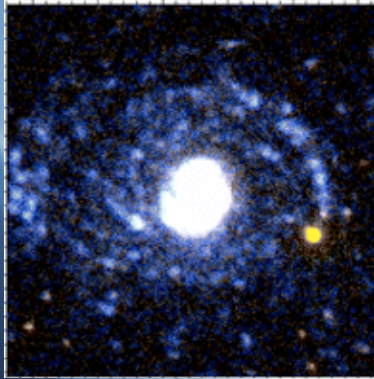
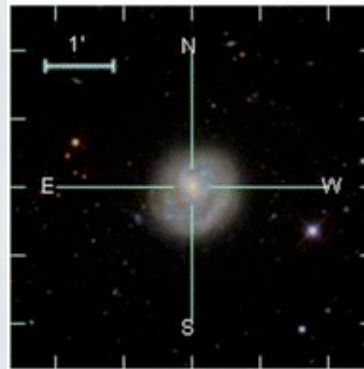


Exploring Outer Disk Star Formation



Thilker et al. 2007



SFR@50 - July 8, 2009

Stephanie J. Bush (Harvard-Smithsonian CfA)

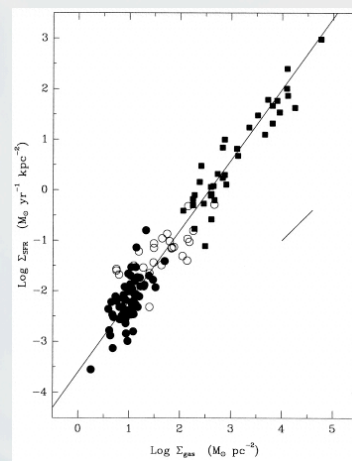
T.J. Cox (CfA), Chris Hayward (CfA), David Thilker (JHU),
Lars Hernquist (CfA), Gurtina Besla (CfA), Zhong Wang (CfA)

Star Formation Relations in Galaxies

- Kennicutt-Schmidt Star Formation: (Kennicutt 1998)

$$\Sigma_{SFR} \propto \Sigma_{gas}^{1.4 \pm 0.15}$$

- Threshold Density: 3-5 M_{\odot}/pc^2 (Kennicutt 1989, Martin & Kennicutt 2001)



Kennicutt 1989 & 1998

Outer Disk Star Formation

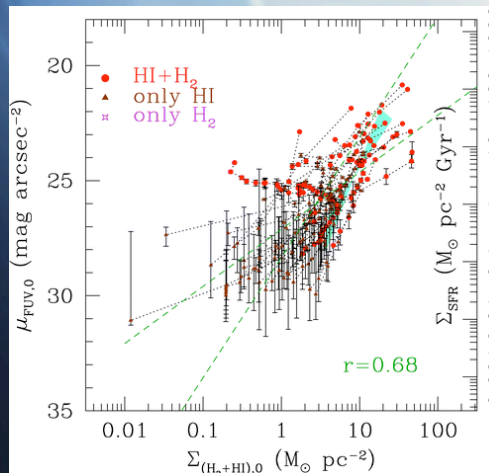


- H α knots exist beyond H α break!
(Ferguson et al. 1998, Martin & Kennicutt 2001, Werk et al. 2008)
- GALEX discovery: **30% of disks show UV emission beyond optical radius**, XUV disks (Thilker et al. 2007, Zaritsky & Christlein 2007)

Questions:

- Can outer disk star formation be described by the same 'laws' as inner disks?
- What is the star formation history of outer disks?

Theories



Boissier et al. 2007

- **Over-densities** due to interactions, spiral structure, etc. **locally exceed the star formation threshold** in outer disk (e.g. Martin & Kennicutt 2001, Elmegreen & Hunter 2006)
- No threshold? (Boissier et al. 2007)
- IMF changes (Pflamm-Altenberg & Kroupa 2008)

