Генеральная Ассамблея МАС

Вена, 20-31 августа 2018

Общенародные события:

- Новое руководство – 3(!) женщины
- Закон Хаббла переименован в закон Хаббла-Леметра
- Следующая ГенАссамблея (2021) – в Южной Корее
- Выбрано место для ГенАссамблеи 2024 года – это Кейптаун (ЮАР)
- В 2019 году – 100-летие МАС; дан старт празднествам.

Научные события:

- Симпозиумы МАС №343-349.
- 15 «фокус-митингов» - до 3 дней. заседаний, практически это симпозиумы.
- 9 двухдневных собраний подразделений.
- Приглашенные пленарные лекции – про грав. волны, «галактики в 3D» (Лиза Кьюли) и формирование планет; еще две смежные лекции по поводу второй замкнутой орбиты звезды S2 в центре Галактики.

Фокус-митинг «Угловой момент галактик»

- В основном, конечно, модельеры;
- Но есть и наблюдательные результаты:

- второй релиз SAMI (1559 галактик);
- вращение на больших радиусах по результатам обзора SLUGGS, и вот-вот обещают опубликовать результаты ePN.S (33 галактики): по крайней мере 40% триаксиальны!

- Обзоры нейтрального водорода, в том числе в карликах (Ченгалур, Murugeshan).

По поводу модельеров:

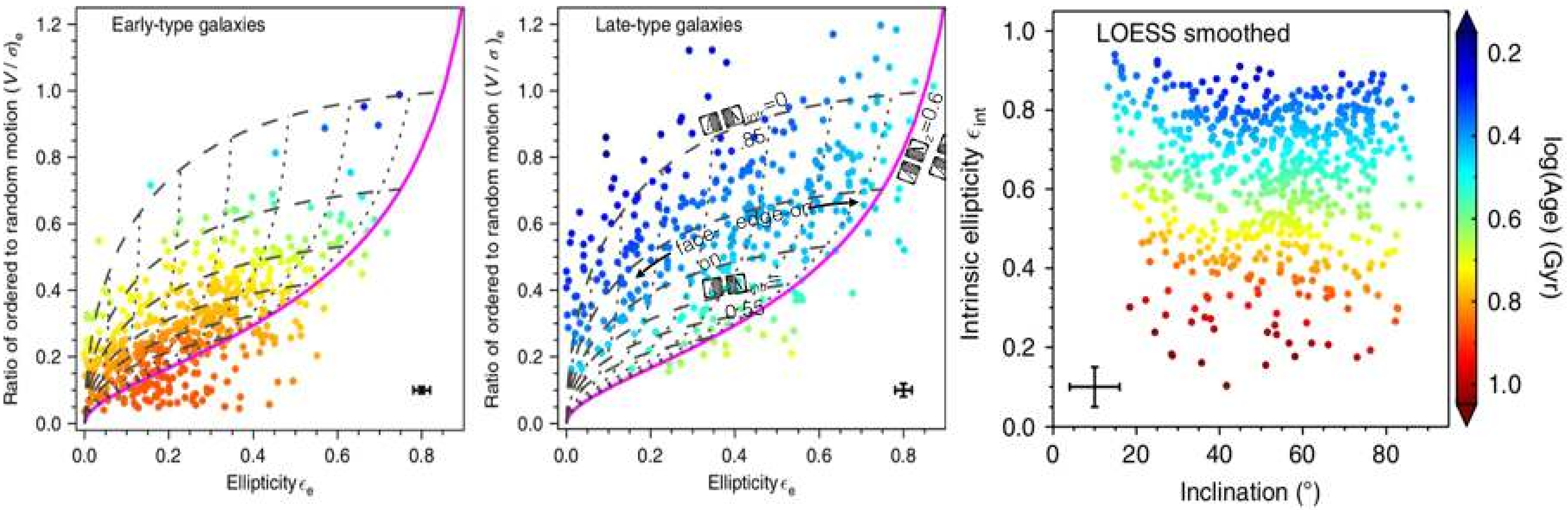
- Отличная цитата из Patricia Sanchez-Blazquez: “Models and cosmological simulations are able to reproduce the mass trends, but the physical processes remain unknown”.

SAMI: Colless

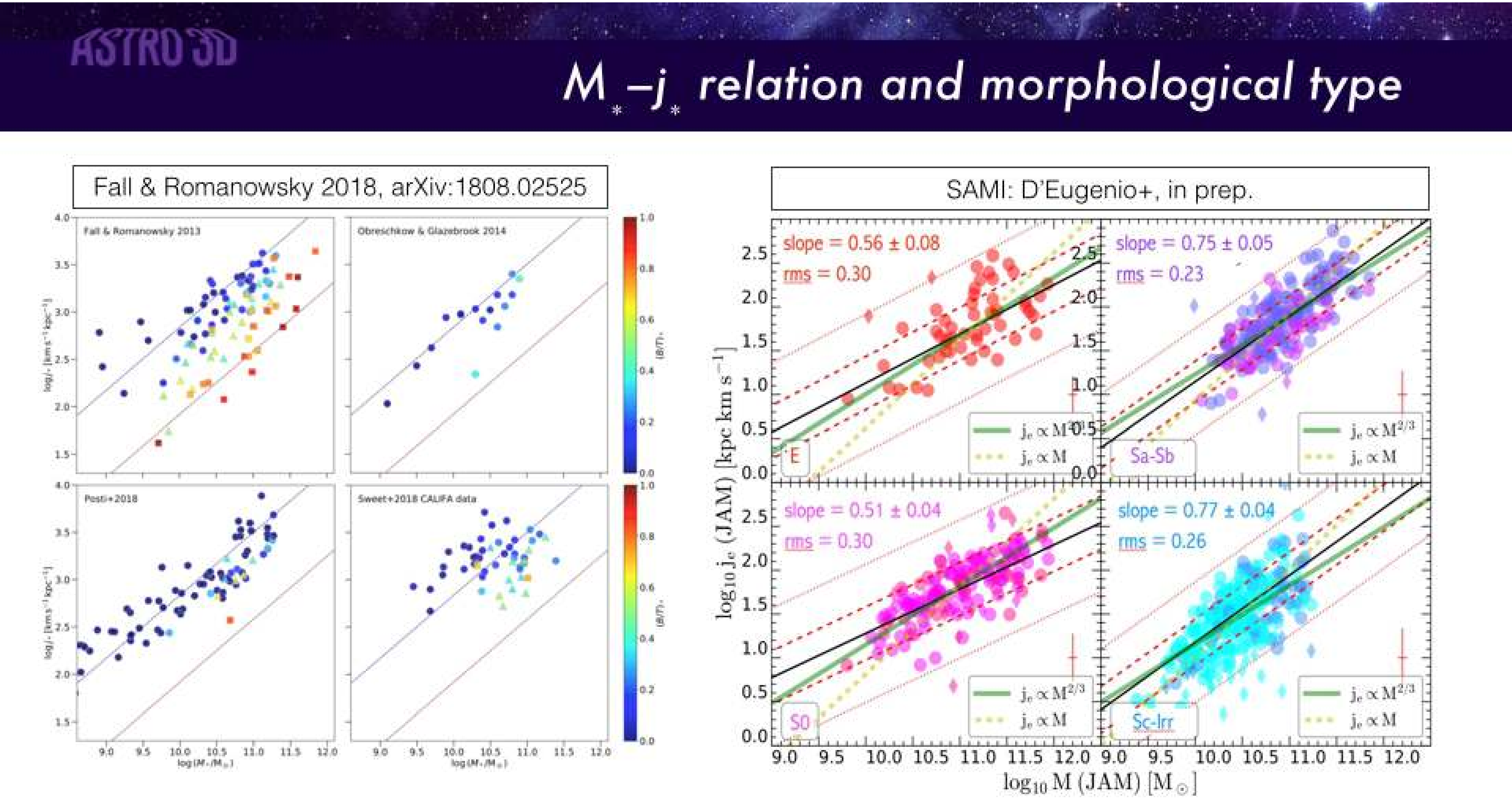
ASTRO 3D

$\lambda_R-\varepsilon$ *and stellar population age*

SAMI: van de Sande+ 2018, Nature Astronomy, 2, 483



SAMI: Colless



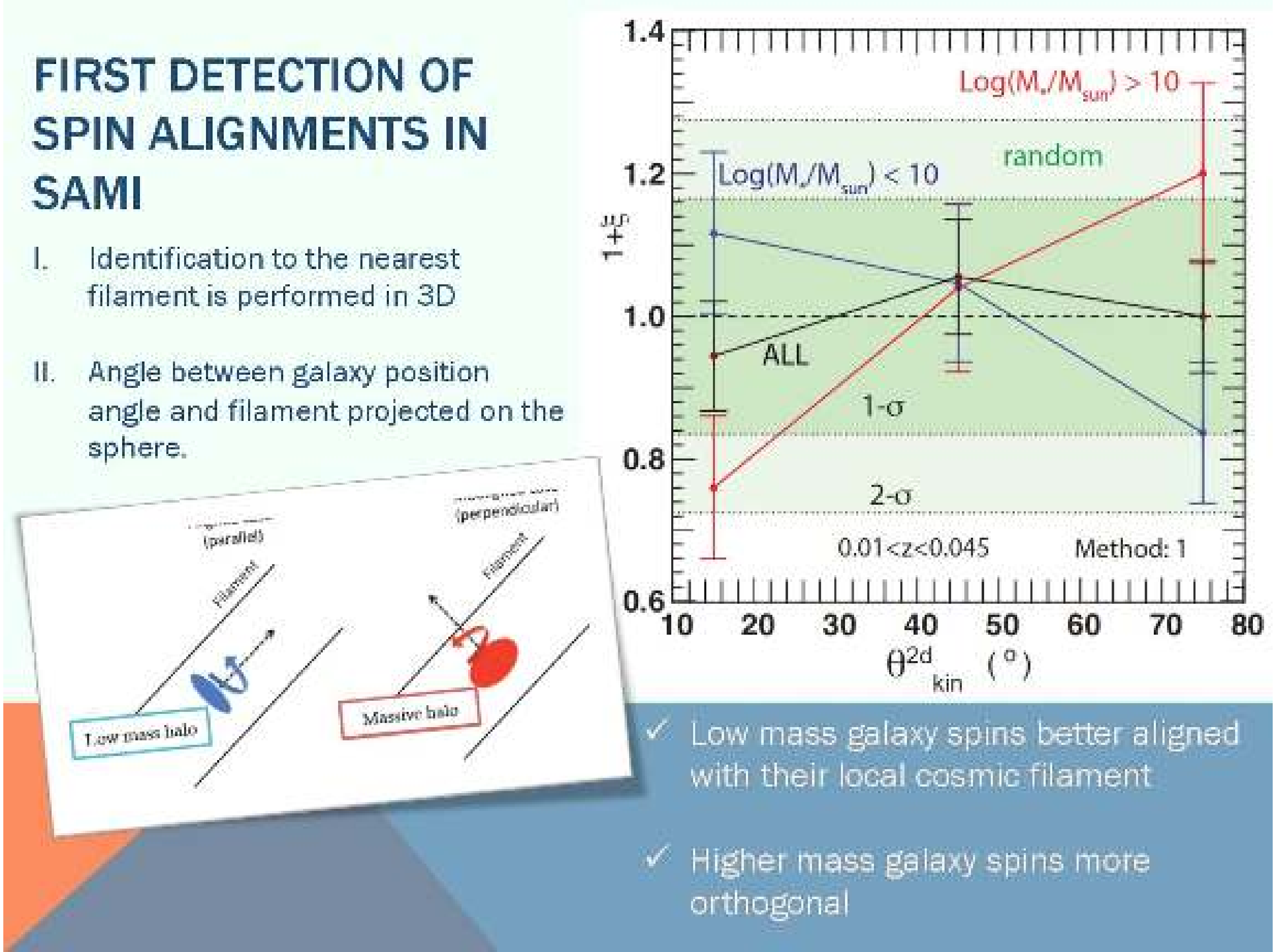
ASTRO 3D

M_*–j_* relation and morphological type

Fall & Romanowsky 2018, arXiv:1808.02525

SAMI: D'Eugenio+, in prep.

SAMI: отношение к филаментам



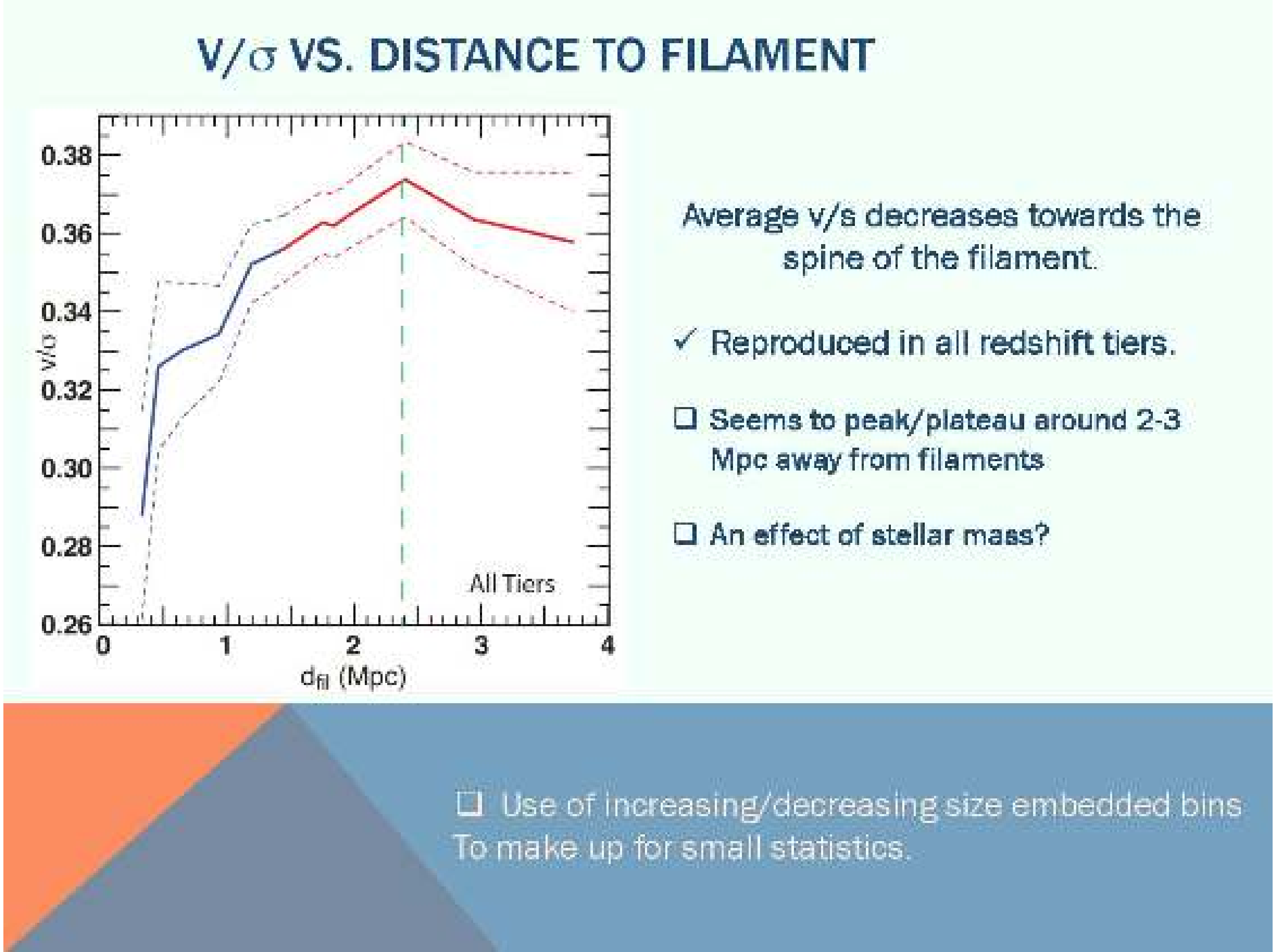
FIRST DETECTION OF SPIN ALIGNMENTS IN SAMI

I. Identification to the nearest filament is performed in 3D

II. Angle between galaxy position angle and filament projected on the sphere.

- ✓ Low mass galaxy spins better aligned with their local cosmic filament
- ✓ Higher mass galaxy spins more orthogonal

SAMI: отношение к филаментам



V/σ VS. DISTANCE TO FILAMENT

Average v/s decreases towards the spine of the filament.

