

# Из чего и КАК сделаны галактики?

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ГАИШ МГУ

# Морфологический тип определяется соотношением диск:балдж

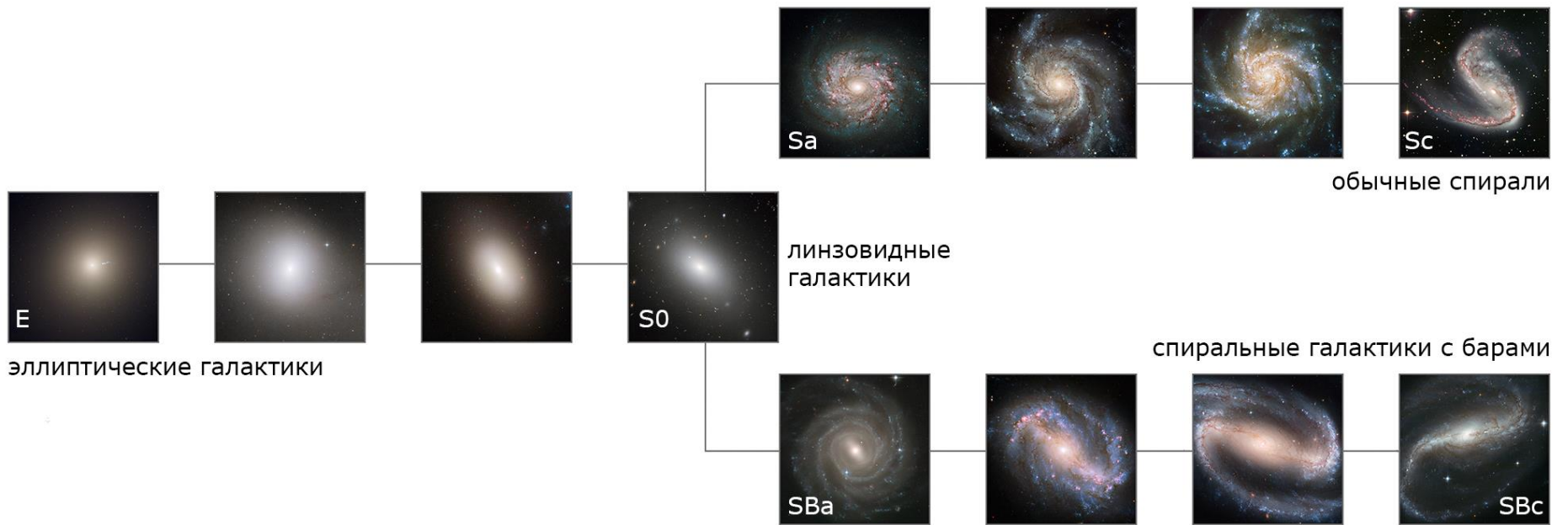


NGC 4565

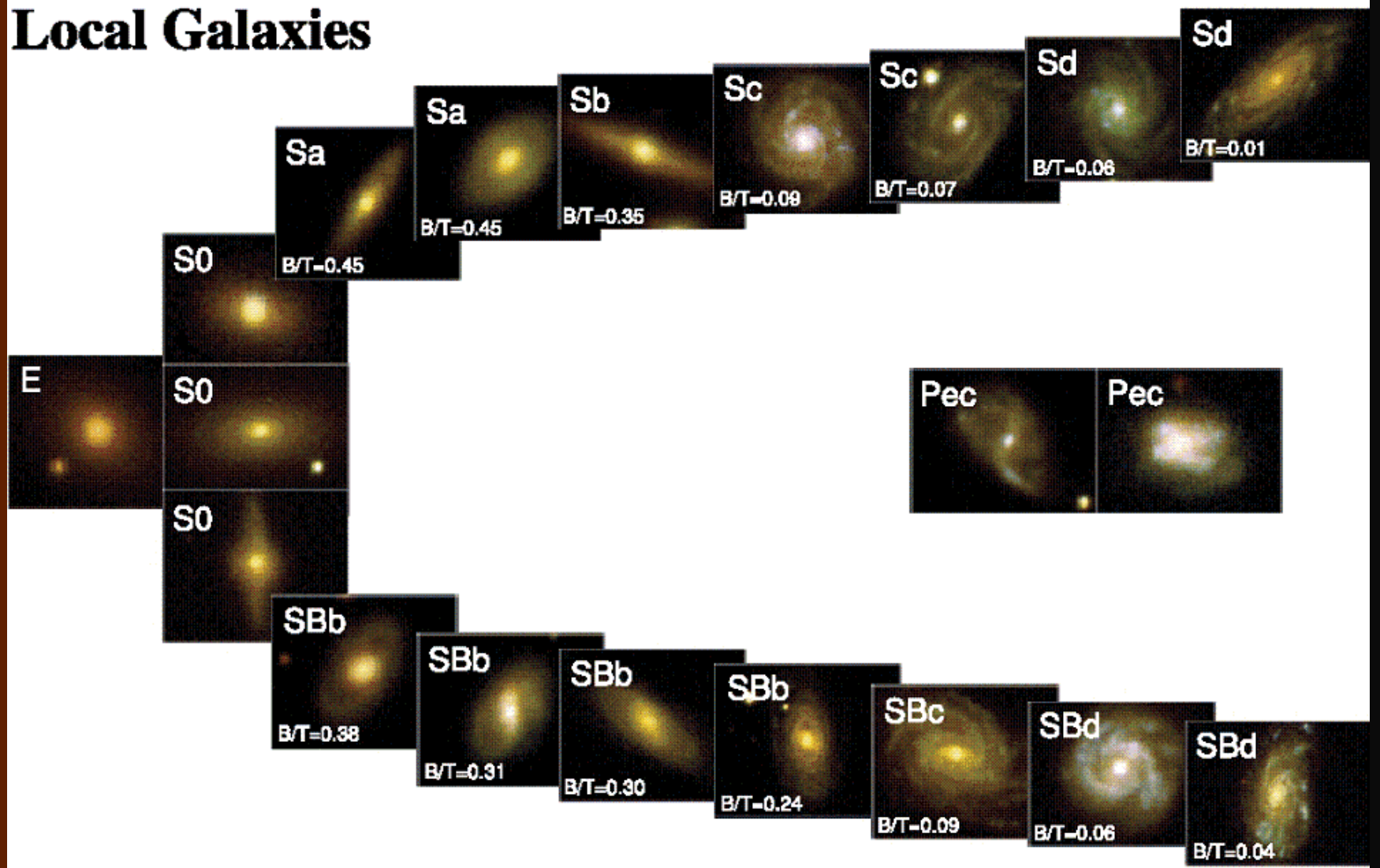


NGC 4594

# Классификация галактик по Хаббл



# Local Galaxies

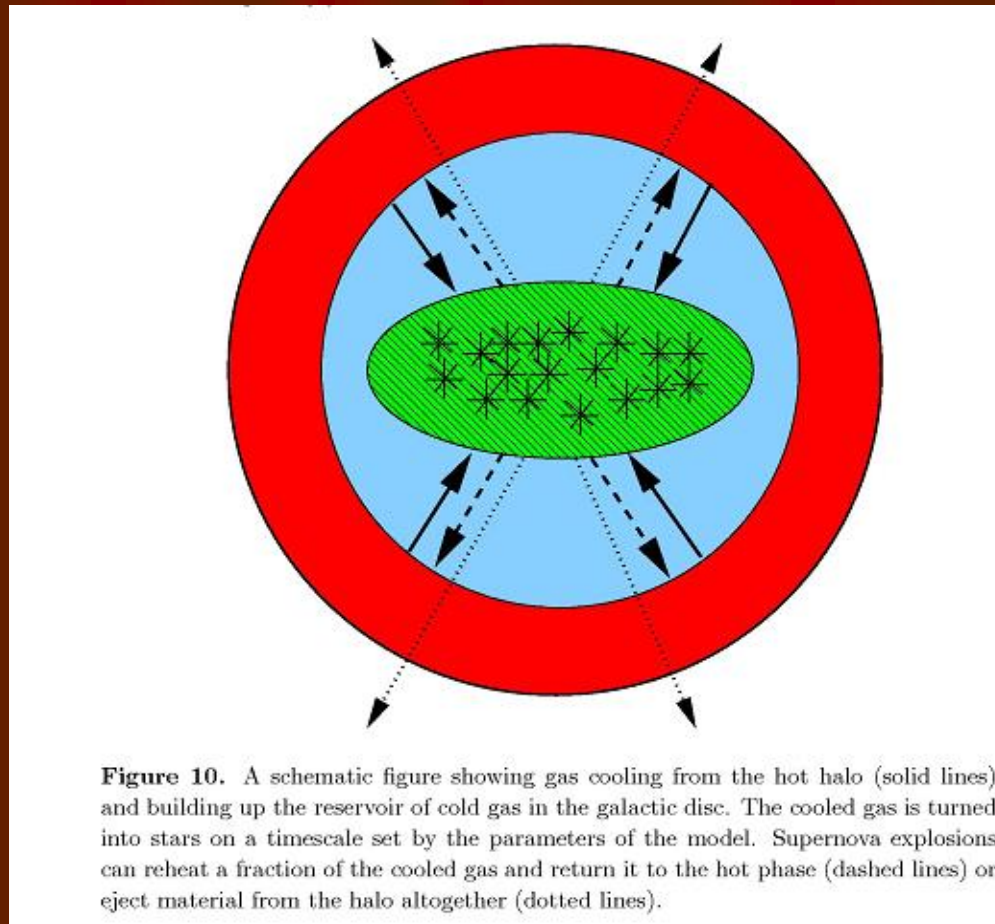


<b>E</b> 3%	<b>S0</b> 15%	<b>Spiral</b> 72%	<b>Peculiar</b> 10%
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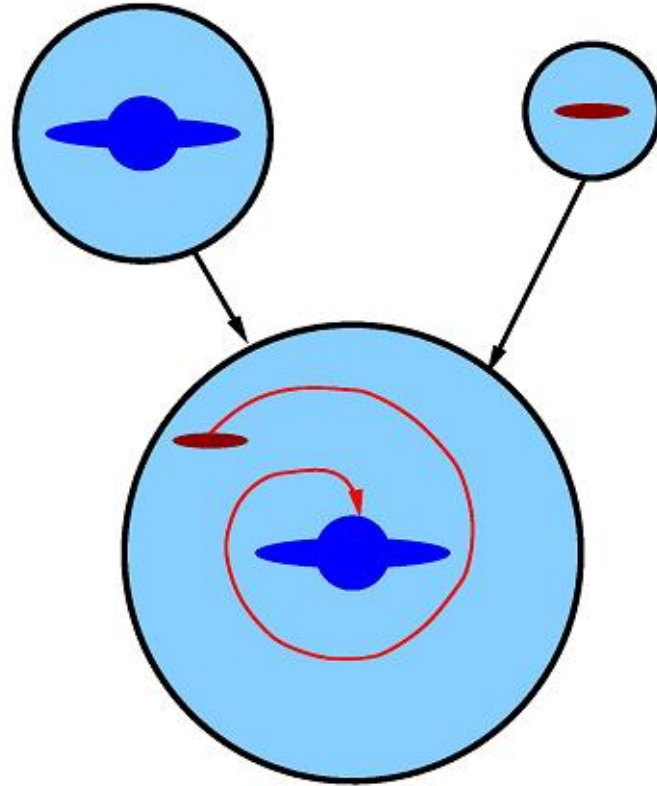
# Теоретическое направление «собирания» галактик:

- Иерархическое скучивание – сначала маленькие галактики, потом большие галактики – слиянием малых; потом к настоящей эпохе уже скопления галактик – самые массивные гравитационно-связанные объекты из наблюдаемых.

