LSB Galaxies and their Dark Matter Halos

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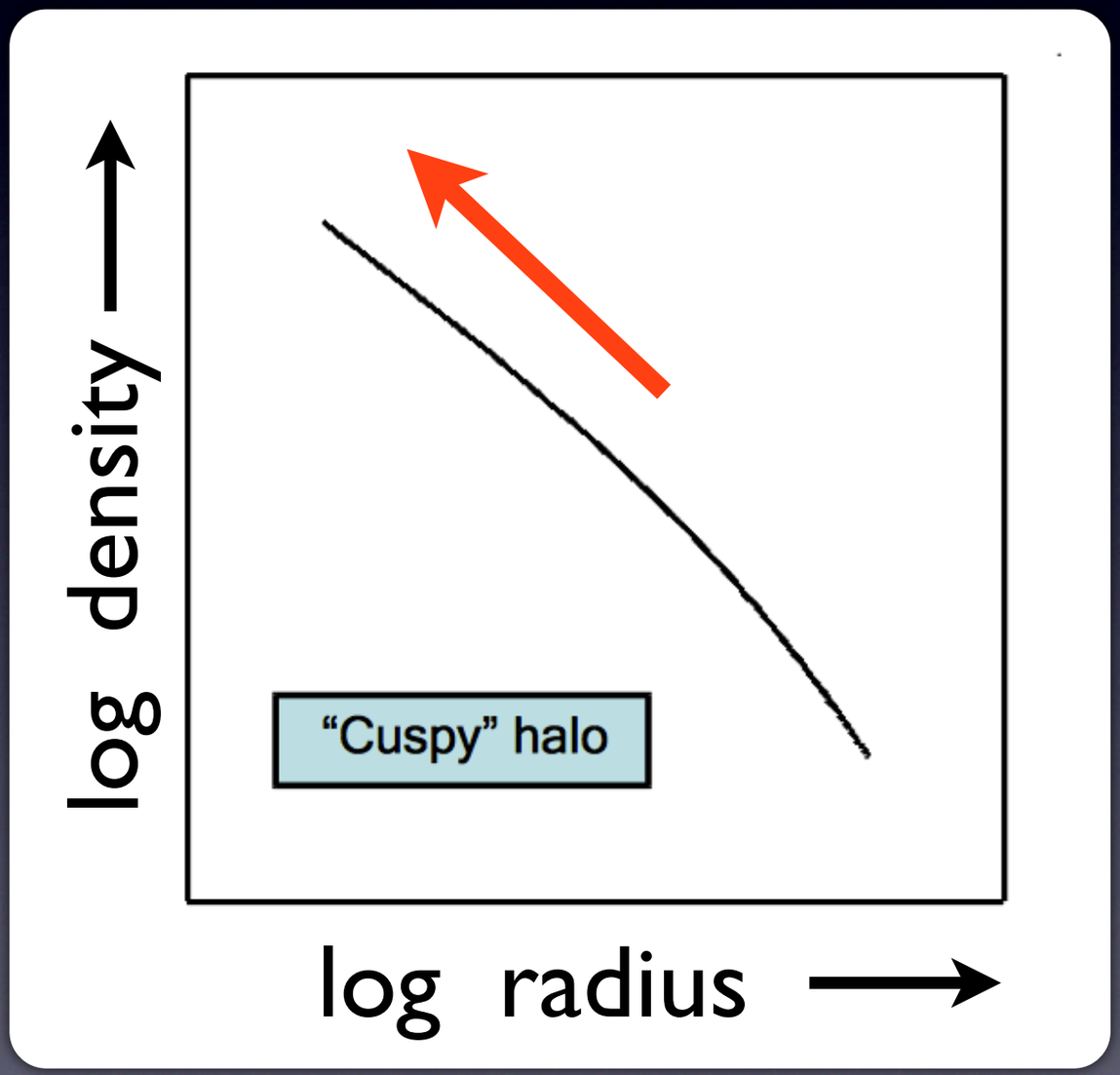
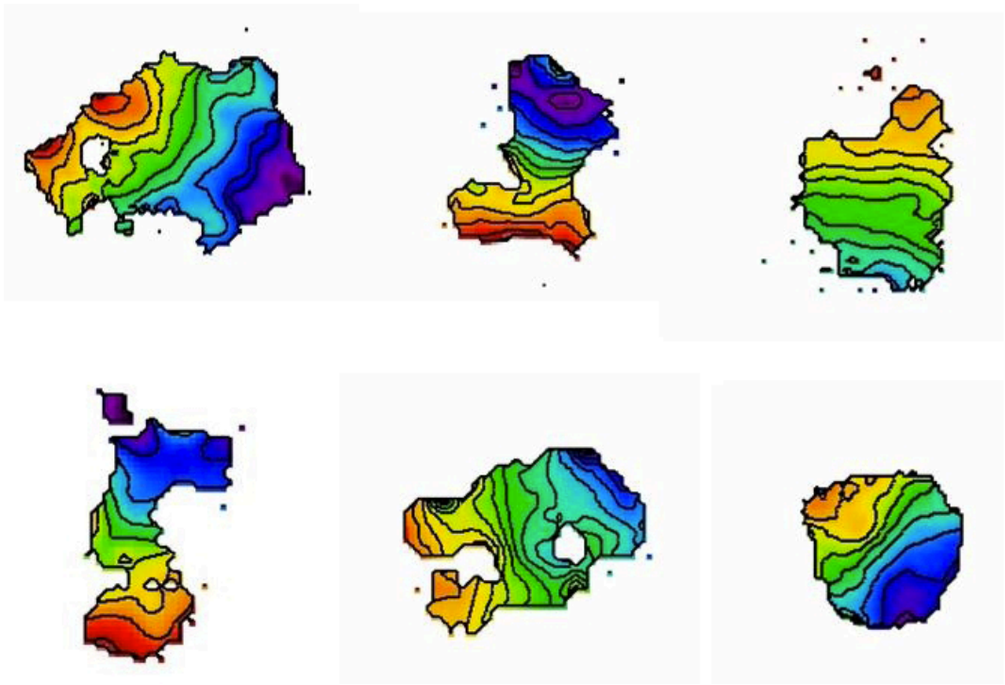
CDM Halos in Collisionless Simulations

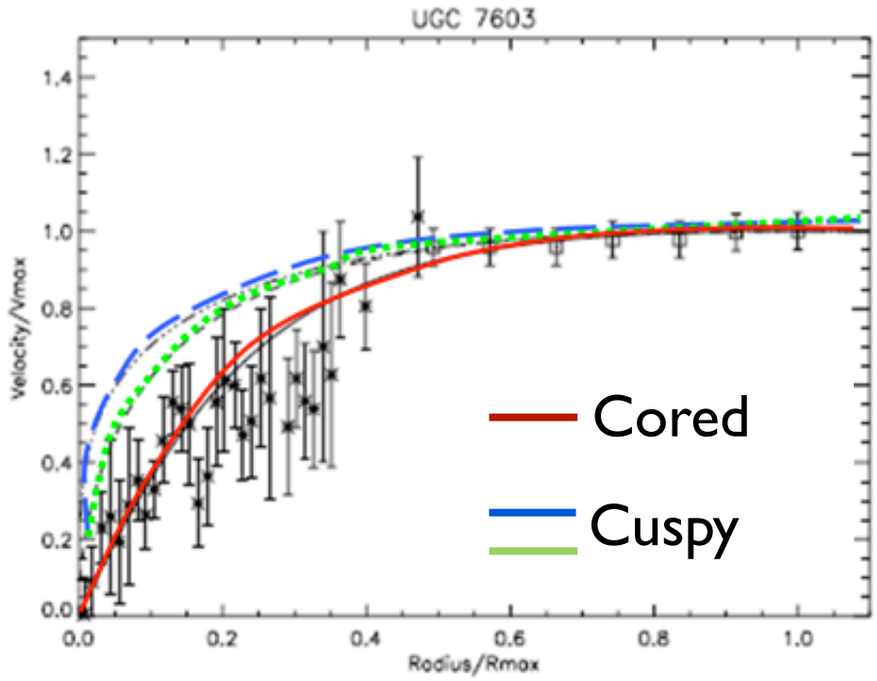


- Steeply-rising density profiles
- Triaxial shapes

Observations of Dark Matter-Dominated Galaxies



Kuzio de Naray et al. (2006, 2008)



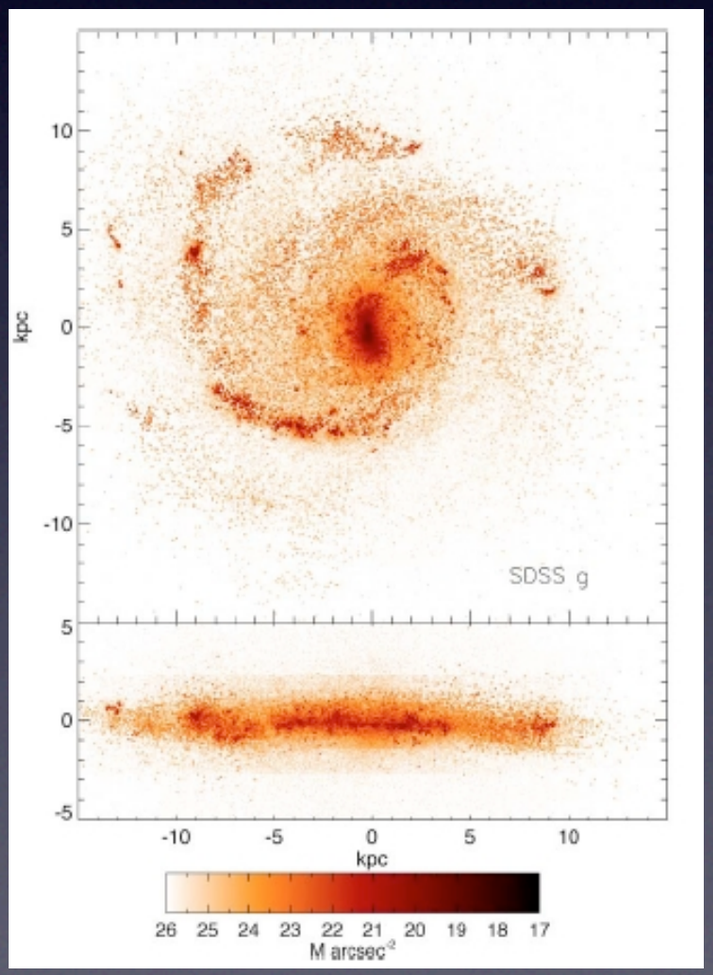
Marchesini et al. (2002)

