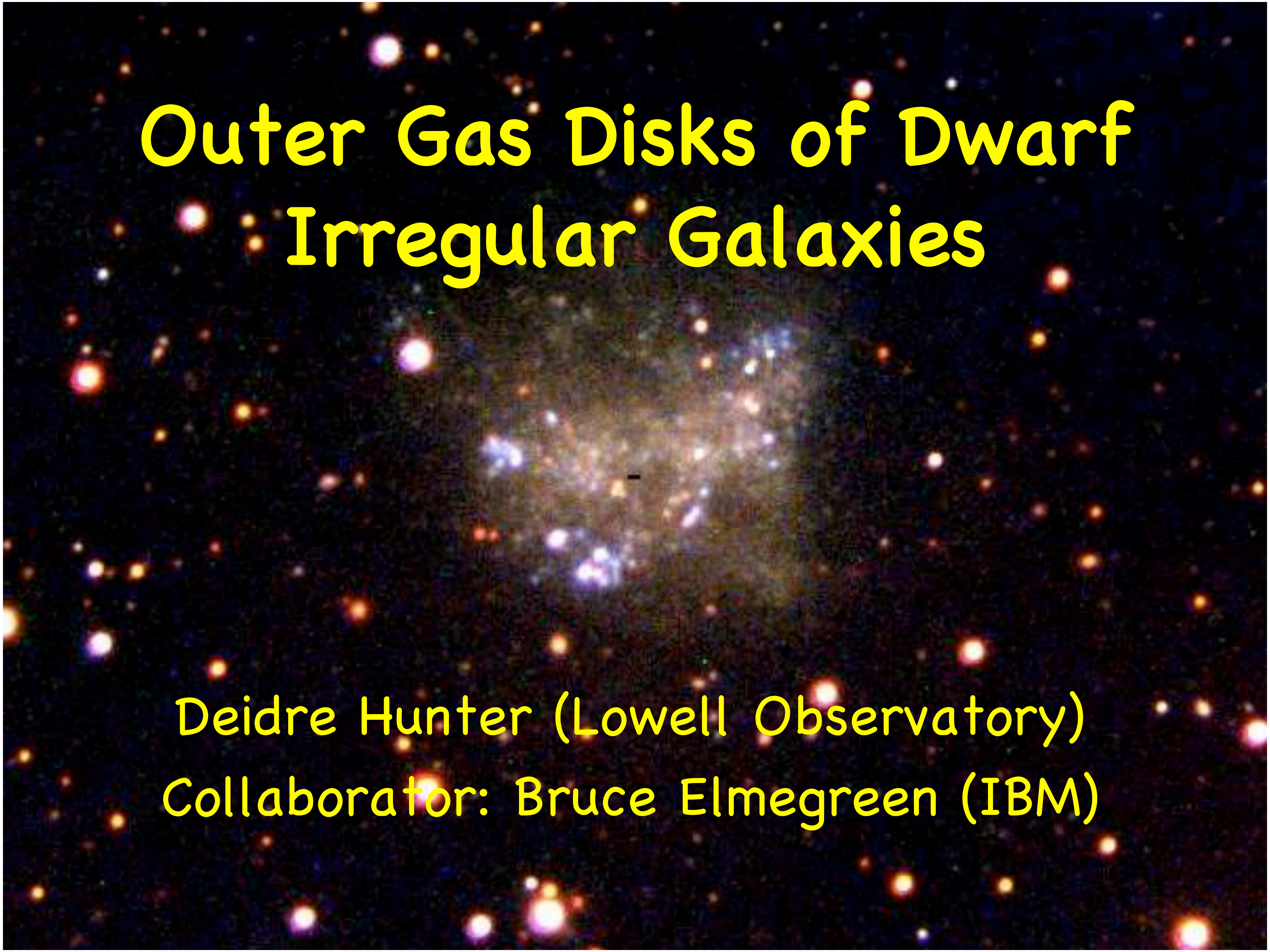
Outer Gas Disks of Dwarf Irregular Galaxies



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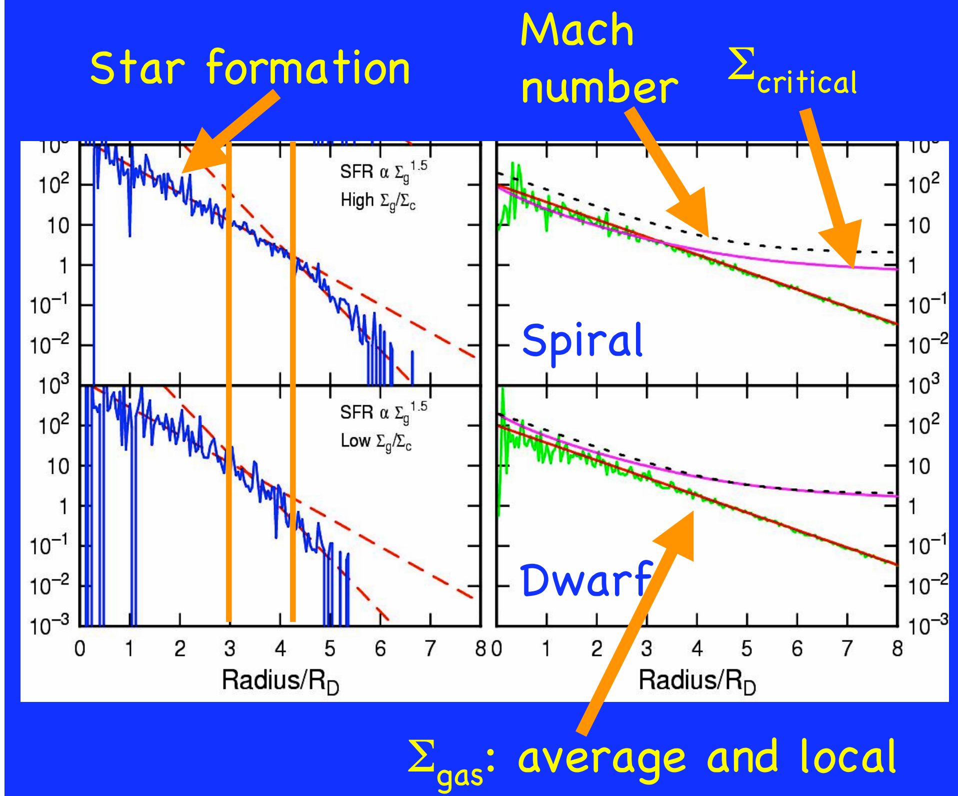
Motivation