# Три фазы эволюции: 1. медленная аккреция горячего газа гало



# Три фазы эволюции в жизни каждой галактики: 2. слияния

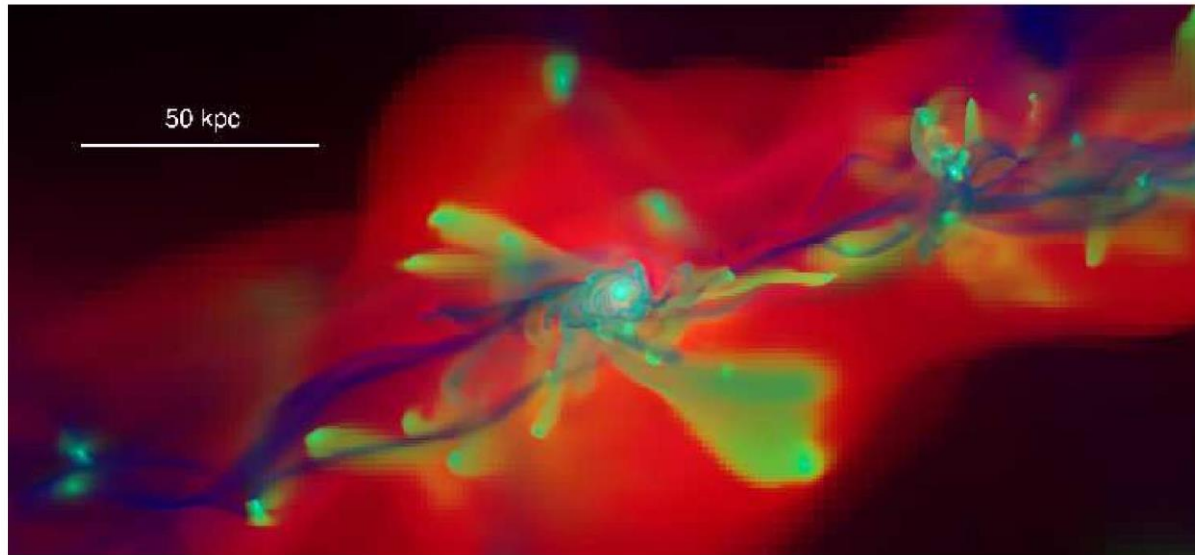


Major merging:

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.

# 3-я фаза: "Собирание" диска натеканием холодного газа вдоль узких ЖГУТОВ



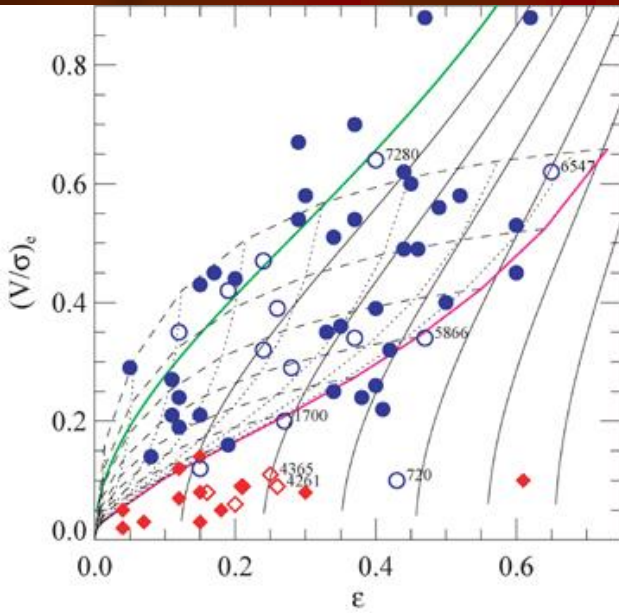
**Figure 1.** An *RGB*-image of the gas showing the disk and accretion region at  $z \sim 3$ . The image is constructed using  $R$ =temperature,  $G$ =metals and  $B$ =density. We can clearly distinguish the cold pristine gas streams in blue connecting directly onto the edge of the disk, the shock heated 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.



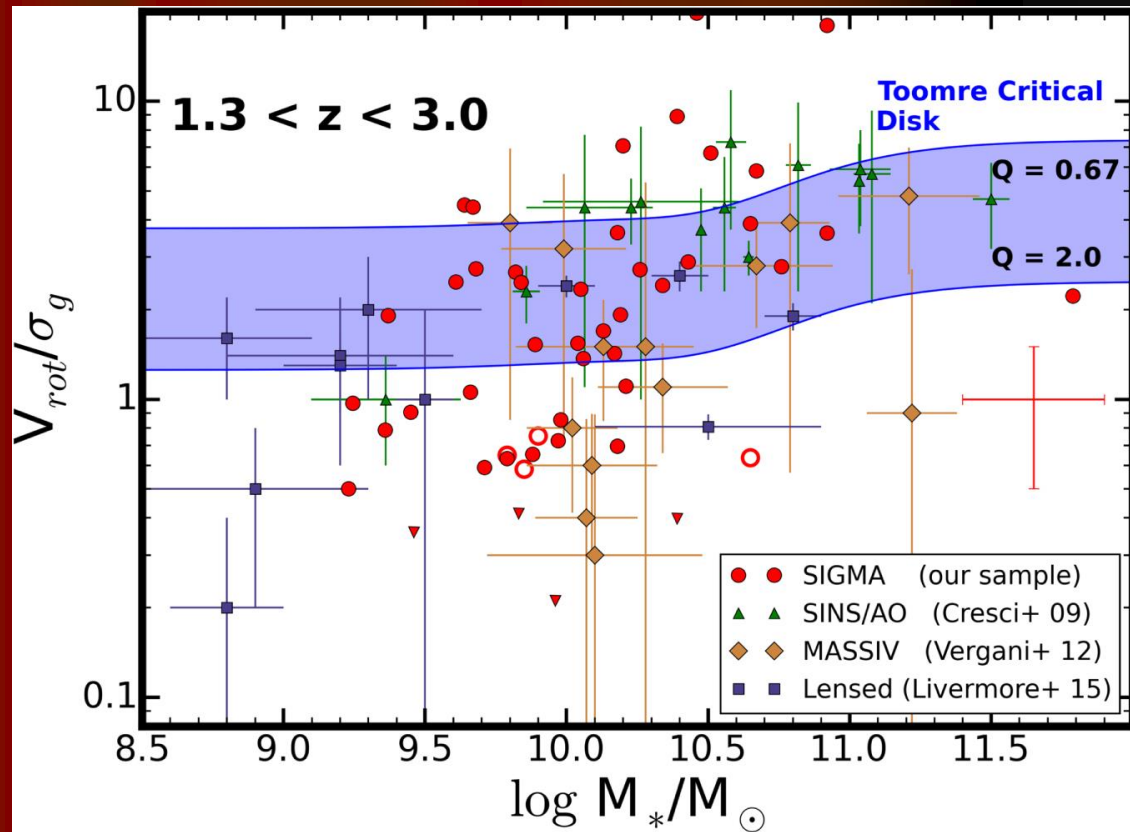
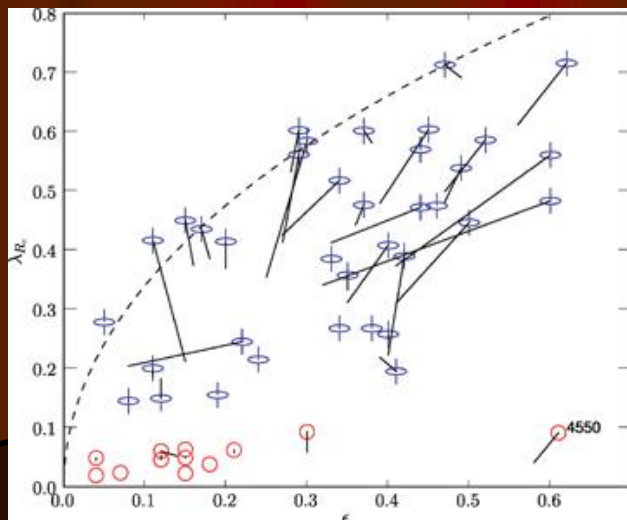
# Видимые последствия:

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

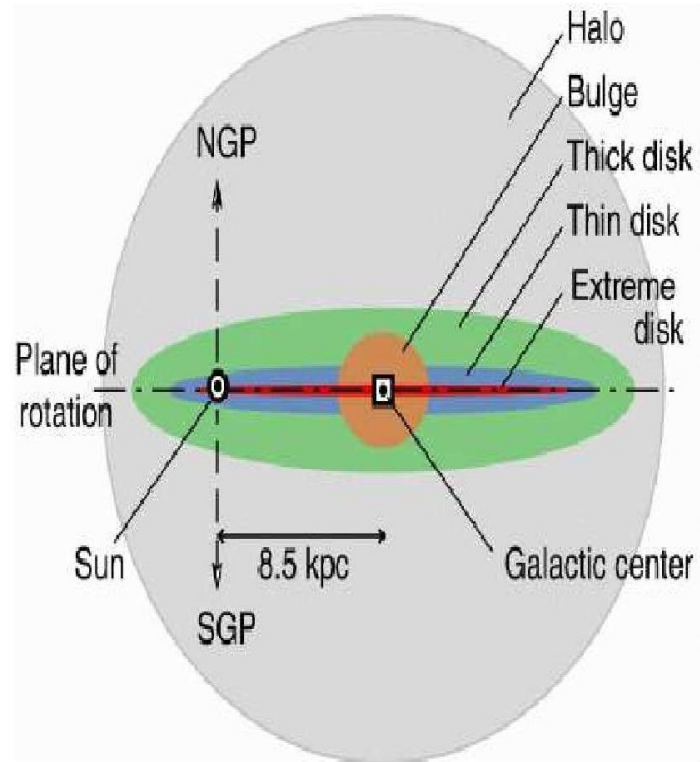
# В сфероидах быстры хаотические движения звезд, в дисках – регулярное вращение газа и звезд