- Roughly constant-density, cored, round halos
- The “cusp-core” problem

Baryons are Important

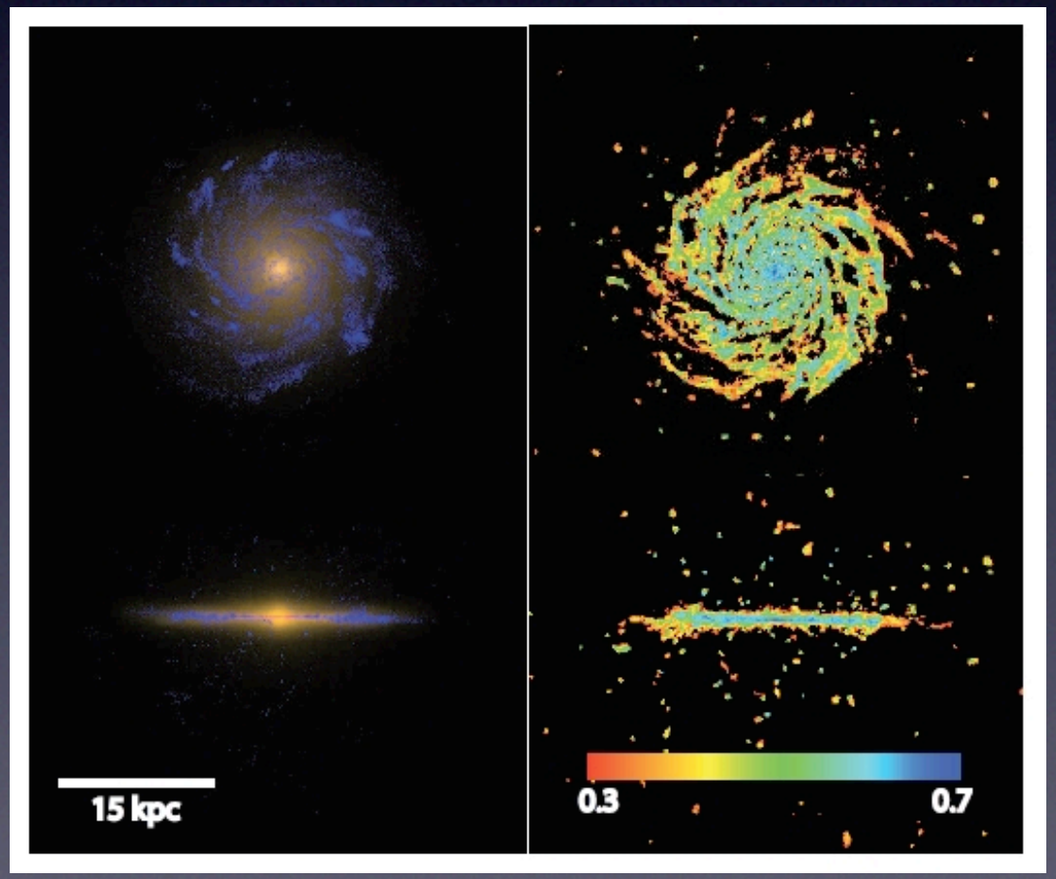
- ISM physics helps simulate realistic "bulgeless" disks

Brook et al. 2011



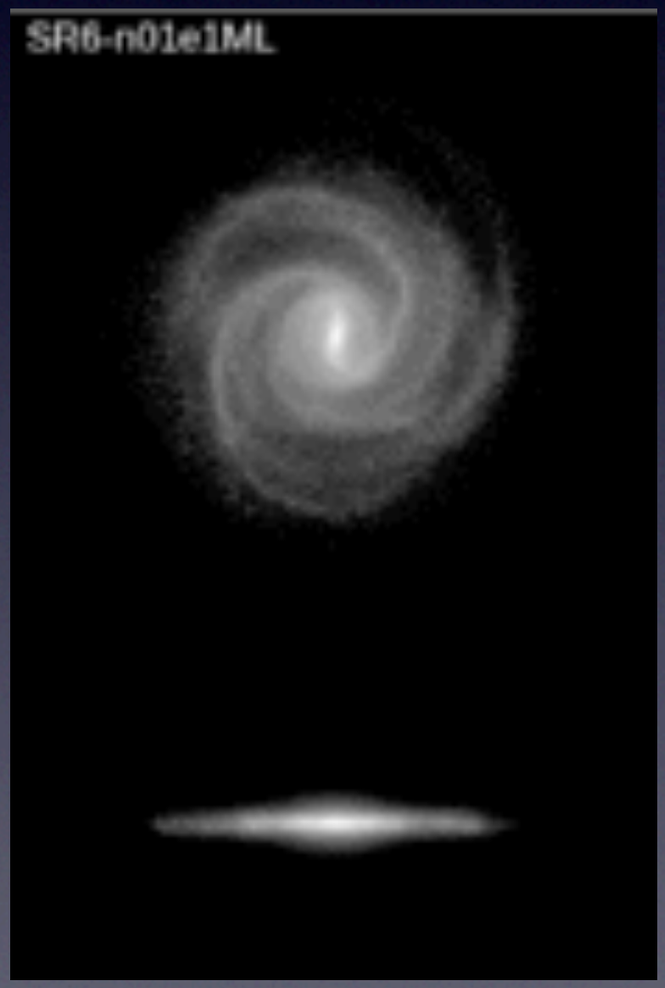
Vflat ~ 140 km/s

Guedes et al. 2011



Vflat ~ 150 km/s

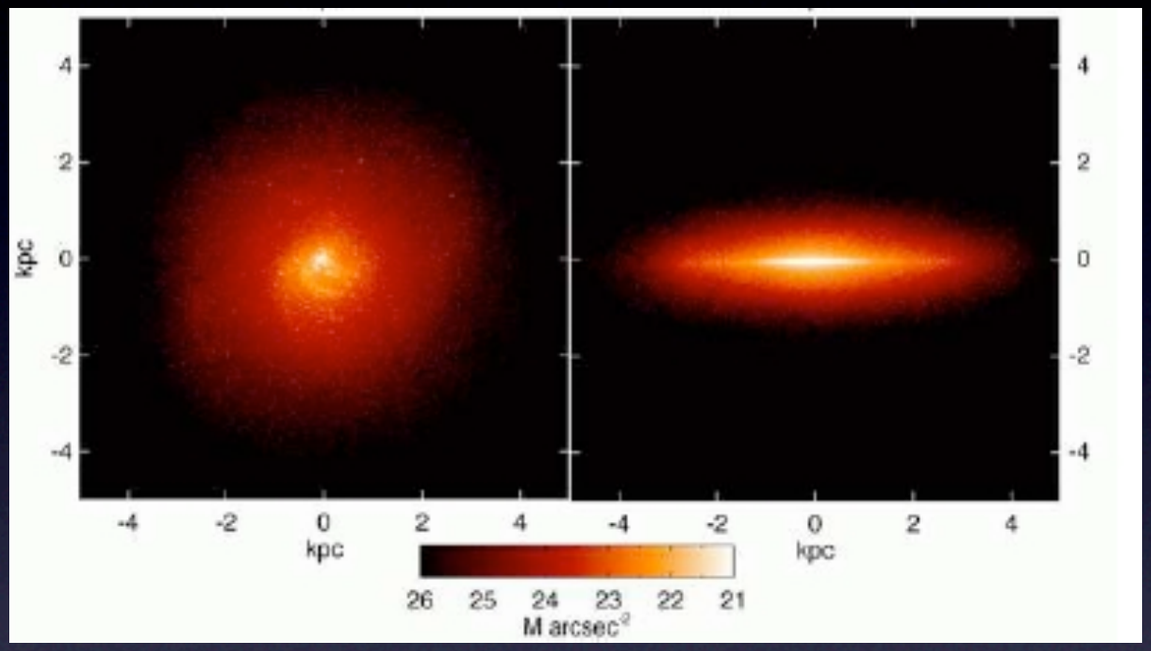
Agertz et al. 2011



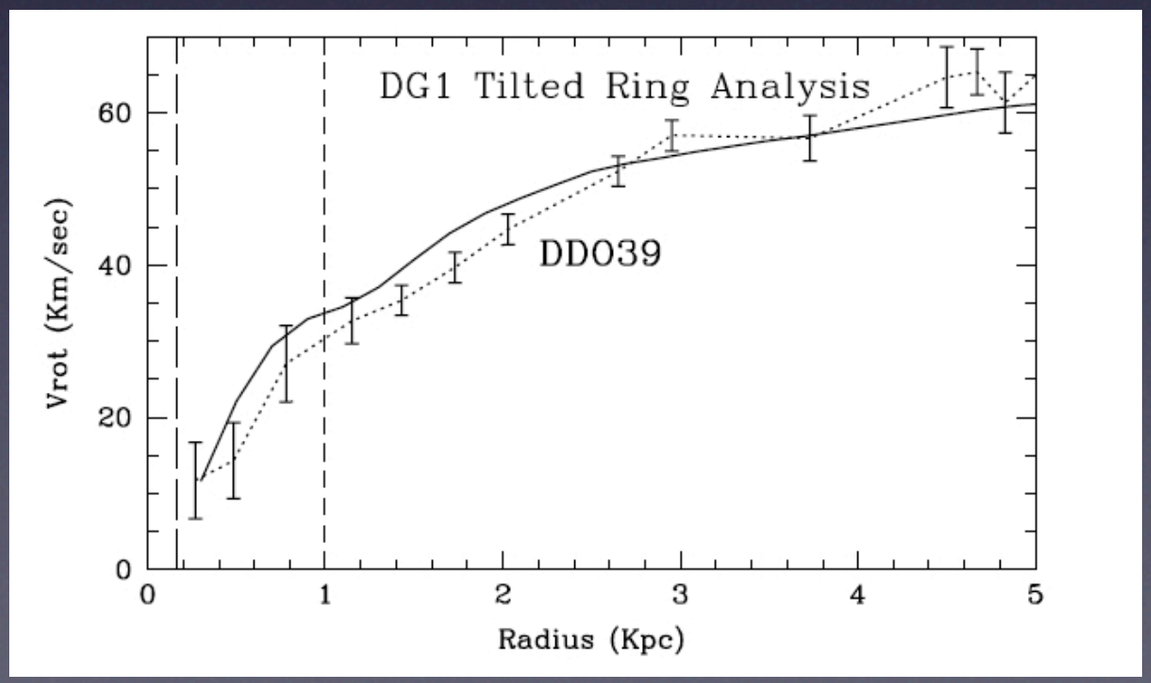
Vflat ~ 250 km/s

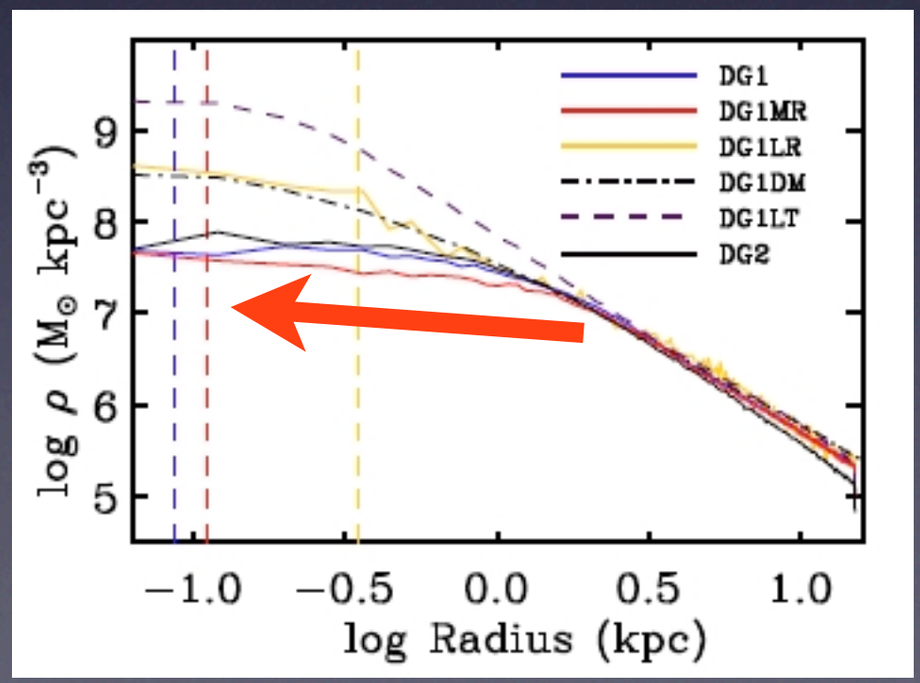
Baryons are Important

Governato et al. 2010



- Bulgeless dwarf V_{flat} ~ 60 km/s
- Slowly-rising rotation curve
- Change a cusp to a core

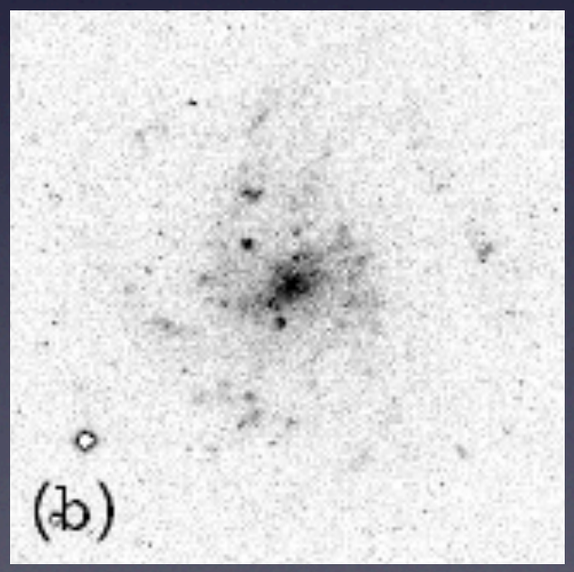




Are Baryons Effective in LSBs?