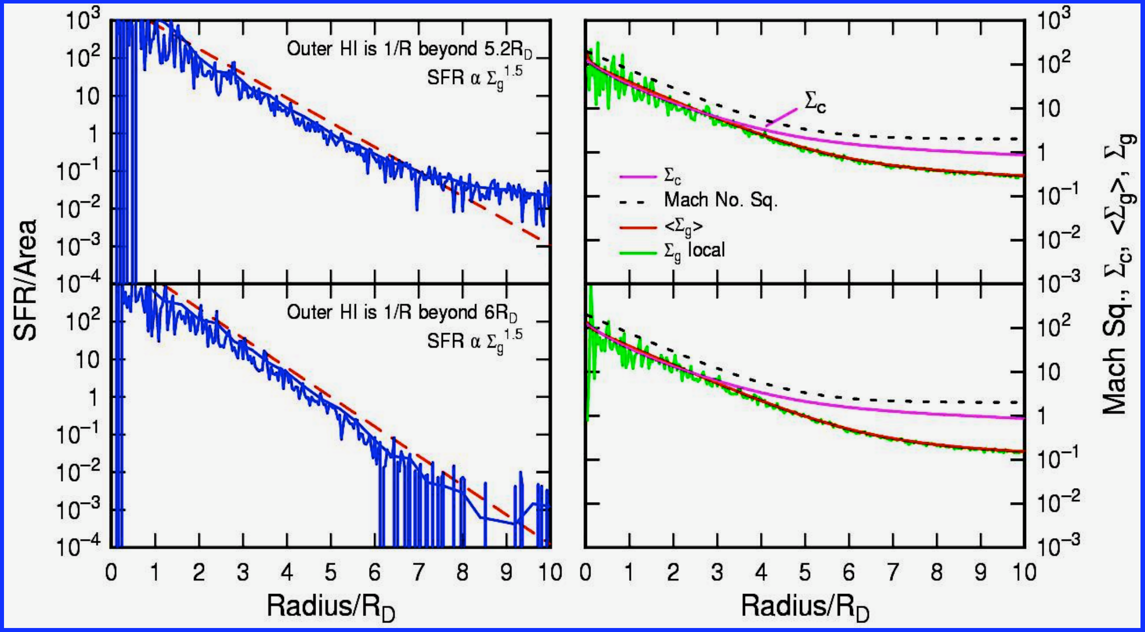
- Star formation processes in outer stellar disks of dwarfs
- The role of the HI in determining the nature of stellar disks
  - In most dIm, the gas density even in the central regions is below the threshold for spontaneous cloud formation through large-scale gravitational processes (Toomre 1964).
  - Outer stellar disks of dIm present a particularly difficult test of our understanding of the cloud/star formation process.

A model of star formation applicable to the outer parts of dIm and spiral disks (Elmegreen & Hunter 2006)



- Large-scale gravitational instabilities plus local compression mechanisms (turbulence, etc)
- In outer disks: turbulence forms clouds that locally exceed the Toomre critical gas density.
  - Patchy star formation
  - Steeper stellar exponential profile
    - 24% of 94 dIm show this (Hunter & Elmegreen 2006)

But, the star formation profile depends on the details of how the gas drops off.



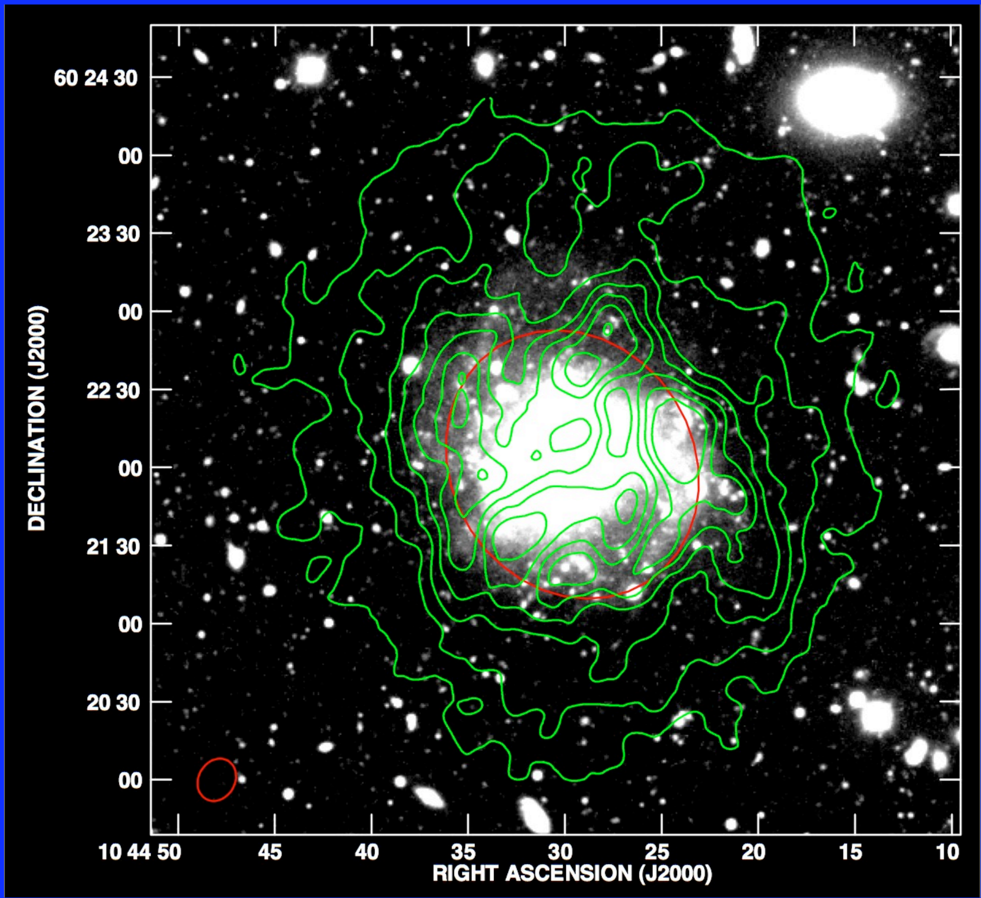
- Example: If the gas profile becomes shallower in the outer parts, the star formation profile can be either a single exponential or become shallower, depending on the details of the gas distribution

