The angular momentum of hot coronae around spiral galaxies

Gabriele Pezzulli (Oxford)

Filippo Fraternali (Bologna, Groningen)
James Binney (Oxford)

Cozumel, 15 April 2016

Baryon “budget” of spiral galaxies

(Easily) visible matter
Stars + cold gas
~ 30% of (expected) baryons

Dutton et al. (2010)
Papastergis et al. (2012)

70 % baryons “missing”!

Maybe in hot diffuse gas?

Galactic coronae

LARGE reservoirs of HOT gas

R ~ Rvir ~ 200 kpc

T ~ Tvir ~ 10^6 K

CORONA

Fuel for galaxy growth!

Gradual accretion of metal-poor gas:
As needed by galaxy evolution!

Cfr. Mary Putman's talk!

THEORY:

Relics of galaxy formation

Fukugita & Peebles (2006)

OBSERVATIONS

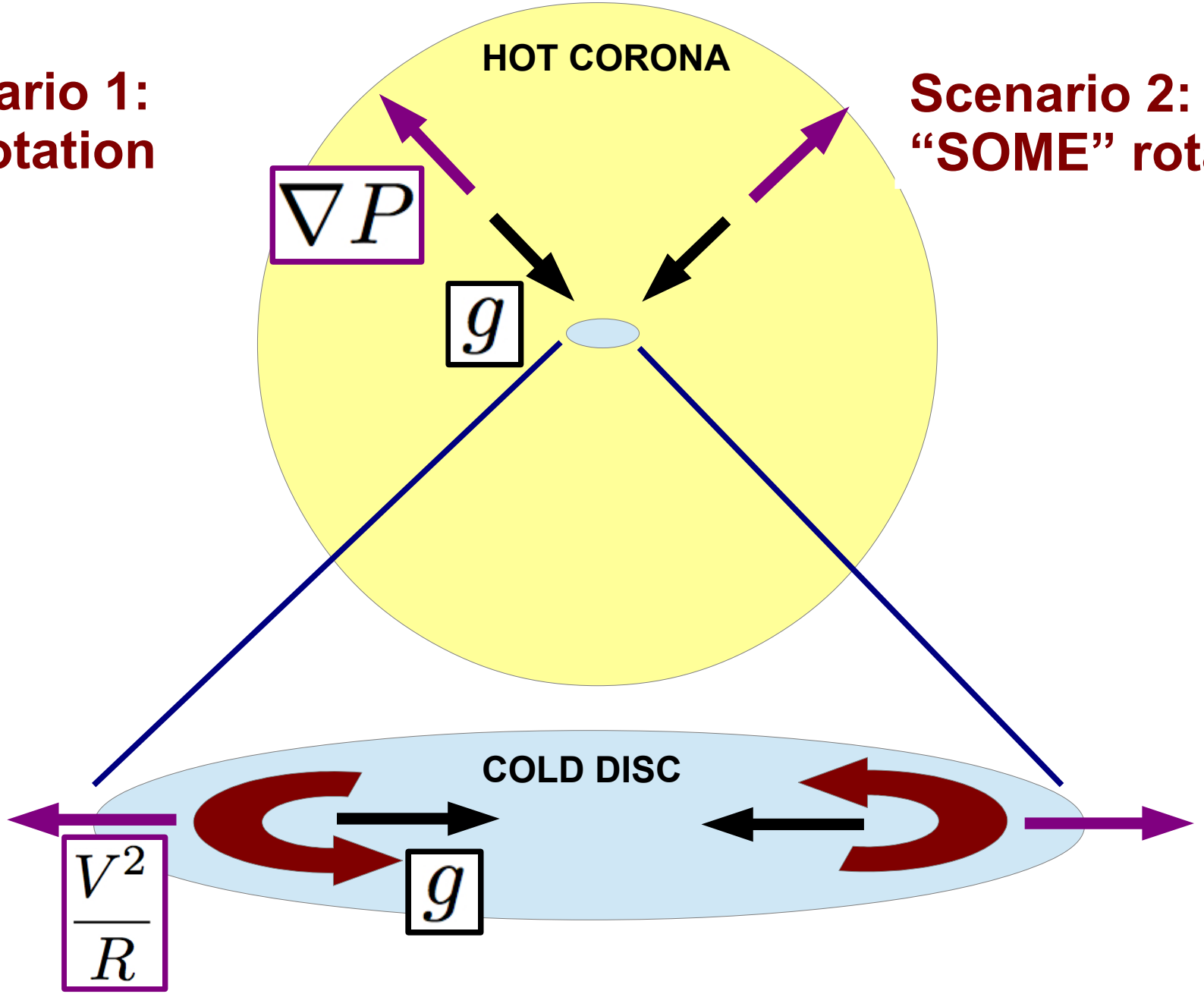
Detected X-ray emission!

Anderson & Bregman (2011)
Bogdan et al. (2013)

