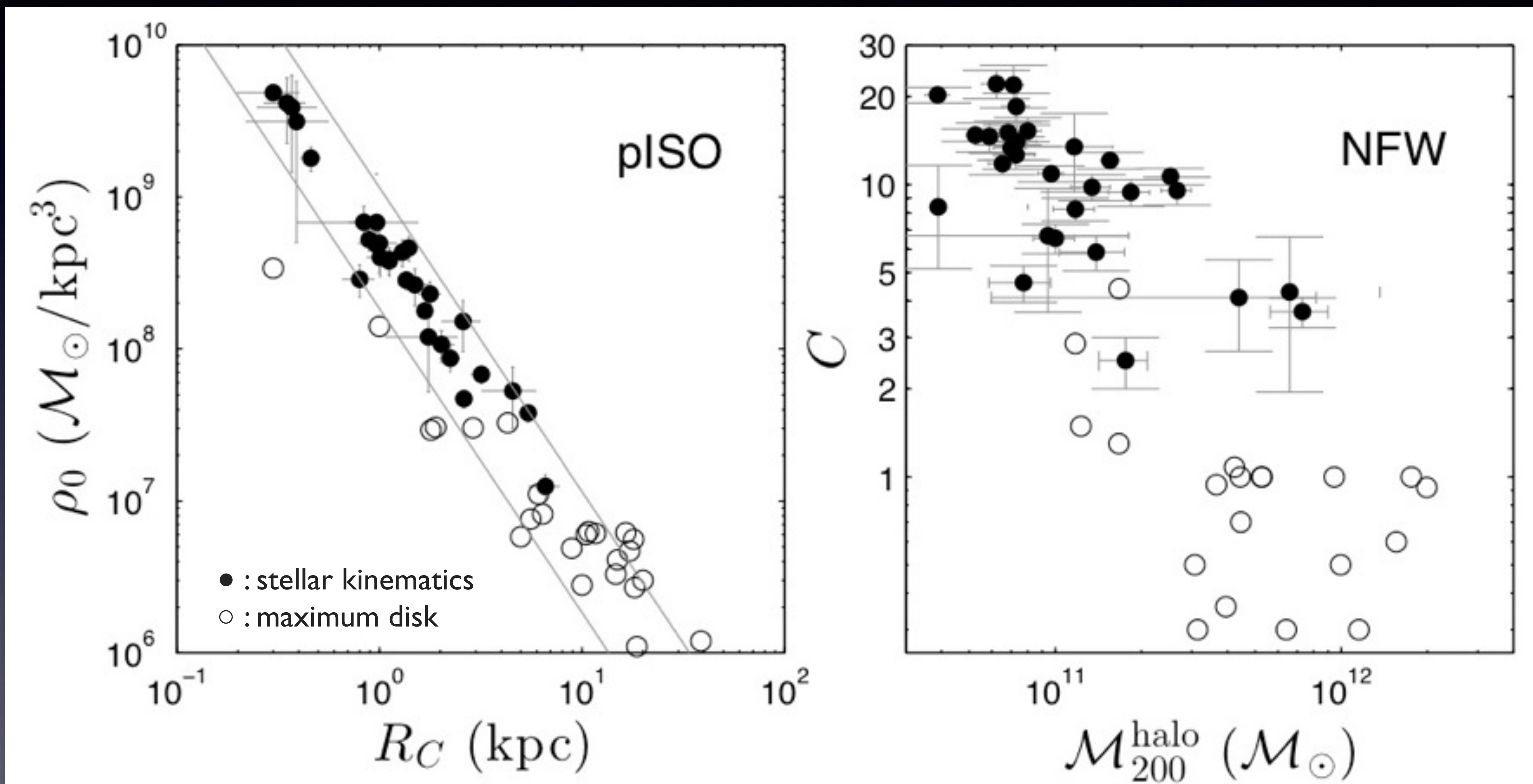
maximum-disk

Martinsson+ (2013b)

Baryonic RCs are sub-maximal and nearly flat...