Approach

- Add **extended gas disks** to a Milky Way analogue and evolve using **usual star formation laws**
 - Kennicutt-Schmidt with volume density threshold
- Run a set of simulations **varying gas profiles**
- Use **Gadget-2** to run **SPH** simulations (Springel 2005, Springel & Hernquist 2003)
 - multiphase model - tracks hot and cold phases of gas
 - Star formation occurs out of cold phase (\sim HI and H_2)
- Use the radiative transfer code *Sunrise* to **create FUV and Ks-band images** (Jonsson 2006)
 - Applies population synthesis spectrum to each stellar particle
 - Includes absorption and scattering from dust

Types of XUV Disks (Thilker et al. 2007)

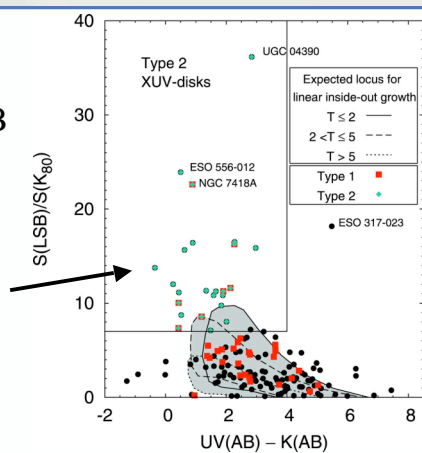
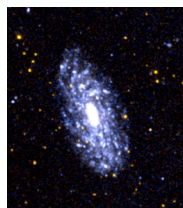
Type I

Structured UV knots (20%)



Type II

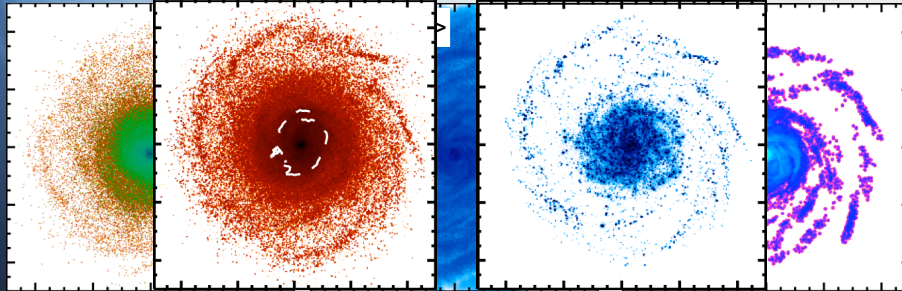
UV bright LSB zone (10%)



Thilker et al. 2007

An Example

Constant density outer disk gas profile ($5 M_{\text{sun}}/\text{pc}^2$)

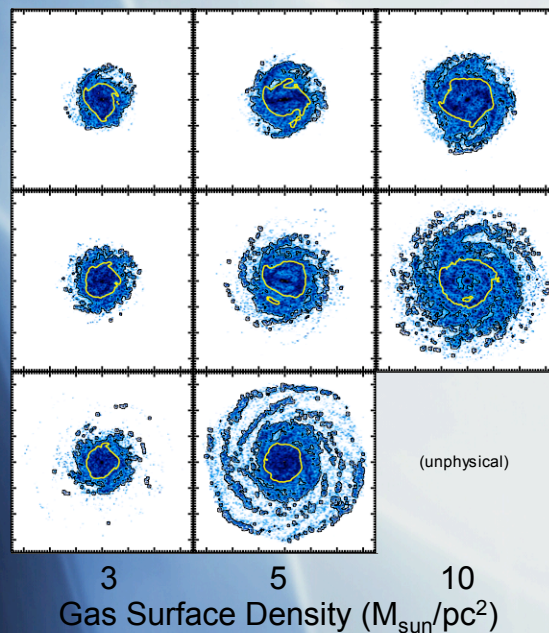


Bush et al. 2009 in prep.

Spiral structure propagates through to the outer disk, causing star formation where the gas density exceeds the threshold.
(see Bush et al. 2008)

A star formation density threshold is not the same as a star formation threshold radius.

