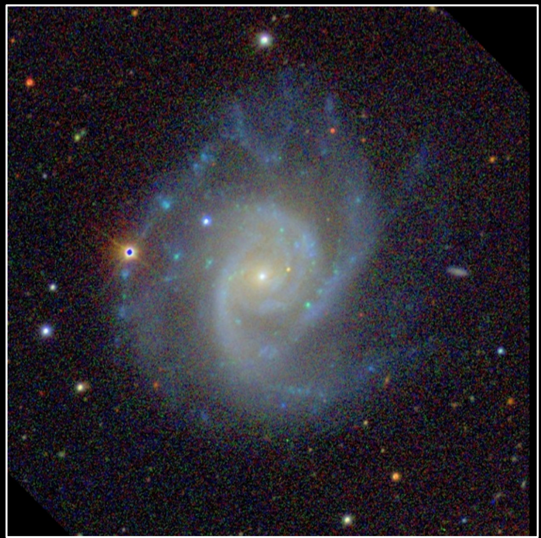
International Centre for Radio
Astronomy Research
University of Western
Australia

Angular Momentum in the Era of the SKA

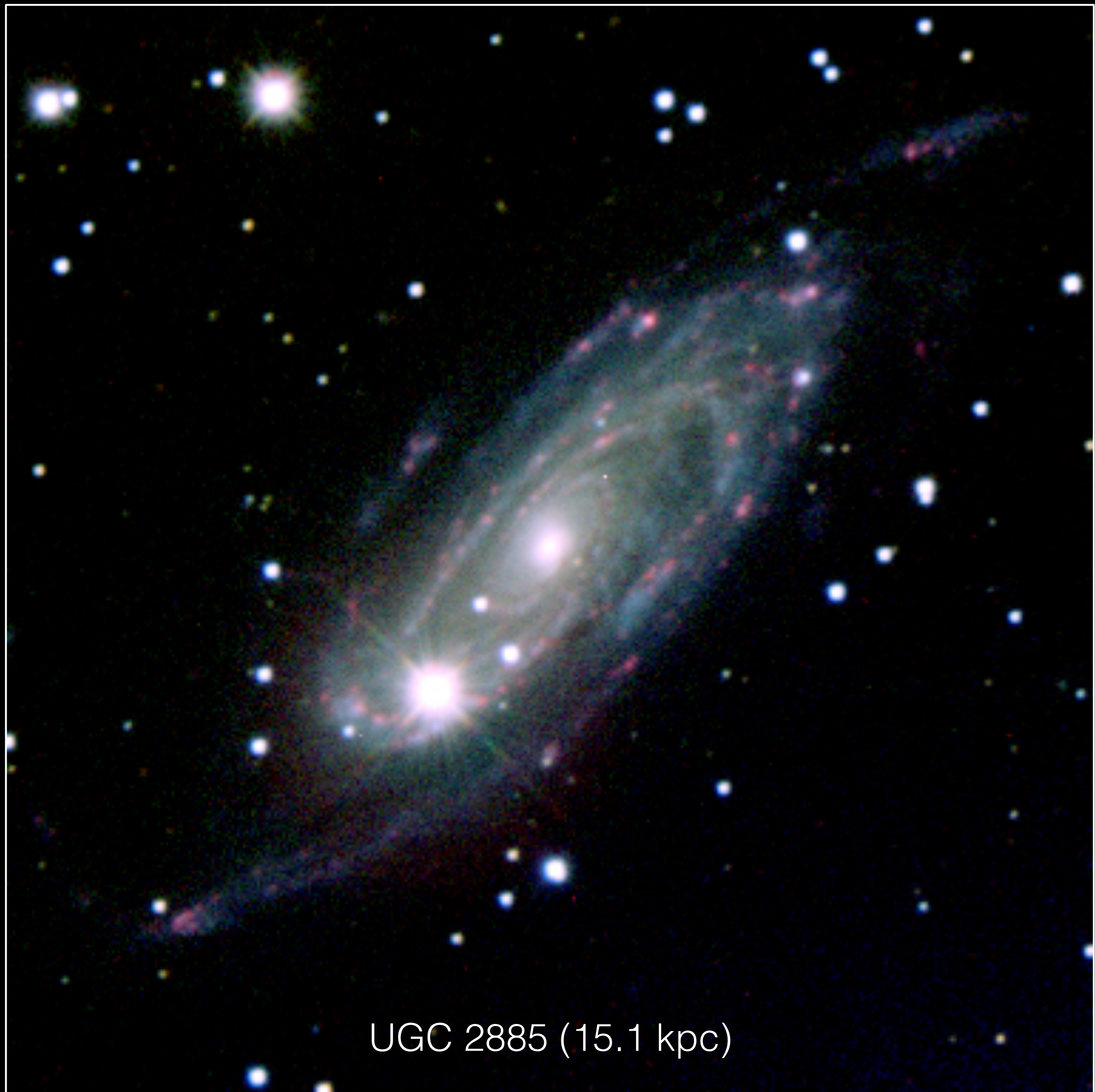
Danail Obreschkow

Dwingeloo, 17 March 2014

Which galaxy is the biggest?



Sizes to scale

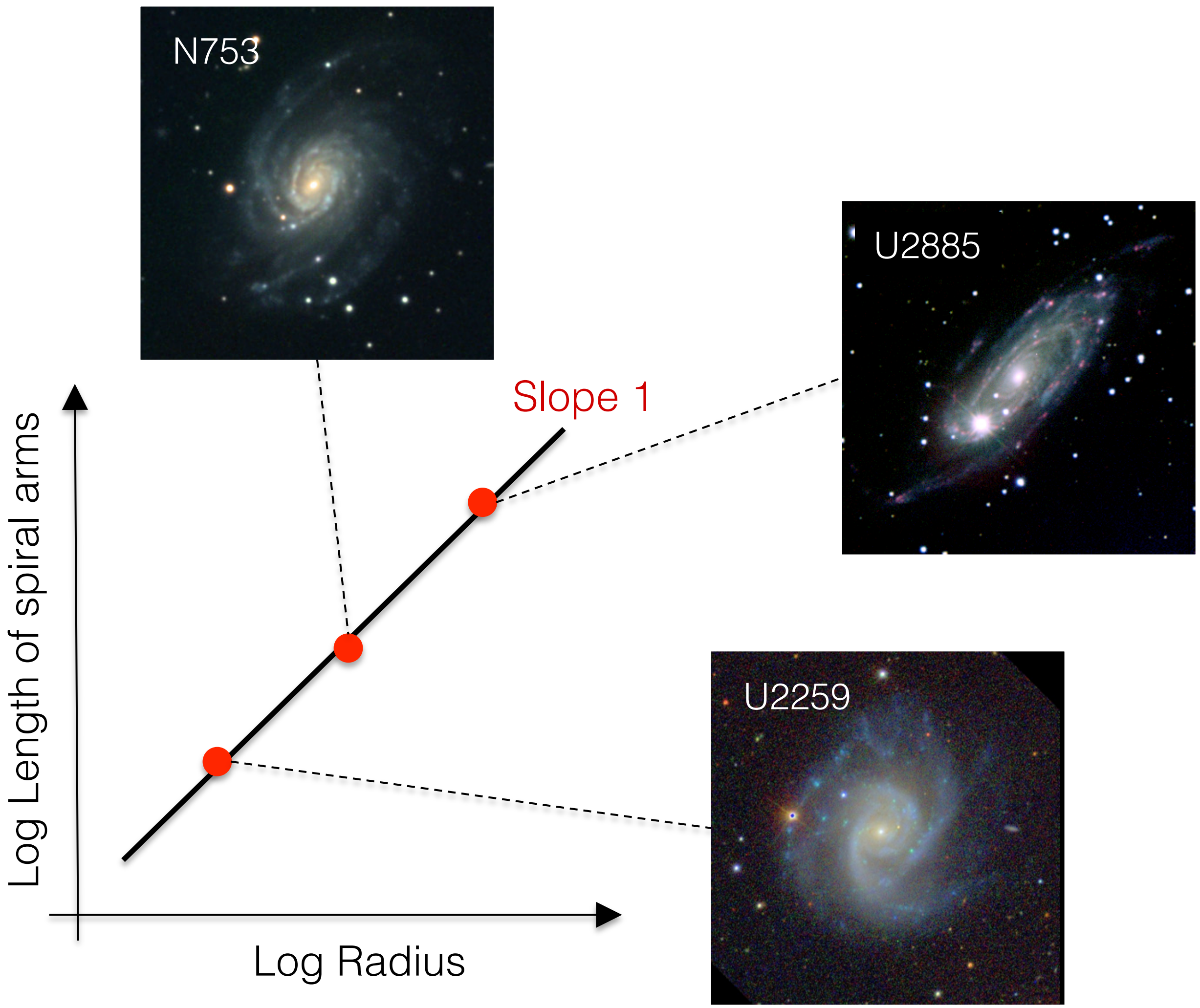


UGC 2885 (15.1 kpc)

NGC 753 (4.8 kpc)

UGC 2259
(1.1 kpc)

