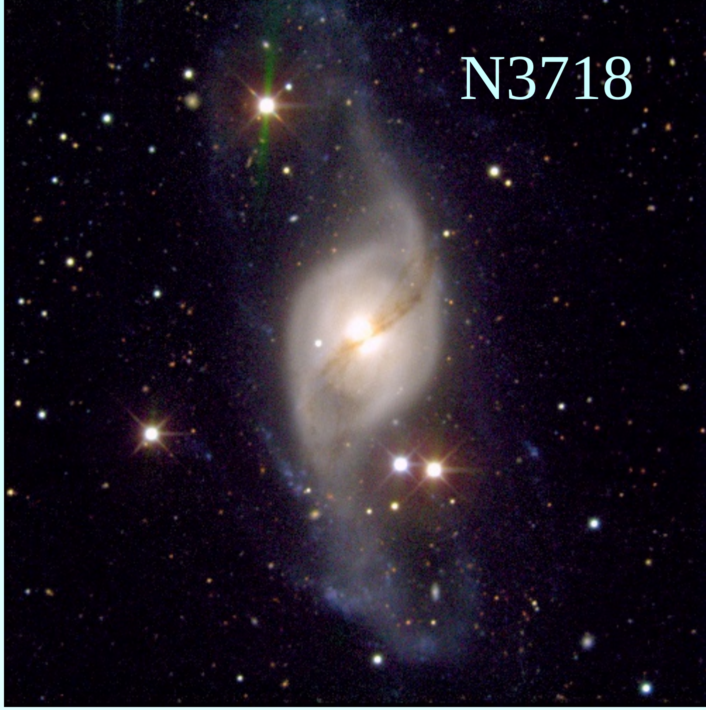
Kinematically decoupled galaxies



Outline:

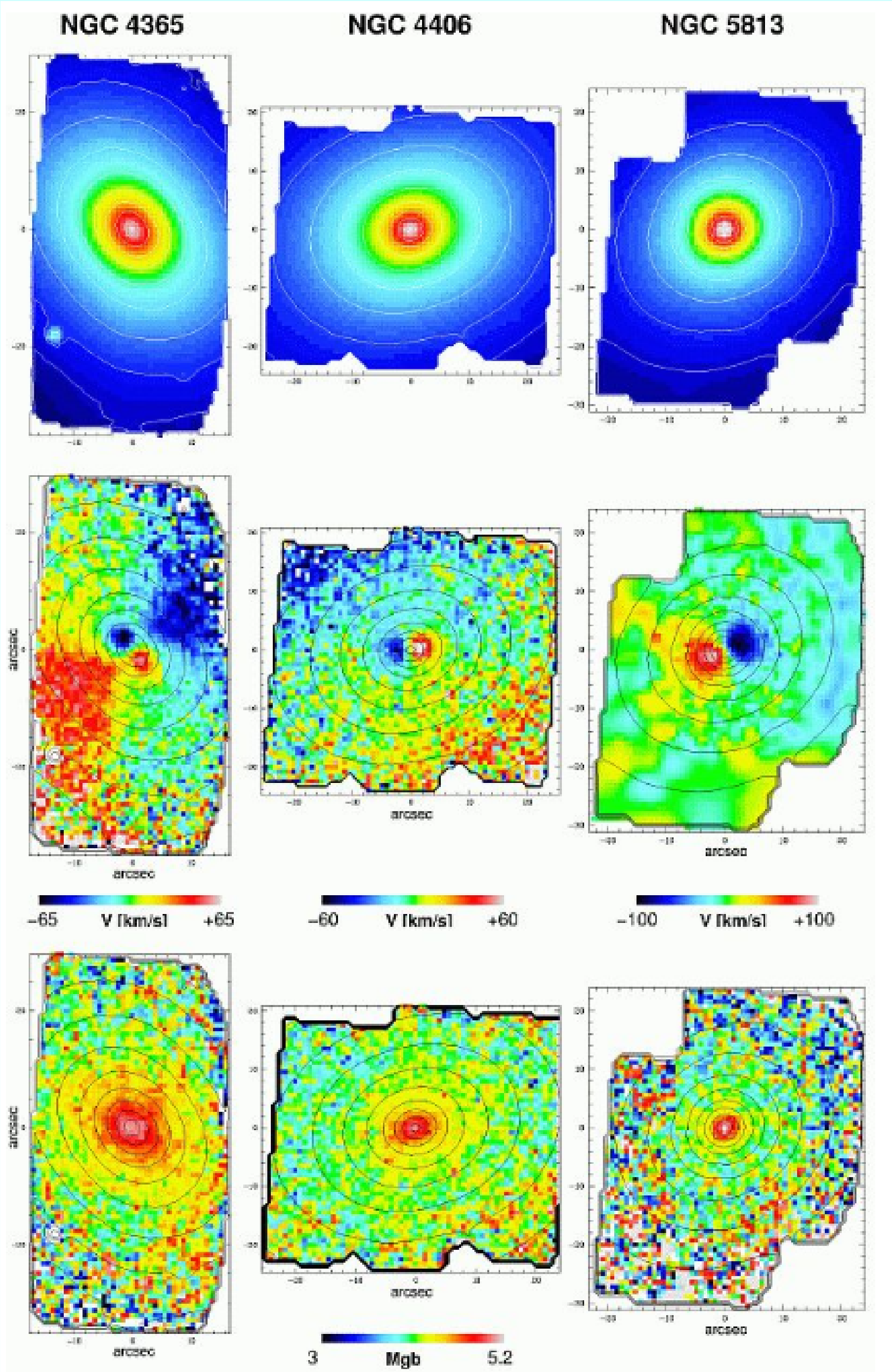
- ➔KDC large or small
- ➔Counter-rotating components
- ➔Polar rings
- ➔Hierarchical or gas accretion?

Françoise Combes

JENAM, 20 April 2009

l'Observatoire de Paris LERMA

Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique



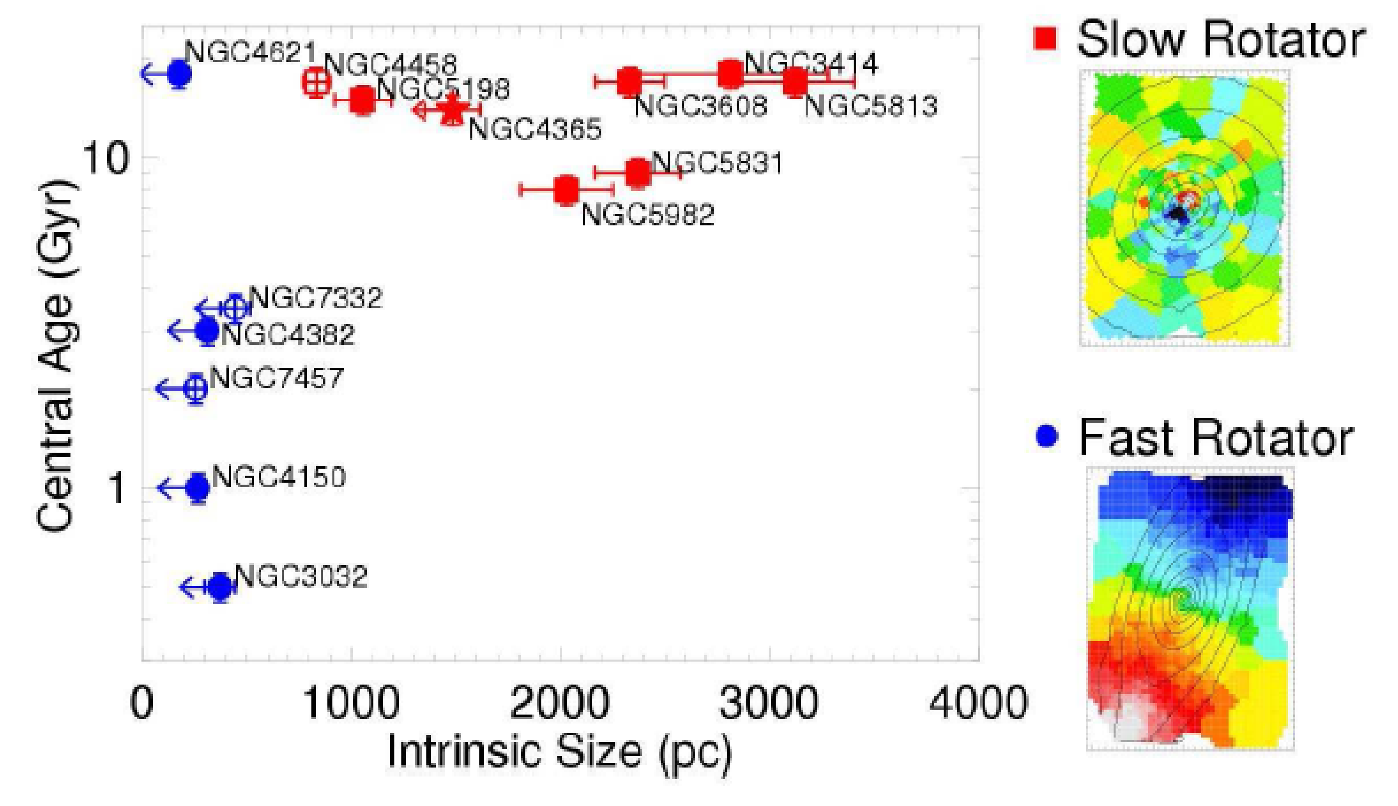
30% of early-types have Kinematically Decoupled Cores (KDC)

