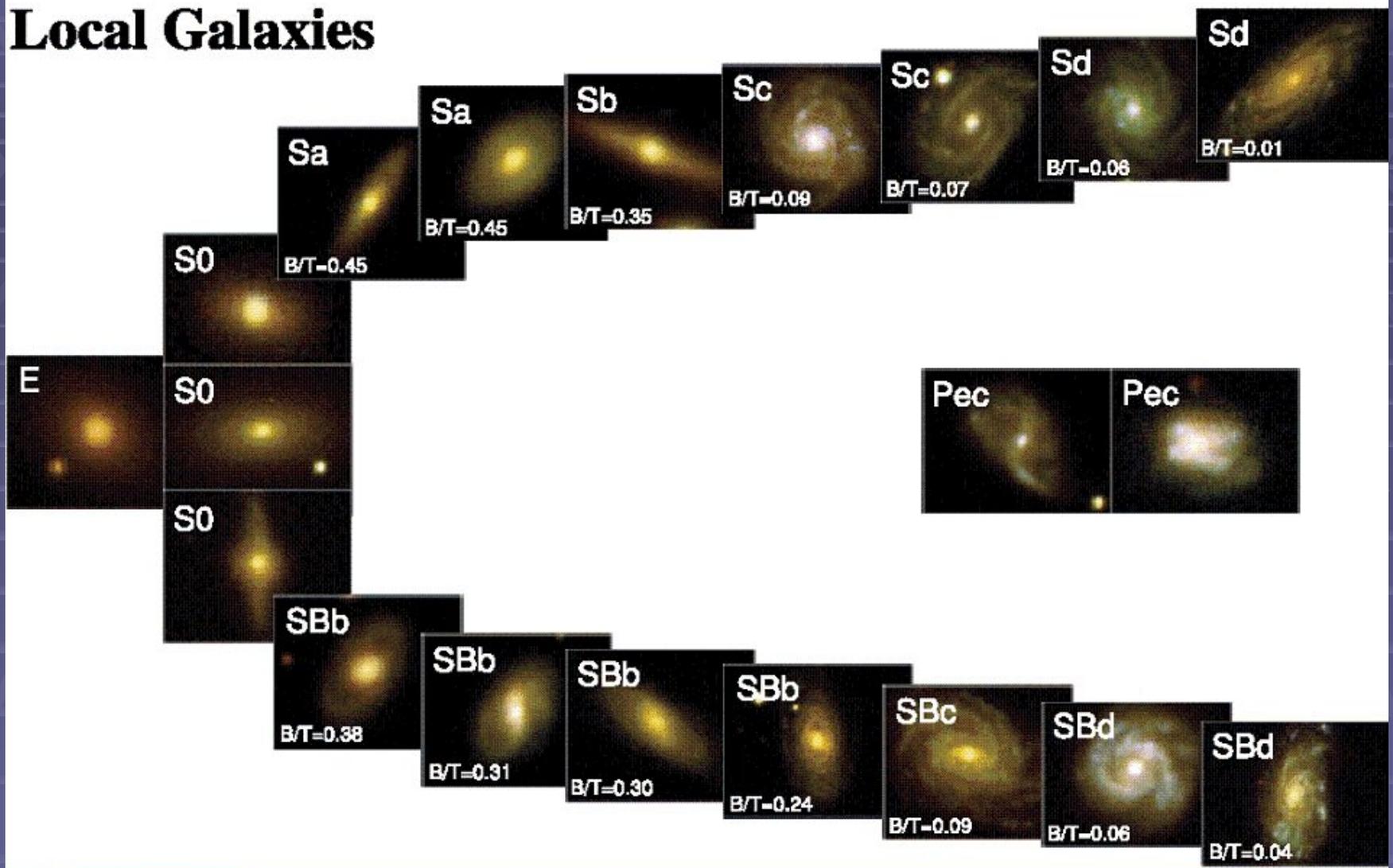


# Как рождались галактики

Сильченко О.К.

ГАИШ МГУ

# Local Galaxies



Из каких глобальных компонент  
состоит дисковая галактика?