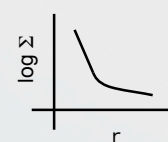
Varying the Gas Distribution



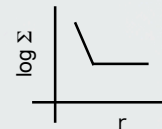
Exponential



1/R (Mestel)



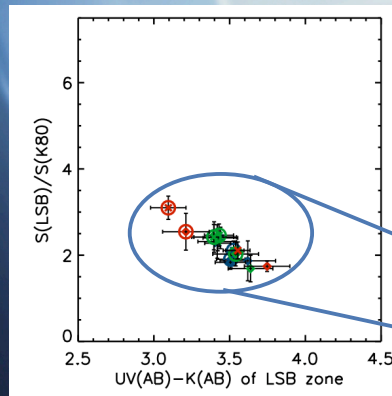
Constant



(unphysical)

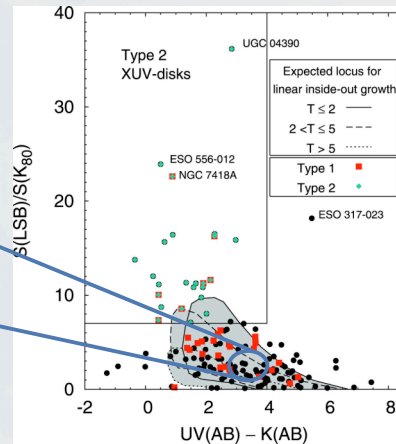
Bush et al. 2009 in prep.

Type Classification



Bush et al. 2009 in prep.