Stellar populations and ages are the same in the KDC and the host

KDC not visible in the line maps

The events are at least 12 Gyr
SAURON & Davies et al 2001

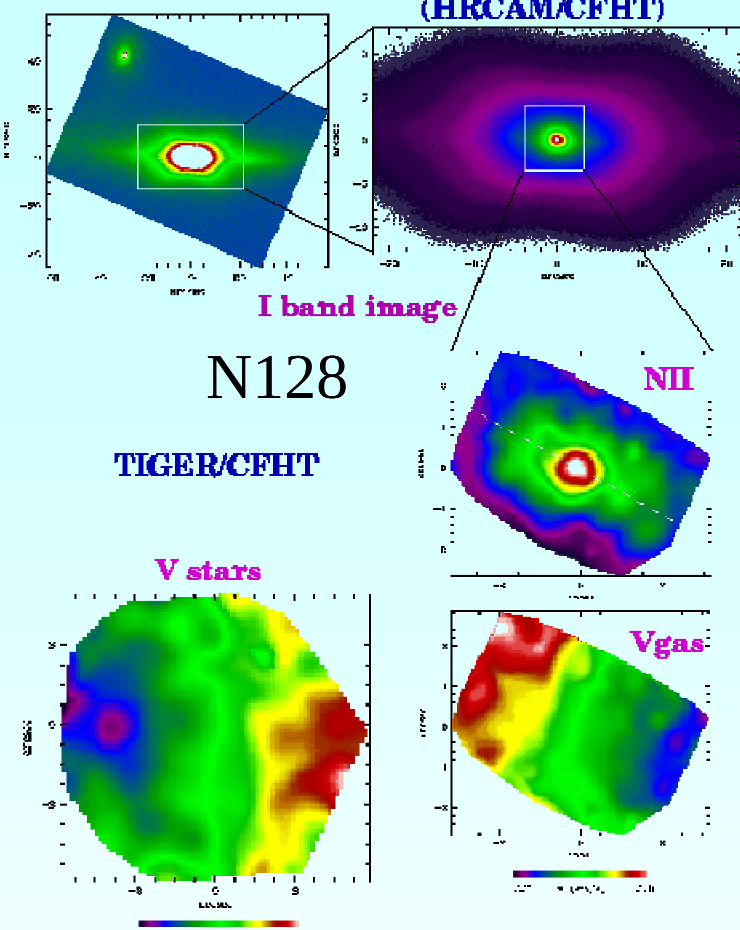
Large KDC are old, slow rotators



The small ones will fade out and not be visible after a few Gyr

McDermid et al 2006

High fraction of counter-rotating gas



Emsellem+ 97

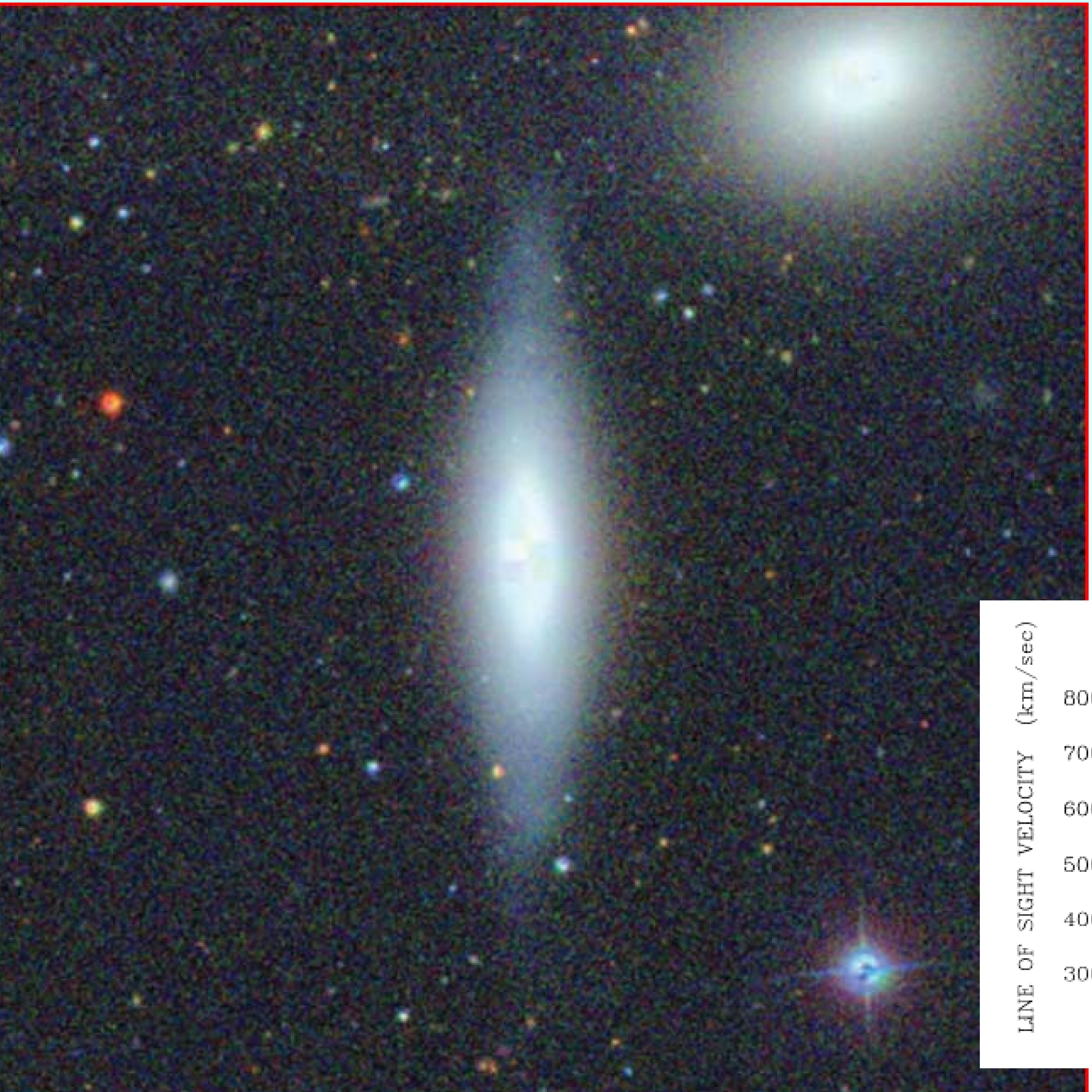
10% in late spirals
21% in S0
27% in S0 with extended ionised gas
Bureau & Cheung 2006

More in gas (24%) than in stars (10%)
Merrifield et al 1996

Counter-rotating also in dwarfs

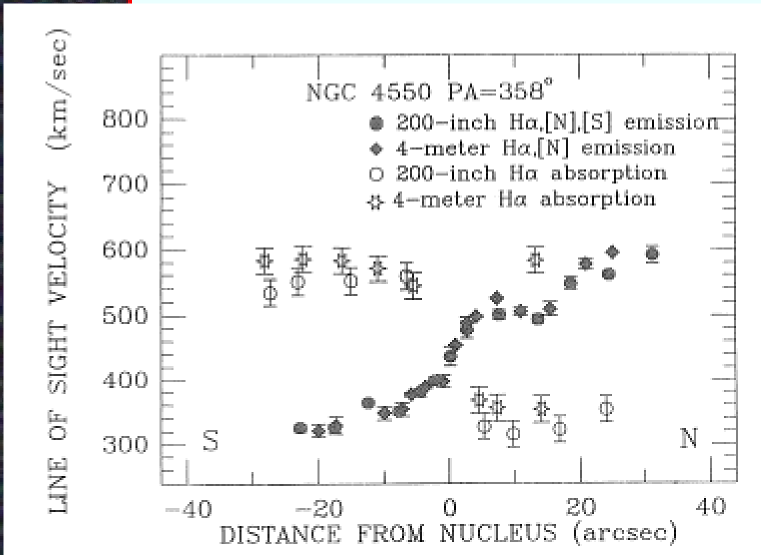
VCC 510, one of the smallest systems, *Thomas et al 2006*
Virgo cluster dE/dS0, *Chilingarian 2009*
In a cluster: Gas accretion or mergers?

NGC 4550

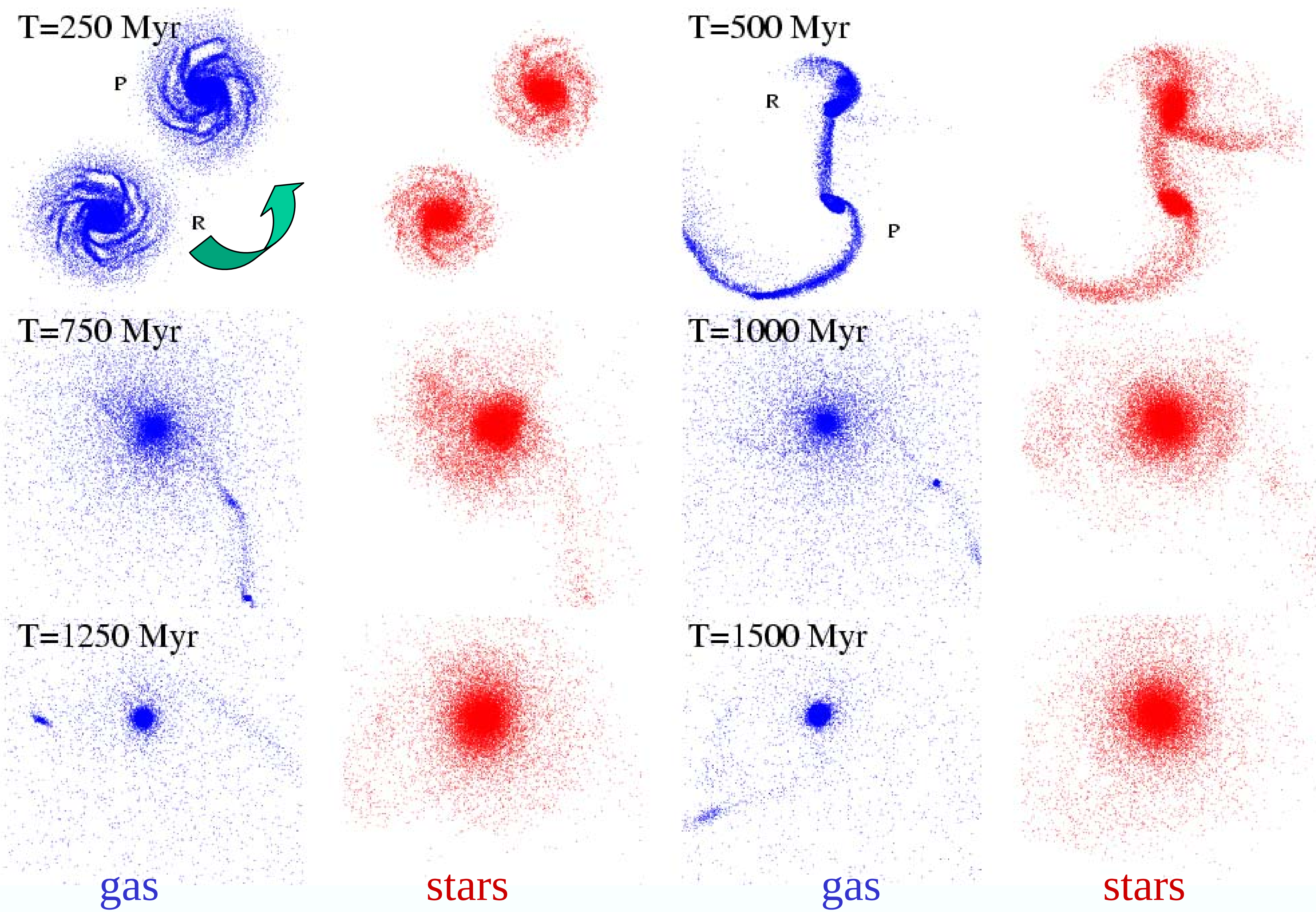


Two disks of stars, coplanar
Counter-rotating
(Rubin et al 92)