# Морфологический тип определяется соотношением диск:балдж

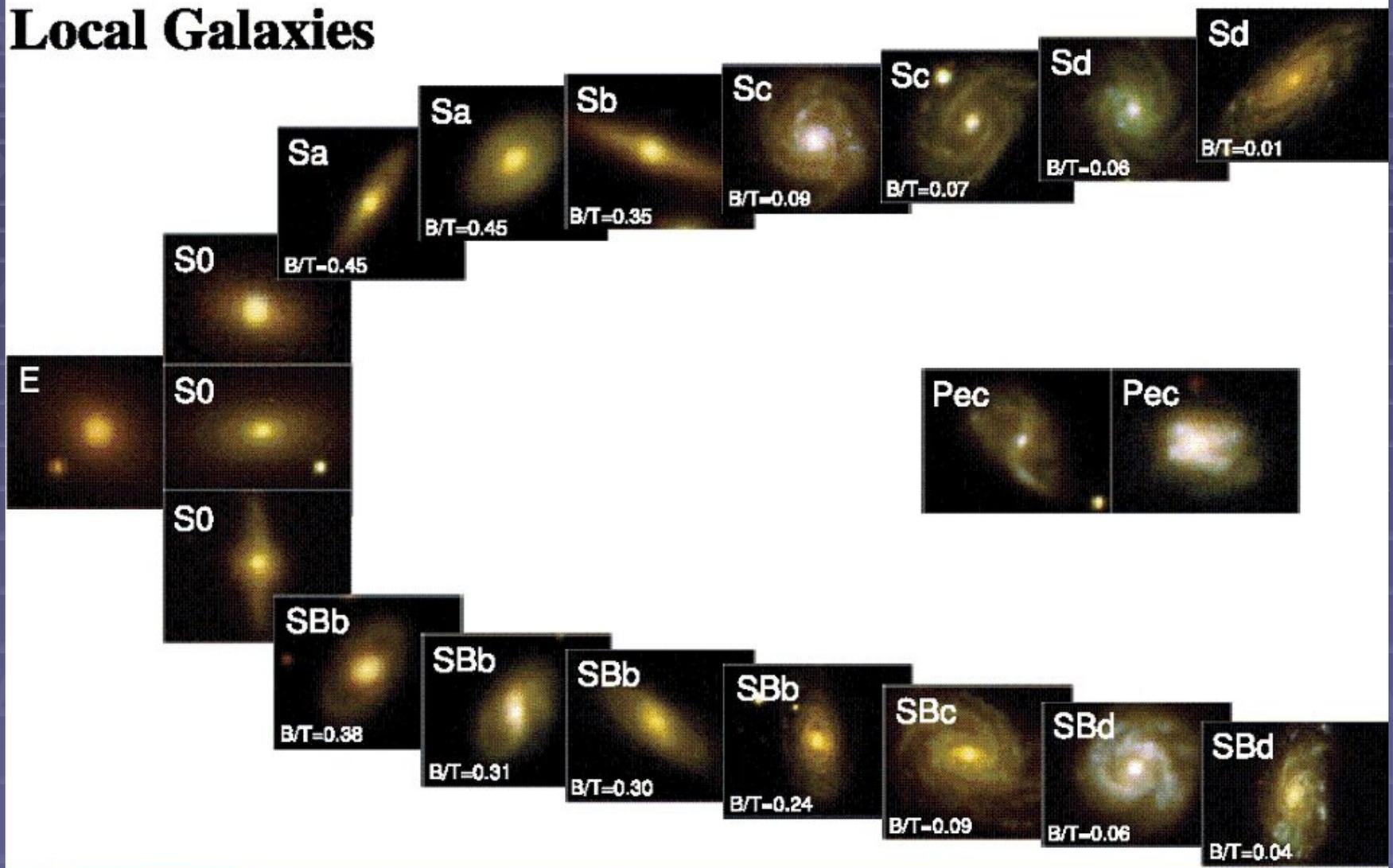


NGC 4565



NGC 4594

# Local Galaxies



# Рядом с нами галактики резко делятся на красные и голубые: голубые более слабые и не имеют балджей

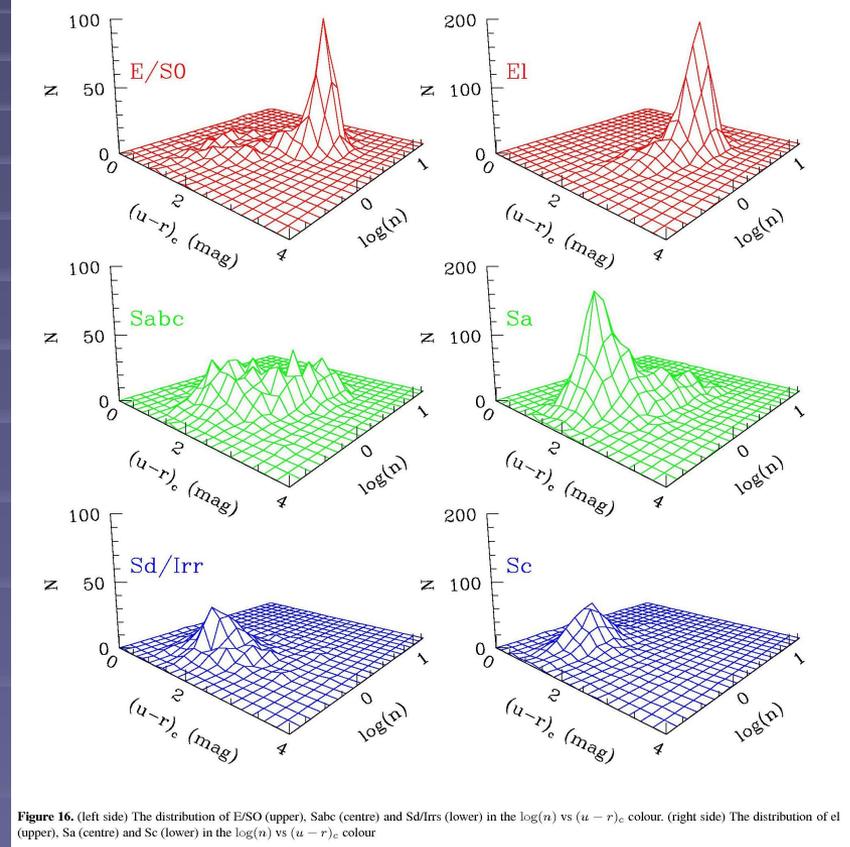
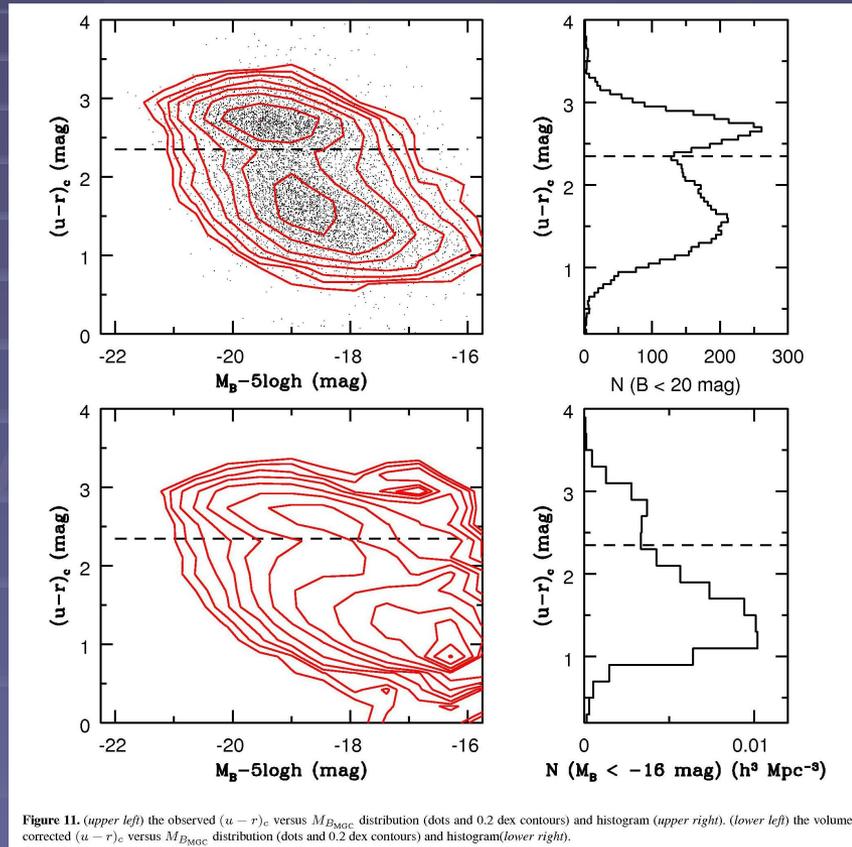


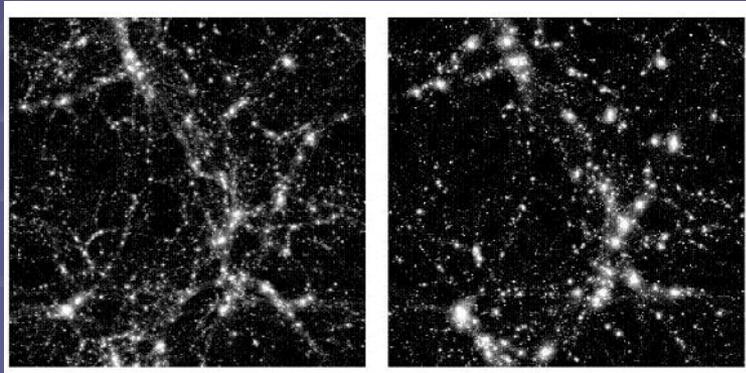
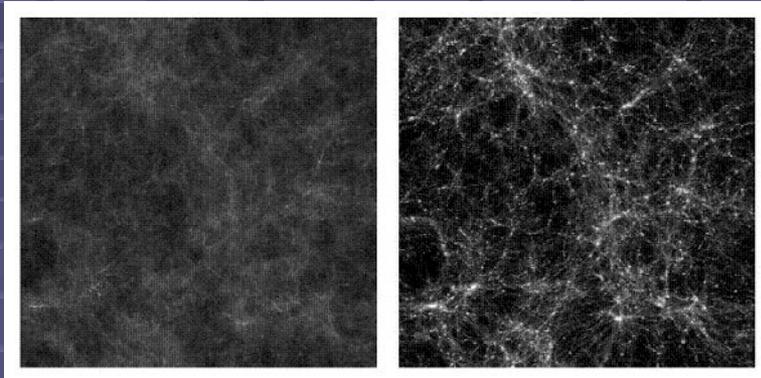
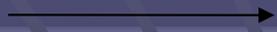
Figure 11. (upper left) the observed  $(u-r)_c$  versus  $M_{B,MC}$  distribution (dots and 0.2 dex contours) and histogram (upper right). (lower left) the volume-corrected  $(u-r)_c$  versus  $M_{B,MC}$  distribution (dots and 0.2 dex contours) and histogram (lower right).

Figure 16. (left side) The distribution of E/SO (upper), Sabc (centre) and Sd/Irrs (lower) in the  $\log(n)$  vs  $(u-r)_c$  colour. (right side) The distribution of E1 (upper), Sa (centre) and Sc (lower) in the  $\log(n)$  vs  $(u-r)_c$  colour

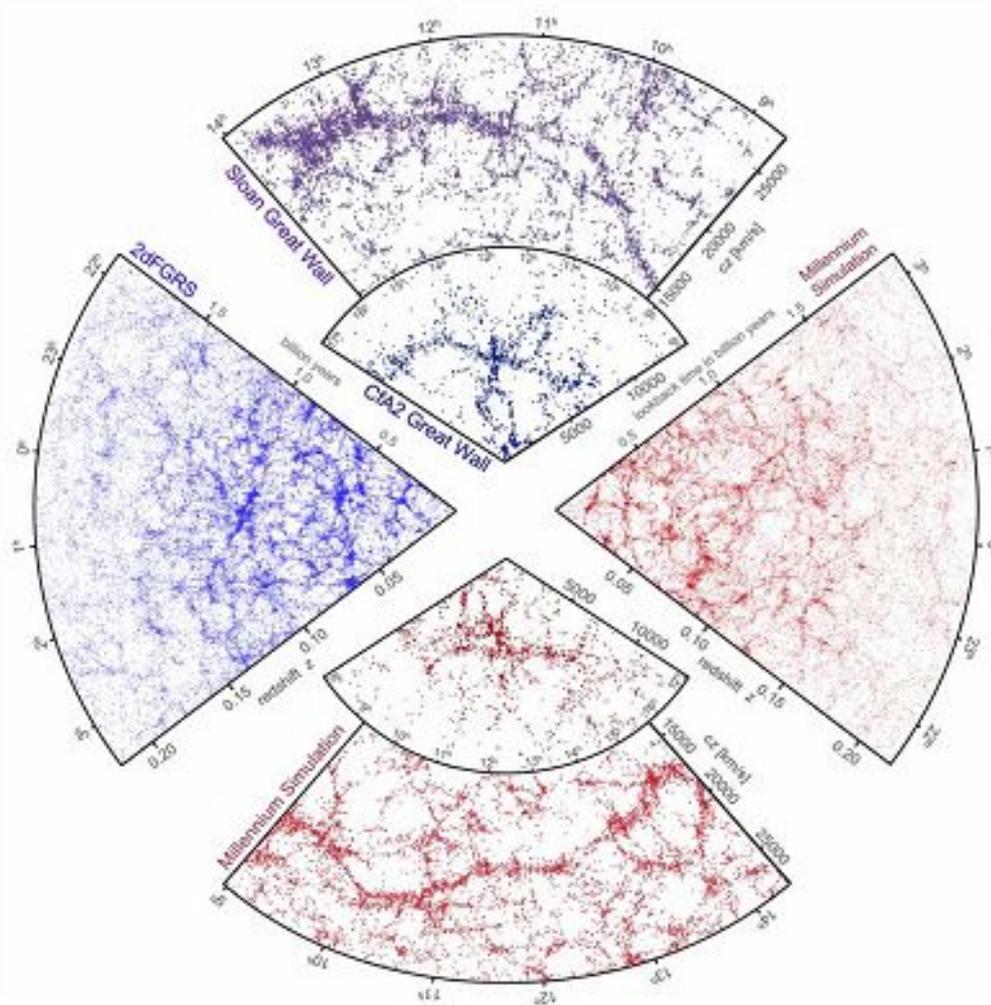
# Главное различие галактик ранних и поздних типов:

- Голубой цвет = современное образование новых звезд
- Новые звезды в наше время образуются в дисках