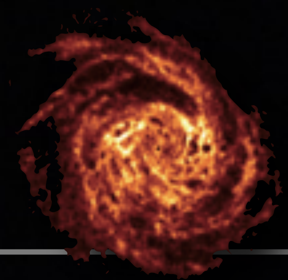
Dark Matter halo rotation curves

pseudo-isothermal NFW



Martinsson+ (2013b)

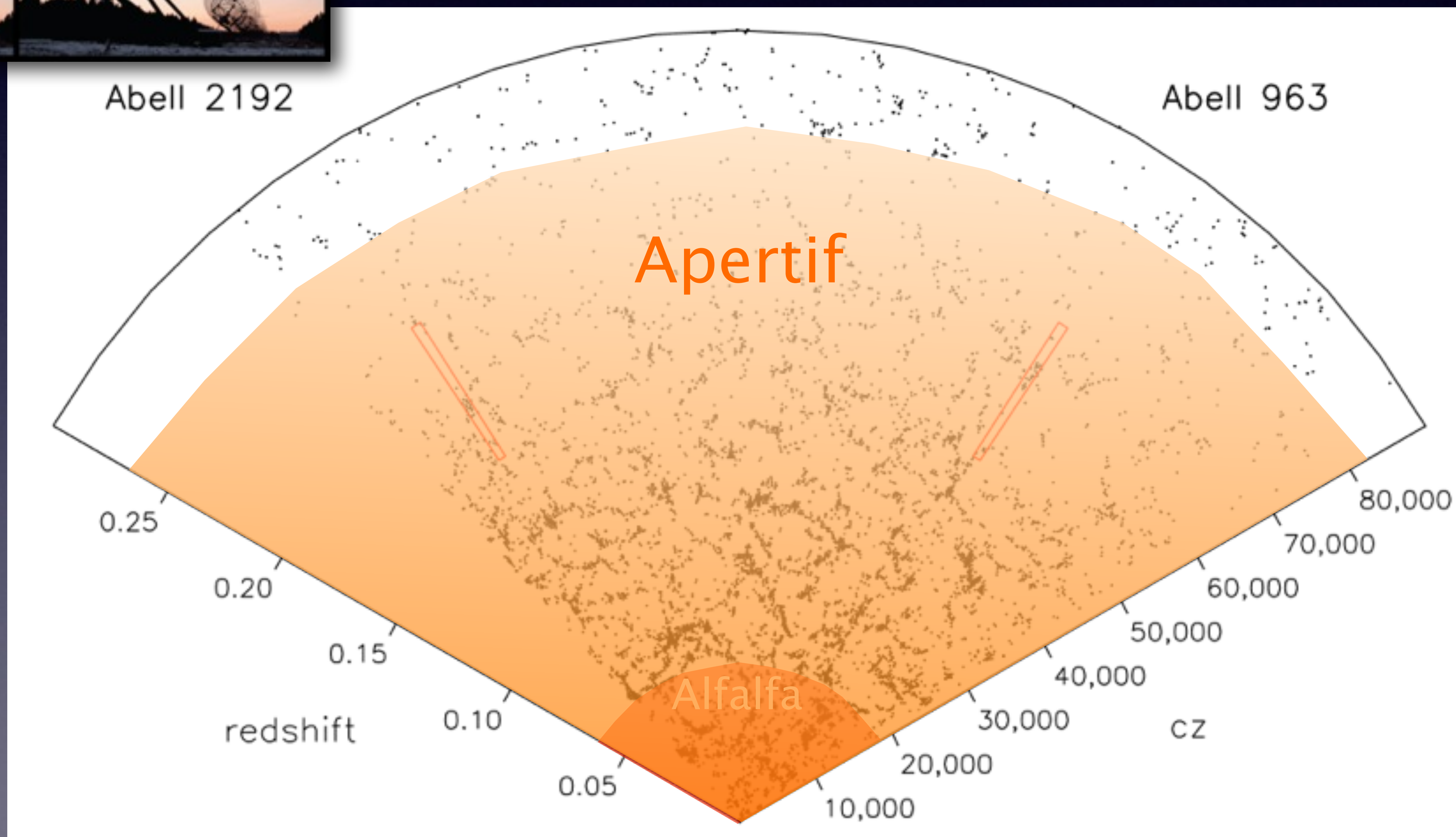
$\rho_{DM}(r)$ from max-disk decompositions inconsistent with NFW.