In the Virgo Cluster

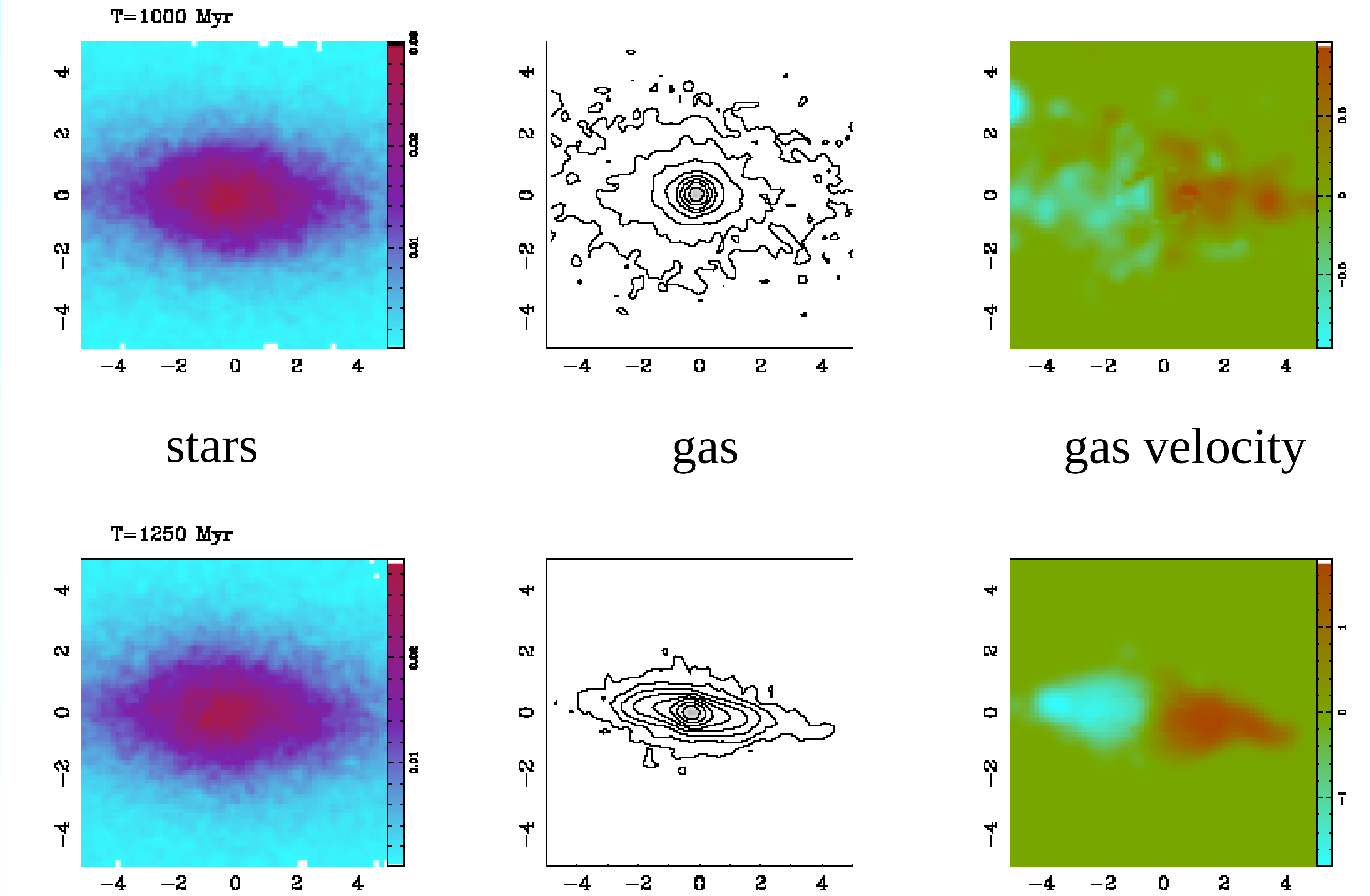


Major merger, N4550 prototype with opposite spins



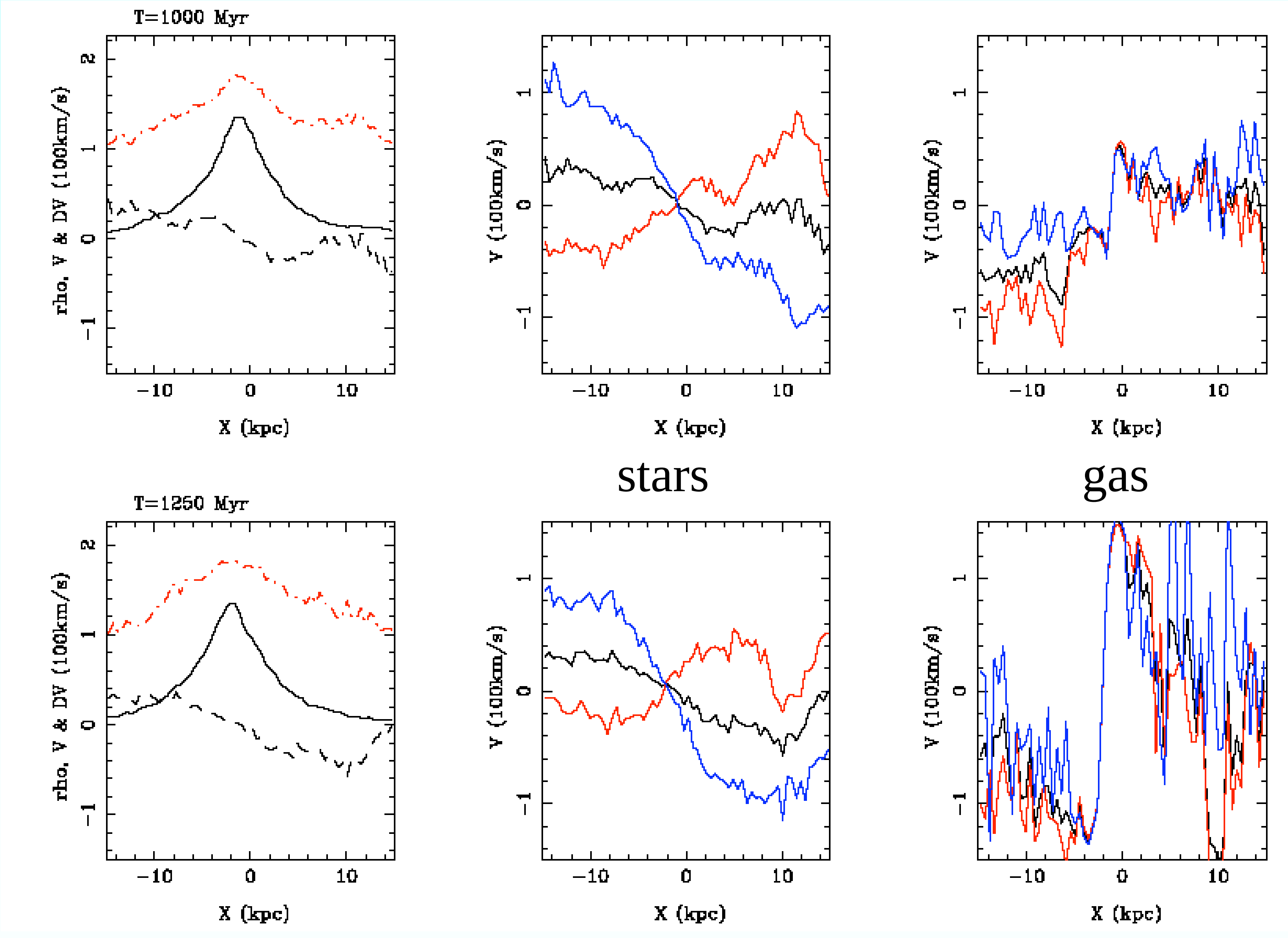
Formation of the counter-rotating disk

Gas settles in the prograde sense.

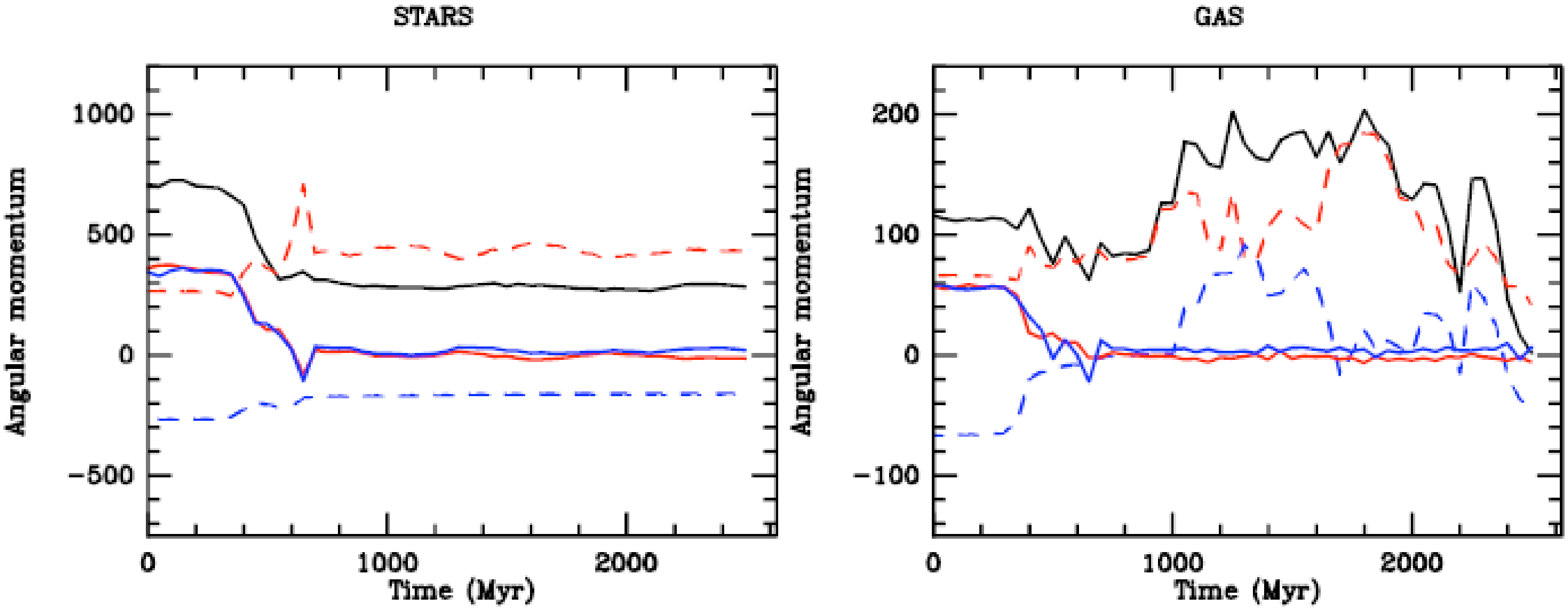


2 CR stellar disks, but only one gas rotation

Red= prograde galaxy, Blue= retrograde galaxy, Black=total



Angular momentum exchange



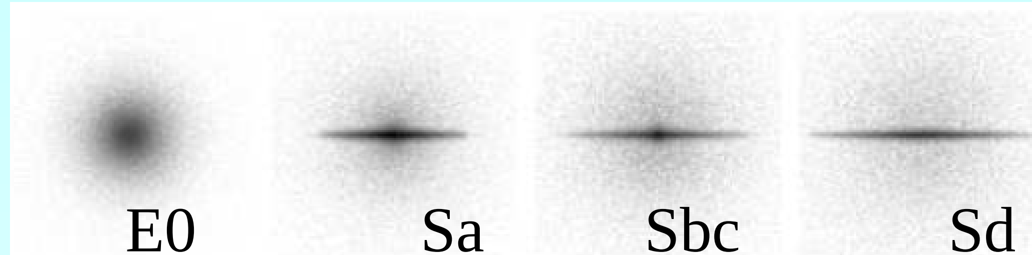
Red= prograde galaxy, Blue= retrograde galaxy, Black=total
Full lines= orbital AM, Dash lines= individual spins

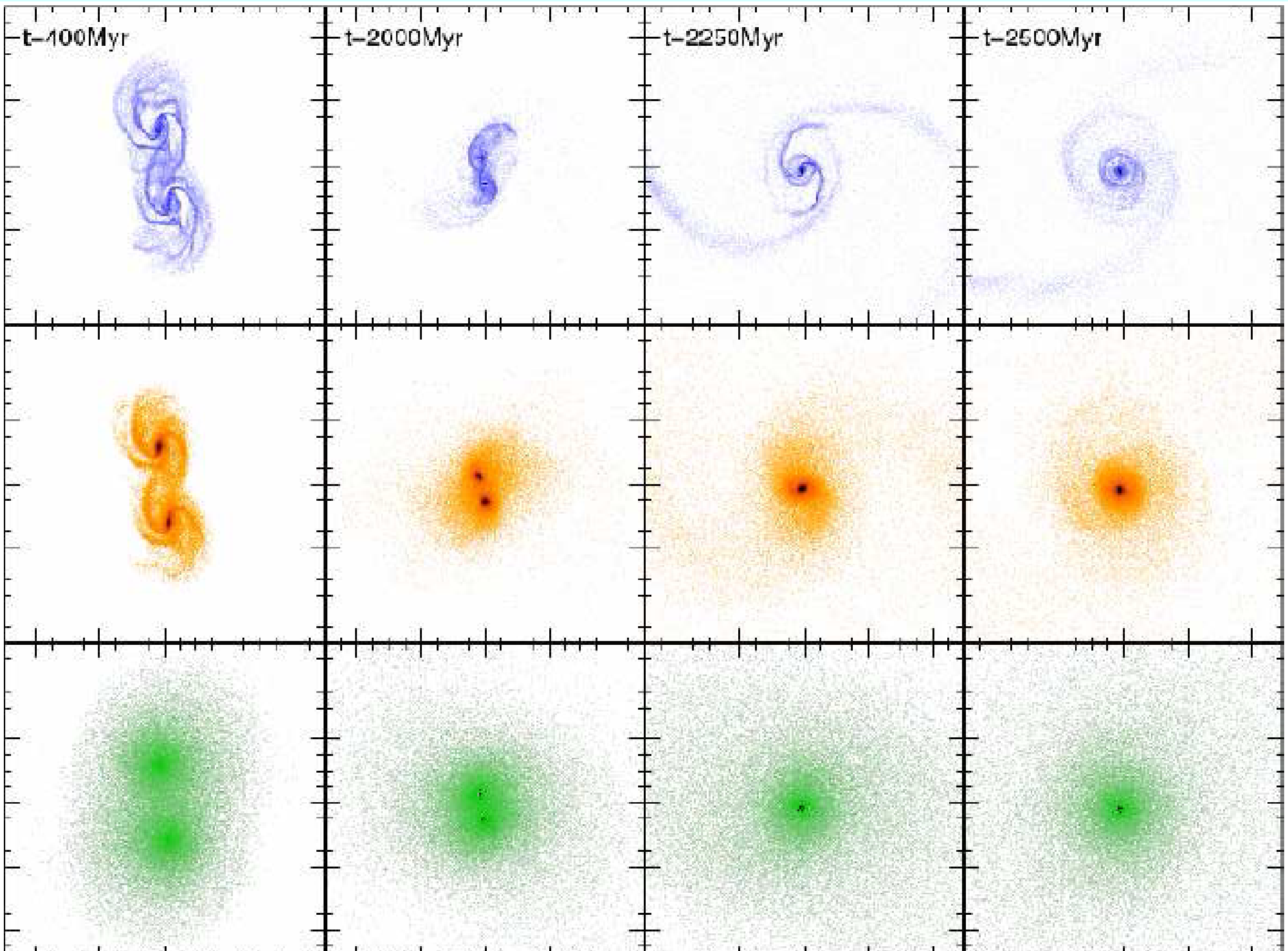
The gas settles in corotation with the thicker, more perturbed, disk
Formation of a bulge with low n ~1-2
Special geometry, of aligned or anti-aligned spins

