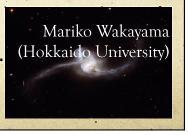
10.10.14

How do disks survive mergers?



Hopkins et al 2009.

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Merger scenario

- What happen to the primary galaxy in mergers?
  - The secondary galaxy induces internal gravitational torque, and we can call this asymmetric torque stellar bar and gas bar.
  - Gas within a characteristic radius lose angular momentum to internal torque and fall into center and cause starburst. Gas outside of the characteristic radius reform a stellar disk.

gas rich → Small characteristic radius → disk survives!

  - Stars whose mass nearly equals secondary mass undergo violent relaxation and form a bulge.

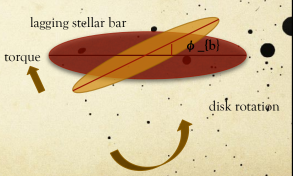
Surviving disk consists of surviving stellar disk and new stars which are made of the gas outside of the characteristic radius that dose not lose angular momentum.

3) Merger scenario①

How does the gas lose its angular momentum?

Inertial torques by the stellar bar in the same disk are most effective.
The gas within a characteristic radius lose angular momentum.

- Secondary galaxy make nonaxisymmetric perturbation, so the stellar bar and the gas bar form.
- The stellar bar lags behind the gas bar by small offset because the gas is collisional and stars are collisionless.
- The stellar bar therefore torques the gas bar, draining its angular momentum and causing the gas to collapse to the center.
- Hydrodynamic torques and direct torque by the secondary are second order effects (Barnes & Hernquist 1996 ; Barnes 1998).



3) Merger scenario②

Their simple dynamical model

The characteristic radius is described with 3 factors,
gas fraction, orbital parameters and mass ratio.

$$\frac{R_{\rm gas}}{R_{\rm d}} \leqslant \alpha\,(1-f_{\rm gas})\,f_{\rm disk}\,F(\theta,b)\,G(\mu),$$

$$F(\theta,b) \equiv \left(\frac{1}{1+[b/R_{\rm d}]^2}\right)^{3/2}\frac{1}{1-\Omega_{\rm o}/\Omega_{\rm d}}$$

$$G(\mu) \equiv \frac{2\mu}{(1+\mu)}$$

The equation which we would like to get.

notation

$$M_{\rm disk} = f_{\rm disk}\,M \text{ (disk mass)}$$
$$M_{\rm bar} = f_{\rm bar}\,M \text{ (stellar bar mass)}$$
$$v_c = \sqrt{\frac{G\,M}{R_{\rm d}}} \text{ (characteristic circular velocity)}$$
$$\Omega_{\rm d} = \frac{v_c}{R_{\rm d}} \text{ (characteristic frequency)}$$
$$P = \frac{2\pi}{\Omega_{\rm d}} \text{ (rotation period).}$$
$$\tilde{x} = x/R_{\rm d}$$
$$\tilde{y} = y/R_{\rm d}$$
$$\tilde{R} \equiv \sqrt{x^2+y^2}/R_{\rm d}.$$

$$\frac{dj}{dt} = \tilde{x}\,R_{\rm d}\,\frac{dv_y}{dt} = -\frac{G\,M_{\rm bar}}{R_{\rm d}}\,I_0(\phi_b,\tilde{x})$$

I means torque

$$\tau \equiv \frac{\Omega_{\rm d}}{2\pi}\,t = \frac{v_c}{R_{\rm d}}\,t = \sqrt{\frac{G\,M}{R_{\rm d}^3}}\,t$$

$$\tilde{x} \ll \Delta\tau\,\frac{d\tilde{x}}{d\tau}$$

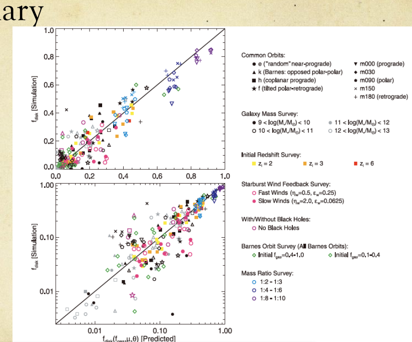
lose angular momentum

$$\frac{R_{\rm gas}}{R_{\rm d}} \lesssim (1-f_{\rm gas})\,f_{\rm disk}\,\Psi_{\rm bar}(\phi_b,\tilde{H},\ldots)$$

Ψ represents bar efficiency

4) Simple dynamical model ①

Summary



Their simple dynamical model agree with simulations.

5) Summary

Conclusion and discussion

- In sufficiently gas- rich mergers (with quite general orbital parameters) even 1:1 mass ratio mergers can yield disk- dominated remnants, and more realistic 1:3-1:4 mass ratio major mergers can yield systems with < 20% of their mass in bulges.
- They show that, in an immediate (short-term) sense, the amount of stellar or gaseous disk that survives or re-firms following a given interaction can be understood purely in terms of simple, well understood gravitational physics.
- Bulge formation is suppressed at increasing redshift at which many gas-rich galaxy exist.
- Large fraction of bulges and disks survive mergers together, rather than being formed entirely separately.

6) Conclusion and discussion