The promise of Apertif

A wide-field HI radio ‘camera’ for the WSRT

10^5 detections, 10^4 resolved disks



The promise of Apertif

APERTIF

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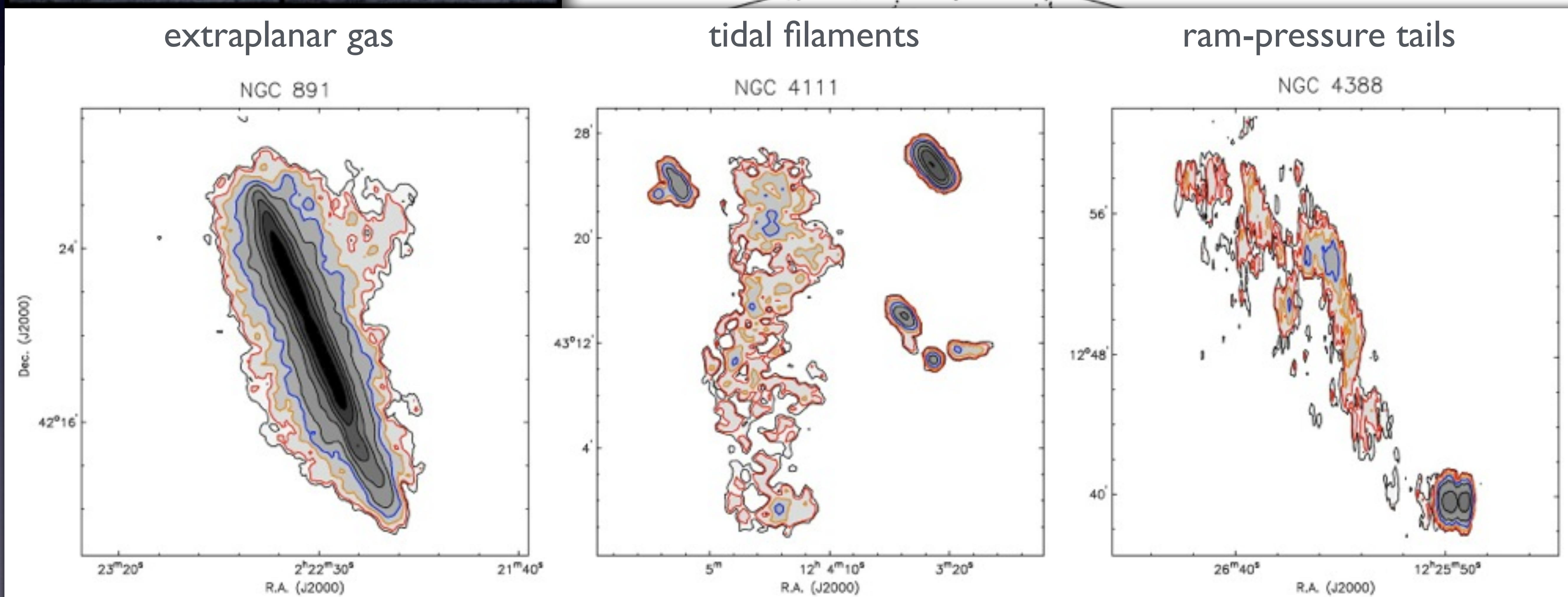
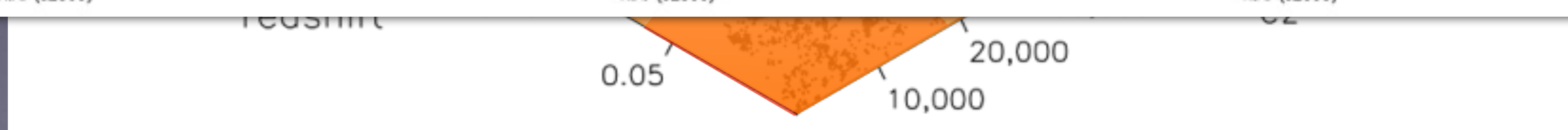
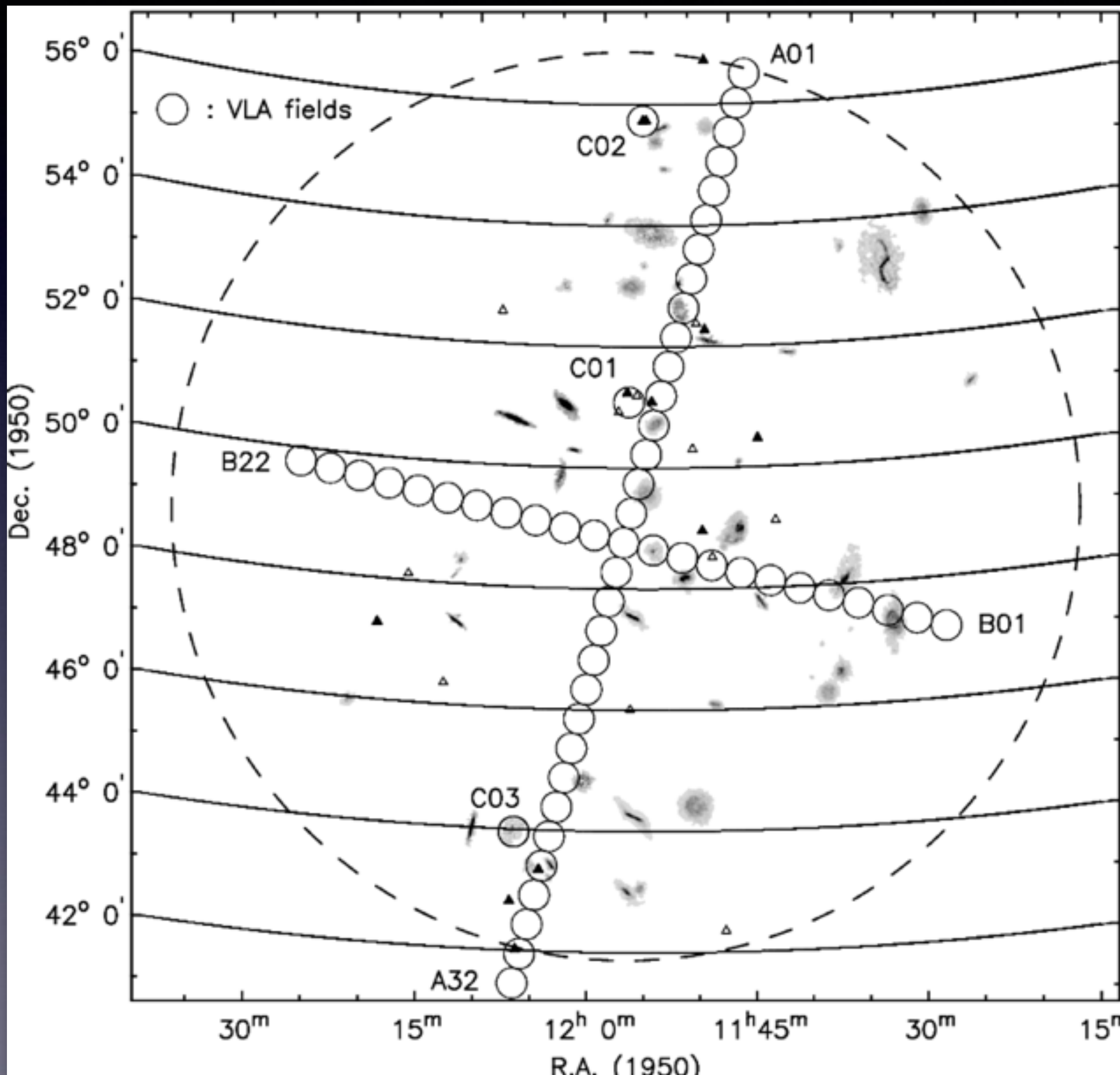