Crocker et al 2008

A library of Galaxy Mergers

All galaxy types of
Hubble sequence





GALMER
Project
Di Matteo et al 07

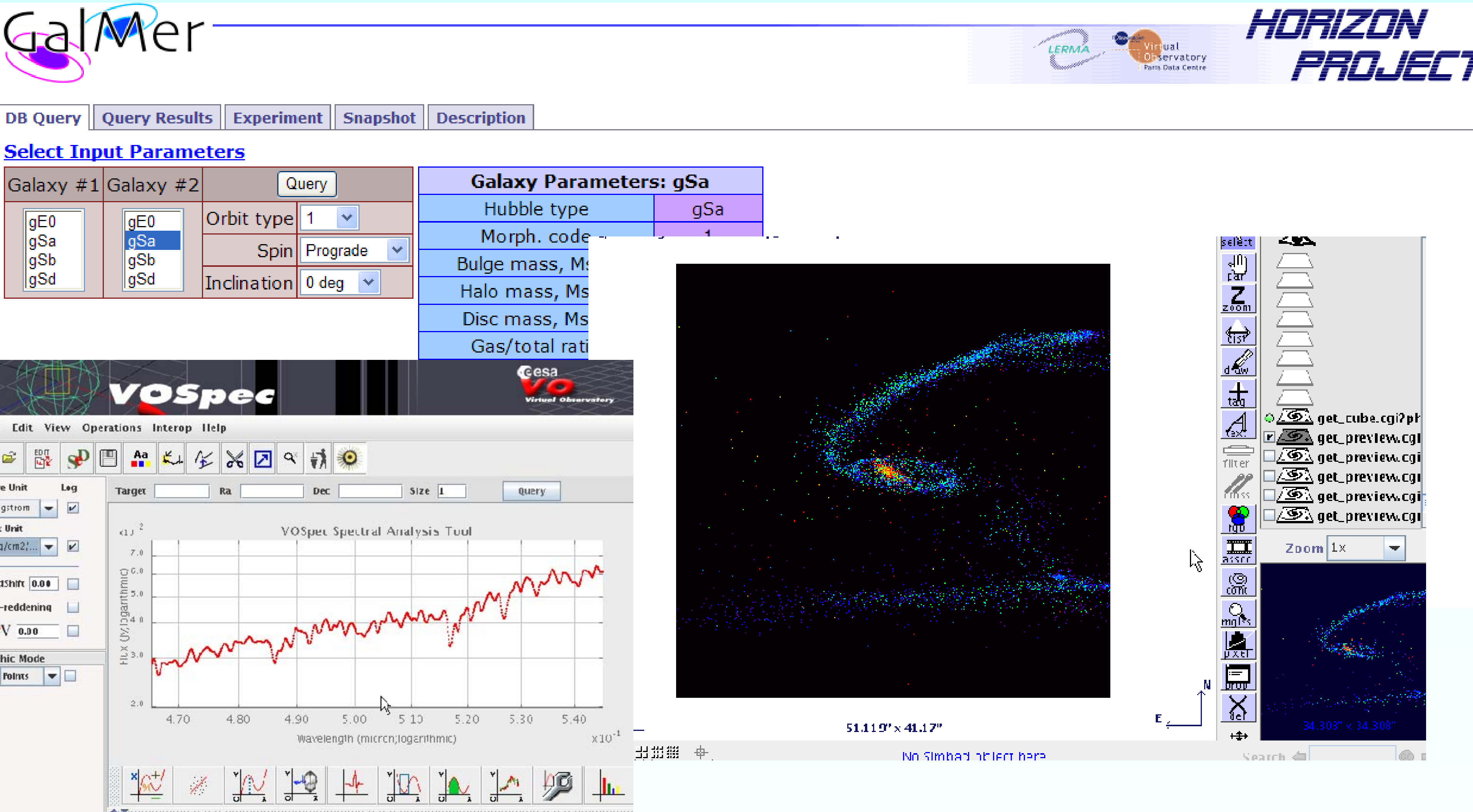
Tree-SPH
2 10^5 part
SF+ feedback

Direct orbit merger
gSb gSb

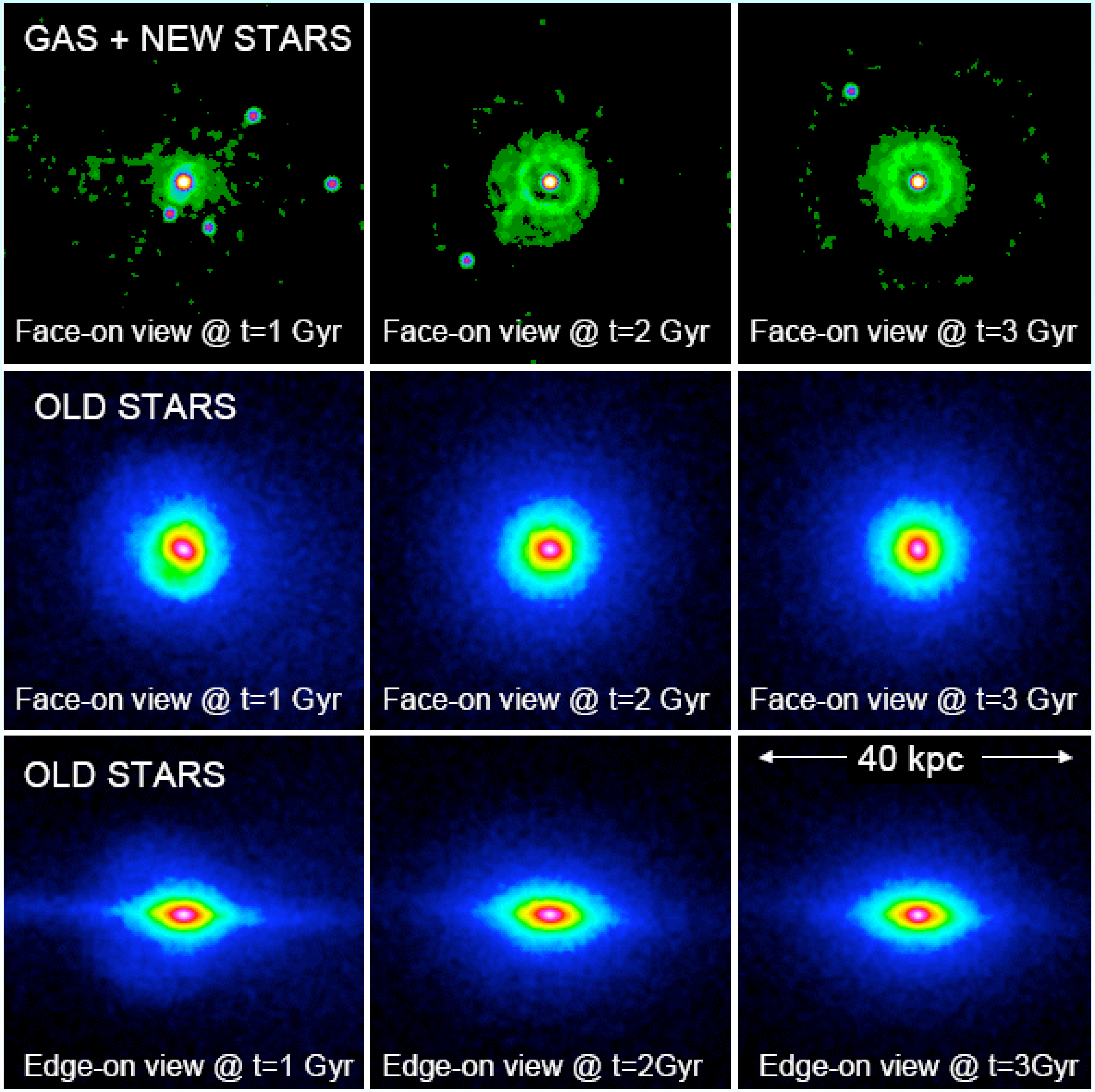
GALMER: Data base with on-the-fly computations

SED of galaxies pixel by pixel, dust, spectra, etc..

Chilingarian et al 2008 **http://galmer.obspm.fr**



Formation of Counter-rotating cores



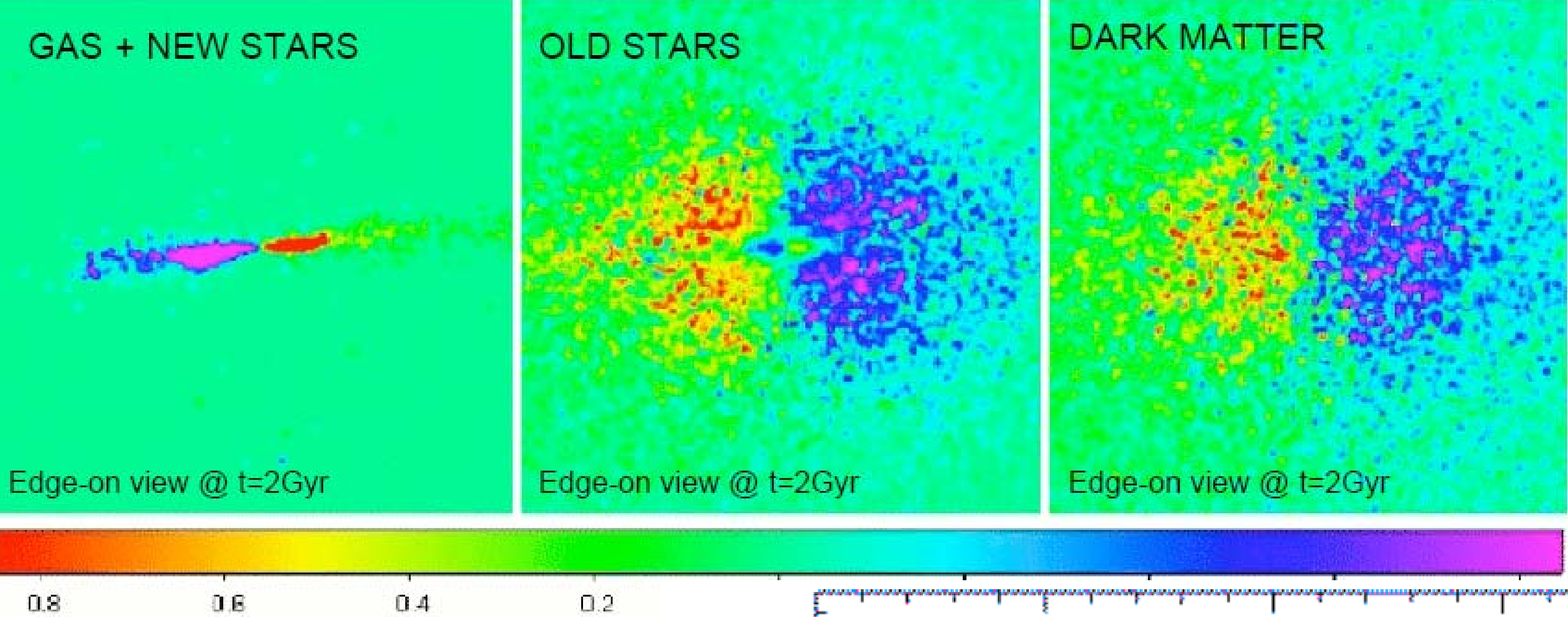
A dissipative encounter between a spiral and an E-gal

➔Retrograde orbit

Tidal forces are strong in the outer parts

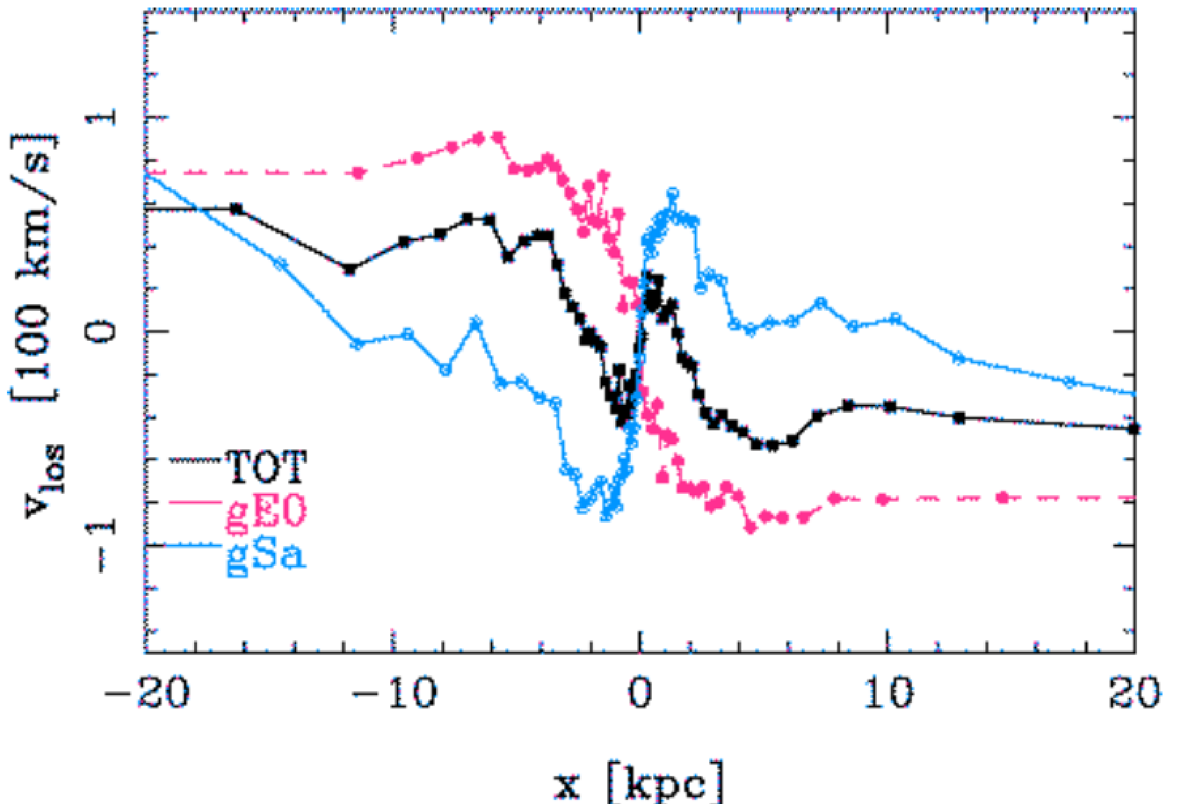
The center is unaffected
Keeps spin orientation

