Evolution of Galaxies

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Lambda-CDM

- Describes the large scale structure in galaxy distribution.
- Clustering and merging is how galaxies gain in mass.
- Also affects shape and structure.

Dynamical Evolution

Dynamical Relaxation

- Aside from periodic bars and spiral patterns, gravitational potential in galaxies appears to be changing slowly over time.

$$\varepsilon = \frac{1}{2} m\vec{v} + m\vec{v} \cdot \nabla\phi(\vec{x}) = 0$$

- This equation tells us a star's energy is almost constant along its orbit (eqn. 3.27)

Dynamical Relaxation

- While the galaxy was forming the potential at any point would swing up and down by large amounts.
- This changes the stars energy.
- Stars mix among various orbits giving them equal random motions in all directions

- N-body projections of galaxy distribution.
- a) initial state
- b) An irregular distribution with subclustering
- c) A bimodal distribution in the cluster
- d) The final relaxed configuration

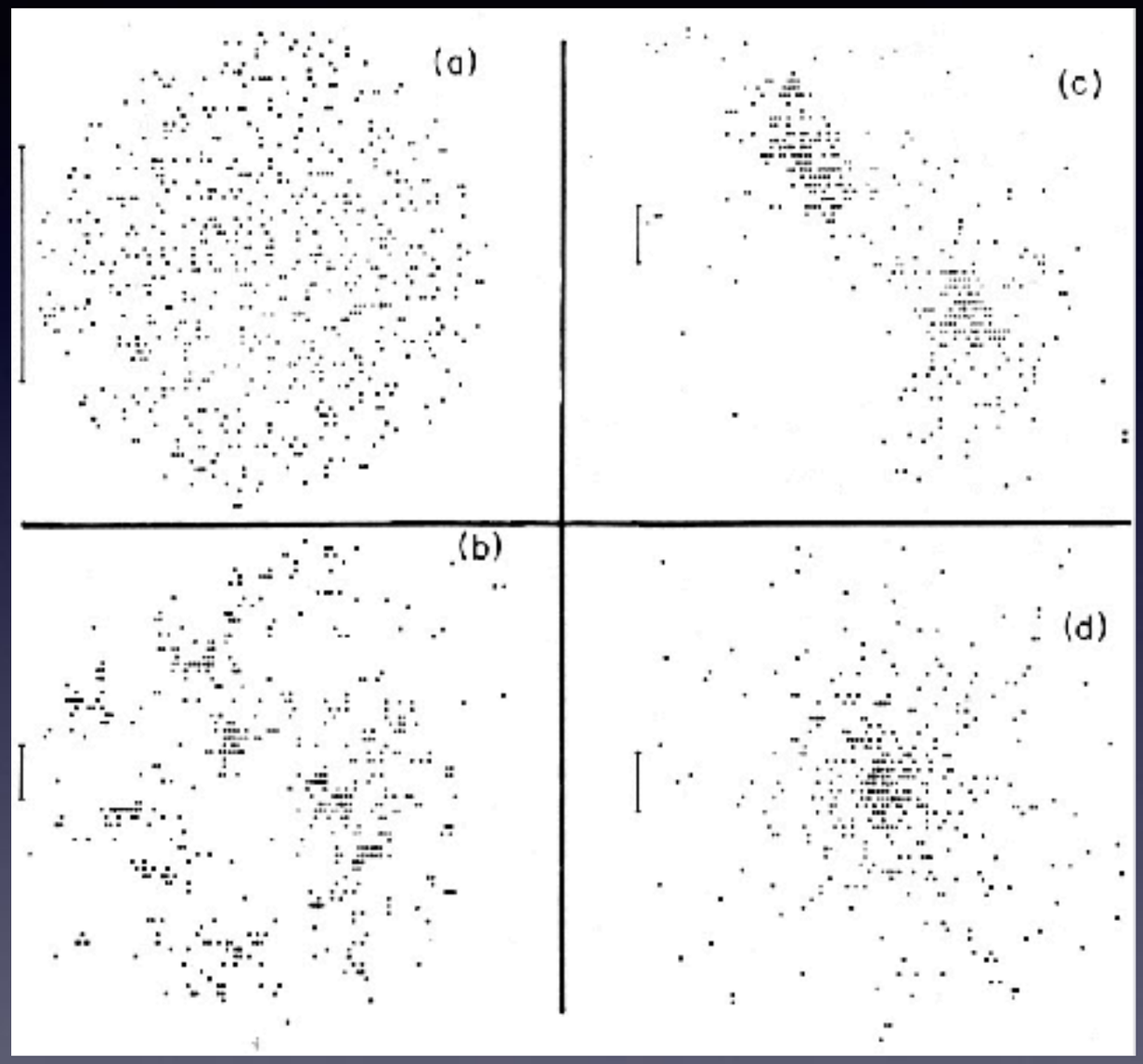


Image from NED

Star Formation Rate

- There are Two modes of star formation in galaxies.
- Main Sequence
- Starburst Galaxies