# Эволюция крупномасштабной структуры темной материи

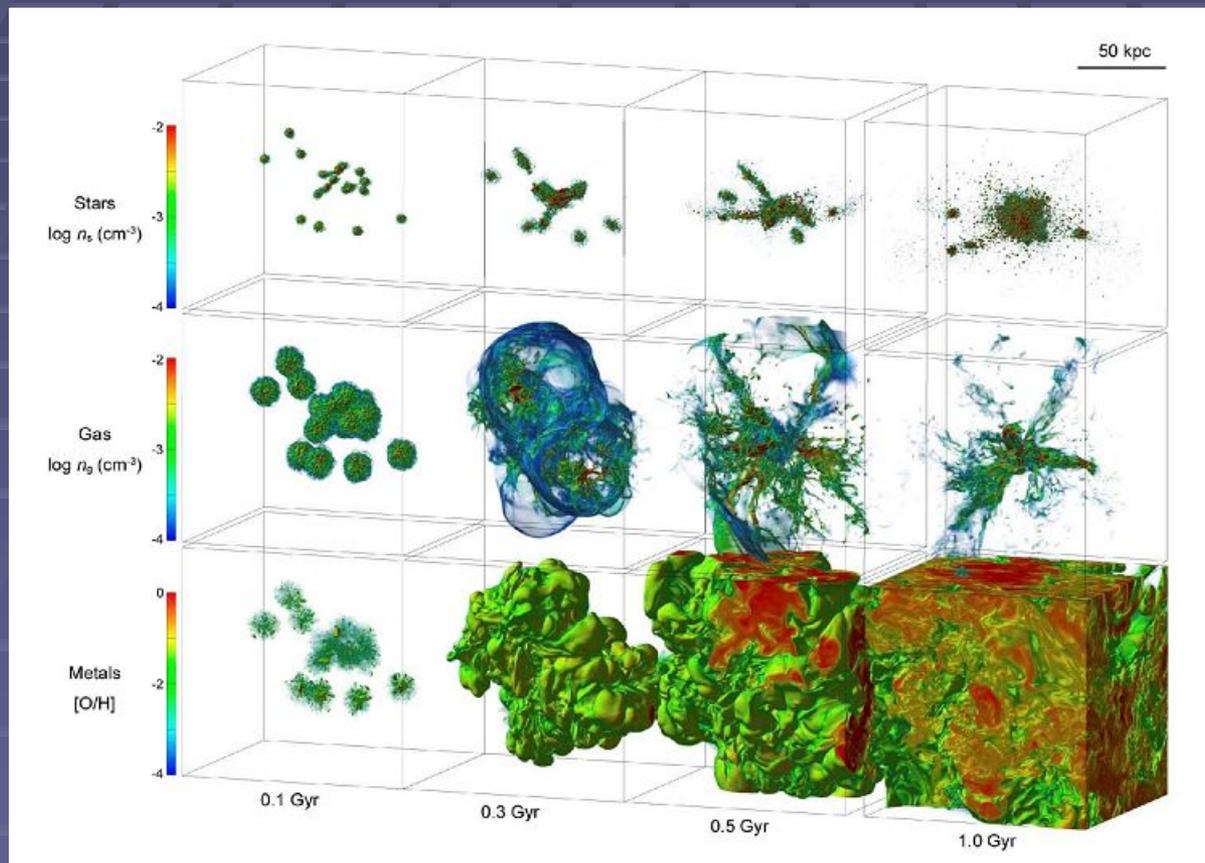


- Основной механизм – иерархическое скучивание материи под действием гравитационной неустойчивости
- Подбор параметров – чтобы получить правильную конечную картину к моменту  $z=0$



**Figure 1: The galaxy distribution obtained from spectroscopic redshift surveys and from mock catalogues constructed from cosmological simulations.** The small slice at the top shows the CIA2 “Great Wall”<sup>3</sup>, with the Coma cluster at the centre. Drawn to the same scale is a small section of the SDSS, in which an even larger “Sloan Great Wall” has been identified<sup>100</sup>. This is one of the largest observed structures in the Universe, containing over 10,000 galaxies and stretching over more than 1.37 billion light years. The wedge on the left shows one-half of the 2dFGRS, which determined distances to more than 220,000 galaxies in the southern sky out to a depth of 2 billion light years. The SDSS has a similar depth but a larger solid angle and currently includes over 650,000 observed redshifts in the northern sky. At the bottom and on the right, mock galaxy surveys constructed using semi-analytic techniques to simulate the formation and evolution of galaxies within the evolving dark matter distribution of the “Millennium” simulation<sup>5</sup> are shown, selected with matching survey geometries and magnitude limits.

# Первый миллиард лет звездообразования

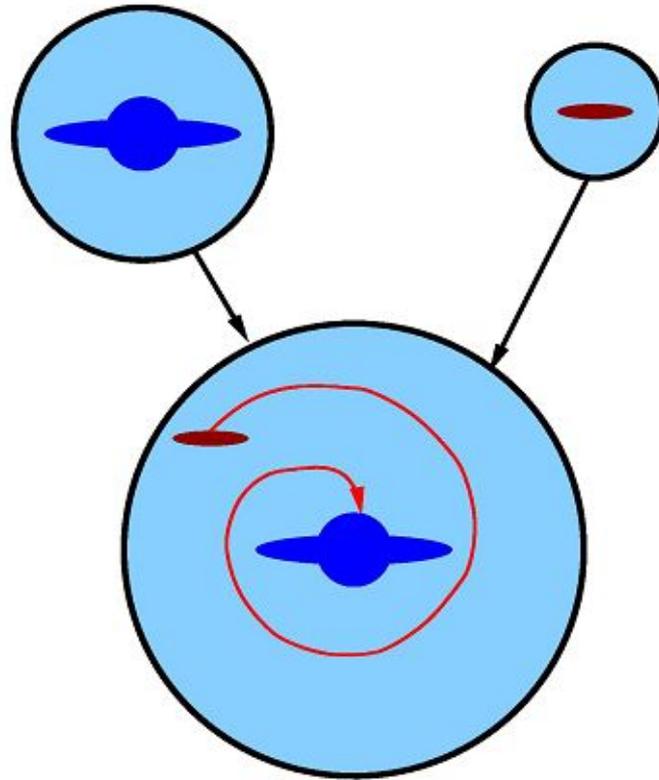


Звезды

Газ

Новые хим.  
элементы

# Три фазы эволюции: 1. слияния

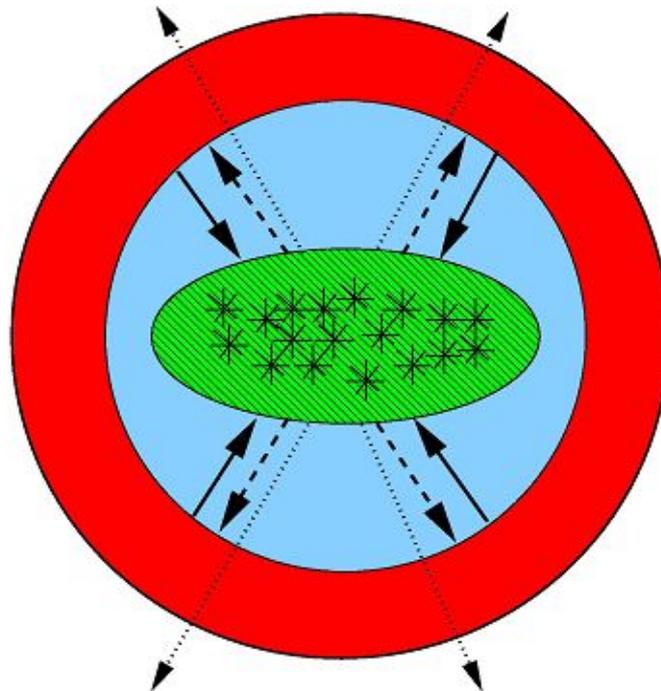


Major merging:

Отношение масс 1:1-1:4

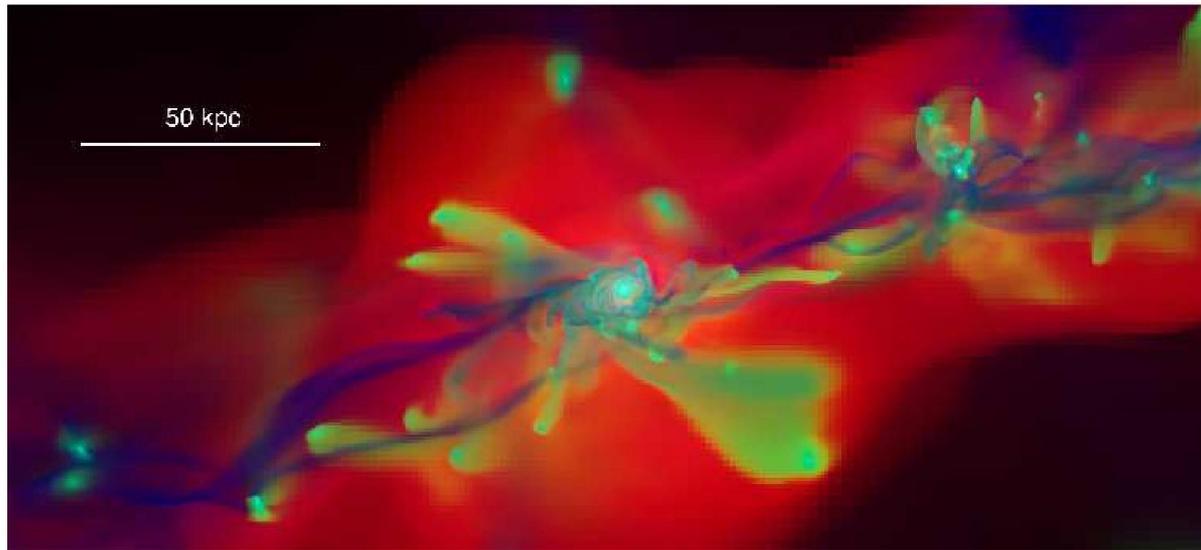
**Figure 11.** A schematic of a merger between two dark matter haloes. The progenitors of the final halo each contain a galaxy. After the haloes merge, the more massive galaxy is placed at the centre of the newly formed halo. Any hot gas that cools would be directed onto the central galaxy (for simplicity, in this illustration, the haloes have exhausted their supply of hot gas). The smaller galaxy becomes a satellite of the central galaxy. The orbit of the satellite galaxy decays due to dynamical friction. The satellite may eventually merge with the central galaxy.