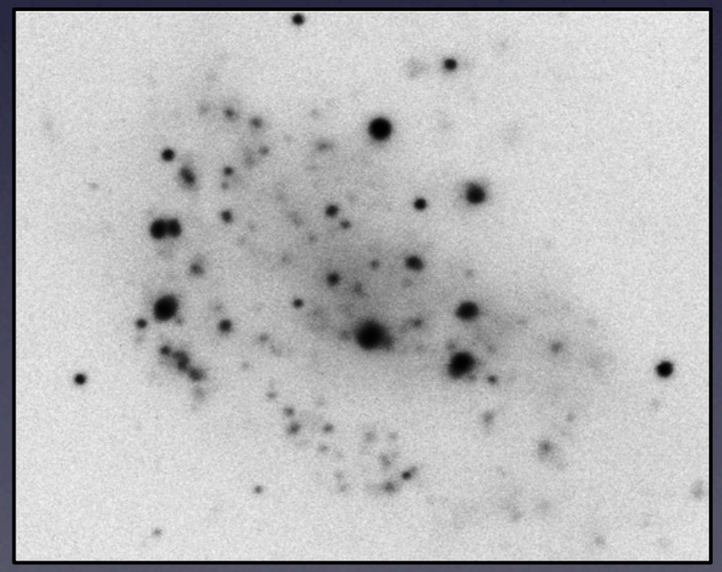
- Blue, dark matter-dominated, late-type disks
- Low gas surface densities, inefficient star-formers

UGC 1230



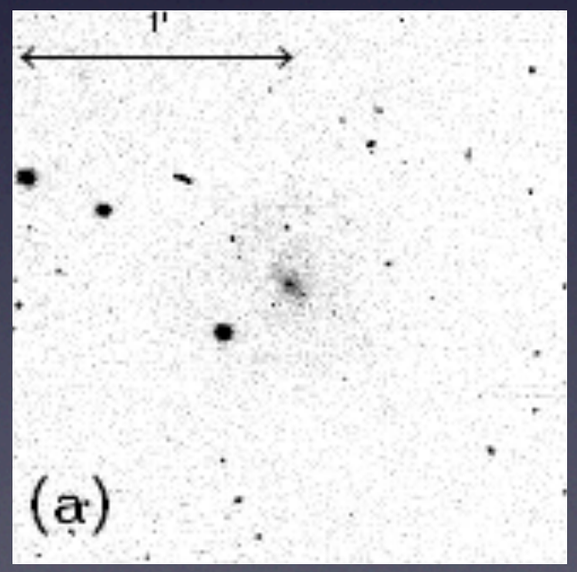
V_{flat} ~ 103 km s^{-1}

UGC 4325



V_{flat} ~ 123 km s^{-1}

F568-1



V_{flat} ~ 142 km s^{-1}

(Kuzio de Naray 2007; Kim 2007)

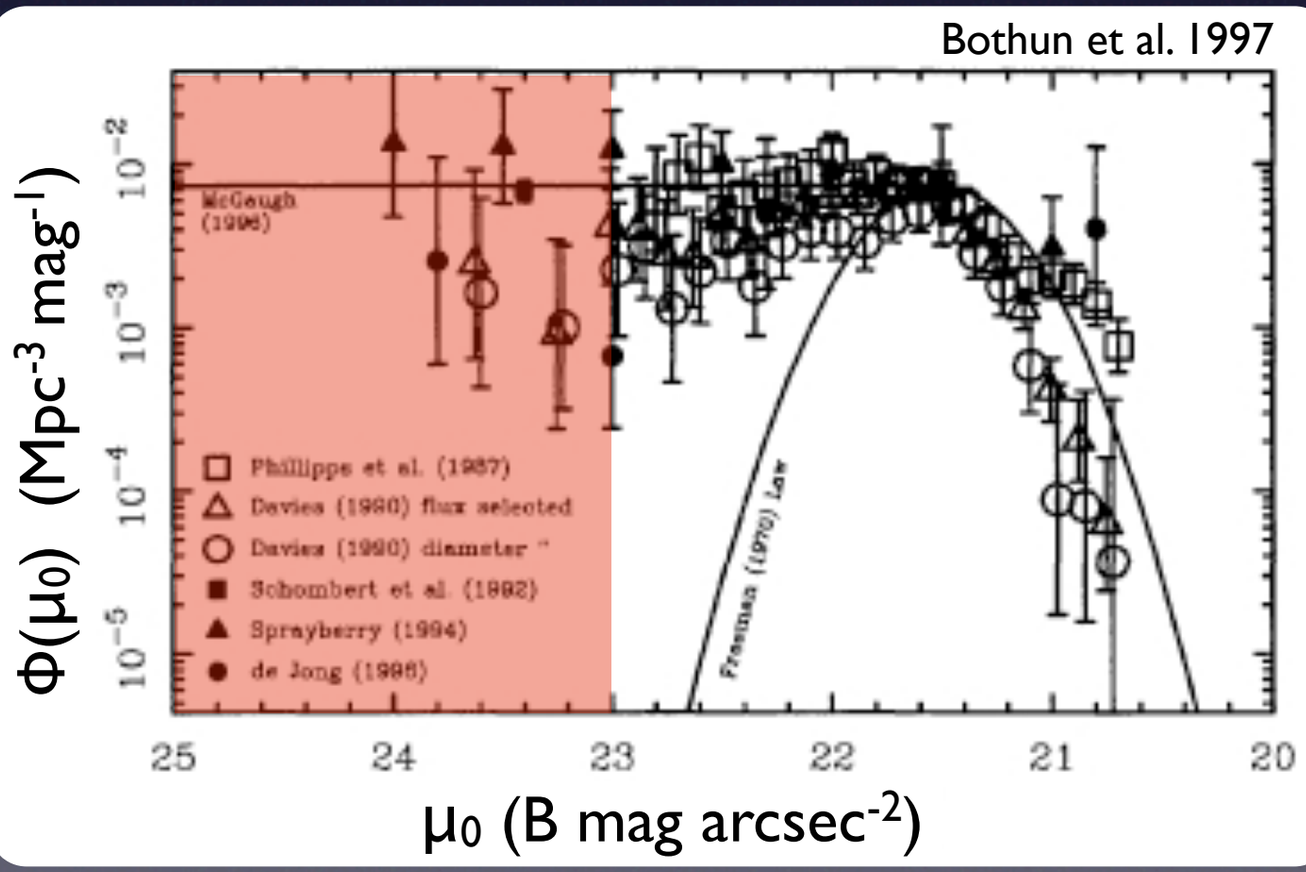
LSB Galaxies Are Not Rare

While tempting, cannot sweep LSBs into a "special" category

Number density of LSBs is comparable to or
greater than HSBs of similar size or luminosity

(Dalcanton et al. 1997)

Bothun et al. 1997



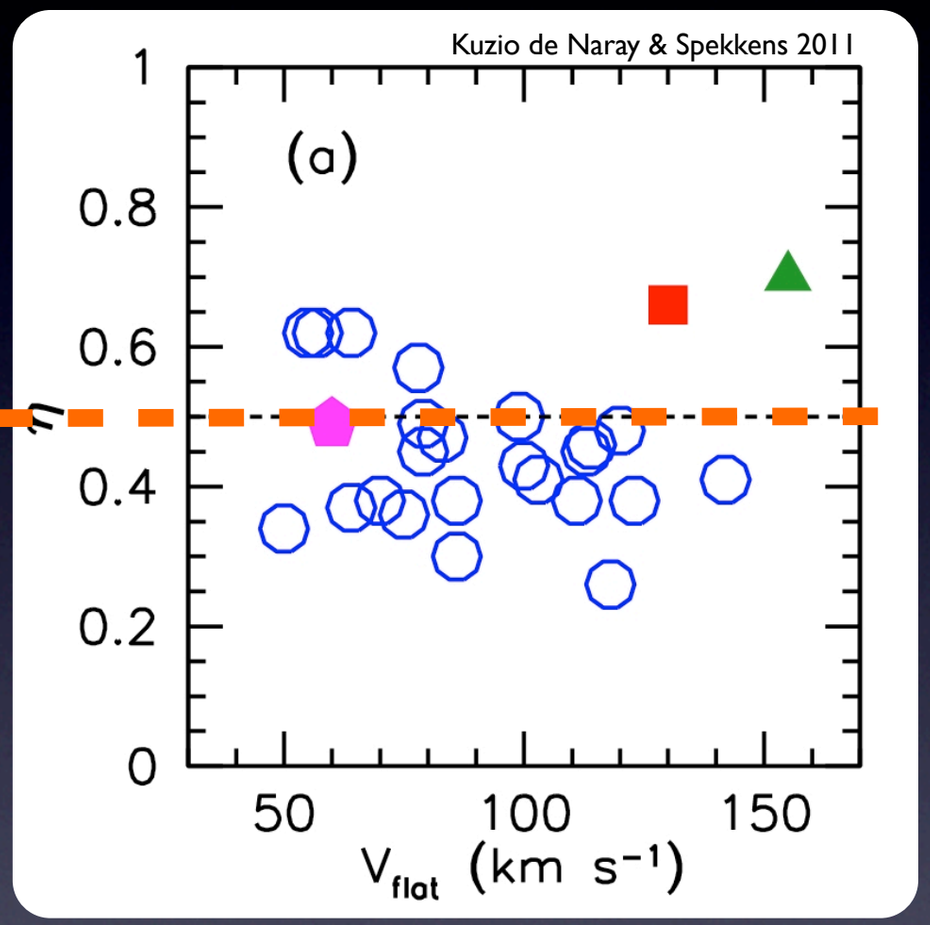
Can Baryons Sphericalize the Halo?