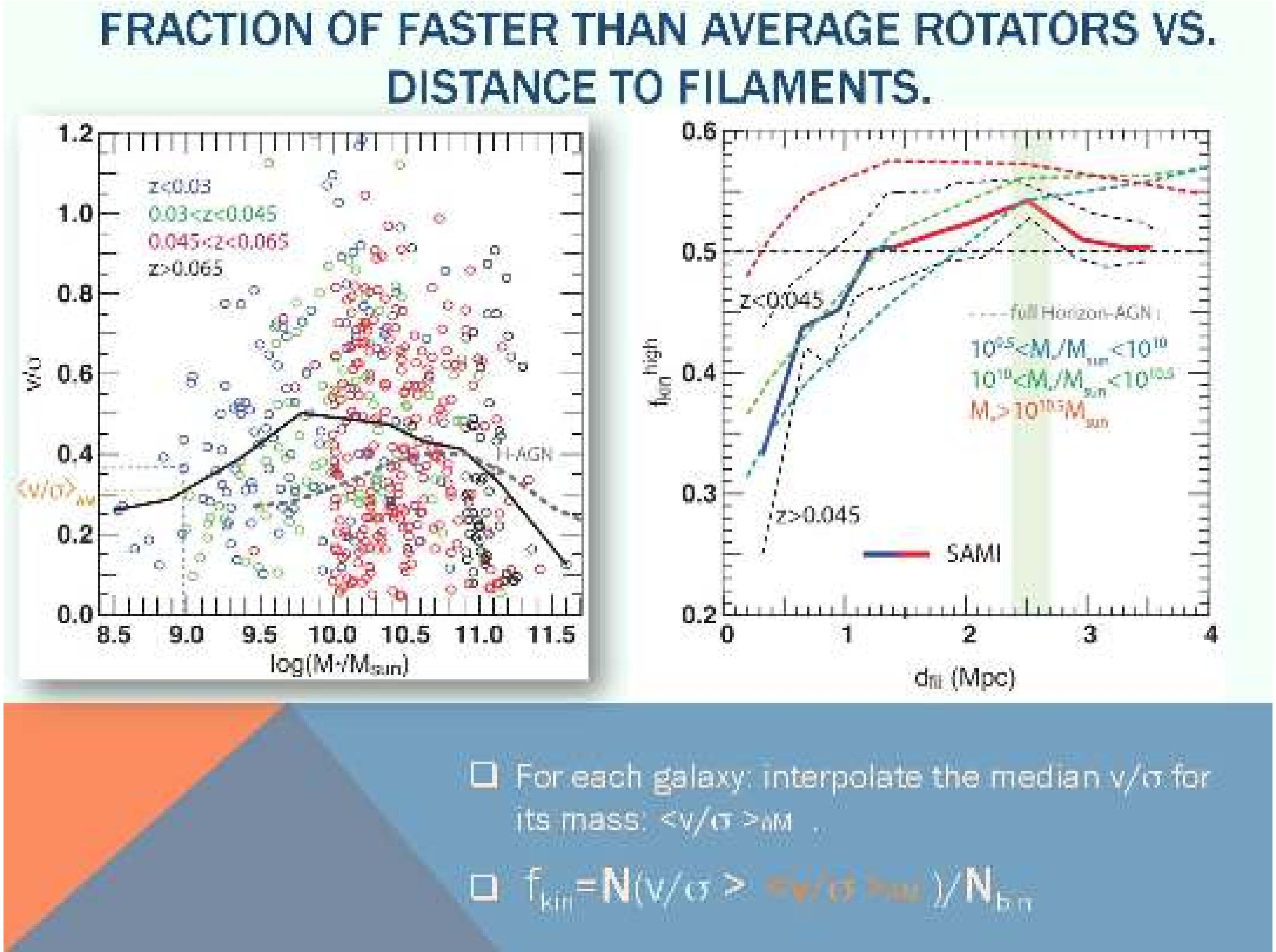
✓ Reproduced in all redshift tiers.

☐ Seems to peak/plateau around 2-3 Mpc away from filaments

☐ An effect of stellar mass?

☐ Use of increasing/decreasing size embedded bins
To make up for small statistics.

Отражение сегрегации по массам?

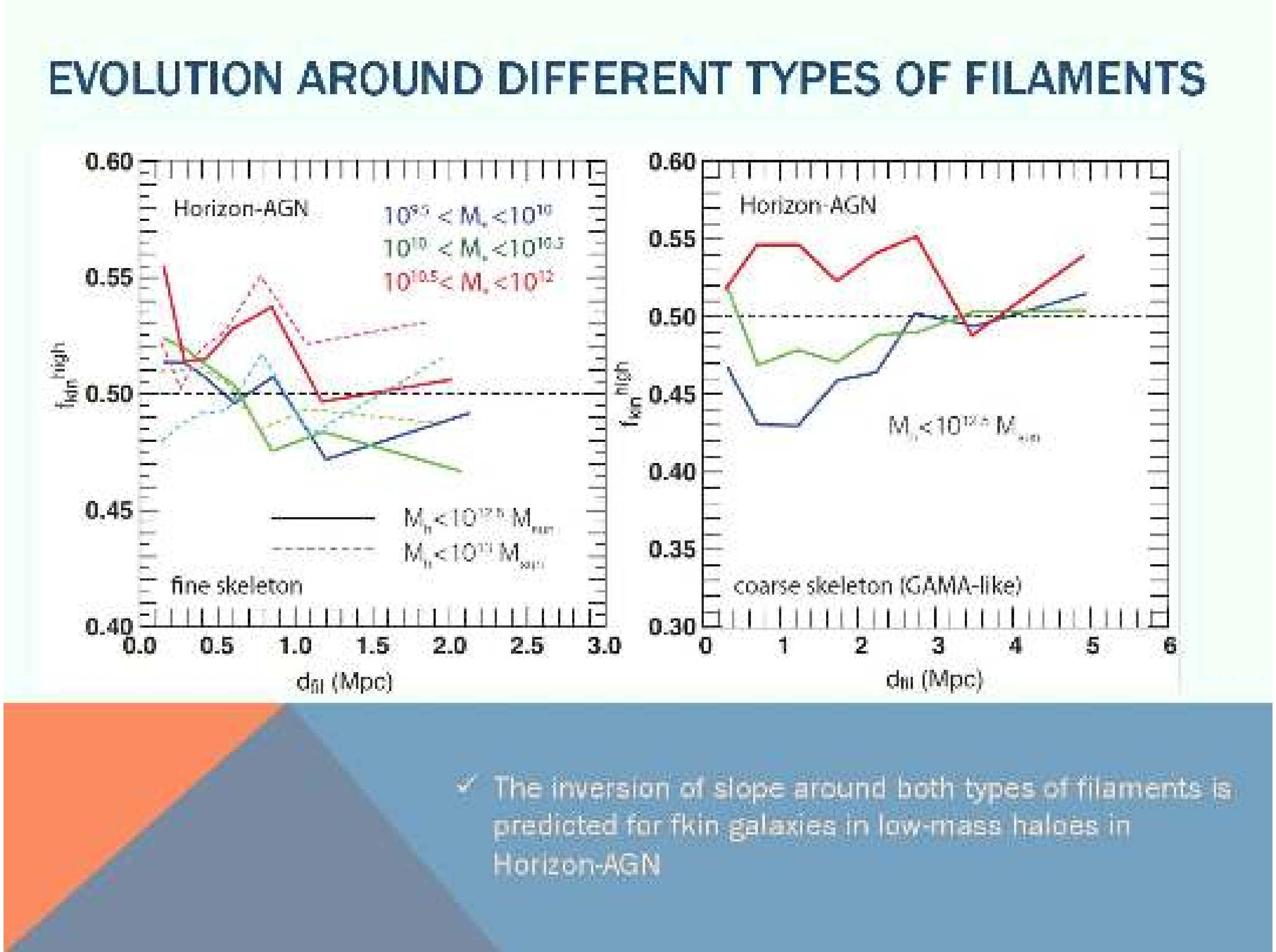


FRACTION OF FASTER THAN AVERAGE ROTATORS VS. DISTANCE TO FILAMENTS.

☐ For each galaxy: interpolate the median v/σ for its mass: <v/σ >ΔM .

☐ f_{kin}=N(v/σ > <v/σ >ΔM)/N_{bin}

Во всяком случае, теория НЕ предсказывает такой немонотонности



EVOLUTION AROUND DIFFERENT TYPES OF FILAMENTS

- ✓ The inversion of slope around both types of filaments is predicted for fkin galaxies in low-mass haloes in Horizon-AGN

Фокус-митинг «Градиенты металличности»

- Новость (для меня, по крайней мере): рассосался излом градиента металличности по цефеидам в окрестности Солнца. ЕГО больше НЕТ.
- Астросейсмология красных гигантов→ массы → возраста→эволюция градиента металличности:

- APOGEE+Gaia: эволюции НЕТ
- LAMOST: в толстом диске нет градиента металличности, в тонком -0.12 dex/кпк
- Последнее подтверждается рассеянными скоплениями (Gaia-ESO)

Фокус-митинг «Градиенты металличности» - а не Milky Way?

- Berg: Отличный обзор CHAOS: multi-object на LBT, полные диапазон с разрешением 2000, близкие галактики, до 50-100 HII-областей на галактику.
- Температуру измеряют по [NII] или [SII] – кислород не годится на (суб)солнечных металличностях, там линия железа проецируется на 4363А.
- НЕТ градиента металличности в M51.

Специально для Вани Каткова:

- Пытаясь промоделировать формирование арахисообразного балджа в нашей Галактике секулярной эволюцией, Frakoudi пришла к выводу, что можно это сделать ТОЛЬКО стартуя с ТРЕХ дисков – одного тонкого и двух(!) толстых, с вертикальными шкалами 400 и 800 пк и единой радиальной шкалой 2 кпк.

Отделение J: скопления галактик

- Продолжаются открытия скоплений галактик на красных смещениях >1.
- Свежее определение массы по слабому линзированию для SpARCSJ1049 ($z=1.7$): 3.8×10^{14} масс Солнца.
- Начались обзоры с KMOS полей скоростей и темпов звездообразования в H-alpha для галактик скоплений на $z=1.39$, 1.47.

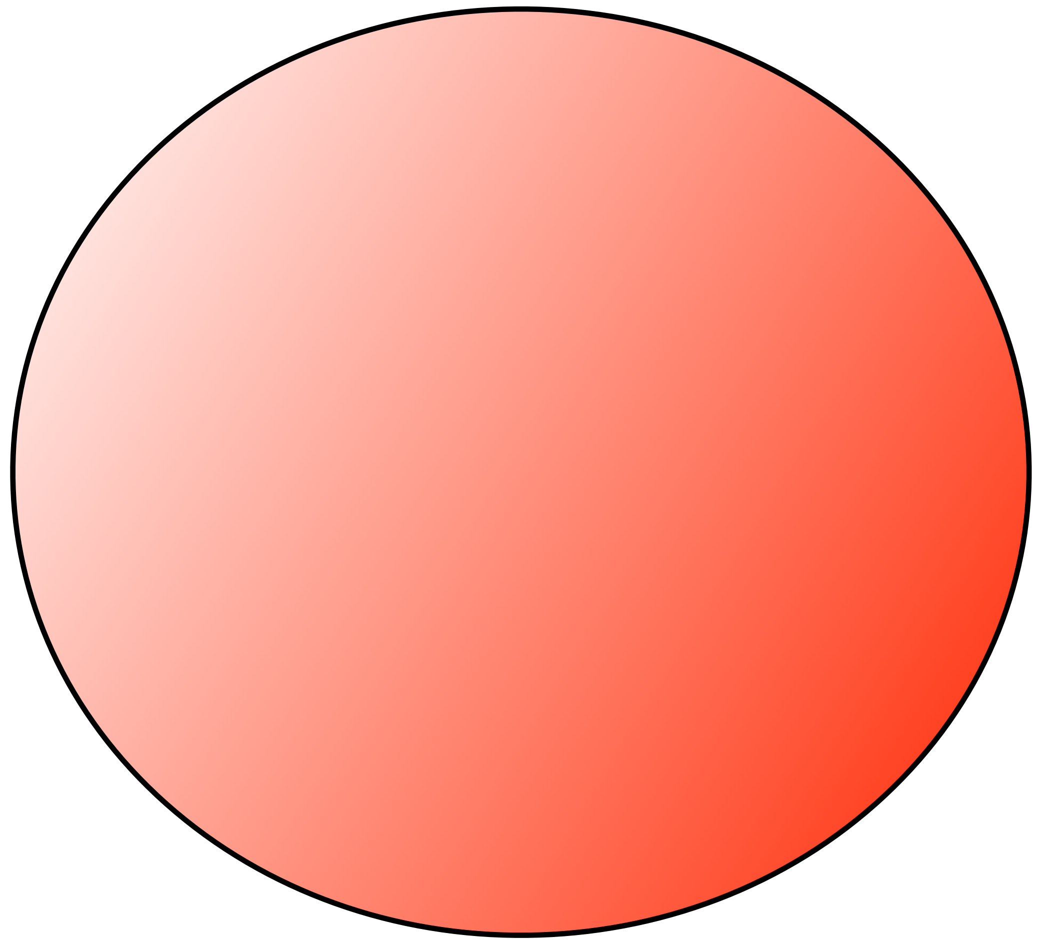
Angular momentum in the gas that builds galaxies

James Bullock (UC Irvine)

Kyle Stewart, Shea Garrison-Kimmel

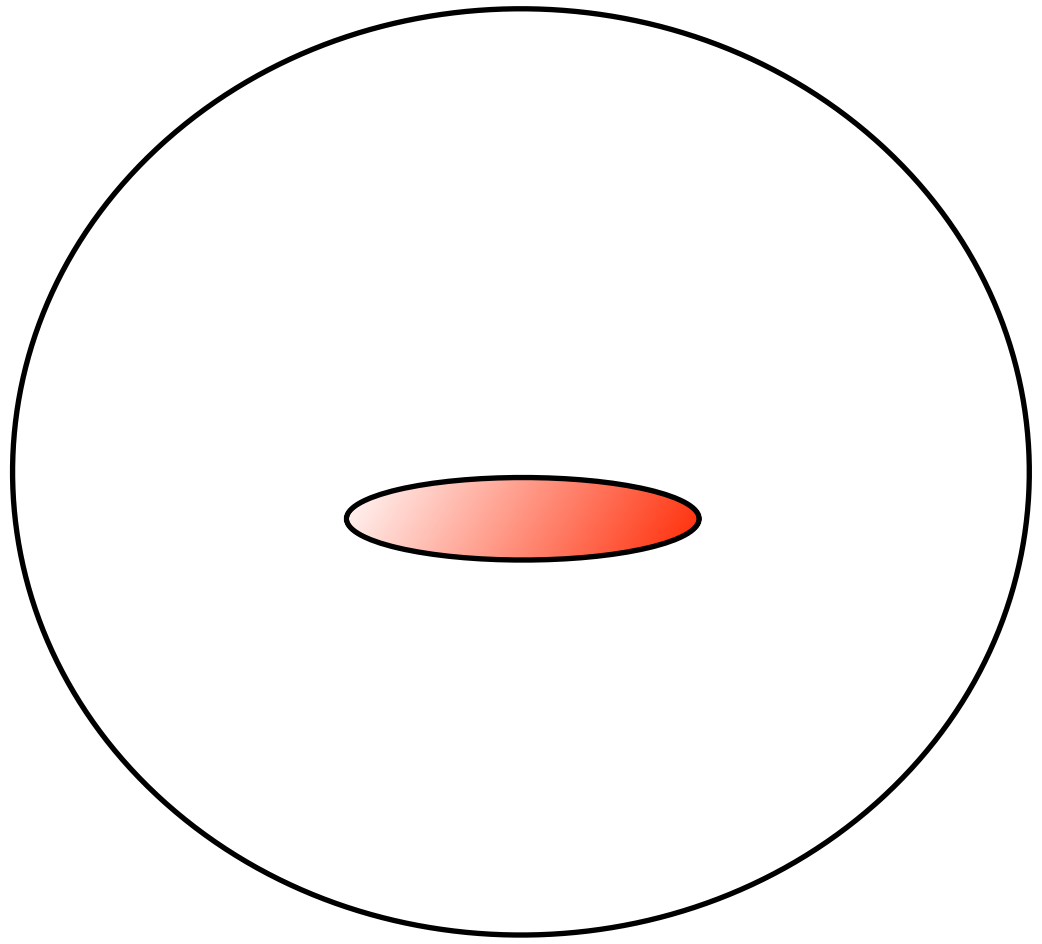
Cartoon of Galaxy Formation

Shock-heated hot gas traces the extended DM halo.



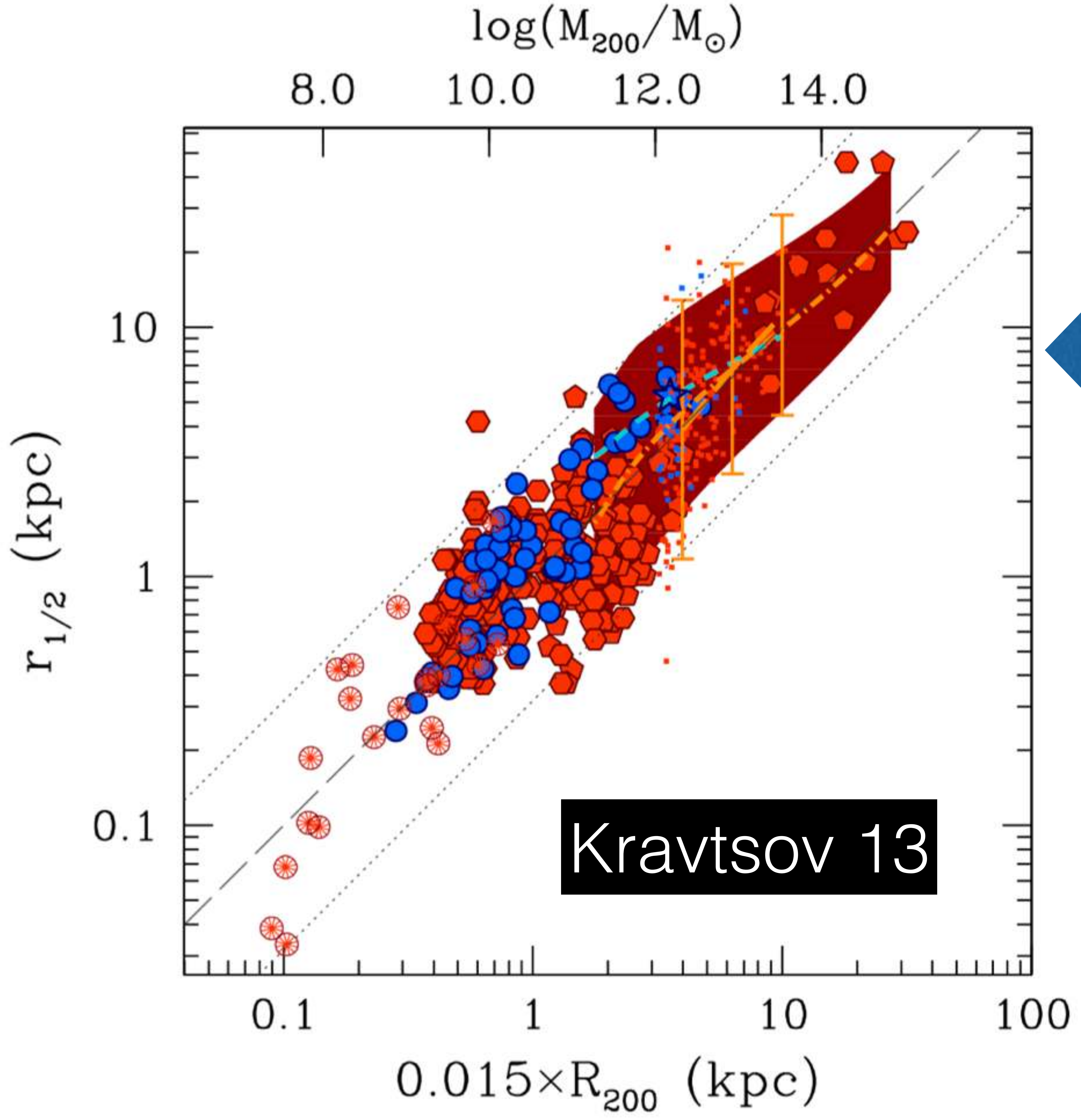
$$\lambda \equiv \frac{J\sqrt{E}}{GM^{5/2}} \simeq \frac{j}{\sqrt{2}VR} \simeq 0.03$$