вращение газа и звезд

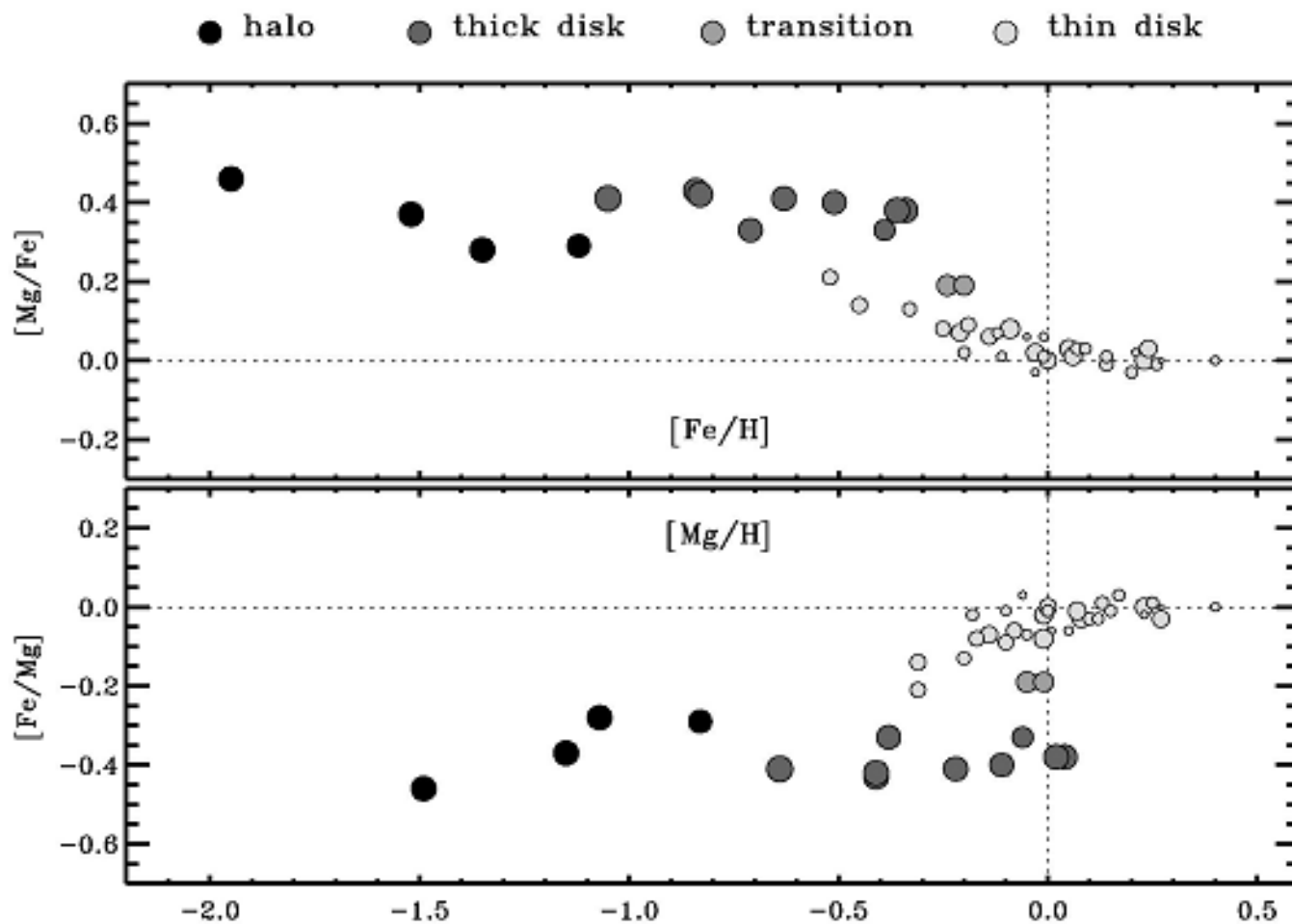


# Наблюдения: наша Галактика

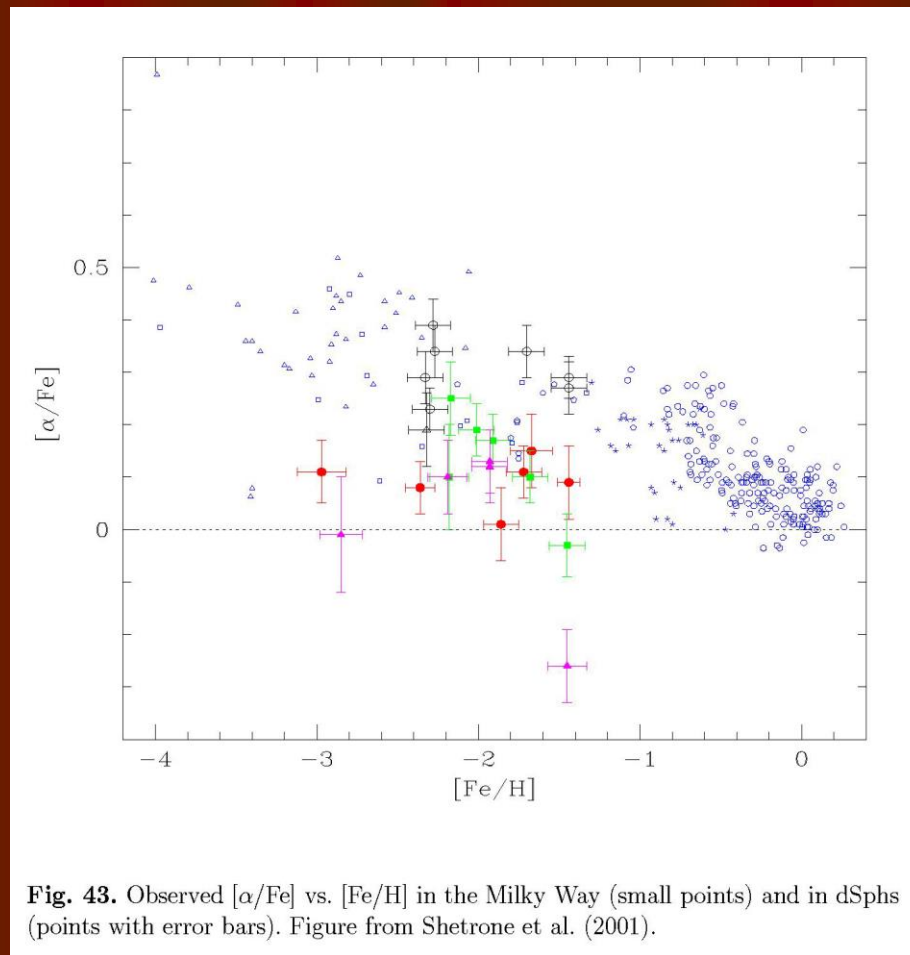


**Fig. 12.** Schematic edge-on view of the major components of the Milky Way. Illustration credit from