Kazantzidis et al. 2010:

$$\eta \equiv \frac{V_{disk}}{V_{circ}} \gtrsim 0.5$$

Round

Triaxial



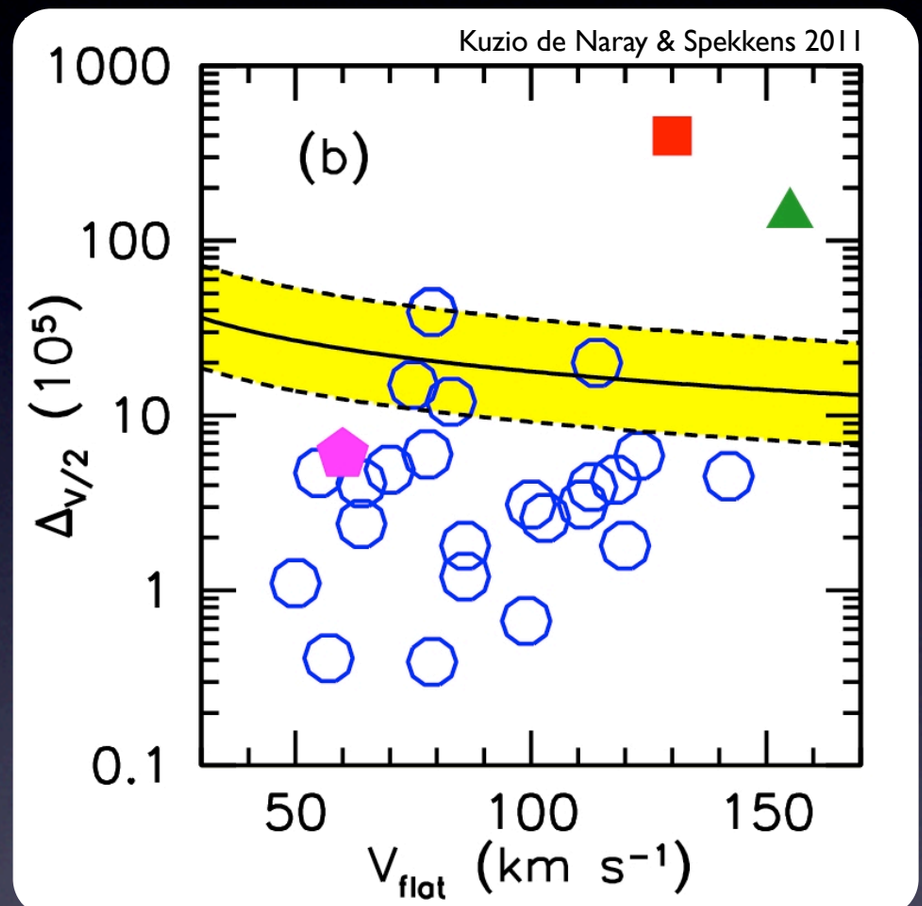
Present-day LSB disks aren't massive enough to reshape their halos

They must have had more baryons in the past

- LSBs
- Governato et al. 2010
- Brook et al. 2011
- Guedes et al. 2011

Can Baryons Change a Cusp to a Core?

LSB halos are underdense compared to LCDM



LSBs
Governato et al. 2010
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Can feedback and outflows from star formation flatten the inner density cusp?

Reconciling LSBs with LCDM

The Scenario:

LSBs had more baryons in the past to sphericalize and erase the cusp and were then blown out

The Challenge:

Do this while preserving/producing the observational properties of LSBs

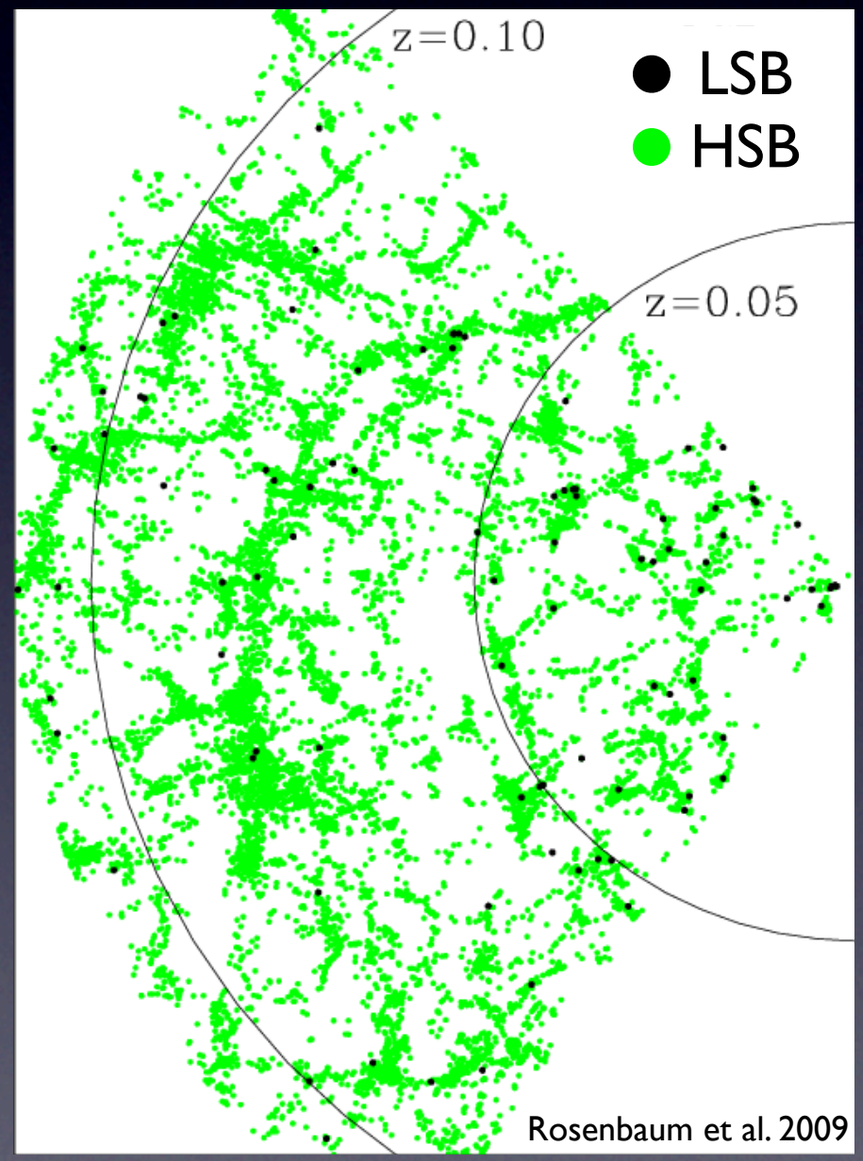
Inducing Star Formation

→ **Effectiveness of Feedback**

→ **LSB Star Formation Histories**

Inducing Star Formation

Need to funnel gas to the galaxy center



Inducing Star Formation

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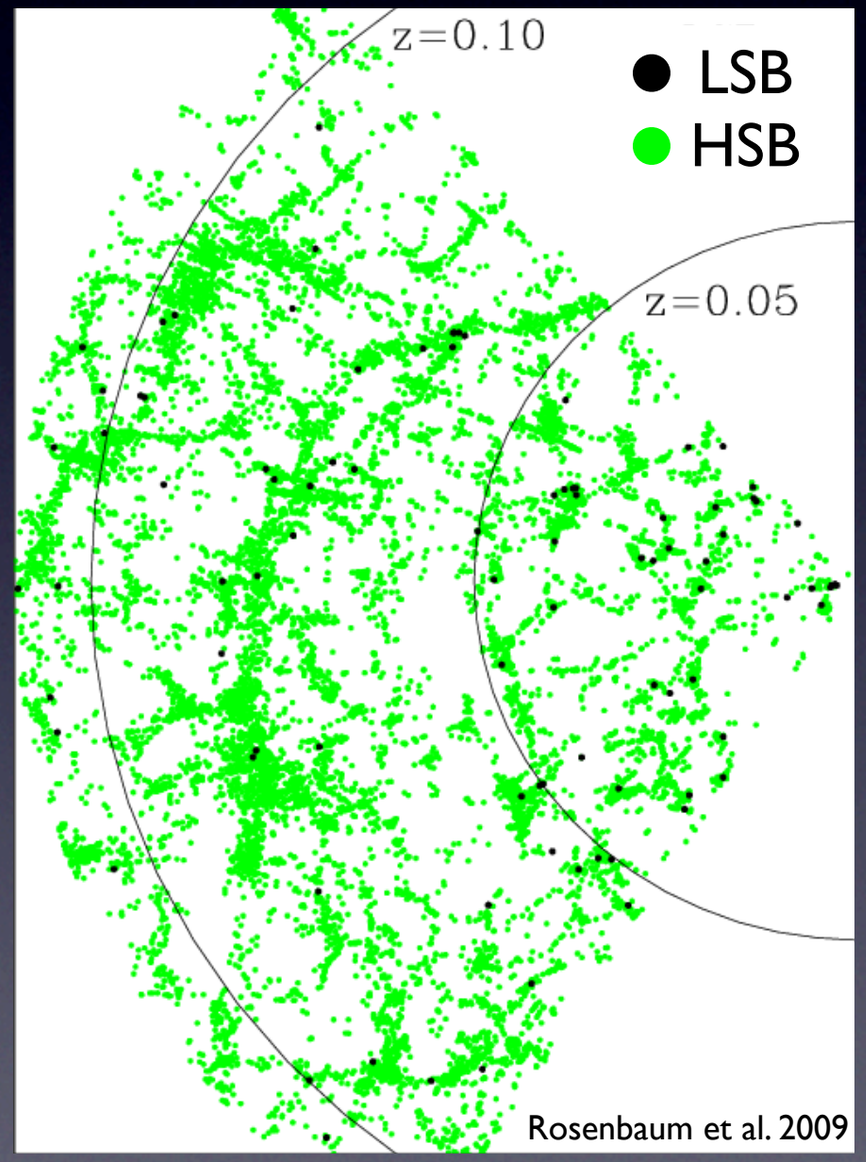
- **Mergers and Interactions**
  - ↳ relatively isolated & on edges of LSS
    (Bothun et al. 1997; Rosenbaum et al. 2009)



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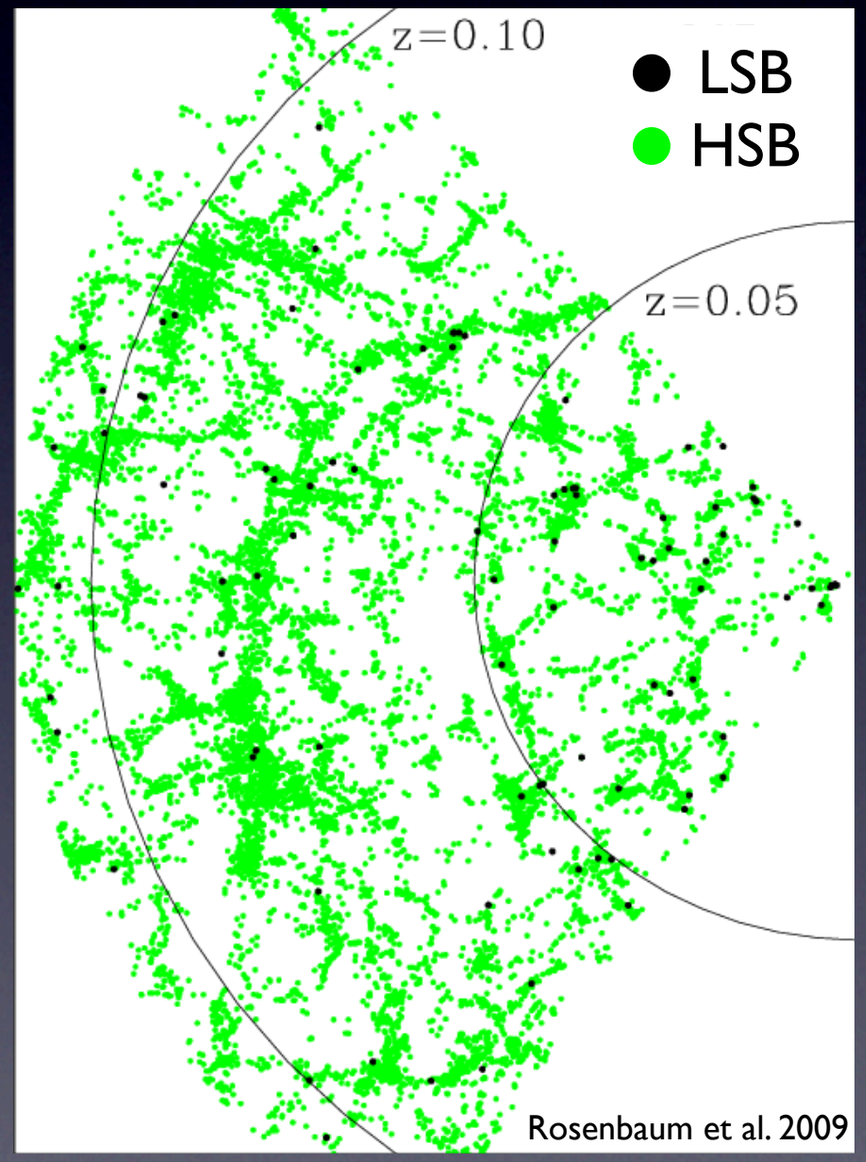