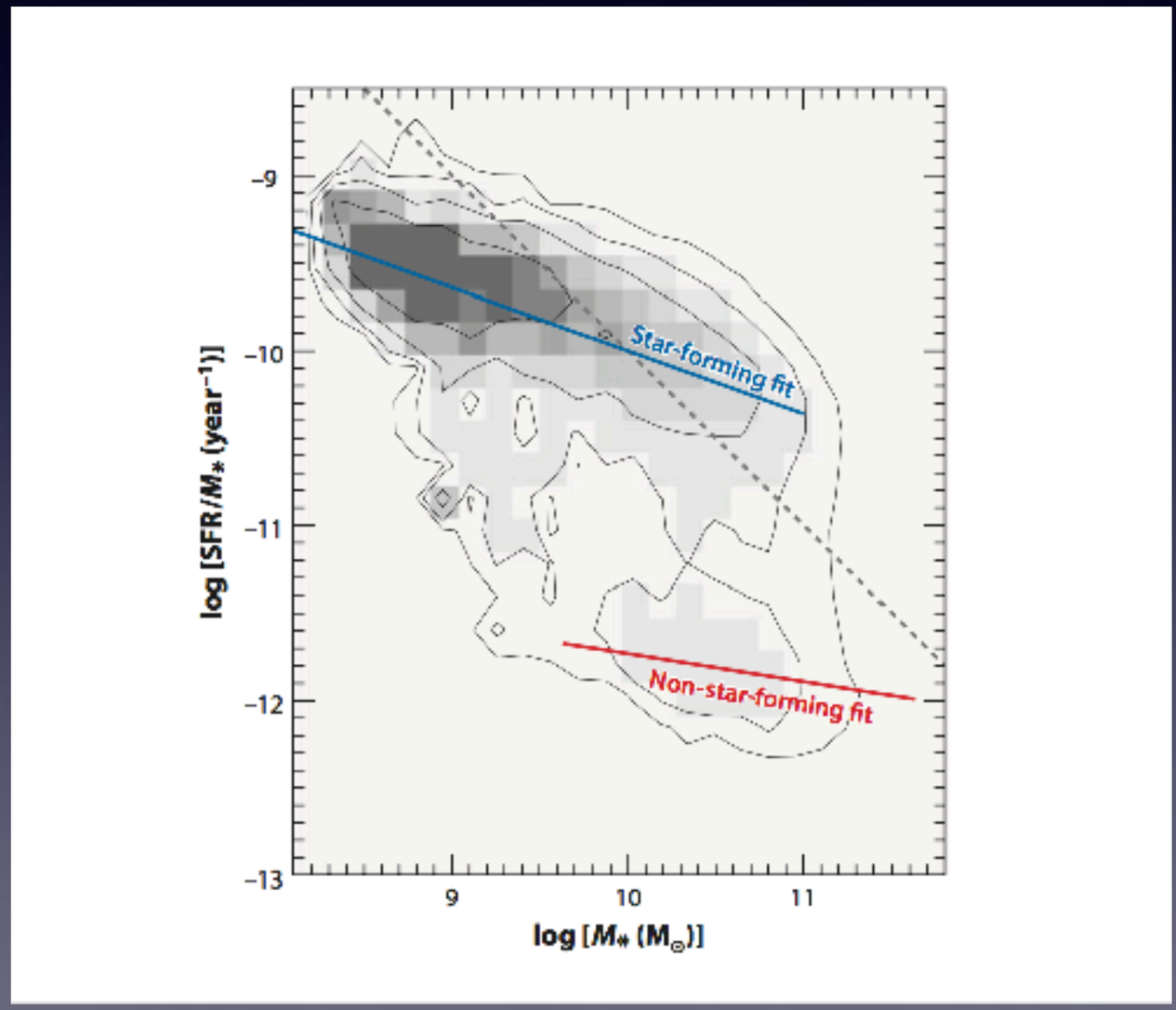
Starburst Galaxies

- Starburst Galaxy: A galaxy undergoing an exceptionally high rate of star formation compared to the long term average