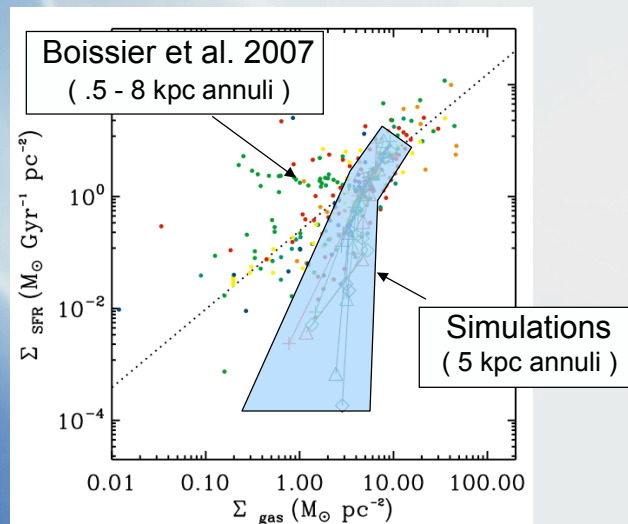
Simulations



Thilker et al. 2007

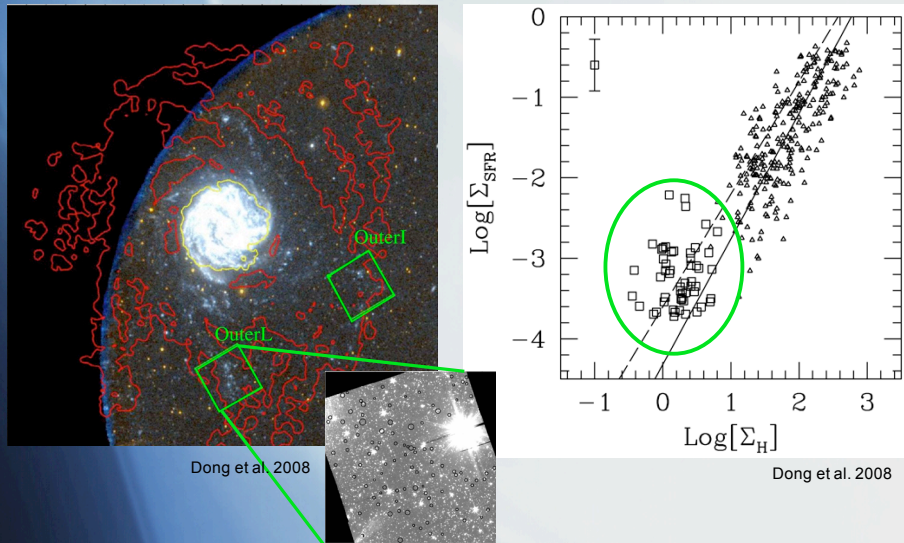
We do not reproduce Type II disks

Radial Kennicutt-Schmidt Plots



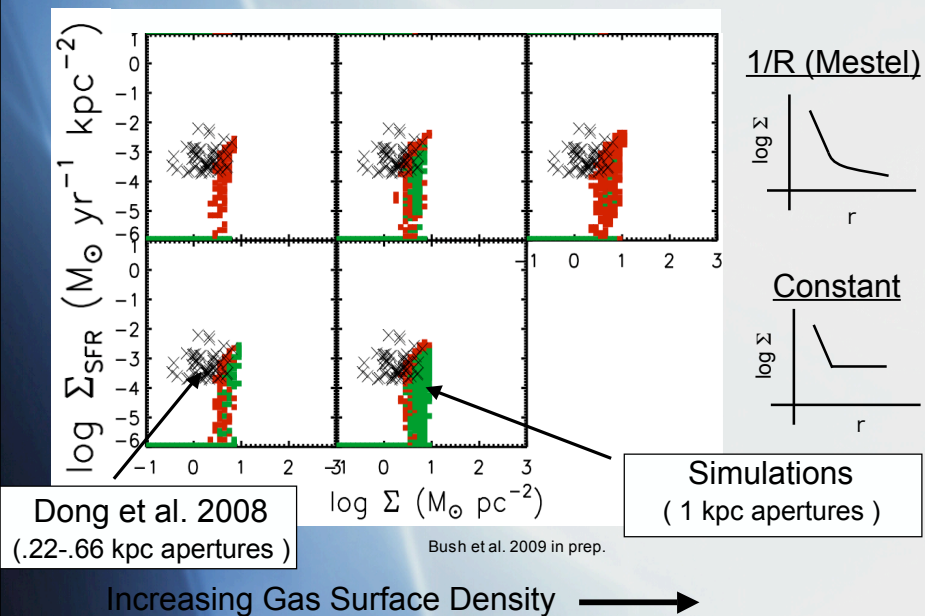
Bush et al. 2009 in prep.

Local Kennicutt-Schmidt in M83

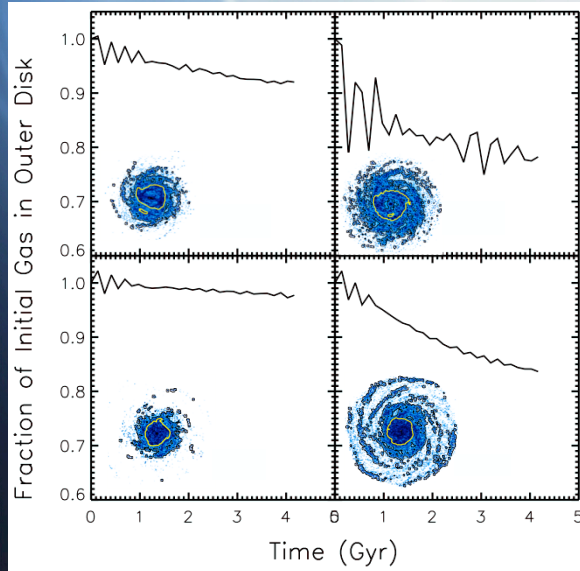


- UV selected objects in the outer disk of M 83 are consistent with a Toomre threshold and Kennicutt-Schmidt law

Local Kennicutt-Schmidt Plots



Gas Consumption



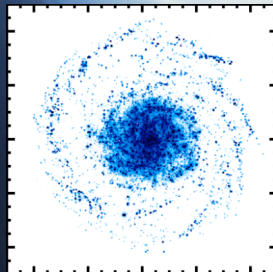
Bush et al. 2009 in prep.

- Maximum gas consumption in outer disk
~20% at 4 Gyr
- Outer disk star formation can be long lived
- Consistent with H I content of outer disks (e.g. Gil de Paz 2007)

Conclusions and Future Work



Thilker et al. 2007



Bush et al. 2009 in prep.

- Outer disk star formation such as that in Type I XUV disks can be recreated qualitatively with the **usual star formation prescriptions** and an **extended gas disk** near the threshold density
- We do not create Type II disks with these simulations
- If this is the case, outer disk star formation can be long lived
- Future Work:
 - How does the morphology/amount of star formation change if outer perturbations are caused by interactions?
 - Other star formation prescriptions