# Три фазы эволюции: 2. медленная аккреция горячего газа гало



**Figure 10.** A schematic figure showing gas cooling from the hot halo (solid lines) and building up the reservoir of cold gas in the galactic disc. The cooled gas is turned into stars on a timescale set by the parameters of the model. Supernova explosions can reheat a fraction of the cooled gas and return it to the hot phase (dashed lines) or eject material from the halo altogether (dotted lines).

# 3-я фаза: “Собирание” диска натеканием холодного газа вдоль узких жгутов?

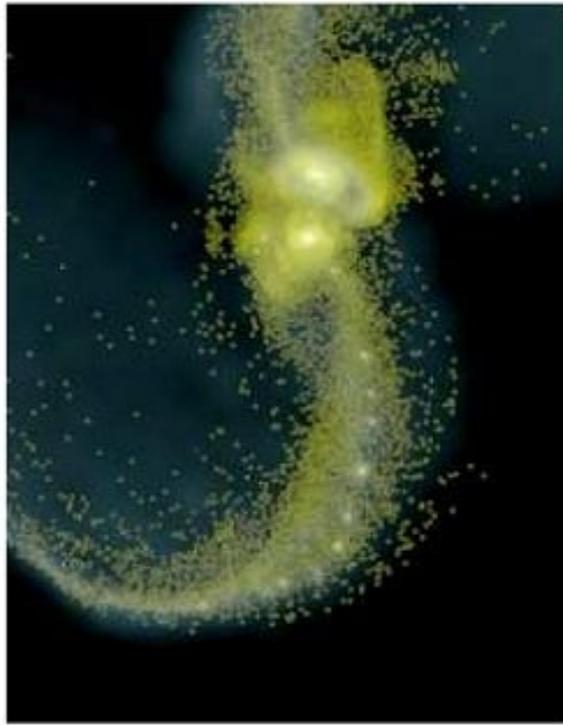


**Figure 1.** An *RGB*-image of the gas showing the disk and accretion region at  $z \sim 3$ . The image is constructed using  $R$ =temperature,  $G$ =metals and  $B$ =density. We can clearly distinguish the cold pristine gas streams in blue connecting directly onto the edge of the disk, the shock heated gas in red surrounding the disk and metal rich gas in green being stripped from smaller galaxies interacting with the halo and streams of gas. The disk and the interacting satellites stand out since they are cold, dense and metal rich. The distance measure is in physical units.

# Видимые последствия:

- Большие слияния (отношения масс  $>1:4$ ) разрушают диски и формируют сфероиды;
- Малые слияния НЕ разрушают диски, но «греют» их – делают толстыми;
- Плавная аккреция газа извне позволяет в стационарном режиме питать звездообразование и формировать тонкие звездные диски.

# Как формируются сфероиды? Большим мержингом – слиянием дисков близких масс



SPH simulation of a major merger by Wetzstein et al. (2007)

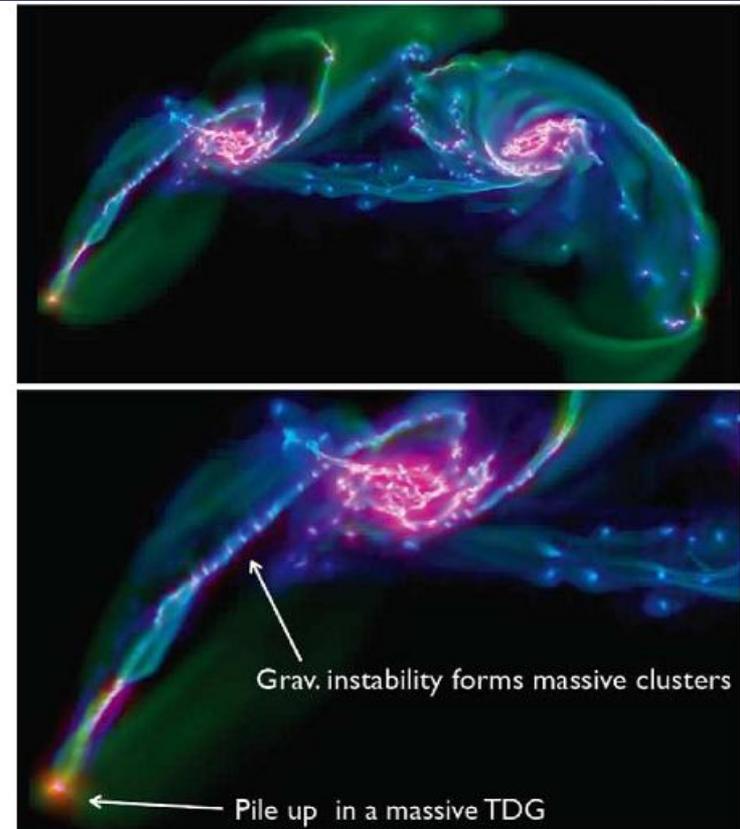
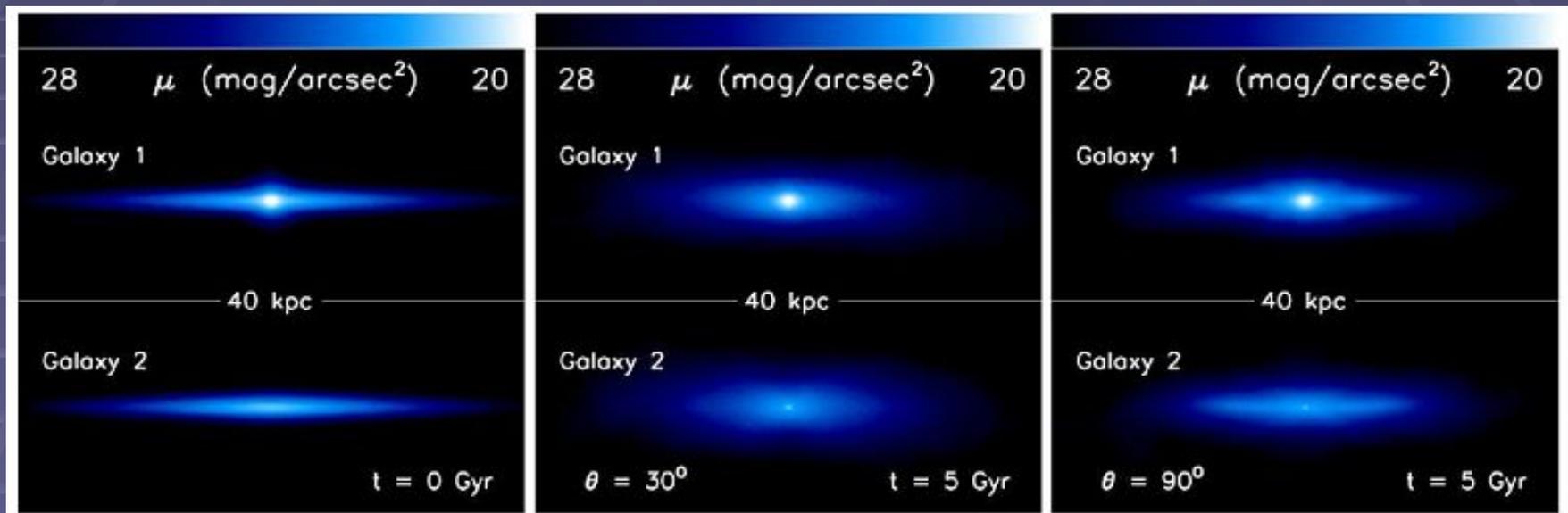


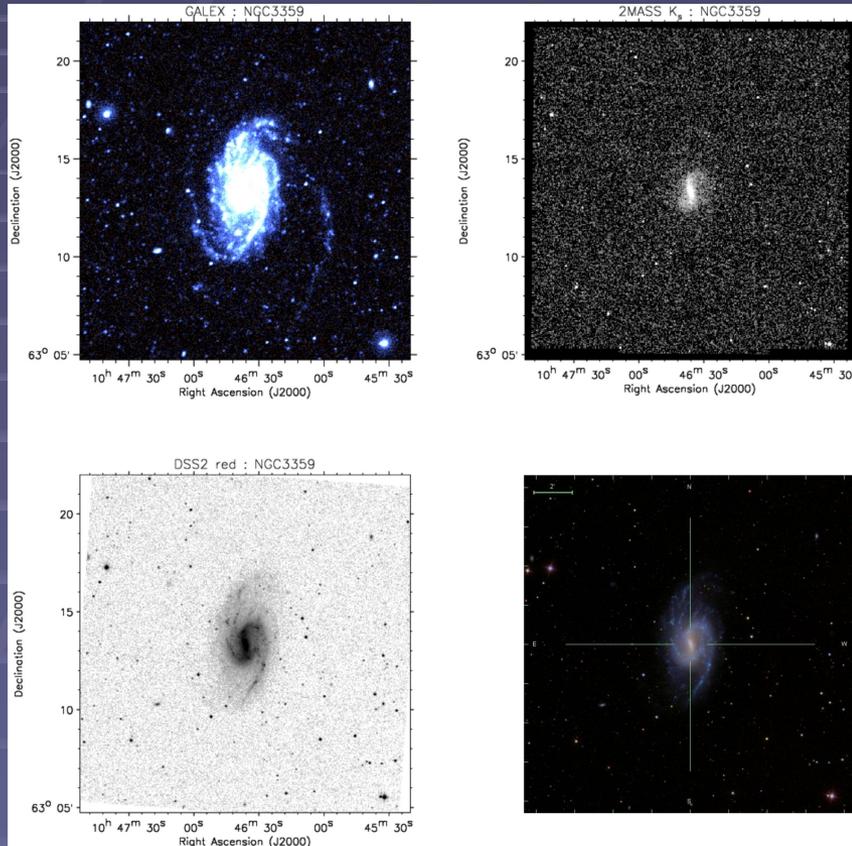
Figure 5. Grid hydrodynamic (AMR) simulation of a major merger by Chapon et al. (in preparation).