Gas density profiles $\Sigma_{gas}(R)$

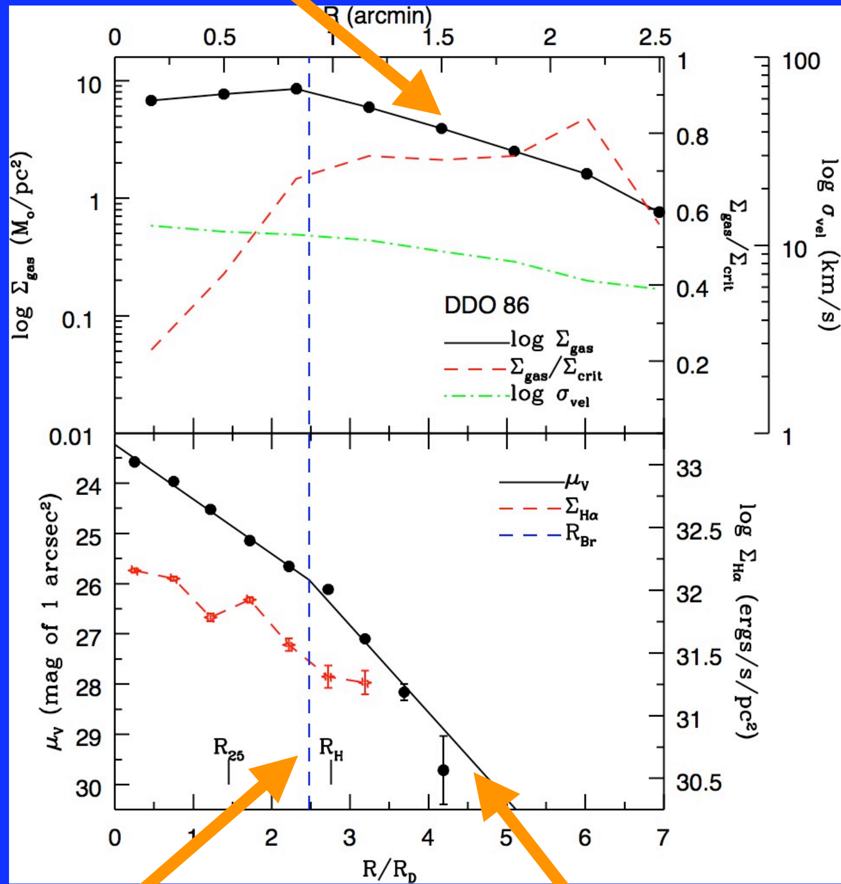
- 15 dIm, 2 BCDs, 2 Sms (subset of survey of 136 dwarfs)
  - 3 dIm, 2 BCDs have peculiar HI kinematics (plotted as red points).
- HI data from
  - DDO 43: Simpson, Hunter, & Nordgren 2005
  - DDO 50: Puche et al. 1992
  - DDO 53, DDO 86, DDO 87, DDO 133, NGC 4163, Haro 14, UGC 11820: Hunter et al., in preparation
  - DDO 105, DDO 168: Broeils 1992
  - DDO 154: Carignan & Beaulieu 1989
  - DDO 155: Carignan et al. 1990
  - IC 1613: Wilcots 2001
  - NGC 2366: Hunter, Elmegreen, & van Woerden 2001
  - WLM: Kepley, Wilcots, Hunter, & Nordgren 2007
  - DDO 210: Iyer, Simpson, & Hunter 2006, submitted
  - VII Zw 403: Simpson et al, in preparation
  - DDO 88: Simpson, Hunter, & Knezek 2005

Example: DDO 86

Integrated HI contours on *V* image



Σ_{gas}



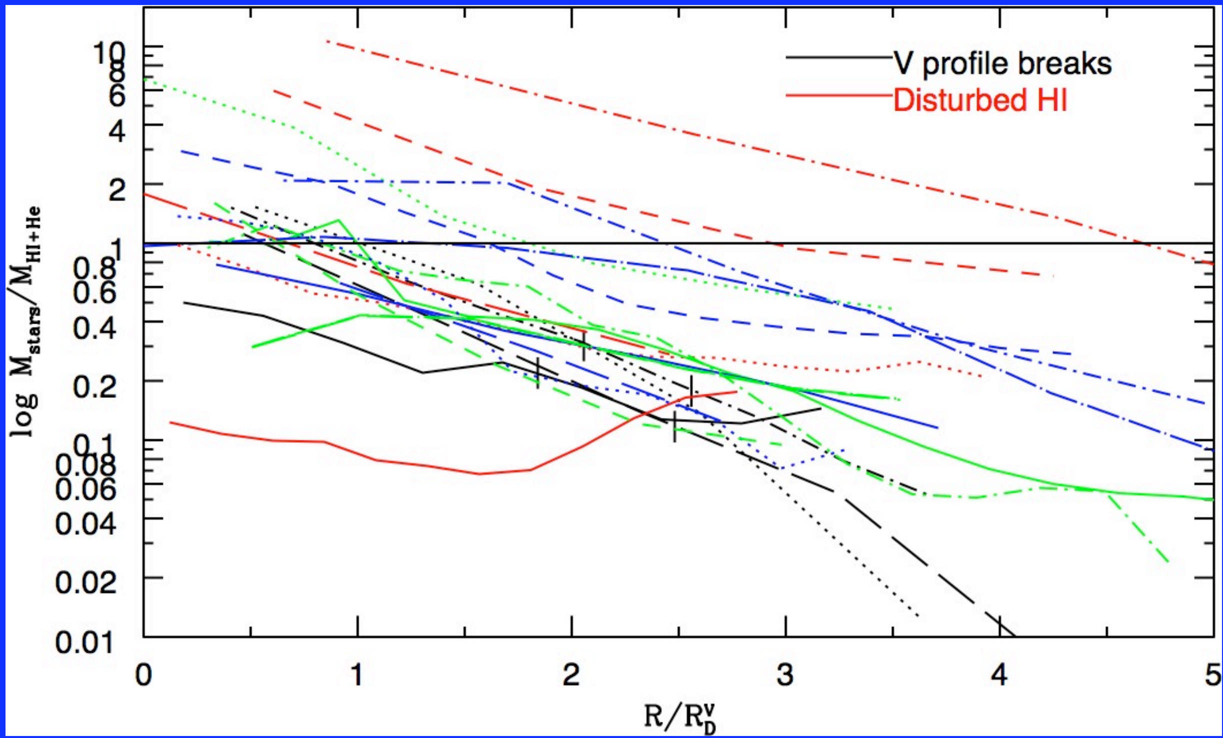
V

Break in *V* exponential profile.

M_{stars}/M_{gas} (R)

- M_{gas} is HI plus He
- M_{stars} from azimuthally-averaged L_V and constant stellar mass/light ratio of 0.57
  - Average of Bell & de Jong (2001) models with "scaled Salpeter" stellar initial mass function for average B–V=0.35 of dIm

