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”!

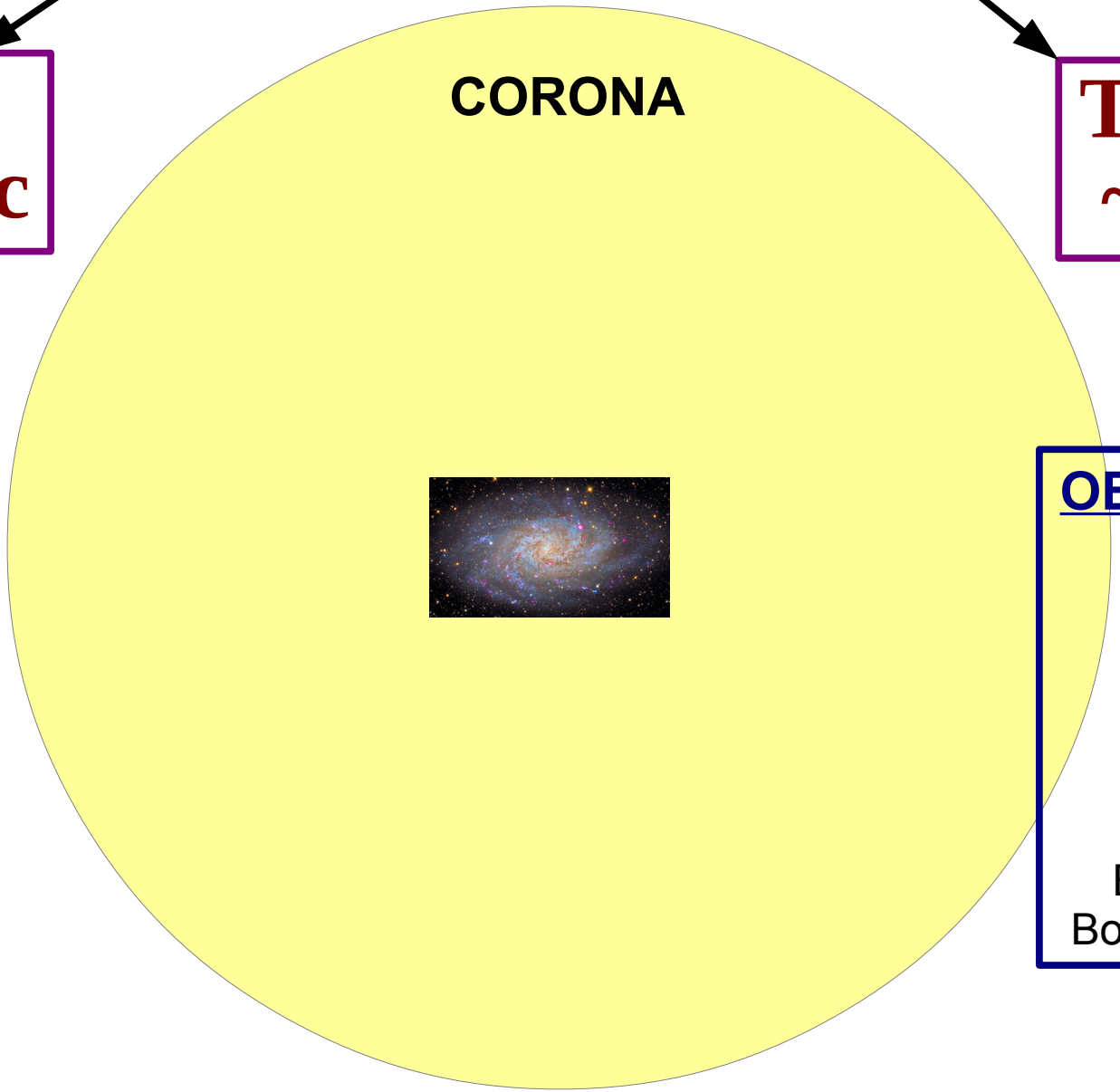
Maybe in hot diffuse gas?

Galactic coronae

LARGE reservoirs of HOT gas

R ~ Rvir ~ 200 kpc

T ~ Tvir ~ 10^6 K



THEORY:

Relics of galaxy formation

Fukugita & Peebles (2006)

OBSERVATIONS

Detected X-ray emission!

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

Galactic coronae

LARGE reservoirs of HOT gas

R ~ Rvir ~ 200 kpc

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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

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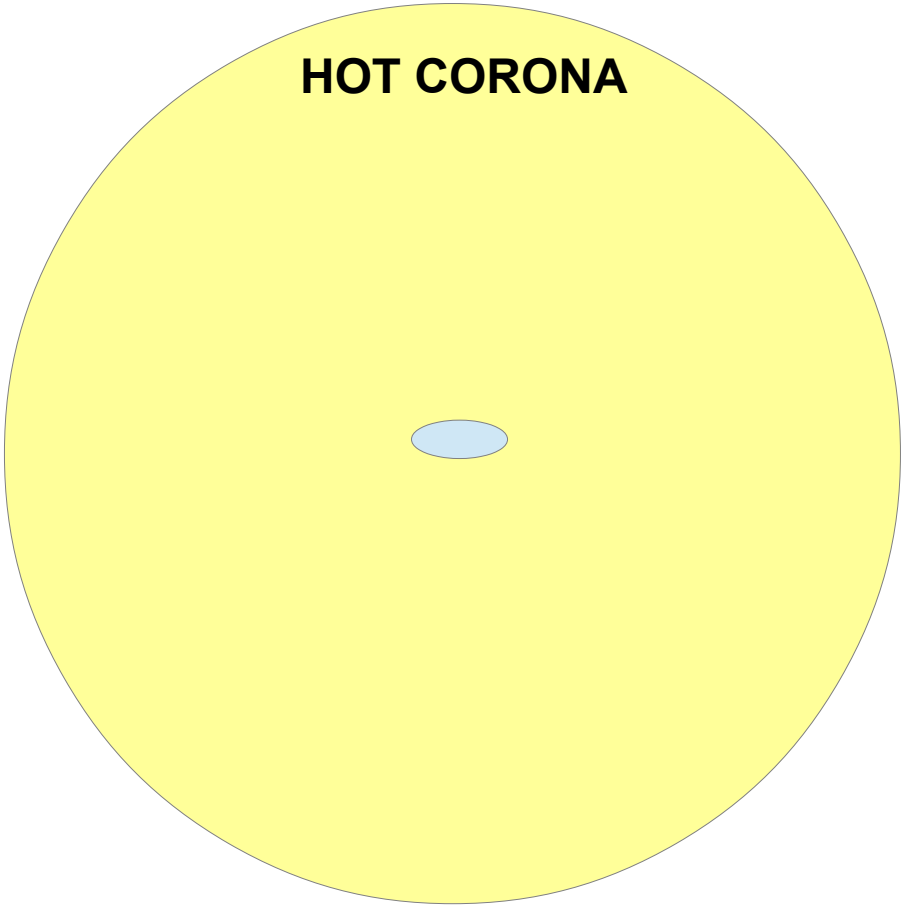
Rotation of galactic coronae



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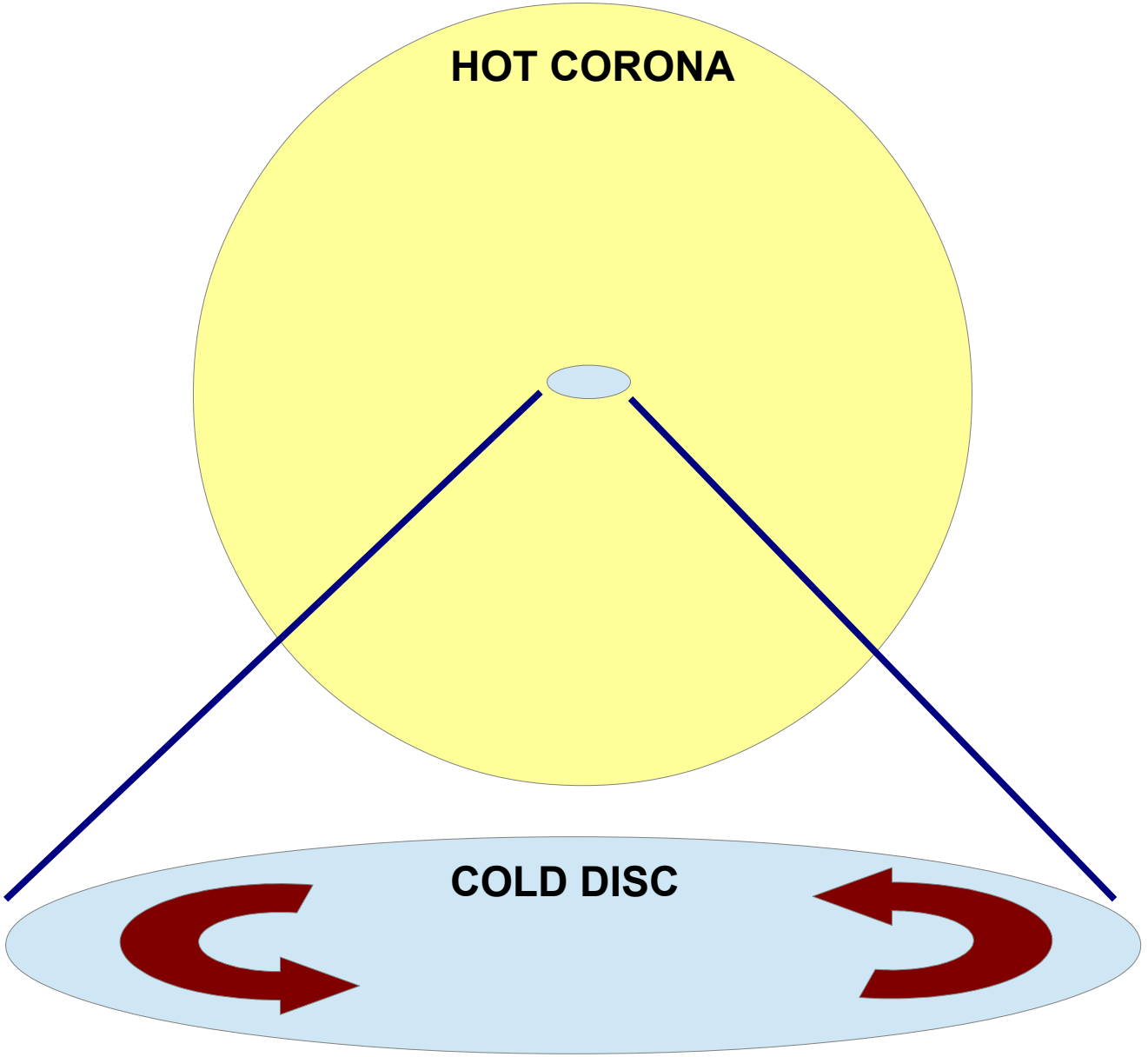

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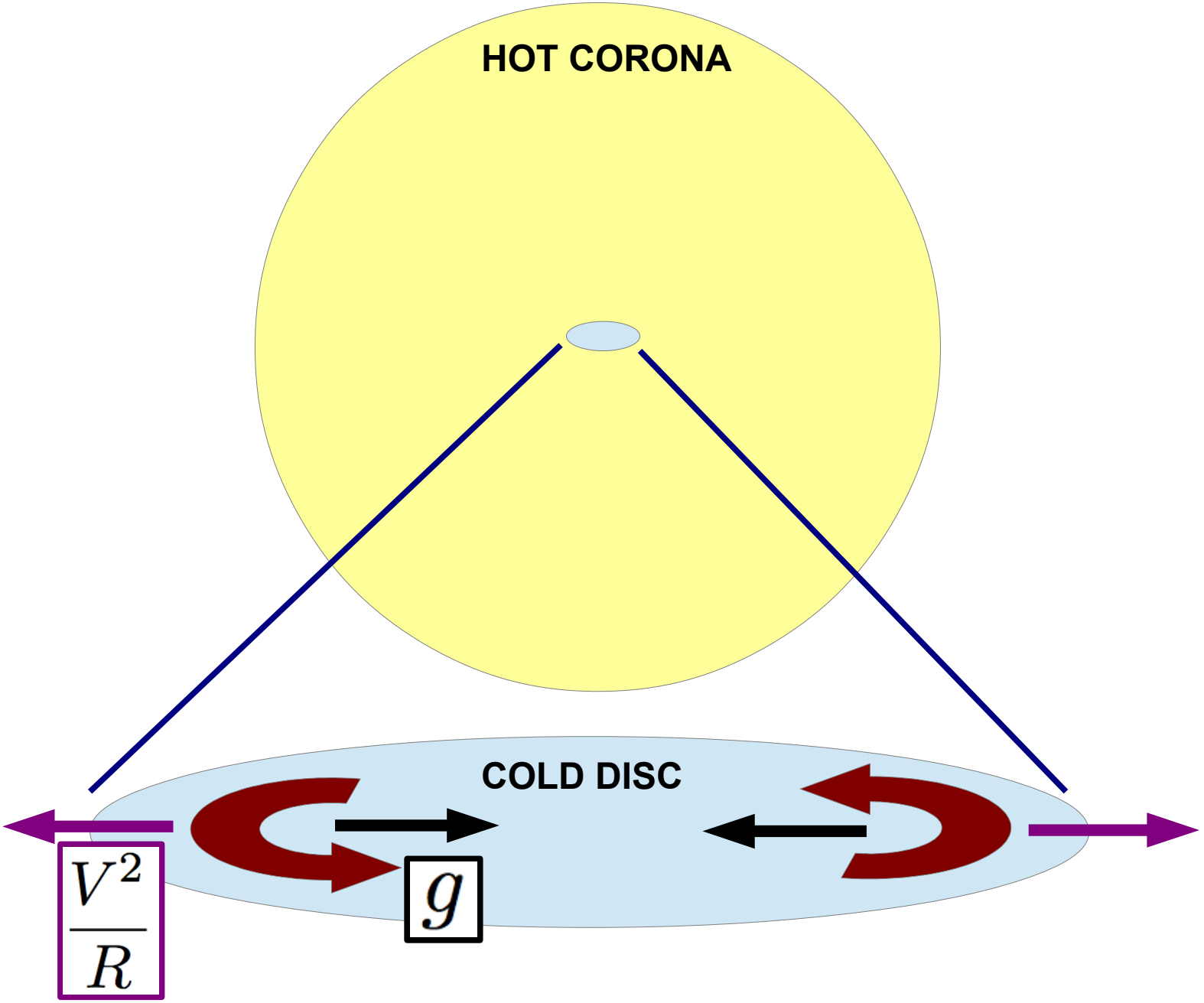