Effect opposite to Balcells & Gonzalez 98



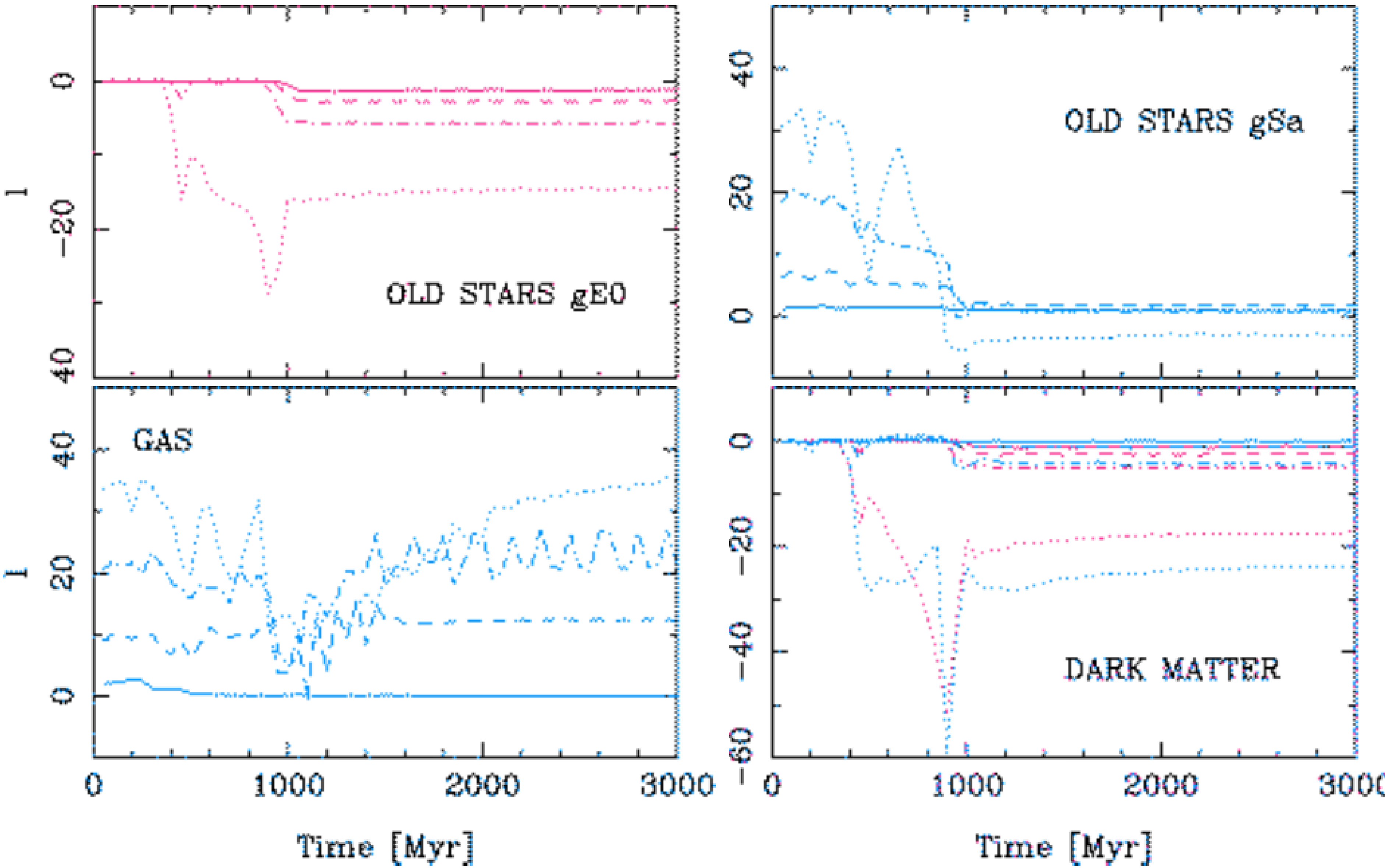
Elliptical + spiral merger

With or without gas,
Efficient mechanism



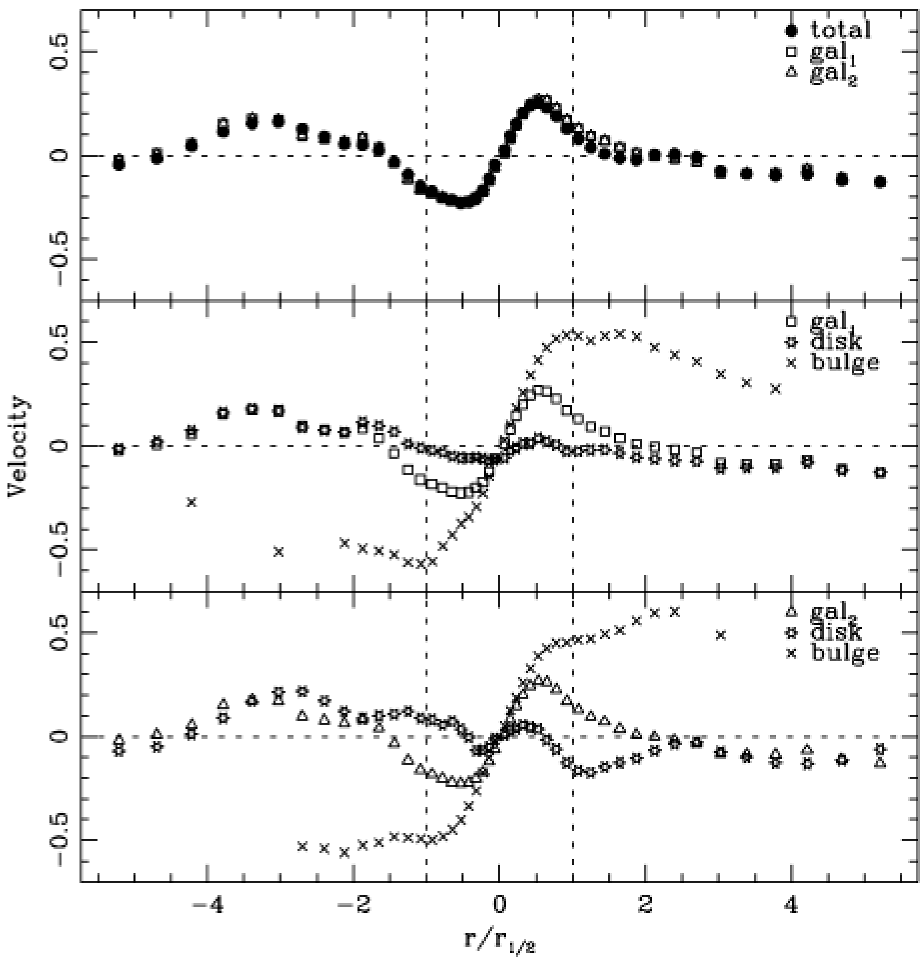
Angular momentum exchange

Solid r < 2kpc
Dash 2< r <5kpc
Dot-dash 5<r<10
Dots r>10kpc



Other mechanisms to form KDC

Balcells & Gonzalez 98: ➔**Stellar spiral-spiral mergers**



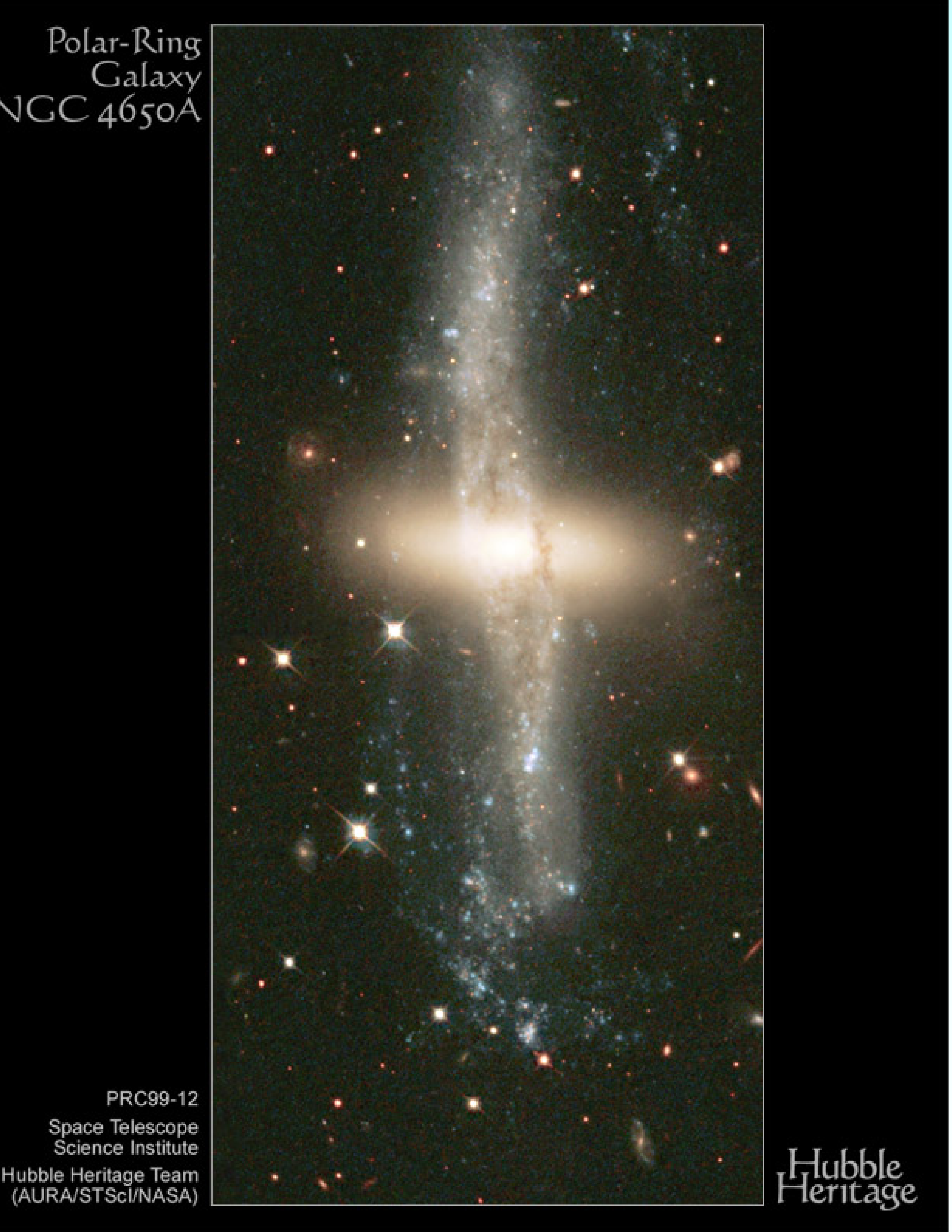
Bulges drag the orbital spin inside

While the outer parts keep the precursor internal spins
Both disks rotate opposite to orbit

➔Merger between 2 gas-rich spirals
NGC 7252 type

CR * disk built afterwards, from gas

Return of tidal material
Hernquist & Barnes 1991
Hibbard & Mihos 1995



Formation of Polar rings

Either by galaxy merger with perpendicular J

Or by gas accretion in the outer parts

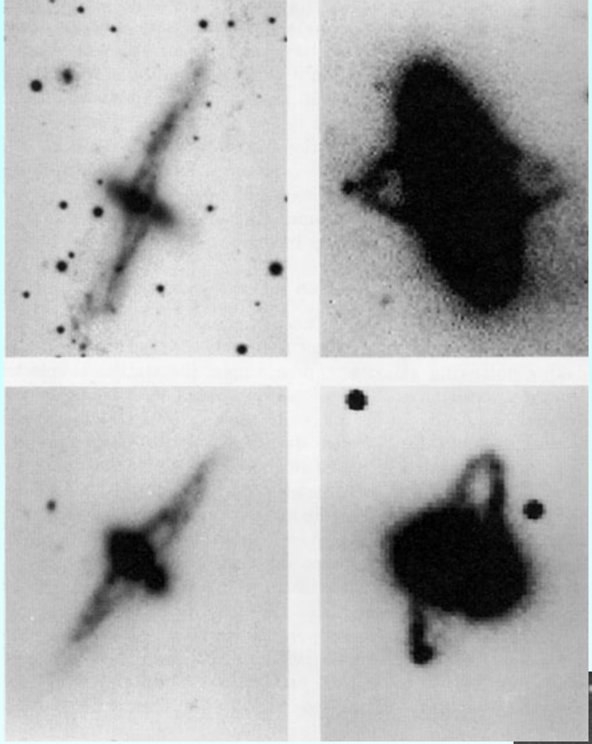
3D shaped of the dark matter?