Rotation of galactic coronae

Scenario 1:
NO rotation

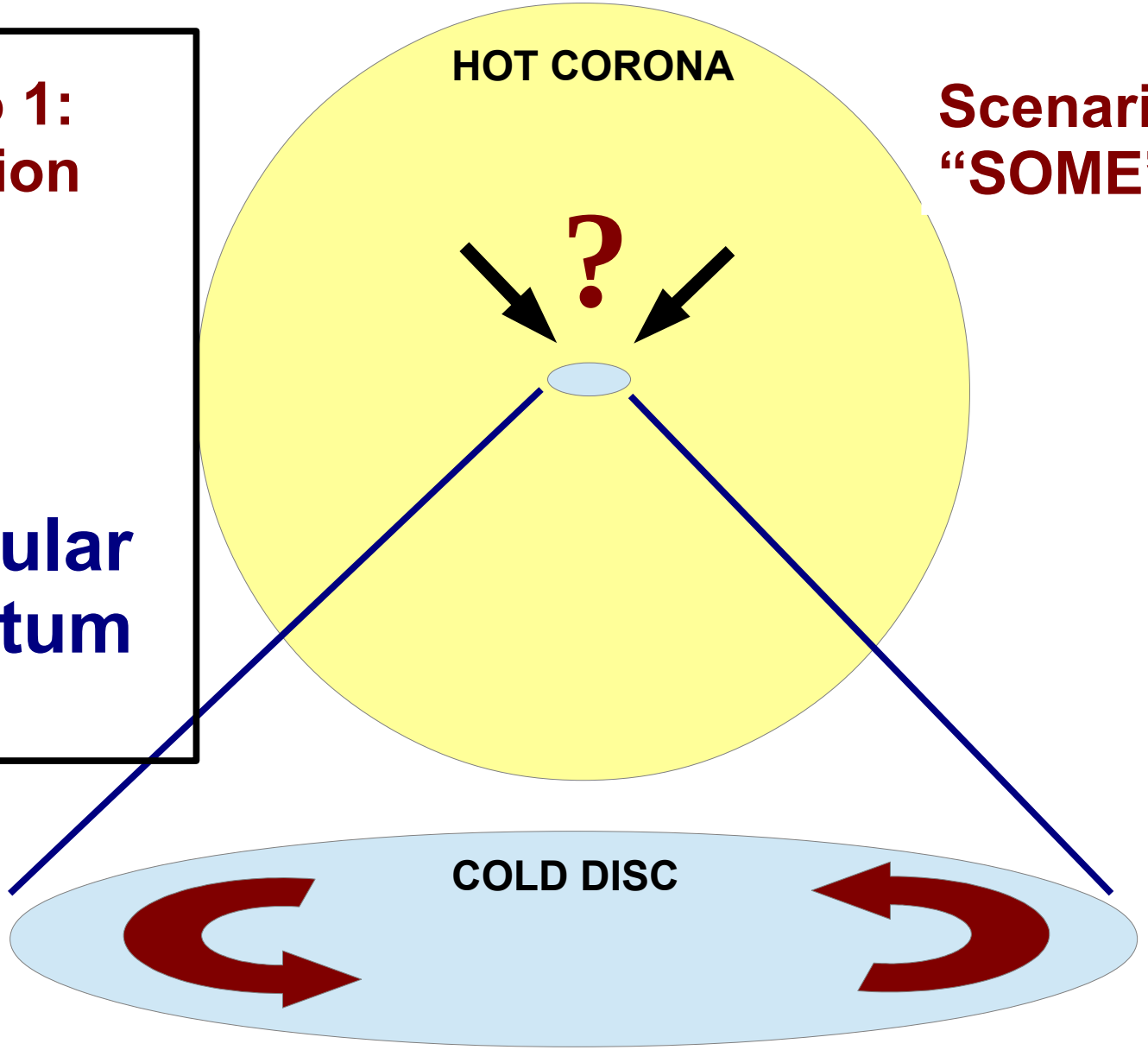
Scenario 2:
“SOME” rotation



Rotation of galactic coronae

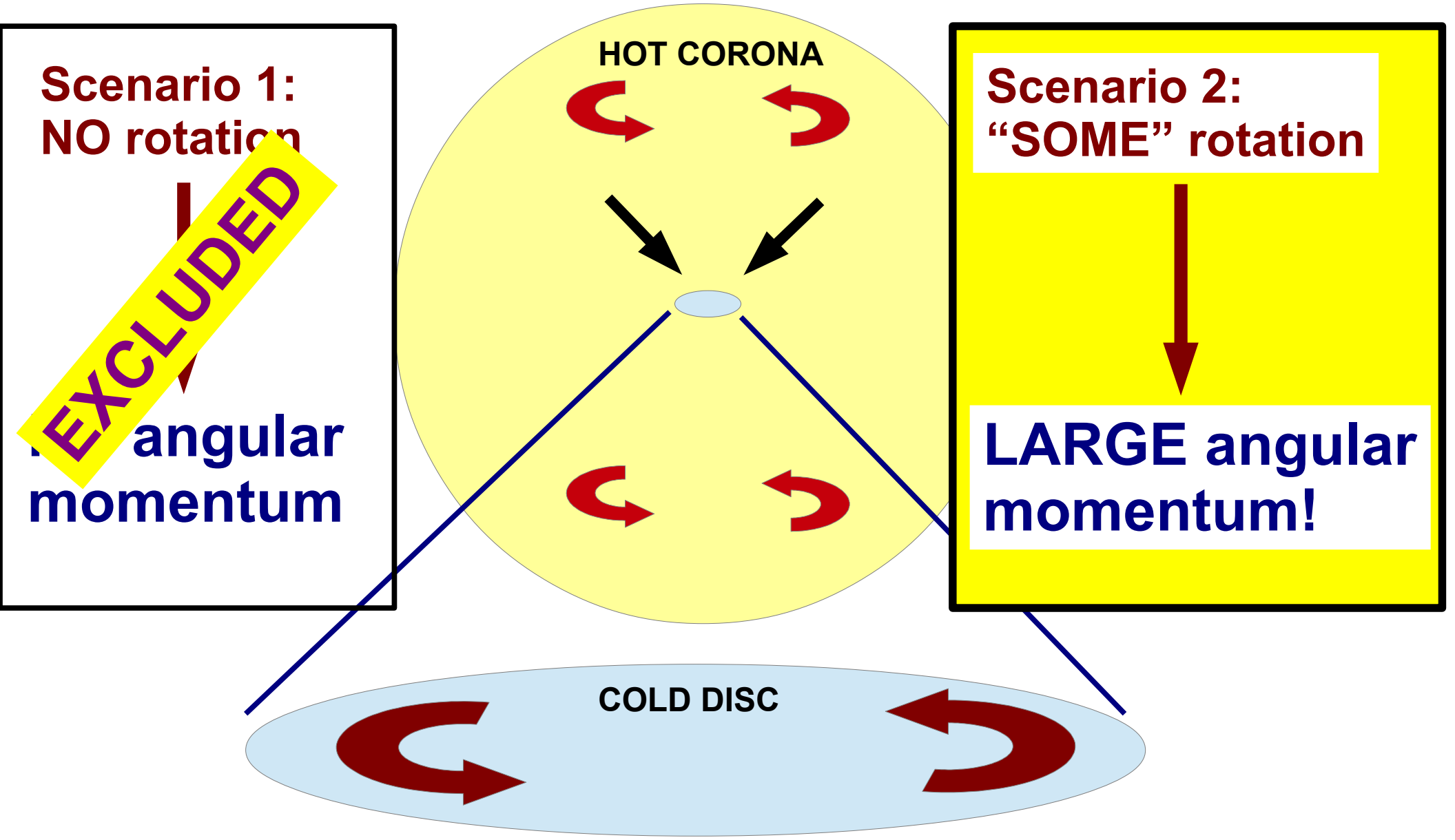