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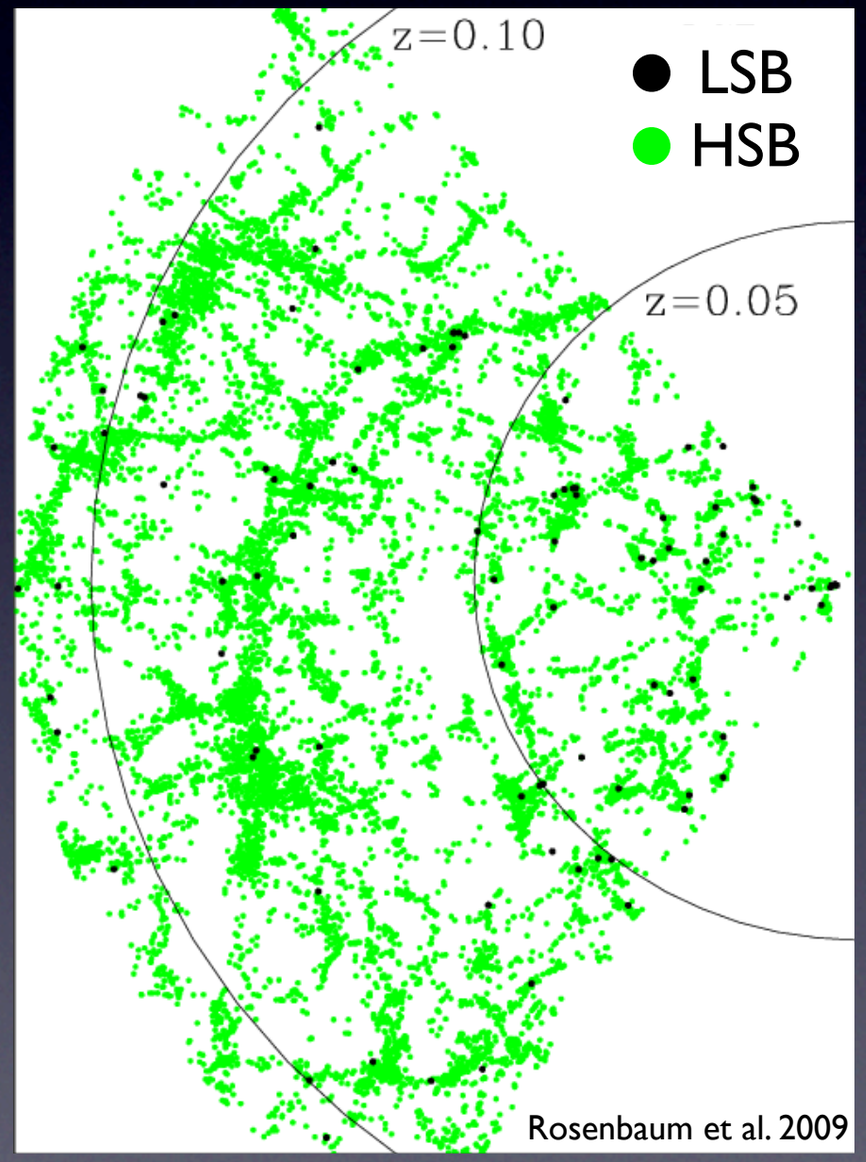
  - ↳ high(er) angular momentum threshold
    (Dalcanton et al. 1997)



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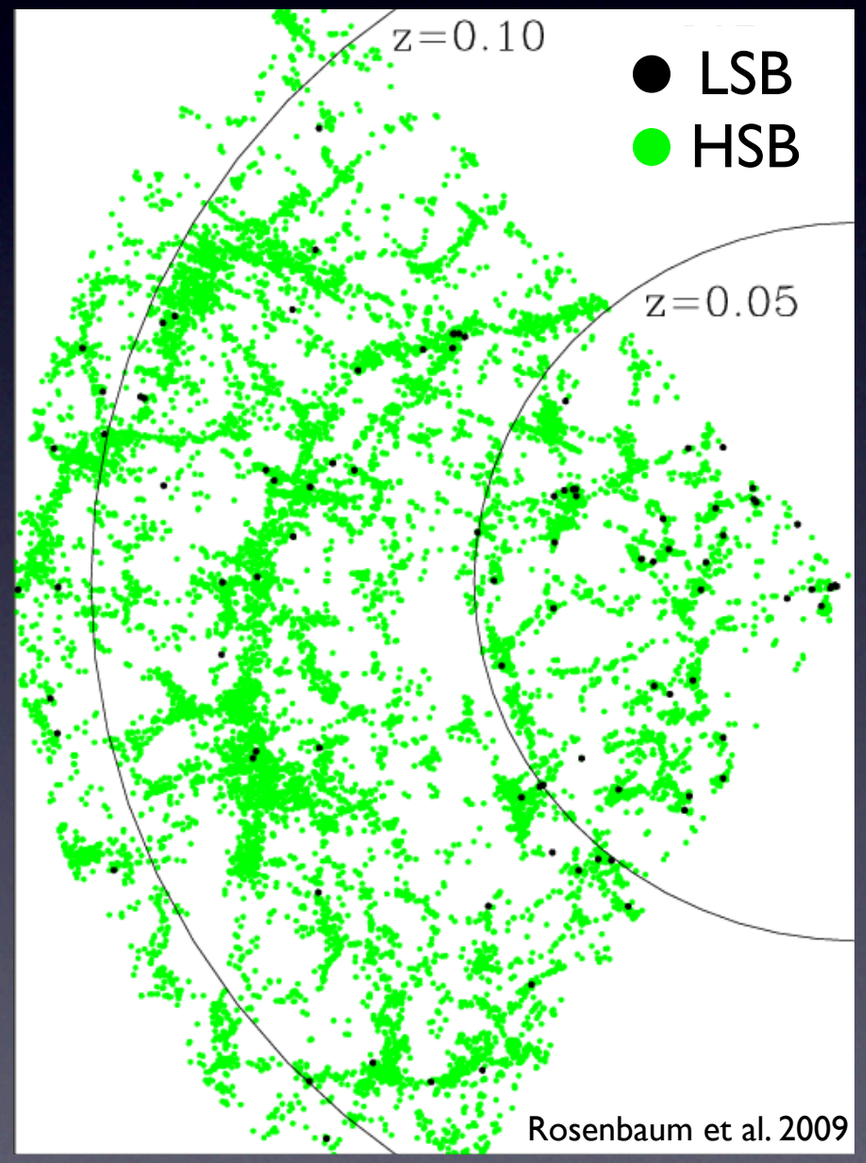
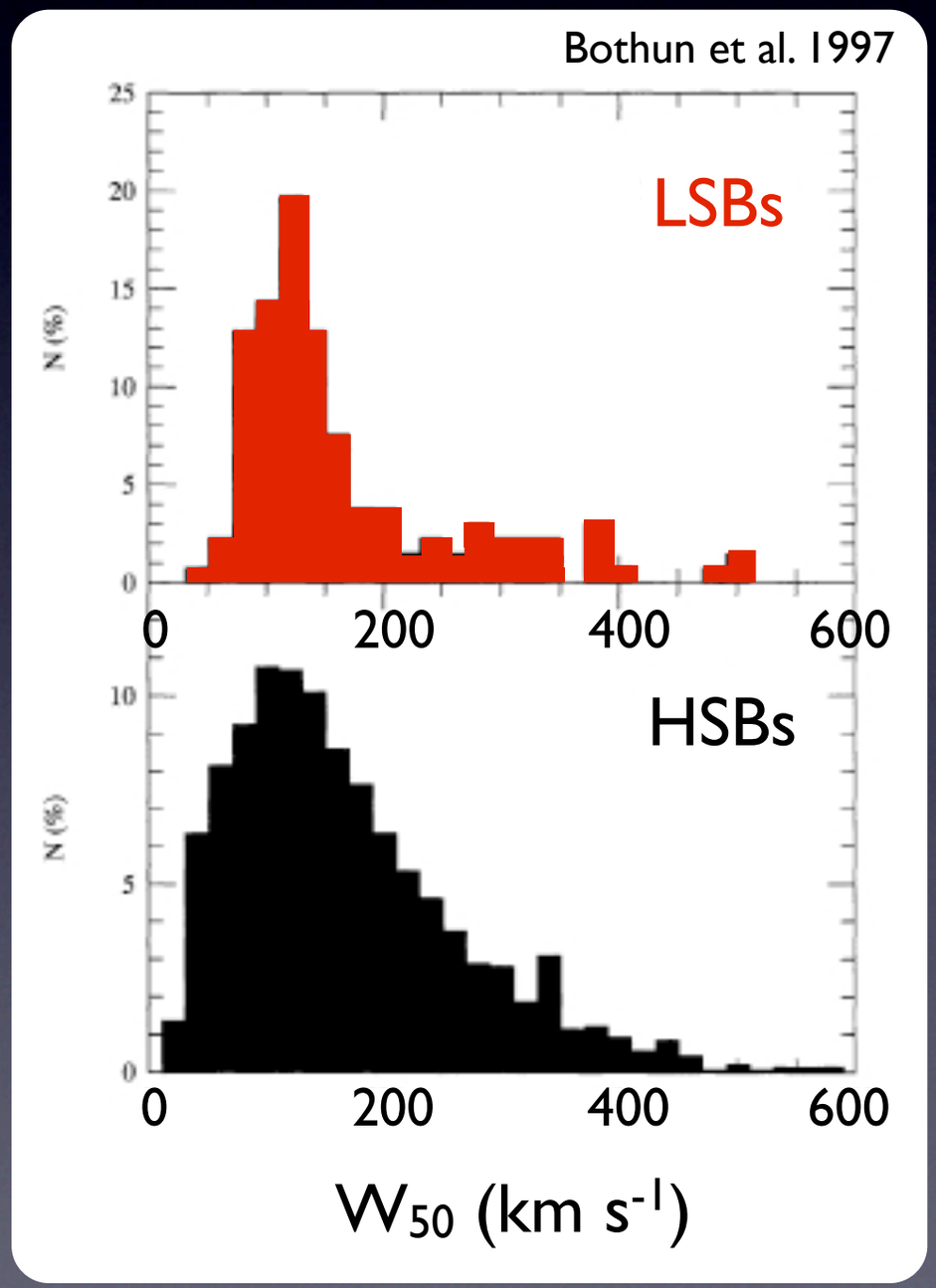