Gas cools to form angular-momentum supported disk



$$r_{\rm d} \simeq \lambda R_{\rm v} \sim 5{\rm kpc}$$

e.g. White & Rees 78; Fall & Efstathiou 80; Mo, Mao & White 97; …



Kravtsov 13

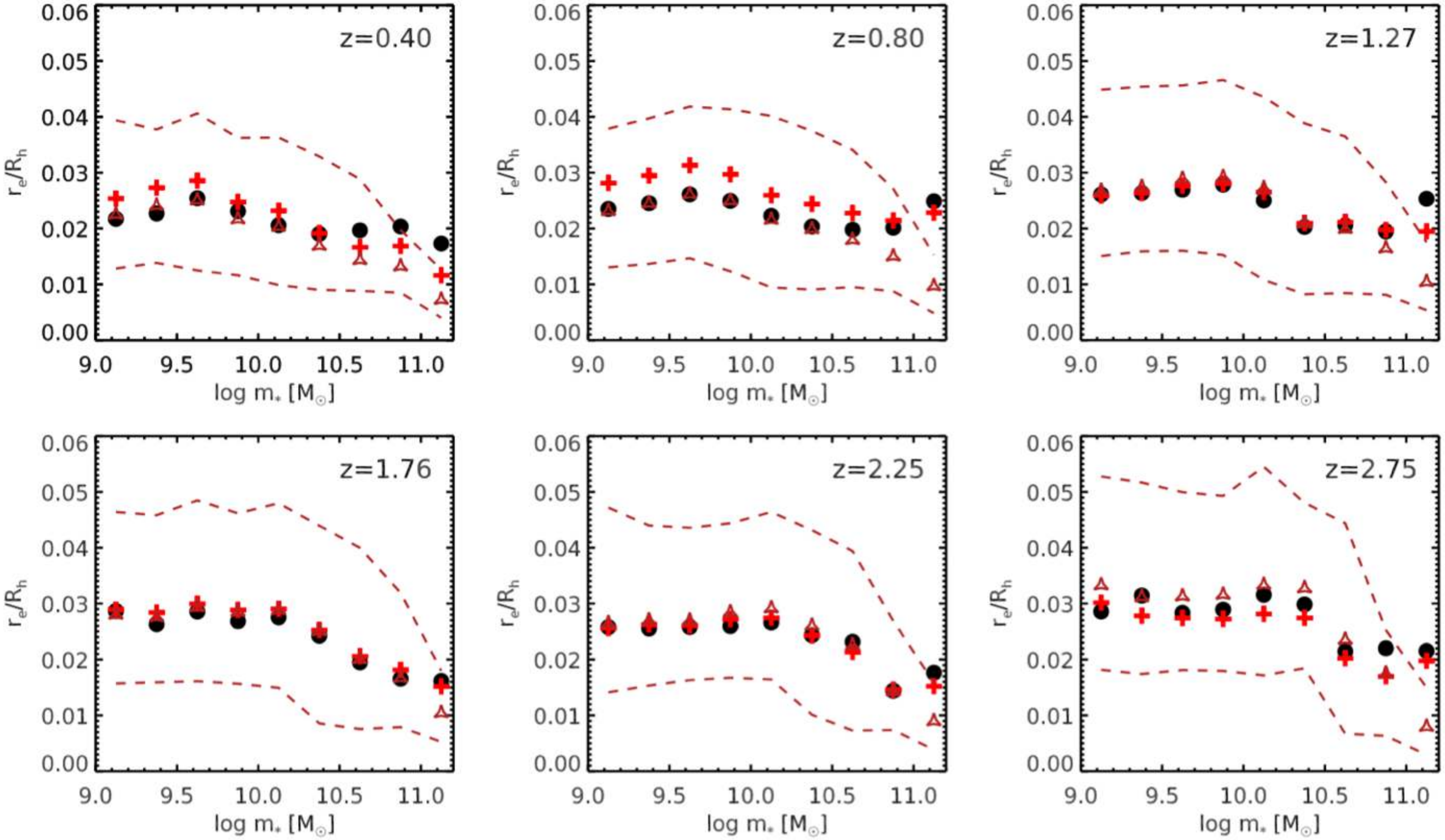
Important, empirical trend

$$r_{\rm d} \simeq \lambda R_{\rm v}$$

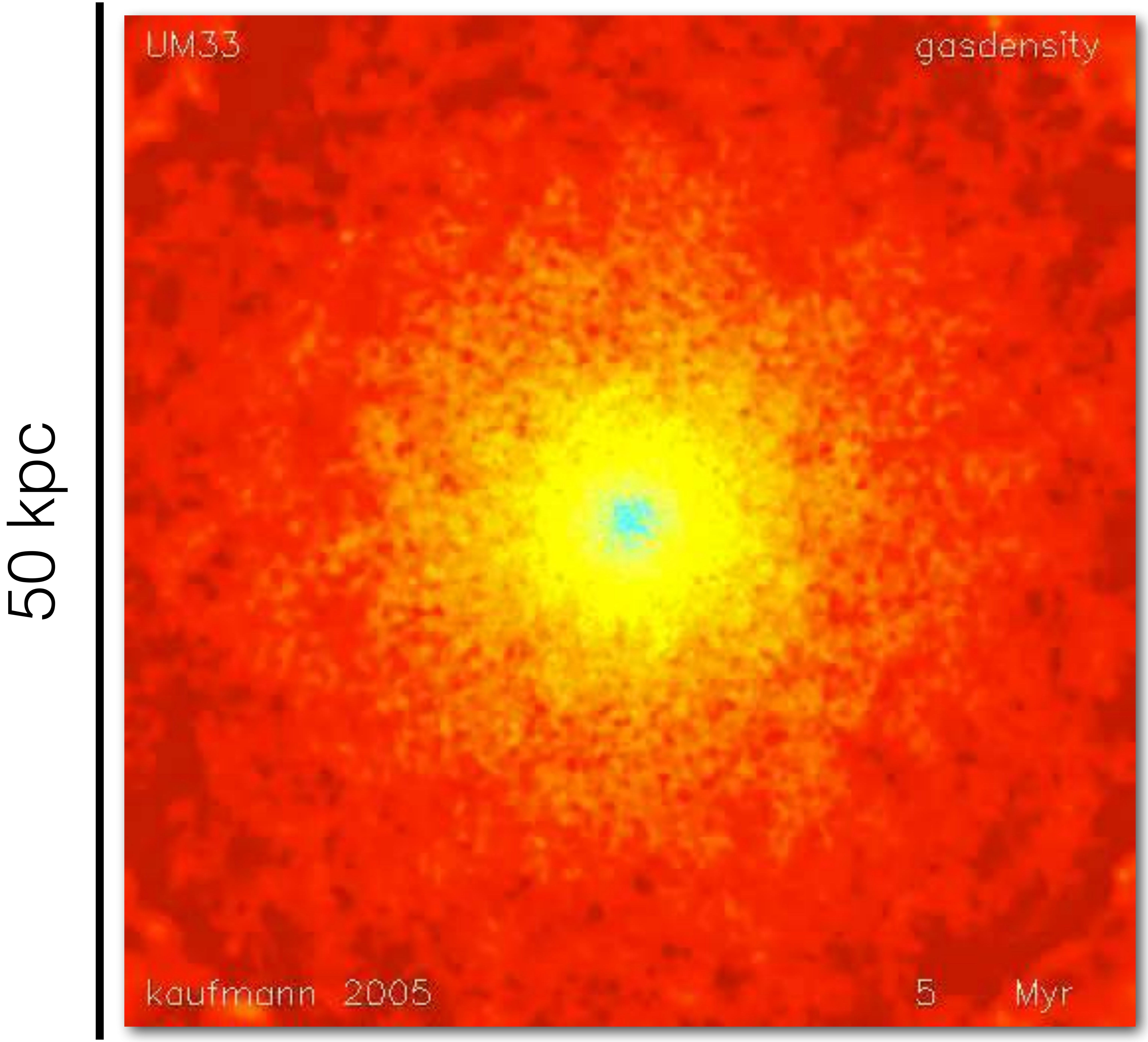
Evidence that this picture is correct?

Higher redshift too!

$$r_{\rm d} \simeq \lambda R_{\rm v}$$



Somerville+17

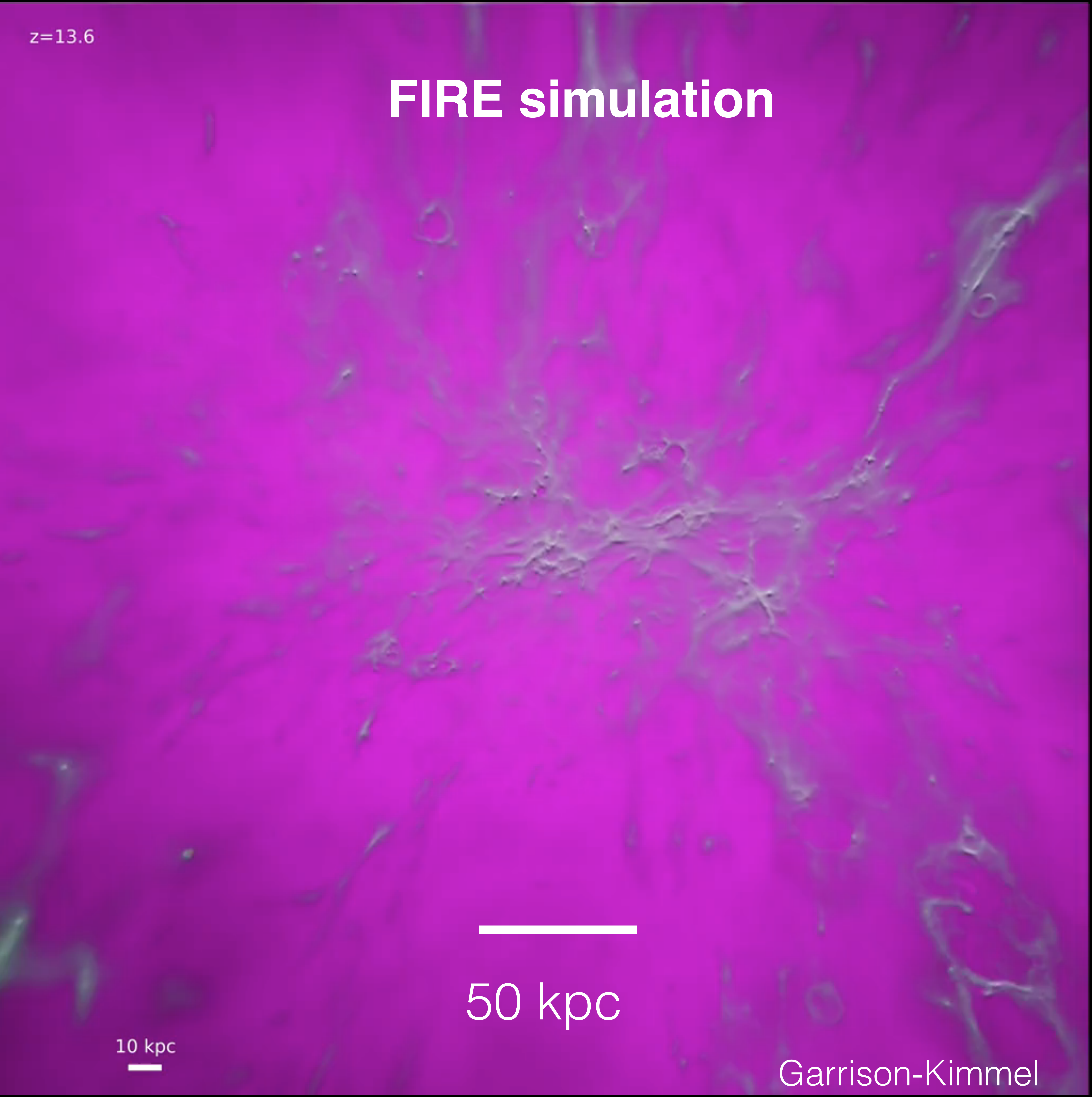


$$r_{\mathrm{d}} \simeq \lambda R_{\mathrm{v}}$$

One problem…

-This isn’t how (we think) galaxies form

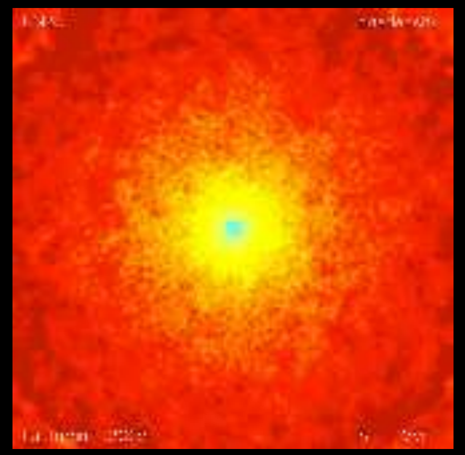
FIRE simulation



50 kpc

Garrison-Kimmel

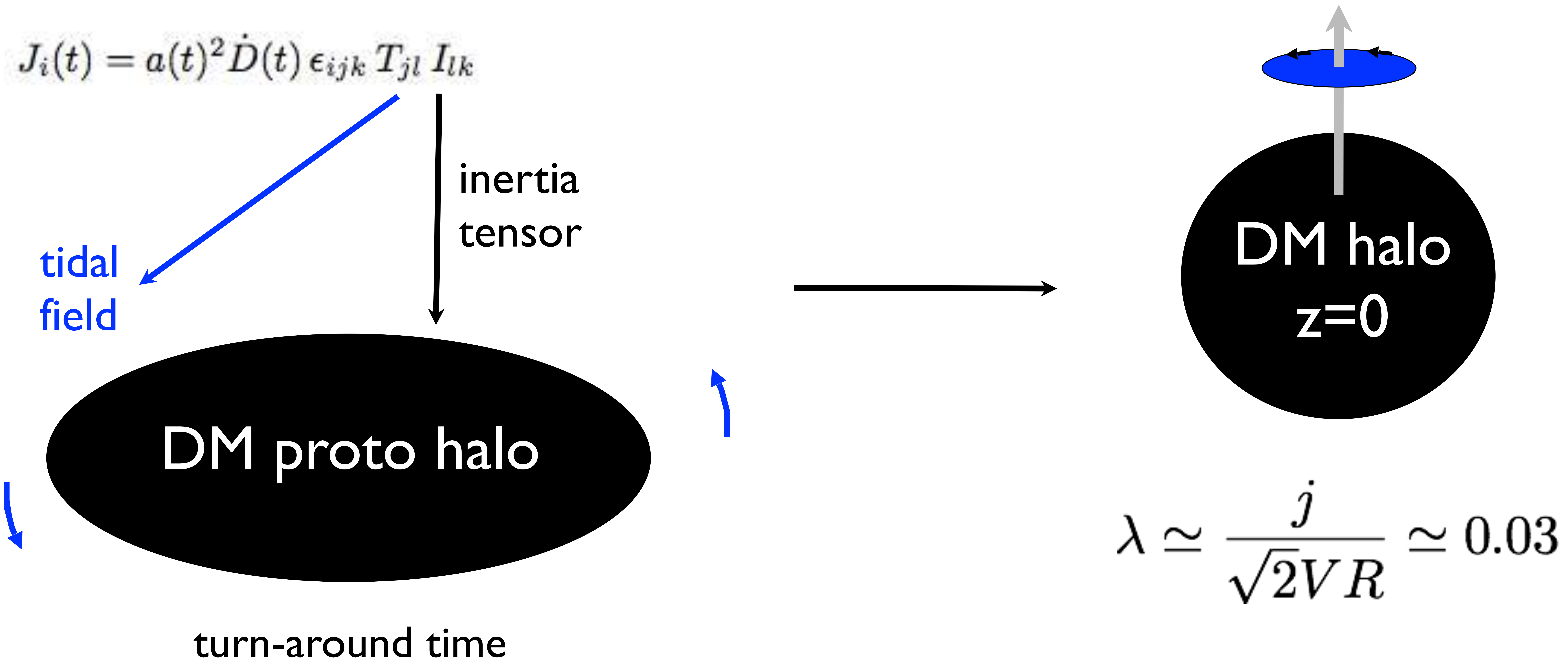
Cartoon simulation



50 kpc

What’s the angular momentum of cold/accreting gas?