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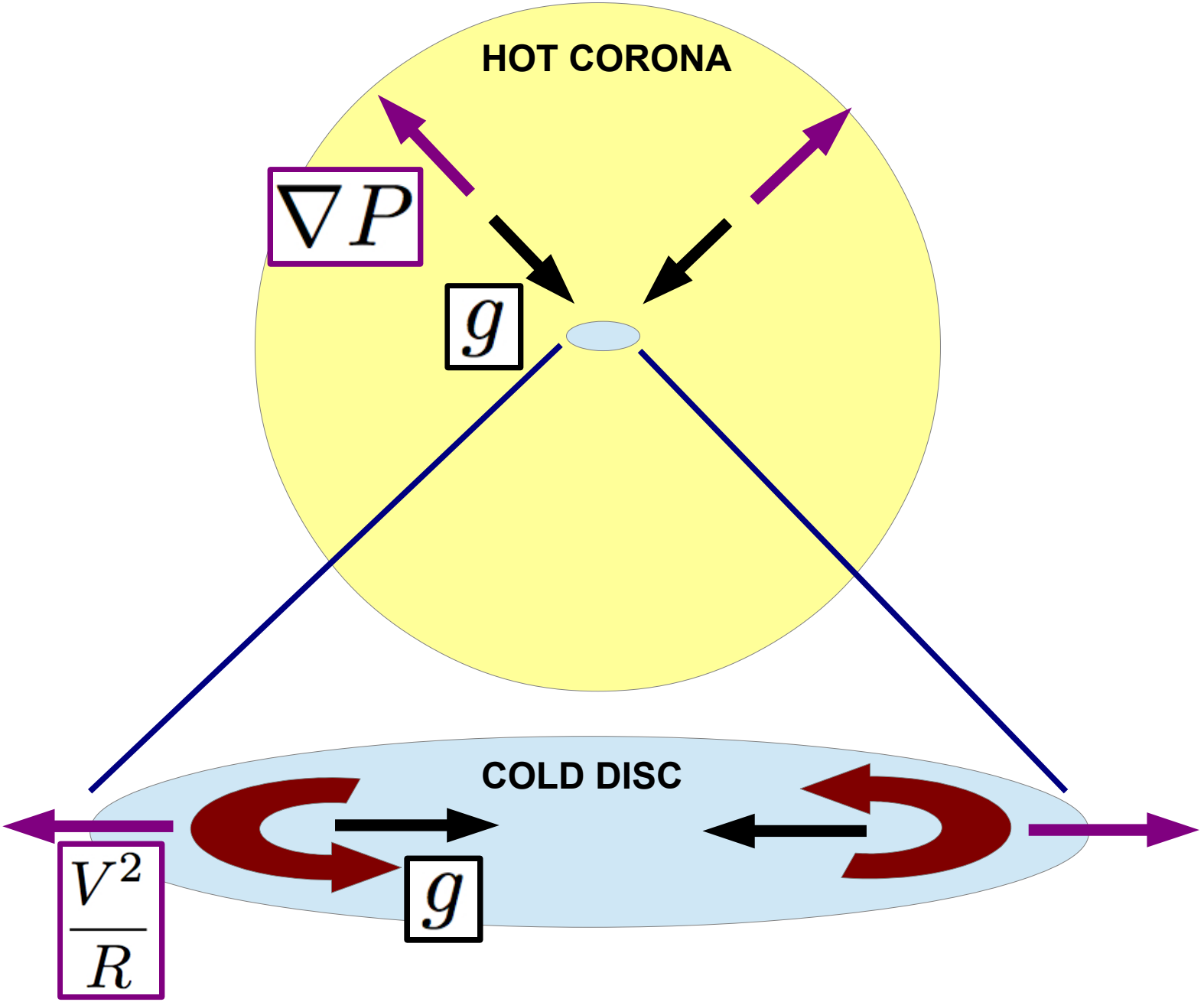
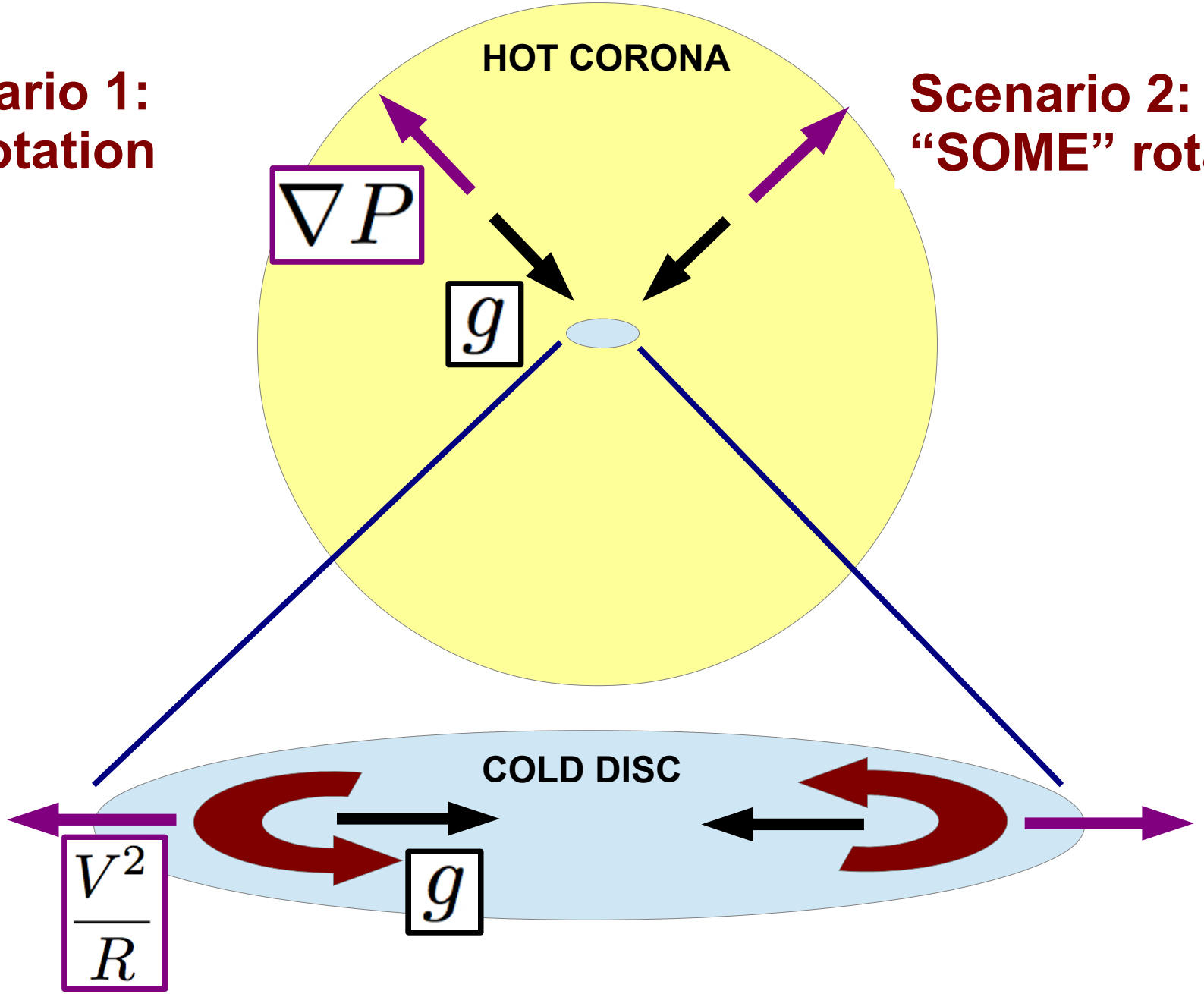


Rotation of galactic coronae

Scenario 1:
NO rotation

Scenario 2:
“SOME” rotation



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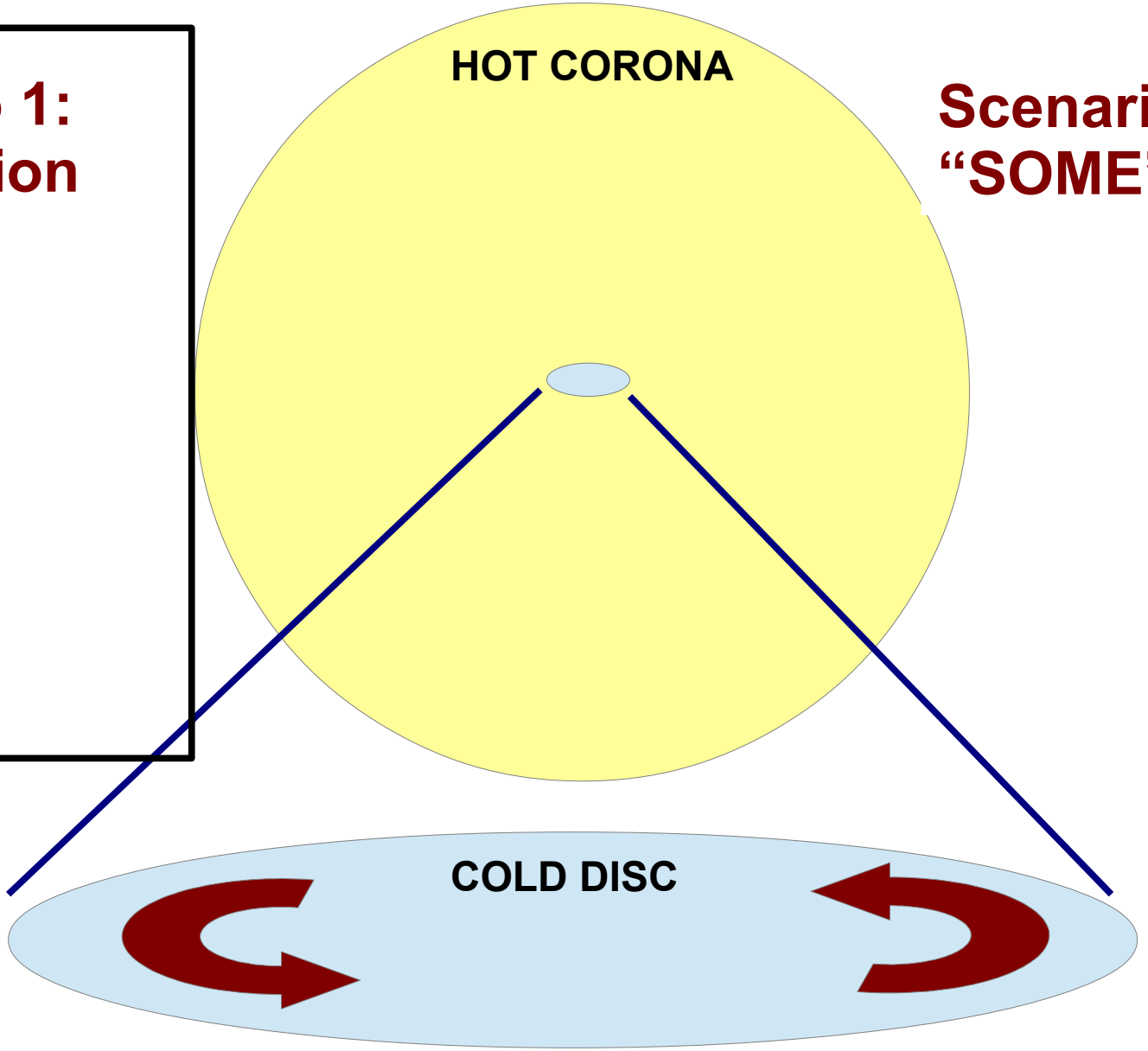

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Rotation of galactic coronae

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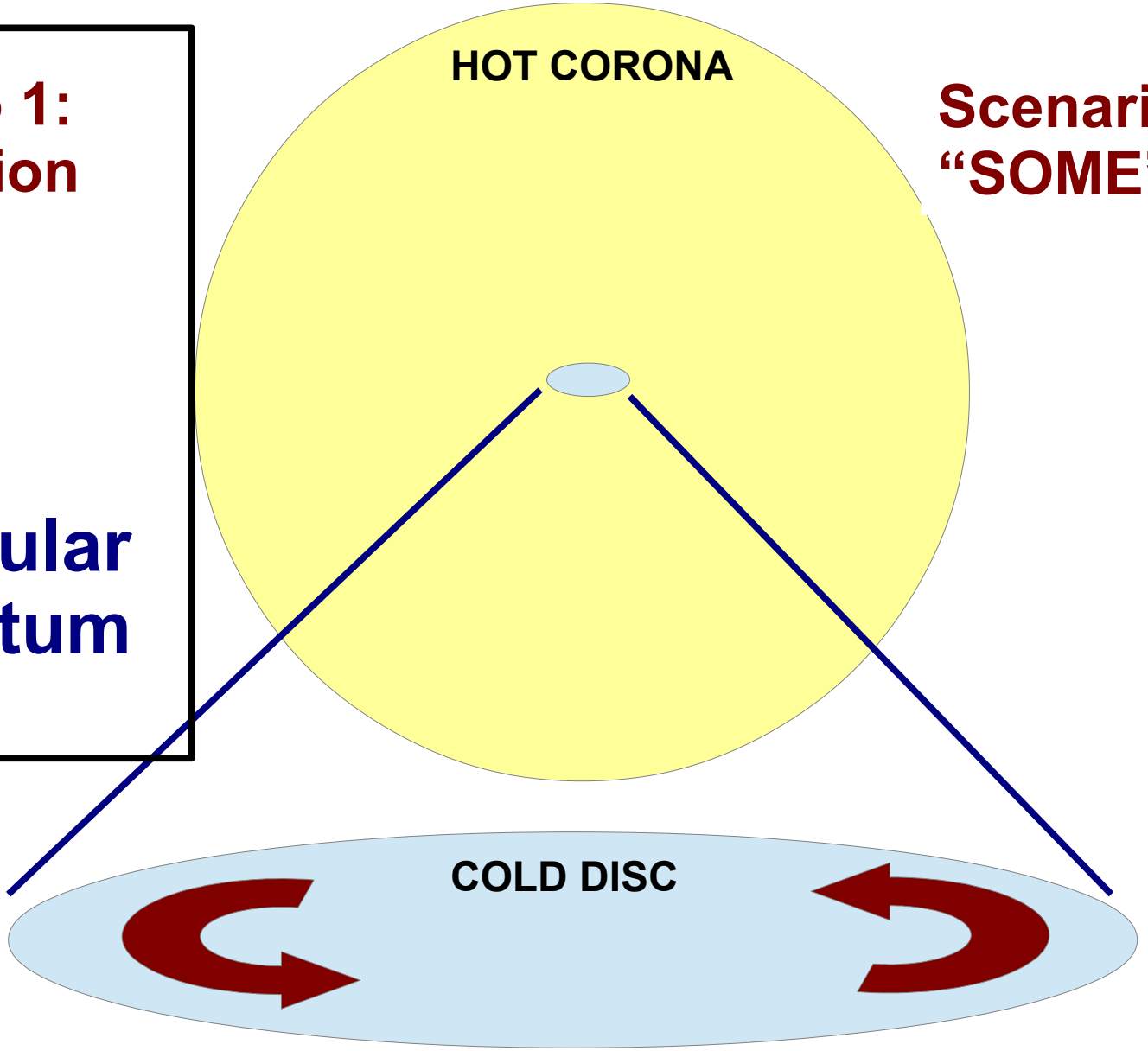

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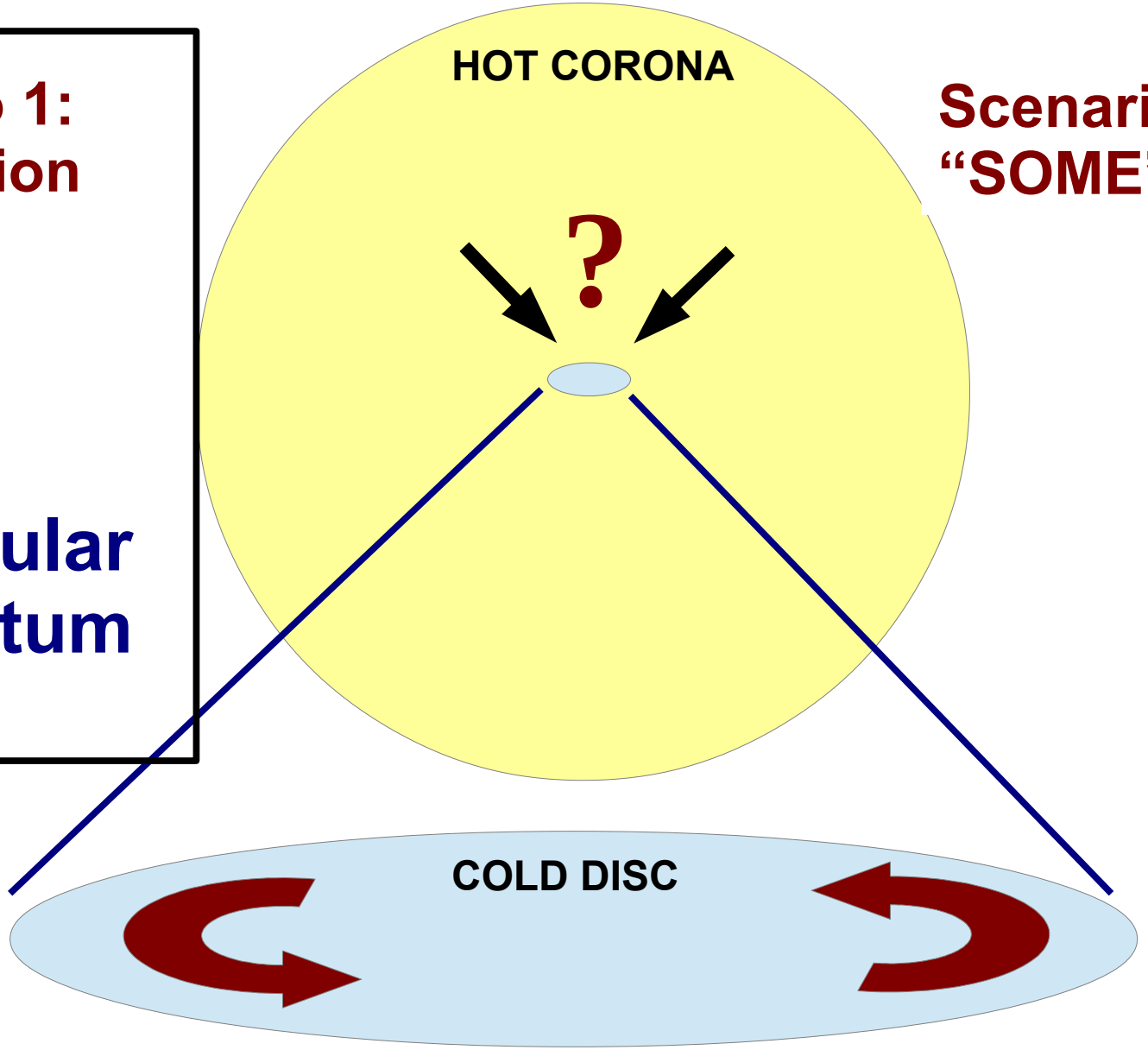