Scenario 1:
NO rotation

NO angular momentum

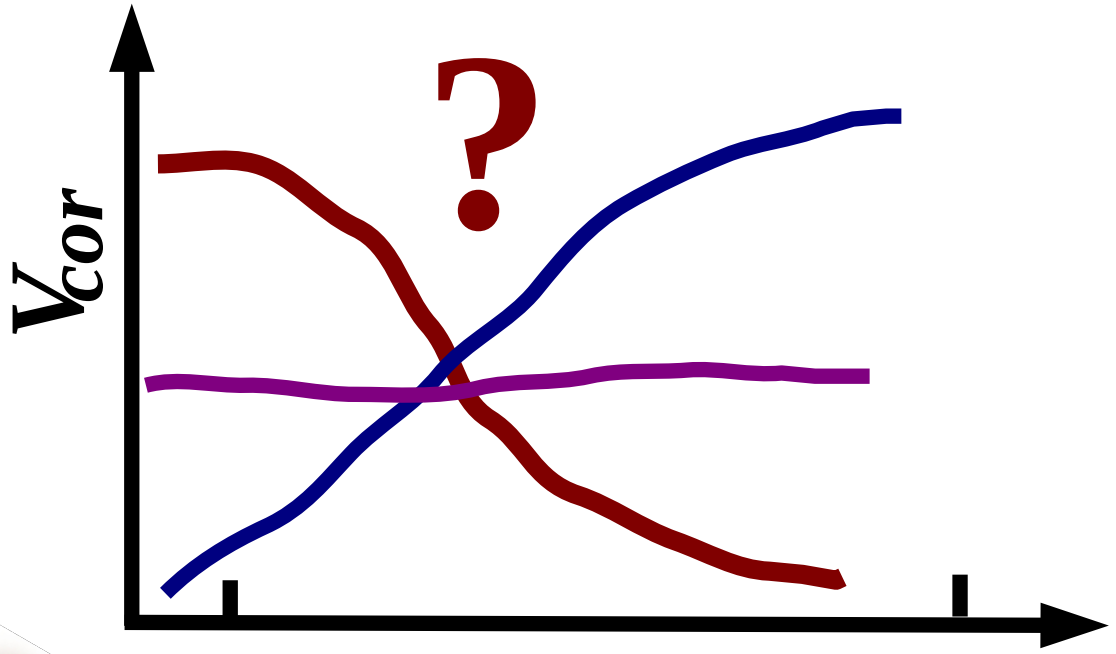


Scenario 2:
“SOME” rotation

Rotation of galactic coronae



HOW does the corona rotate?