R. Buser, [www.astro.unibas.ch/forschung/rb/structure.shtml](http://www.astro.unibas.ch/forschung/rb/structure.shtml).

# Наблюдения: наша Галактика

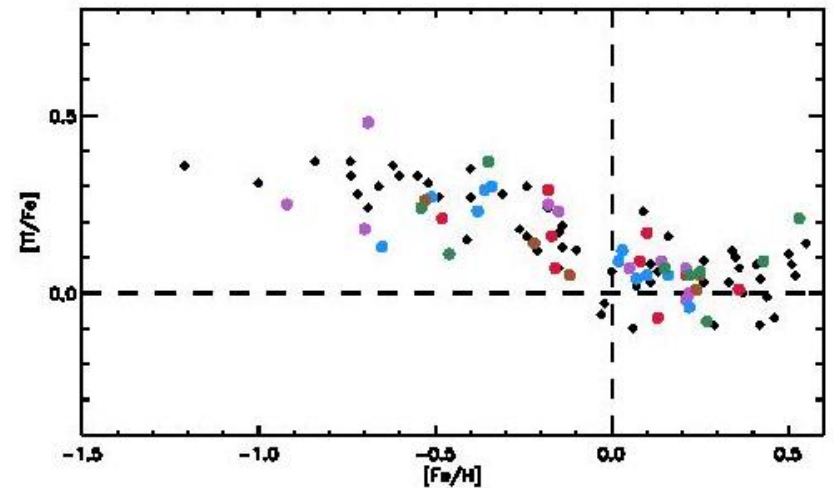
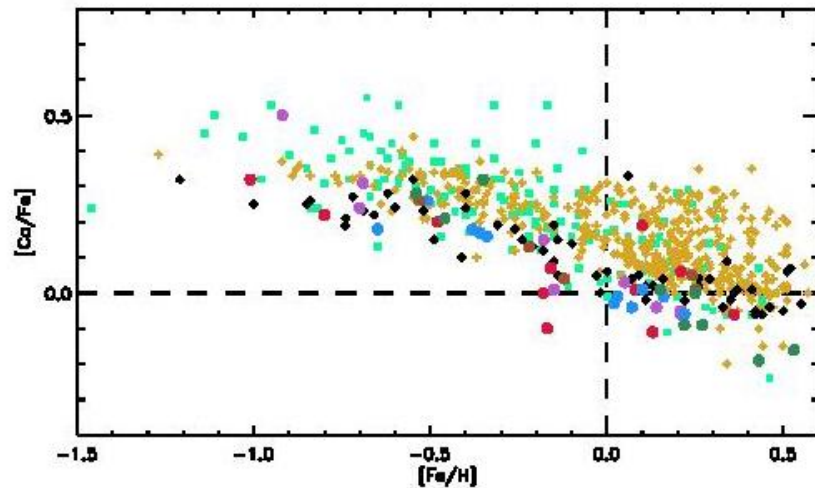
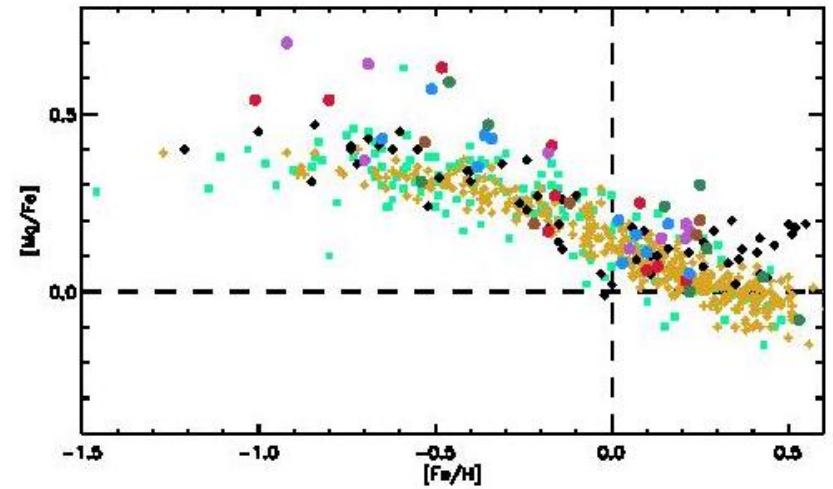
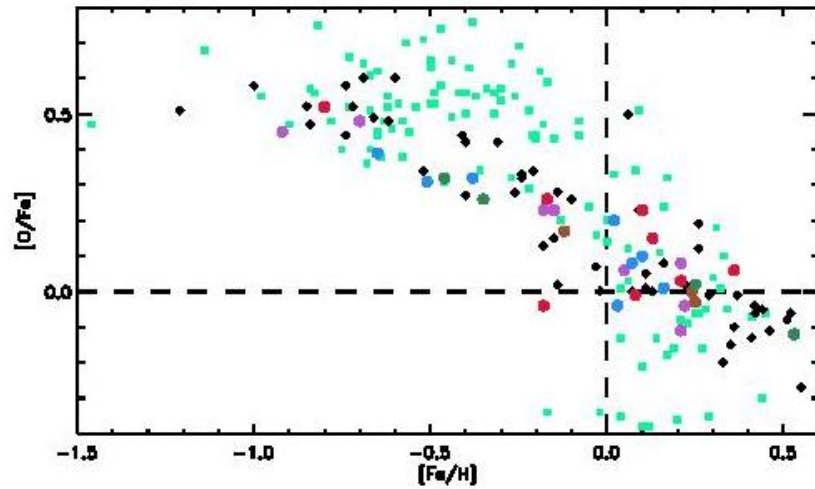