The Antennae Galaxies

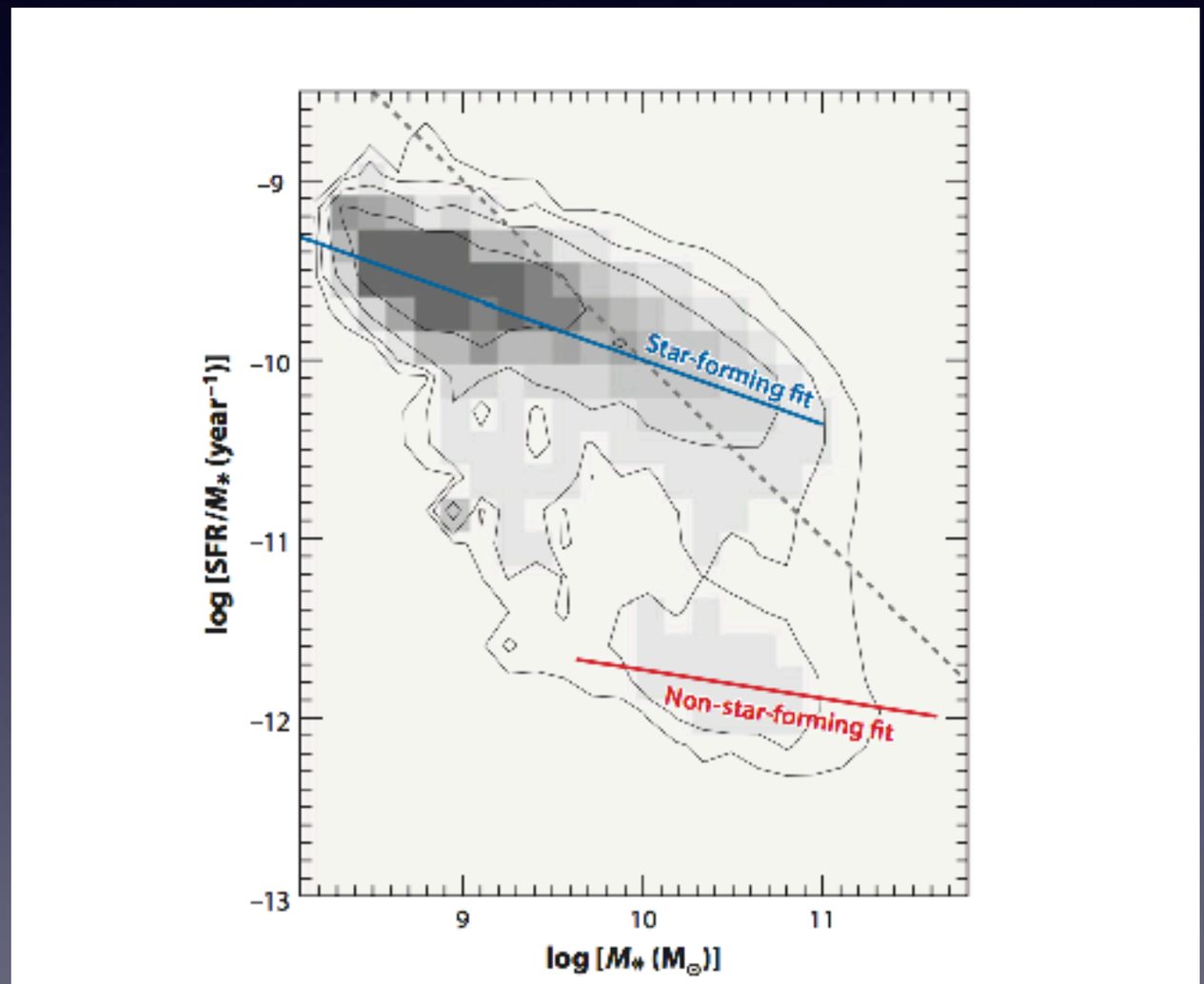
Main Sequence

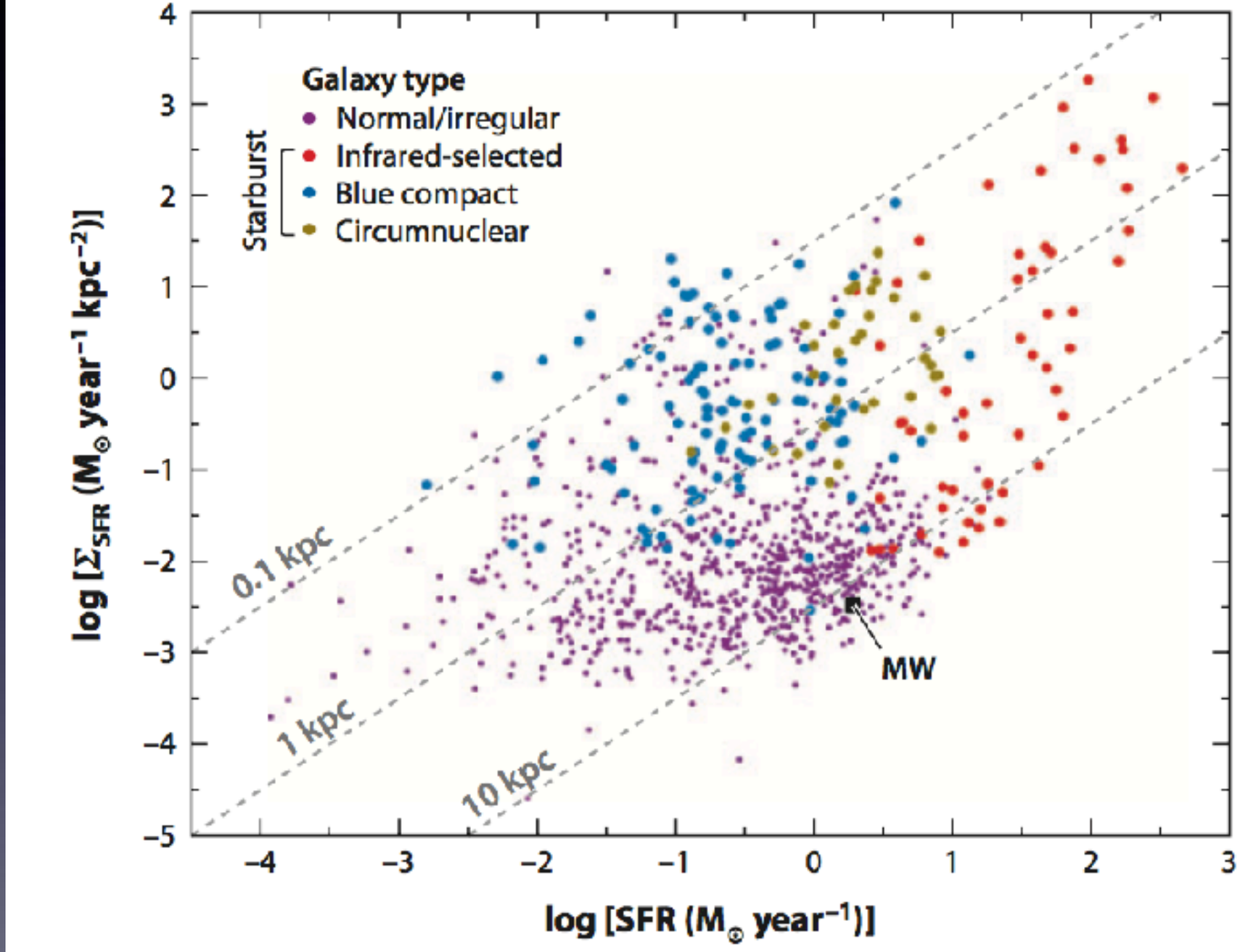
- Blue Cloud
- Red & Dead Sequence
- Green Valley



Downsizing

- SFR's can be seen to be higher in lower mass galaxies.
- Gradually migrated over time from more massive to less massive galaxies.