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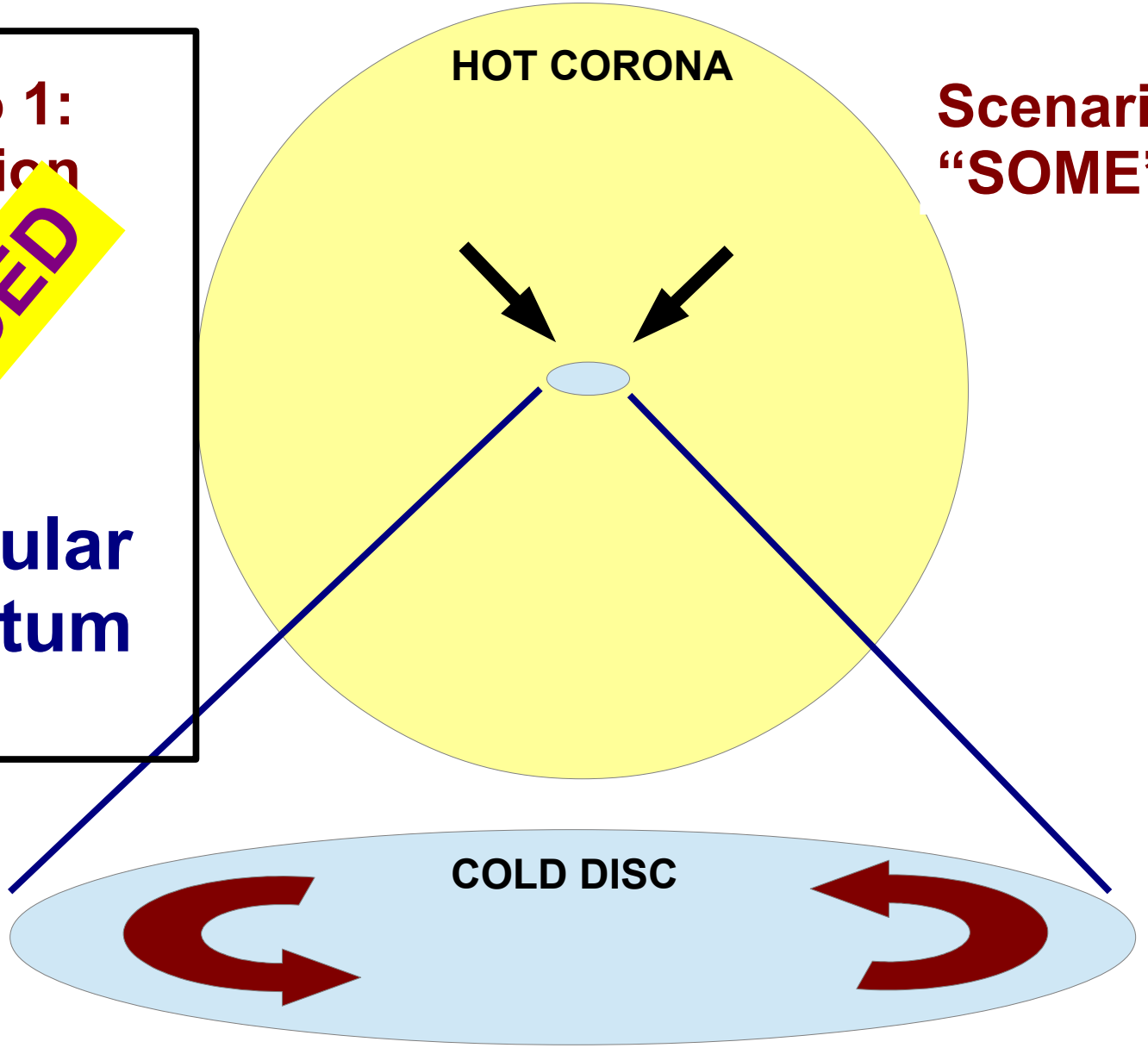
angular momentum



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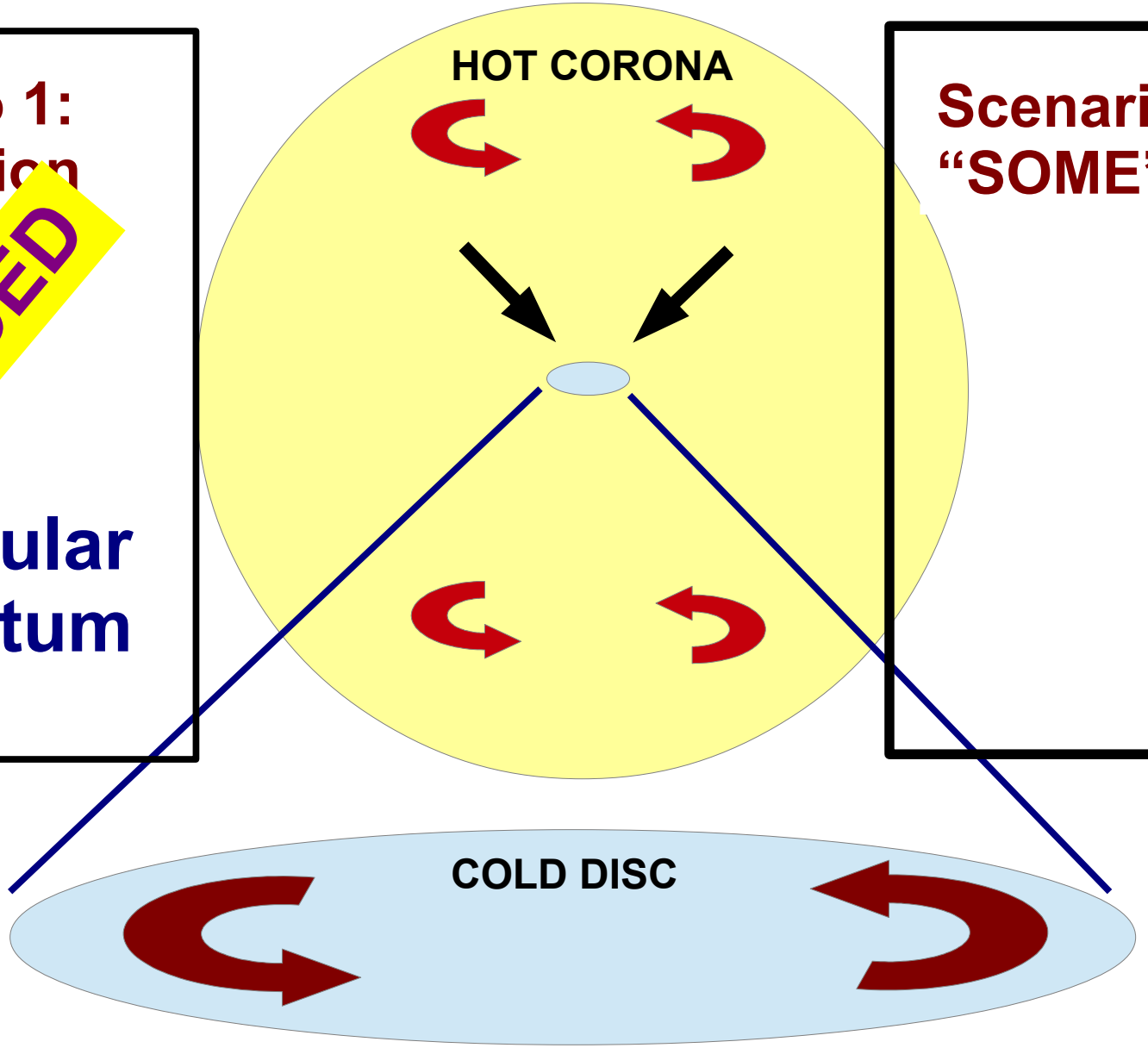

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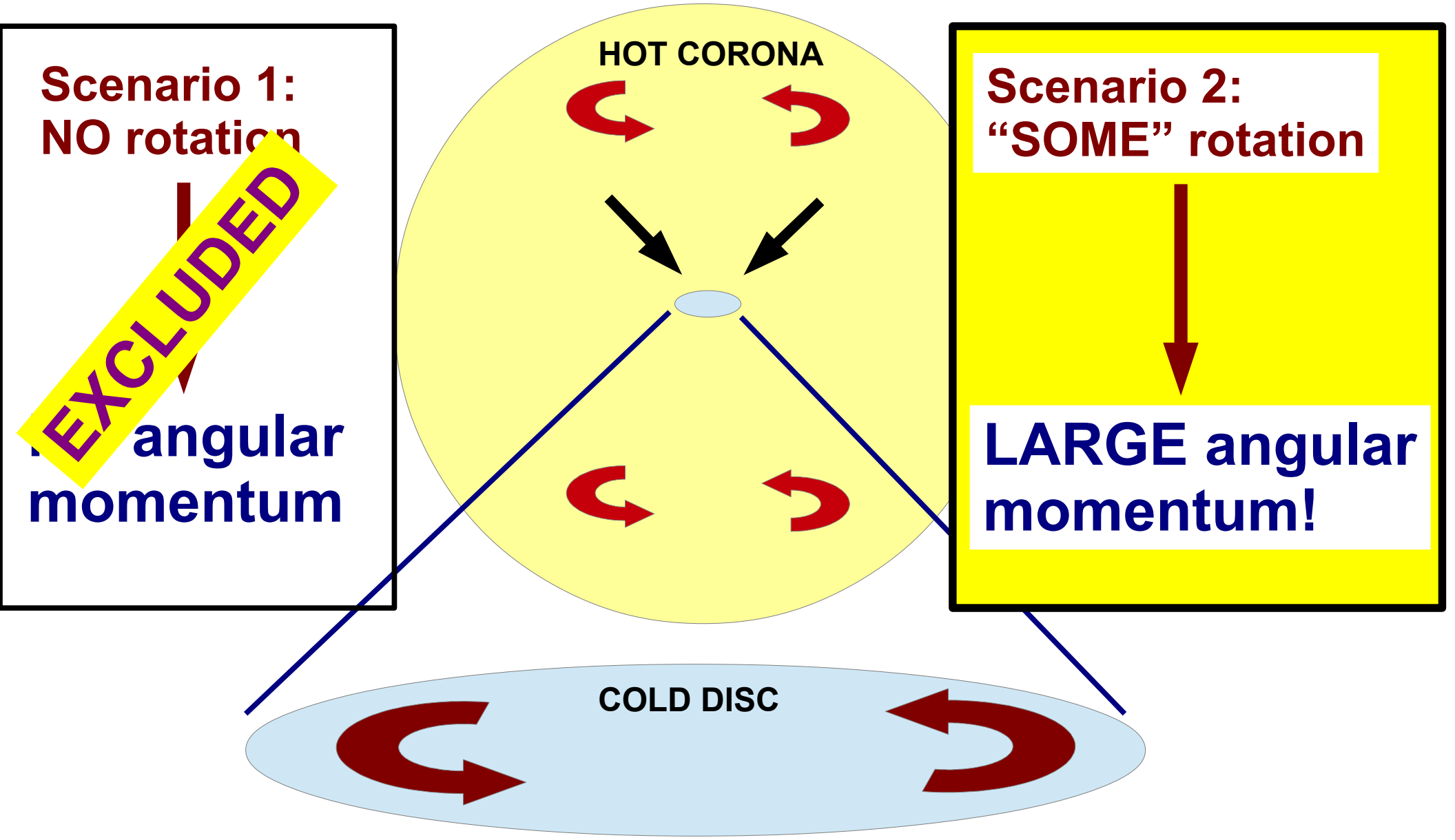

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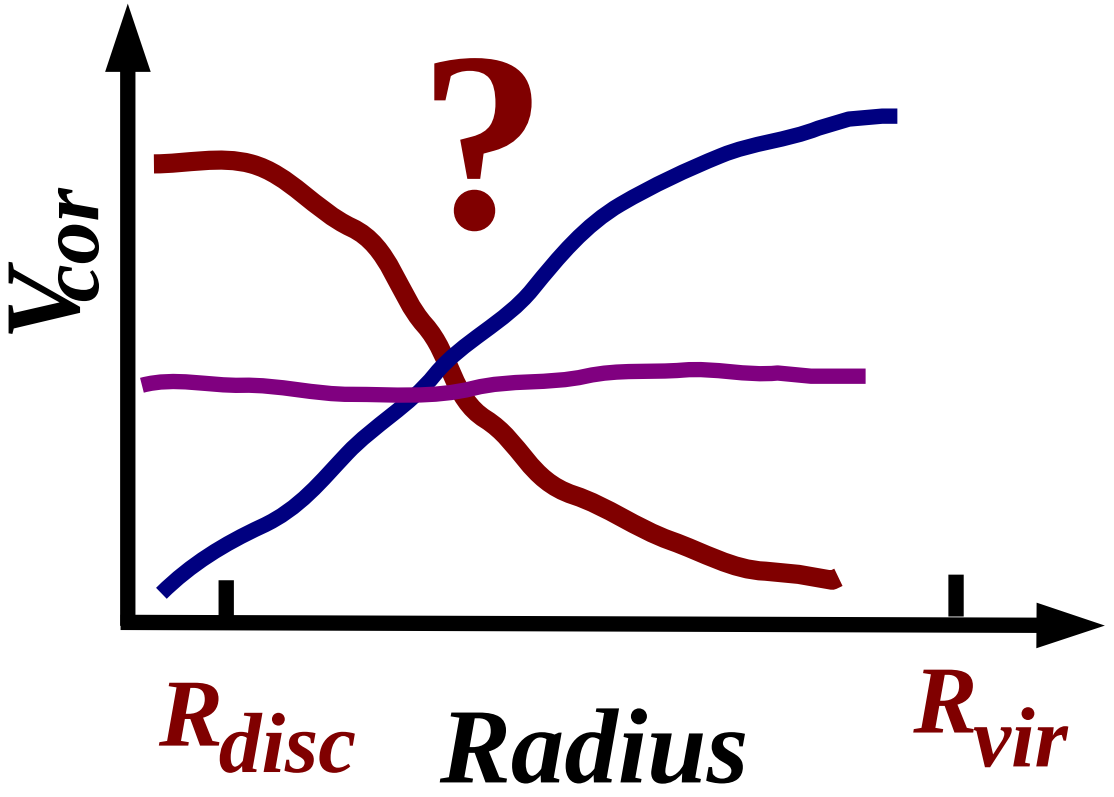

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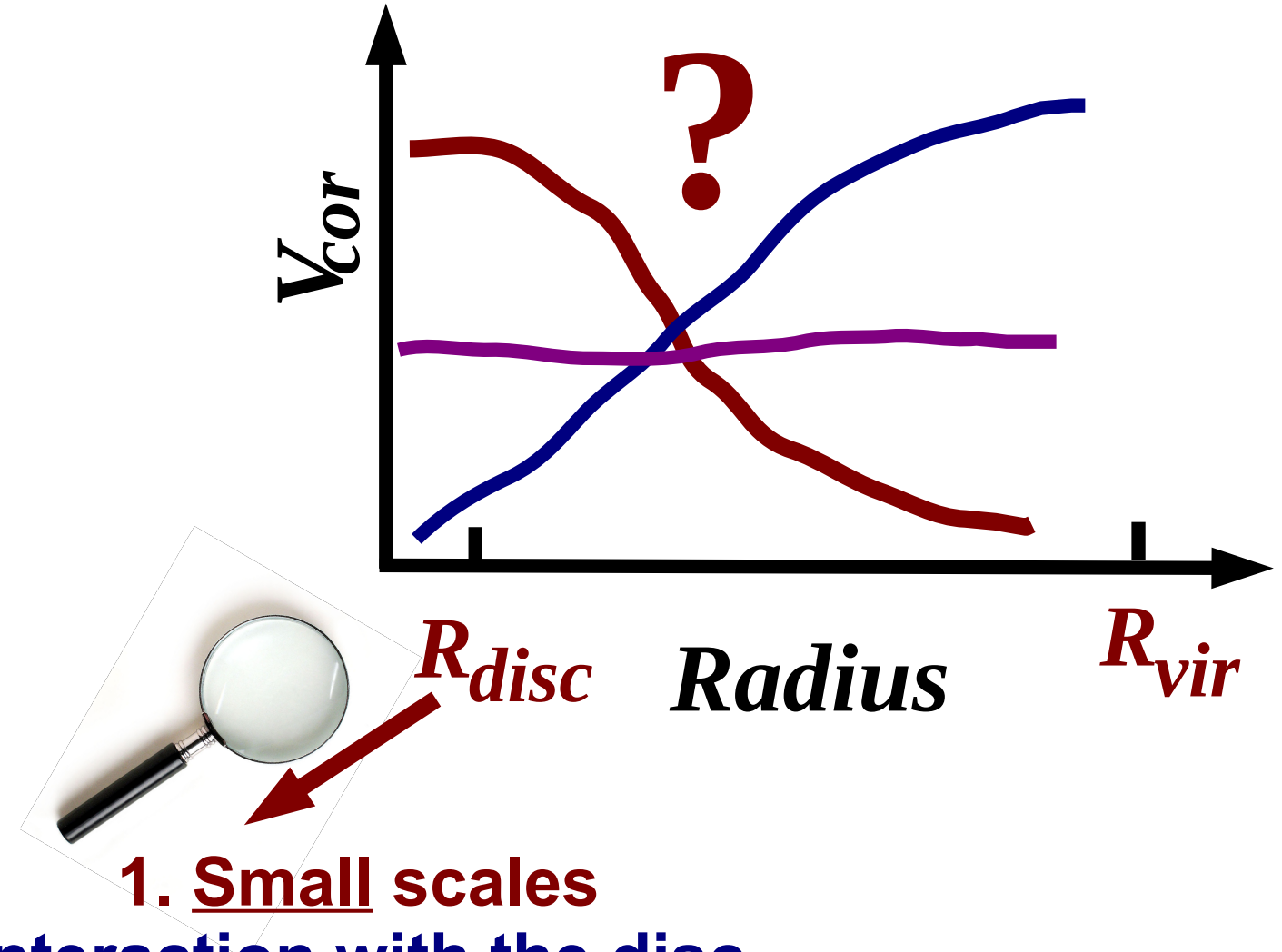