Scale-free geometry



Dynamical scalings

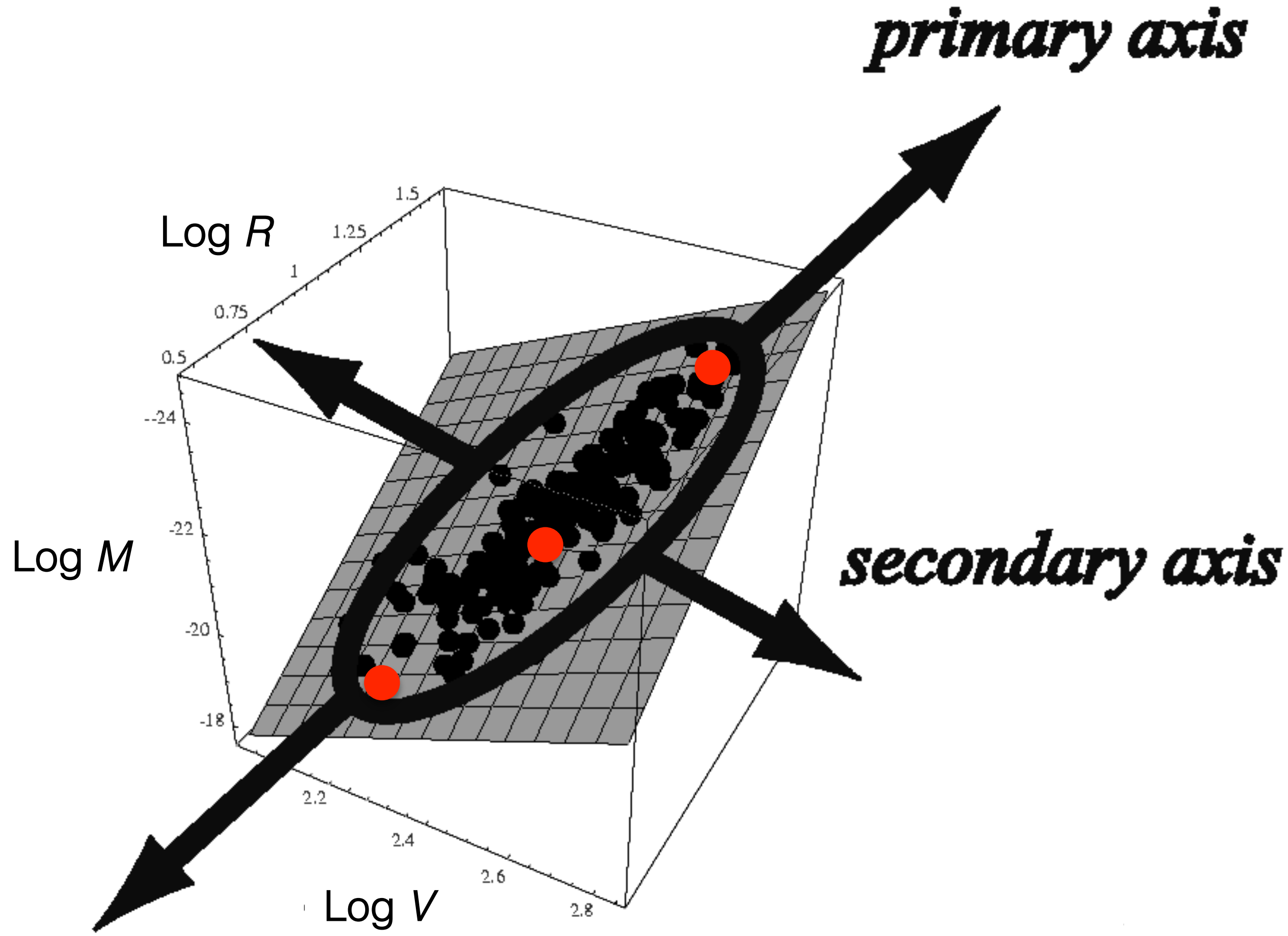
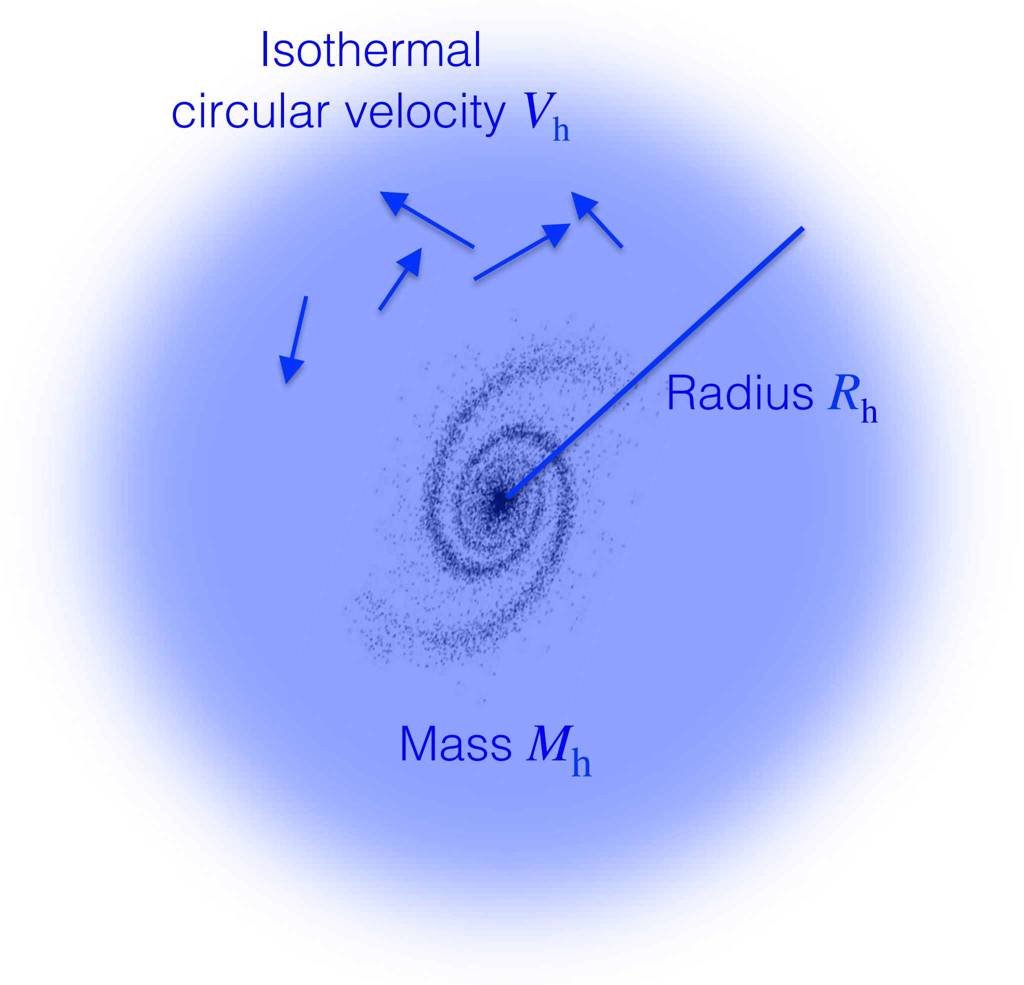


Figure: Koda et al, ApJ 531 (2000)

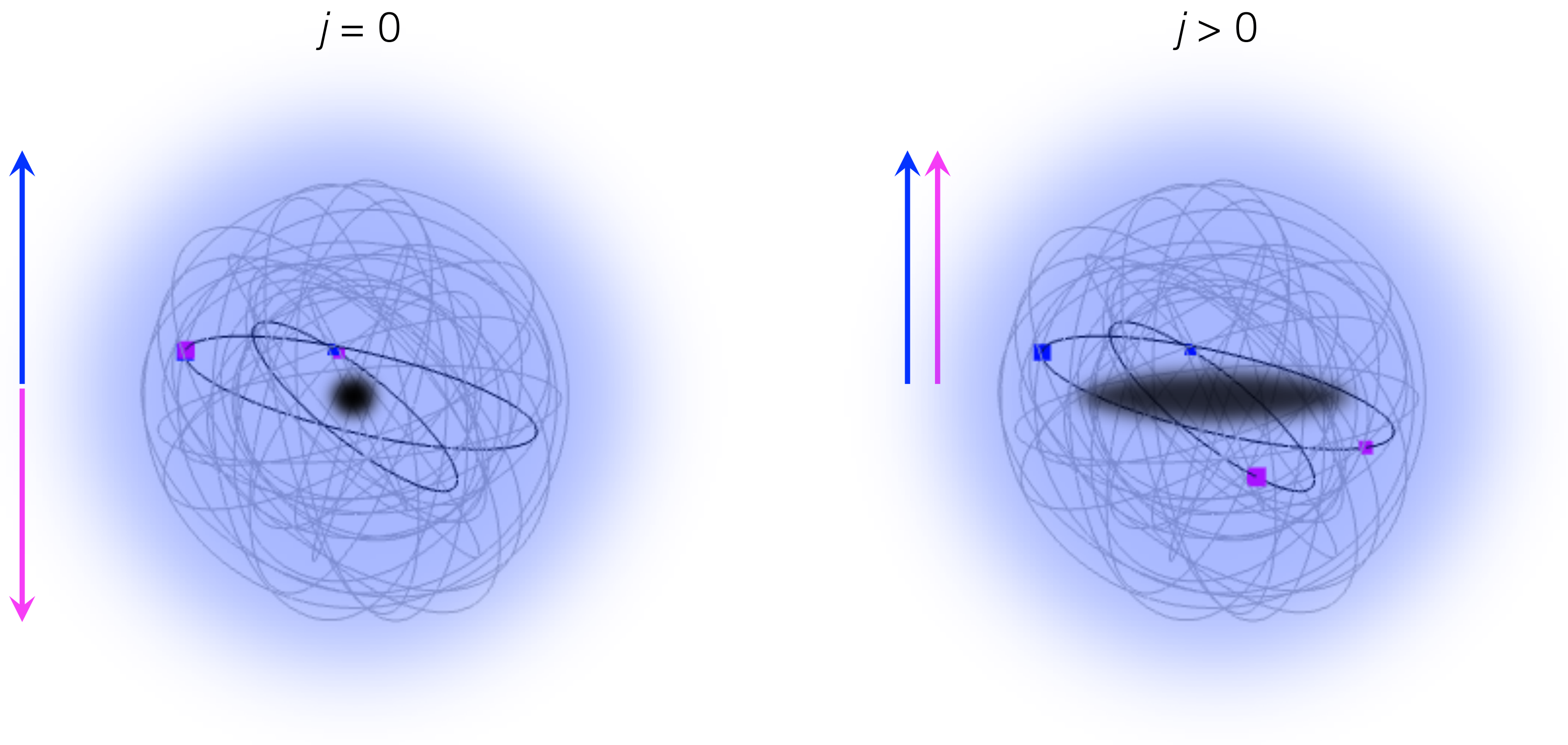
Basic model



Halo: $M_{\mathrm{h}}^{1/3} \propto V_{\mathrm{h}} \propto R_{\mathrm{h}}$

Galaxy: $M^{1/3} \propto V$

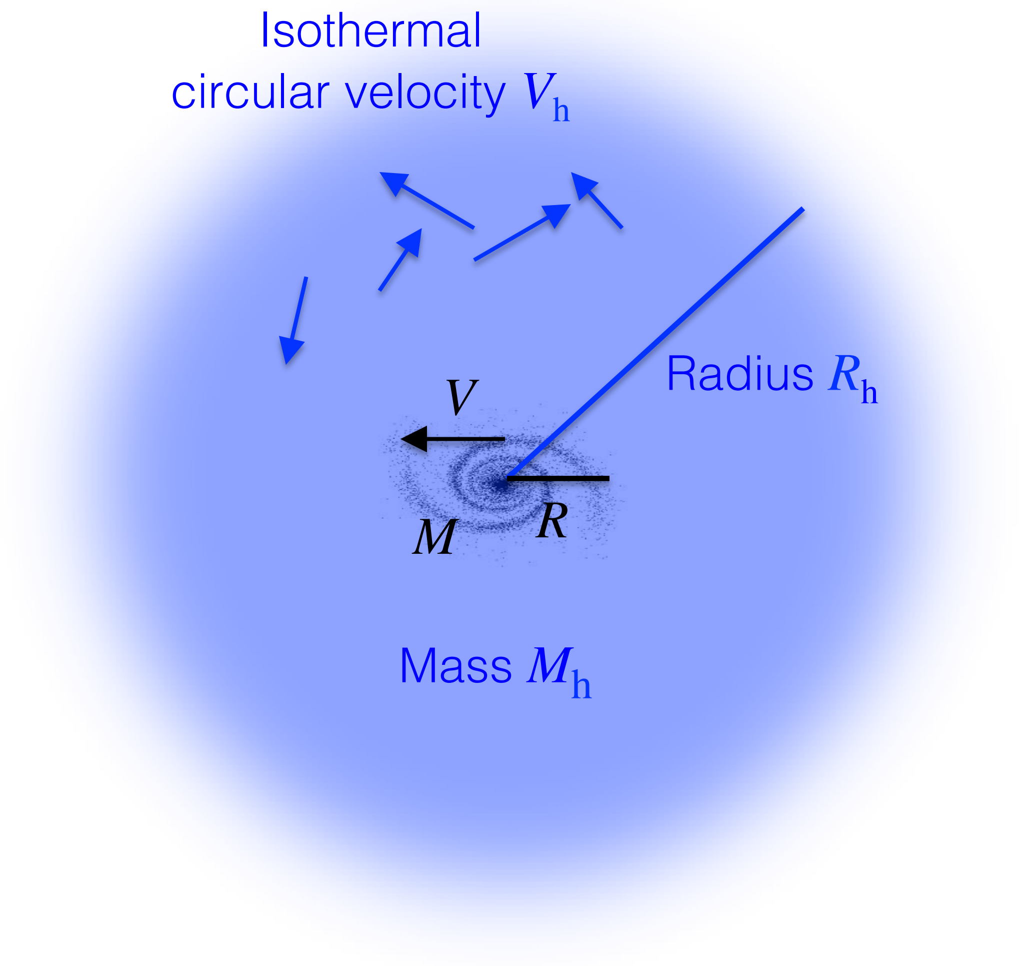
Angular momentum toy model



$$\vec{j} = \frac{1}{M}\int dM\ \vec{r}\times\vec{v}$$

"specific angular momentum"