M_{stars}/M_{gas}



$M_{stars}>M_{gas}$

$M_{stars}=M_{gas}$

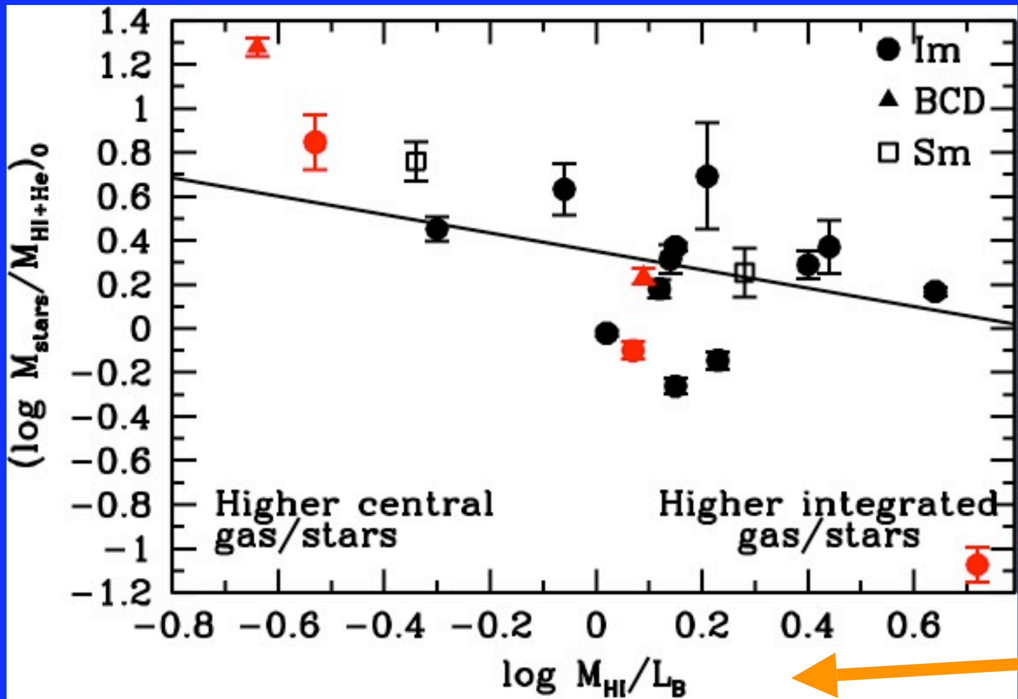
$M_{stars}<M_{gas}$

➔In most, the galaxy is gas-dominated and becomes increasingly gas-rich with radius, implying a decreasing large-scale star formation efficiency.

➔Lack of sharp transitions in the star/gas ratio, including at breaks in the optical exponential profiles, suggests that the factors dominating the change in star formation with radius are changing steadily.

M_{stars}/M_{gas} --- the central ratio

Central stars/gas



Integrated HI/starlight

➔Galaxies with a higher central ratio of gas/stars have a higher integrated ratio of gas/stars.

We fit the fall-off of the gas surface density with a Sersic function:

$$I(R) = I_0\, e^{-(R/R_0)^{1/n}}$$

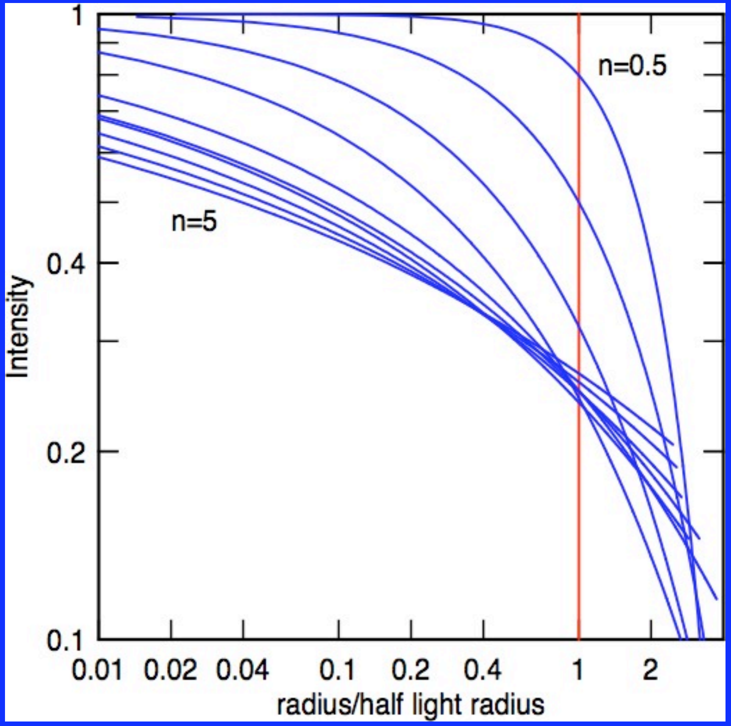
Written here as:

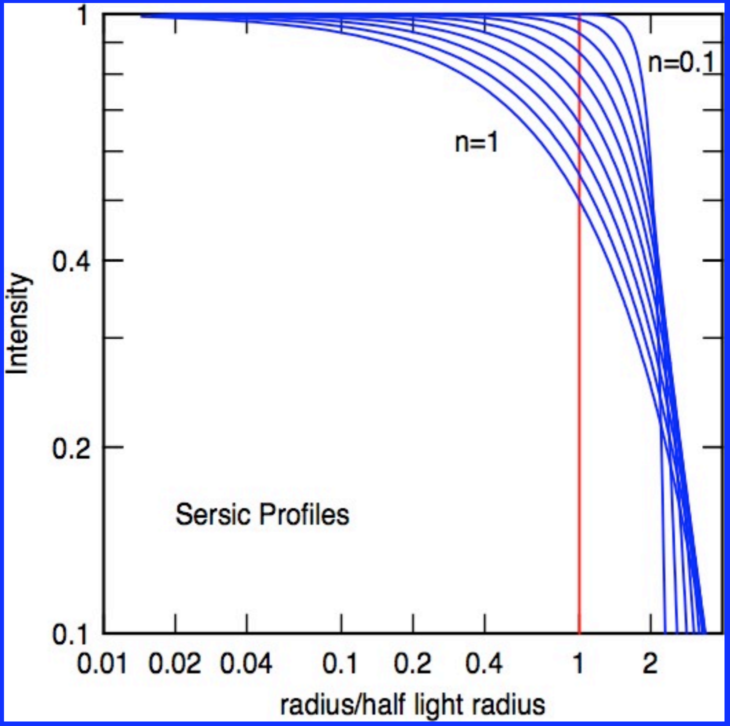
$$\log \Sigma_{gas}(R) = (\log \Sigma_{gas})_0 - 0.434\, (R/R_0)^{1/n}$$

Optical profiles of elliptical galaxies are fit with n=4 and exponential disks with n=1.

➔ Here, the HI profiles of dwarfs are fit well with n≤1.

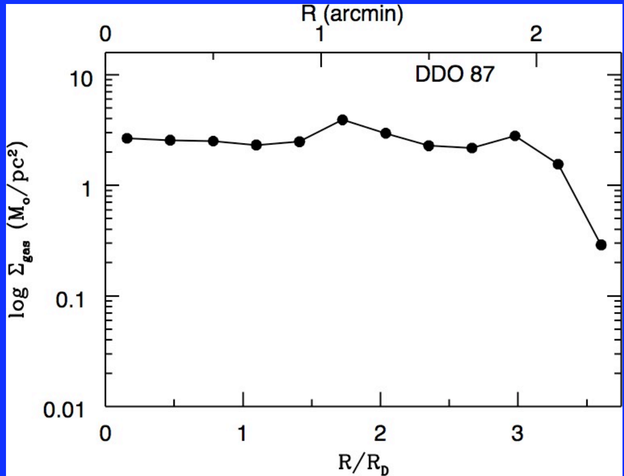
Sersic profiles as a function of *R* normalized to the half light radius.



