Observational Evidence for the Evolution of Dwarf Irregular Galaxy Disks

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Dwarf Irregulars: Lumpy little galaxies with gas
Leo T

- $M_V = -8$
- $M_* = 10^5 M_\odot$, $M_{HI} = 3M_*$
- $\Sigma_{HI}(\text{max}) = 7 \times 10^{20} \text{ cm}^{-2}$
- Old stars + young (200 Myr-1 Gyr) stars

(Ryan-Weber et al. 2008)

de Jong et al. 2008

Irwin et al. 2007
IC 10

Survey of the Resolved Stellar Content of Nearby Galaxies Currently Forming Stars, Massey et al. 2007

- $M_V \sim -16$, $M_{HI} = 3 \times 10^7 \, M_\odot$, $\Sigma_{HI}(\text{max}) = 10^{22} \, \text{cm}^{-2}$
- Extraordinary number of WR stars/area (Massey & Holmes 2002)
- Merger or interaction (Nidever et al. 2013)

Hunter et al. 2012
Surprises about dwarf *irregular* galaxy stellar disks ...
Stellar disks can extend a very long ways in tiny galaxies.

- **LMC** (Saha et al. 2010)
  To 12 disk scale lengths;
  $\mu_l \sim 34$ mag arcsec$^{-2}$

- **Sextans B** Bellazzini et al. 2014
  To 6 disk scale lengths;
  $\mu_V \sim 31$ mag arcsec$^{-2}$

![Surface density of MS stars graph]

![Graph with distance vs. surface density]

5.2  8.7  12.2  15.7  disk scale lengths

R (arcmin)
Extended disks are often well-behaved exponentials.

- LMC (Saha et al. 2010)
- Sextans B Bellazzini et al. 2014

Surface density of MS stars

- Distance Along LMC disk from center (kpc)
- ln(No. of MS stars in field)

- Sextans B
- Surf. phot. from H206
- Star counts
- SP: n=1.1 h=2.0

- Disk scale lengths
  - 5.2
  - 8.7
  - 12.2
  - 15.7

- R (arcmin)
- μ_ν
Mass column densities from deep imaging

\[ \Sigma \left( \frac{M_\odot}{\text{pc}^2} \right) \]

Radius in disk scale lengths

Hunter et al. 2011
Outer disks: stellar surface brightness/mass profiles with breaks

Hunter et al. 2011


Zhang et al. 2012; Herrmann et al., in prep
Spiral and dwarf stellar light profiles break at ~same V-band surface brightness.

Something fundamental happens at the break in both spirals and dwarfs.

See poster by J. Herpich

Herrmann et al 2013;
Star formation at the extremes
Stars have formed at extremely low average gas densities.

UV extends into the outer disk too implying star formation out there. But $\Sigma_{\text{HI}} \sim 1/20$ Toomre $\Sigma_{\text{crit}}$. 

$\mu_V \sim 30 \text{ mag}/\text{arcsec}^2$
FUV knots extend into far outer disks

Radius of furthest FUV knot / disk scale length

Number of LITTLE THINGS galaxies

Gehret, 2014

DDO 50

NGC 2366

4.8 disk scale lengths

4.5 disk scale lengths
Large HI holes are sometimes found in outer disks

Catalogues of holes and analysis of relationship to stellar populations: Pokhrel, PhD in prep
Large HI holes and stars?

Yes stars: Kerp et al 2002, Weisz et al. 2009 (CMDs, but multiple generations)
Constellation III in the LMC

--Diameter ~ 1.8 kpc
--Roughly 2.7 disk scale lengths
--Huge star-forming event 15 Myrs ago

Green = HI
Red = HII
Kim et al. 1999
dlrr disks change with time
Disks change with time: *outside-in*

\[
\frac{\text{SFR}_{0.1\text{Gyr}}}{\text{Stellar mass}}
\]

Similar for \( \frac{\text{SFR}_{1\text{Gyr}}}{\text{Stellar mass}} \)

\[\log M_{\text{bary}} < 8.0\]

\[\log M_{\text{bary}} > 8.0\]

Radius in units of disk scale length

Star formation disk is shrinking with time in dwarfs. But *inside-out* in spiral disks.

Zhang et al. 2012; See also Pan et al. 2015
**Outside-In: LMC** (Meschin et al. 2013)

3.5 – 6 kpc –

Inner – 4 Gyr and 7 Gyr ago formed equal amounts of stars; continuing to form stars into present epoch

Outer – 40% of stars formed at 4 Gyr as at 7 Gyr ago; continued only to 1 Gyr ago
Mismatch of stellar and HI disks

Δ position angle –
Over half of the LITTLE THINGS
galaxies have differences >20°

Indications of an oval disk or
warp? But not all of the criteria
are met. Kormendy 1982

Data from Oh et al. 2015,
Hunter & Elmegreen 2006
Core-like Dark Matter distributions indicate DM in dIrrs have been modified by stellar feedback

(Recall talk by C. Brooks)

Prediction from $\Lambda$CDM

Oh et al. 2015
Take away points

- dlrrs cover a wide range in star formation rates
- dlrrs often have highly extended, well-behaved stellar exponential disks
- Breaks in stellar profiles in outer disks are common in dlrrs and spirals and reveal some common phenomenon
- Young stellar populations are found in far outer disks
- But over a Hubble time dlrr disks are growing from the outside-in and perhaps changing in fundamental ways