Basic model



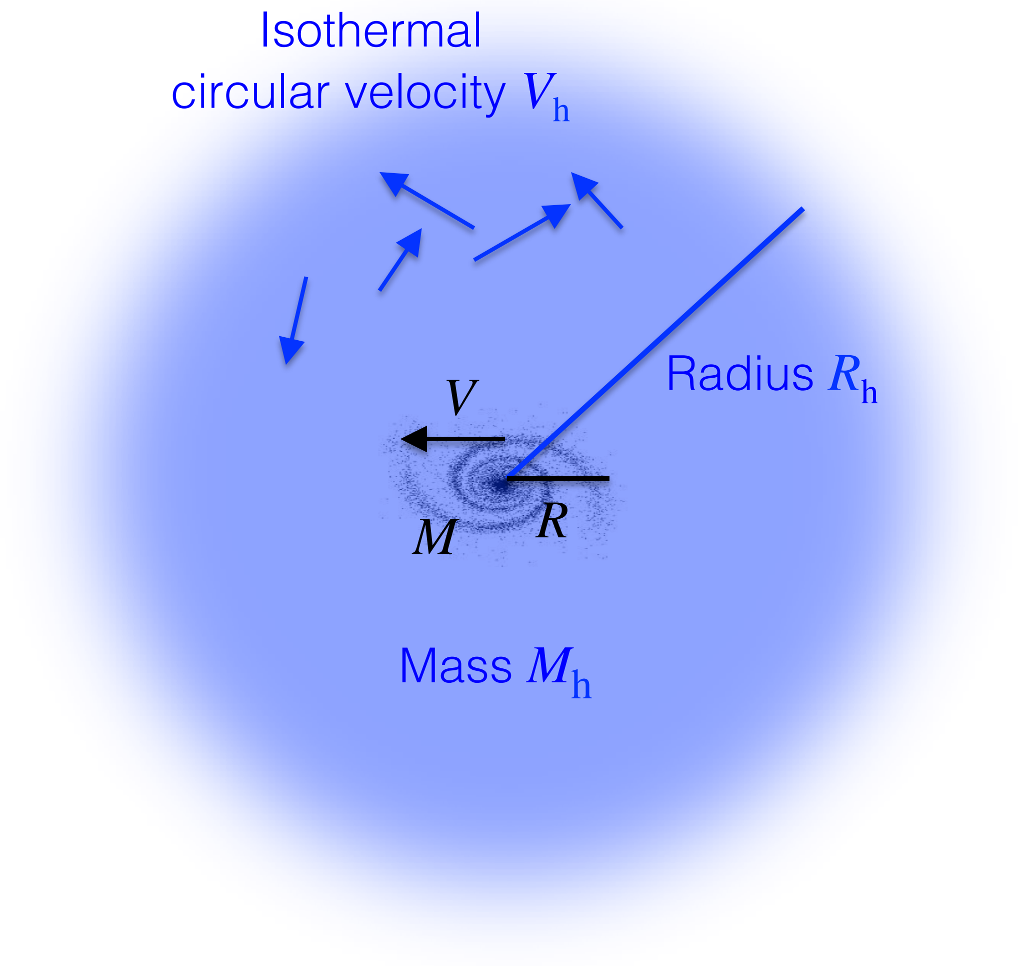
Halo: $M_h^{1/3} \propto V_h \propto R_h$

Galaxy: $M^{1/3} \propto V \propto kR$

$$k \equiv j^{-1} M^{2/3}$$

NB: k is constant for constant spin parameter and fixed angular momentum fraction in the baryons.

Basic model



Halo: $M_h^{1/3} \propto V_h \propto R_h$

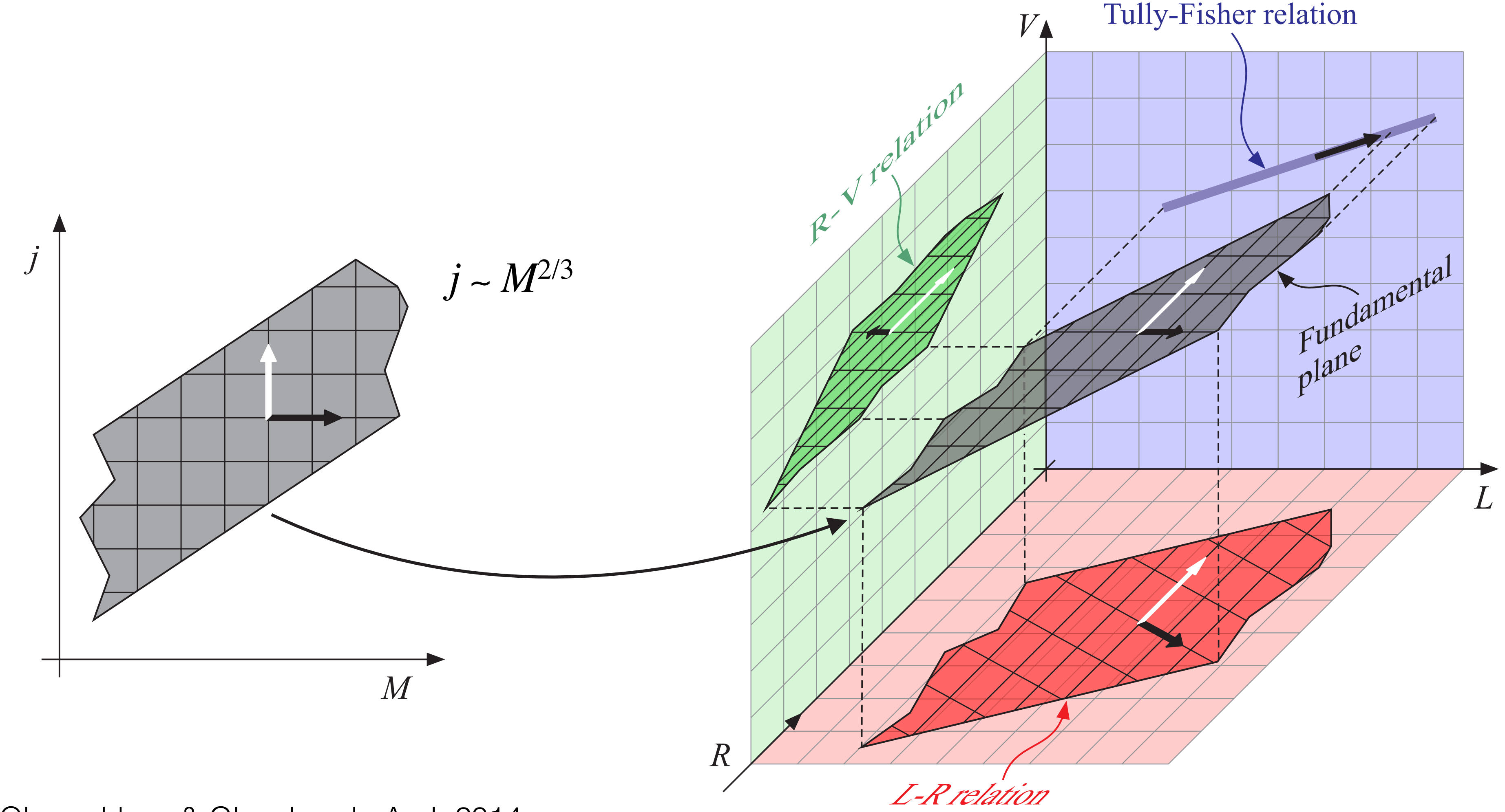
Galaxy: $M^{1/3} \propto V \propto kR$

Velocity:	$V \propto M^{1/3}$
Radius:	$R \propto jM^{-1/3}$
Luminosity:	$L \propto M$