A blind HI imaging survey of Ursa Major

VLA-D
54 pointings



A blind HI imaging survey of Ursa Major

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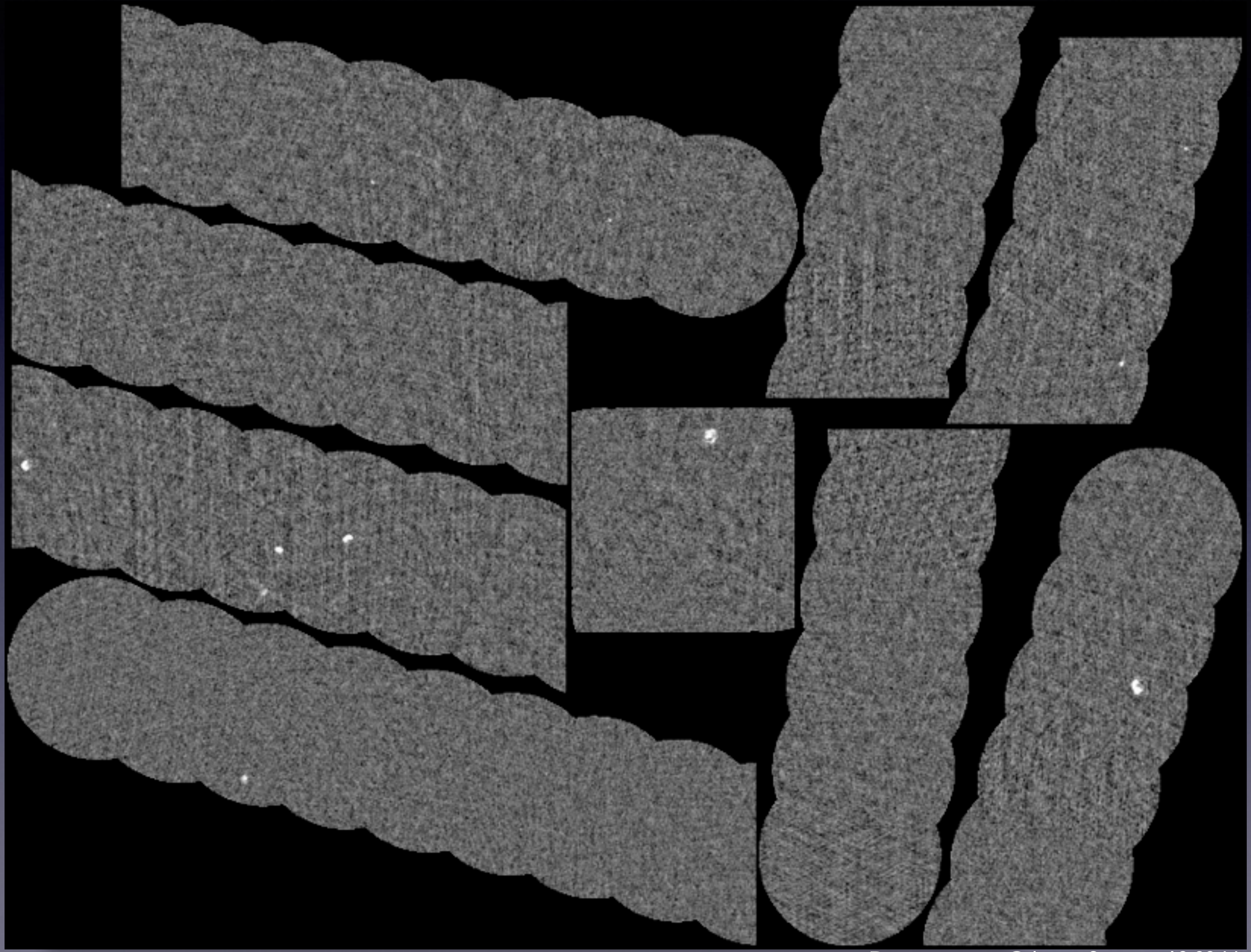
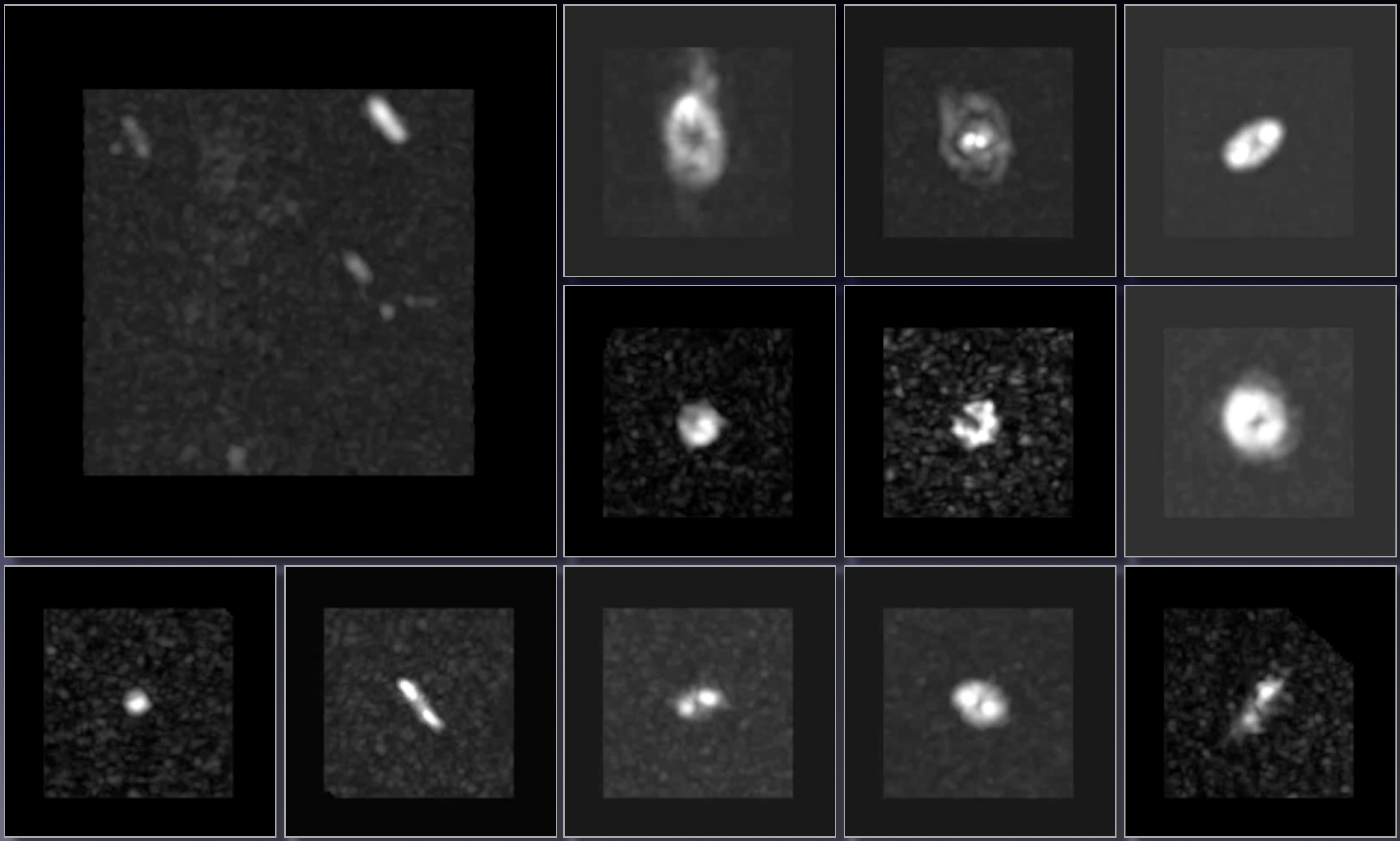
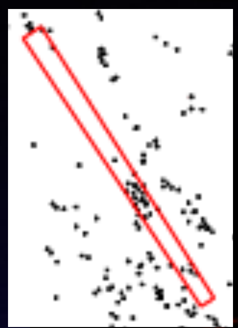