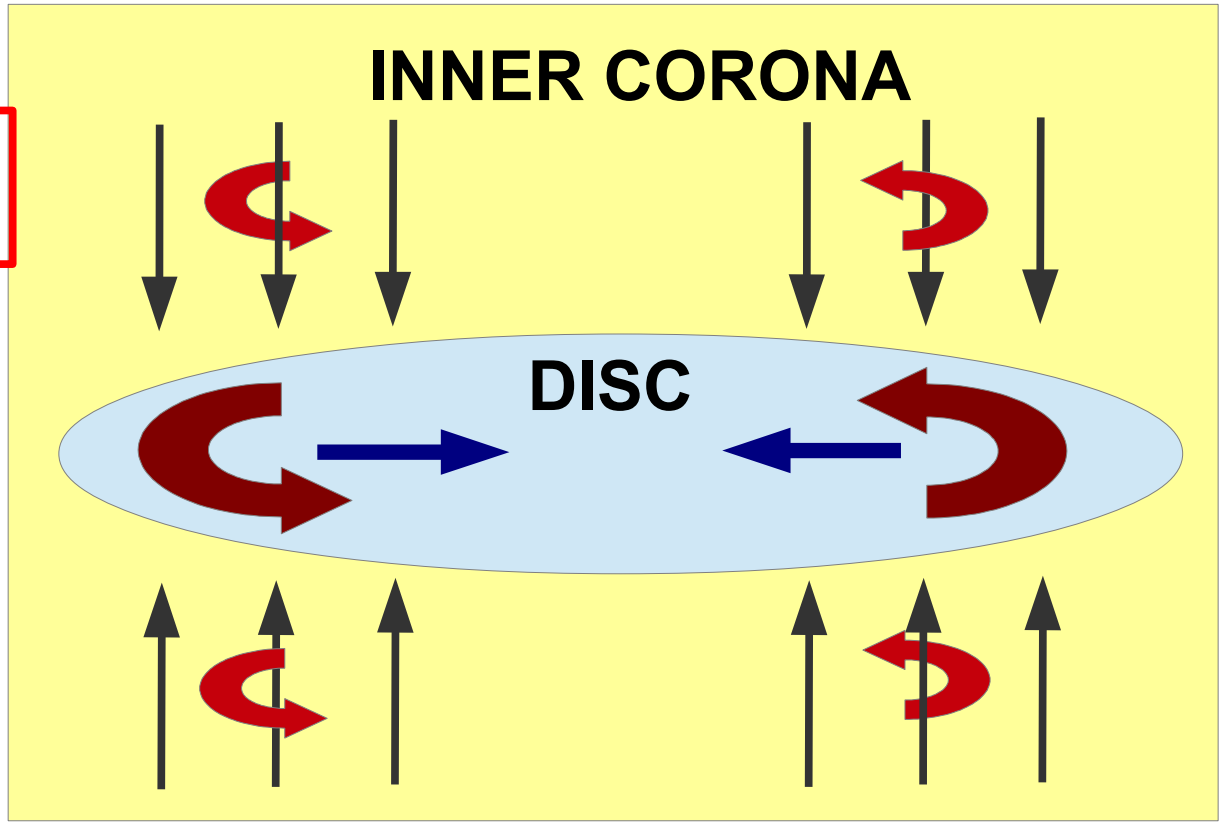


1. Small scales
Interaction with the disc
Galaxy evolution

2. Large scales
Structure formation
Cosmology

Coronal rotation and galaxy dynamics

$V_{cor} < V_{disc}$



ANGULAR MOMENTUM CONSERVATION → **RADIAL GAS FLOWS ~ 1 km/s = 1 kpc/Gyr**

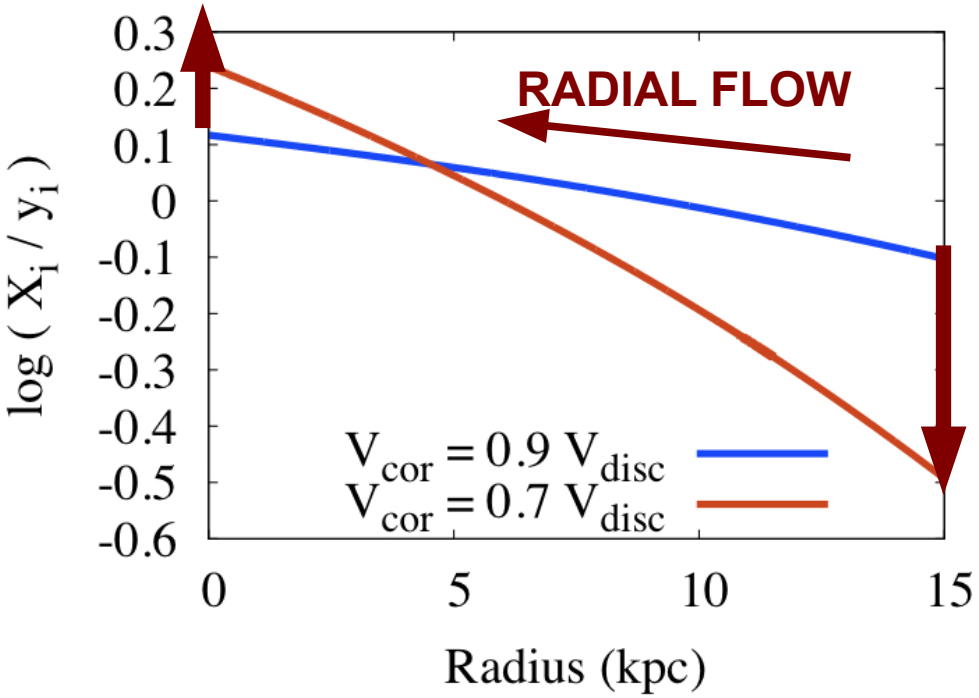
Cfr. Brad Gibson's talk this morning!

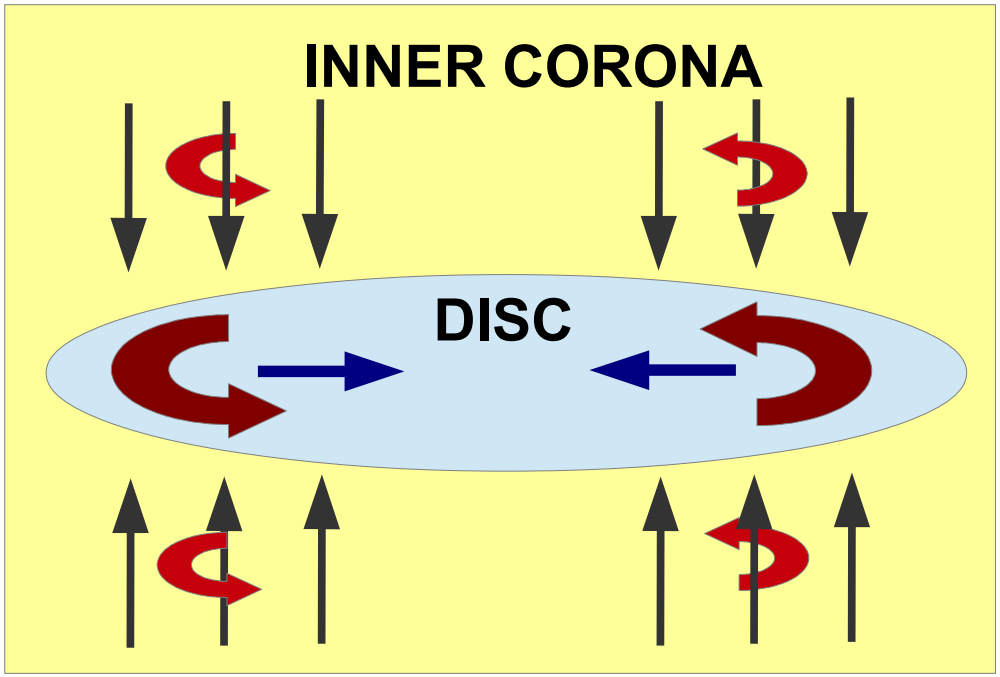
Mayor & Vigroux 1981; Pitts & Tayler 1989;
Bilitewski & Schönrich 2012; Pezzulli & Fraternali 2016

Coronal rotation and chemical evolution

Pezzulli & Fraternali (2016)