Formation of Polar Rings

By accretion?

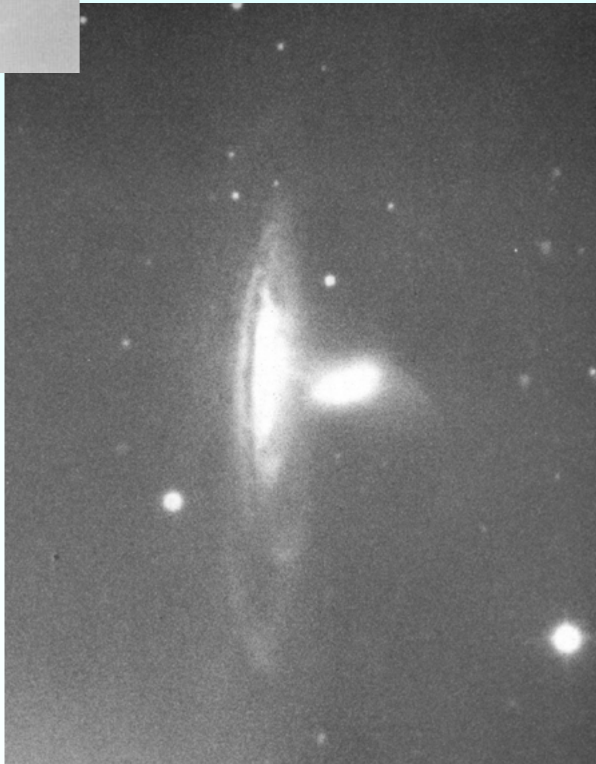
Schweizer et al 83

Reshetnikov et al 97

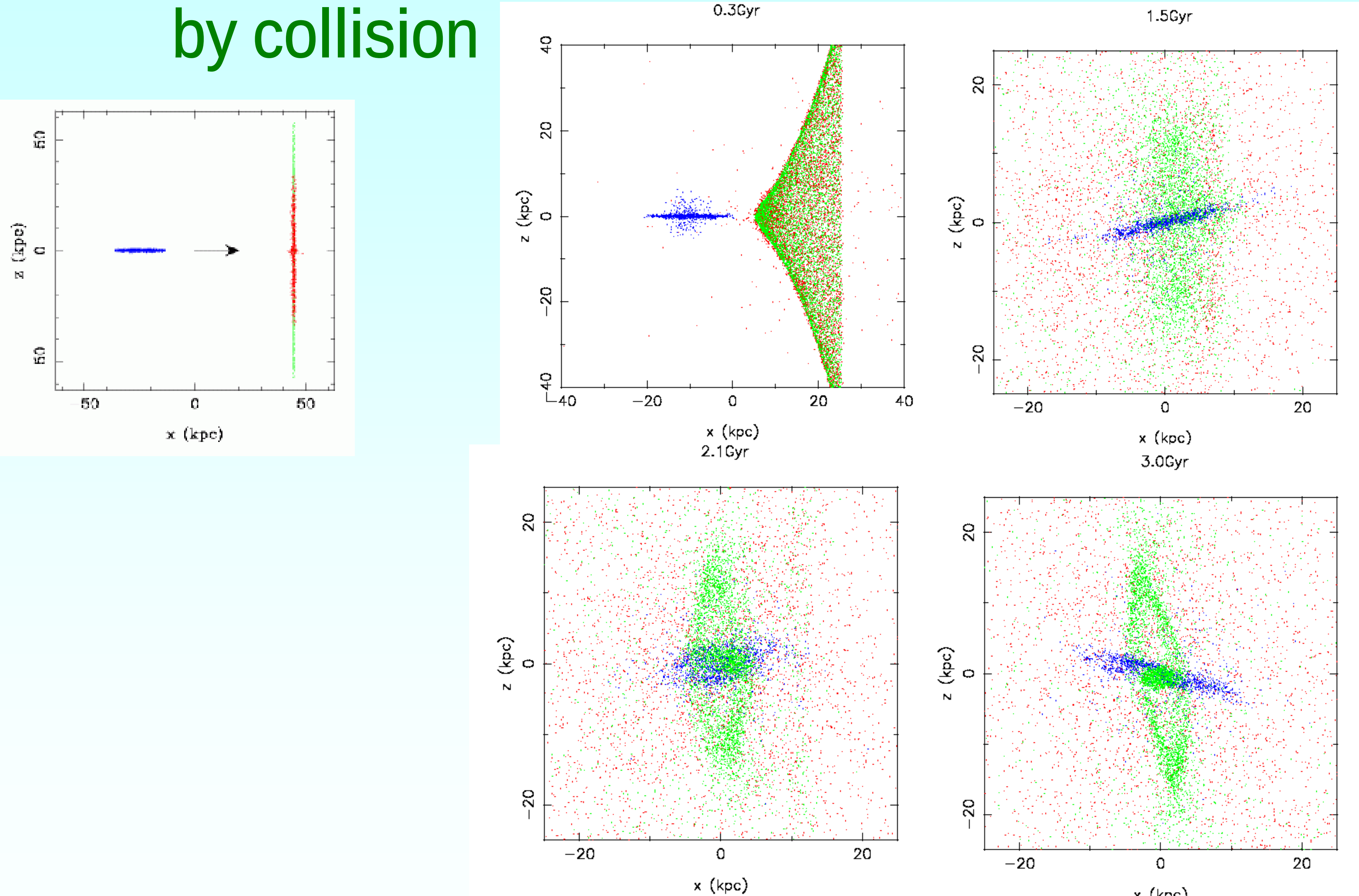


By collision?