# Наблюдения: карликовые сфероидальные галактики

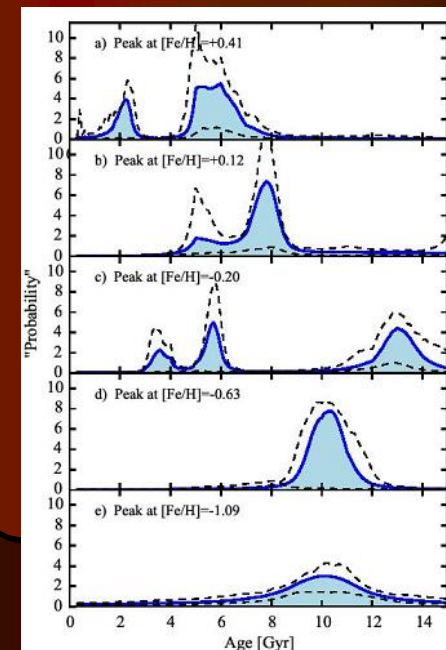
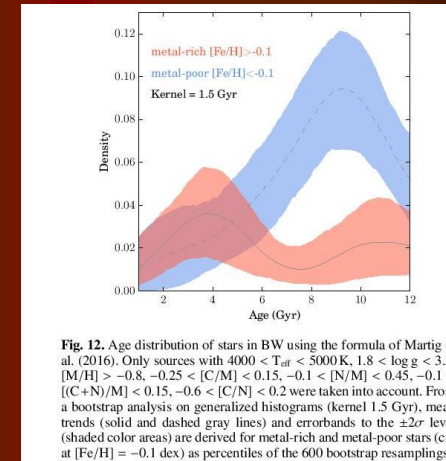
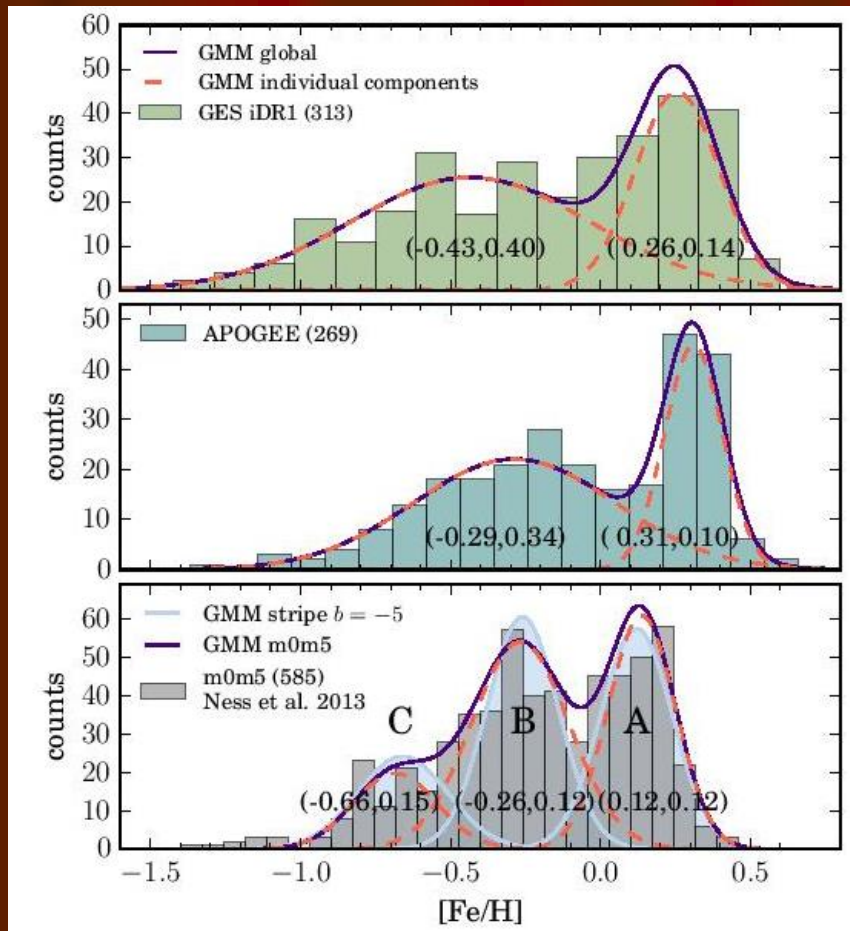


**Fig. 43.** Observed  $[\alpha/\text{Fe}]$  vs.  $[\text{Fe}/\text{H}]$  in the Milky Way (small points) and in dSphs (points with error bars). Figure from Shetrone et al. (2001).