Fundamental mapping

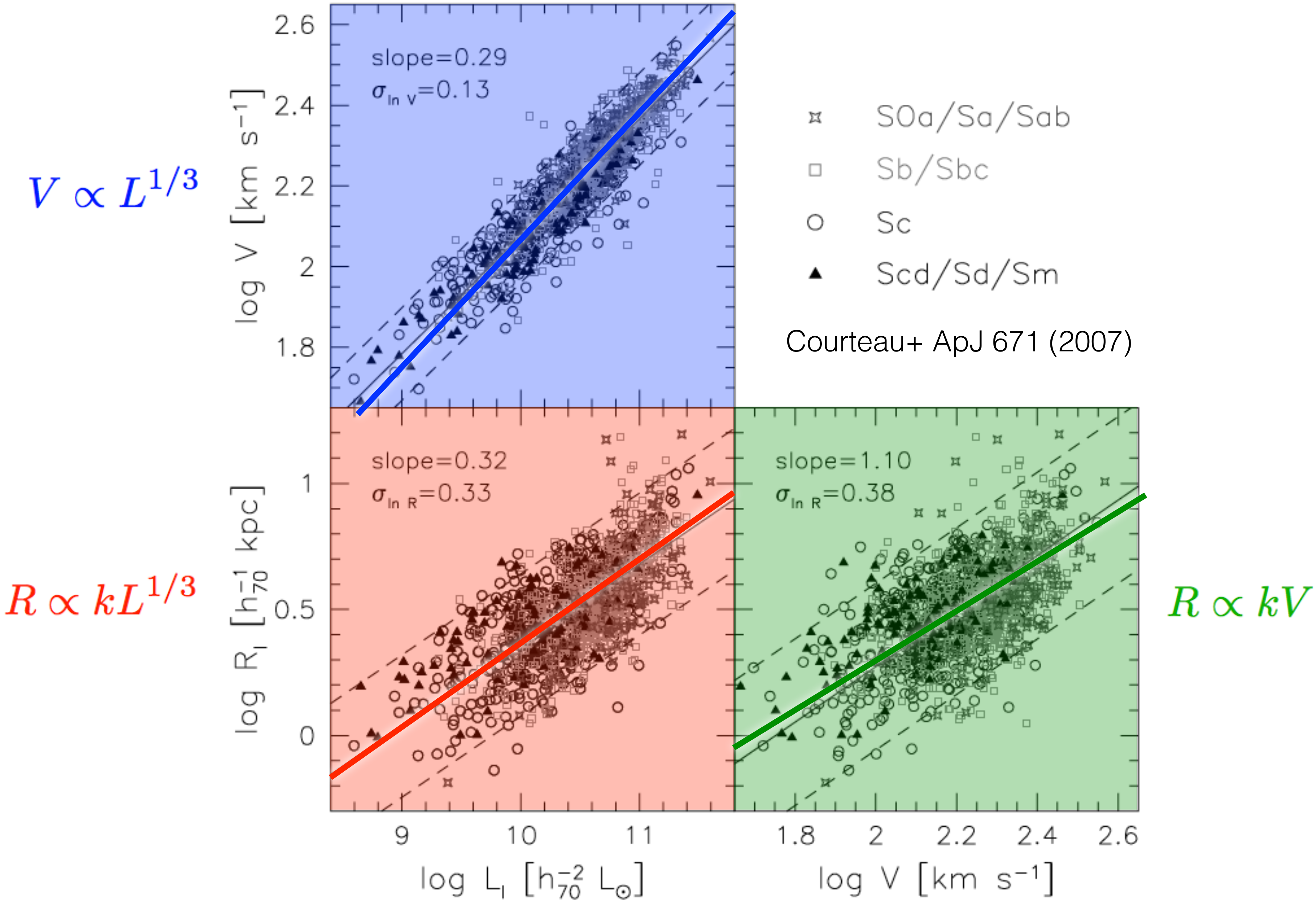
Theoretical (M,j)-plane

Observed (L,R,V)-space



Obreschkow & Glazebrook, ApJ, 2014

Projections of the fundamental plane

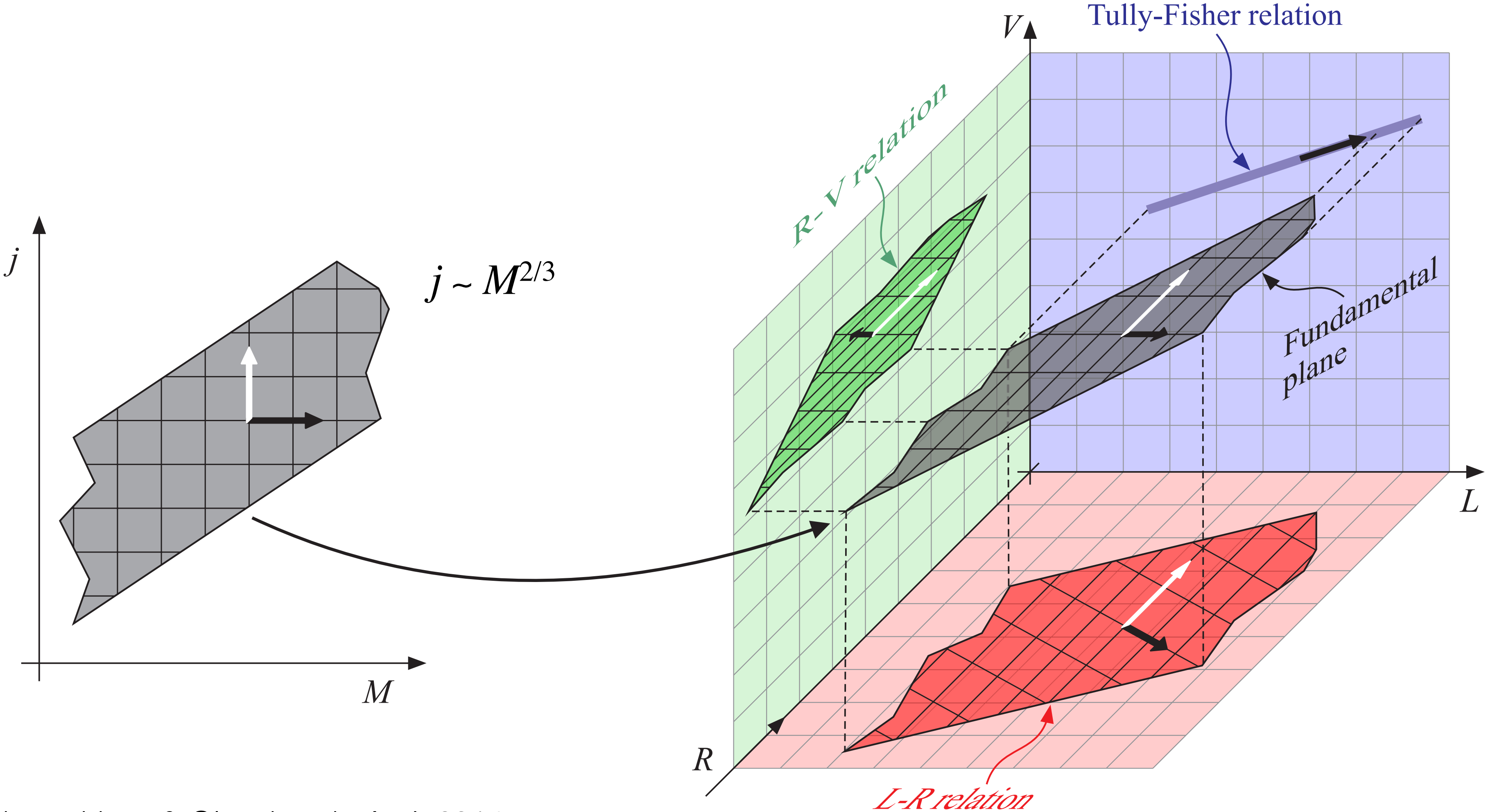


Courteau+ ApJ 671 (2007)