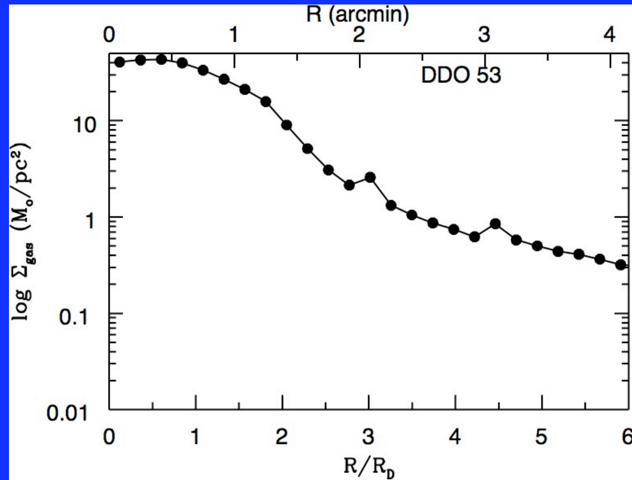


➔There's a wide variety of gas fall-offs with radius.

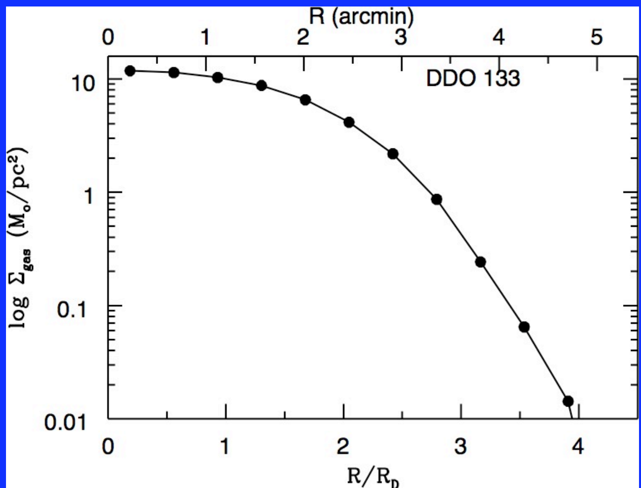
Flat



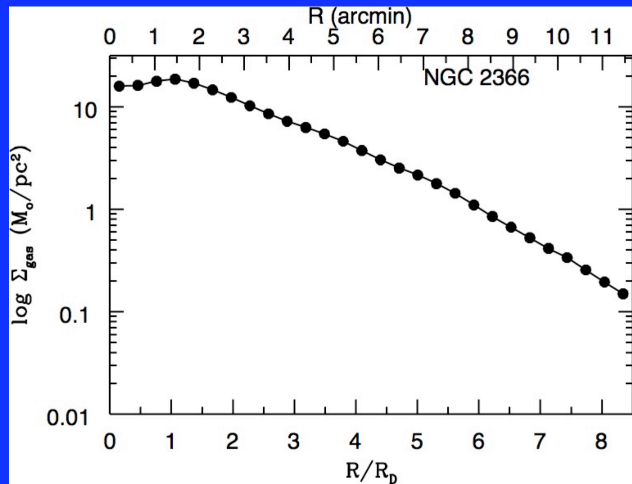
Two parts



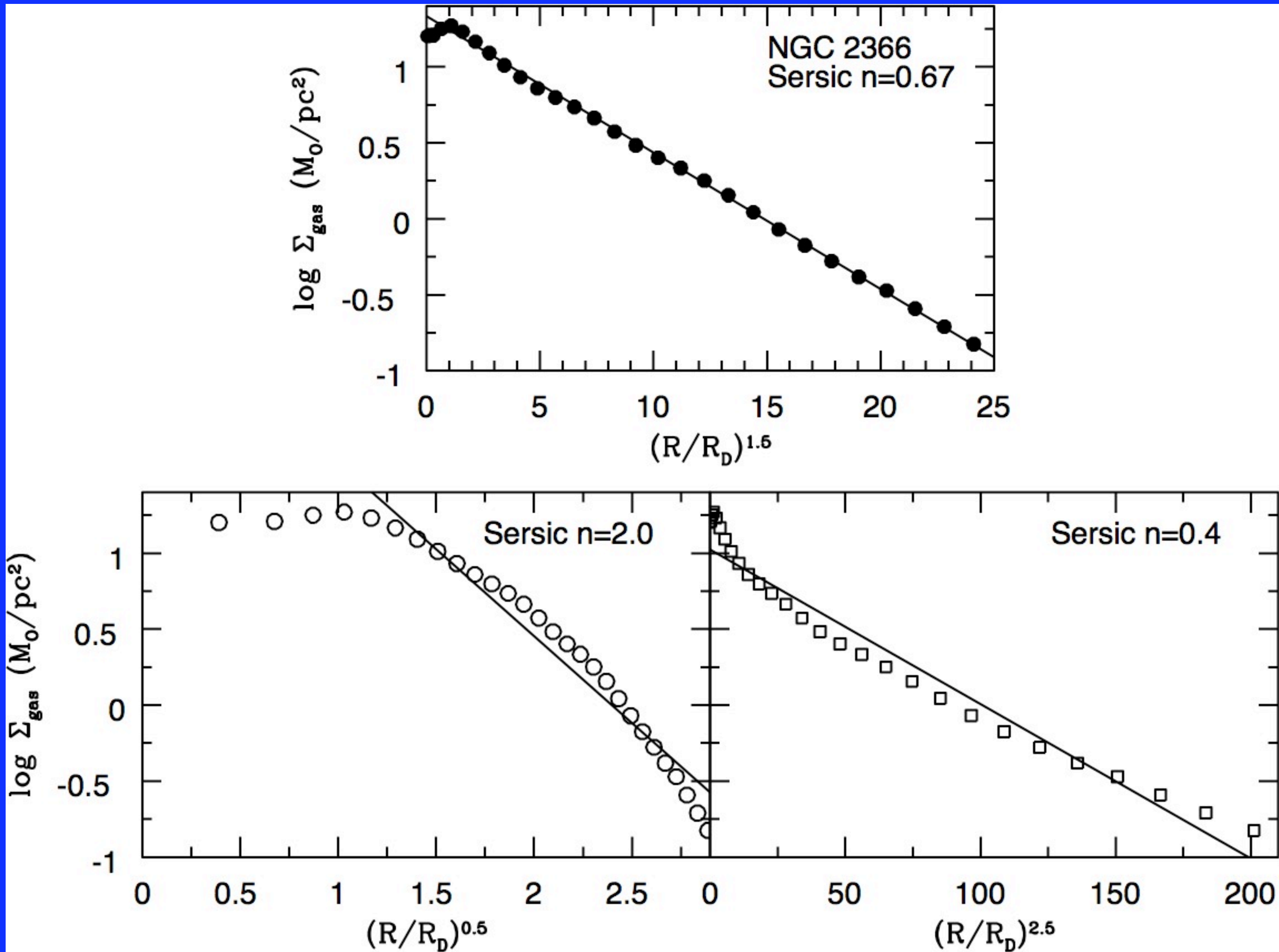
n=0.29



n=0.67

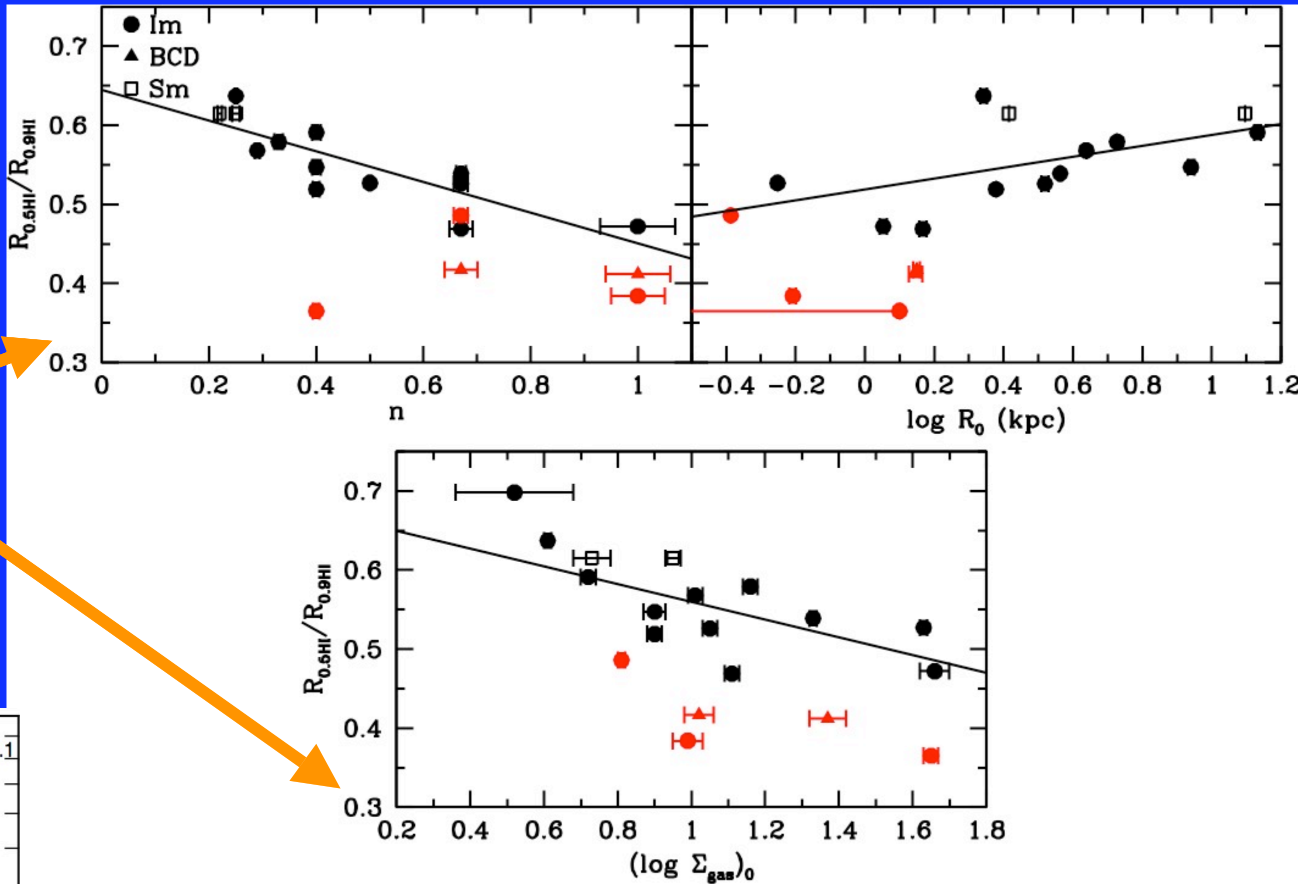


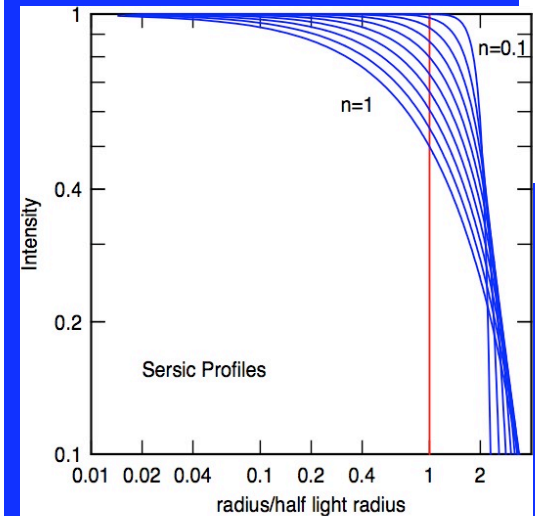
Example: NGC 2366



HI R_{50}/R_{90} and Sersic parameters

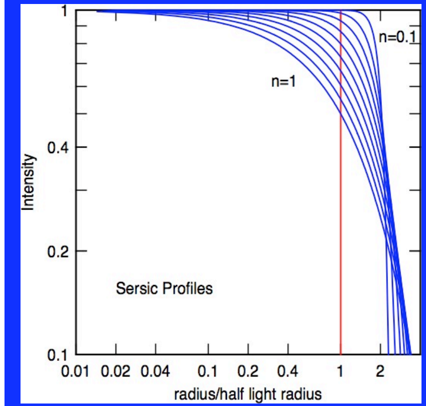