# Наблюдения: балдж Галактики



# Наблюдения: балдж Галактики



Данные 2017 г

# Giraffe: радиальный градиент и карта!

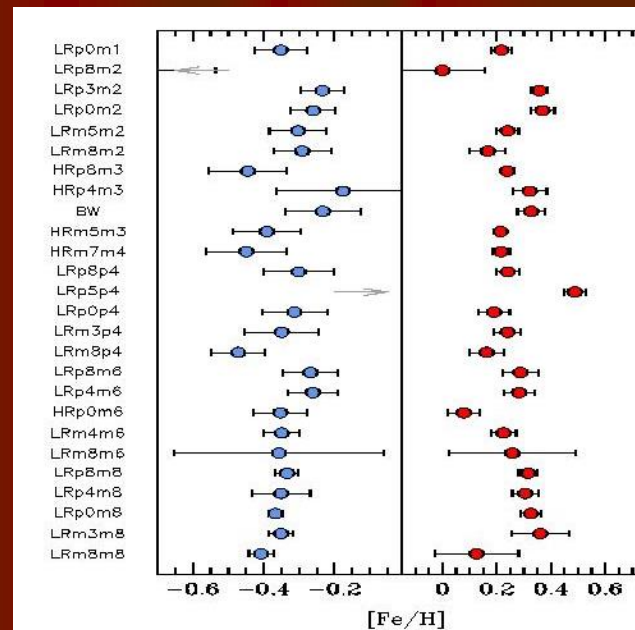
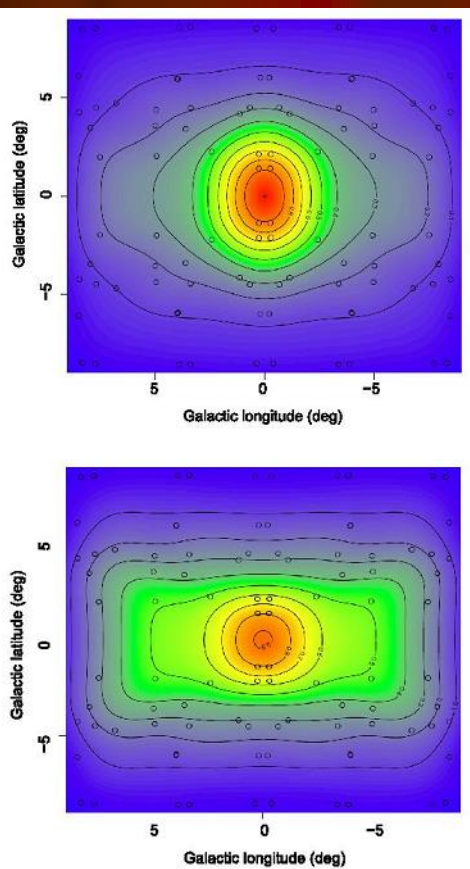
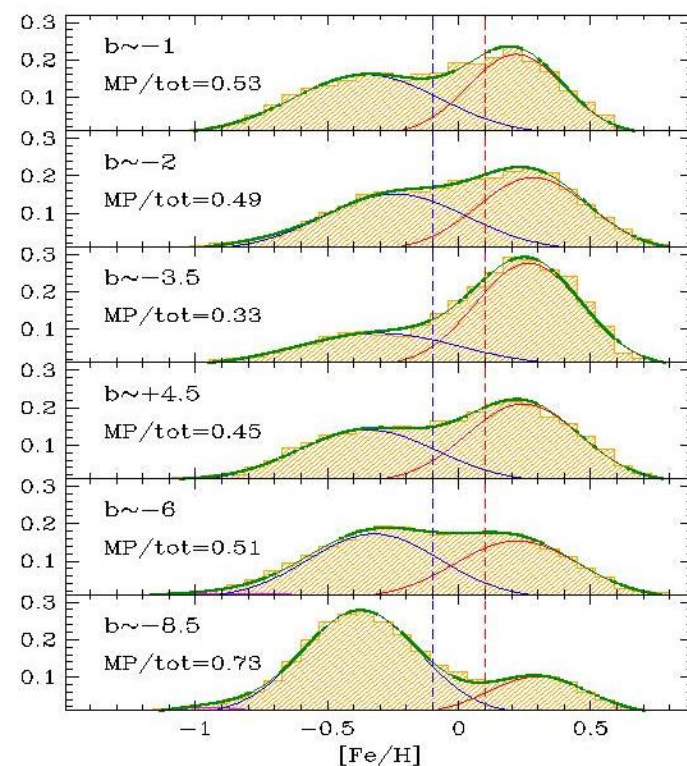


Fig. 6. Peak metallicity of the metal-poor (blue) and metal-rich (red) Gaussians fitted in Fig. 4. The names of the fields are listed on the left, from the closest to the plane at the top, to the ones in the outer bulge at the bottom.