Fundamental mapping

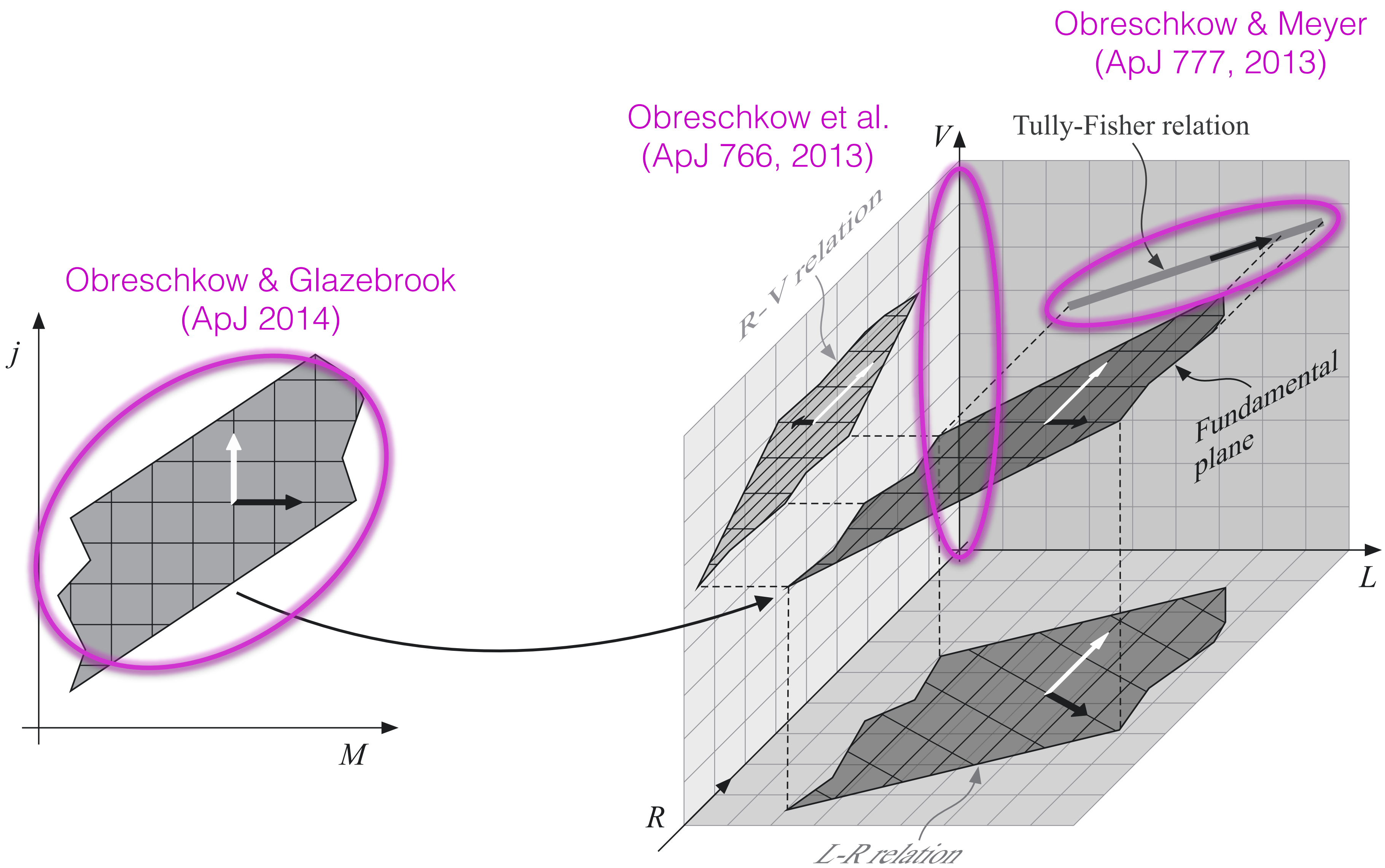
Theoretical (*M*,*j*)-plane

Observed (*L*,*R*,*V*)-space



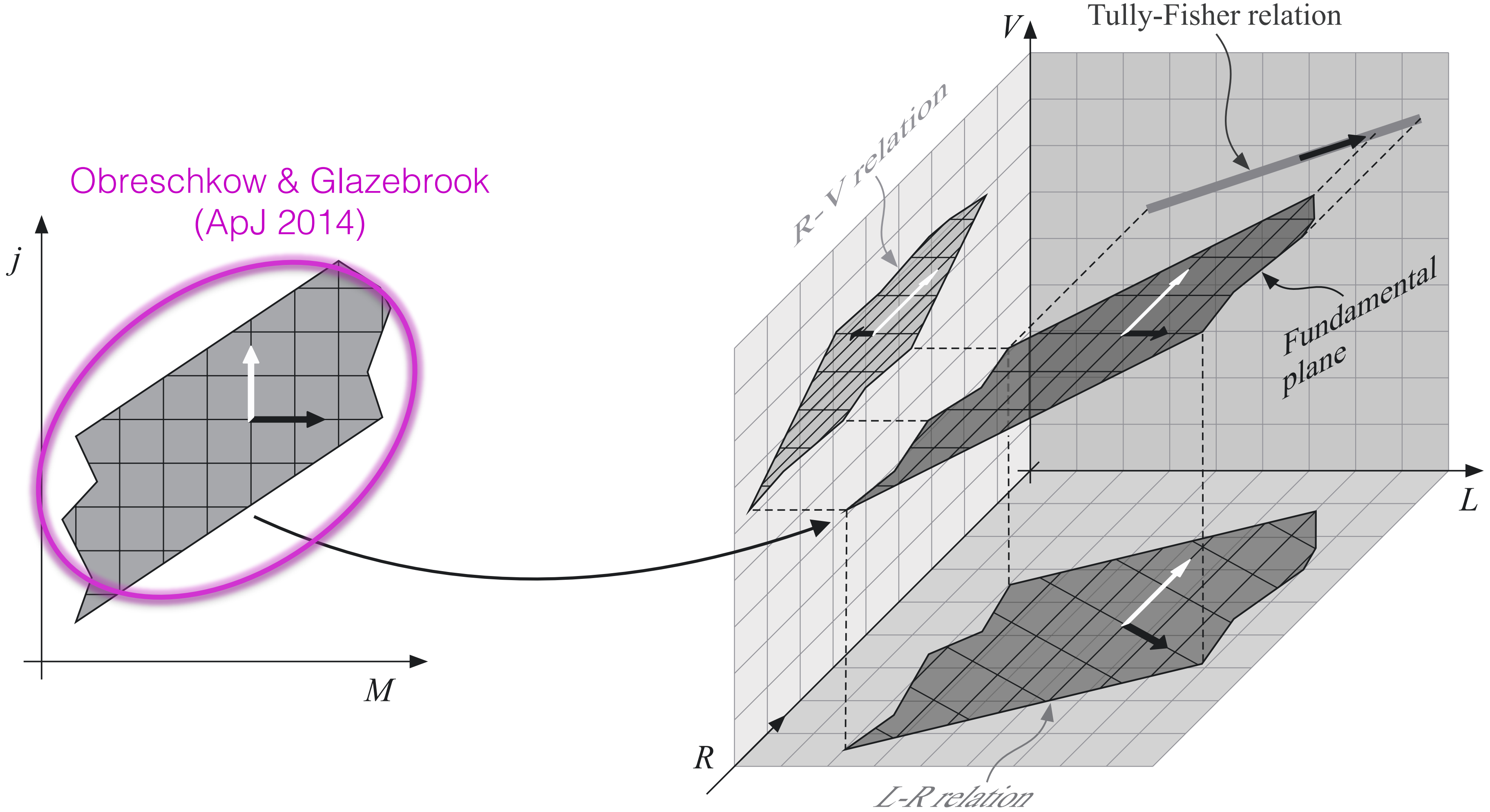
Obreschkow & Glazebrook, ApJ, 2014

Ways of exploiting rotation

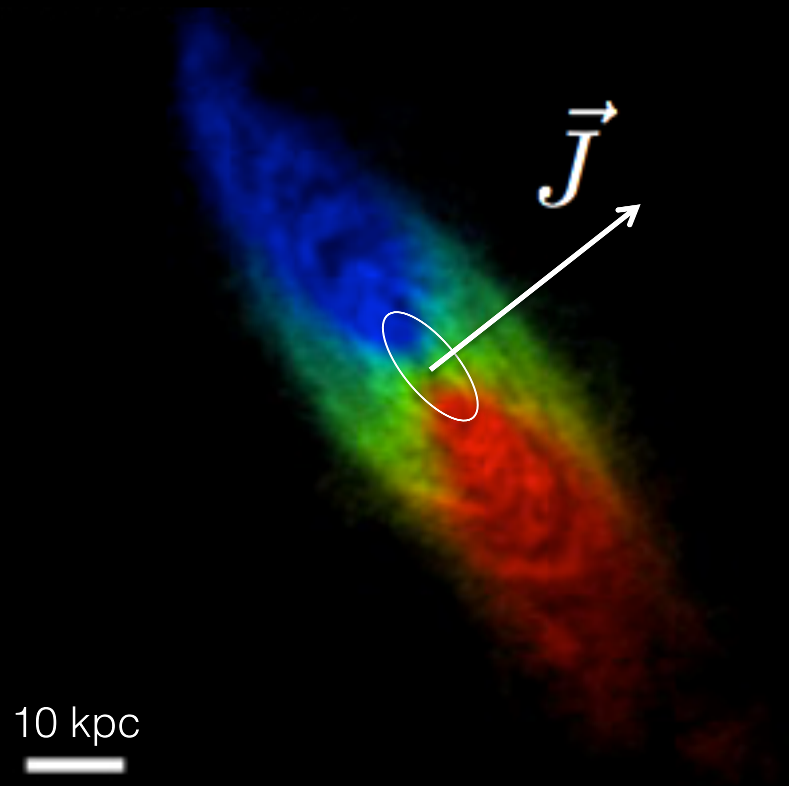


Ways of exploiting rotation

Obreschkow & Glazebrook (ApJ 2014)



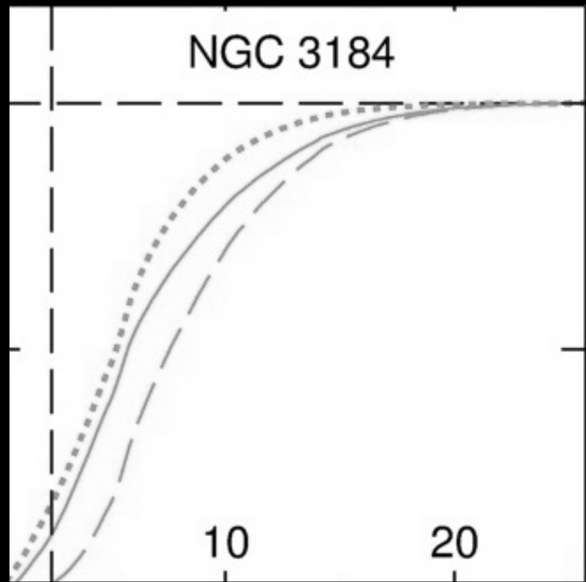
Baryon angular momentum in THINGS



NGC 3198 (VLA)

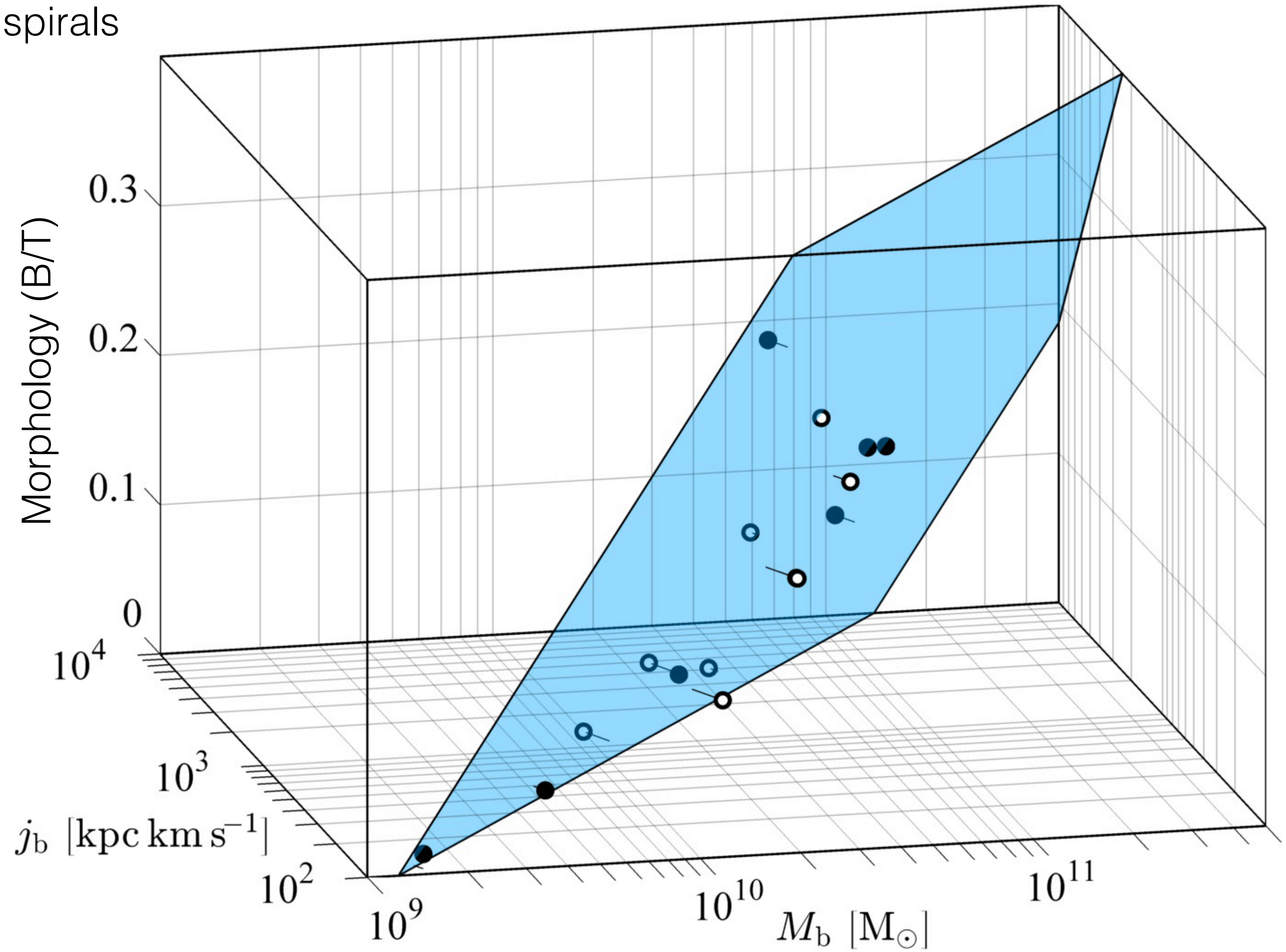
Specific baryon angular momentum

$$j \equiv \frac{|\vec{J}|}{M} = \frac{|\int dA\, \Sigma\, \vec{r} \times \vec{v}\,|}{\int dA\, \Sigma}$$