# Динамическая эволюция звездного диска: поглощение малого спутника

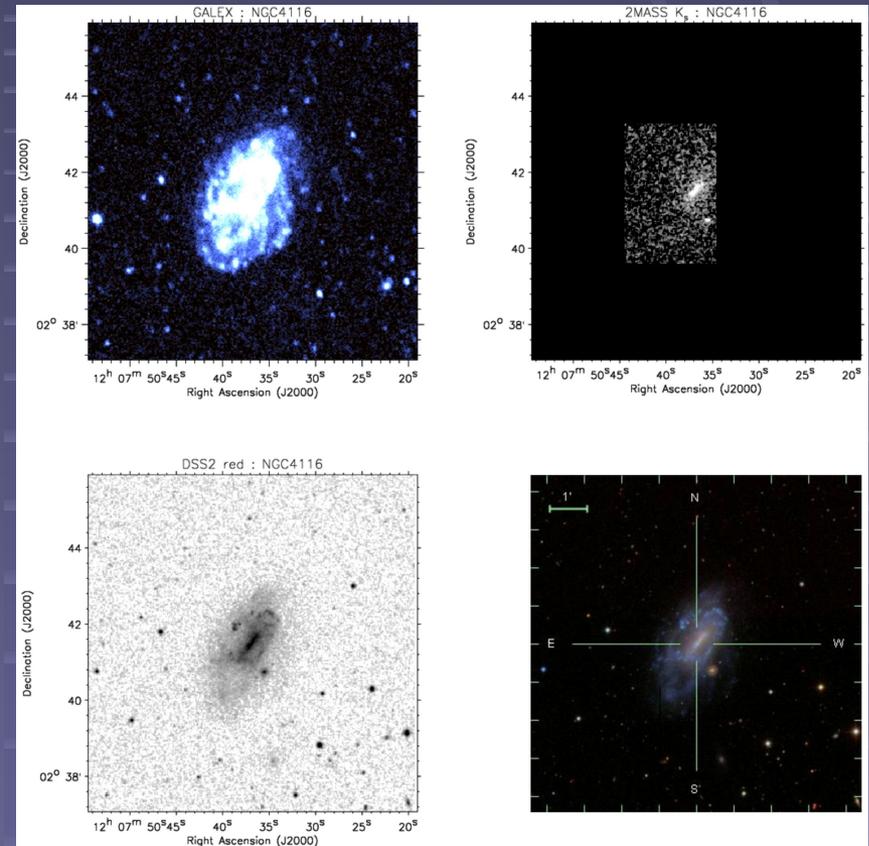


Purcell et al. 2009

# Плавный рост дисков: внешние протяженные ультрафиолетовые диски галактик по данным GALEX

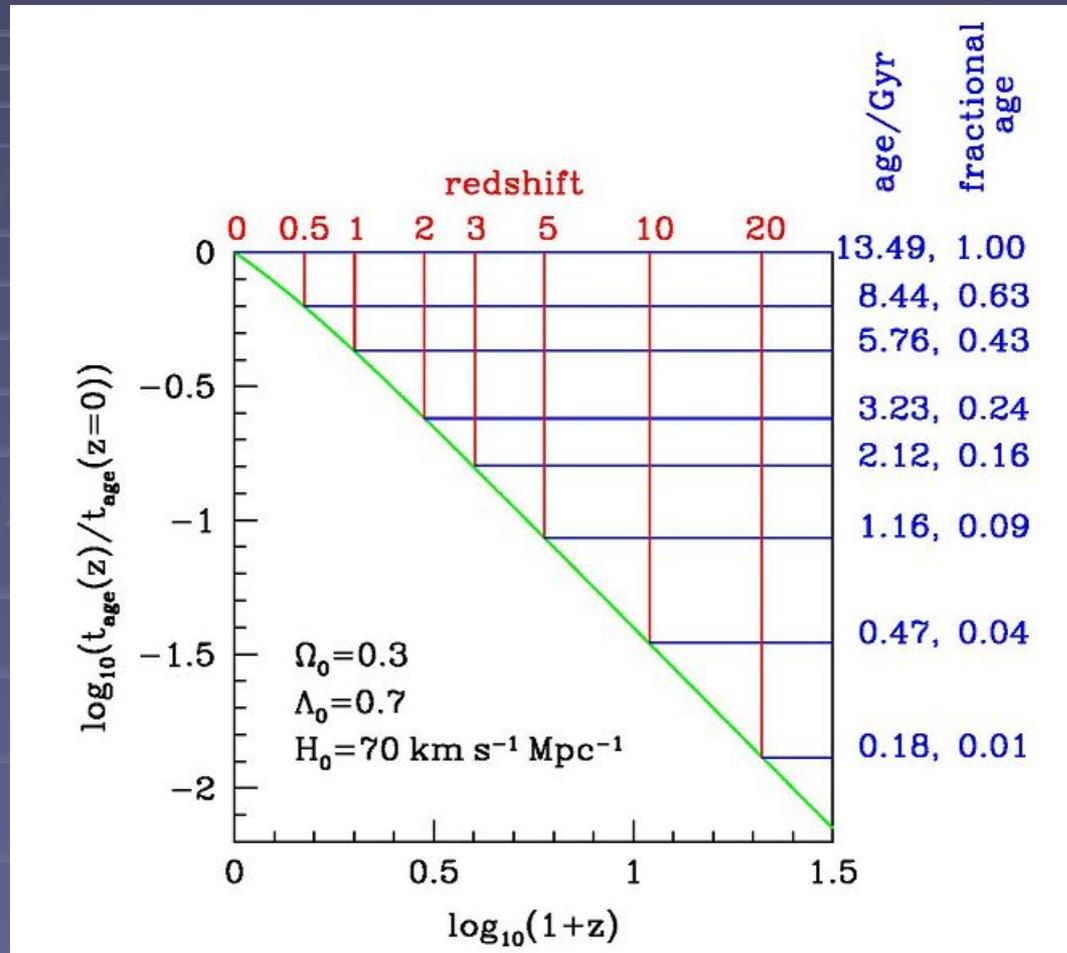


Тип I



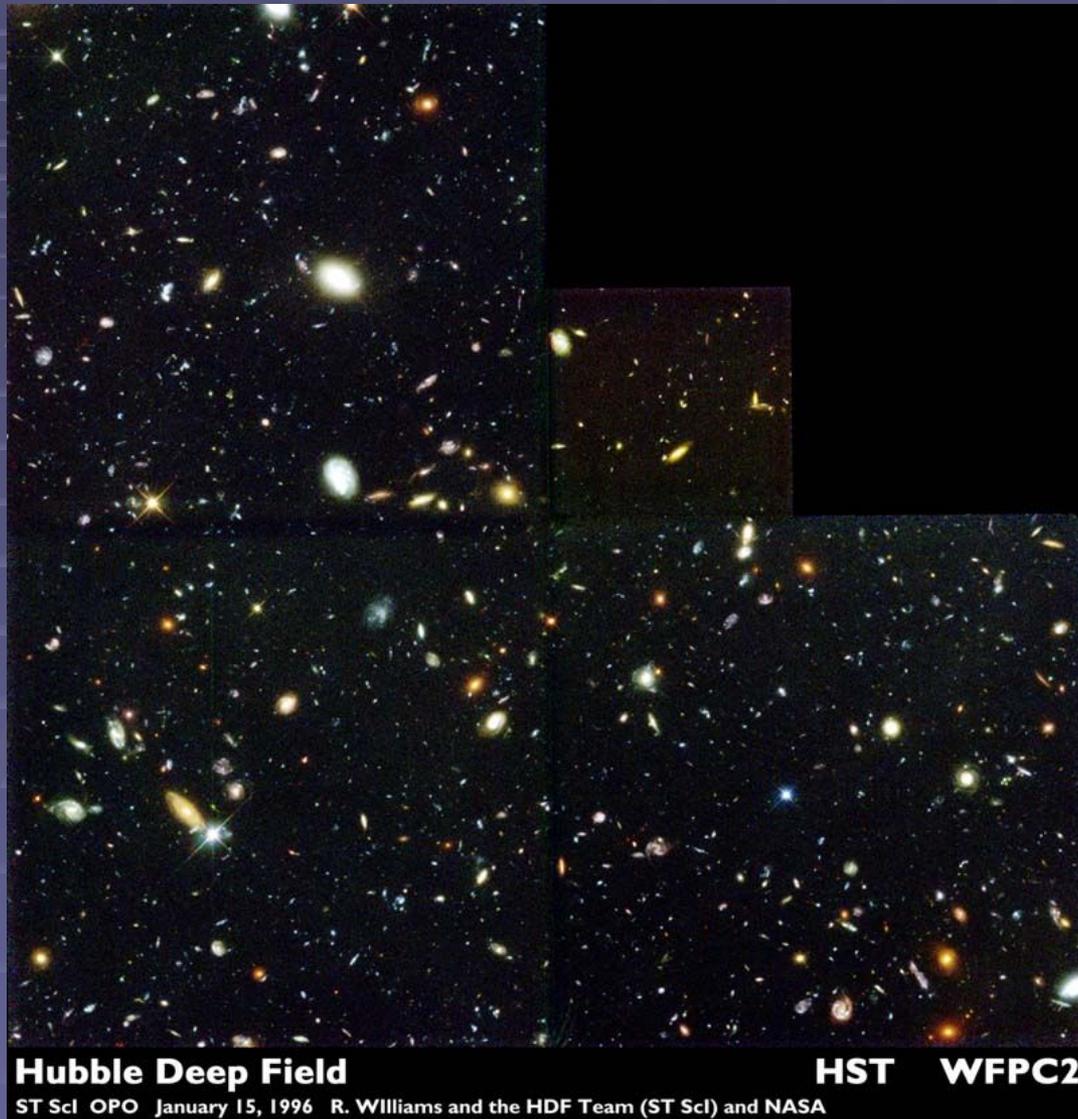
Тип II

# Космологическая модель пространства времени связывает красное смещение и время, затраченное светом, чтобы пройти это расстояние