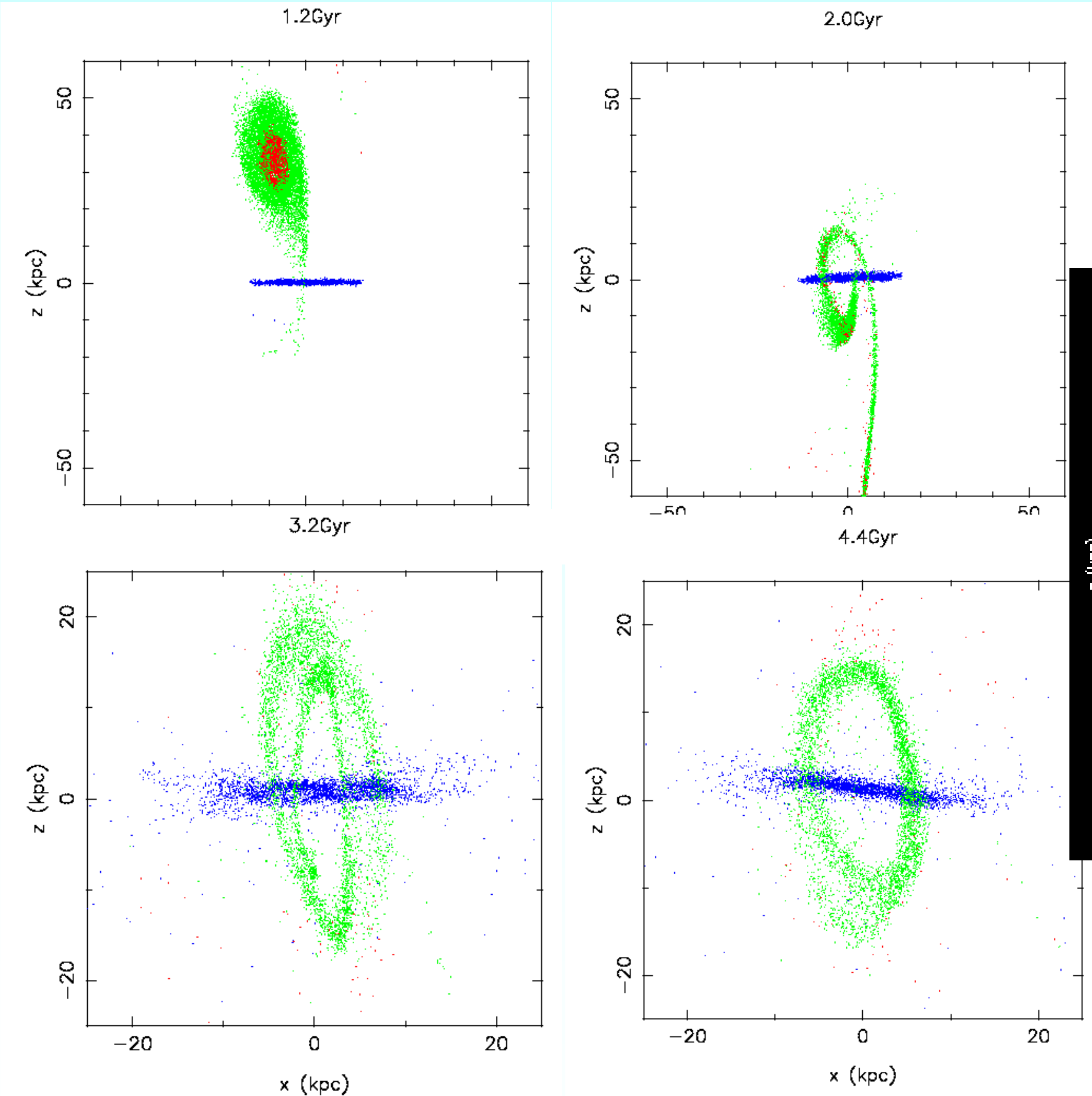
Bekki 97, 98

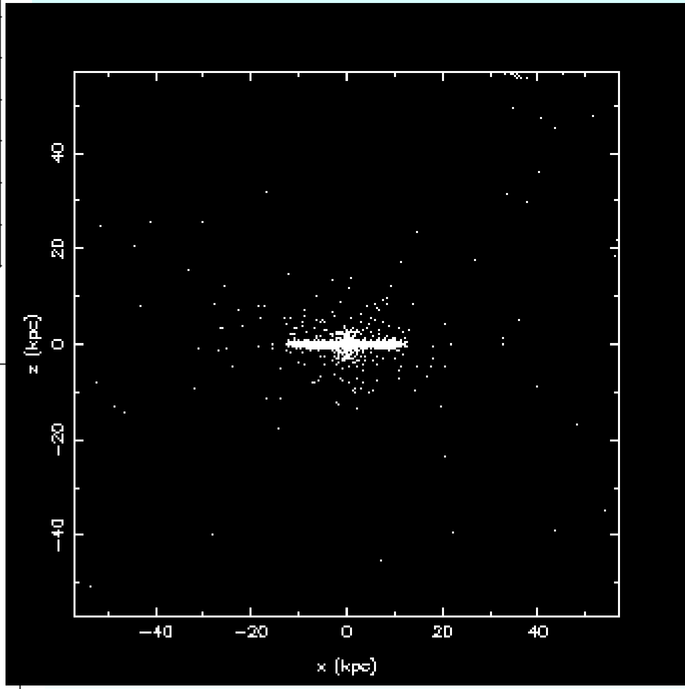


Formation of PRG by collision



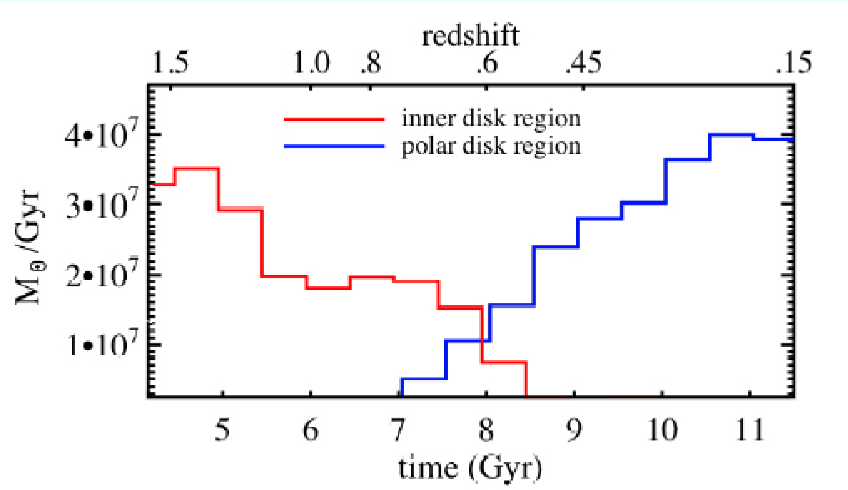
Formation of PRG by accretion



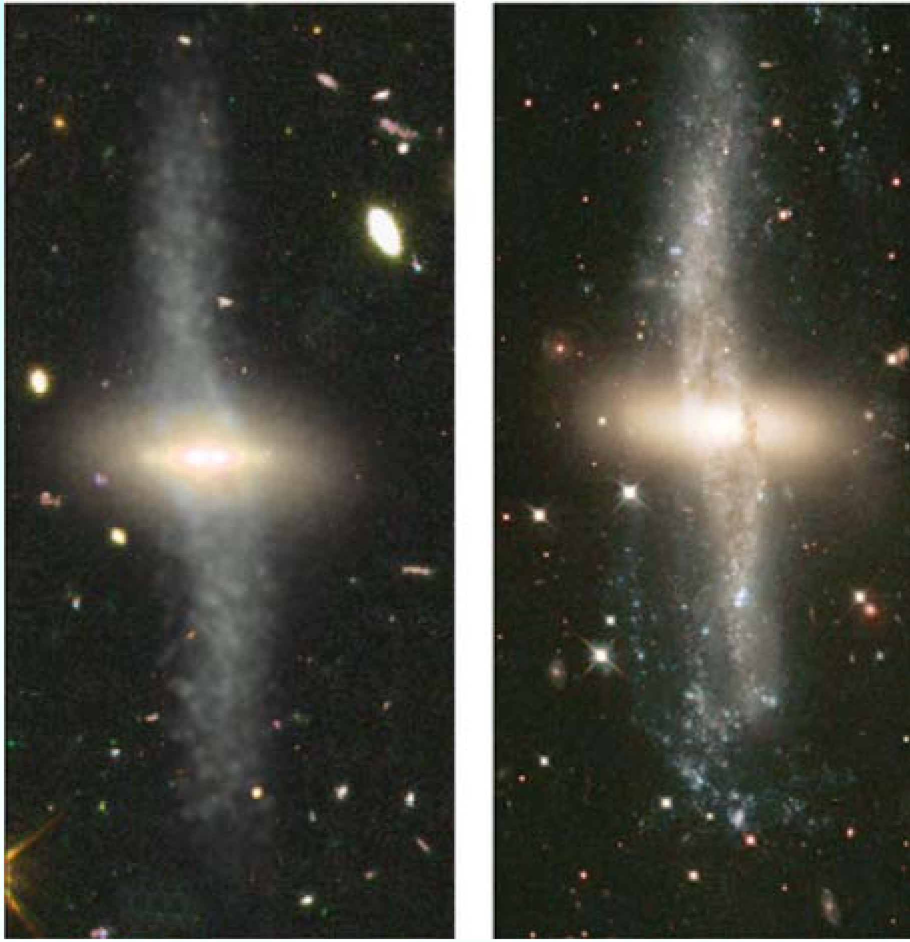


Bournaud & Combes 2003

Polar rings from cosmic gas accretion

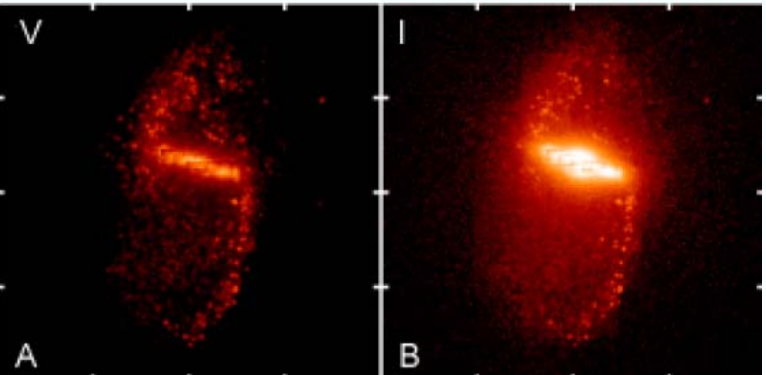


Brook et al 2008



➔After 1.5 Gyr, interaction between the two disks destroys the PRG

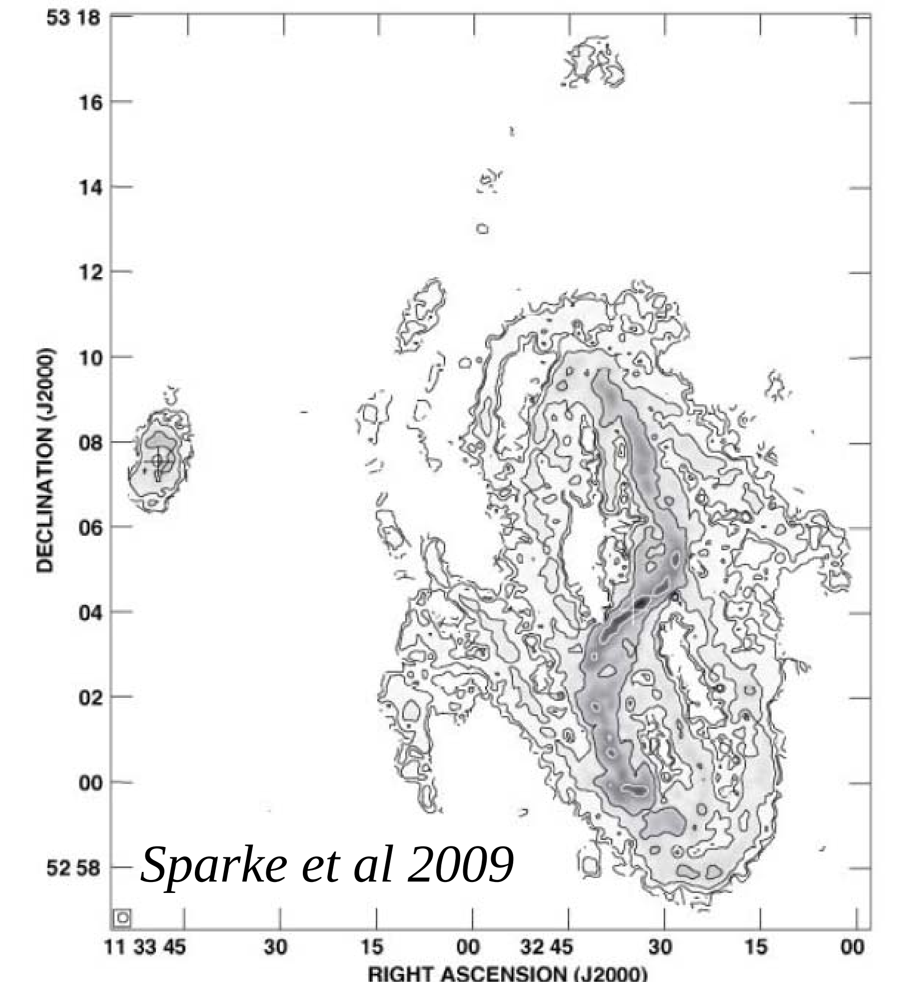
➔Velocity curve about the same in both equatorial and polar planes



NGC 3718, face-on spiral + Polar ring

HI until 42kpc, symmetric to 35kpc where period is 1 Gyr

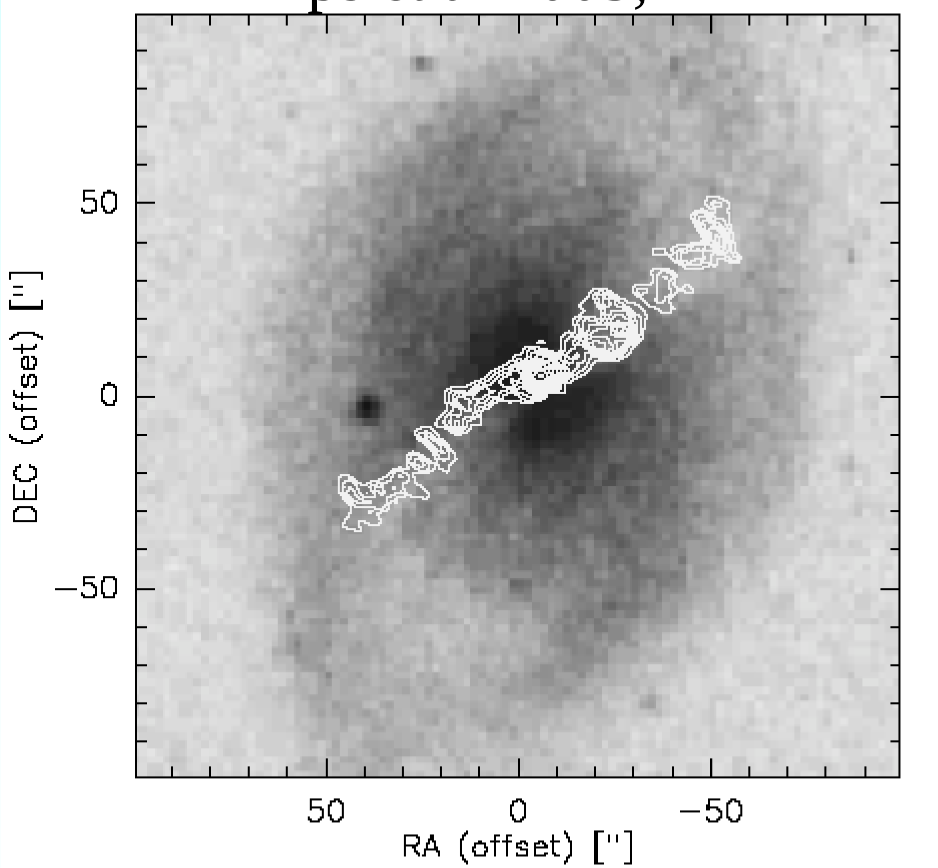
Tilt with radius➔ precess rigidly



Formation of the N3718 ring?

Gas still accreting at 60kpc, and young stars form in this accreted gas
In the symmetrical part, must be lasting since 2-3 Gyr
Swing of the gas of 100° Polar at the center, and going
towards the plane, 25°

Krips et al 2005, IRAM



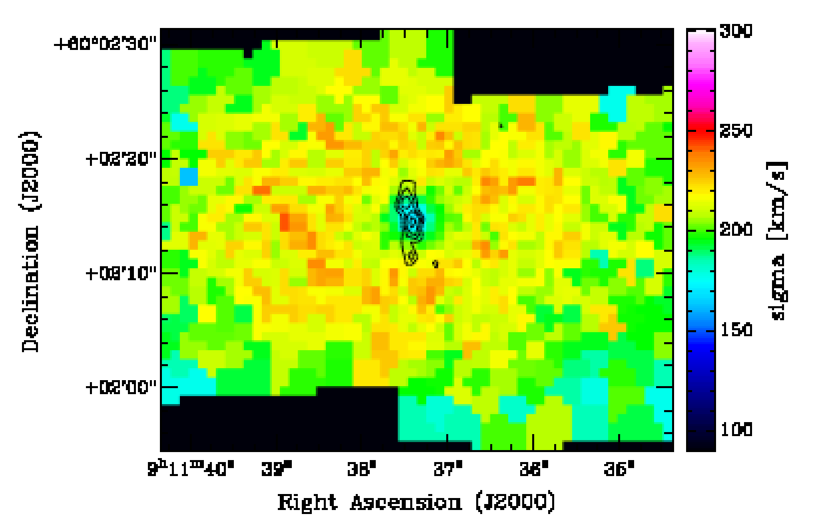
Line of nodes twists by 90°
In the plane of the face-on spiral

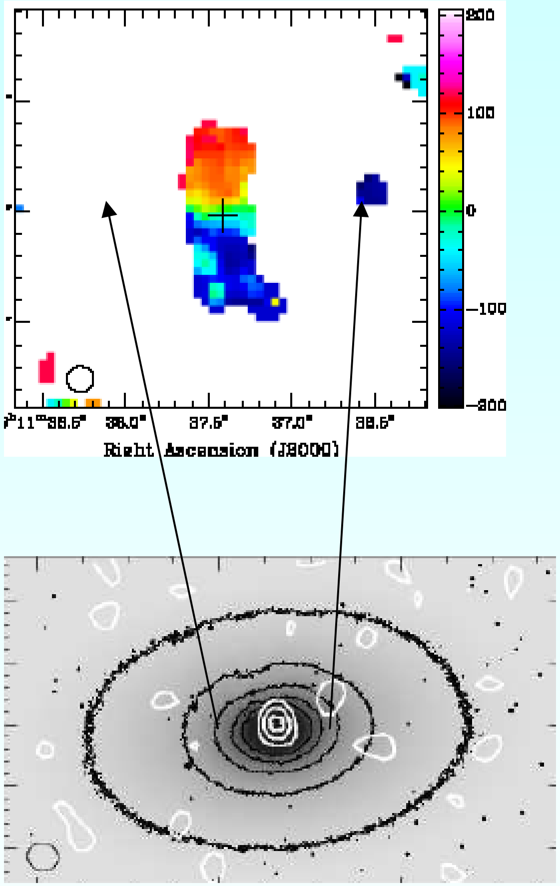
Compatible with a round DM halo,
And differential precession
With self-gravity of the disk