HI more centrally concentrated

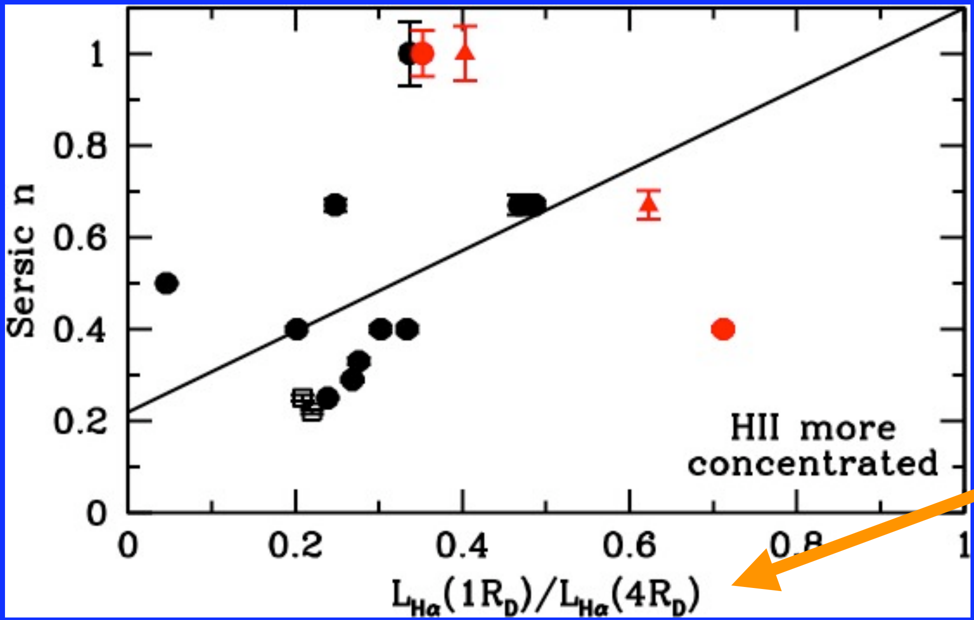




→ The more centrally concentrated the HI, the
higher n
lower R_0
higher central gas density

Sersic n and central concentration of star formation



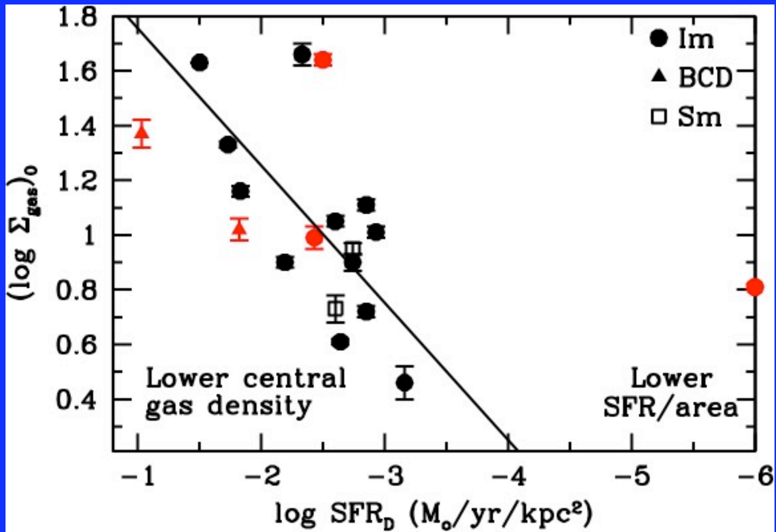


Degree of central concentration of current star formation.

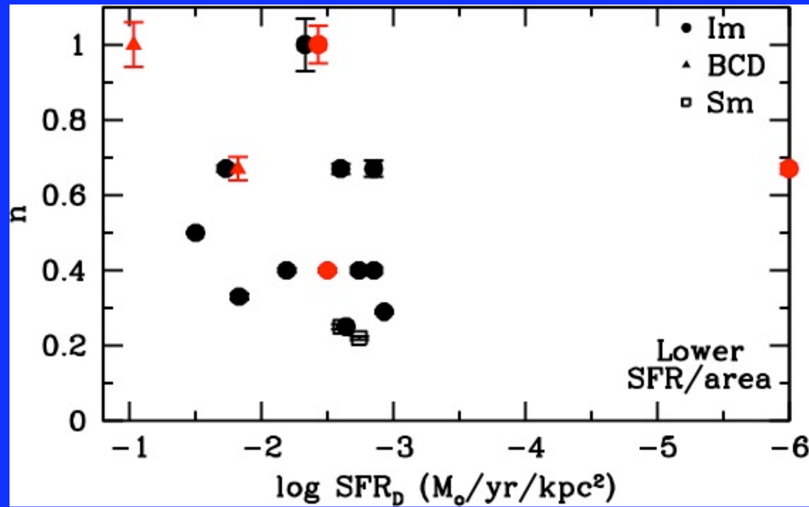