1. Small scales
Interaction with the disc
Galaxy evolution

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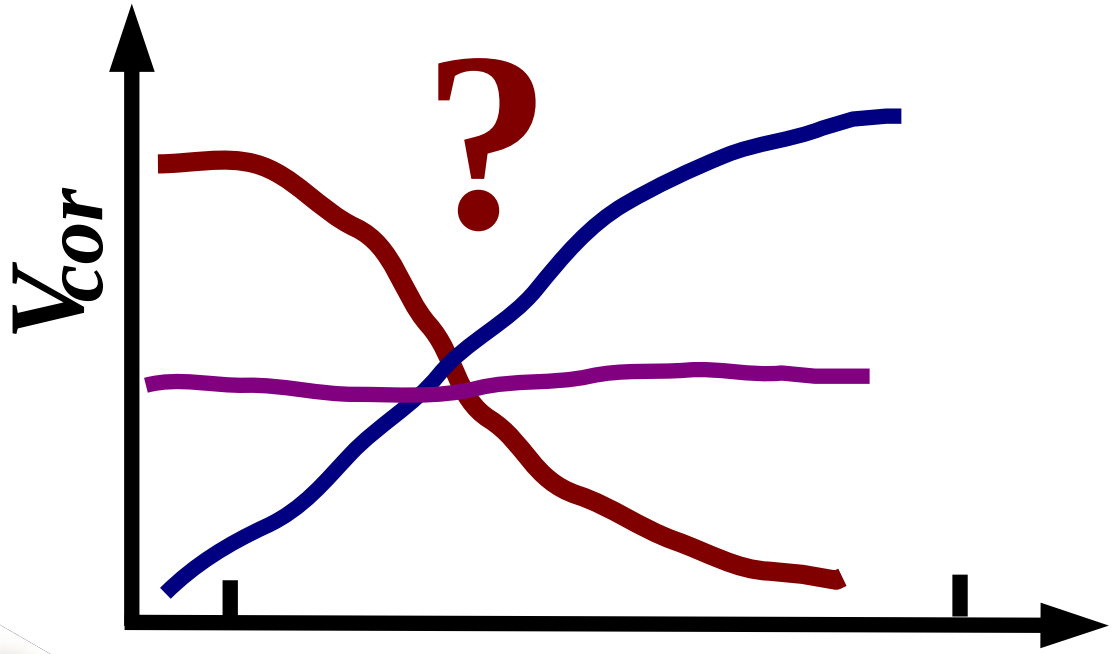

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2. Large scales
Structure formation
Cosmology

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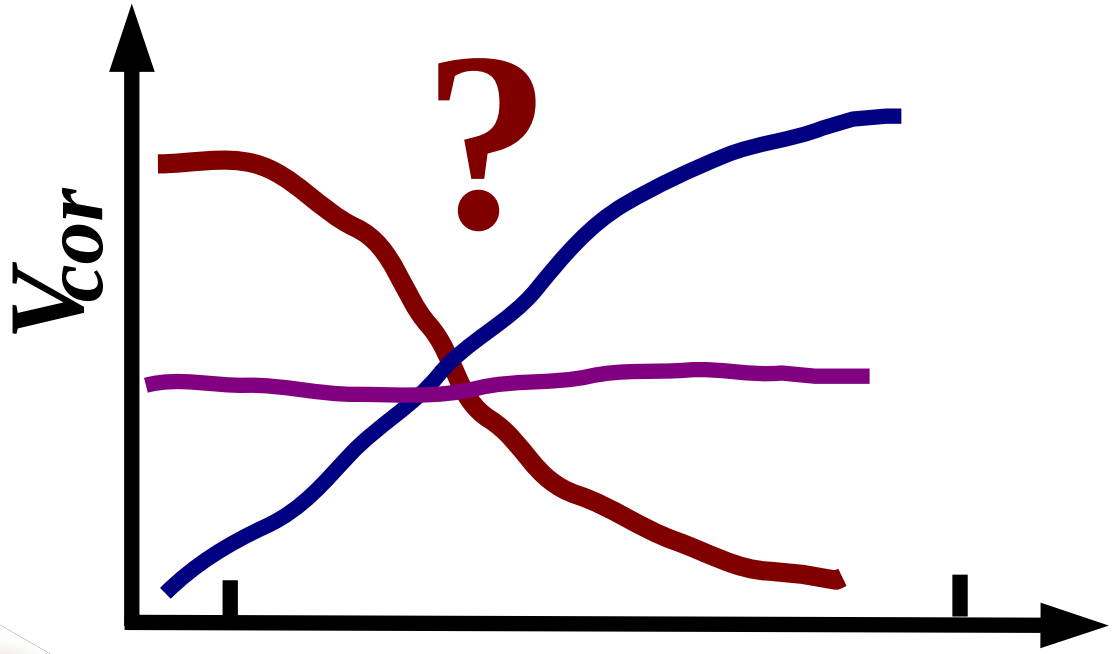

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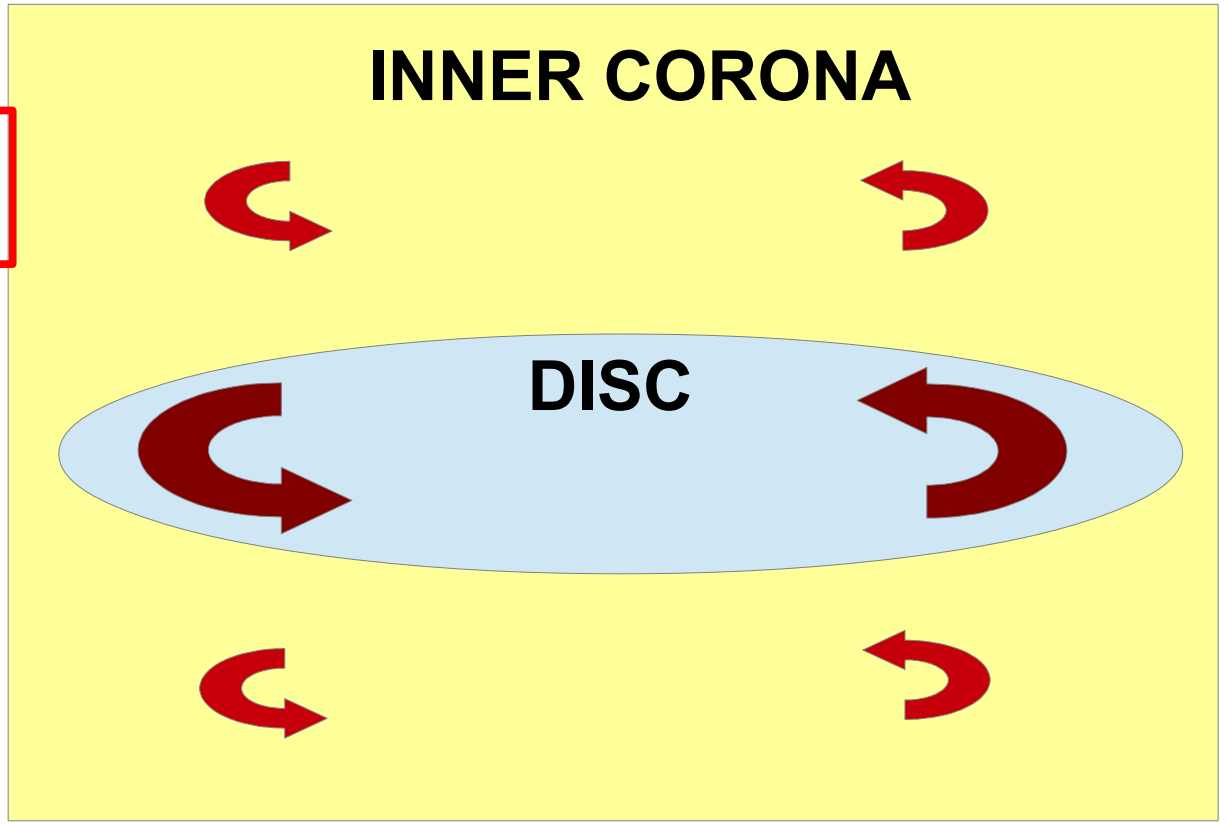
Coronal rotation and galaxy dynamics

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

Coronal rotation and galaxy dynamics

$V_{cor} < V_{disc}$



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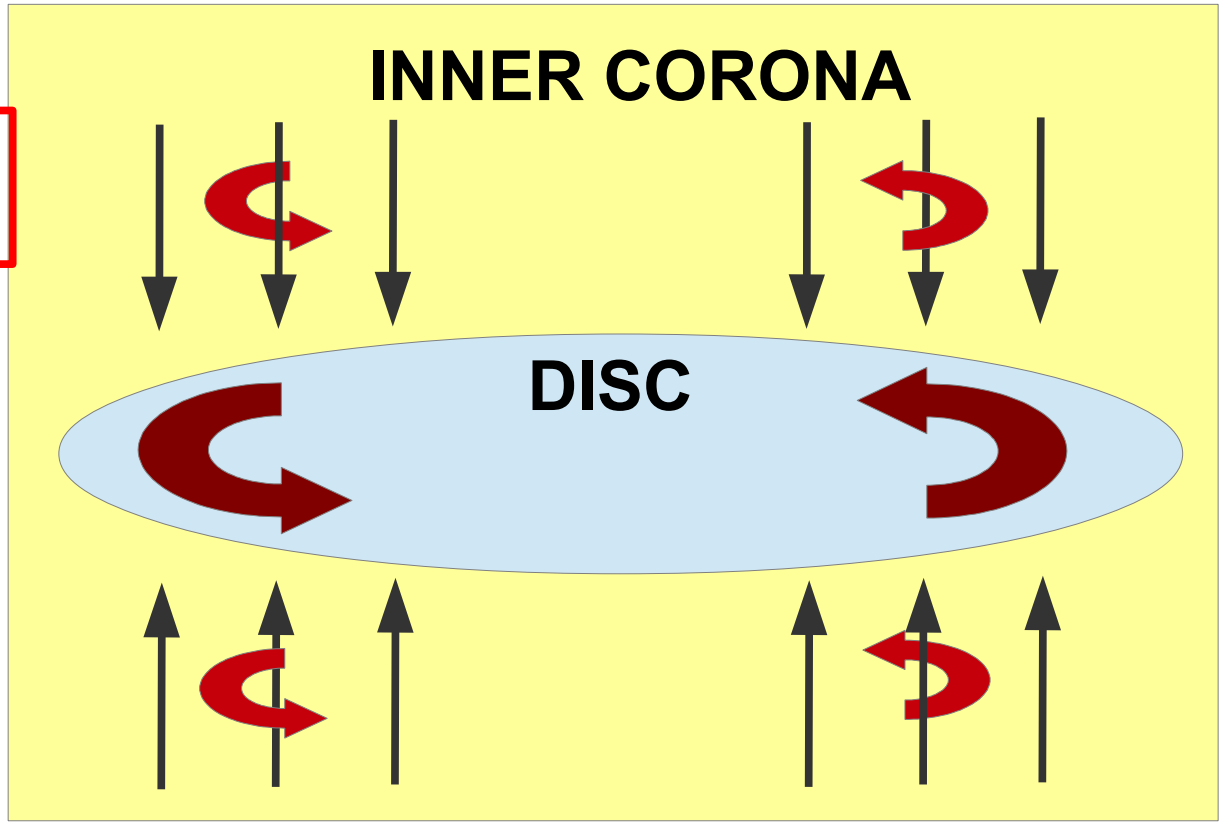

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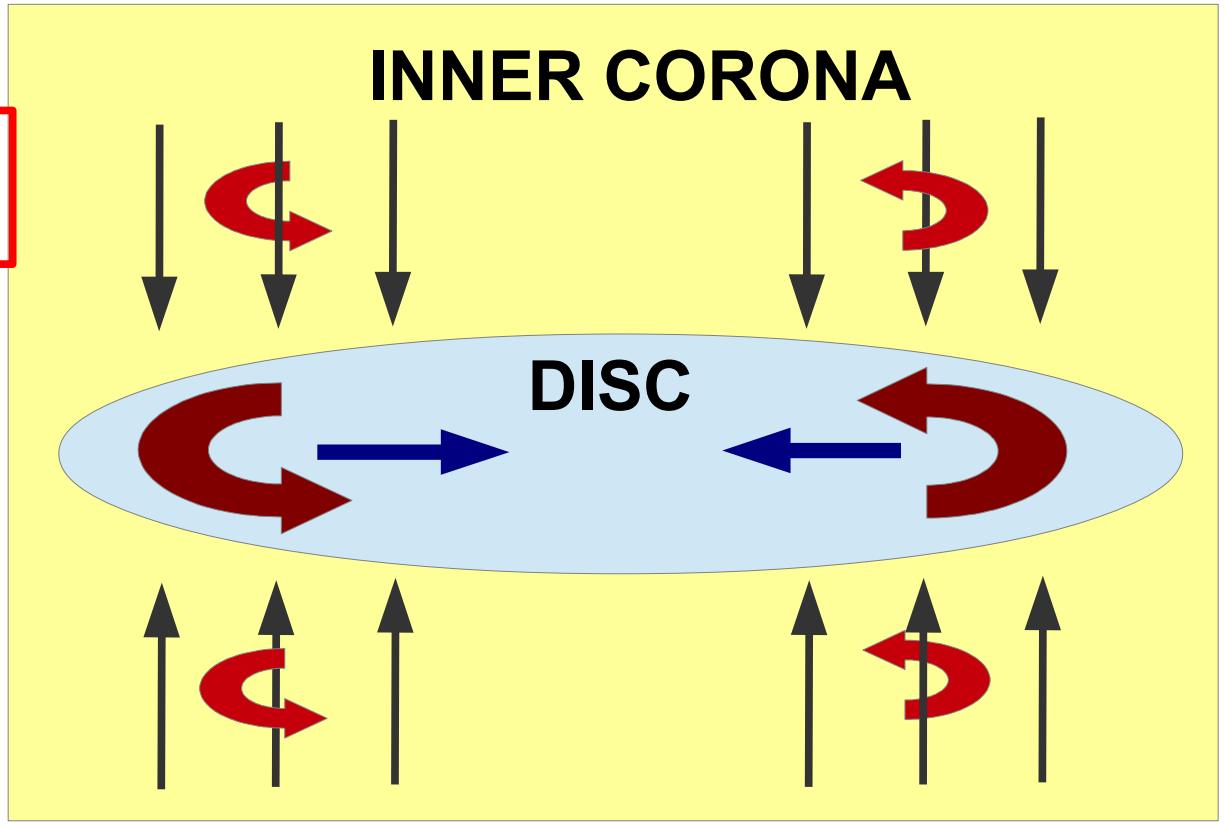

ANGULAR MOMENTUM CONSERVATION → **RADIAL GAS FLOWS ~ 1 km/s = 1 kpc/Gyr**

Cfr. Brad Gibson's talk this morning!

Mayor & Vigroux 1981; Pitts & Tayler 1989;
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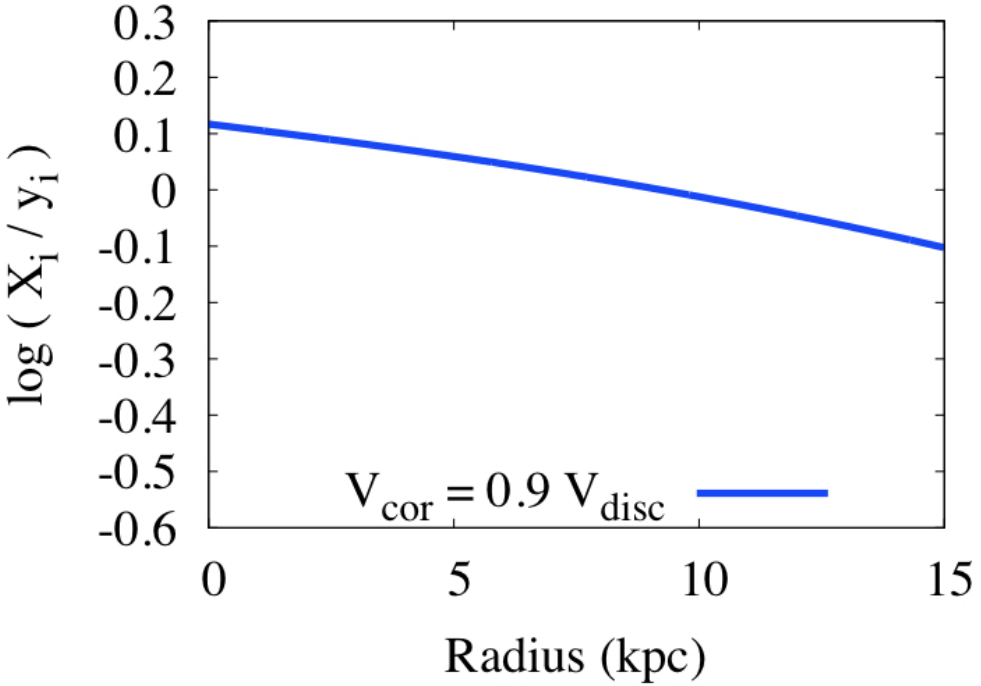
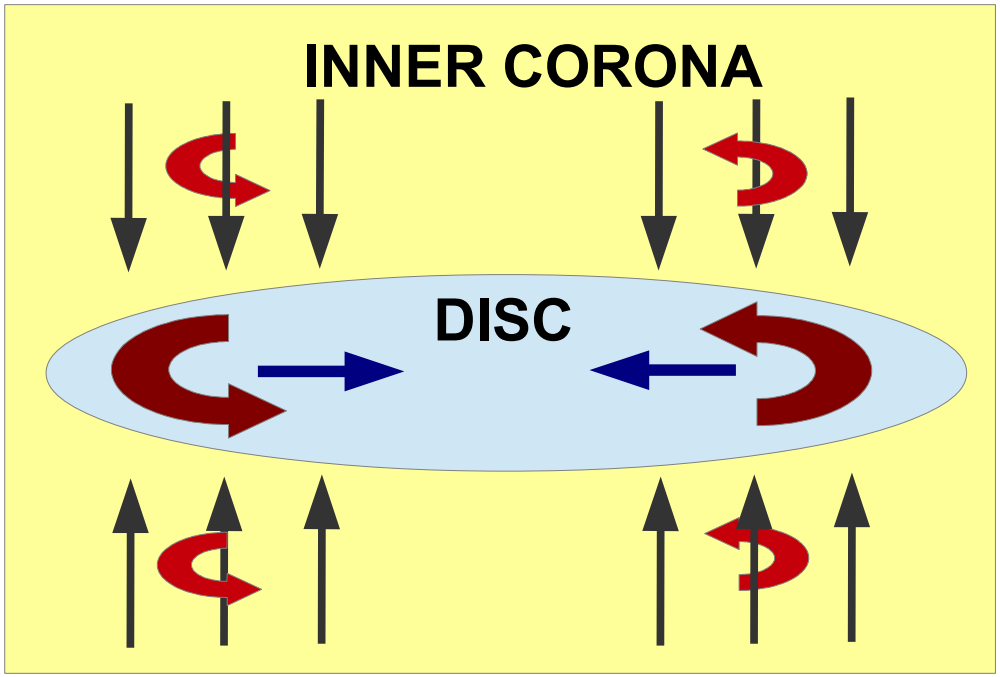
Coronal rotation and chemical evolution