j is converged to >99%

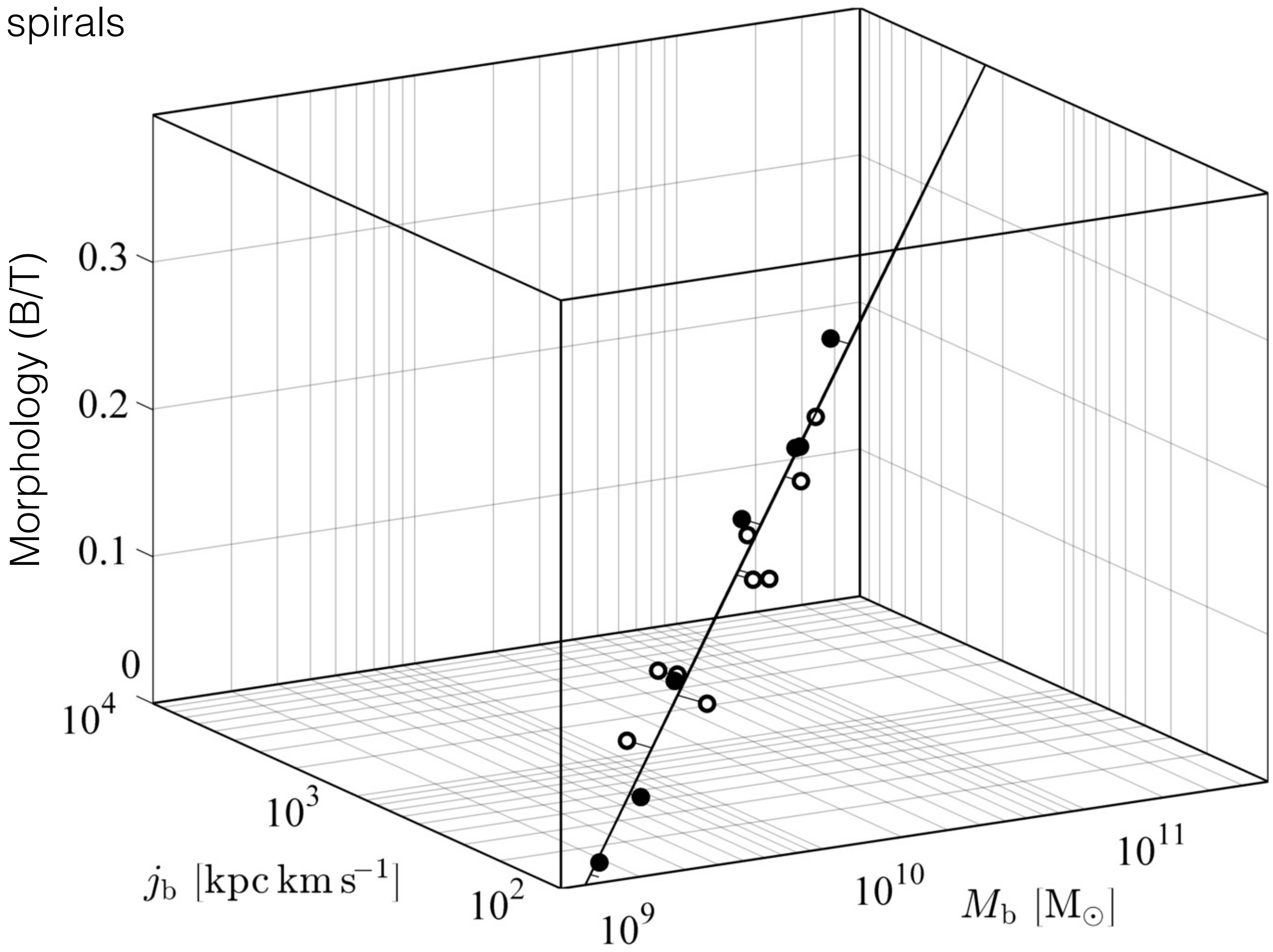
- Unbarred spirals
- Barred spirals



Obreschkow & Glazebrook, ApJ, 2014

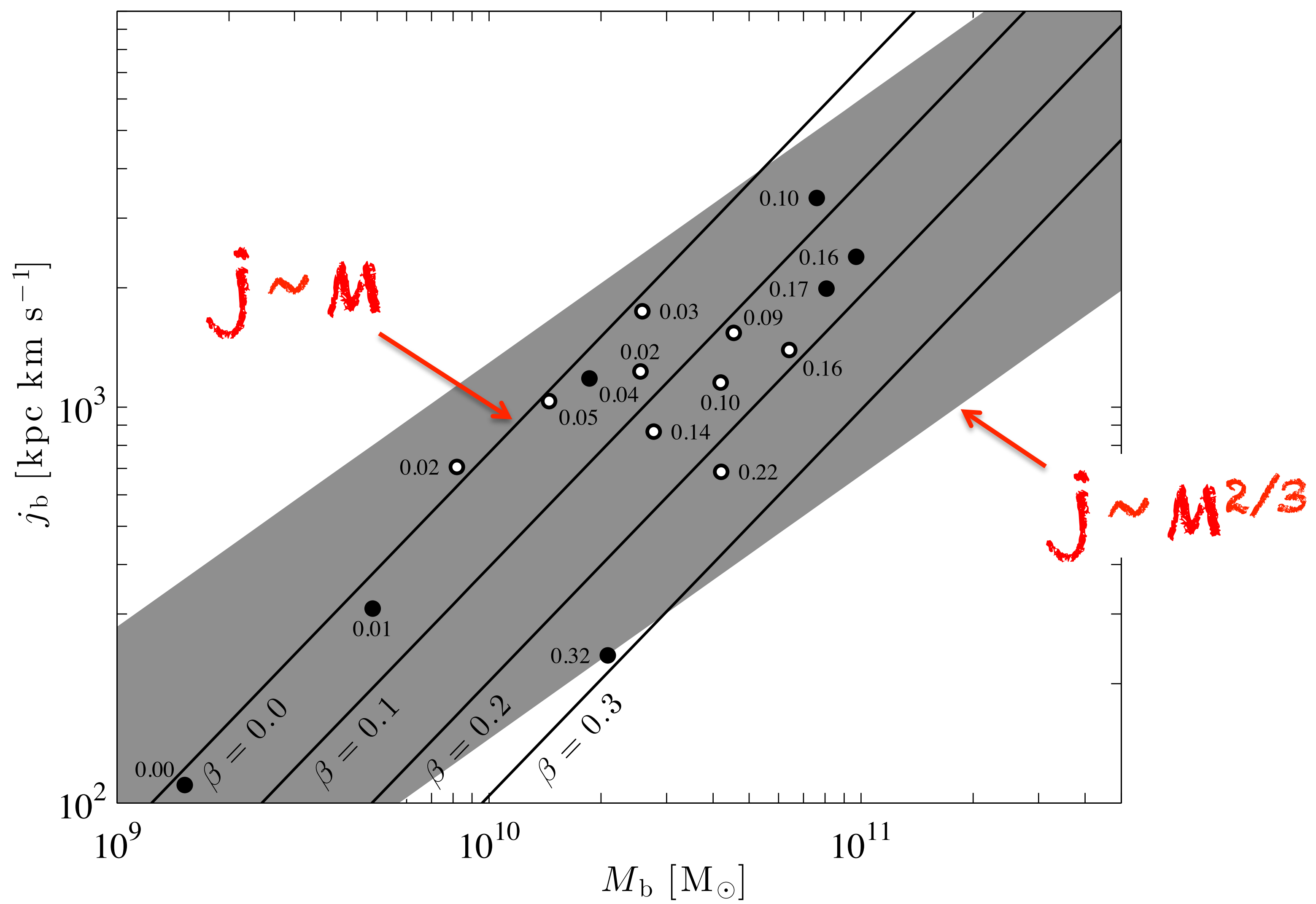
Mass-spin-morphology relation

- ● Unbarred spirals
- ○ Barred spirals



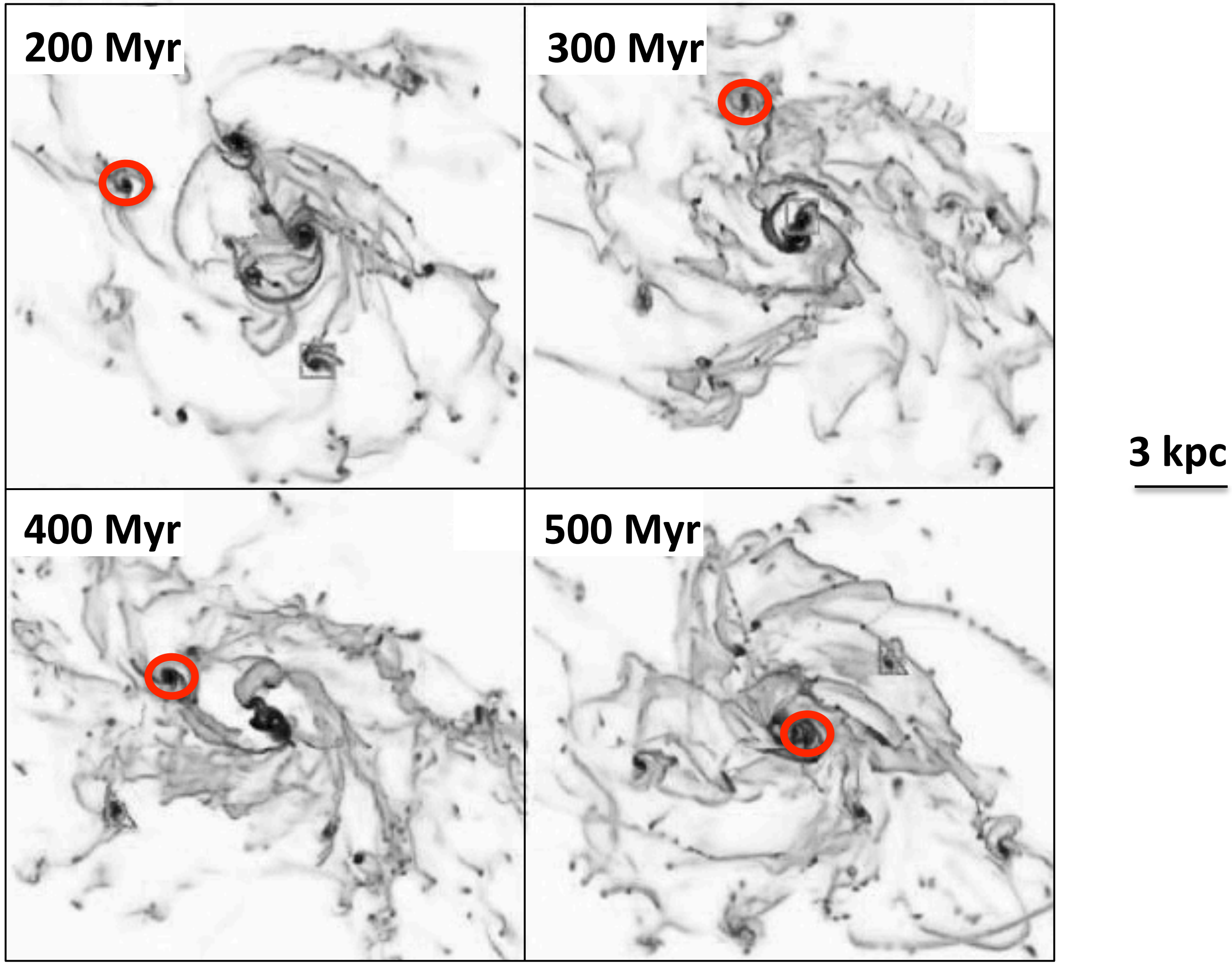
Obreschkow & Glazebrook, ApJ, 2014

Mass-spin-morphology relation



Obreschkow & Glazebrook, ApJ, 2014

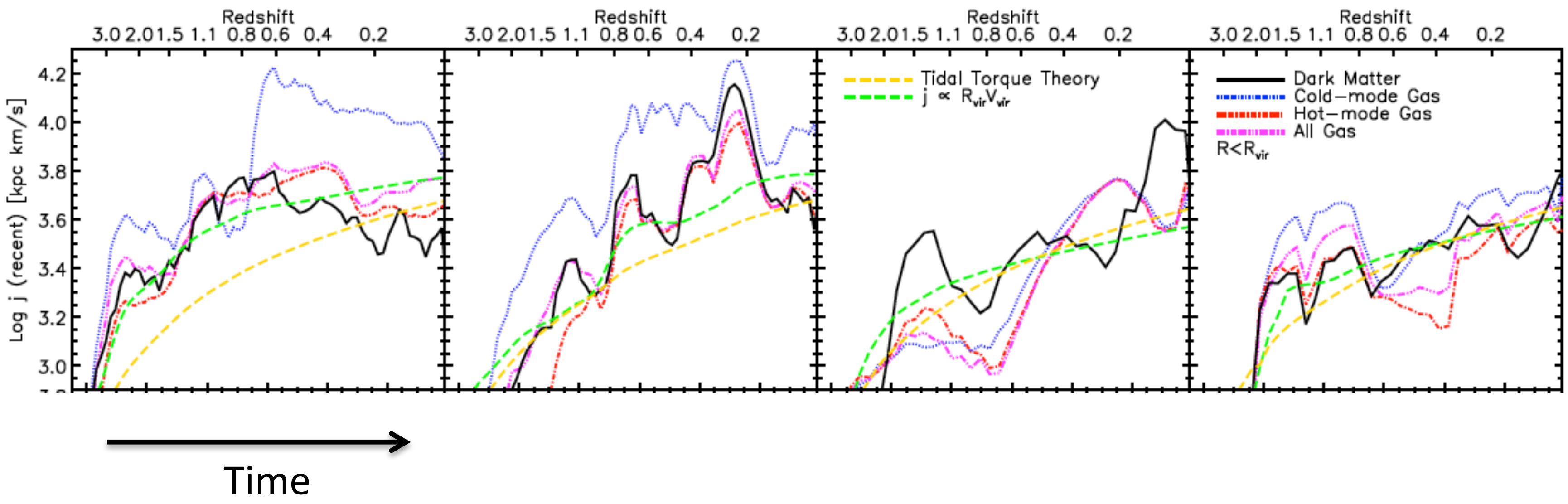
Clump-instabilities?