How dark matter gets its spin



$$J_i(t) = a(t)^2 \dot{D}(t)\, \epsilon_{ijk}\, T_{jl}\, I_{lk}$$

tidal field

inertia tensor

DM proto halo

turn-around time

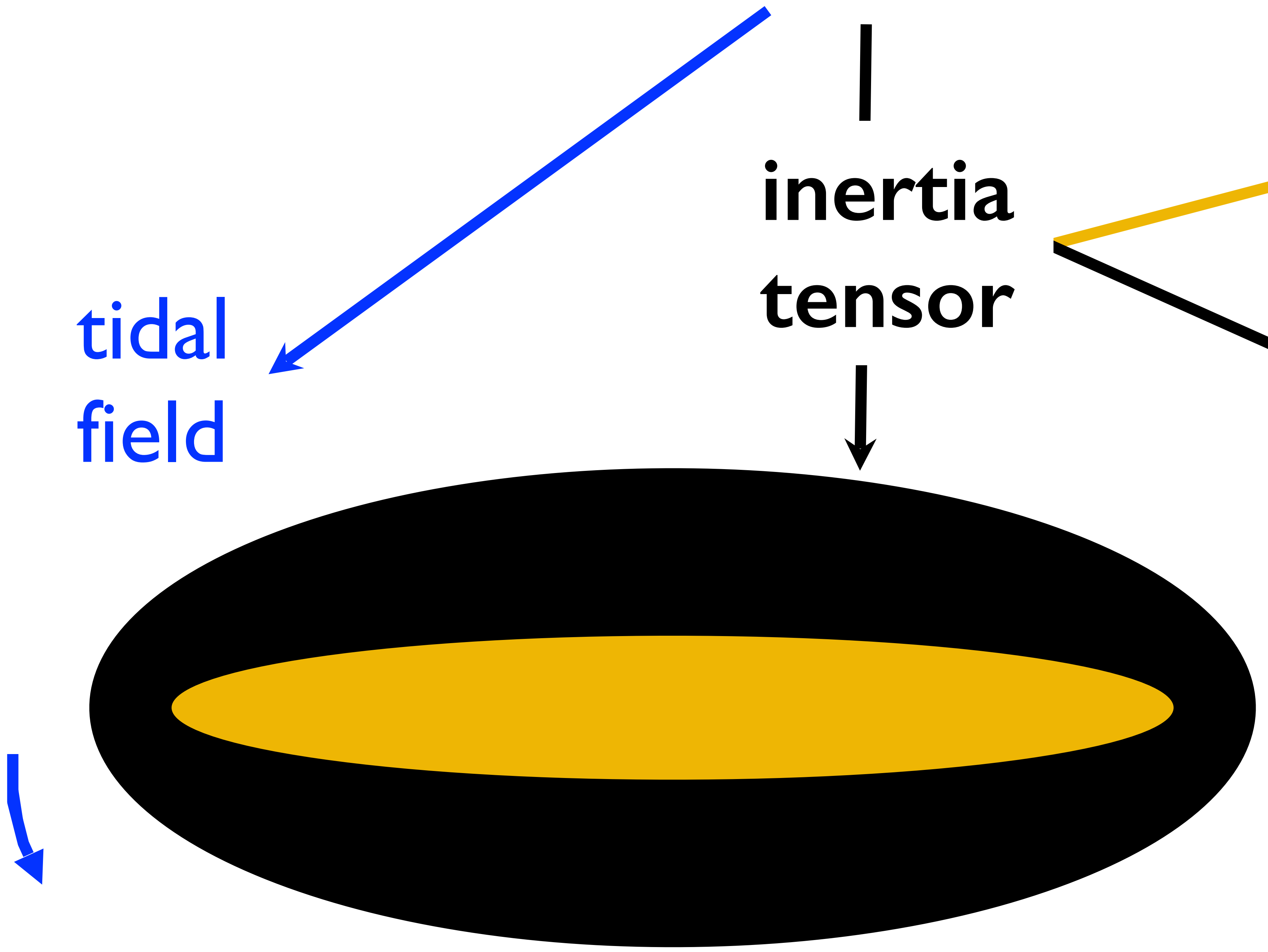
DM halo
z=0

$$\lambda \simeq \frac{j}{\sqrt{2}VR} \simeq 0.03$$

Peebles (1969); Doroshkevich (1970); White (1984)

Cool Gas vs. DM Inertia Tensor

$$J_i(t) = a(t)^2 \dot{D}(t)\, \epsilon_{ijk}\, T_{jl}\, I_{lk}$$

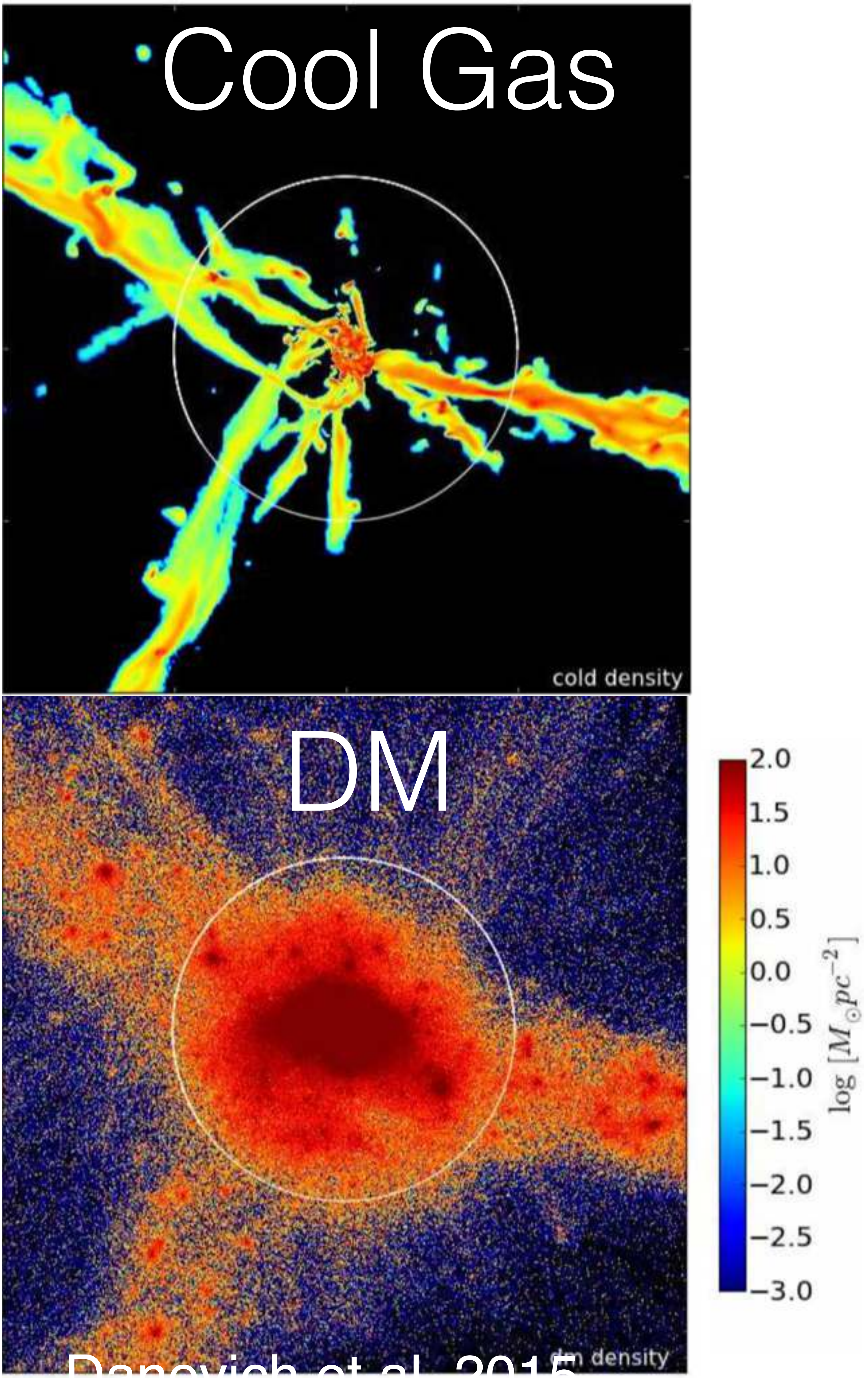


tidal field

inertia tensor

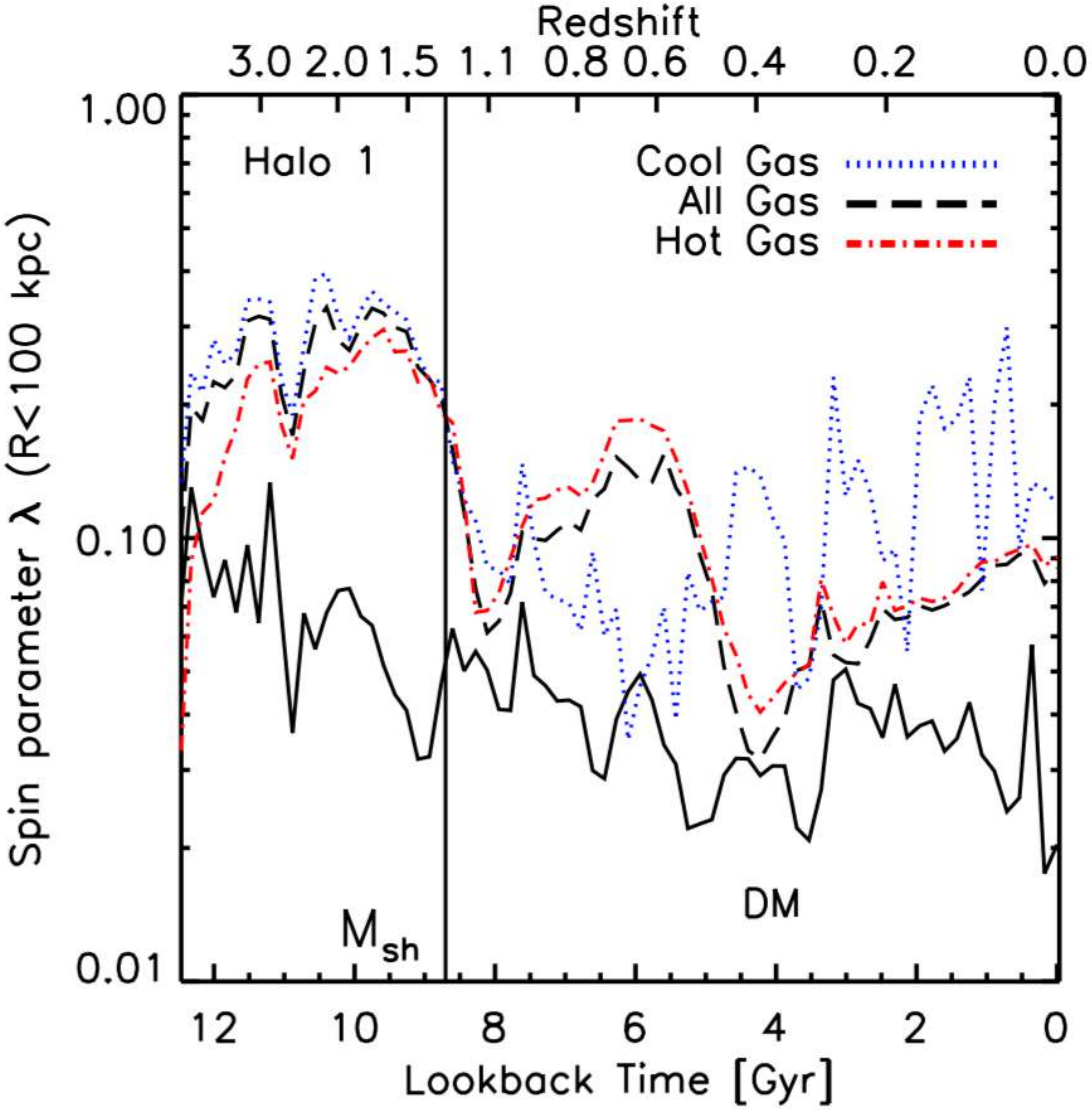
turn-around time

quadrupole moment of cold gas ~50% higher than DM



Danovich et al. 2015

Peebles (1969); Doroshkevich (1970); White (1984)



Stewart+2011 [Gasoline]

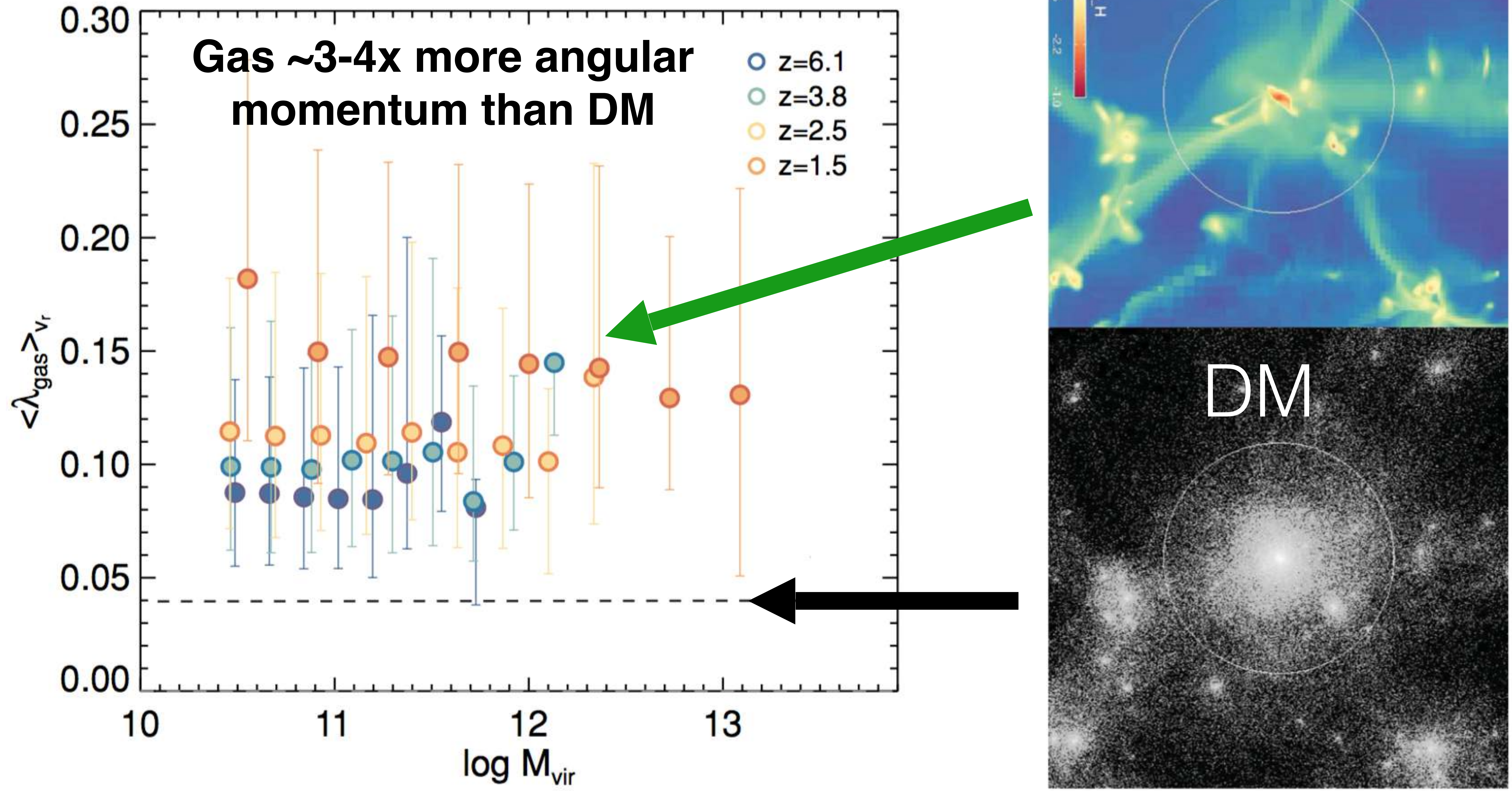
Typically:

Cool gas ~3x spin of DM

Hot gas ~2x spin of DM

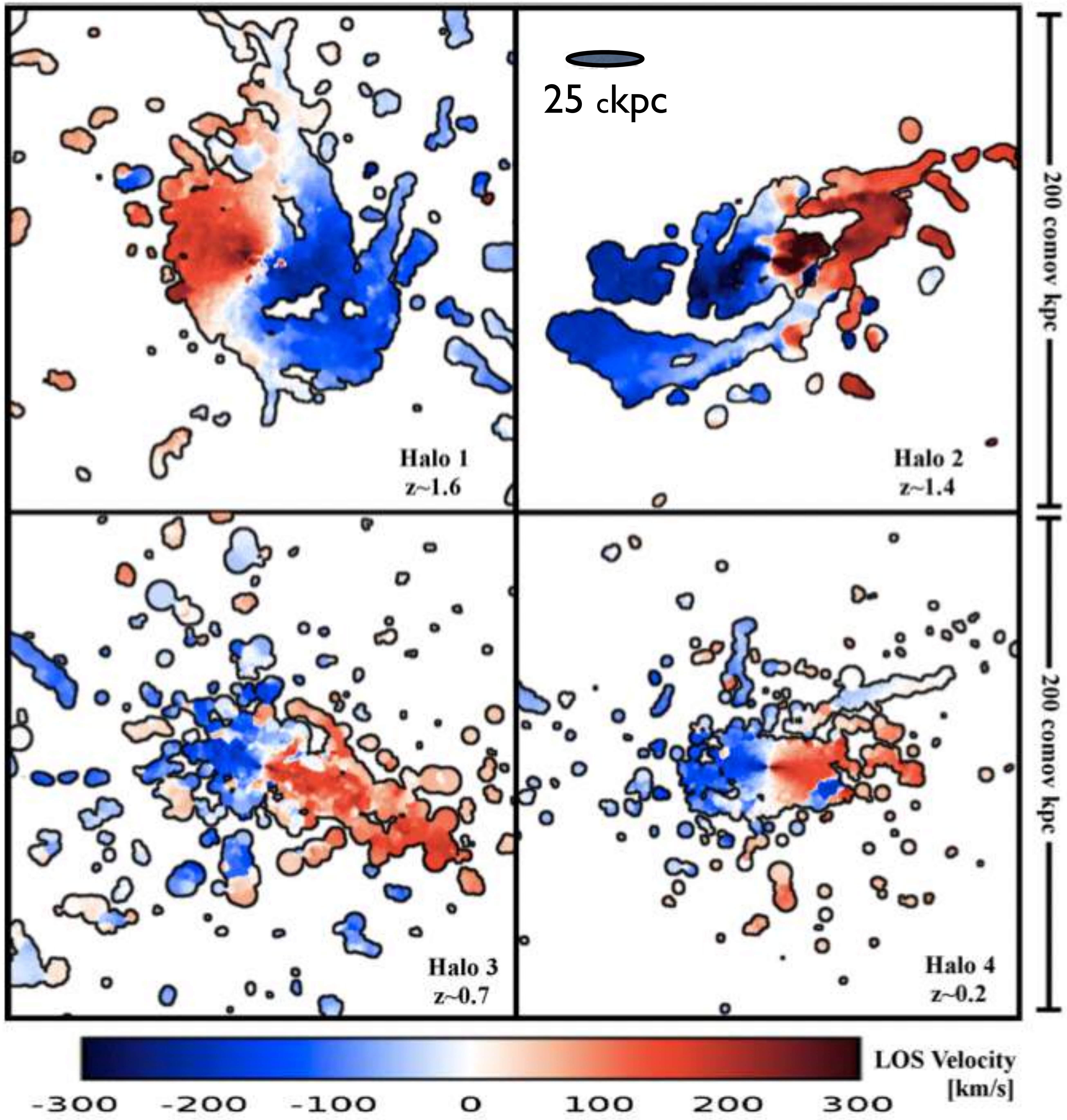
Cool gas can show spin parameters up to **~10x** DM (almost rotationally supported)

Pichon+2011 [RAMSES]



Gas ~3-4x more angular momentum than DM

Stewart et al. 2013



Cool CGM is spinning fast

This is the gas that will build the disk.