➔Star formation in galaxies with larger Sersic n parameters tends to be more concentrated to the galaxy center.

Sersic (log Σ_{gas})$_0$ and integrated star formation

Central gas density



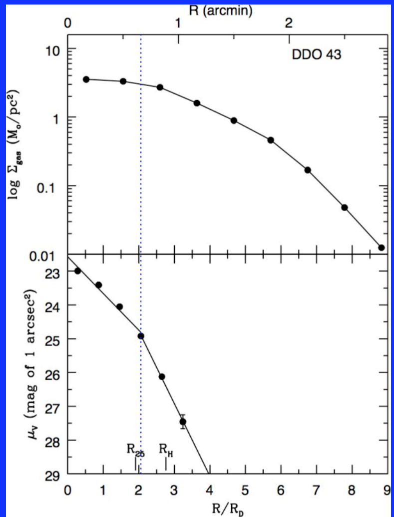
Sersic n

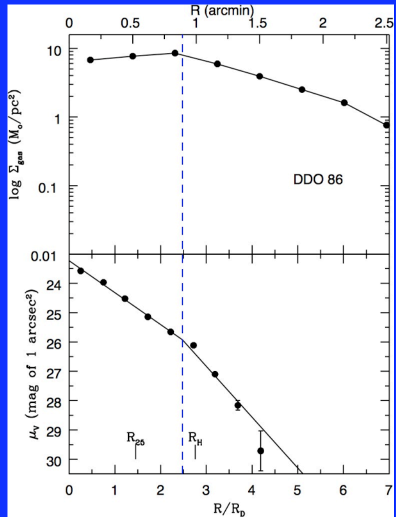


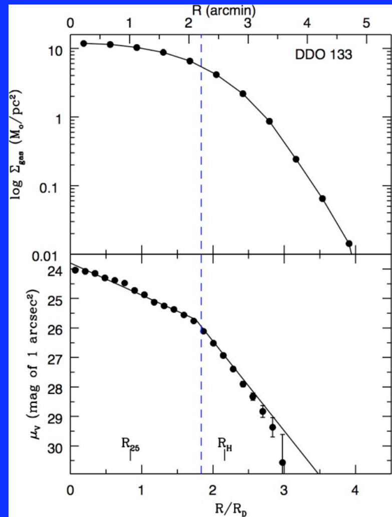
SFR/πR_D^2 measured from Hα

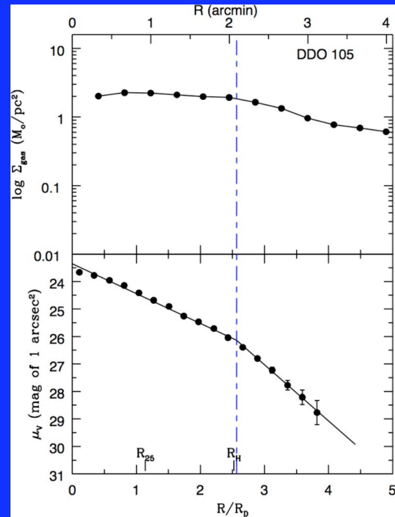
➔The higher the central gas density, the higher the integrated star formation rate.