Возраст  
 Вселенной на  
 разных красных  
 смещениях

# Глубокое Хаббловское поле



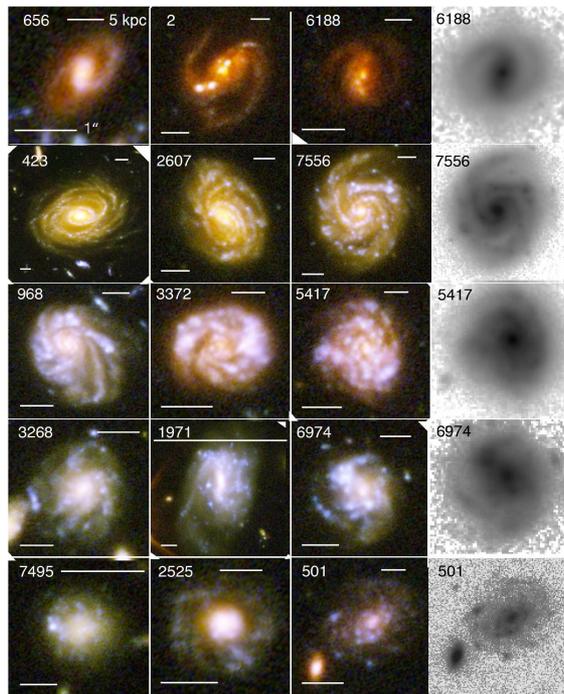
**Hubble Deep Field**

**HST WFPC2**

ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

# Еще 8-9 млрд лет назад галактики были такие же, как сегодня...

- 17 -



Z=1.03

Z=0.53

Z=1.11

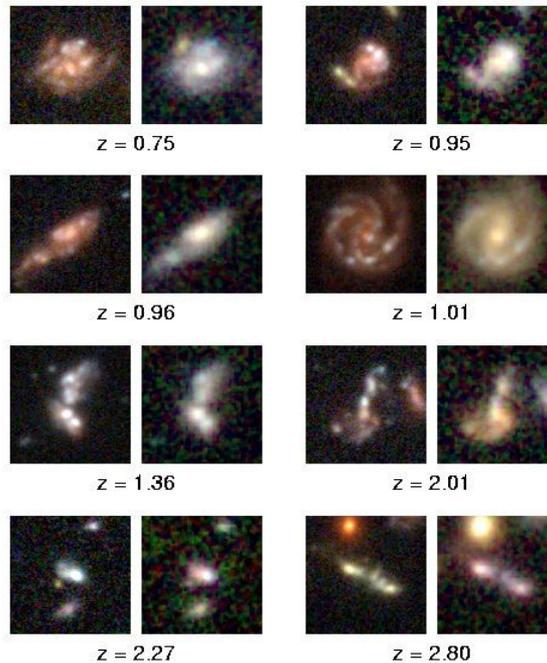
Z=0.50

Z=1.37

Fig. 1.— Five spiral arm morphologies in the UDF with three examples of each (in color) and an H-band image of the right-most example in black and white. In each image, the bar on the lower left indicates an angular scale of 1", while the bar on the upper right indicates a linear scale of 5 kpc. From top to bottom, the morphologies are: grand design, normal multiple arm, woolly, irregular long-arm, and flocculent. The properties of these galaxies are in Table 1. What we call woolly consists of thick, patchy and long arms, in contrast to flocculent galaxies which have numerous short and patchy arms. The irregular long-arm type consists of numerous thin arms with bright beads of star formation in them and an overall irregular or asymmetric structure.

Elmegreen and Elmegreen (2013)

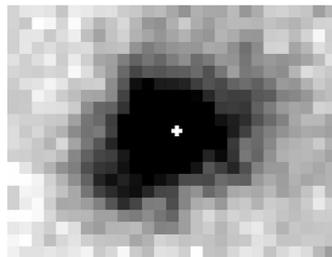
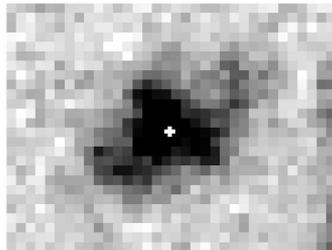
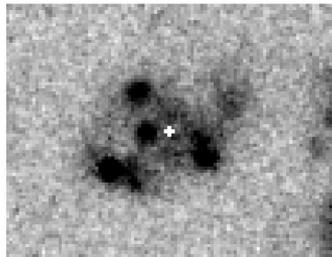
# Морфология галактик в Глубоком Хаббловском поле (северном)



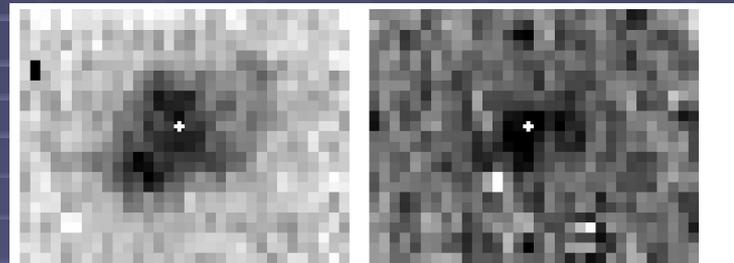
# Что значит клочковатость далеких галактик?

- Звездообразование идет в крупных комплексах?
- Большие галактики на глазах образуются слиянием малых галактик?

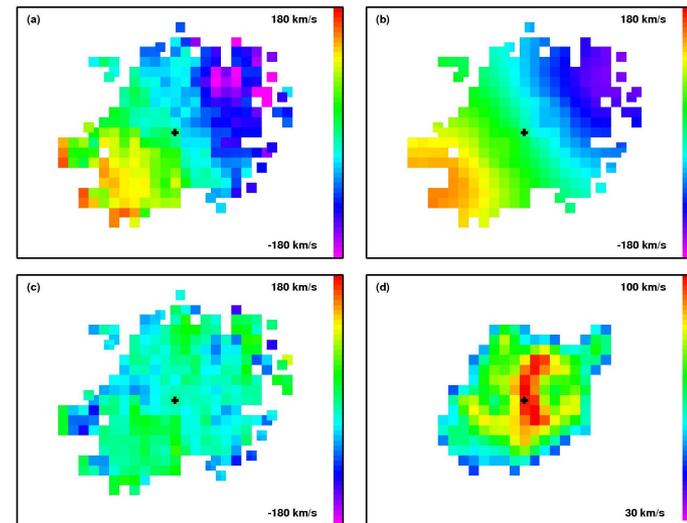
# Как оказалось, все клочки участвуют в едином вращении:



**Fig. 1.** From top to bottom: F814W image, NICMOS H band image and Ks image from FRES data. Image size is always  $3''$  times  $4''$  and the images have been rotated so that east is to the top and north is to the right. The (K band) center from the FRES data is marked by the white crosses.