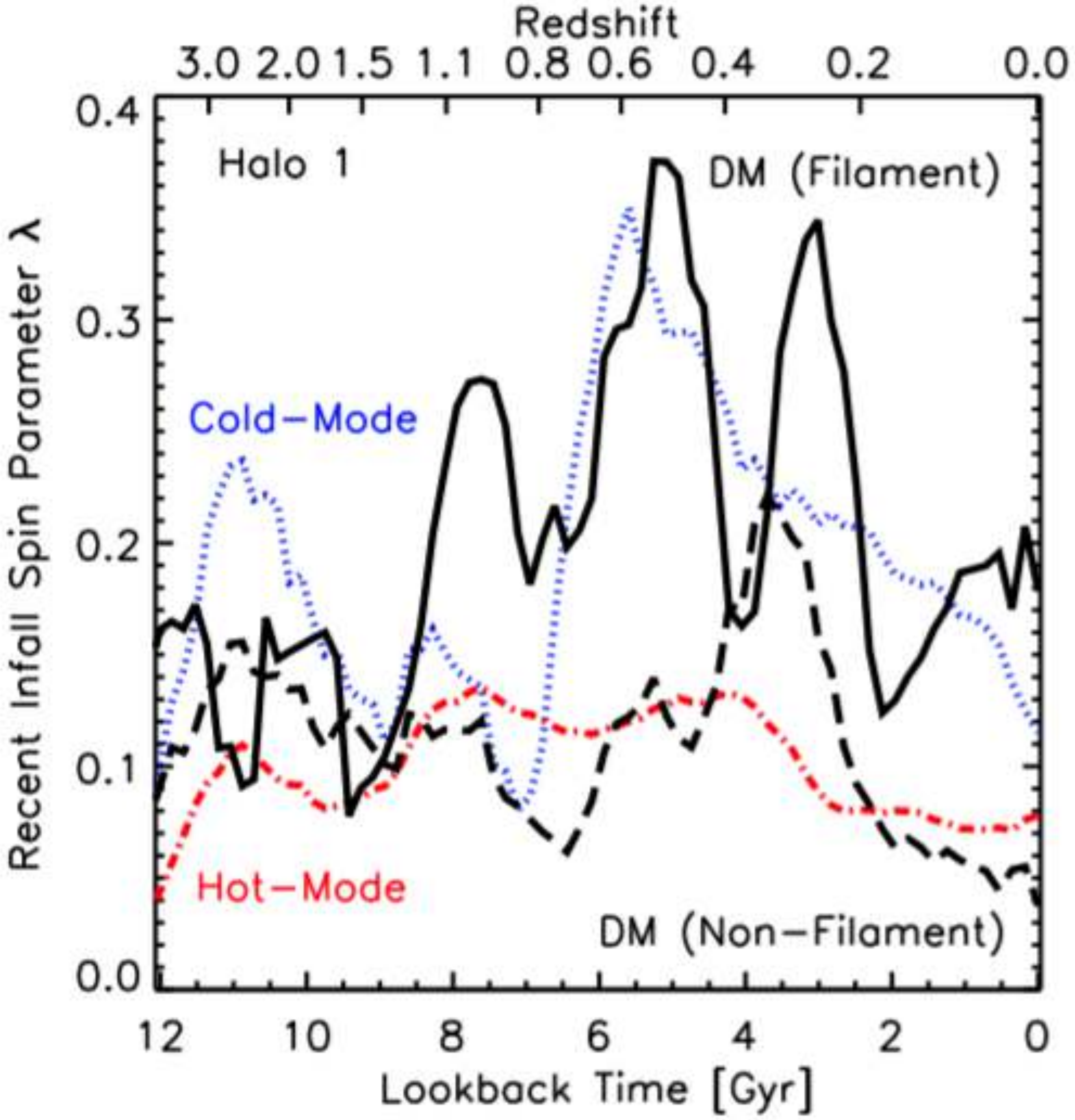
GASOLINE (SPH)

Black contours have $N_{\rm H\,I} > 10^{16}$ cm^{-2}

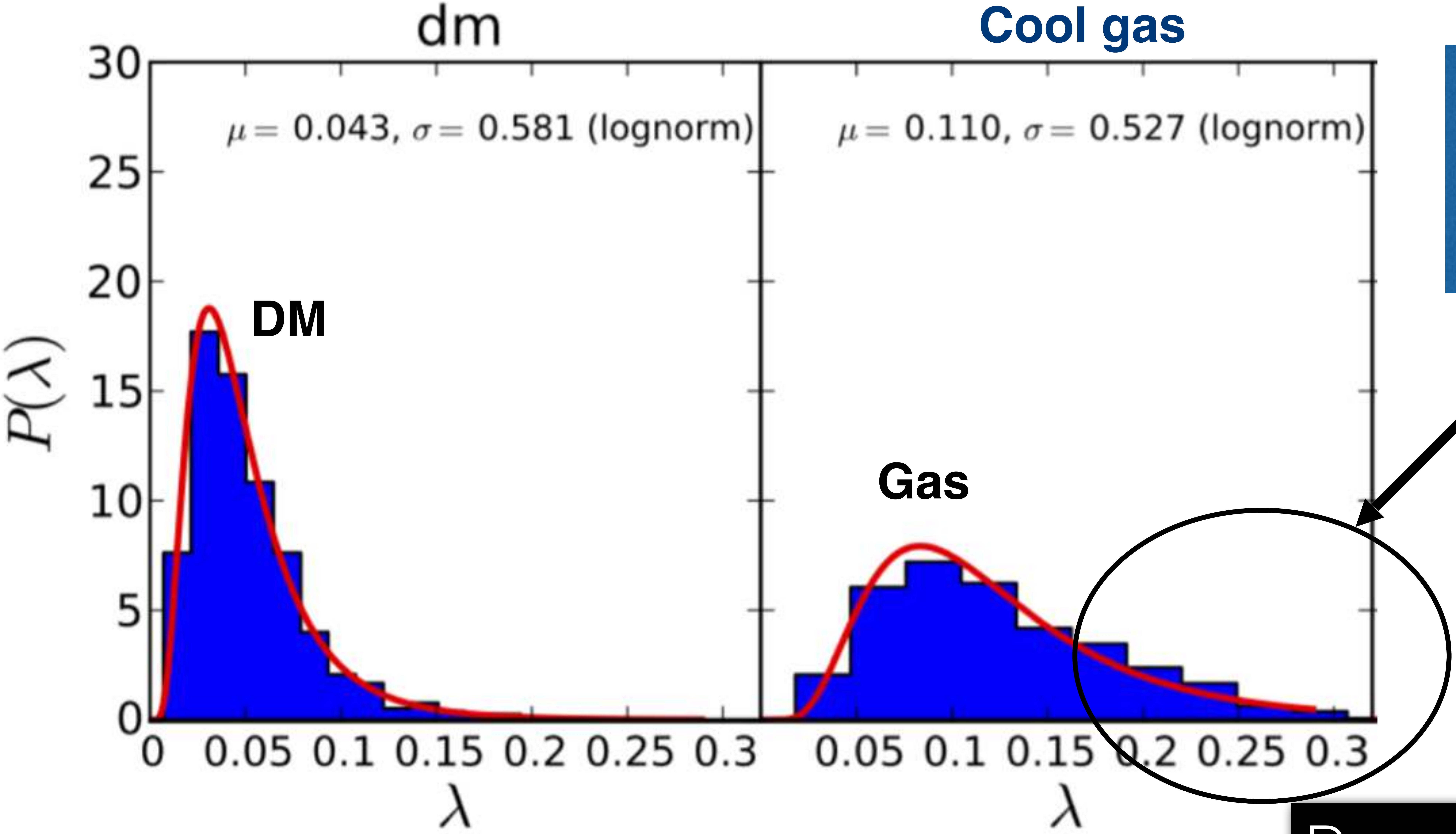
Restrict to DM falling in along same cylinder as gas => spin parameters match.

Suggests its a geometric effect, coming from inertia tensor.

Stewart et al. 2013



Spin of material between 0.1-1 R_{vir}



$\lambda > 0.2$!
(unheard of
for DM)

29 high resolution cosmological hydrodynamic "zoom–in" sims

Danovich et al. 2015

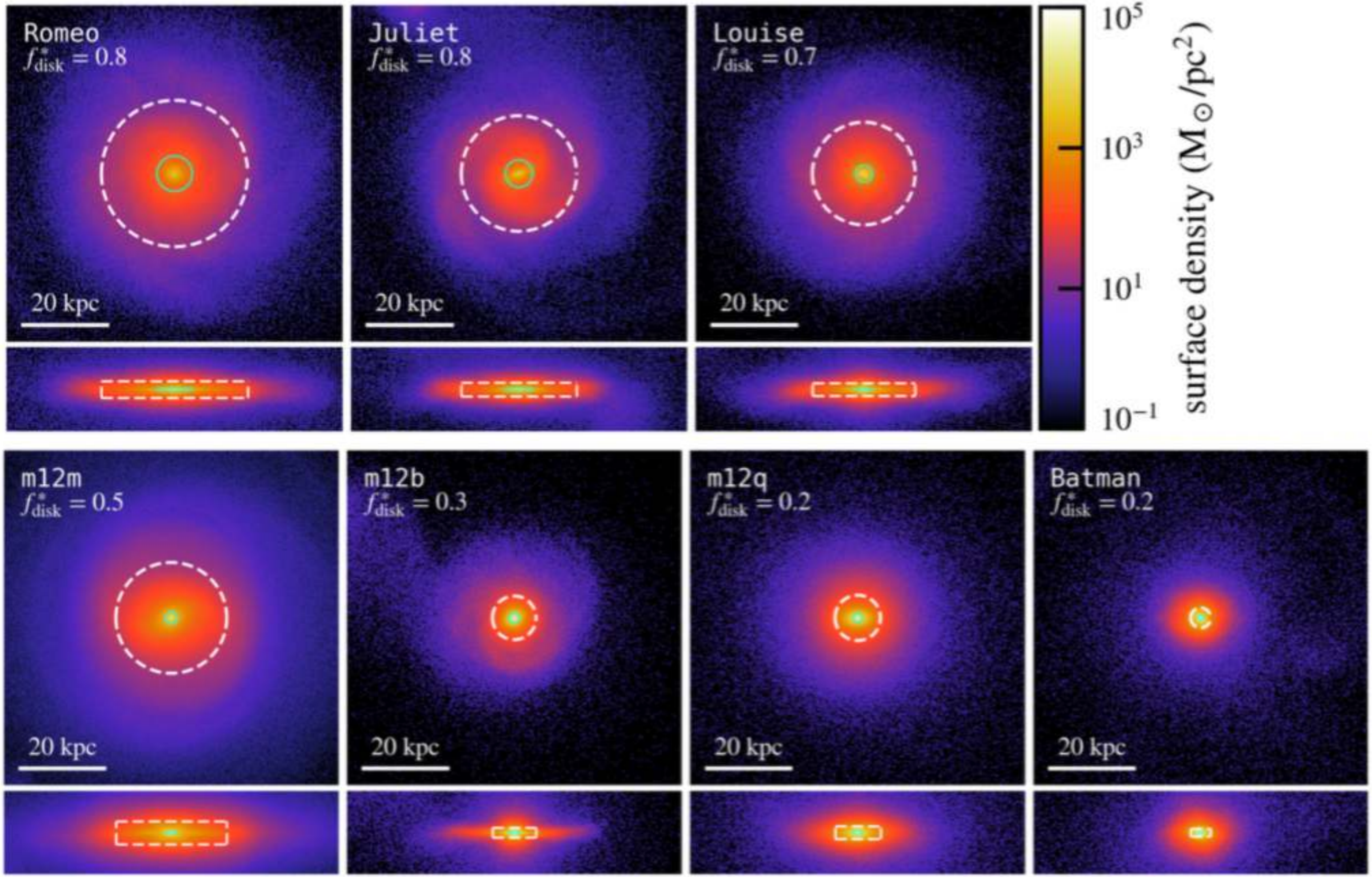
Do any of these simulations agree on anything?

Stewart et al. 2017

YES! Cold gas is spinning w/ ~3x specific j as DM

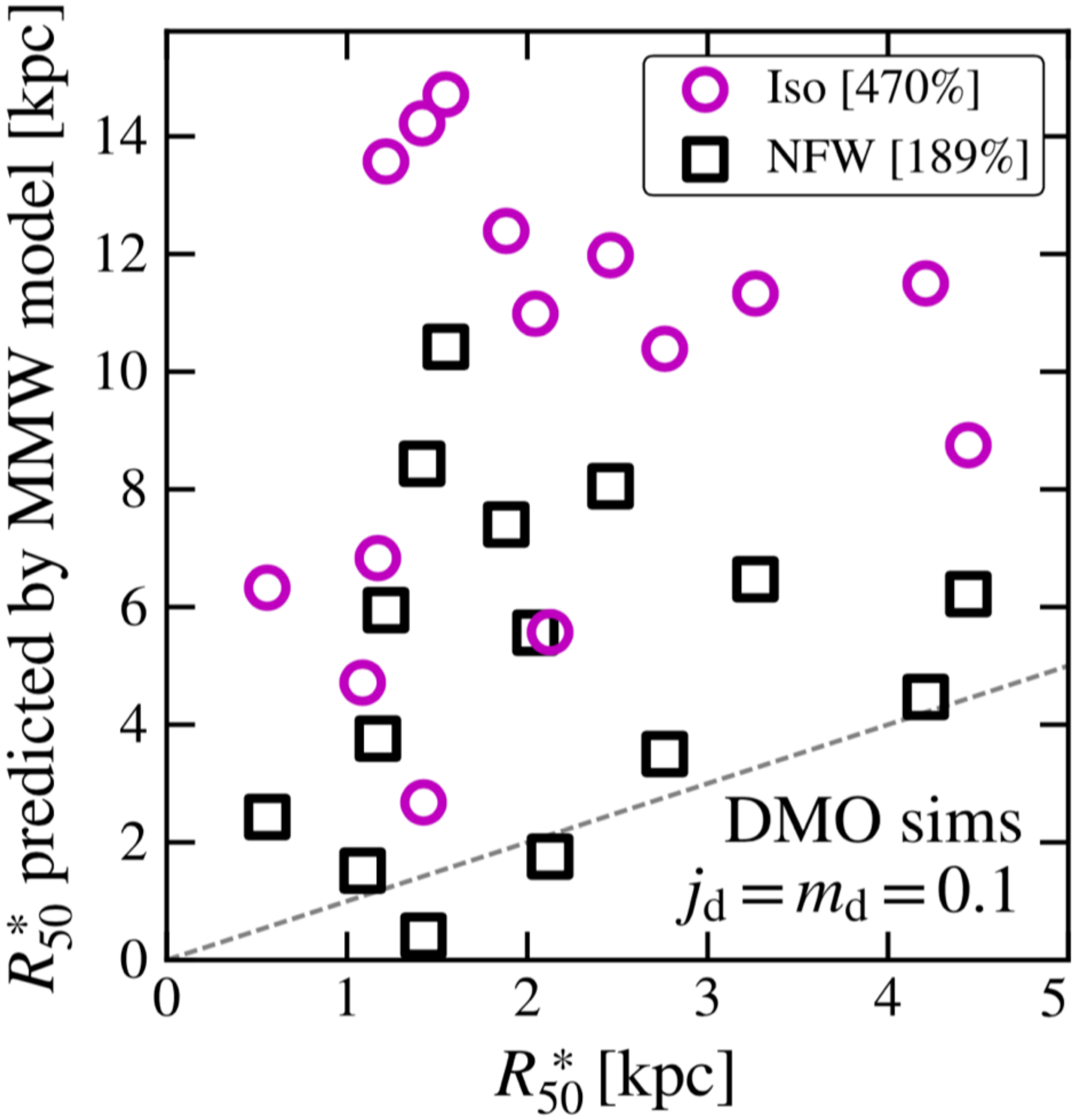
What sets galaxy sizes?

Garrison-Kimmel et al. 2018a [FIRE simulations]


Romeo
$f^*_{\rm disk} = 0.8$
20 kpc
Juliet
$f^*_{\rm disk} = 0.8$
20 kpc
Louise
$f^*_{\rm disk} = 0.7$
20 kpc
m12m
$f^*_{\rm disk} = 0.5$
20 kpc
m12b
$f^*_{\rm disk} = 0.3$
20 kpc
m12q
$f^*_{\rm disk} = 0.2$
20 kpc
Batman
$f^*_{\rm disk} = 0.2$
20 kpc
10^5
10^3
10^1
10^{-1}
surface density ($\rm M_\odot/pc^2$)

~L* galaxy sizes in FIRE simulations **do not correlate w/ DM halo** spin as expected in standard picture.