ABUNDANCE GRADIENT



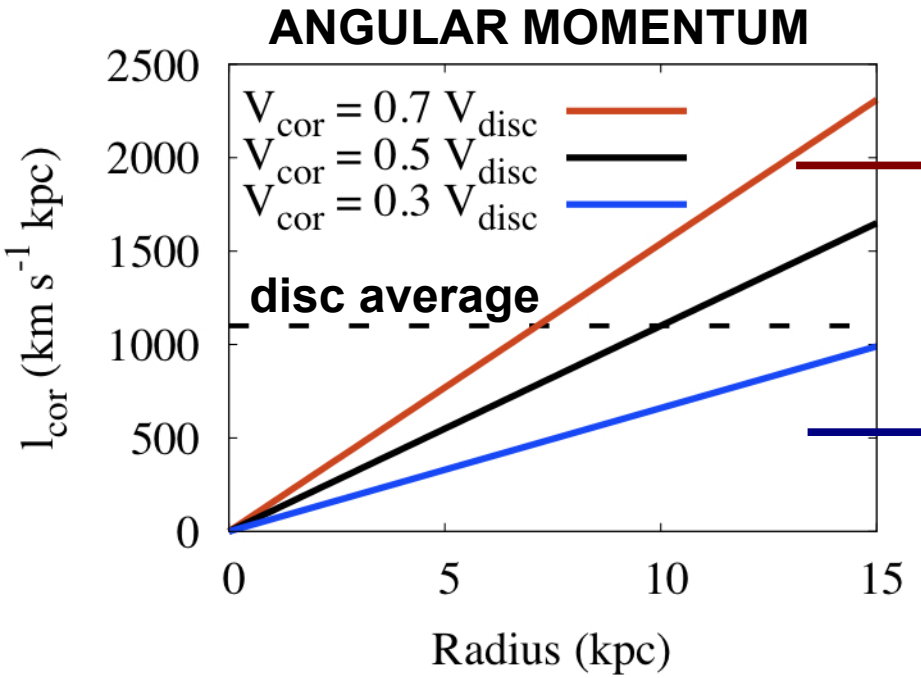


Abundance **gradients** sensitive **probes** of **rotation** of the inner corona

For the MILKY WAY:

Vcor ~ (70 – 80) % Vdisc
~ 170 km/s
close to the disc

Coronal rotation and inside-out growth



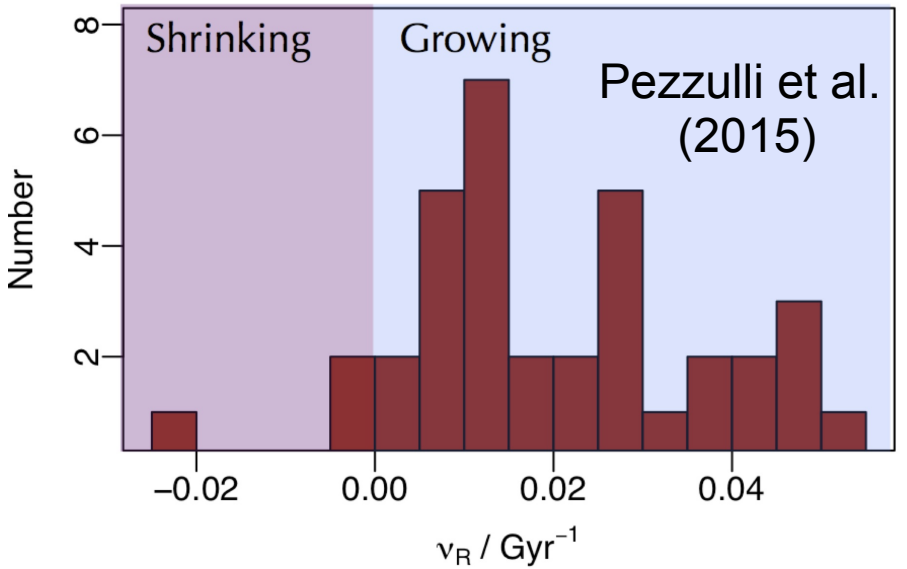
Large V
Large AM → **Inside-out growth!**