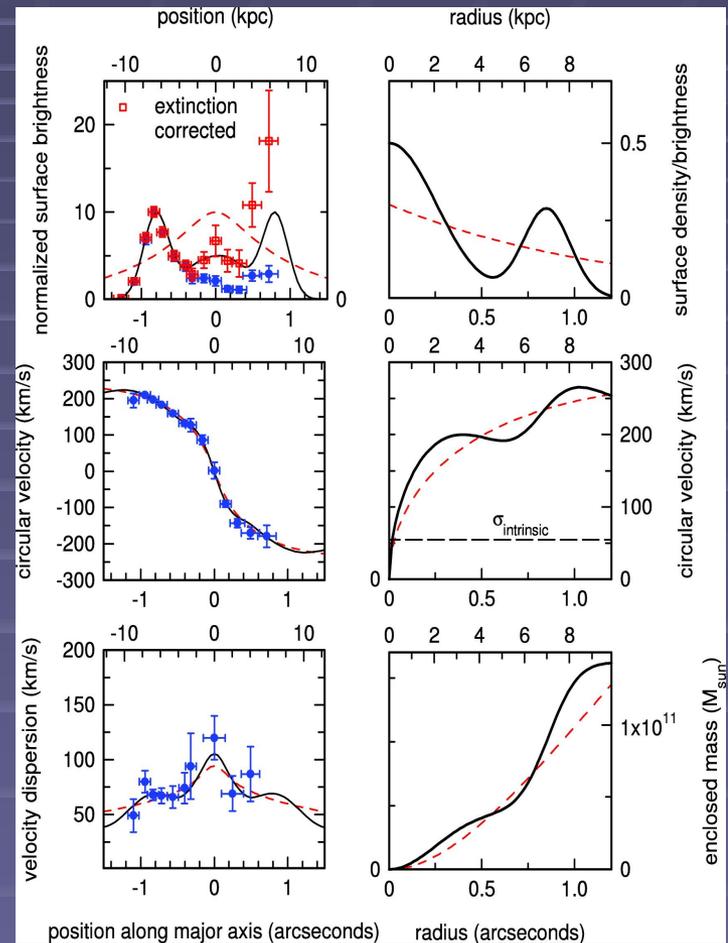
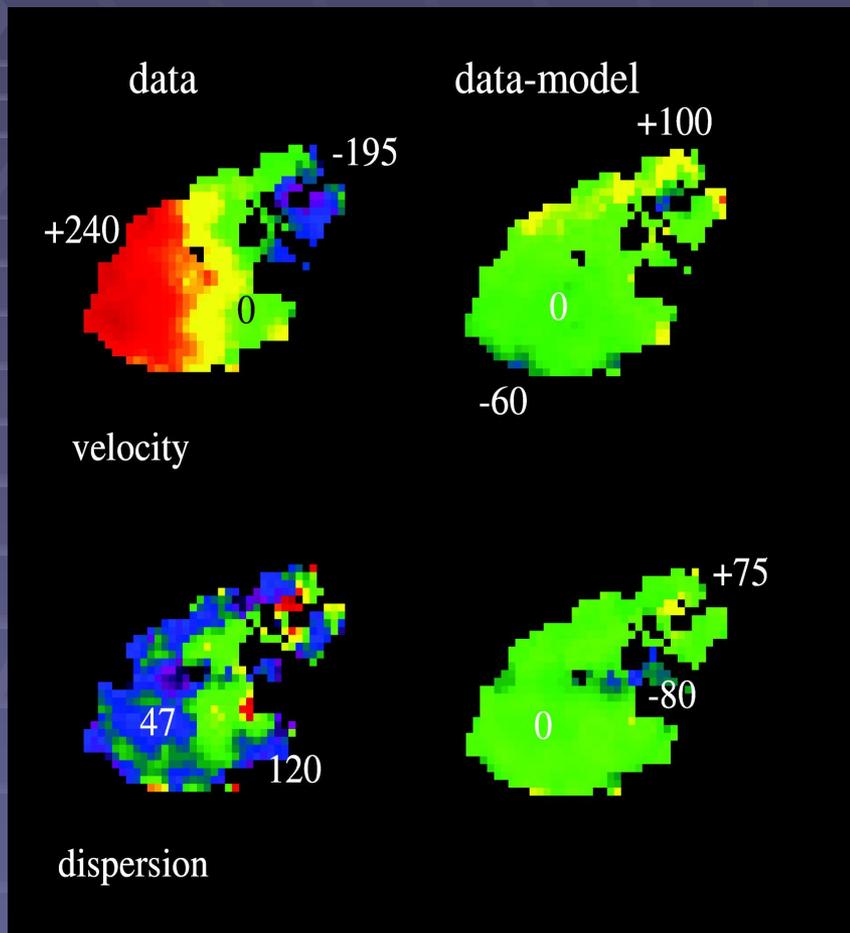


**Fig. 5.** a. Hor line map. b. [N II]46583 line map. Image size is again  $3''$  times  $4''$  and the images have been rotated so that east is to the top and north is to the right. The white crosses mark again the (K band) center (here determined from the PSF star positions).

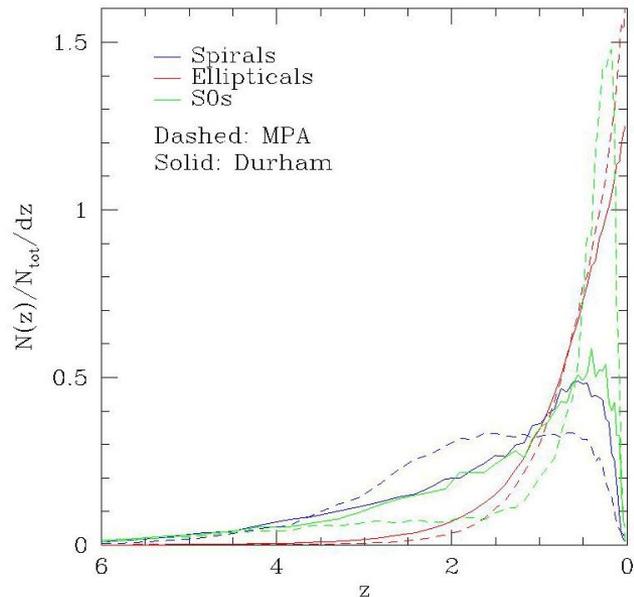


**Fig. 6.** a. The observed velocity field (not corrected for inclination). Some points at the edges are the average of four pixels. b. Best fit model velocity field. c. Residuals from the fit. d. Velocity dispersion field. The extent is smaller than for the velocity field due to the lower  $S/N$ . Instrumental resolution is  $32 \text{ km s}^{-1}$ . Note that the velocity scale is different for this figure. The spatial scale and orientation is the same as in previous figures and the cross point marks again the (dynamical and photometric) center.

# Genzel et al. (2008): галактики со звездообразованием на $z > 2$

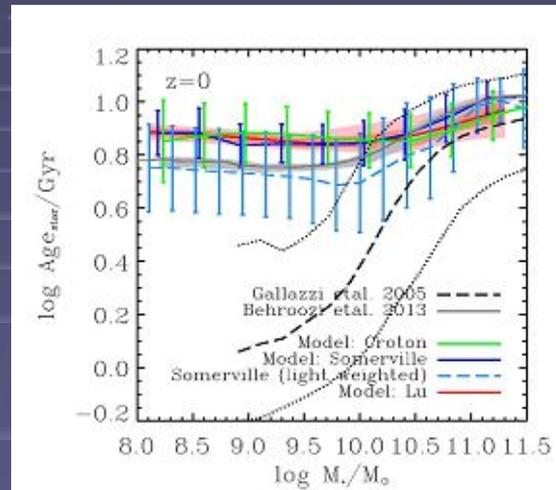


# ЭВОЛЮЦИЯ В ЗАВИСИМОСТИ ОТ МОРФОЛОГИИ ГАЛАКТИК



**Figure 7.** The distribution of the last (main branch) major merger experienced by spirals (blue), S0s (green) and ellipticals (red) in the Durham (solid line) and MPA (dashed line) bright ( $M_B < -18.7$ ) galaxy populations. Each curve is normalised such that the area under it is unity. The median values of  $z_{mm}$  are 1.39, 0.46, and 0.41 for spirals, S0s and ellipticals respectively in the MPA model, and 1.28, 1.17 and 0.51 in the Durham model.

# Эволюция в зависимости от массы галактик



Lu et al. 2013

- Темпы эволюции галактик в первую очередь зависят от ее массы. Downsizing: все изменения быстро проходят и рано заканчиваются у массивных галактик, звездообразование сосредоточено в галактиках маломассивных

# Downsizing!

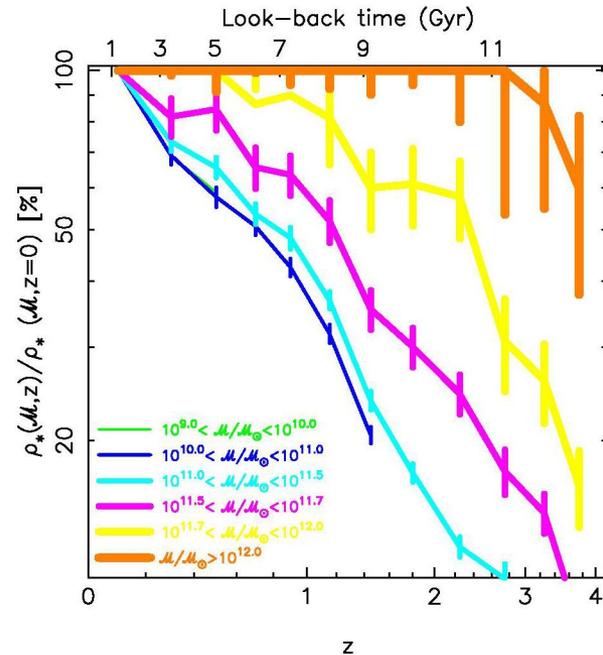
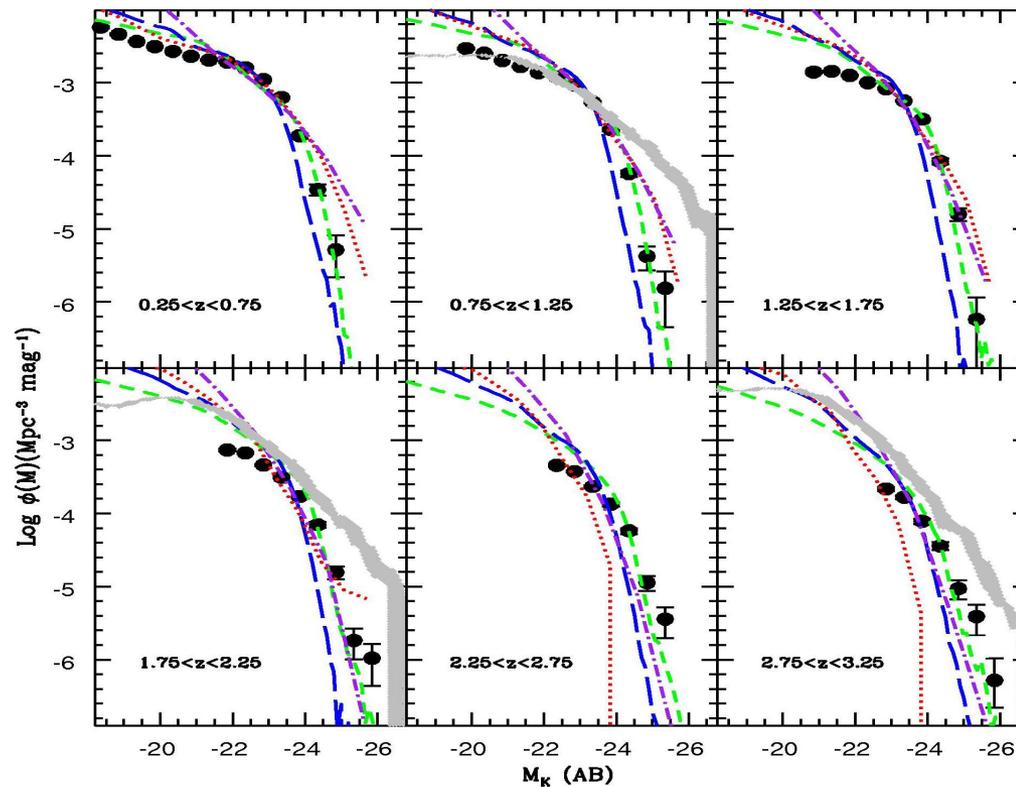