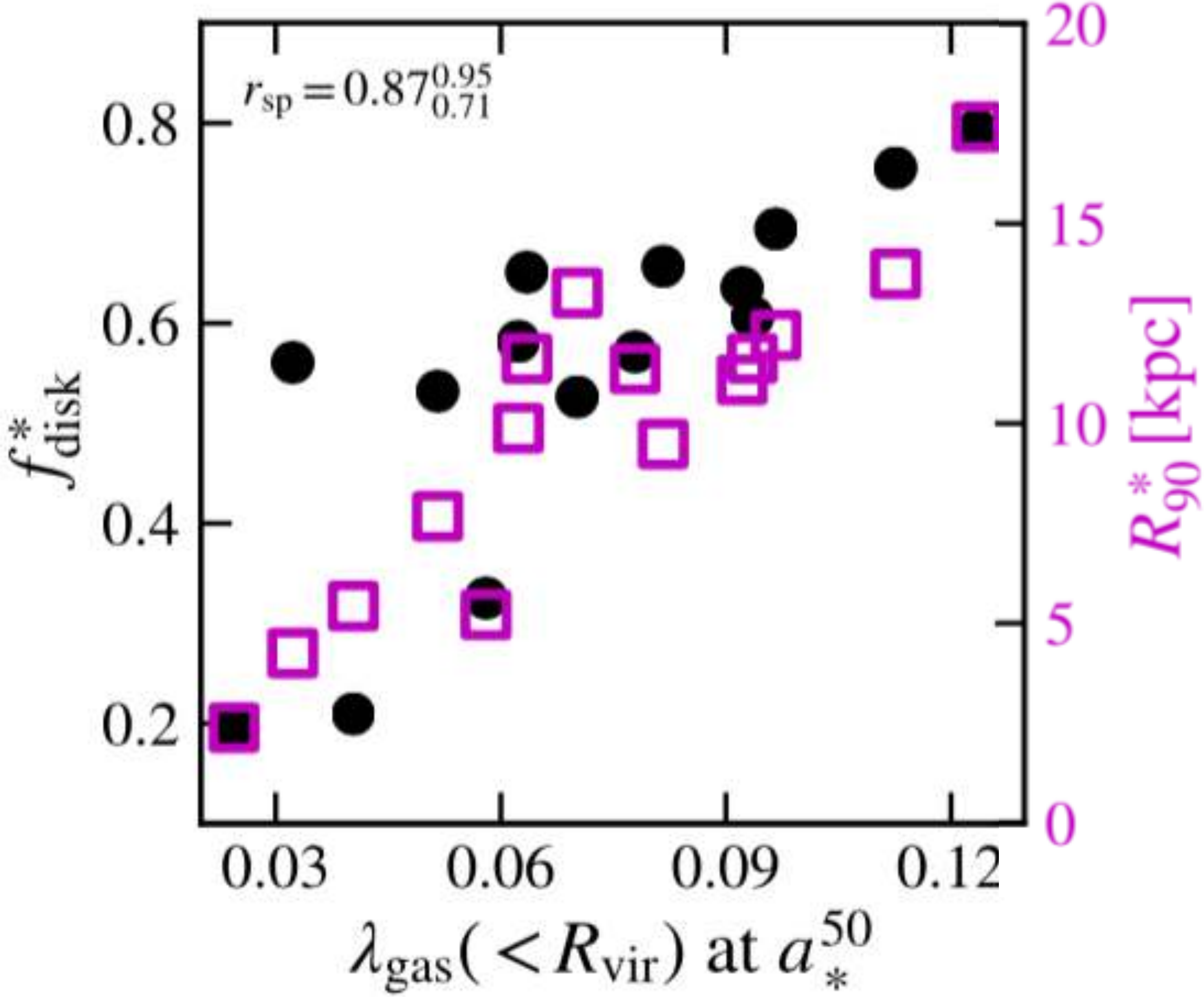
Garrison-Kimmel+ 2018



What sets galaxy sizes?

Spin of the <u>gas</u> at early times - the cold gas that builds the disk.

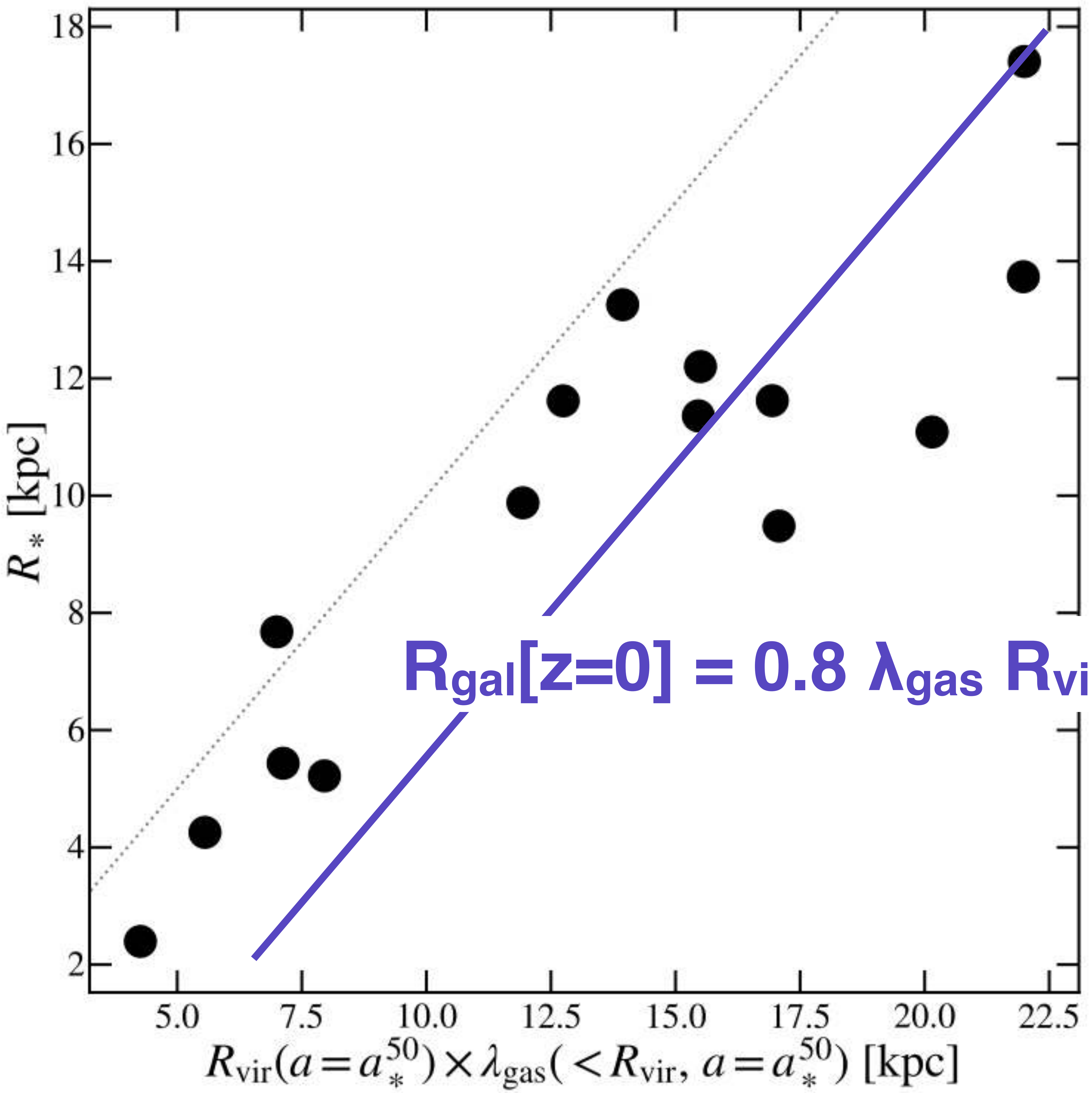
NOT spin of the dark matter at z=0.



Garrison-Kimmel+ 2018

gas spin
at z~1
correlates
w/ galaxy
size at z~0

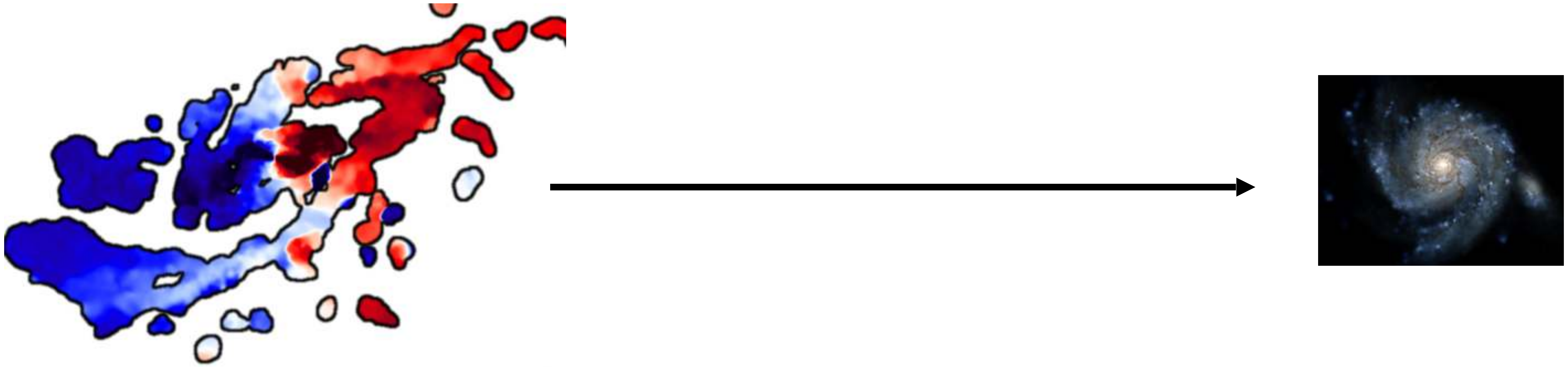
galaxy size z=0



$R_{gal}[z=0] = 0.8\ \lambda_{gas}\ R_{vir}\ [z_{form}]$

λ_{gas} x R_{vir} $[z_{form}]$

Garrison-Kimmel+ 2018



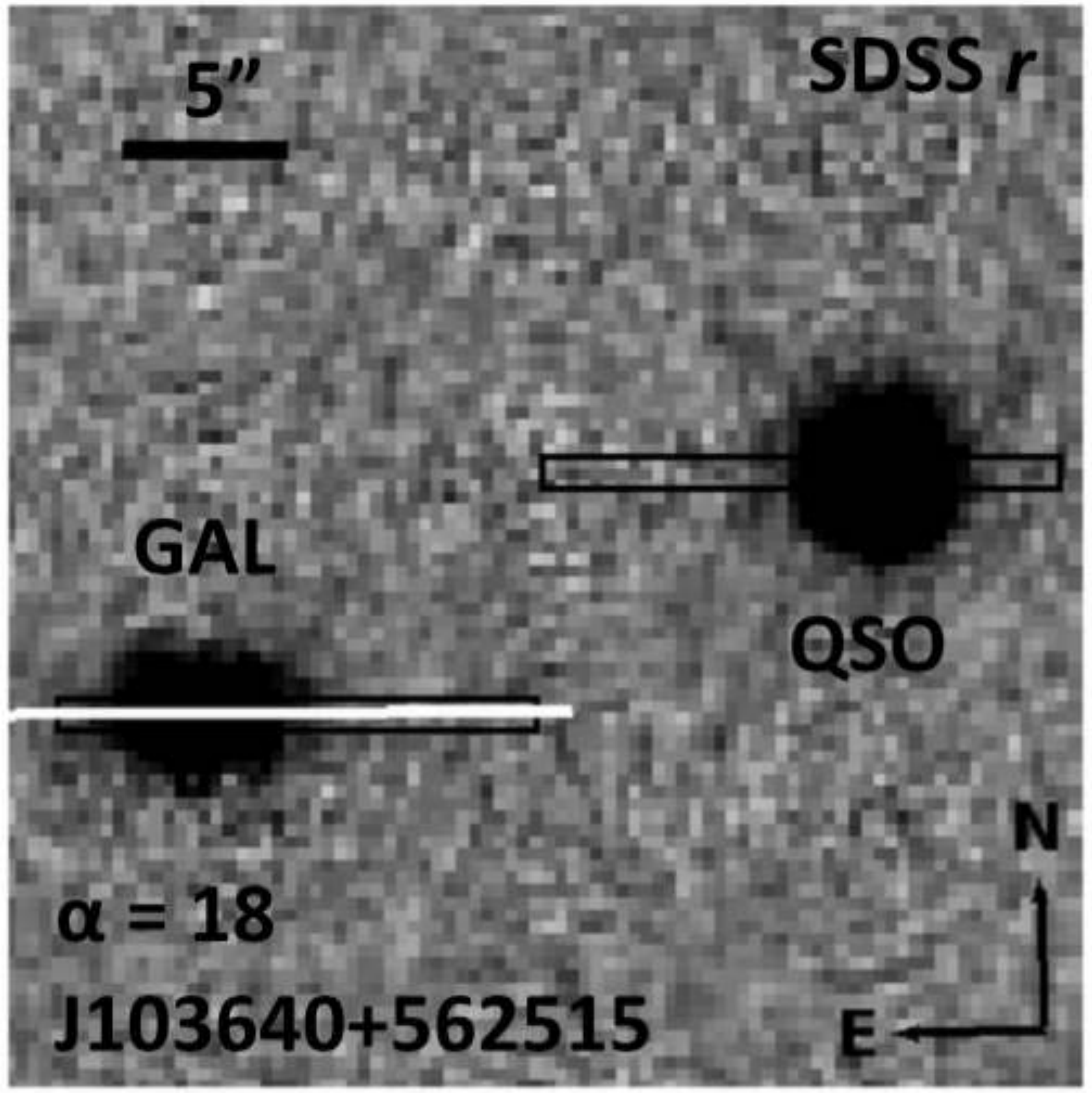
Produces similar order-of-magnitude result as old picture:

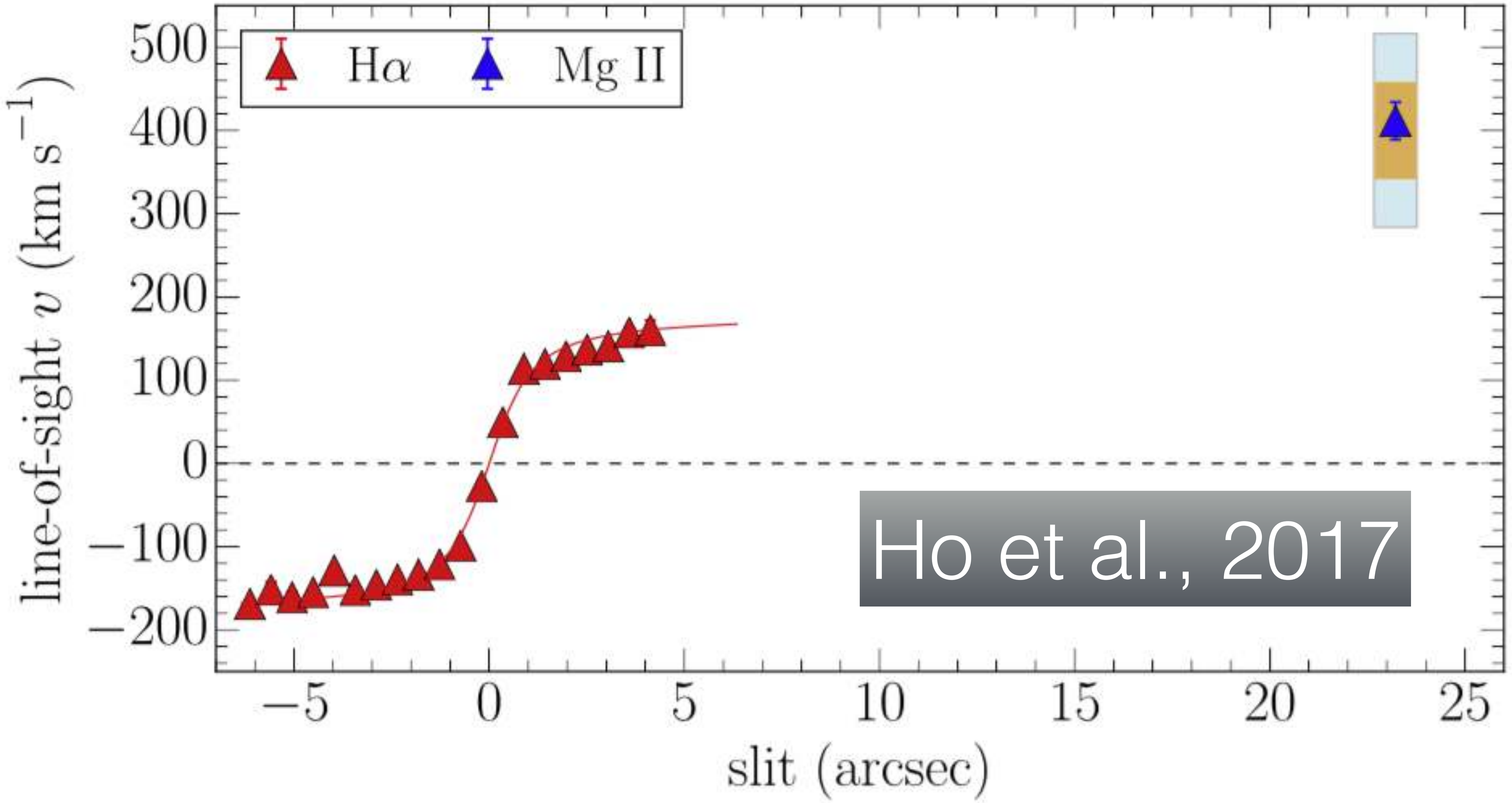
$$\underset{\underset{\mathbf{\sim 0.09}}{\uparrow}}{\lambda_{\rm gas}(z\sim 1)}\,\underset{\underset{\mathbf{\sim 100\ kpc}}{\uparrow}}{R_{\rm vir}(z\sim 1)} \simeq \underset{\underset{\mathbf{\sim 0.03}}{\uparrow}}{\lambda_{\rm dm}(z=0)}\,\underset{\underset{\mathbf{\sim 300\ kpc}}{\uparrow}}{R_{\rm vir}(z=0)}$$

This approximate equality is true statistically, <u>NOT</u> halo-by-halo

Does cool CGM gas spin as expected?