Initiating starbursts seems difficult

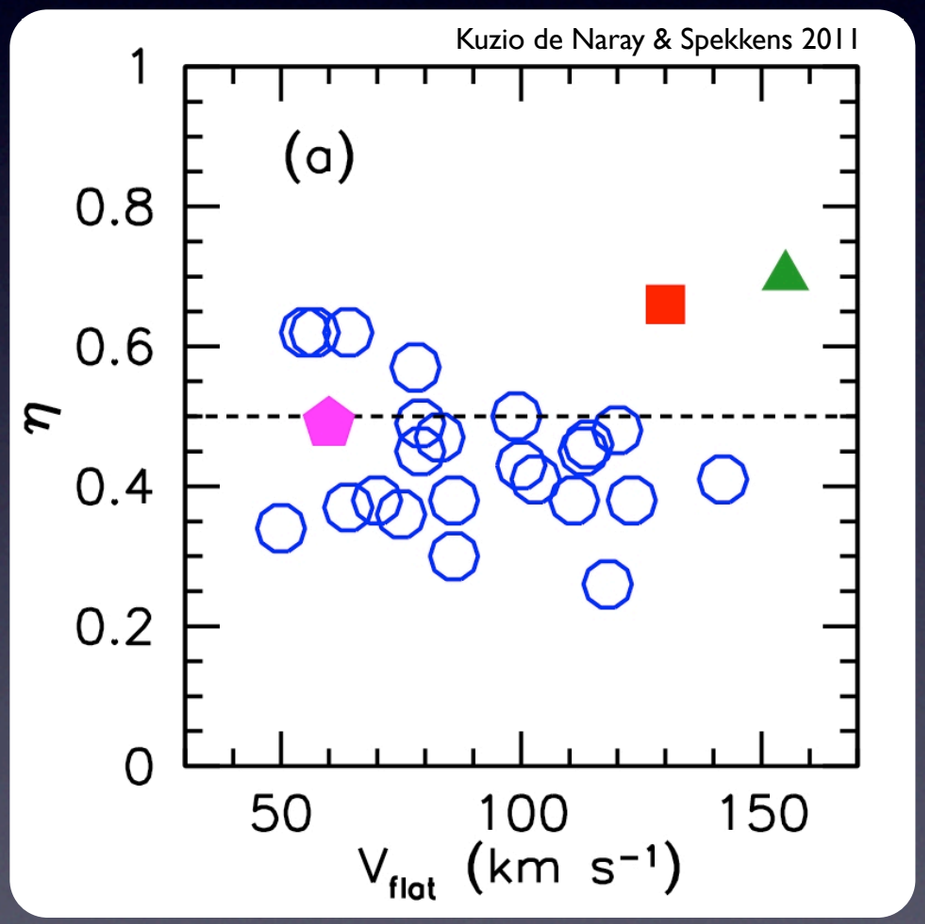
Effectiveness of Feedback

LSBs are not exclusively low mass



Effectiveness of Feedback

Need to remove baryons from LSBs *with a range of masses*



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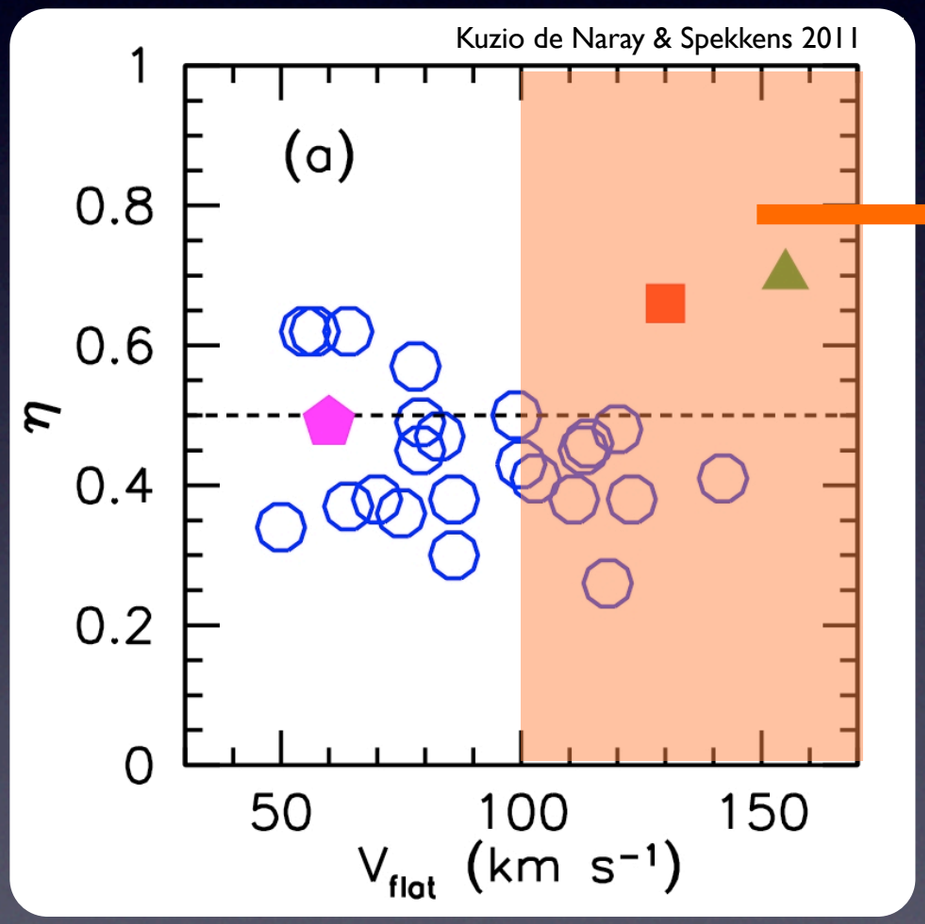

Supernova winds ineffective in galaxies with $V_{flat} \gtrsim 100$ km/s

(Dekel & Silk 1986)

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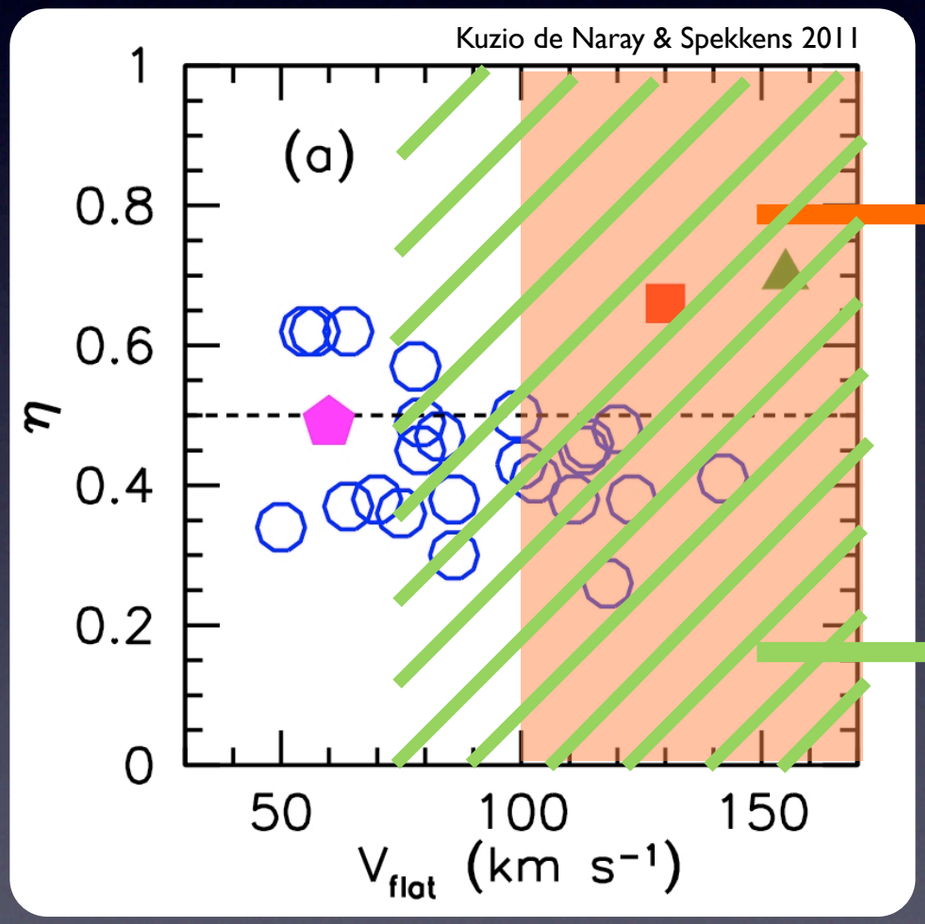

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High star formation rates necessary when $M_{galaxy} > 10^9\ M_\odot$

(Kereš et al. 2009)

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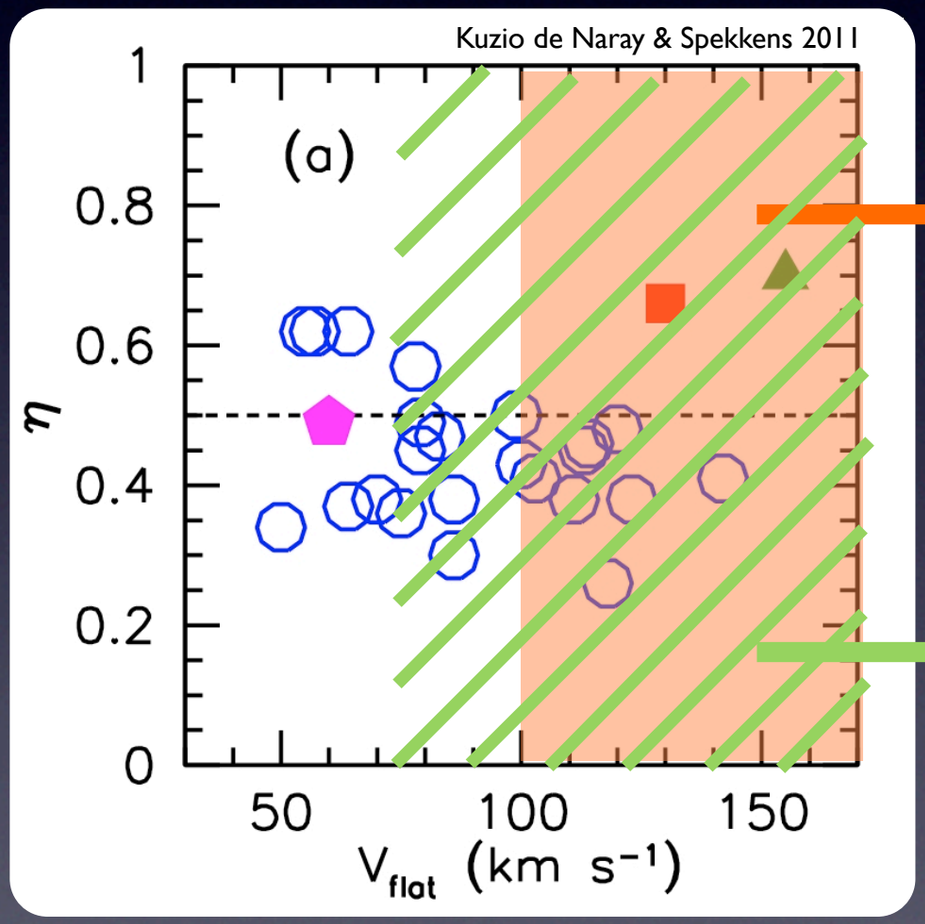