Pezzulli & Fraternali (2016)

ABUNDANCE GRADIENT





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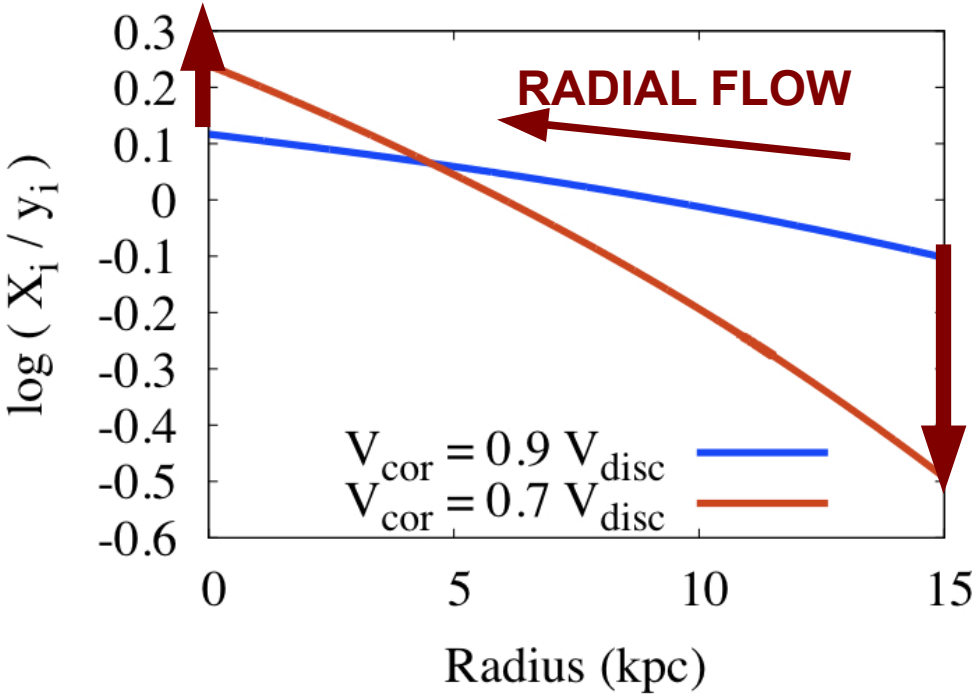

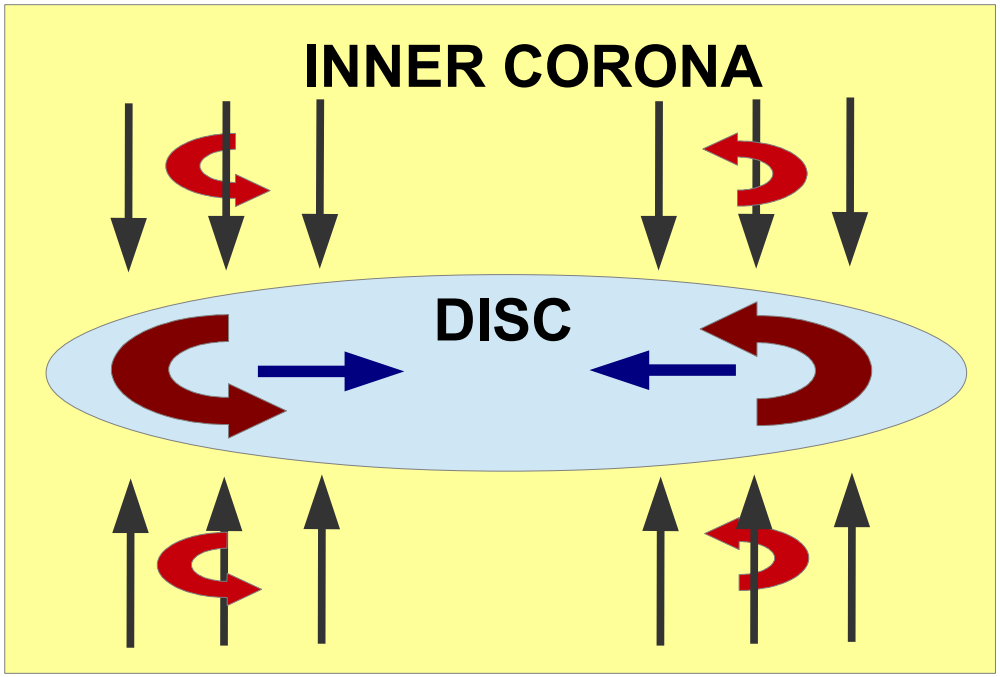

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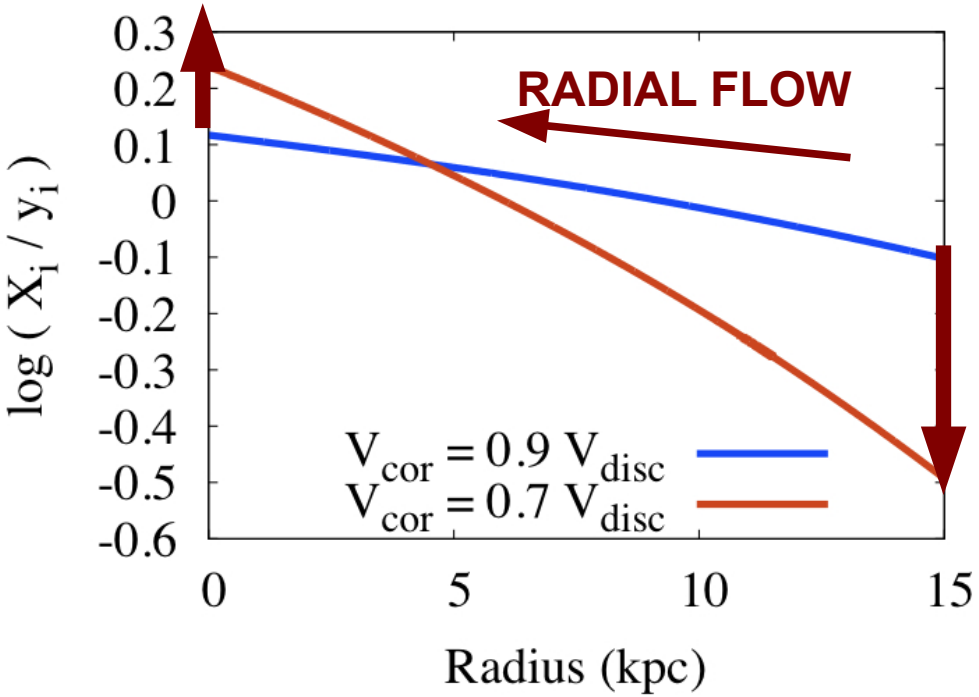

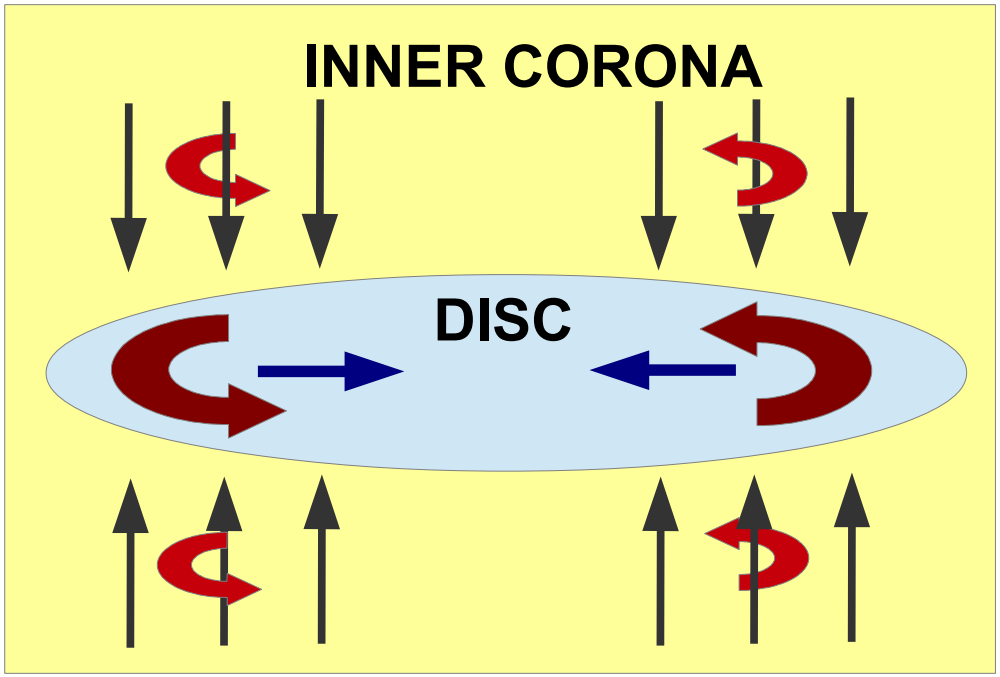

Abundance **gradients** sensitive **probes** of **rotation** of the inner corona

Coronal rotation and chemical evolution

Pezzulli & Fraternali (2016)

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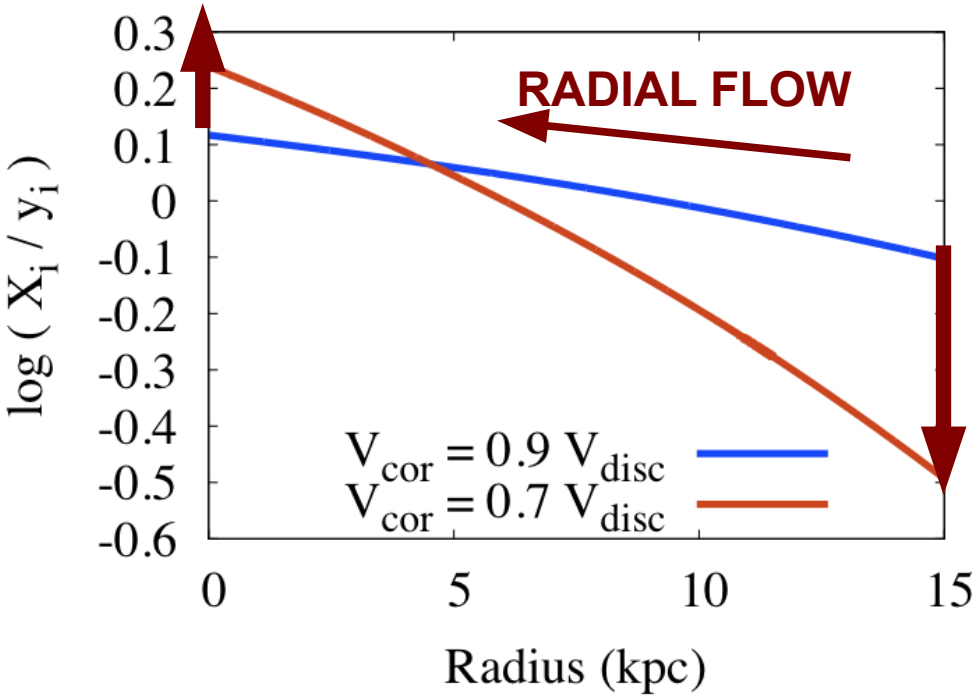
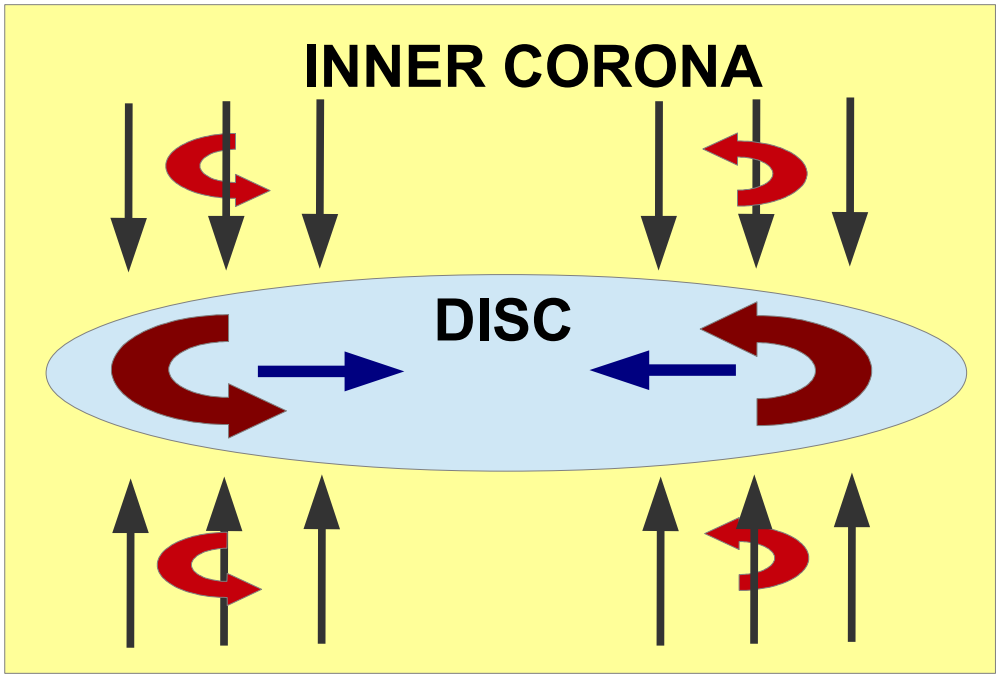


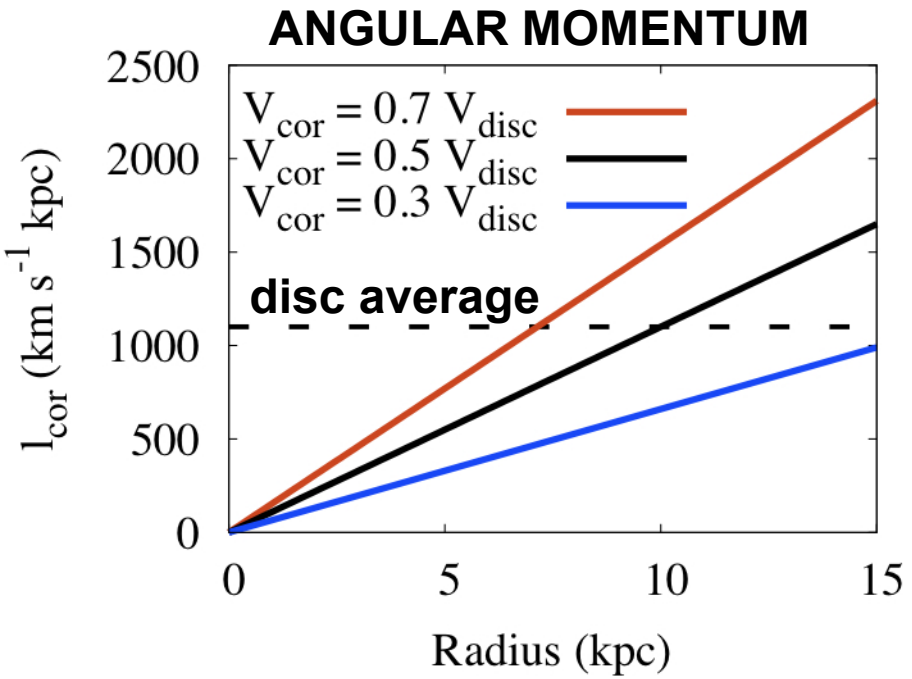


Abundance **gradients** sensitive **probes** of **rotation** of the inner corona

For the MILKY WAY:

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

Coronal rotation and inside-out growth



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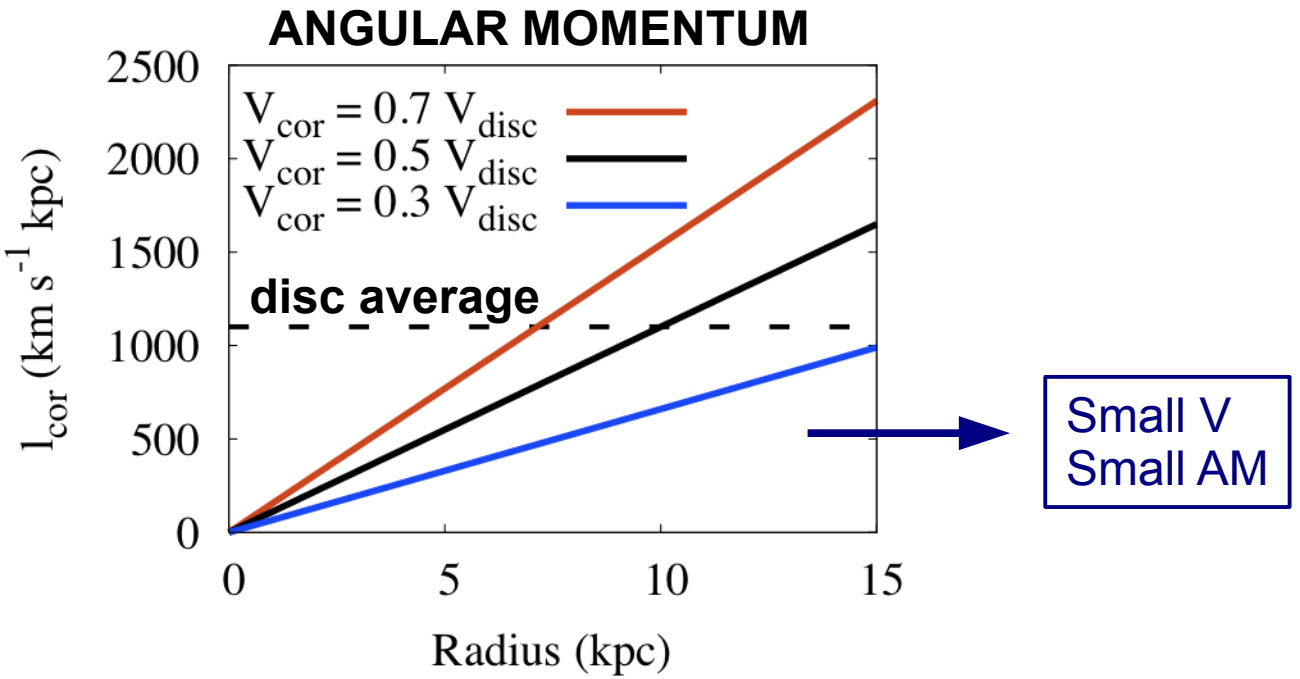
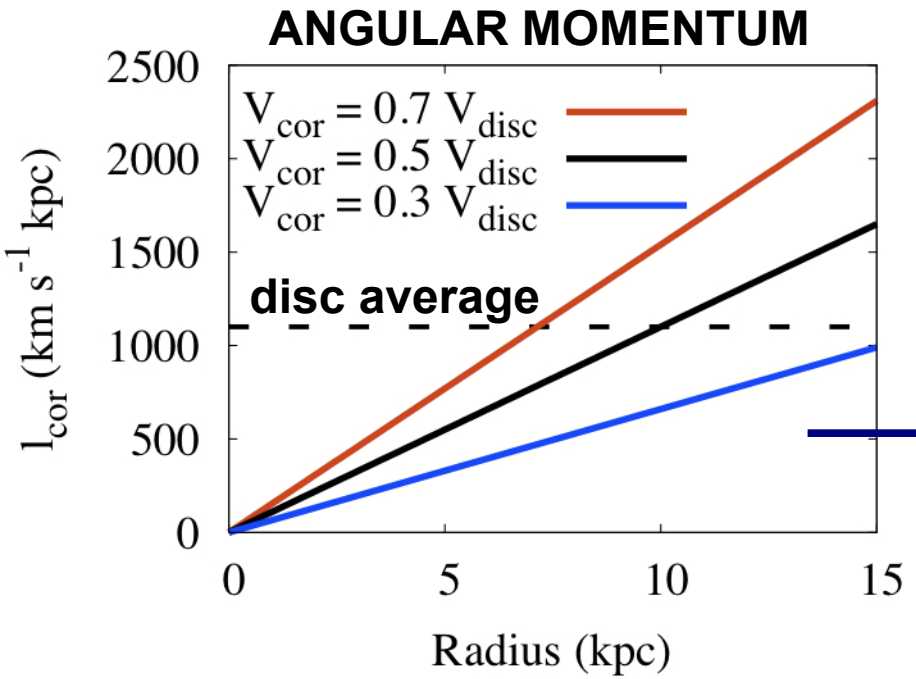


Small V
Small AM

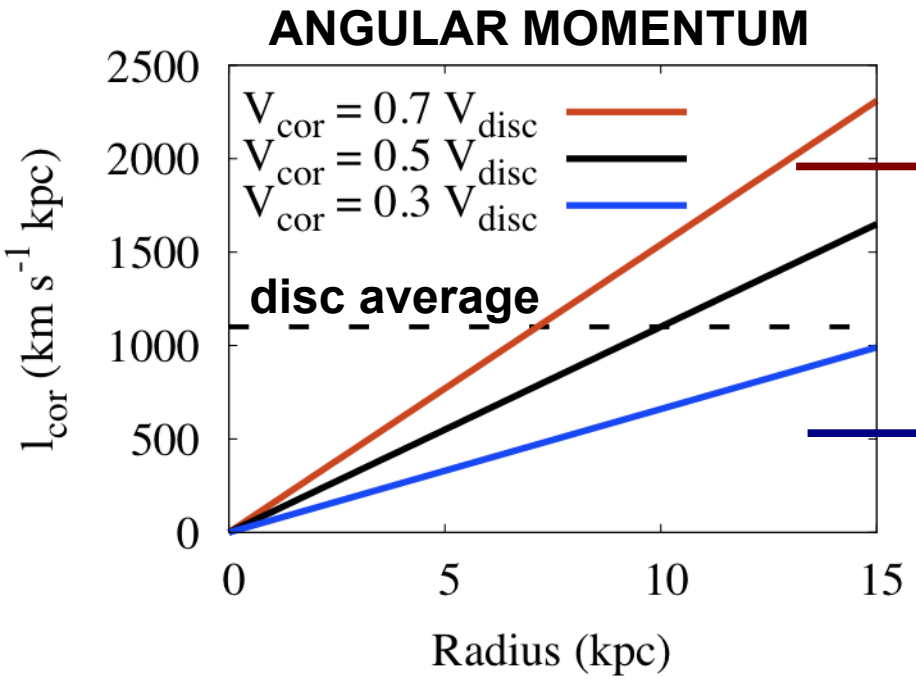
Coronal rotation and inside-out growth



Small V
Small AM

The disc would shrink...

Coronal rotation and inside-out growth



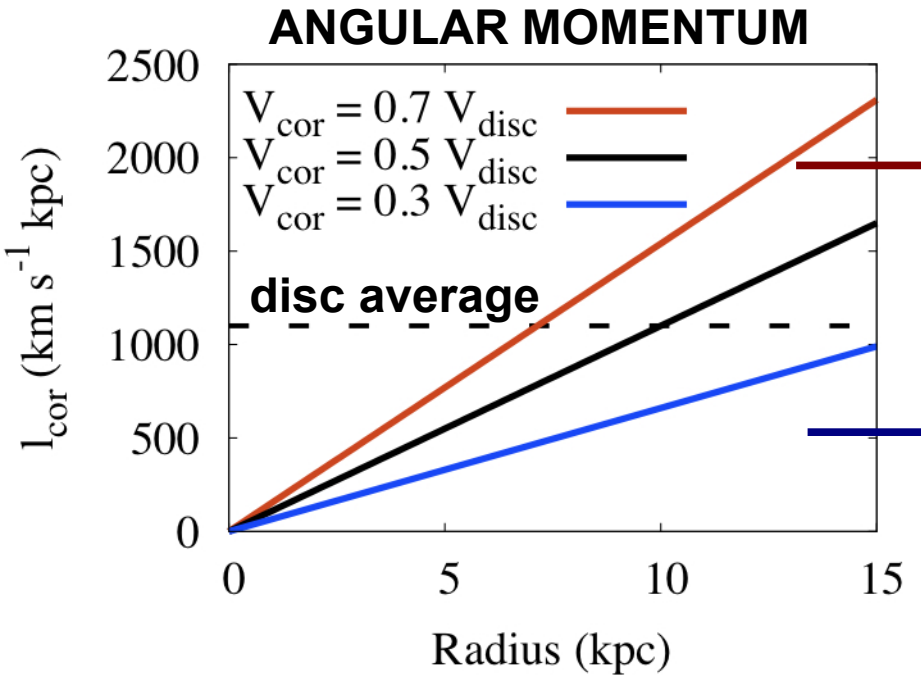
Large V
Large AM

Inside-out growth!

Small V
Small AM

The disc would shrink...

Coronal rotation and inside-out growth



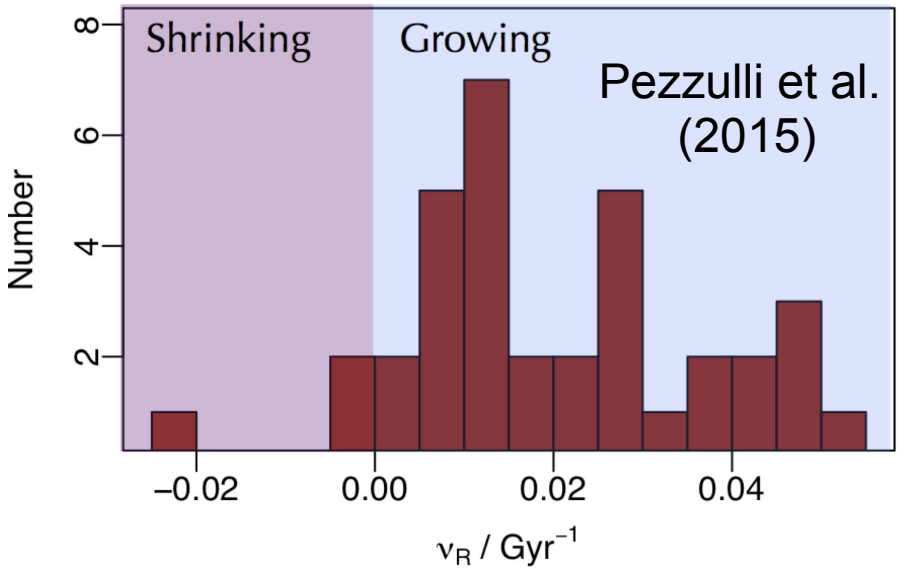
Large V
Large AM → **Inside-out growth!**

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

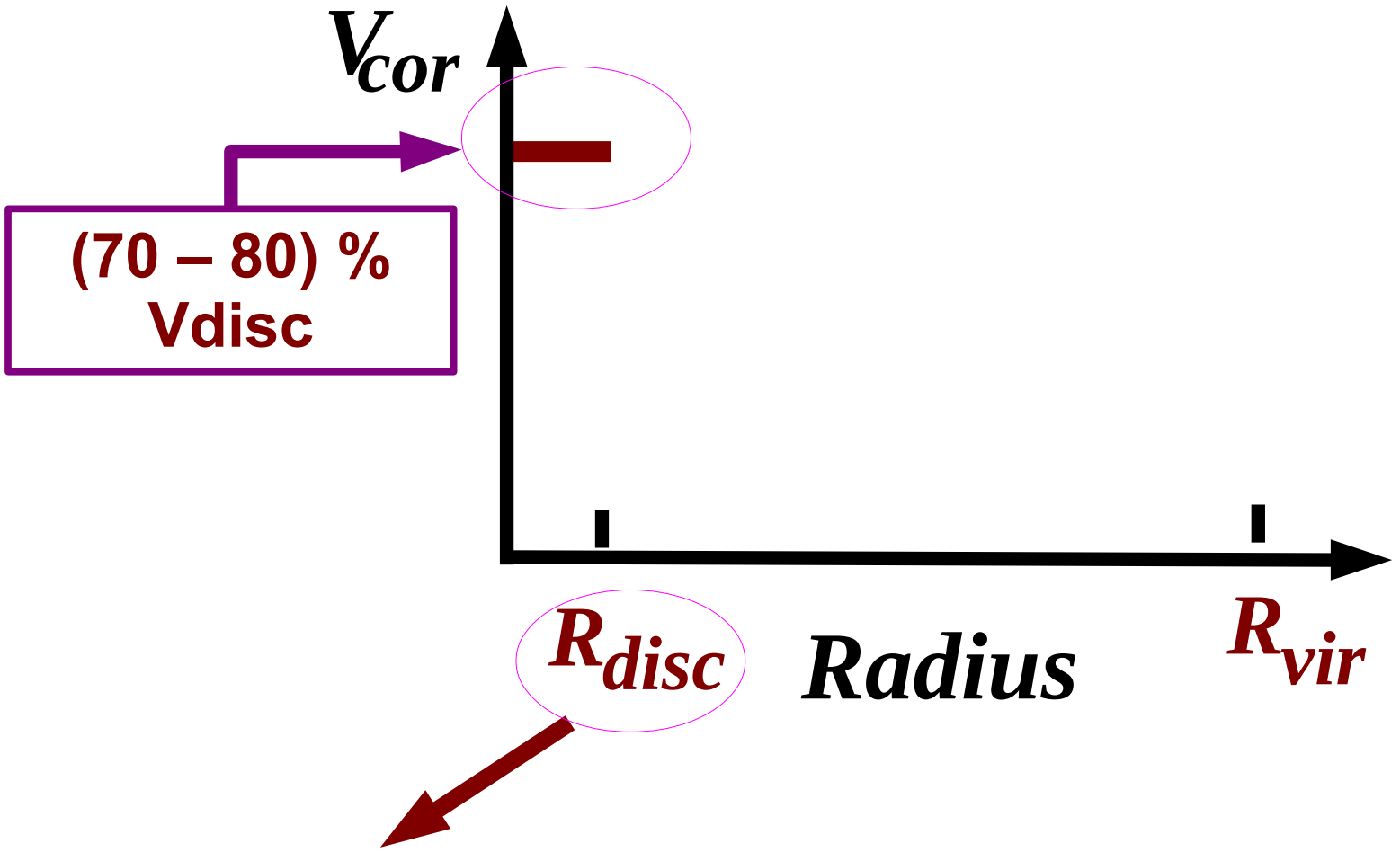
Most spirals are growing

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

Must accrete angular-momentum-rich coronal gas



Reconstructing coronal rotation



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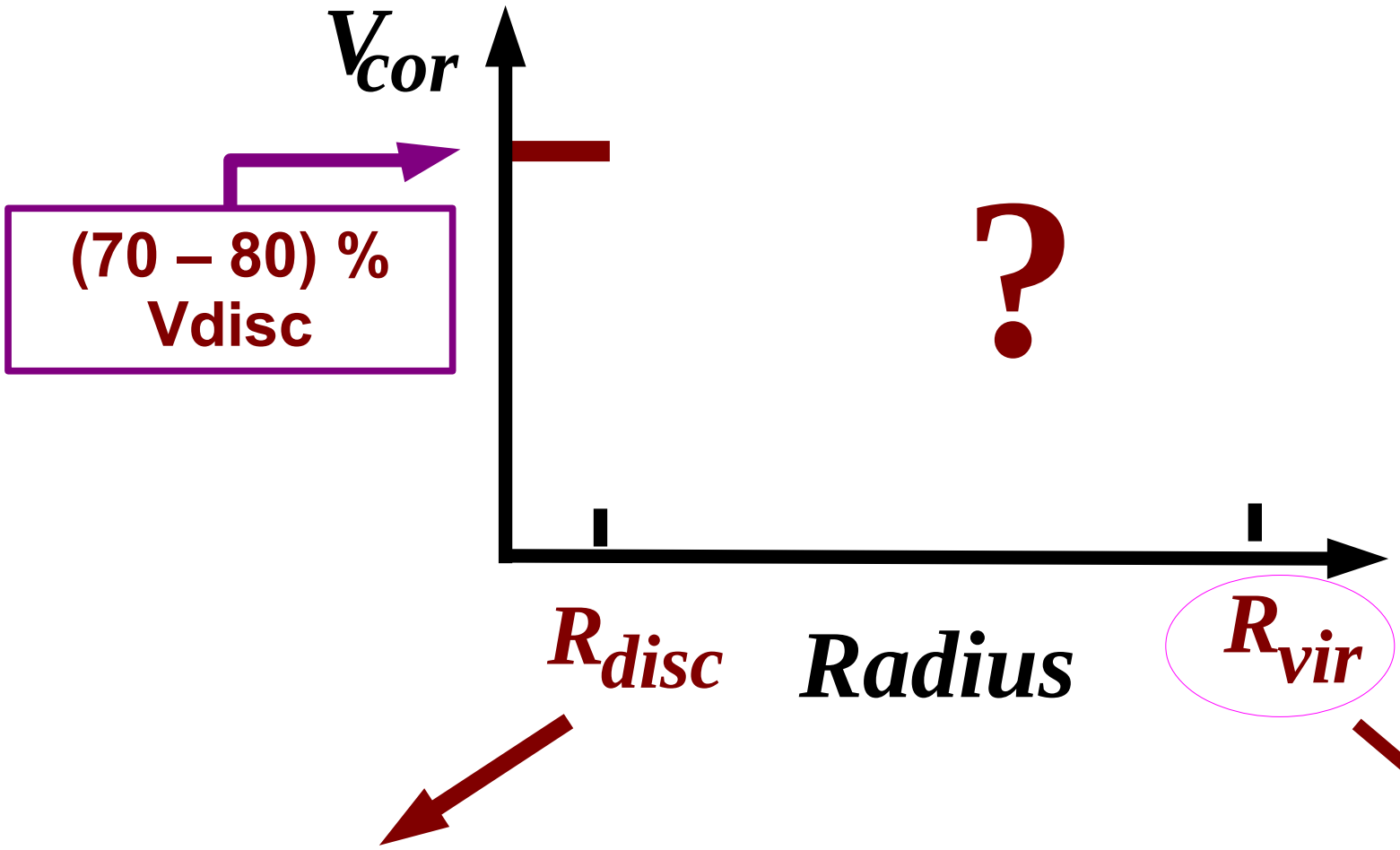