=> Bulge growth depends on disk stability, which depends on $Q \sim \Sigma^{-1} \sim j/M$

Bournaud 2013 [Ramses AMR hydro simulation with stellar feedback]

Cosmic evolution of *j*



Stewart et al., ApJ (2013)

What's in the app?

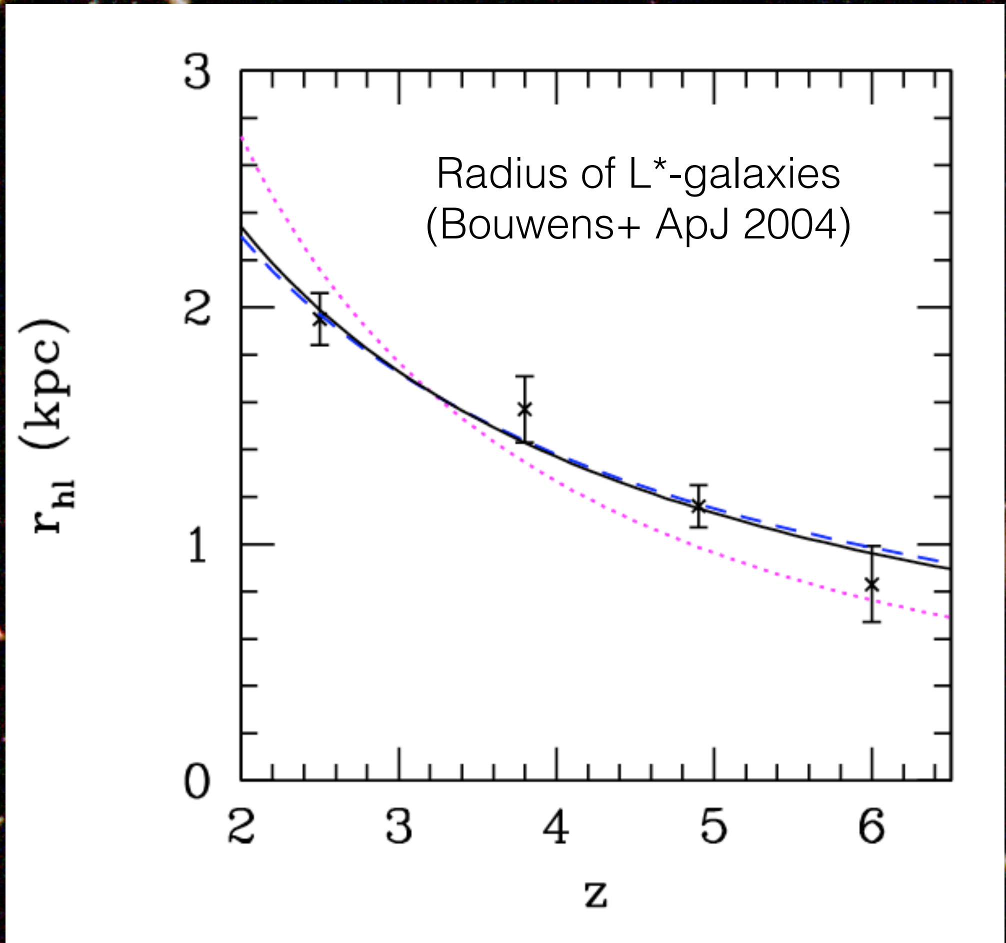
1. $(M, j) \mapsto (L, R, V)$

2. In CDM, LTGs populate a band around $j \alpha M^{2/3}$

3. Constant surface densities satisfy $j \alpha M$

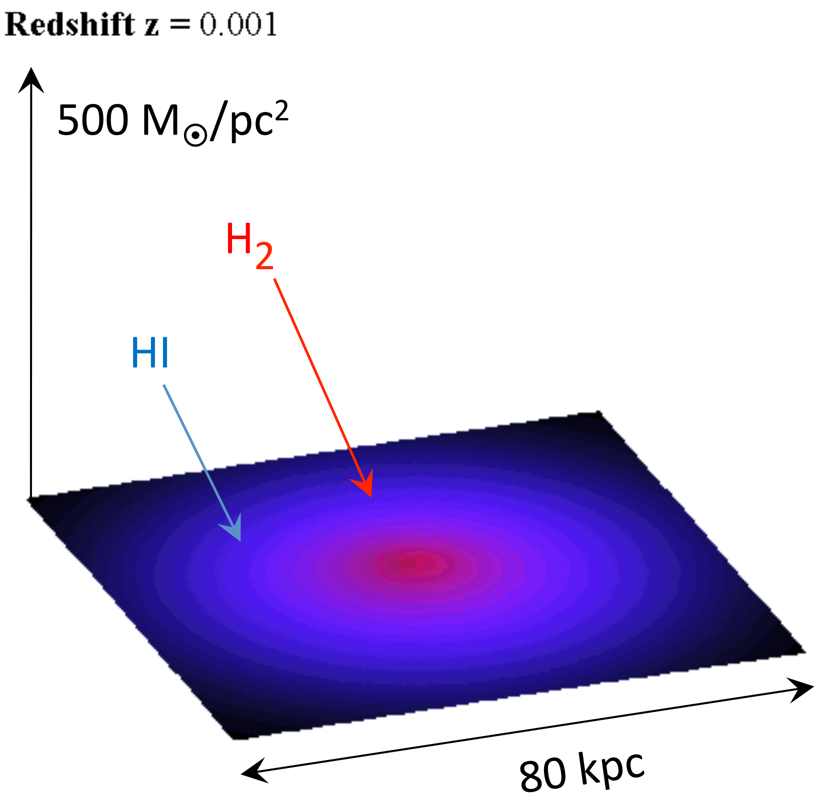
4. *j* increases with cosmic time (as $[1+z]^{-1}$)

Example 1: Size evolution

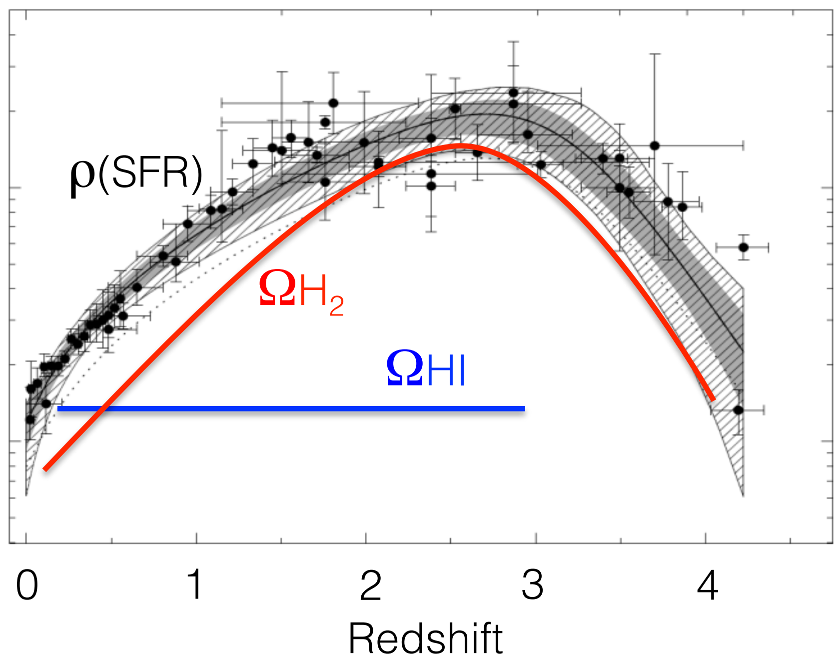


Hubble Ultra Deep Field

Example 2: Evolution of HI and H_2



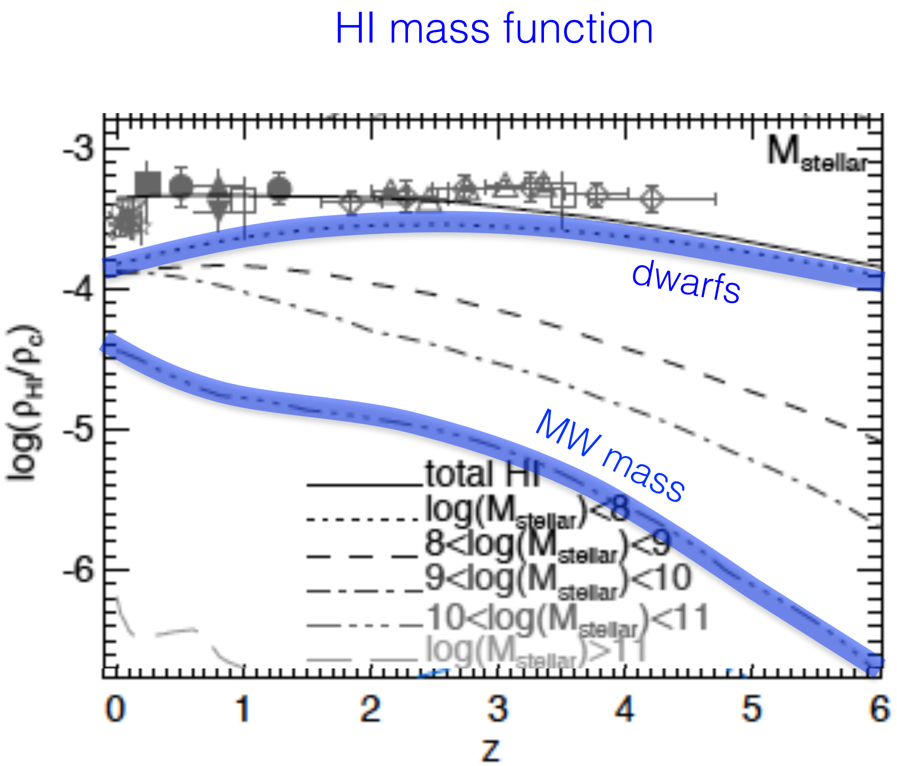
Average surface density of the 2000 MWs.

