Oxygen abundances in outer galaxy disks

Fabio Bresolin
Institute for Astronomy
University of Hawaii
gas depletion times (yr)

Spirals $r < 2r_{25}$

Inner disks

Outer disks

Bigiel et al. 2010
at low SFR levels the number of ionizing O stars becomes very small, subject to stochastic sampling of the upper IMF

the UV comes from longer-lived (100 Myr), smaller mass B stars

NO NEED for IMF changes

**a gas density threshold for star formation? Different IMF?**

Boissier et al. 2007
why do stars form in outer disks?

Localized higher gas density

(Dong et al. 2008, Bush et al. 2008)
why do stars form in outer disks?

Galaxy interactions

(Gil de Paz et al. 2005)
young?

inside-out
Kennicutt, Bresolin & Garnett 2003; Bresolin 2007
ABUNDANCE GRADIENTS IN OUTER DISKS

M83

Bresolin, Kennicutt, Ryan-Weber & Goddard 2009
Star formation efficiency: $\Sigma_{\text{SFR}} / \Sigma_{\text{gas}} \ (\text{FUV/HI})$

$$\frac{O}{H} = \frac{y_O t \Sigma_{\text{SFR}}}{\mu \Sigma_{\text{HI}}} \propto SFE$$

Bigiel et al. 2010
FLAT GRADIENTS

‘Intermediate age’ (>1 Gyr) stars present

eg M81, M83, M33, NGC 2403
(Davidge 2009, Barker et al. 2012)

Vlajic et al. 2009
FLAT GRADIENTS

Milky Way Cepheids
Acharova et al. 2010
(also Andrievski et al 2004)

[Fe/H] vs. Galactic radius (kpc)

Milky Way
Lepine et al. 2011

NGC 2915
Werk et al. 2010, 2011

12 + log(O/H) vs. R/R_{Ho}
The timescales for obtaining the currently observed O/H ratio appear to be longer than a Hubble time.

**BUT**

Analysis of stellar content + SFHs of nearby resolved galaxies + age gradients + inside-out growth + results of cosmological simulations suggest that outer disks cannot have formed stars for more than a few (~4) Gyr.

*In situ star formation cannot explain observed O/H*
Radial Mixing

bars
tidal interactions/mergers
satellite encounters
radial gas flows (Lacey & Fall 1985)
resonance scattering with transient spiral density waves (Sellwood & Binney 2002)
spiral+bar resonances (Minchev et al. 2011)

Enriched Infall

Gas accretion modulated by feedback, outflows and SF
Circumgalactic medium enriched via galactic winds (eg ‘wind recycling’ models, Oppenheimer & Dave’ 2008)
LOW SURFACE BRIGHTNESS GALAXIES

$\mu_{o,B} > 23$ mag arcsec$^{-2}$

$\mu_{o,B} = 23.8$ mag arcsec$^{-2}$

$\mu_{o,B} = 23.5$ mag arcsec$^{-2}$

$\mu_{o,B} = 23.6$ mag arcsec$^{-2}$

de Blok & van der Hulst 1998
\( \mu_{0,B} \text{ (disk)} = 23.1 \text{ mag arcsec}^{-2} \)

\( \mu_{0,B} \text{ (disk)} = 24.0 \text{ mag arcsec}^{-2} \)
EARLY-TYPE GALAXIES

Salim & Rich 2010
EARLY-TYPE GALAXIES

NGC 404
(S0)