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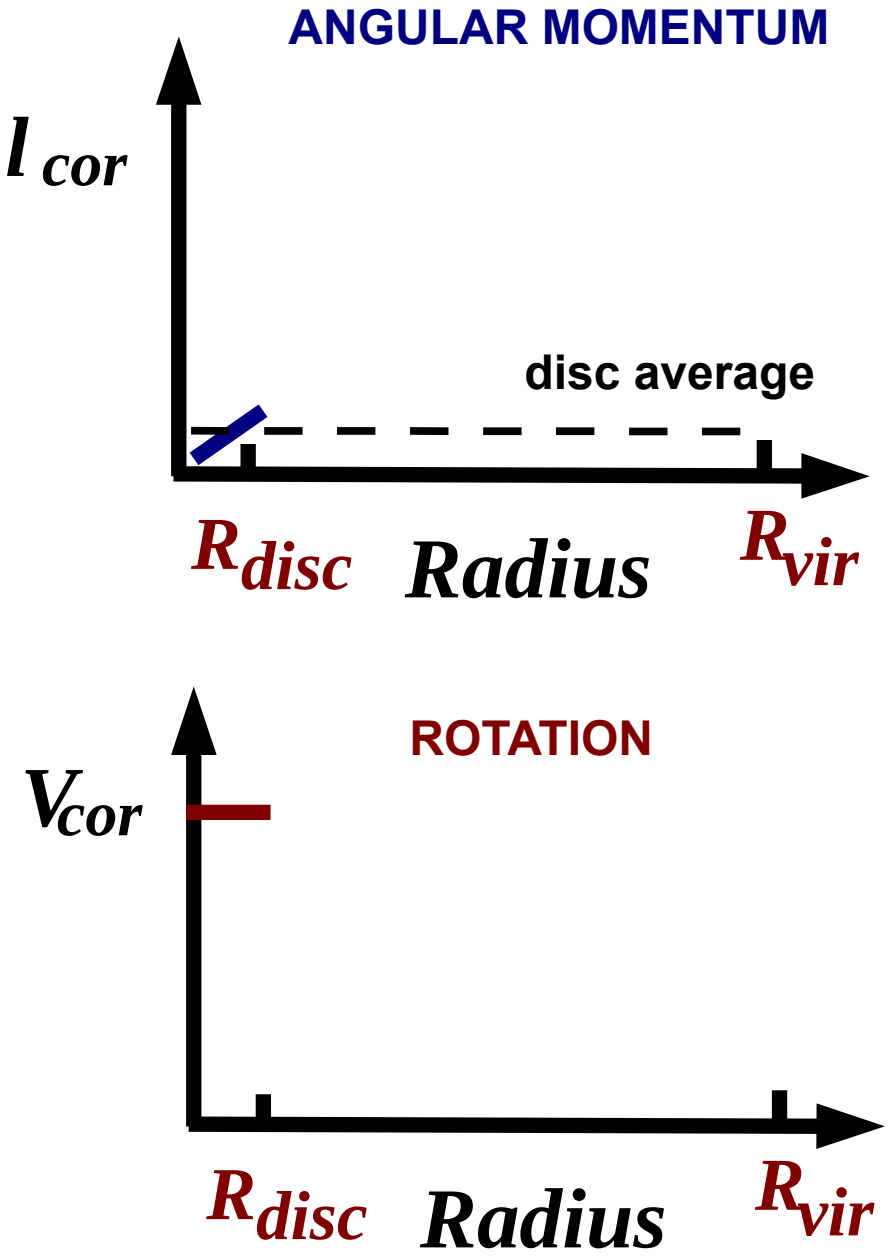
Coronal rotation and cosmology



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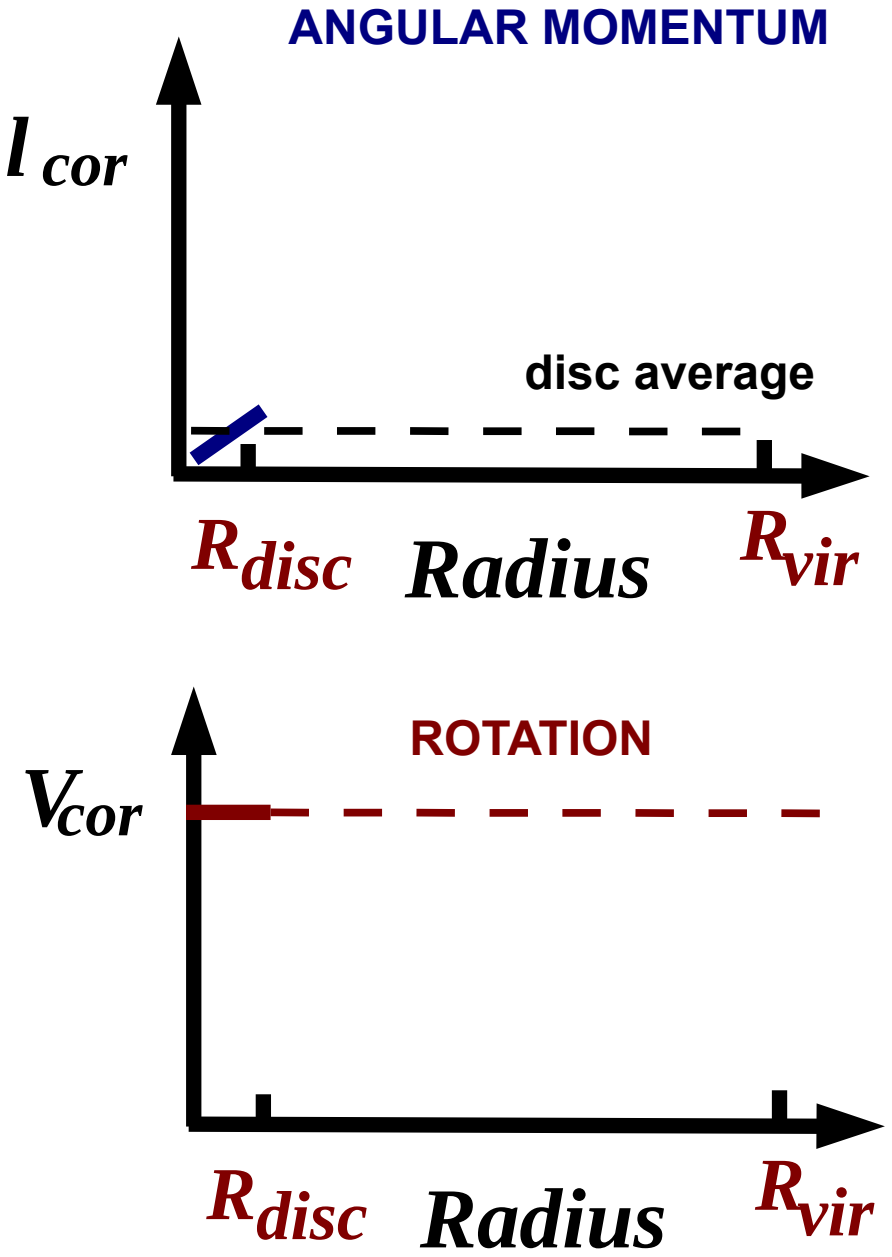

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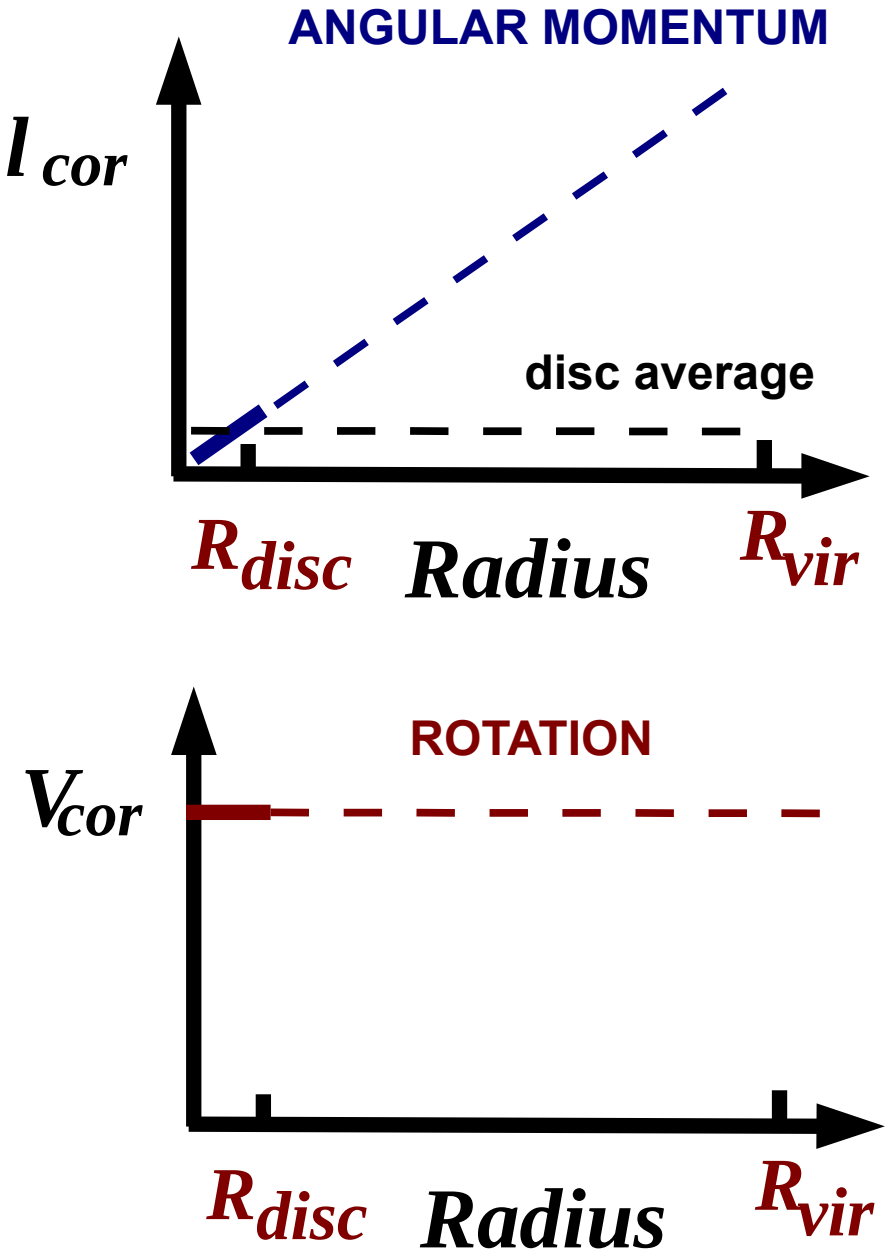

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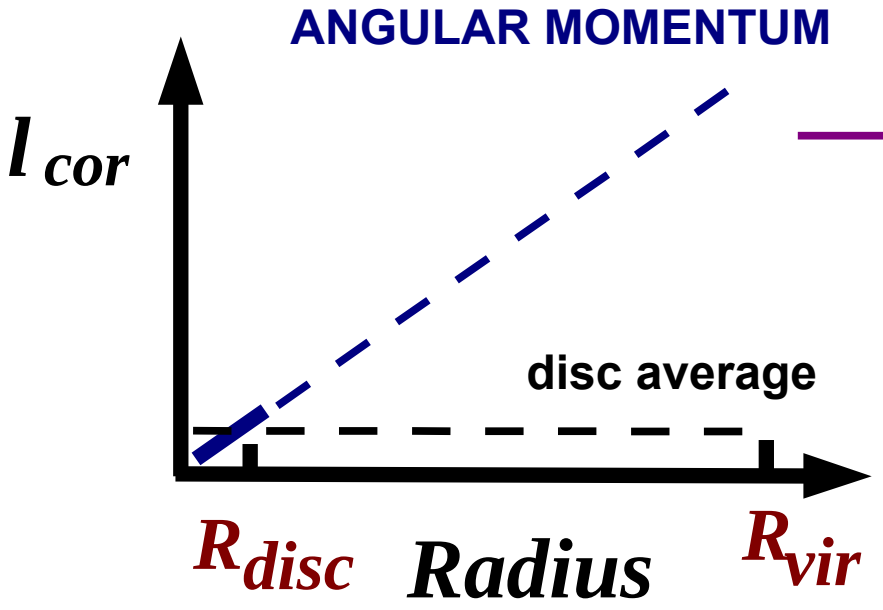
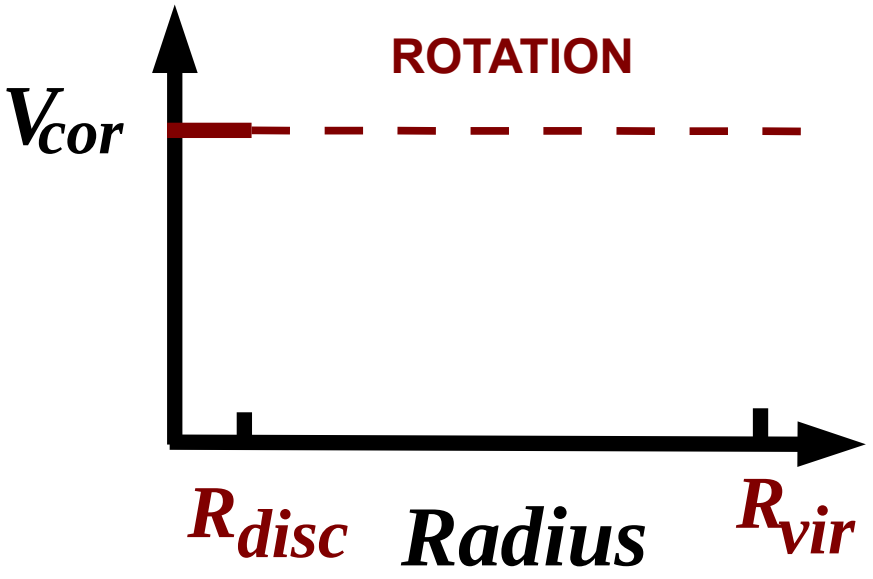


Very large angular momentum!

$\lambda \sim 0.3$



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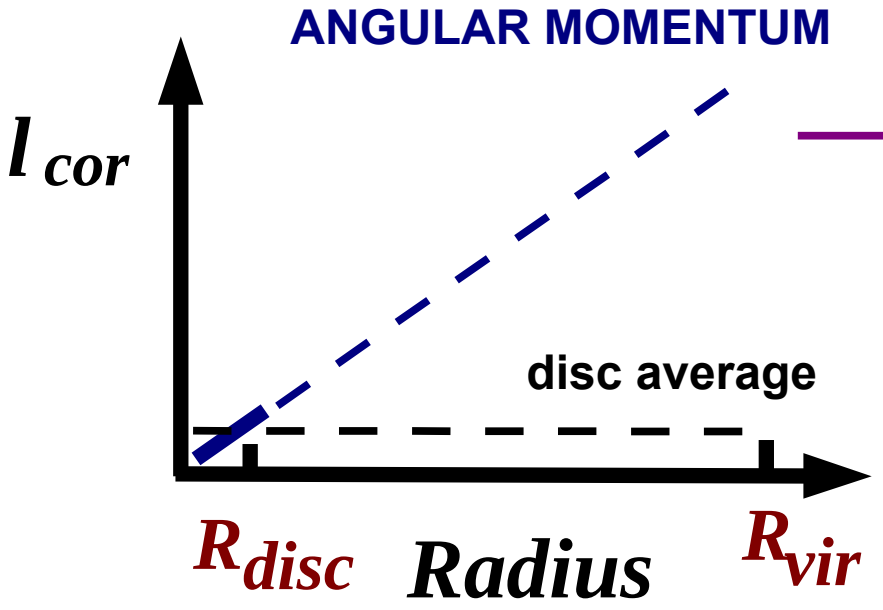

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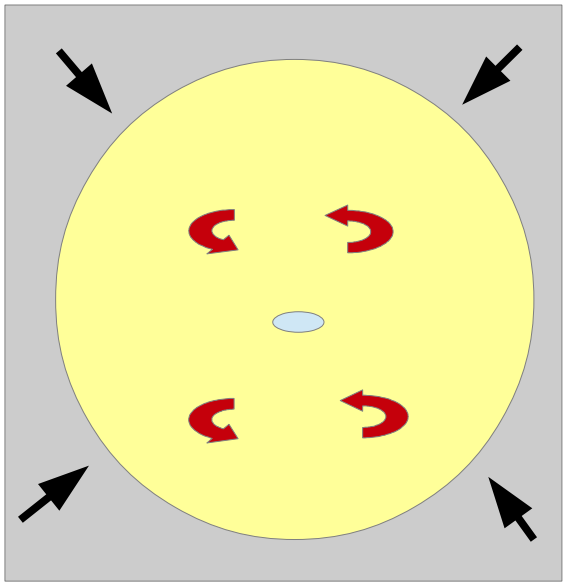
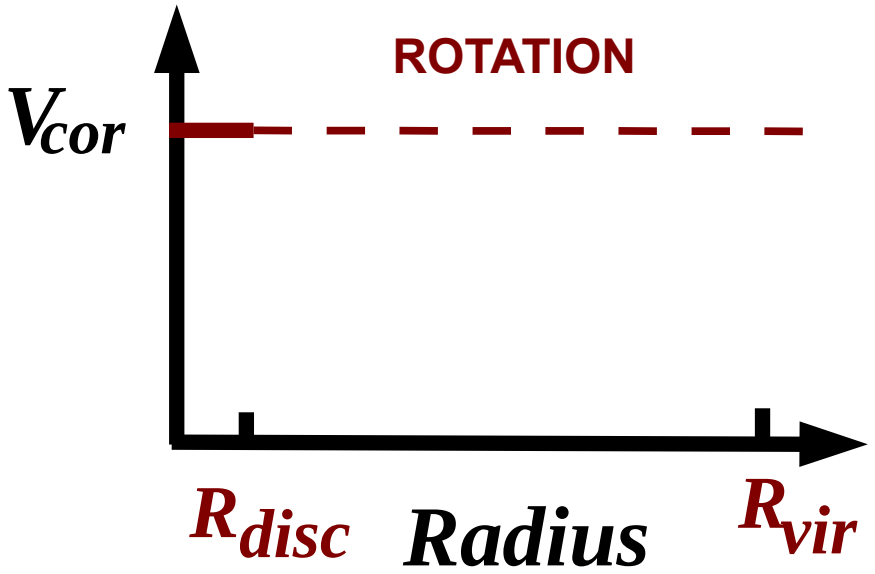
Incompatible with cosmology!