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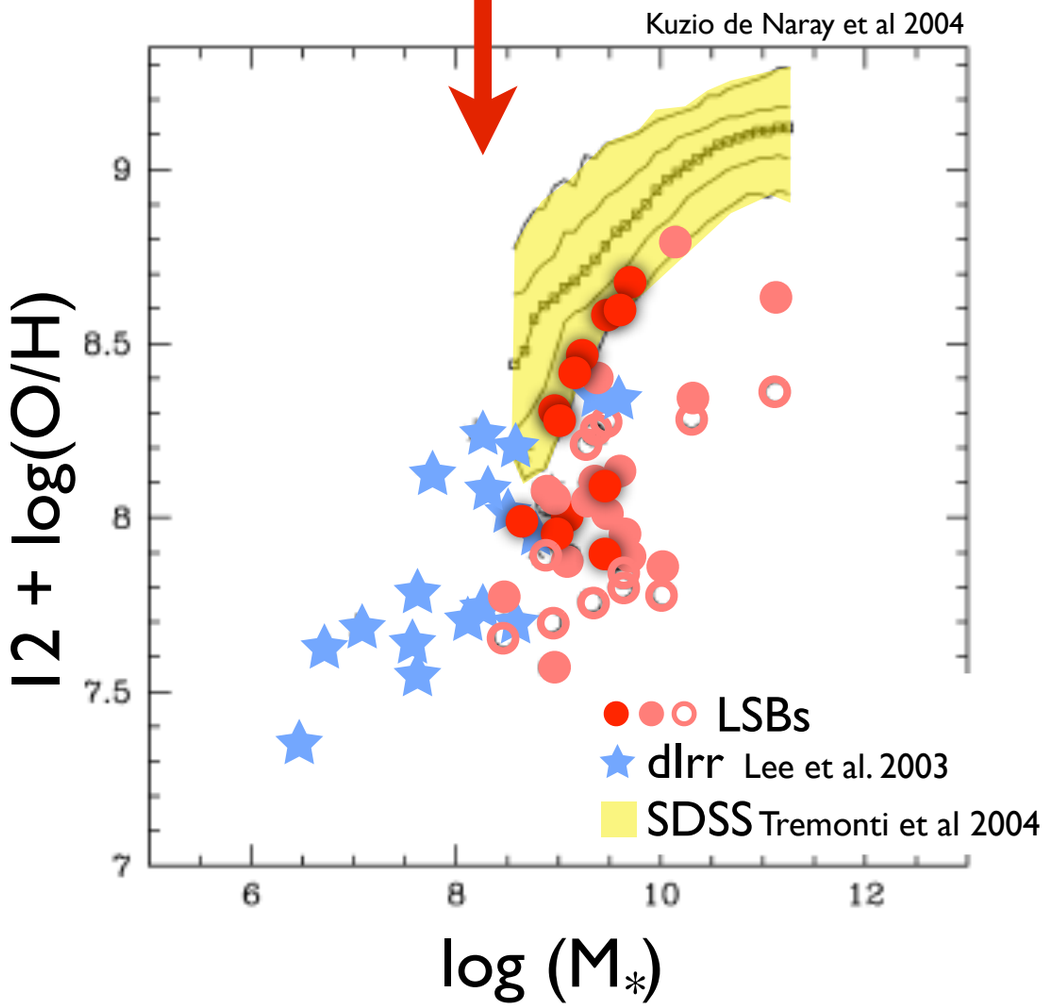
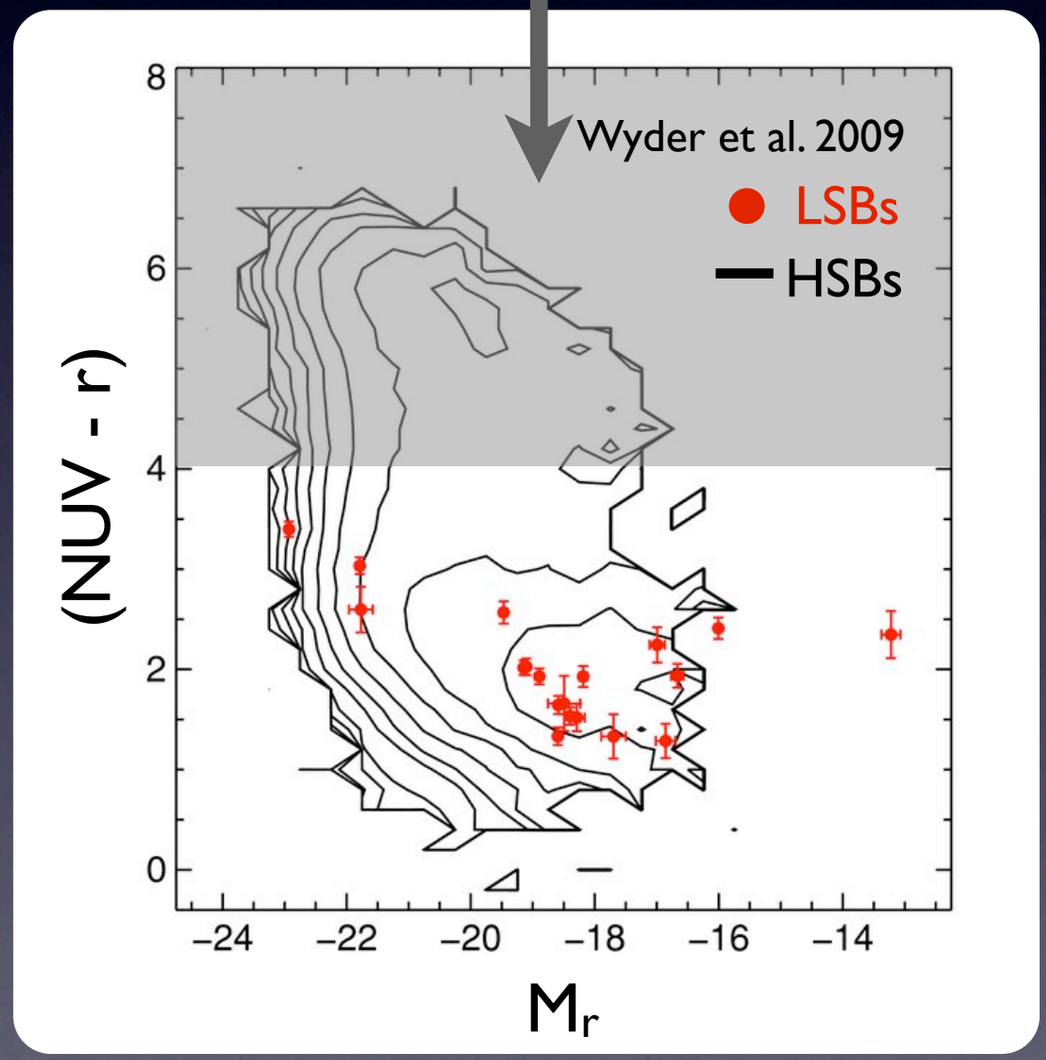
May be challenging to blow baryons out and keep them out