Optical double exponential disks --- HI profiles

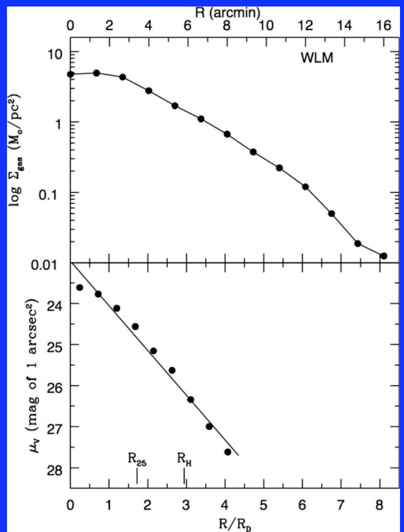


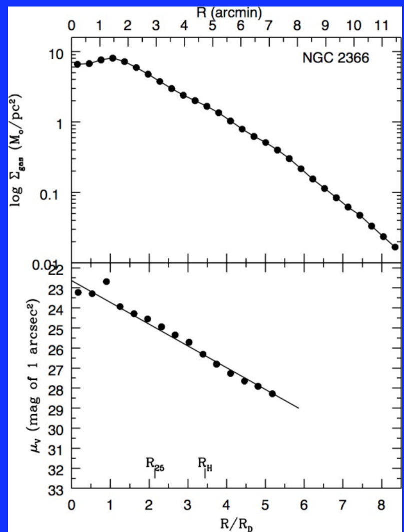


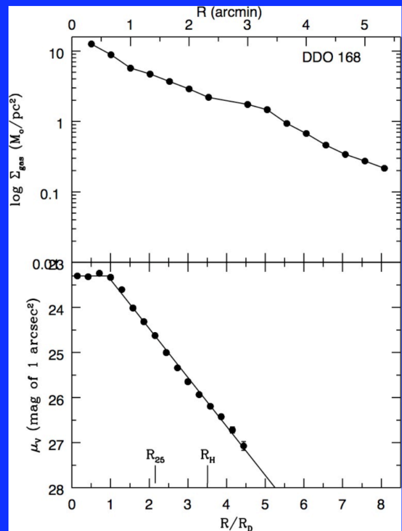


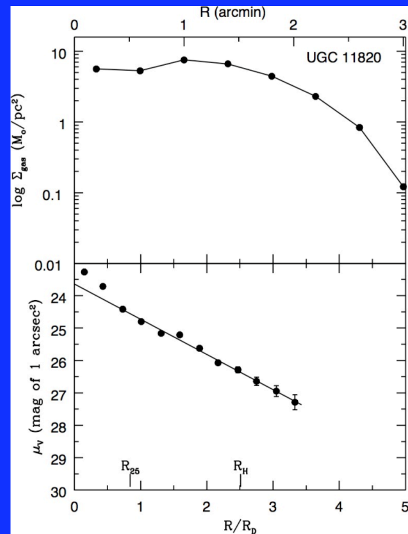


Galaxies with comparable M_V:





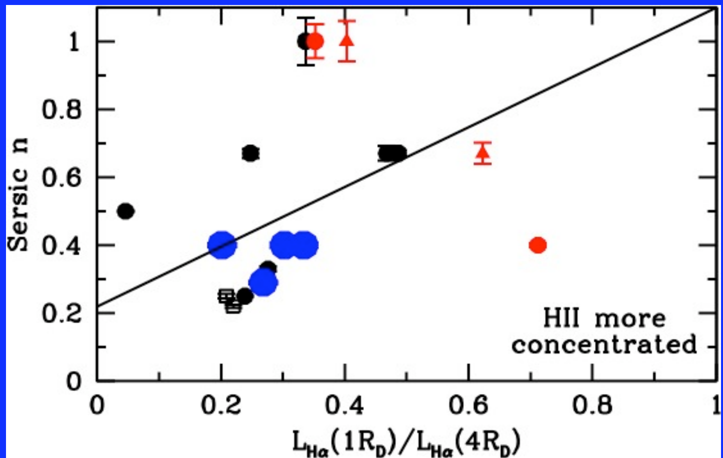




Optical double exponential disks --- Trends

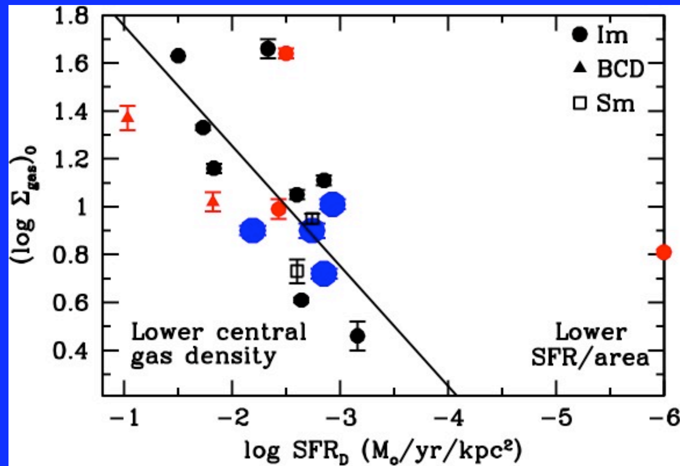
Big blue points: galaxies with double exponential *V* profiles

Sersic n

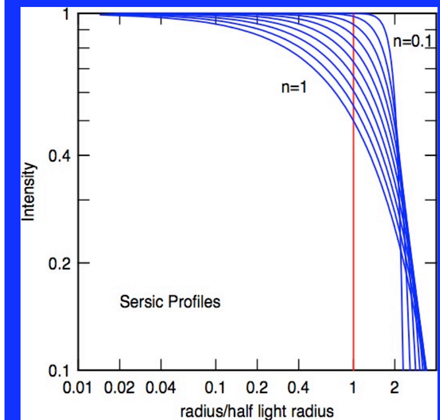


Degree of central concentration of current star formation.

Central gas density



Normalized star formation rate



➔ Sersic n tends to be lower.

➔ Central gas density tends to be lower.

Conclusions

- The factor dominating the star formation activity with radius changes steadily, even in galaxies with optical exponential breaks.
- The gas density profiles of dwarf galaxies are well fit by Sersic profiles with $n \leq 1$.
- The central gas density seems to be more important in determining *integrated* star formation rates than the details of how the gas falls off with radius.
- Star formation activity tends to be more centrally concentrated in galaxies with a shorter relatively flat part of the gas profile.
- The gas density profile in dwarfs with optical double exponential profiles tends to be relatively flat interior to the break and falls beyond that.