Small V
Small AM → **The disc would shrink...**

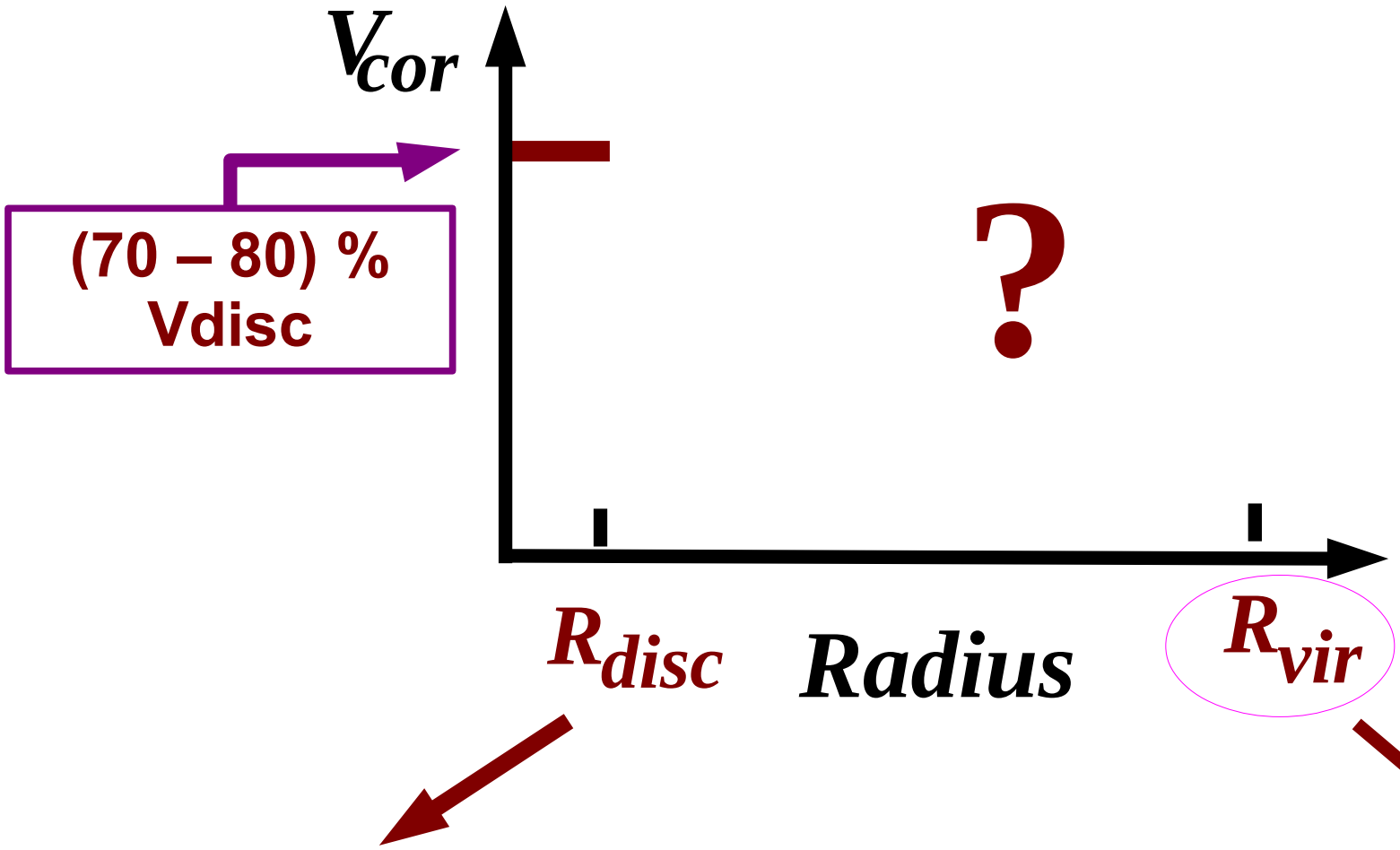
Most spirals are growing

Muñoz-Mateos et al. (2011)
Simard et al. (2005)