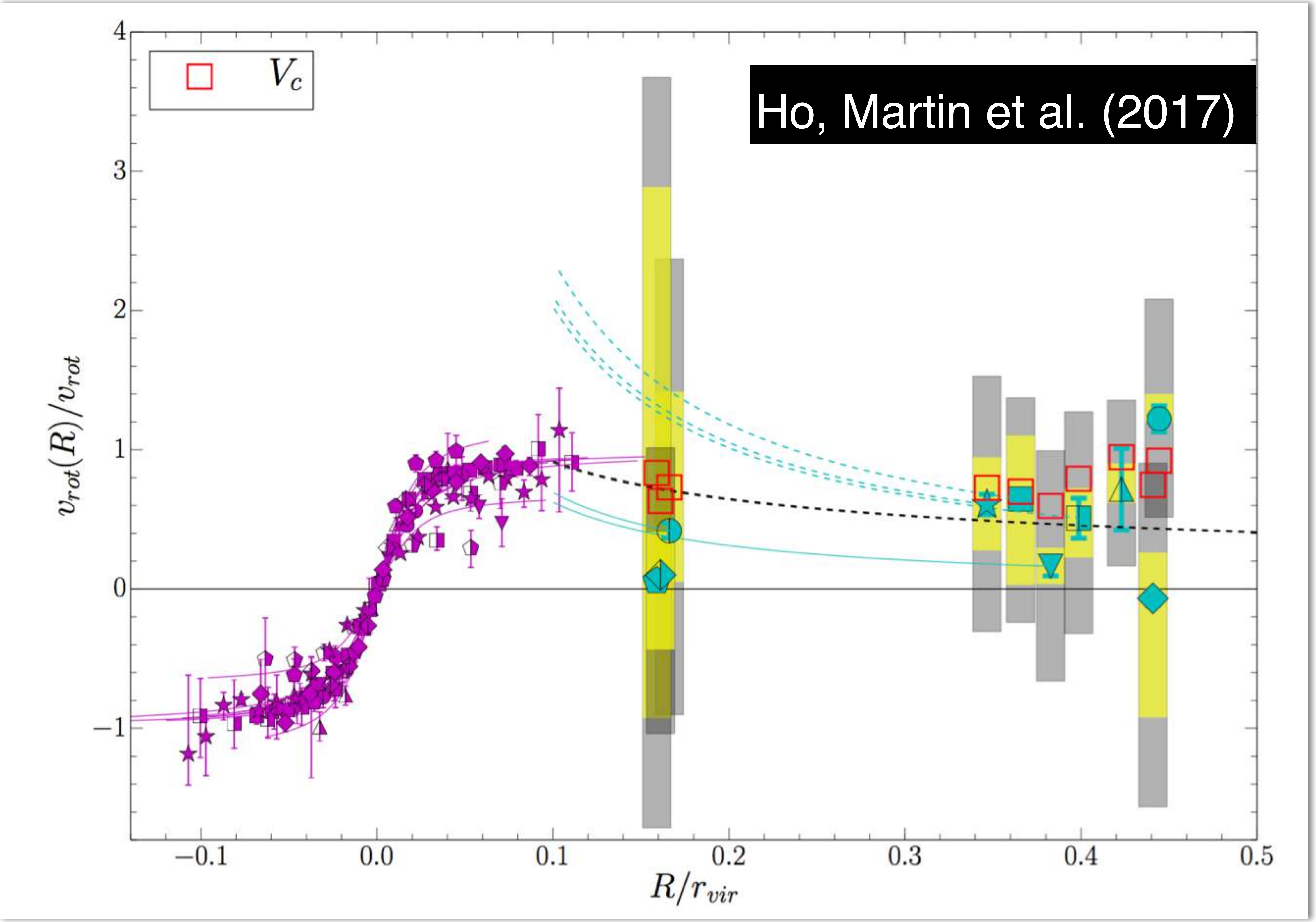
Vast majority of MgII absorber/disk pairs exhibit high-spin accretion kinematics





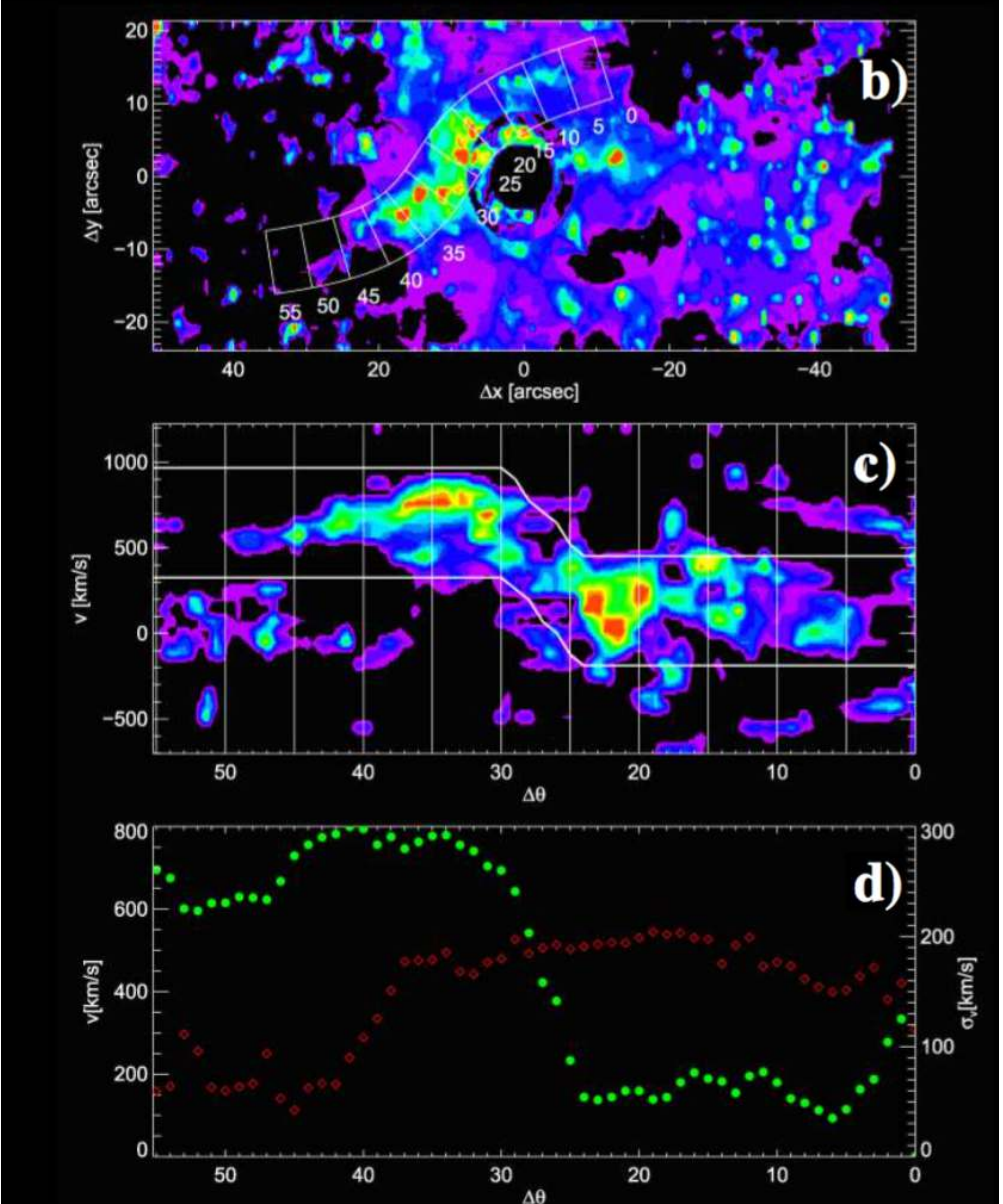
z ≈ 0.2

Steidel et al., 2002; Chen et al., 2005; Kacprzak et al., 2010a, 2011a; Bouche´ et al.,2013; Burchett et al., 2013; Keeney et al., 2013; Jorgenson & Wolfe, 2014; Diamond-Stanic et al., 2016; Bouche´ et al., 2016;



MgII absorbers around inclined, star-forming galaxies at z~0.2

> “Mg II Doppler shifts have the same sign as the galactic rotation, so the cold gas co-rotates with the galaxy.”



Martin et al. 2016

"Cold inflowing disk"

Bright Lyα filament @ z = 2.843

w/ Palomar Cosmic Web Imager

R ~150 kpc gas structure

rotating at V~350 km/s

Looks like ~4x$10^{12}$$M_{sun}$ halo

Conclusions

Cool gas that feeds galaxies is accreted with significant angular momentum, ~3x spin of DM halo

=> Expect orbiting, in-spiraling halo gas

=> Possible way to make very large disks

Galaxy sizes in FIRE/Milky Way simulations correlate with spin of the cool gas at z~1 (**not** DM halo spin at z~0)

=> $R_{gal}(z=0) \sim \lambda_{gas}(z\sim1)\, R_{vir}(z\sim1)$

There is evidence that cool CGM gas spins as predicted.

=> Chance to map out "source term" of angular momentum at z>0 that will set disk sizes at z=0.

Does AM regulate HI gas in HI-deficient spirals?

Chandrashekar Murugeshan

Swinburne University of Technology

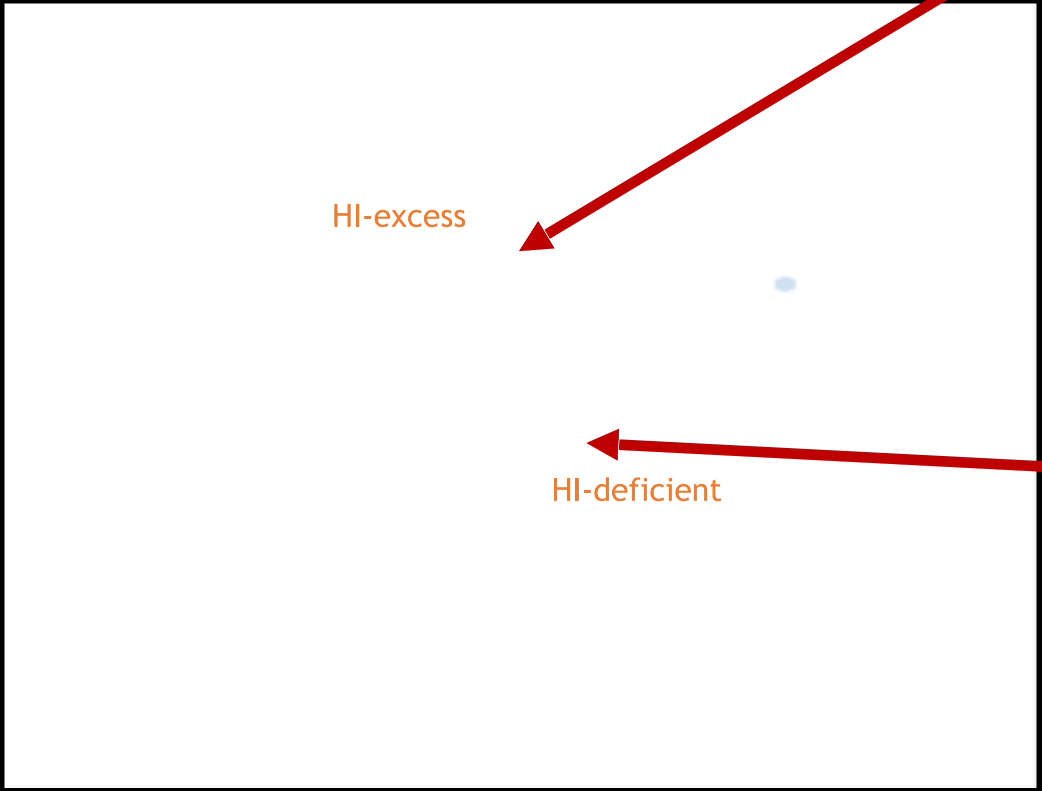
SWIN BUR NE CENTRE FOR ASTROPHYSICS AND SUPERCOMPUTING

IAU General Assembly, Focus Meeting 6

22 August 2018

Scaling relations: HI-excess & HI-deficient galaxies

~ 1700 HIPASS sources



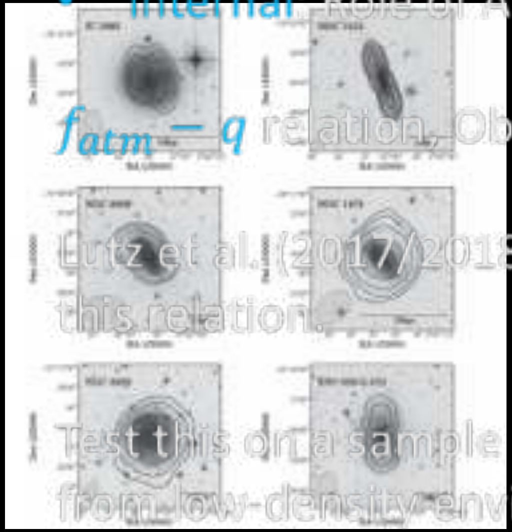
Adopted from Dénes et al. (2014)

Wang et al. (2013)

Reasons?

- Environment: ram pressure and tidal stripping, in compact groups and clusters. What about low-densities? Some galaxies HI-deficient, how and why?

- Internal: Role of Angular momentum ?



Dénes at al. (2016)

$f_{atm} - q$ relation, Obreschkow et al. (2016) [O16]

Lutz et al. (2017/2018) - HI-excess galaxies follow this relation.

Test this on a sample of HI-deficient spirals from low-density environments.

The sample

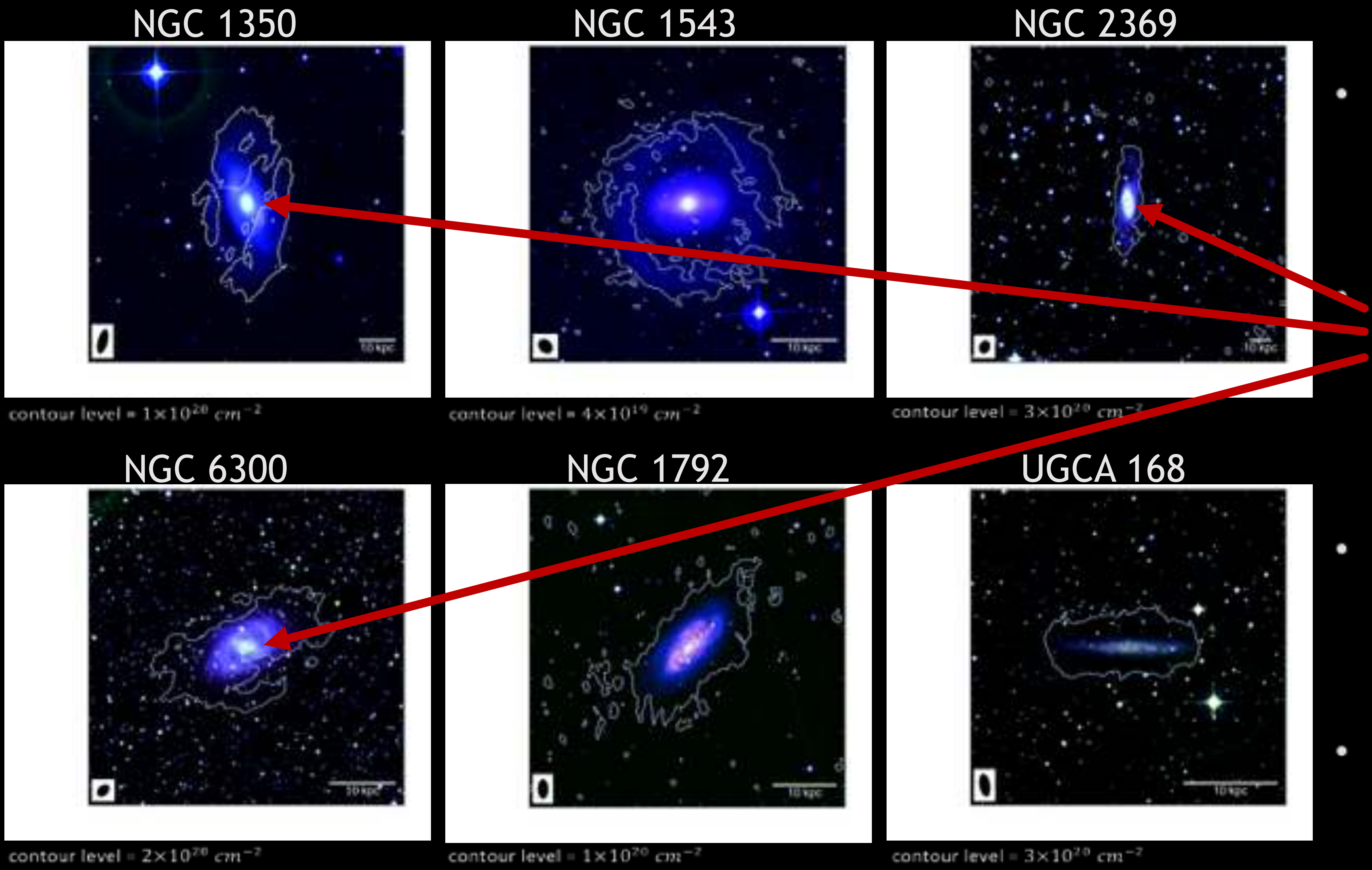
Murugeshan et al. *(in prep)*

- 6 HI-deficient galaxies
- Low-density environments
- $D_{25} > 210''$
- Observed with the Australia Telescope Compact Array (ATCA)
- Max. Baseline ~ 1.5 km
- Resolution ~ $30''$