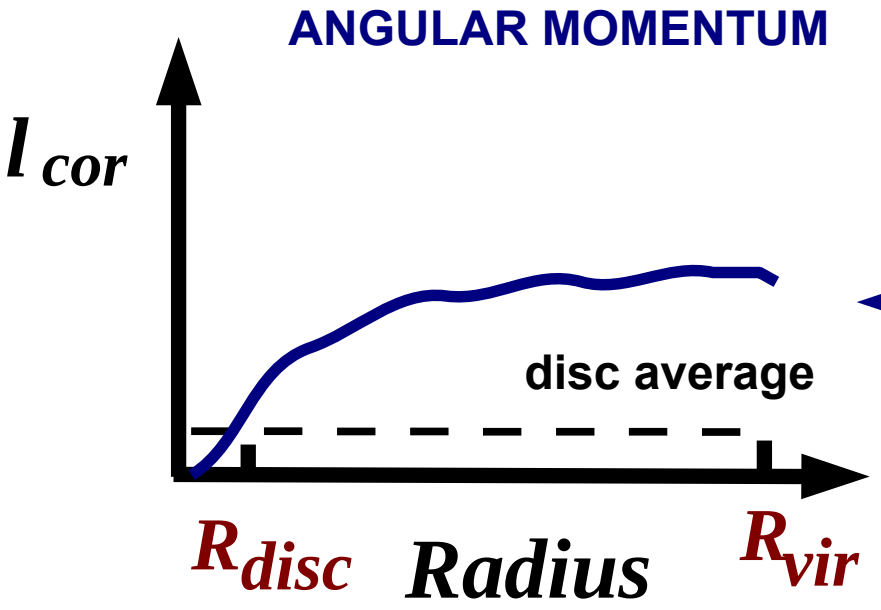


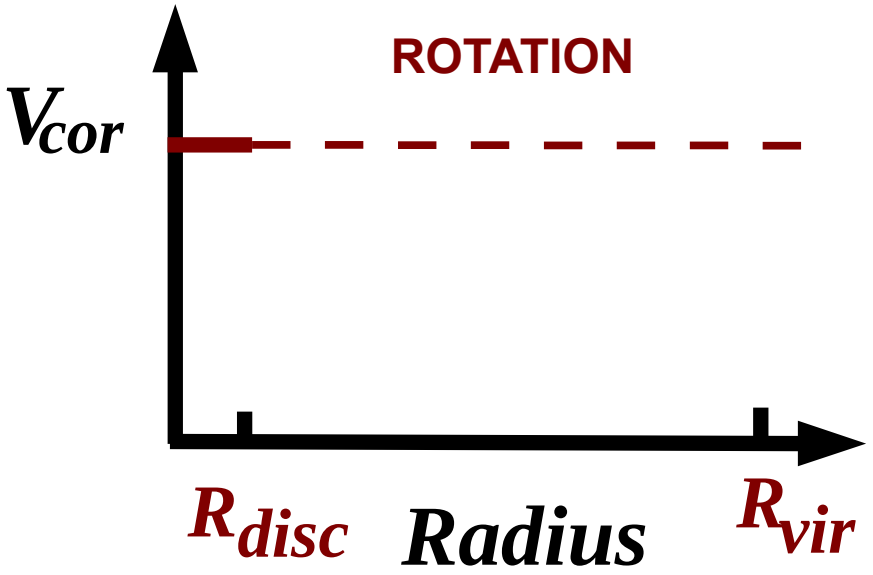
Tidal torque theory

Peebles (1969)
Porciani et al. (2002)

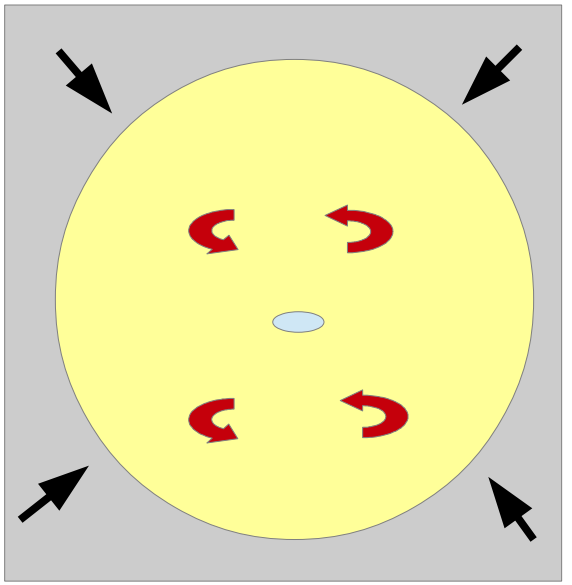
$\lambda \sim 0.04$

Coronal rotation and cosmology





To match comological constraints



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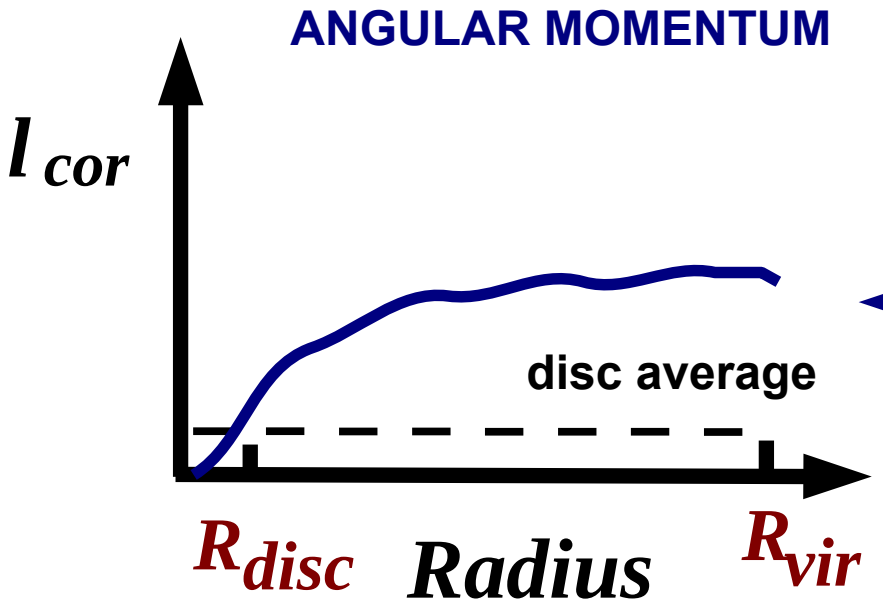

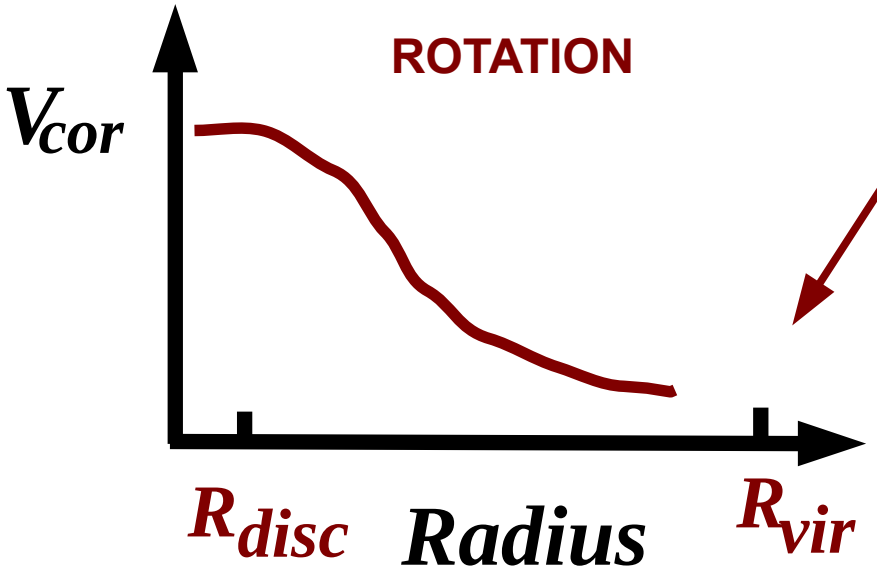

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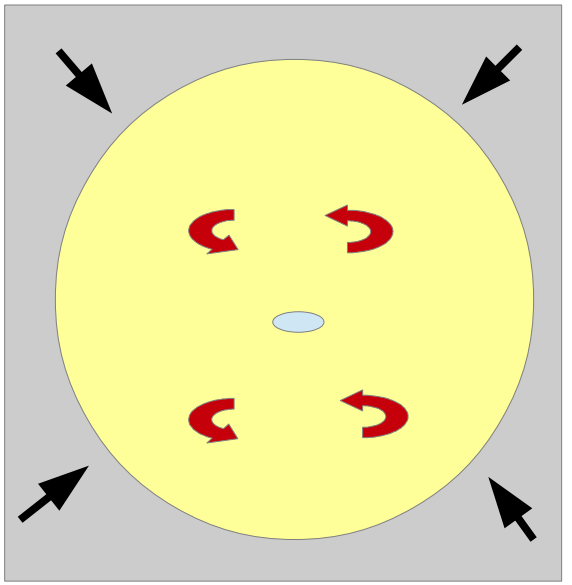

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$\lambda \sim 0.04$

Coronal rotation and cosmology

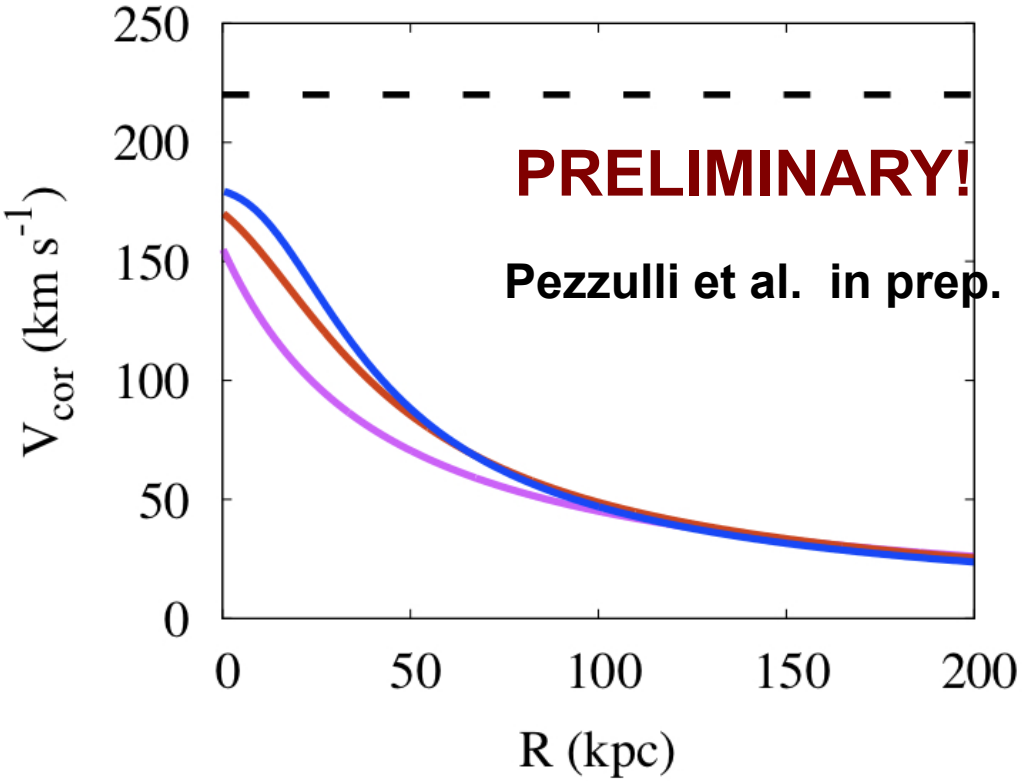
$$\mathbf{g} + \nabla P + \frac{l^2}{R^3}\mathbf{e_R} = 0$$

Rotating equilibrium

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

Angular momentum distribution

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



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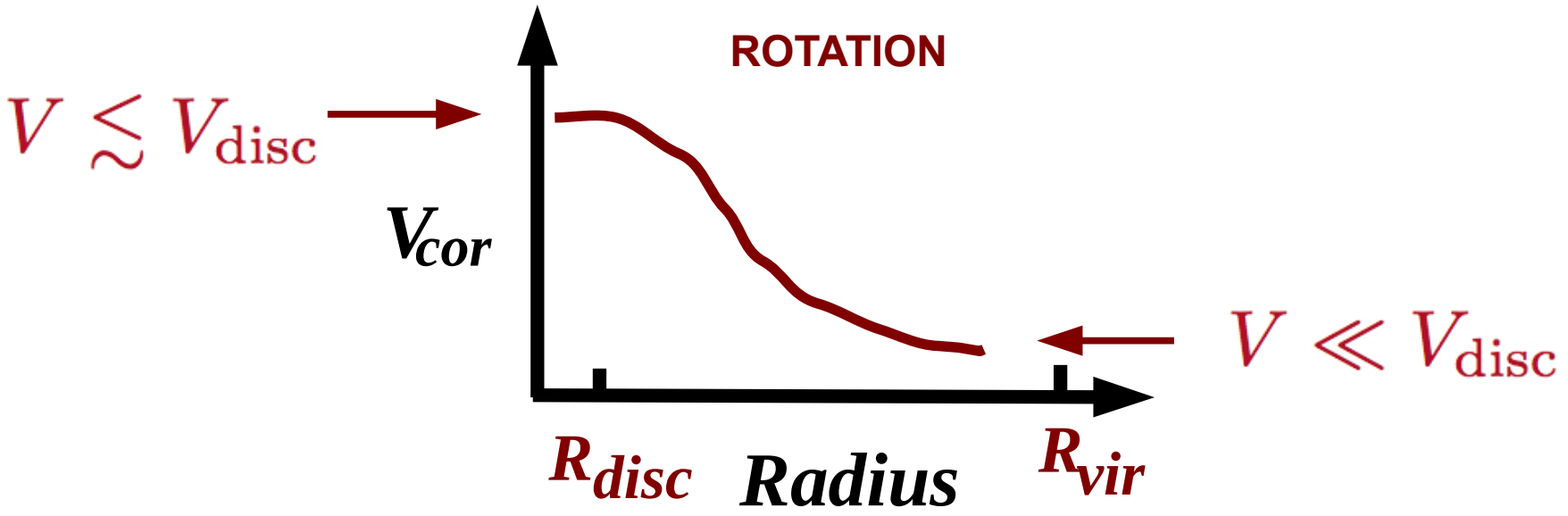

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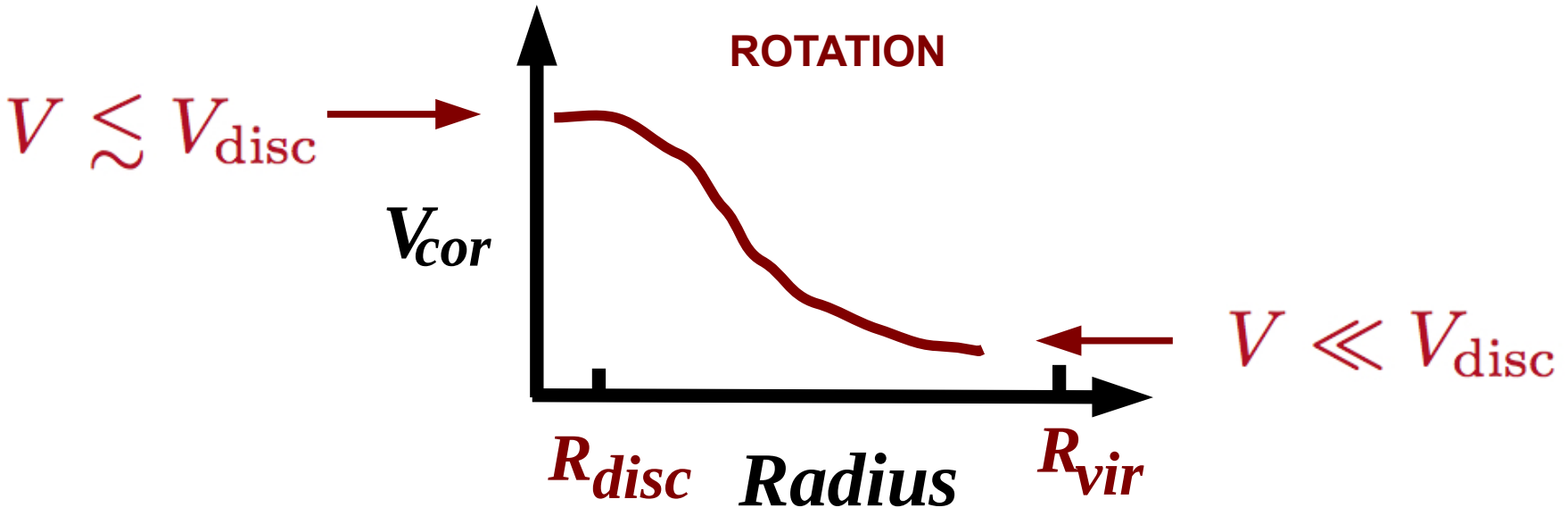

~ THANK YOU! ~