Must accrete angular-momentum-rich coronal gas



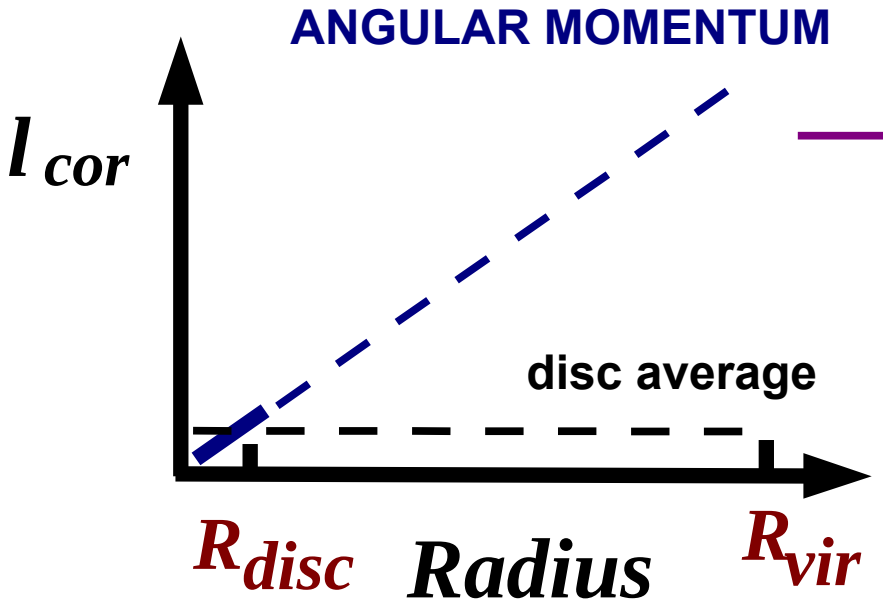
Reconstructing coronal rotation



1. Small scales
Interaction with the disc
Galaxy evolution

2. Large scales
Structure formation
Cosmology

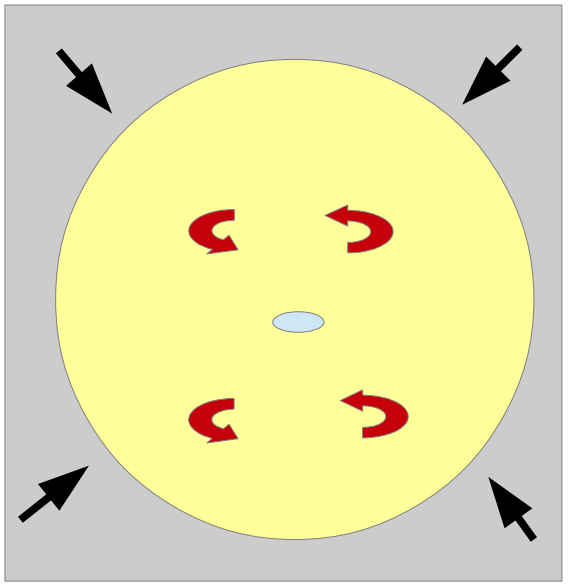
Coronal rotation and cosmology

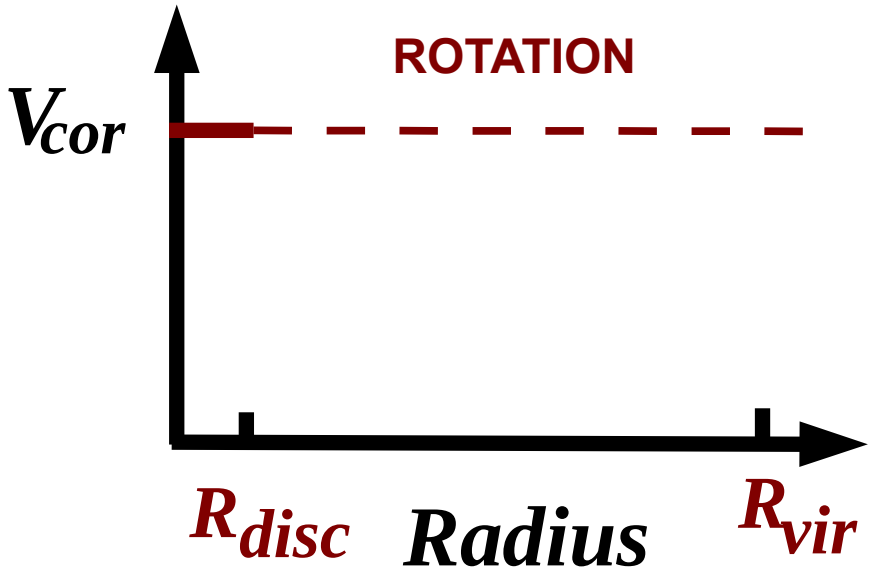


Very large angular momentum!

$\lambda \sim 0.3$

Incompatible with cosmology!



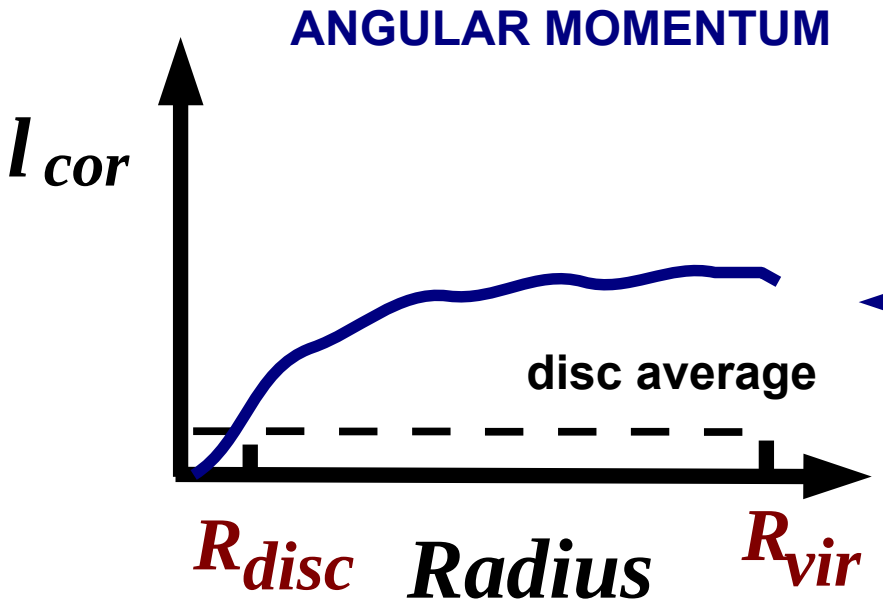


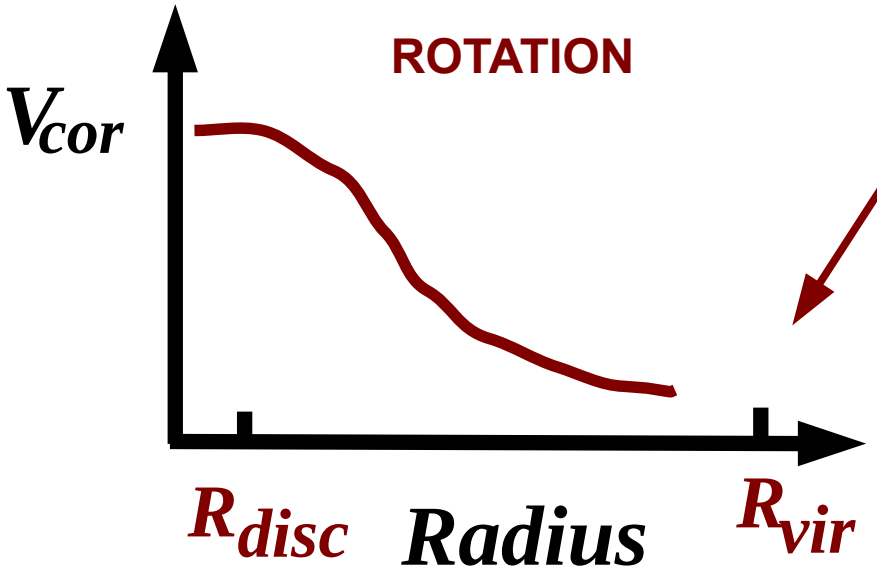
Tidal torque theory

Peebles (1969)
Porciani et al. (2002)

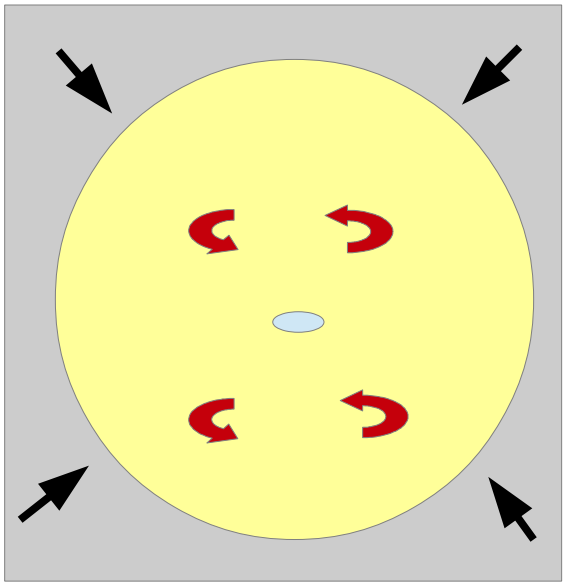
$\lambda \sim 0.04$

Coronal rotation and cosmology





To match comological constraints



Tidal torque theory

Peebles (1969)
Porciani et al. (2002)