detecting & characterizing 3D structures

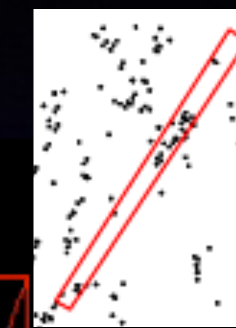


The push to higher redshifts

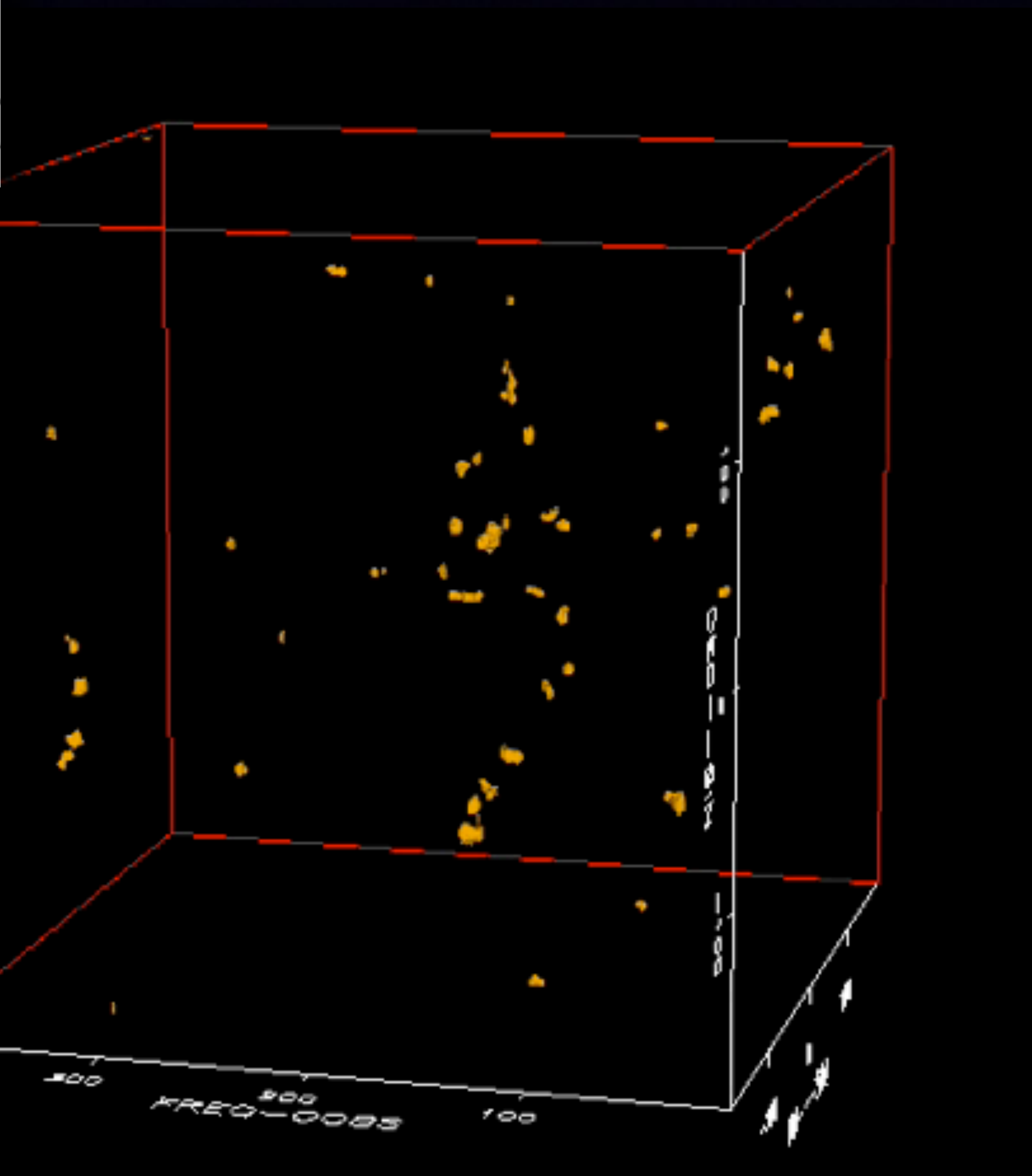
A2192

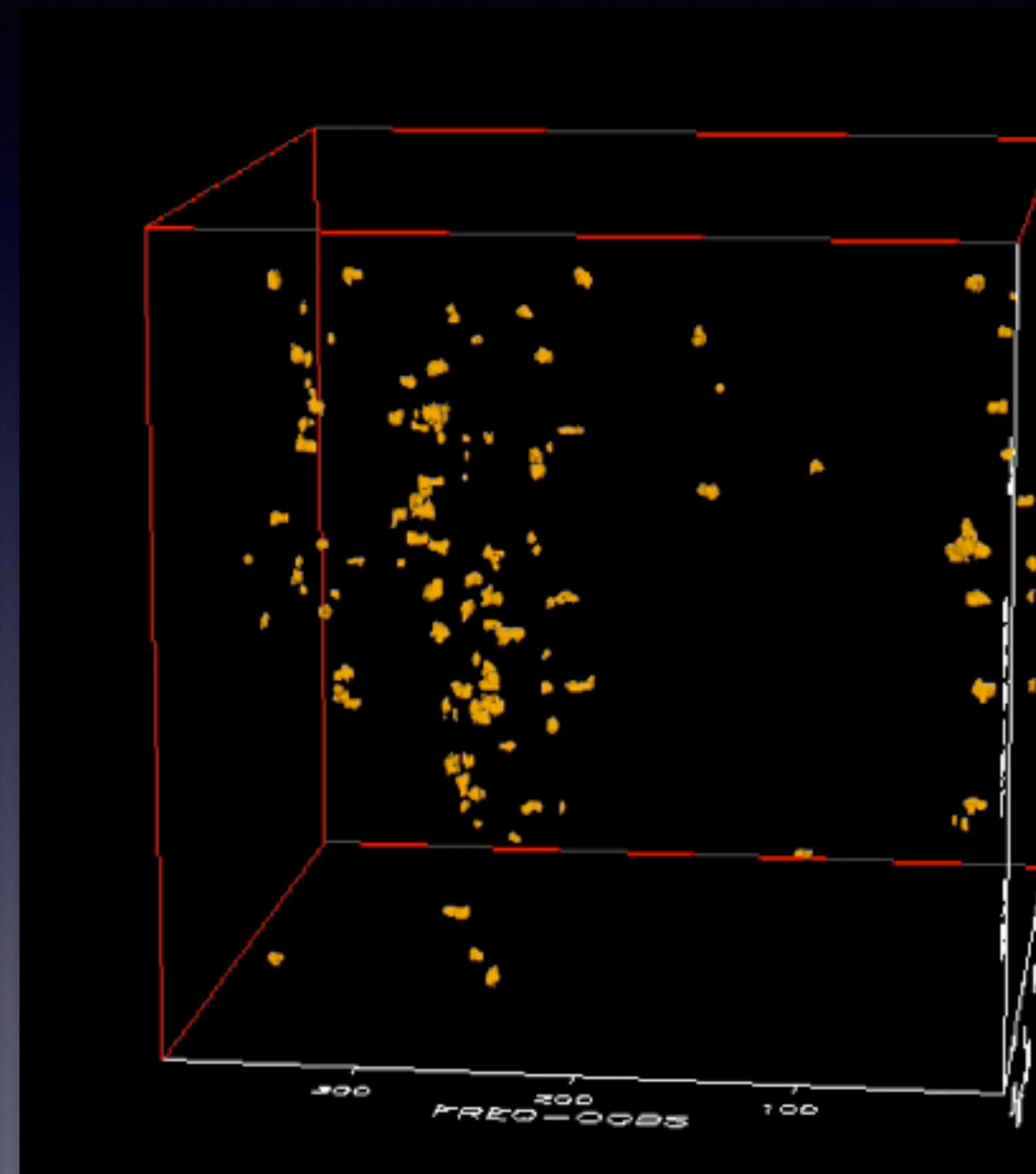


A963



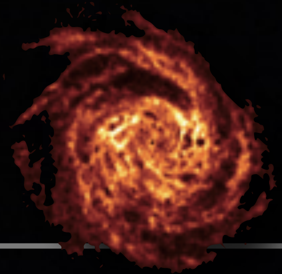
two pencil-beam volumes: Z = 0.164 - 0.224





Cube size : 9.5 x 9.5 x 325 Mpc^3
Beam size : 65 x 80 kpc^2 x 80 km/s

Large-scale structure revealed by blind HI imaging.



Summary

- HI disks are excellent probes of galaxy structure & kinematics
  spiral arms, warps, rotation curves, streaming motions, triaxiality, …
- HI reveals physical processes not/hardly seen otherwise
  tidal interactions, accretion/inflows, tidal/ram-pressure stripping, Galactic fountain, …
- BTFR may have zero intrinsic scatter when using $V_{\underline{flat}}$
- Galaxy disks are sub-maximal with $0.4 < F_{bar} < 0.7$
- Forthcoming blind, large-area HI imaging surveys
  → unbiased view of the role of the environment