STAR FORMATION IN DIM GALAXIES

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The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.

The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.

More information can be found at: http://sings.stsci.edu/
NGC 6946 - typical spiral galaxy

HI more extended than stars, but outweighed by them
Holmberg II - typical dim, gas rich dwarf galaxy

HI more extended than stars, and outweighs them
CCD imager + friends
High Surface Brightness (HSB)

Azimuthally averaged light distribution typically exponential for spiral disks.

Low Surface Brightness (LSB)
LSBGs often well approximated as exponential disks

\[ \mu = 23.52 \]

\[ \alpha = 13.72 \]
Sometimes have central bulge components
DDO 168

Frequently have central light deficit - “flat core” or Type II profiles

\[ \mu = 21.11 \]

\[ \alpha = 35.58 \]
normal spirals

$\mu_0$ (B mag arcsec$^{-2}$) vs. $R_d$ (kpc)

Selected from UGC

Specific to de Jong (1994)
LSB galaxies

McGaugh & Bothun (1994)
de Jong (1994)
Romanishin
Sprayberry

Selected like UGC but from deeper plate material
dwarf LSB galaxies

\[ \mu_0 (\text{B mag arcsec}^{-2}) \]

\[ R_d (\text{kpc}) \]

- McGaugh & Bothun (1994)
- Schombert, Maciel, & McGaugh (2011)
Global color-color diagram for galaxies

13 Gyr SSP

[Fe/H] = +0.4

1 Gyr SSP

[Fe/H] = -2.0

LSB dwarfs

RC3 galaxies
DDO 168

$V_h = 192 \text{ km/sec}$

$m - M = 28.59$

$D = 5.21 \text{ Mpc}$

$\mu_o = 21.1 \text{ V mag arcsec}^{-2}$

$\alpha = 0.5 \text{ kpc}$

F564-V3

$V_h = 483 \text{ km/sec}$

$m - M = 30.09$

$D = 10.4 \text{ Mpc}$

$\mu_o = 23.5 \text{ V mag arcsec}^{-2}$

$\alpha = 0.4 \text{ kpc}$
**D572-2**

- $V_h = 3746$ km/sec
- $m - M = 33.76$
- $D = 56.5$ Mpc
- $\mu_o = 22.3$ V mag arcsec
- $\alpha = 1.4$ kpc

**F561-1**

- $V_h = 4807$ km/sec
- $m - M = 34.22$
- $D = 69.8$ Mpc
- $\mu_o = 22.6$ V mag arcsec
- $\alpha = 1.6$ kpc

[http://abyss.uoregon.edu/~js/lsb/maps/index.html](http://abyss.uoregon.edu/~js/lsb/maps/index.html)
$H\alpha$ traces recent Star Formation

D495-2

D570-3

F611-1

$B - V = 0$

$B - V = 1$
NGC 628 - bright spiral

$\text{H} \alpha$ (pink) traces recent Star Formation
What about old stars?
Inside 4 m dome
SQIID (older IR imager) at 4m Cassegrain focus 3’ x 3’ FOV
NEWFIRM near-IR imager
28’ x 28’ FOV
Kitt Peak 4m + NEWFIRM K’-band (2.2 micron)

LSB galaxies in the near-IR

F561-1

F563-V1

D570-7

D564-9

Kitt Peak 4m + NEWFIRM K’-band (2.2 micron)
Stellar mass from near-IR

e.g., $L_K$ plus B-V color + stellar pop model:

$$\log \frac{M_*}{L_K} = a + b(B - V)$$

$$< \dot{M}_*> \approx M_*H_0$$

past average SFR

Star Formation Rate from H$\alpha$

current SFR

What about the gas?
Spiral Galaxies in THINGS — The HI Nearby Galaxy Survey

star dominated spirals

NGC 5055 (M 63)
NGC 628 (M 74)

NGC 3031 (M 81)
NGC 5194 (M 51)

THINGS
The HI Nearby Galaxy Survey

color coding:
THINGS Atomic Hydrogen
(Very Large Array)
Old stars
(Spitzer Space Telescope)
Star Formation
(GALEX & Spitzer)

scale:
15,000 light years

Image credits:
VLA THINGS: Walter et al. 08
Spitzer SINGS: Kennicutt et al. 03
GALEX NGS: Gil de Paz et al. 07
gas dominated dwarfs

Dwarf Galaxies in THINGS — The HI Nearby Galaxy Survey

THINGS
The HI Nearby Galaxy Survey

color coding:
THINGS Atomic Hydrogen
(Very Large Array)
Old stars
(Spitzer Space Telescope)
Star Formation
(GALEX & Spitzer)

scale:
15,000 light years

Image credits:
VLA THINGS: Walter et al. 08
Spitzer SINGS: Kennicutt et al. 03
GALEX NGS: Gil de Paz et al. 07
Aricebo 305 m
EVLA (HI @ 21 cm)  
CARMA (CO @ 2.6 mm)
CO not detected

CO not detected

CO not detected

CO not detected

SFR correlates roughly 1:1 with stellar mass; correlation with gas mass (mostly HI) steeper

\[ M_g = \eta M_{HI} \quad \eta = \frac{1}{X} \left( 1 + \frac{M_{H_2}}{M_{HI}} \right) \]
Gas fraction correlates with stellar mass; not so much with total gas mass.

\[ M_g = \eta M_{HI} \]

\[ \eta = \frac{1}{X} \left( 1 + \frac{M_{H_2}}{M_{HI}} \right) \]
Holmberg II - again

Note holes in HI distribution... blown by feedback?
A movie of a simulation of the evolution of the gaseous component of a dwarf galaxy may be viewed at

http://www.astro.washington.edu/users/fabio/movies/dwarfCDM2.mov

Governato et al. 2010, Nature, 463, 203