$\lambda \sim 0.04$

Coronal rotation and cosmology

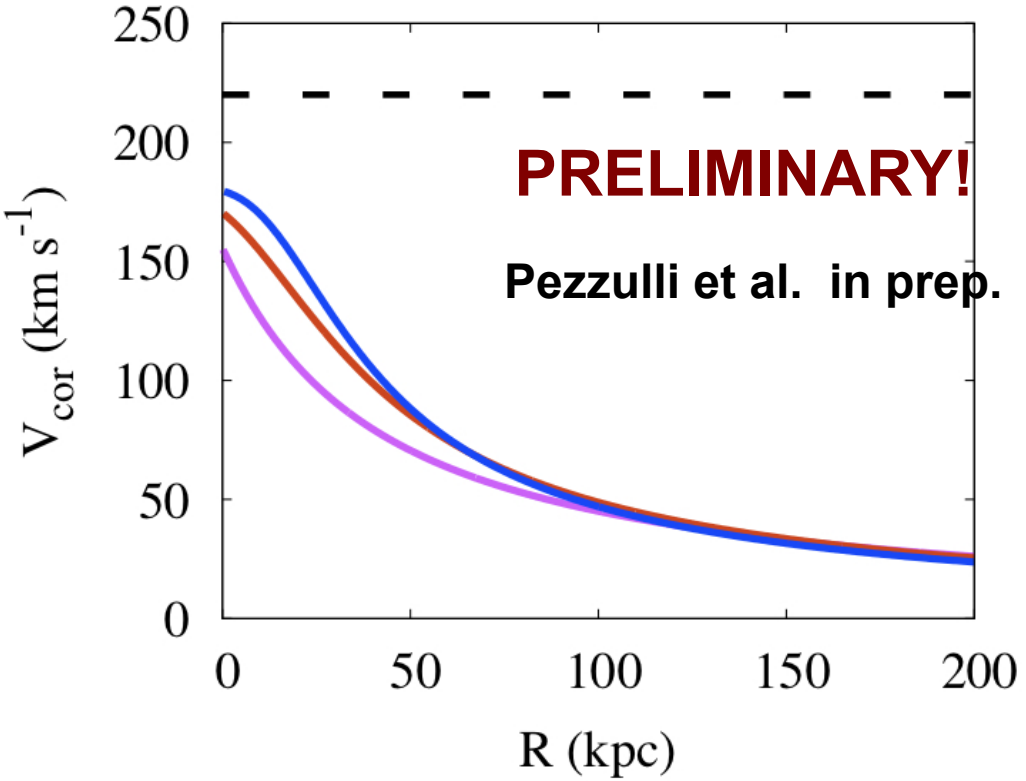
$$\mathbf{g} + \frac{1}{\rho}\nabla P + \frac{l^2}{R^3}\mathbf{e_R} = 0$$

Rotating equilibrium

$$\frac{dM}{dl} = \psi(l)$$

Angular momentum distribution

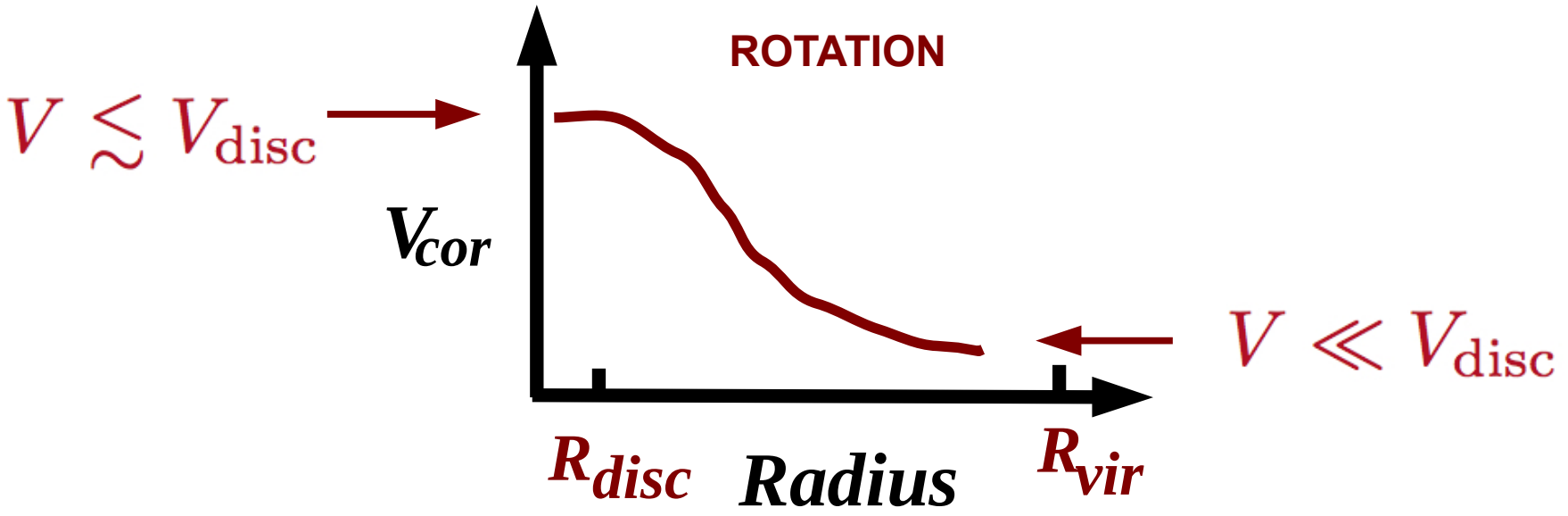
Bullock et al. (2001);
Sharma & Steinmetz (2005)



Summary

Hot coronae around spiral galaxies...

- have significant angular momentum
- feed the inside-out growth of discs
- impact abundance gradients
- should rotate like this:



~ THANK YOU! ~