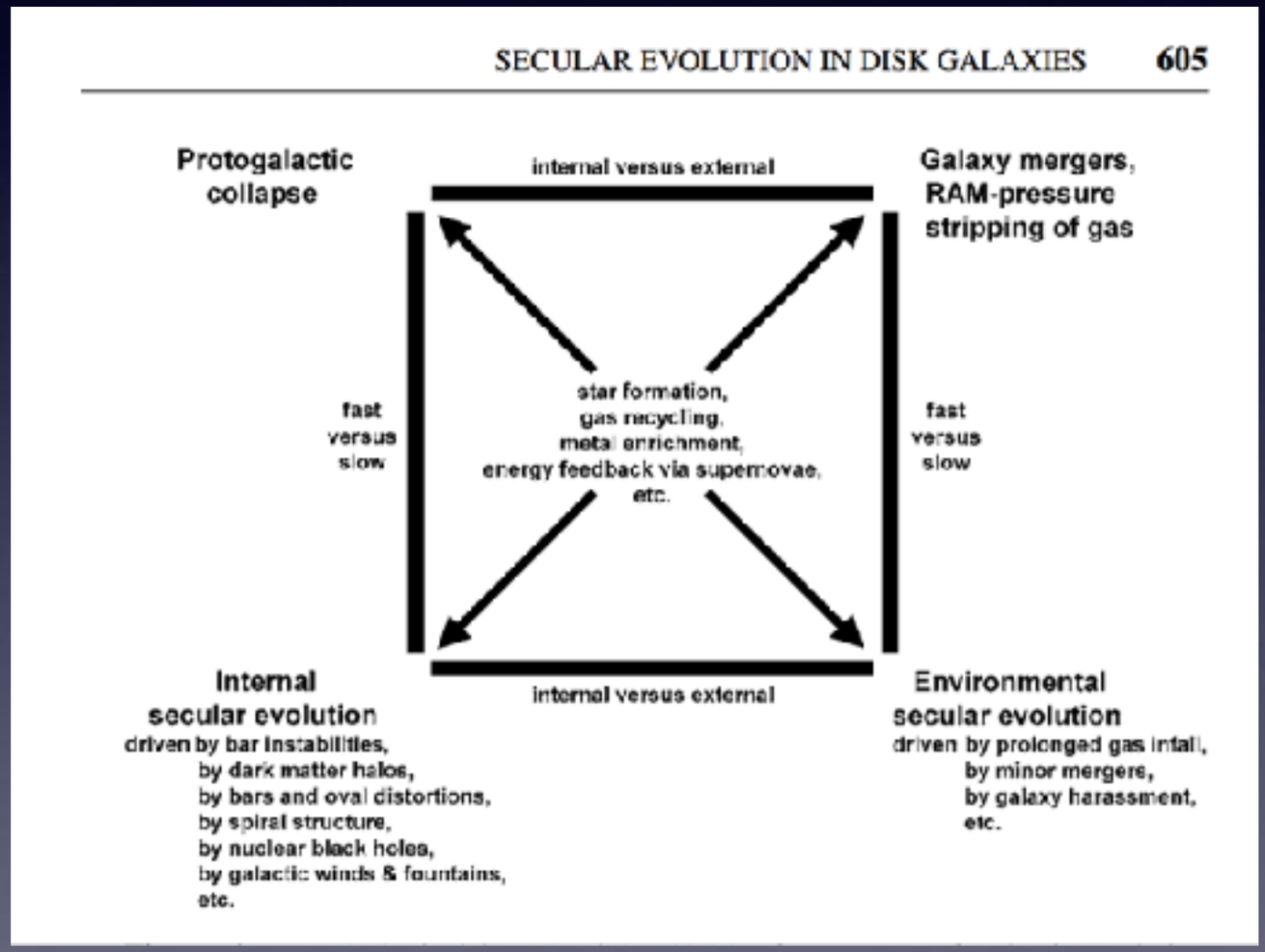



Galaxy type
Normal/irregular
Infrared-selected
Blue compact
Circumnuclear
Starburst
0.1 kpc
1 kpc
10 kpc
MW
log [Σ_{SFR} ($M_\odot$ year^{-1} kpc^{-2})]
log [SFR ($M_\odot$ year^{-1})]
4
3
2
1
0
−1
−2
−3
−4
−5
−4
−3
−2
−1
0
1
2
3

Secular Evolution

- Previously the dominant evolution was hierarchical clustering, and merging.

- In the future the evolution will become secular.



