LSB Galaxies and their Dark Matter Halos

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CDM Halos in Collisionless Simulations

- Steeply-rising density profiles
- Triaxial shapes

![Diagram showing log density vs log radius with a "Cuspy" halo](image)
Observations of Dark Matter-Dominated Galaxies

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

Kuzio de Naray et al. (2006, 2008)
Marchesini et al. (2002)
Baryons are Important

- ISM physics helps simulate realistic “bulgeless” disks

Brook et al. 2011
Guedes et al. 2011
Agertz et al. 2011

V_{flat} \sim 140 \text{ km/s}
V_{flat} \sim 150 \text{ km/s}
V_{flat} \sim 250 \text{ km/s}
Baryons are Important

- Bulgeless dwarf \( V_{\text{flat}} \approx 60 \text{ km/s} \)
- 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

\( V_{\text{flat}} \approx 103 \text{ km s}^{-1} \)
\( V_{\text{flat}} \approx 123 \text{ km s}^{-1} \)
\( V_{\text{flat}} \approx 142 \text{ km s}^{-1} \)

(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)
Can Baryons Sphericalize the Halo?

Kazantzidis et al. 2010:

$$\eta \equiv \frac{V_{\text{disk}}}{V_{\text{circ}}} \geq 0.5$$

Round

Triaxial

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

They must have had more baryons in the past
Can Baryons Change a Cusp to a Core?

LSB halos are underdense compared to LCDM

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

Rosenbaum et al. 2009
Inducing Star Formation

Need to funnel gas to the galaxy center

- **Mergers and Interactions**
  
  relatively isolated & on edges of LSS
  
  (Bothun et al. 1997; Rosenbaum et al. 2009)
Inducing Star Formation
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- **Secular Processes**
  - stable against bar formation
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- **High-Spin Halos**
  - high(er) angular momentum threshold
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*Initiating starbursts seems difficult*
Effectiveness of Feedback

LSBs are not exclusively low mass

Bothun et al. 1997
Effectiveness of Feedback

Need to remove baryons from LSBs with a range of masses

Kuzio de Naray & Spekkens 2011
Effectiveness of Feedback

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

(Dekel & Silk 1986)
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High star formation rates necessary when $M_{\text{galaxy}} > 10^9 M_\odot$

(Kereš et al. 2009)
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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

\[ 12 + \log(O/H) \]

\[ \log(M) \]

Kuzio de Naray et al. 2004

Wyder et al. 2009

LSBs

dIrr

SDSS Tremonti et al. 2004

\[ (NUV - r) \]
LSB Star Formation Histories

Low gas surface density

Low past & present SFR

Large gas fraction

LSBs

Log $\Sigma_{\text{SFR}}$ (M$_{\odot}$ yr$^{-1}$ kpc$^{-2}$)

Log $\Sigma_{\text{Gas}}$ (M$_{\odot}$ pc$^{-2}$)

$f_{\text{gas}}$

$\sigma_{\text{HI}}$ (M$_{\odot}$ pc$^{-2}$)

Type

S0 S0a S0b S0c S0d Im

Wyder et al. 2009

Schombert et al. 2001

de Blok et al. 1996

Low gas surface density

Large gas fraction

Low past & present SFR
LSB Star Formation Histories

Low gas surface density

Low past & present SFR

Large gas fraction

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

Triaxial Round

The Challenge:
sphericalize the halo and flatten the cusp