LSB Star Formation Histories

Form relatively few stars over a Hubble time

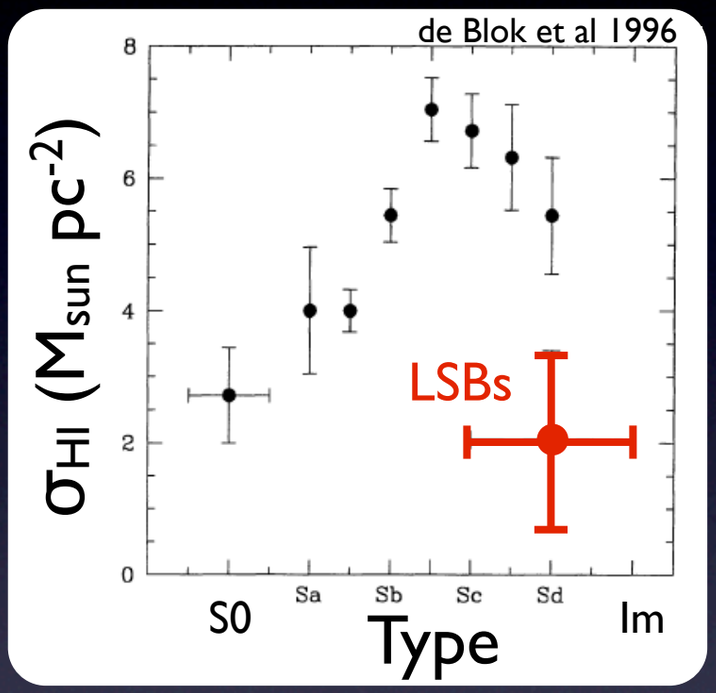


Lacking substantial populations of old stars

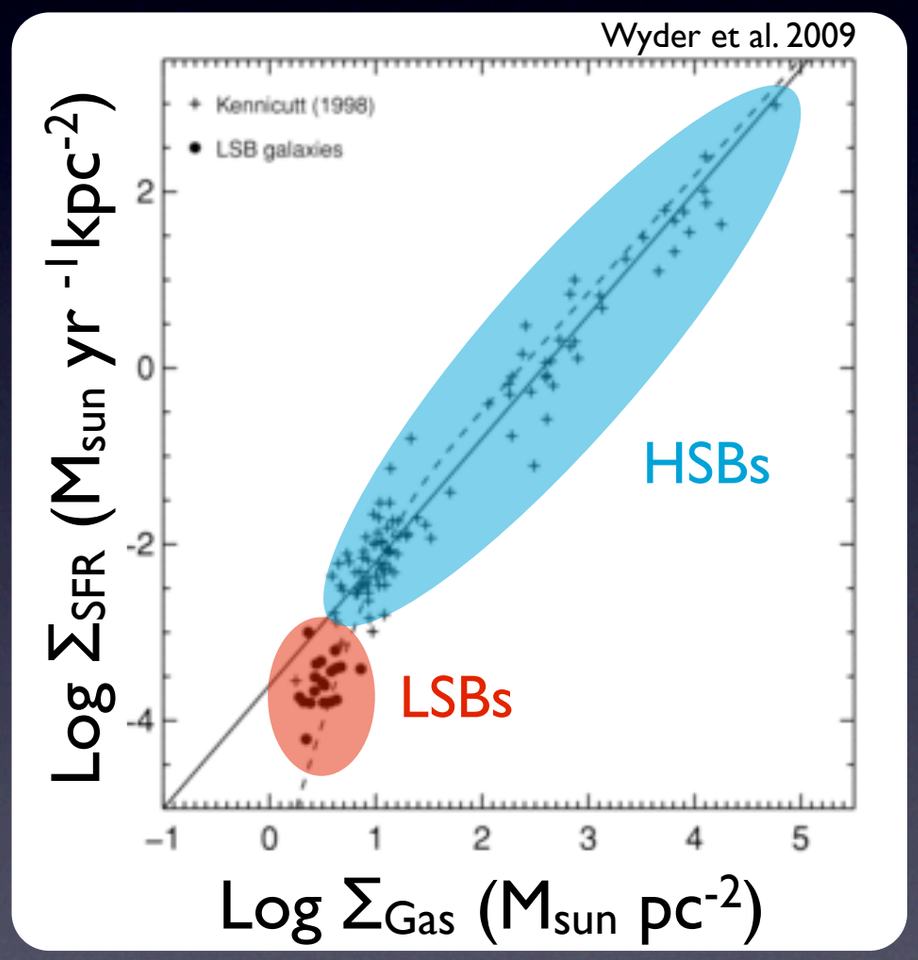


LSB Star Formation Histories

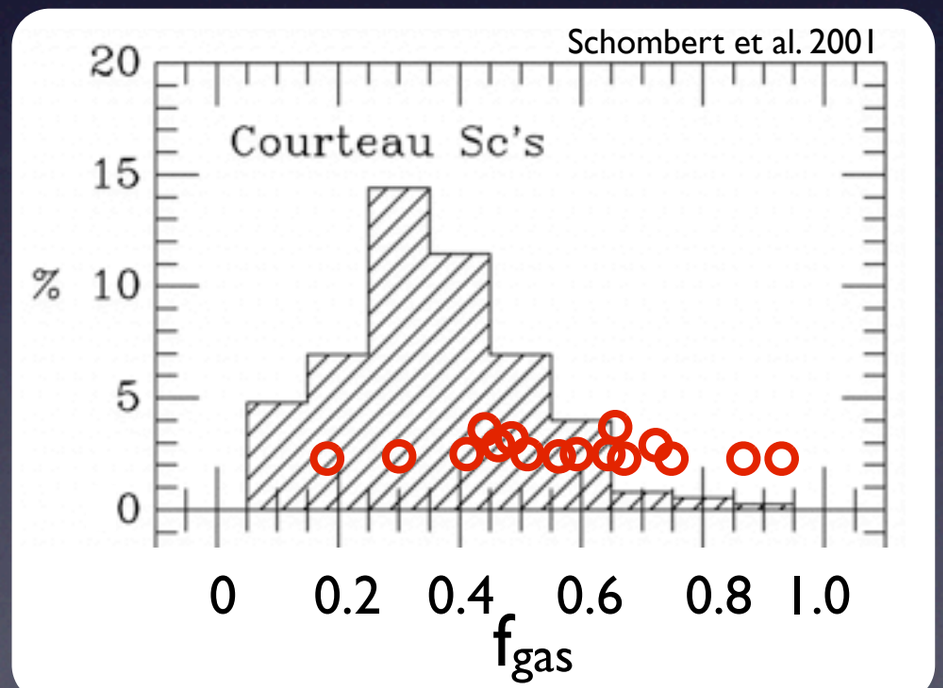
Low gas surface density



Low past & present SFR



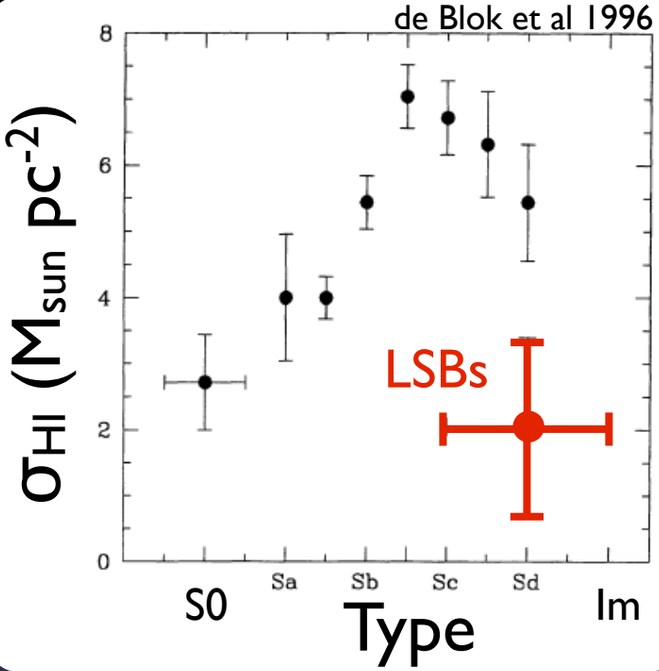
Large gas fraction



LSB Star Formation Histories

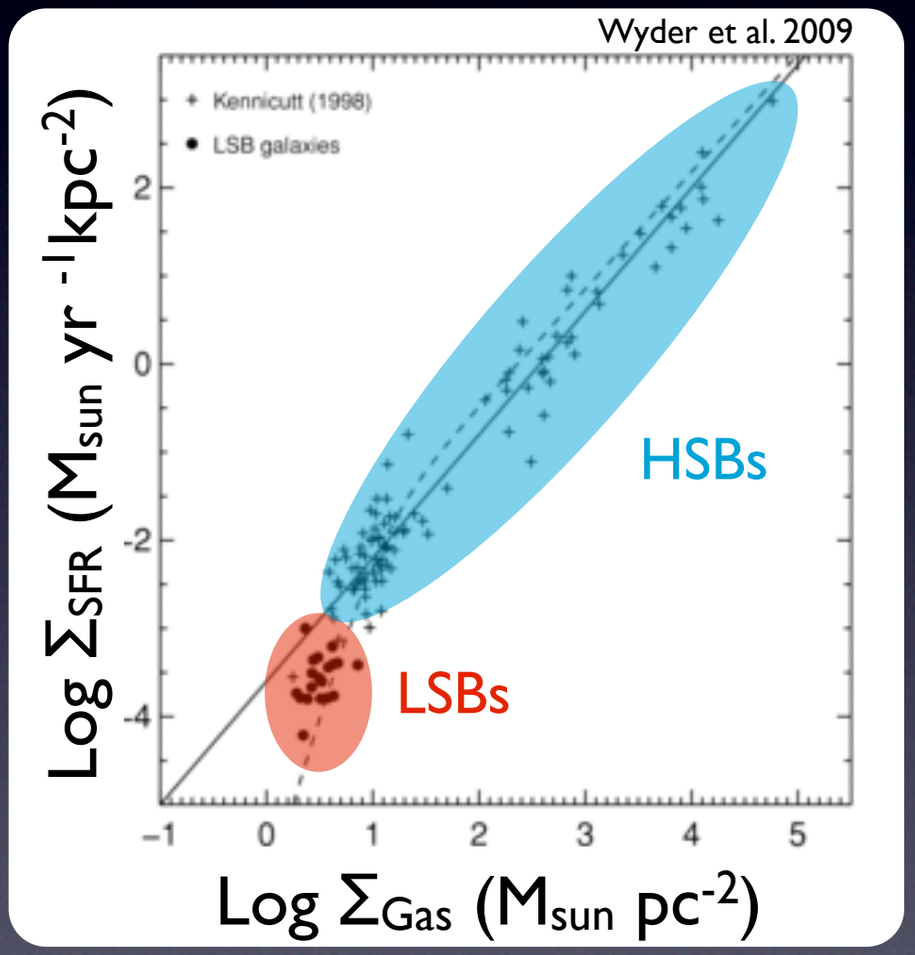
Low gas surface density

de Blok et al 1996



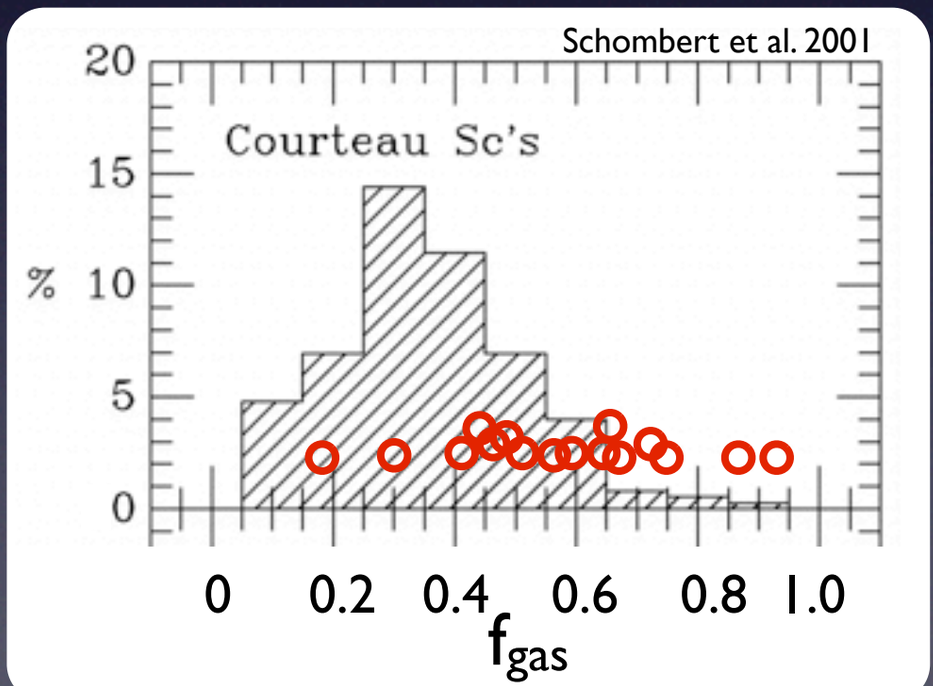
Low past & present SFR

Wyder et al. 2009



Large gas fraction

Schombert et al. 2001



Past star formation could not have been very large

LSBs Remain a Challenge for LCDM?

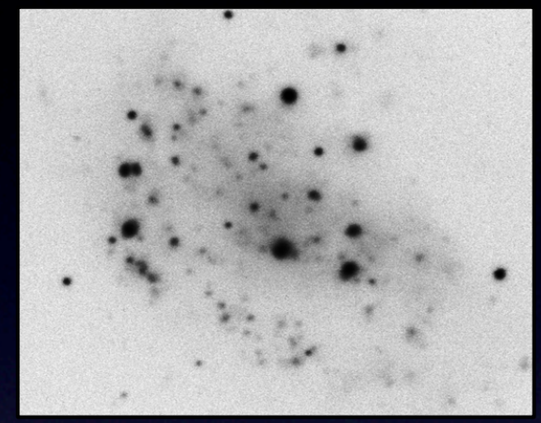
- Slowly and inefficiently form stars
- Appear relatively "unevolved, untouched, pristine"
- Lack signs of early star formation & baryonic mass loss

series of small(er) SF events $4 < z < 2$? (Pontzen & Governato 2011)

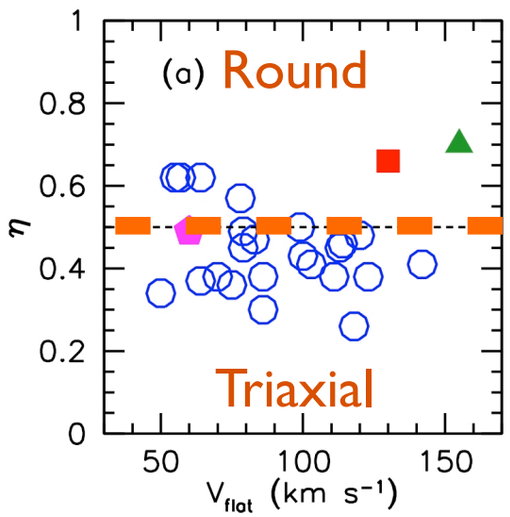
Looks difficult for baryons to modify LSB halos

Simulating LSB Galaxies

Properties to keep in mind:



- *not rare*
- *isolation*
- *range of masses*
- *low surface densities*
- *low metallicities*
- *large gas fractions*
- *low SF efficiencies*
- *low past and present SFRs*



The Challenge:

sphericalize the halo
and
flatten the cusp