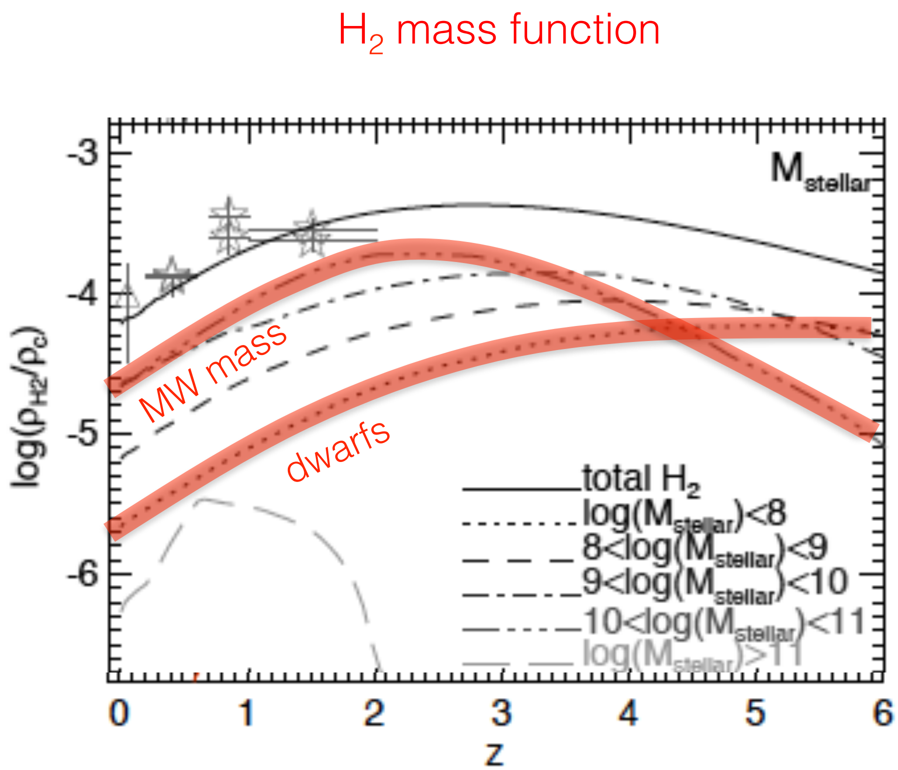


All 30 million mock-galaxies of S3-SAX

Obreschkow (MNRAS 400 2009, ApJ 696 2009)

Example 3: Where is the HI and H_2?



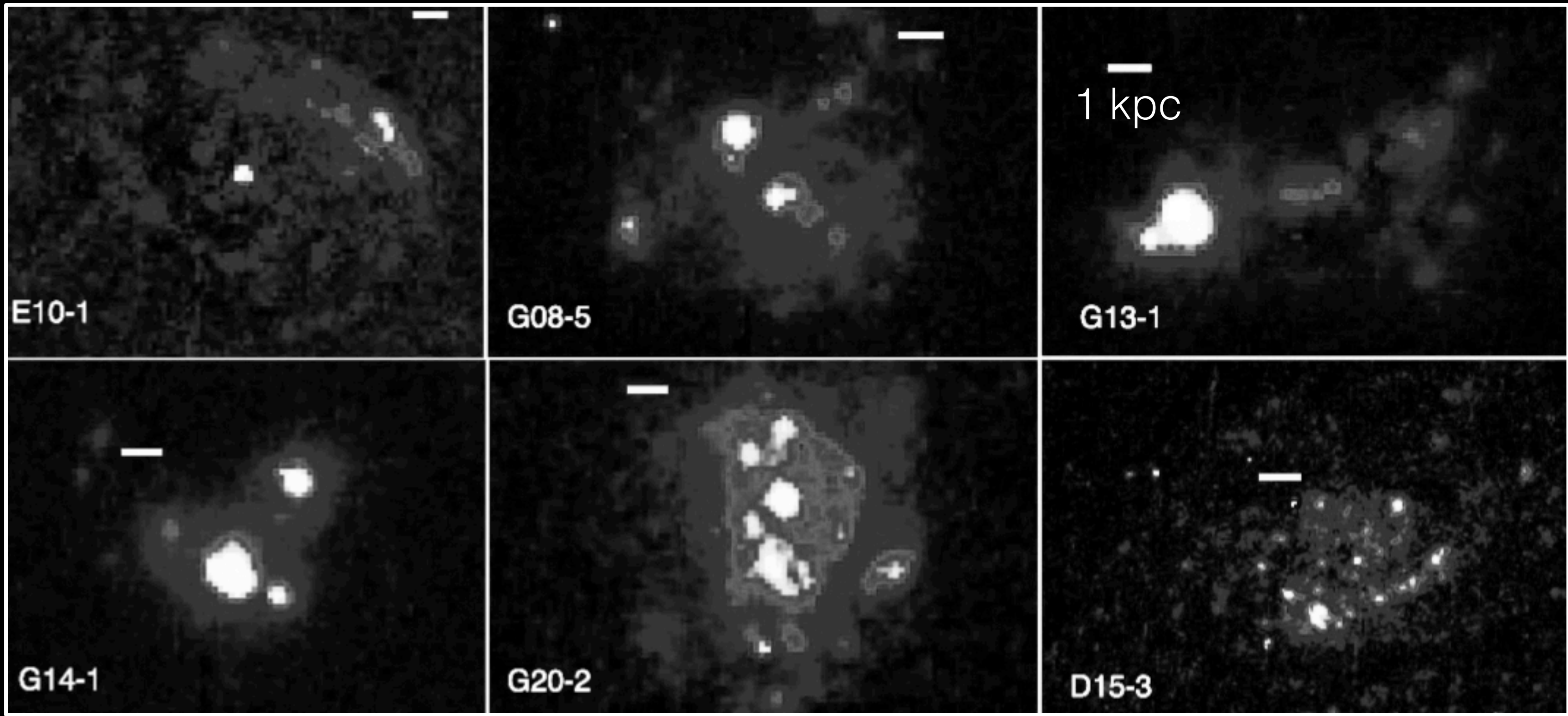


=> HI is locked up in low-mass galaxies; H_2 in high-mass galaxies.

Lagos et al. (MNRAS, 2013)

Example 4: Clumpy galaxies

DYNAMO: sample of turbulent, clumpy, rotating disks in the local universe (z~0.1)

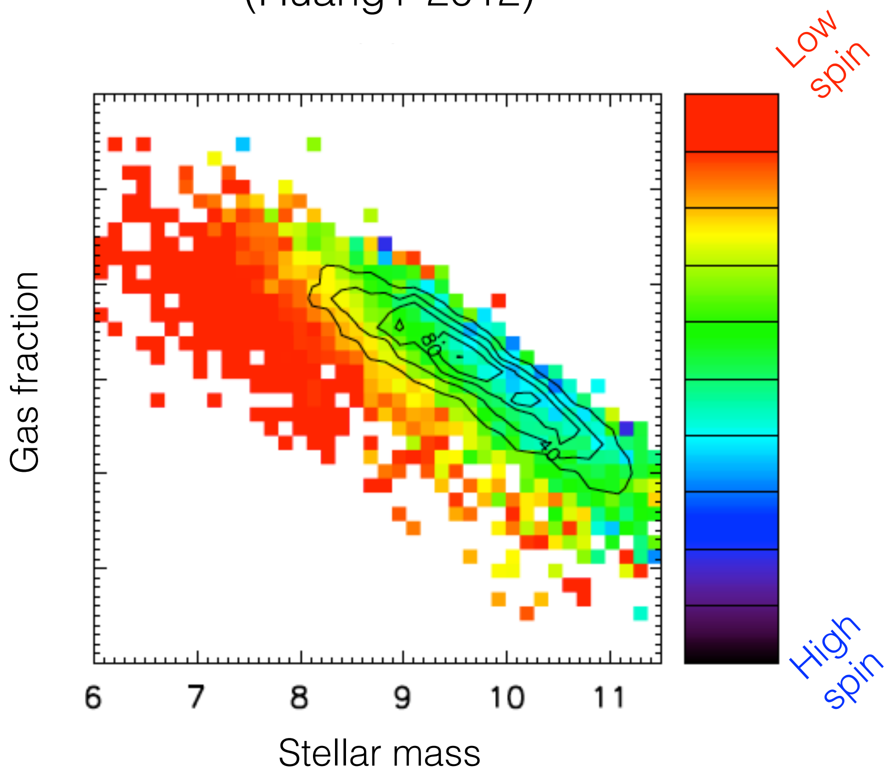


HST Hα maps

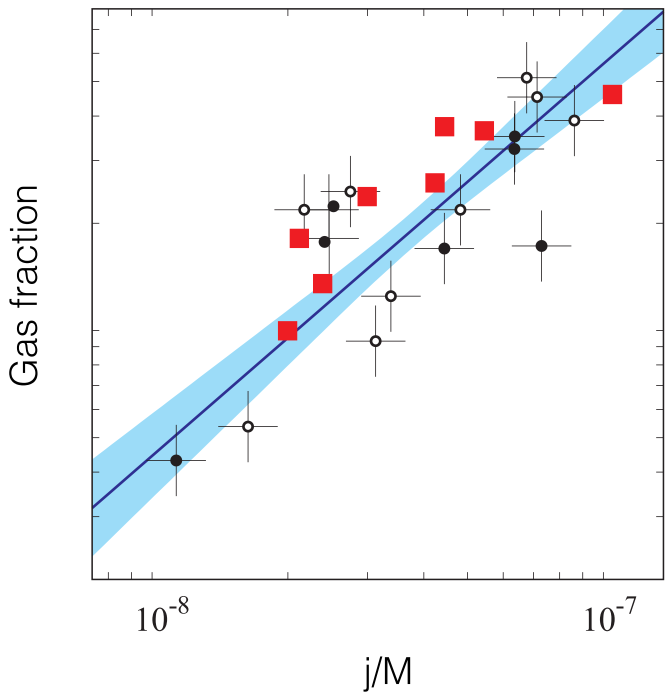
Fisher et al. (in prep.); Team led by K. Glazebrook

Example 5: HI gas fraction

ALFALFA
(Huang+ 2012)



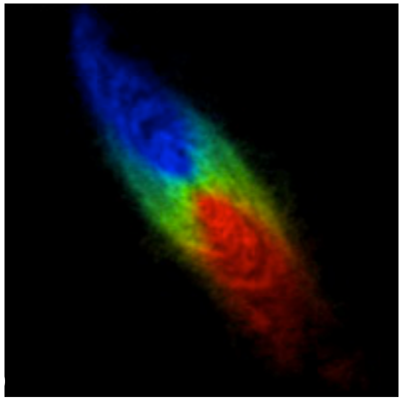
THINGS & N-body sims
(Obreschkow & Brook, in prep.)

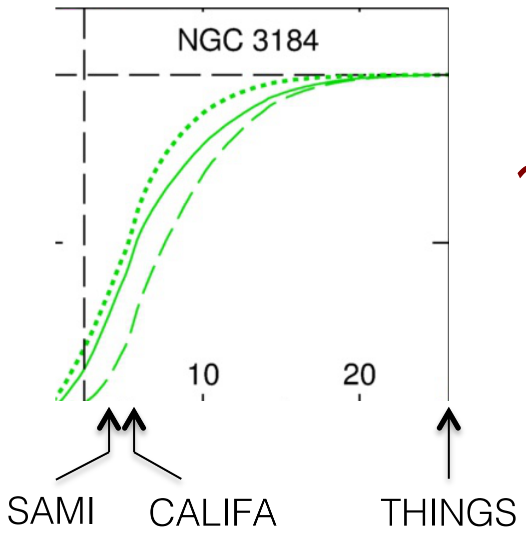


Simulation: MaGICC (Stinson et al., 2013)

Importance of HI in *j*-studies

1. Interferometric HI maps are much deeper than optical IFU





~5%

Get the free app!

2. Unresolved HI-line & optical images

$$j = R_* \; W_{50} \; \sin^{-1} i$$

~50%

3. Unresolved HI-line & optical IFU

$$j = R_* \; W_{50} \; \sin^{-1} i \; \frac{(R_* + R_{\rm flat})^3 - R_{\rm flat}^3}{(R_* + R_{\rm flat})^3}$$

~25%