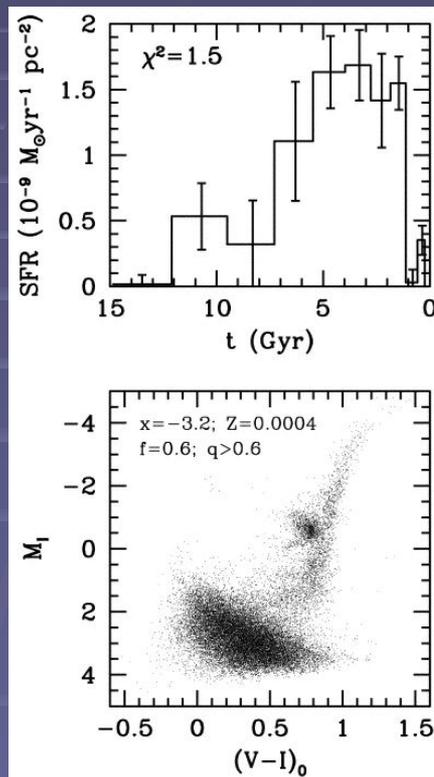
FIG. 6.— Fraction of the local stellar mass density already assembled at a given redshift for several mass intervals (wider lines referring to more massive systems). Only results for masses above our 75% completeness level at each redshift are shown.

# ЭВОЛЮЦИЯ ЧИСЛА ГАЛАКТИК



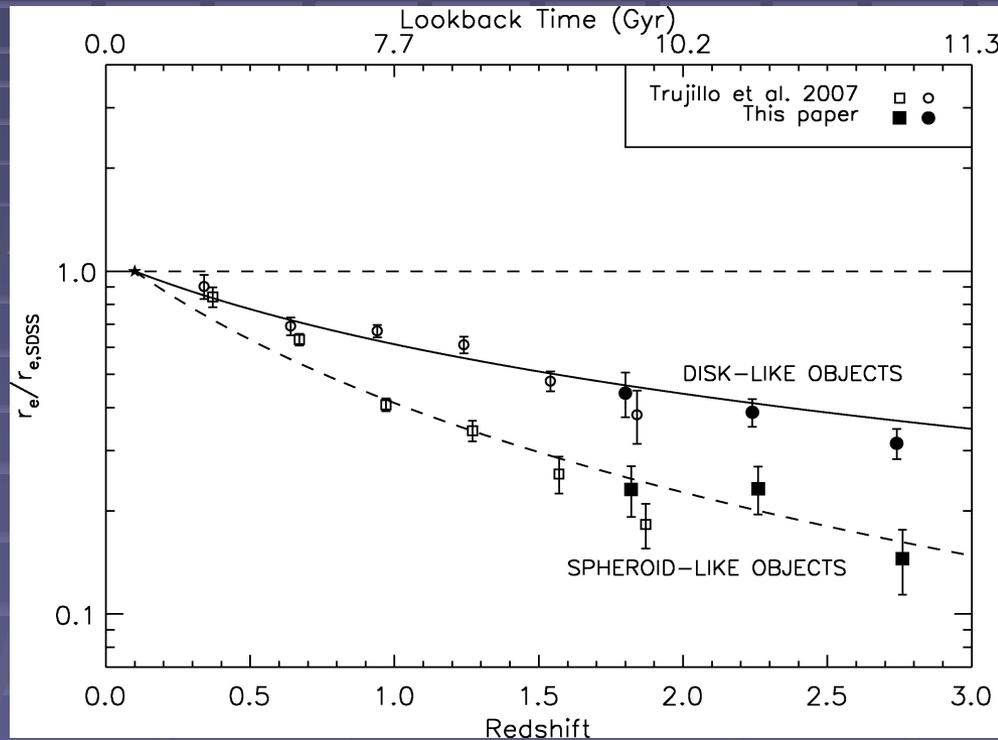
**Figure 6.** Comparison of our determination of the *K*-band LF (solid dots) with predictions of theoretical models. Short and long dashed lines are the predictions obtained by Bower et al. (2006) and De Lucia & Blaizot (2007), respectively. The predictions by Monaco et al. (2007) and Menci et al. (2006) are shown with a red dotted curve and purple dot-dashed curve, respectively. The gray area shows the prediction obtained by hydrodynamical simulations (Nagamine et al. 2006; Cen & Ostriker 2006).

# Наблюдения: карликовые сфероидальные галактики – разброс возрастов звезд

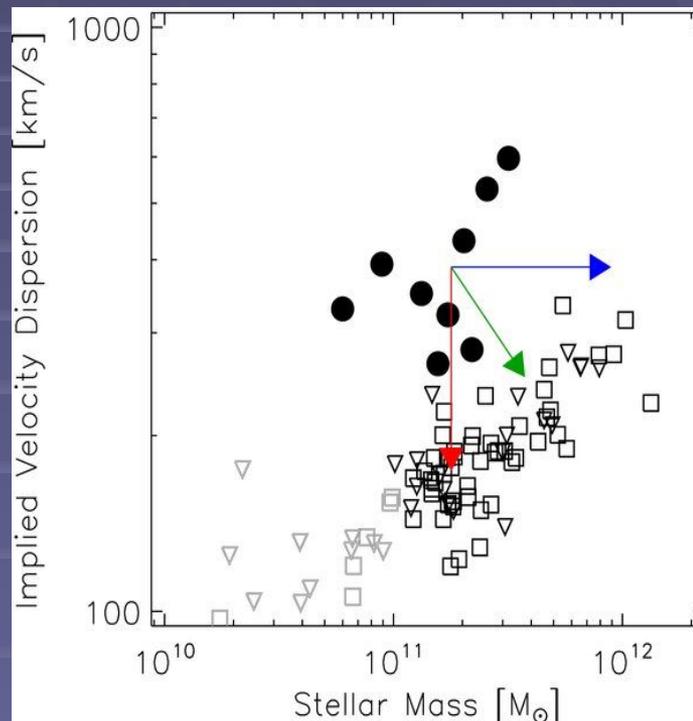
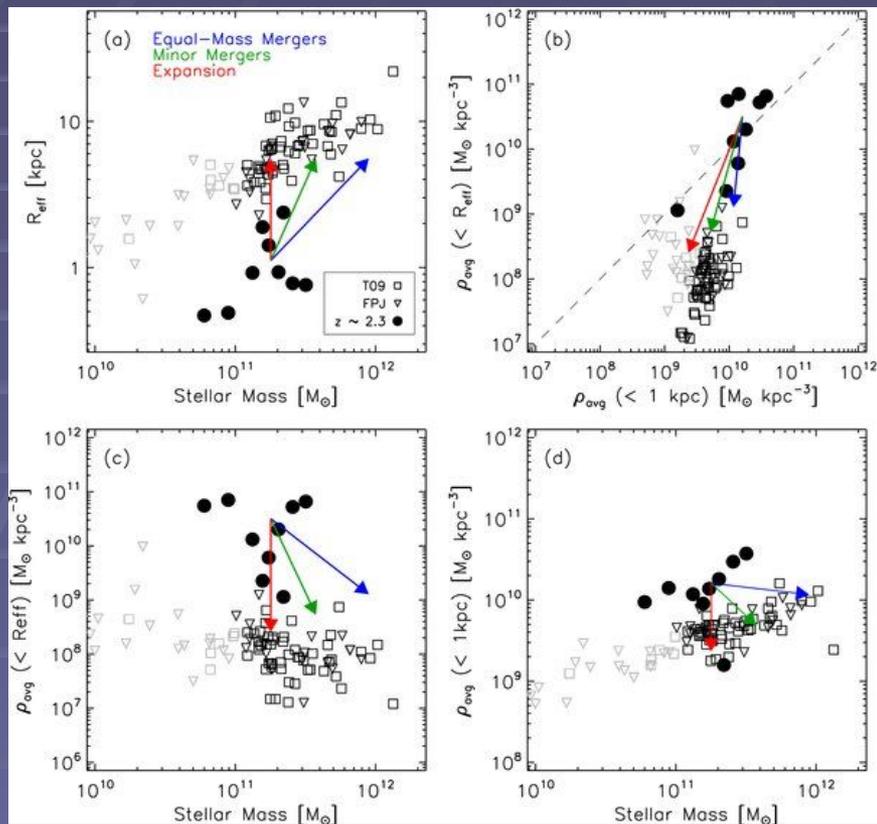


dSph Leo I: Gallart et al. 1999

# Эволюция размеров: особенно сильная у сфероидов



# Аргументы в пользу малого мерджинга: эволюция размера E-галактик



Bezanson et al. 2009

# «Горячие» проблемы:

- Эллиптические галактики: один большой мерджинг или много малых?
- Спиральные галактики: почему такие тонкие диски? Как вообще могут возникнуть галактики без балджей, и в огромном количестве?
- Откуда падает газ в диски? Остывание горячего газа гало? Или натекание вдоль космологических филаментов? Или постоянное падение карликовых спутников?