ATCA

Credit: CSIRO

The sample



NGC 1350

contour level = $1\times10^{20}\ cm^{-2}$

NGC 1543

contour level = $4\times10^{19}\ cm^{-2}$

NGC 2369

contour level = $3\times10^{20}\ cm^{-2}$

NGC 6300

contour level = $2\times10^{20}\ cm^{-2}$

NGC 1792

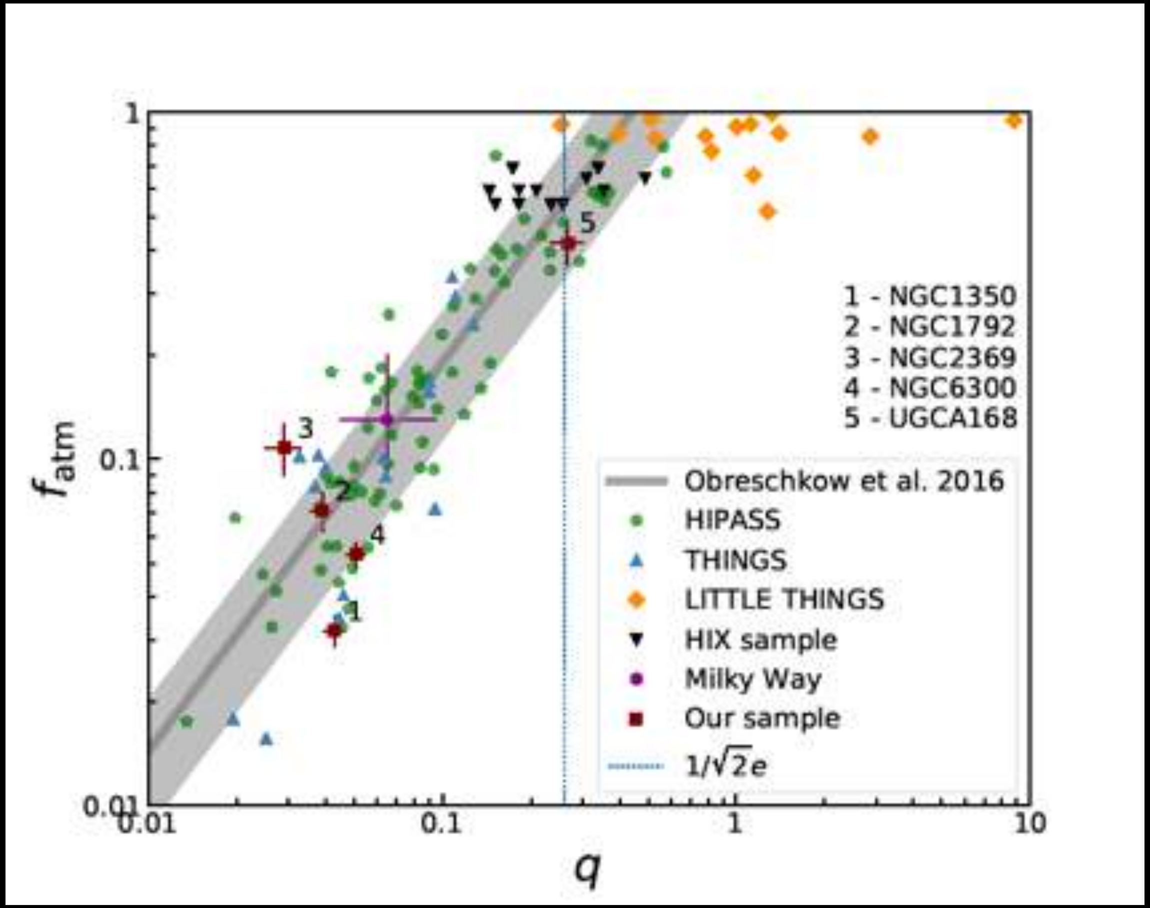
contour level = $1\times10^{20}\ cm^{-2}$

UGCA 168

contour level = $3\times10^{20}\ cm^{-2}$

- No evidence of ram-pressure or tidal stripping
- Central HI "hole" like features observed. Such holes predicted by analytic models in O16 and related to q
- 3D tilted ring kinematic fitting to data - extract i, PA, V_{rot} & Σ_{HI}
- Stellar mass calculated using 2MASS K_S – band images

Results: The $f_{atm} - q$ relation



Murugeshan et al. (*in prep*)

$f_{atm} = \frac{1.35 M_{HI}}{M}$, atomic gas mass fraction

$q = \frac{j\sigma}{GM}$, global stability parameter

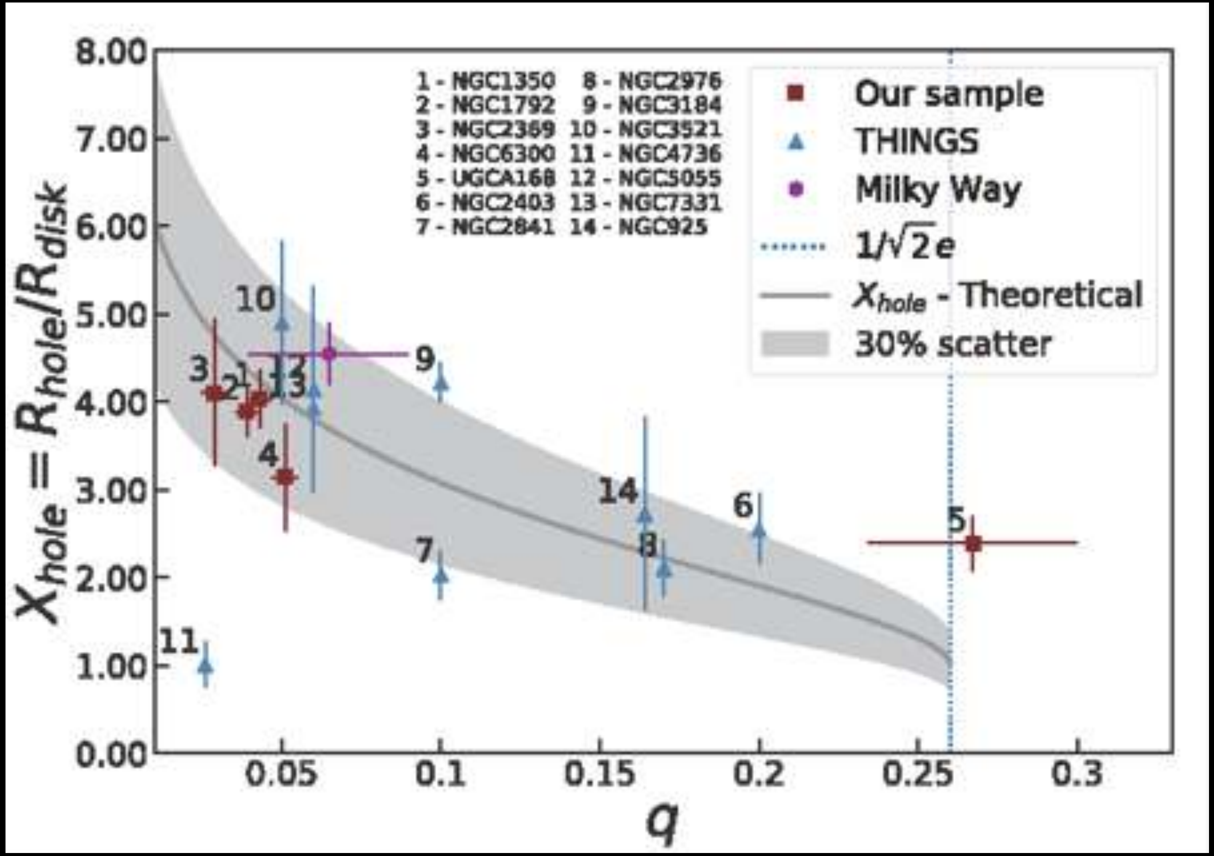
M_{HI} - HI mass; M - total baryonic mass

j - total specific baryonic AM

σ - dispersion velocity of the WNM

- The HI-deficient galaxies consistently follow the relation
- AM regulates f_{atm} in HI-deficient spirals

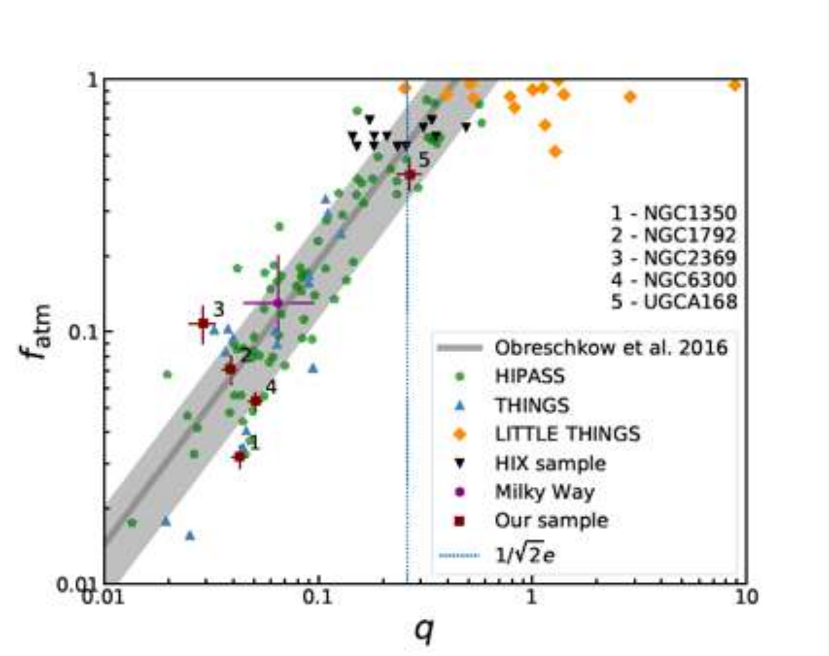
Results: The $X_{hole} - q$ relation

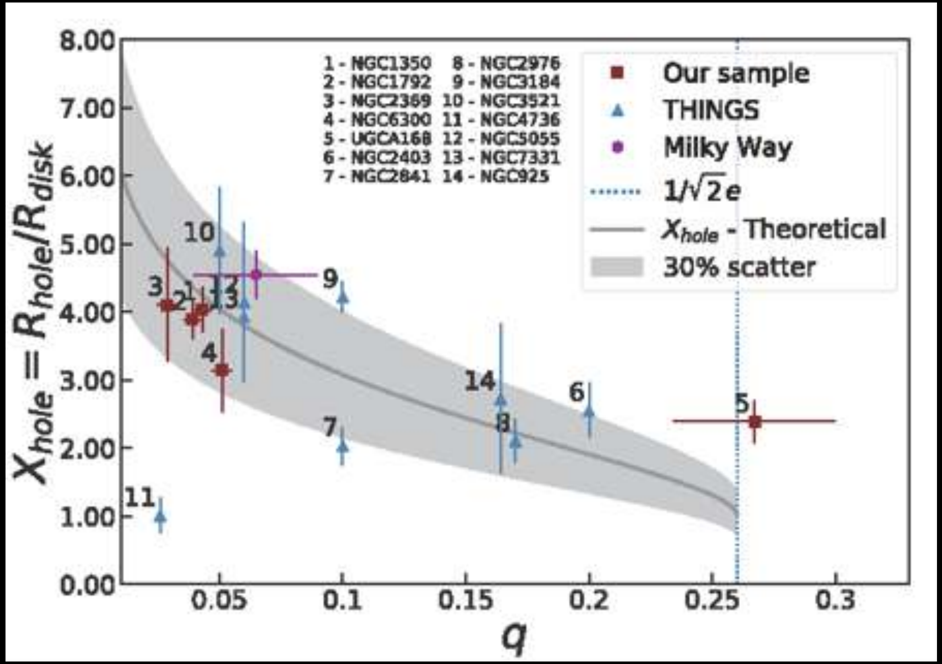


Murugeshan et al. (*in prep*)

- First predicted by O16
- HI hole - regions dominated by non-atomic material
- R_{hole} ~ radius at which HI begins to dominate over stellar+molecular material
- Low q → disc instabilities → increased star formation in central regions → larger hole
- Galaxies follow the model to within 30% scatter about the model

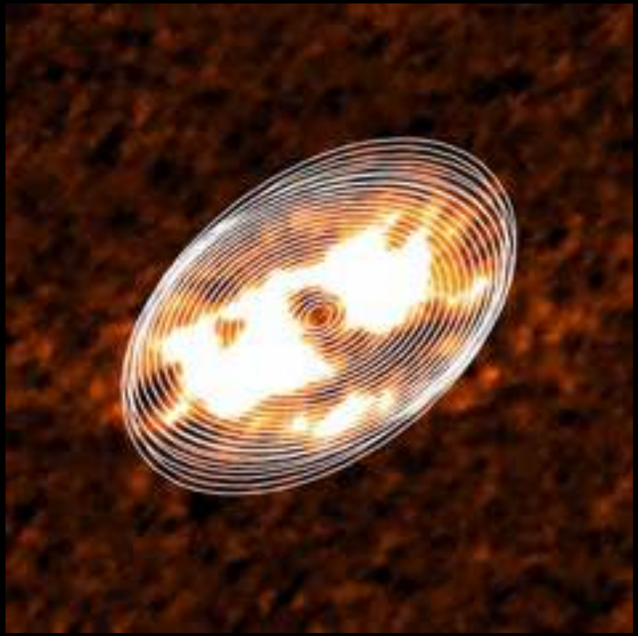
Conclusions





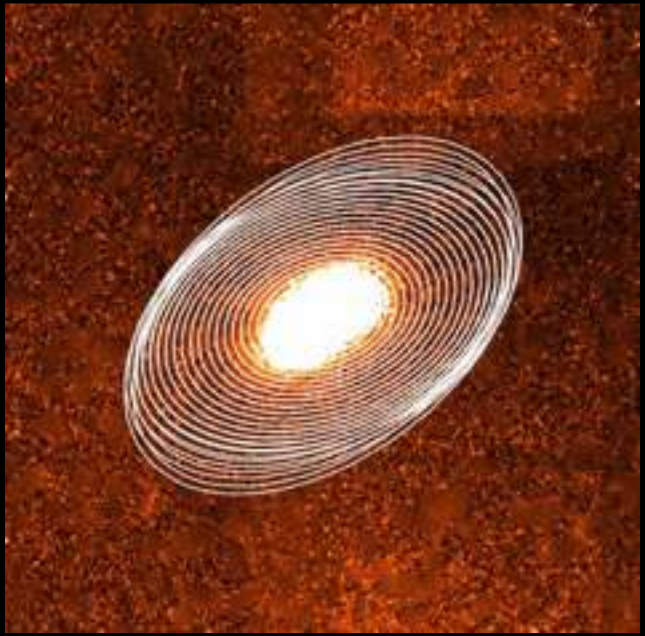
- Identified 6 HI-deficient galaxies from low density environments
- Galaxies consistently follow the $f_{atm} - q$ relation
- AM plays an important role in regulating atomic gas in disc galaxies
- Heuristic method to measure central HI hole sizes - galaxies follow $X_{hole} - q$ relation, as predicted by Obreschkow et al. (2016)
- AM, a fundamental parameter in influencing galaxy evolution

3D tilted ring fitting & calculating *j*



HI intensity map

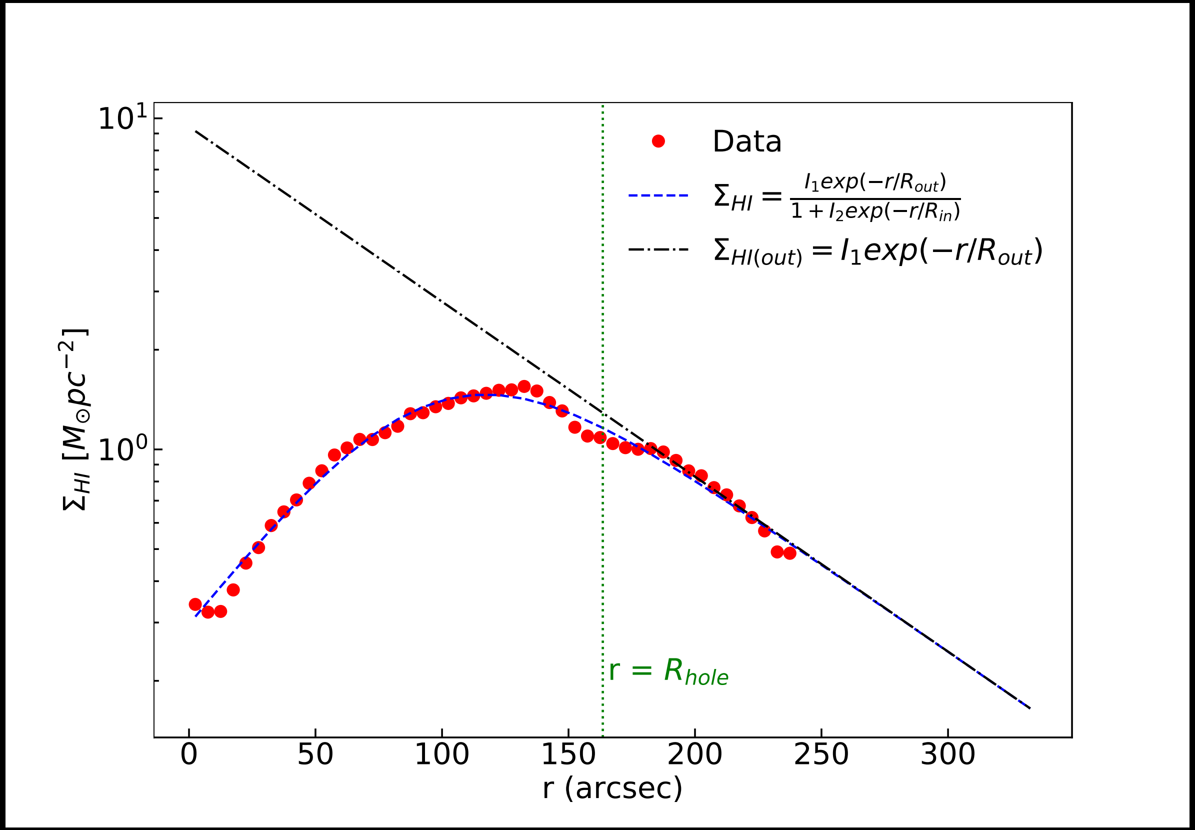
+



2MASS K_s - band image

$$\Rightarrow \quad j = \frac{\sum(1.35M_{HI} + M_\star)V_r r}{\sum(1.35M_{HI} + M_\star)}$$

HI hole size estimation



Murugeshan et al. *(in prep)*

Analytic models for X_{hole} in O16

Obreschkow et al. (2016)

Environment local density - Σ_5

Murugeshan et al. (*in prep)*