Torques balanced by self-g
➔Explains the longevity

NGC 2768: molecular polar disk

Crocker et al 2008





CO(2-1) map superposed
on the velocity dispersion map
of the stellar component

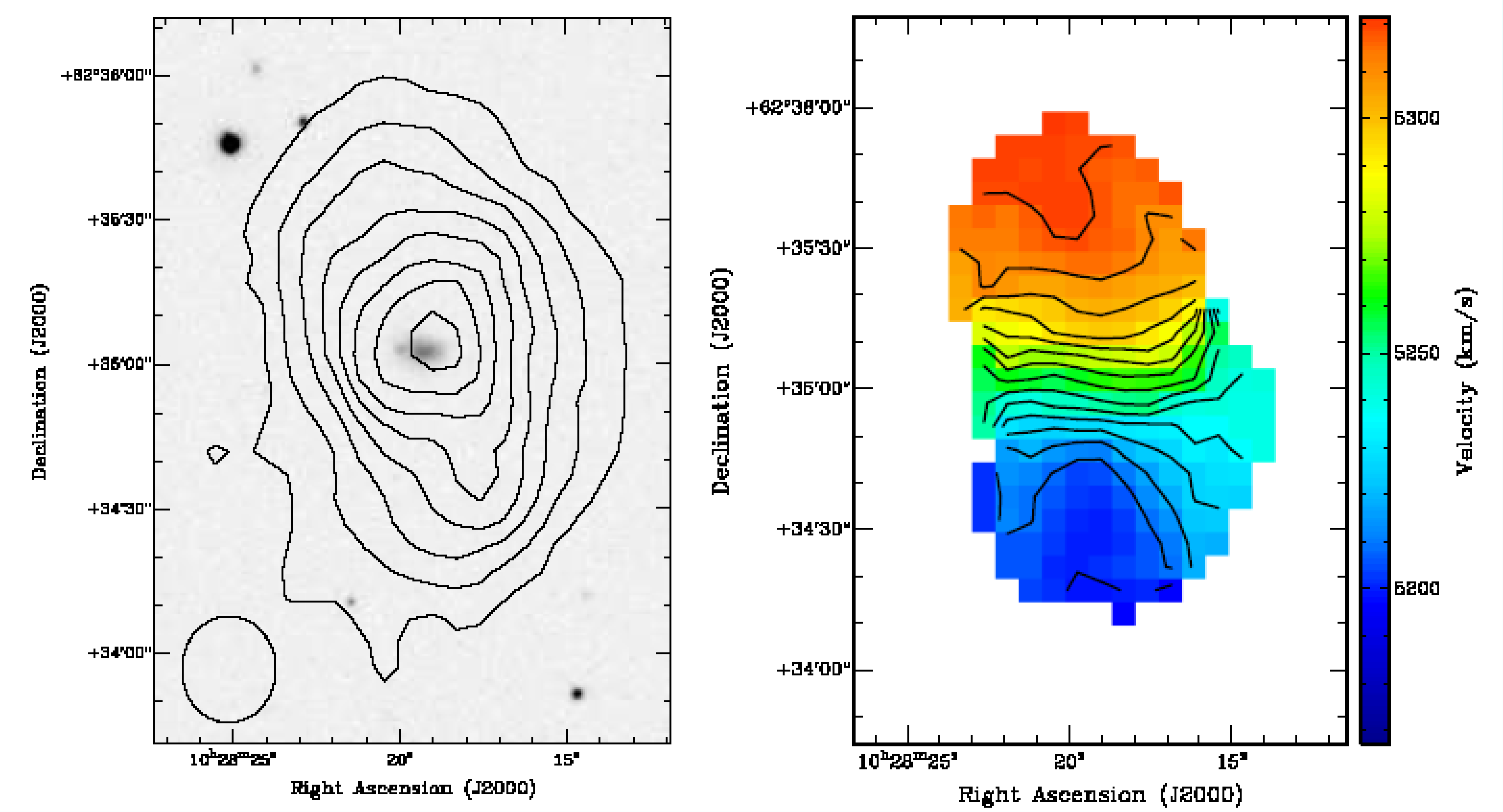
The polar CO disk corresponds to
a sigma-drop

Polar disk accreted from filaments

HI polar disk, with no optical counterpart, must be recent accretion

Mass of HI, equivalent of mass of stars in the normal disk

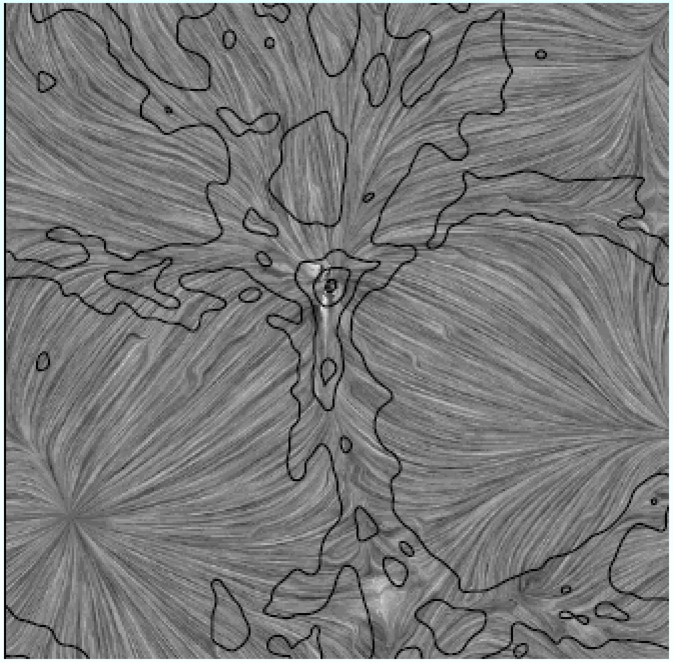
Stanonik et al 2009



Galaxy aligned along a wall between voids

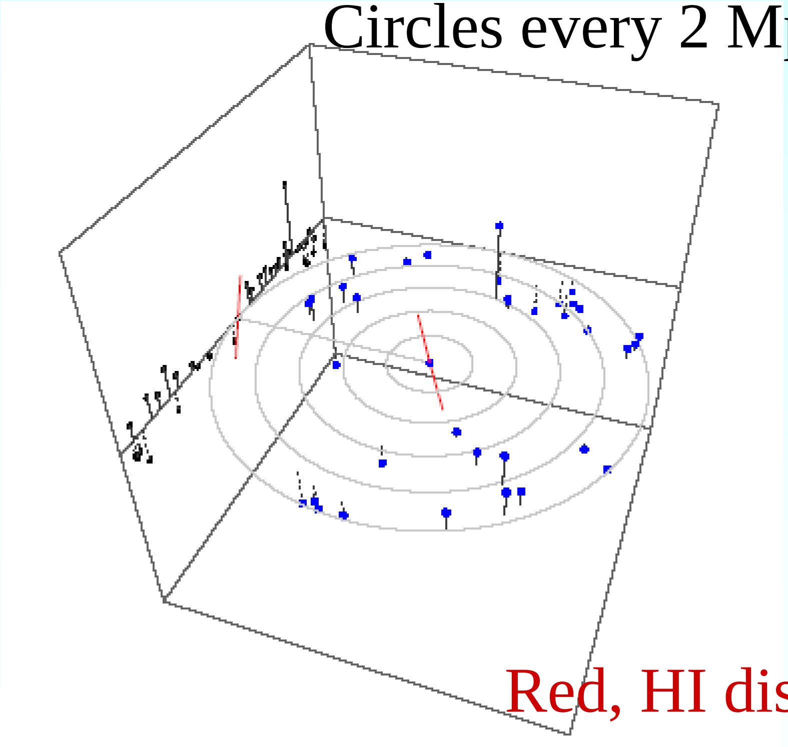
Gas from the cosmic filaments flowing to the wall, and perpendicular to it

➔ Formation of the gaseous polar disk



Up to 10 Mpc

Circles every 2 Mpc

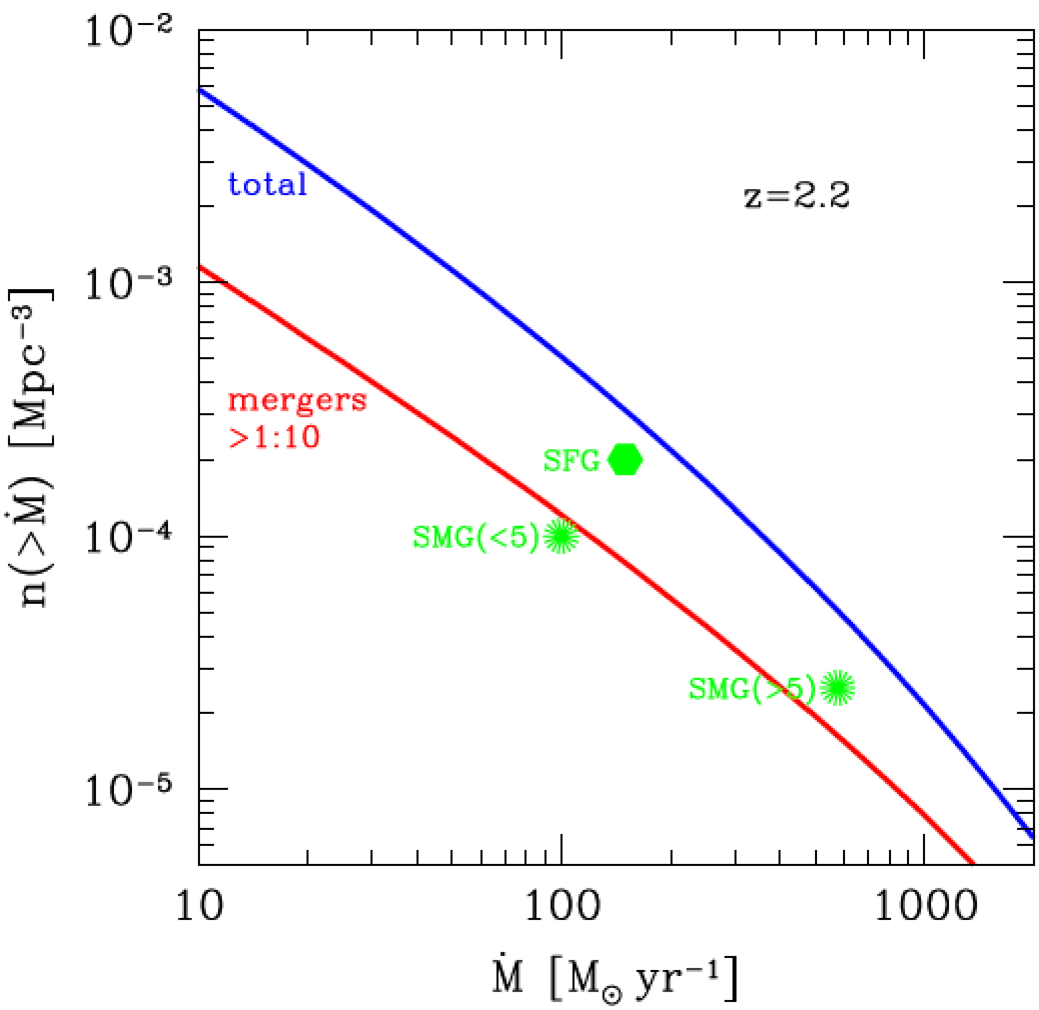


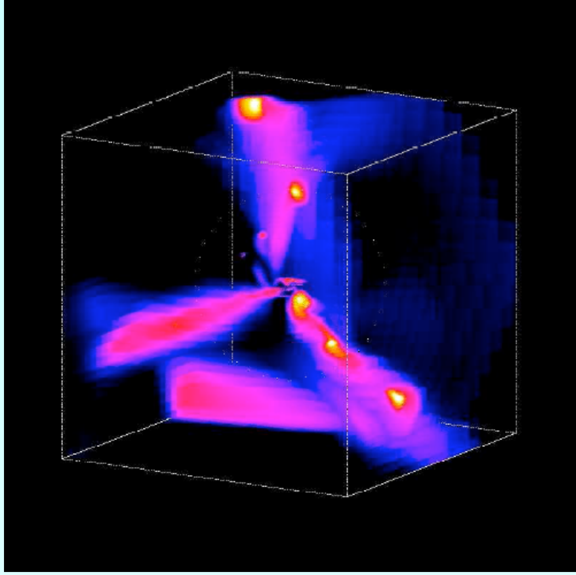
Red, HI disk

Stanonik et al 2009

Relative role of gas accretion and mergers

Dekel et al (2008)





Analysis of results from a cosmological simulation with gas and SF (Horizon) shows that most of the starburst are due to smooth flows

Inflow rates are sufficient to assemble galaxy mass (10-100 Mo/yr)

Conclusion

The fraction of systems seen with kinematically decoupled components can yield clues in the formation mechanisms

➔Cannot be monolithic collapse

➔But Hierachical Scenario:
either collisionless (dry mergers)
or dissipative (hydrodynamics)

➔Or large external accretion, from filaments with changing orientations, and angular momentum