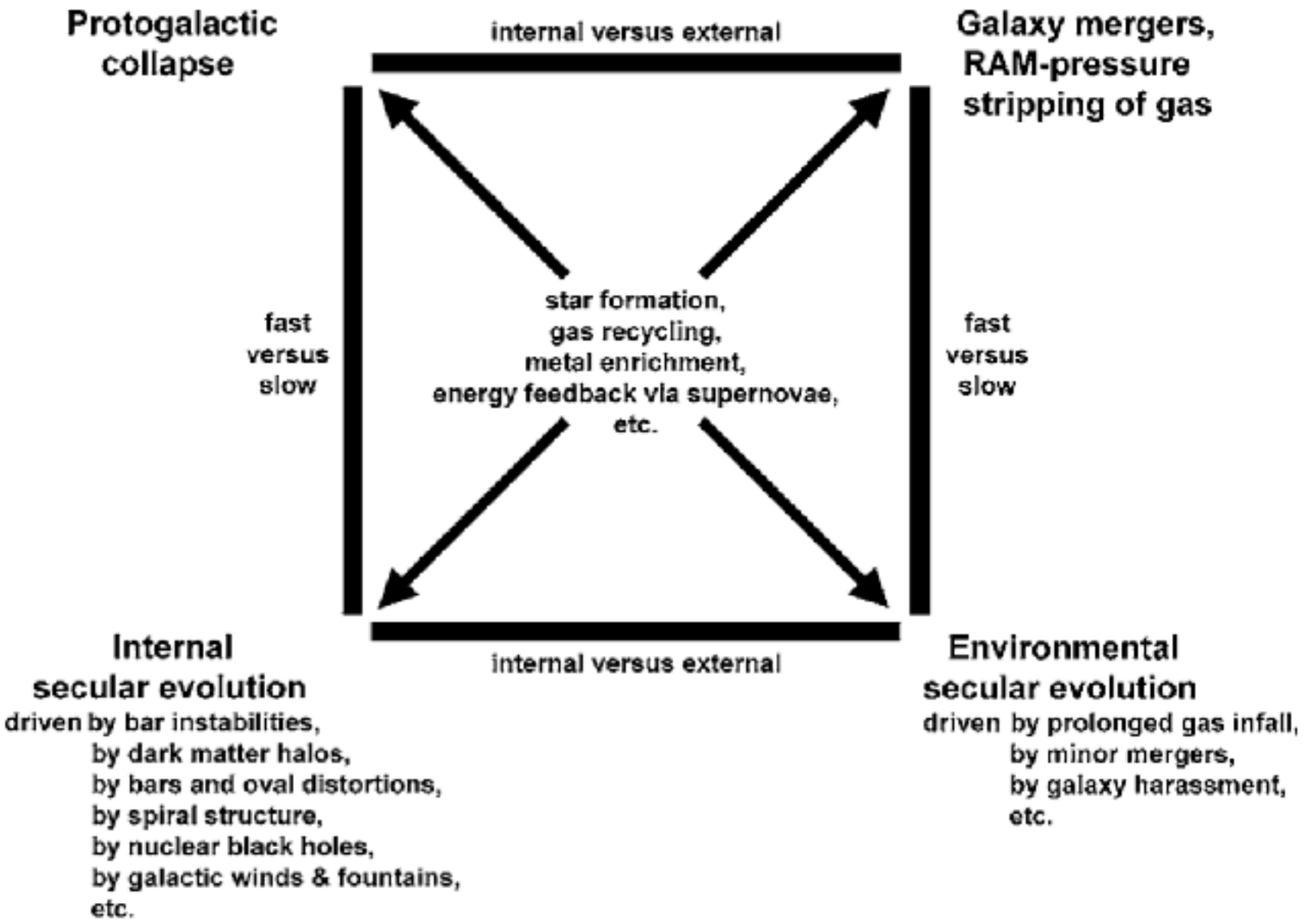


Figure 1 Morphological box (Zwicky 1957) of processes of galactic evolution updated from Kormendy (1982a). Processes are divided vertically into fast (*top*) and slow (*bottom*). Fast evolution happens on a free-fall ("dynamical") timescale, $t_{\rm dyn} \sim (G\rho)^{-1/2}$, where ρ is the density of the object produced and G is the gravitational constant. Slow means many galaxy rotation periods. Processes are divided horizontally into ones that happen purely internally in one galaxy (*left*) and ones that are driven by environmental effects such as galaxy interactions (*right*). The processes at center are aspects of all types of galaxy evolution. This paper is about the internal and slow processes at lower left.