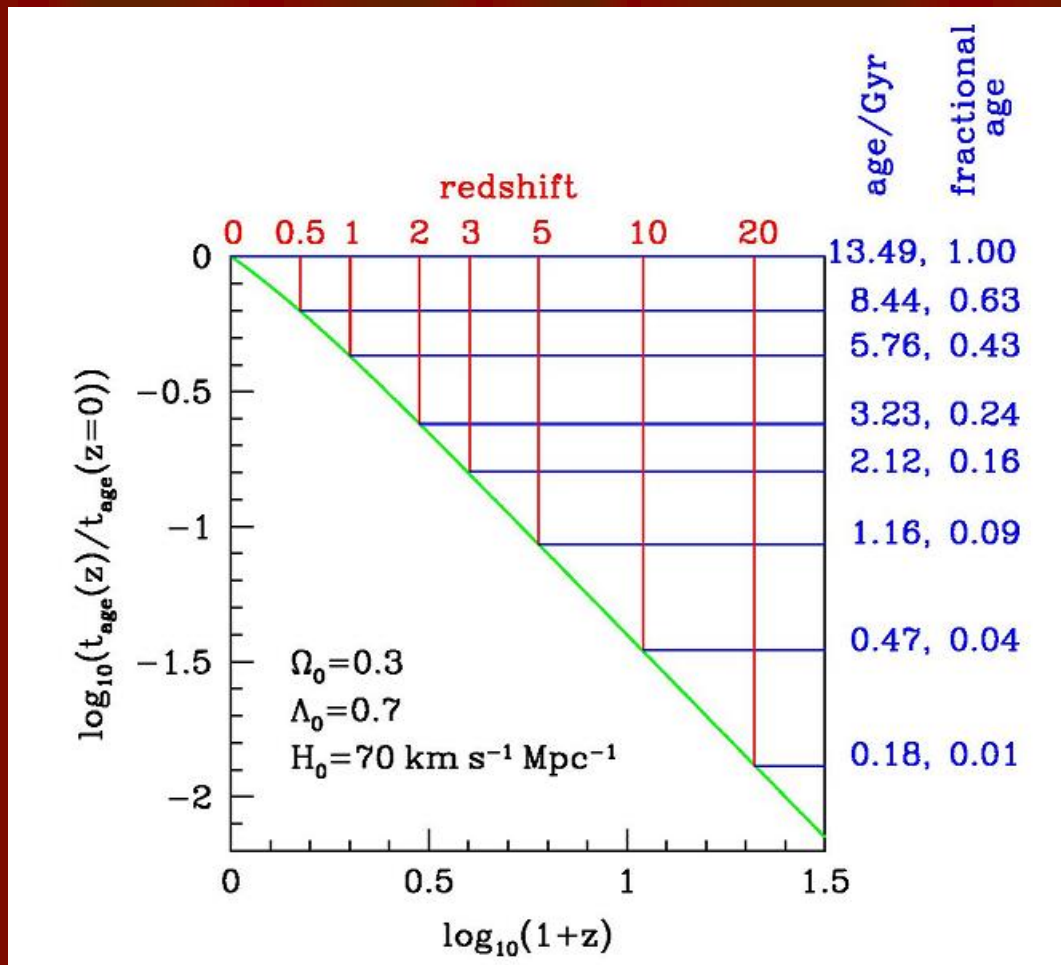




# Наблюдательное исследование эволюции Вселенной

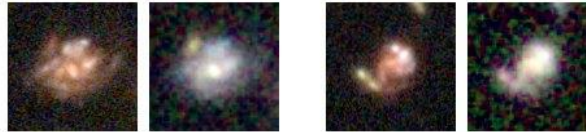
- На больших 8-10 метровых телескопах мы видим всю Вселенную после рекомбинации на просвет...

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



Возраст  
 Вселенной на  
 разных красных  
 смещениях

На красных смещениях  $z > 1.5$  (9 млрд лет назад)  
морфологическая последовательность  
нарушается... (галактики в северном Глубоком  
Хаббловском поле)



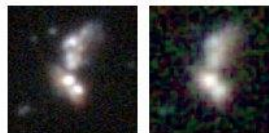
$z = 0.75$

$z = 0.95$



$z = 0.96$

$z = 1.01$



$z = 1.36$

$z = 2.01$



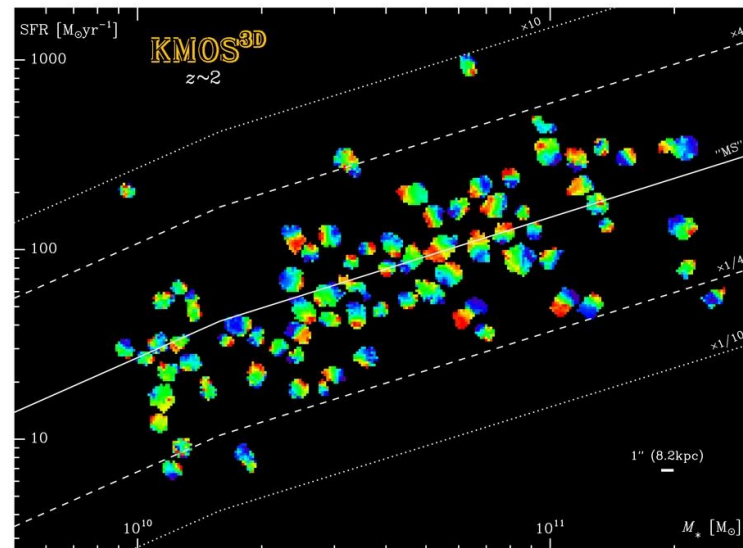
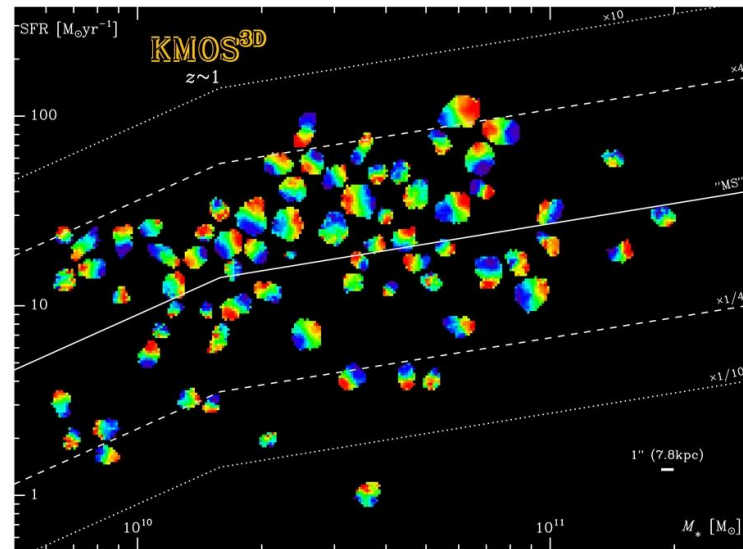
$z = 2.27$

$z = 2.80$

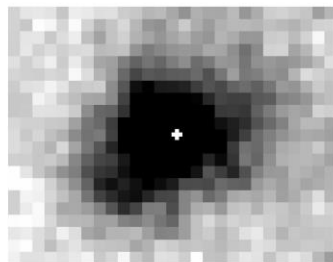
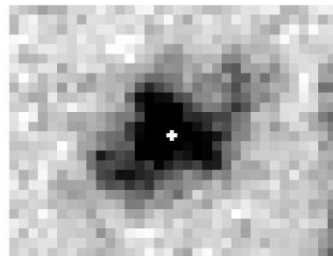
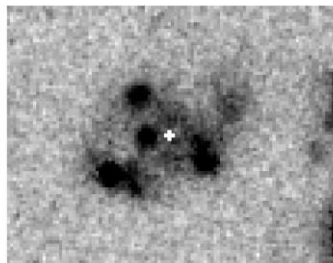
# Что значит клочковатость далеких галактик?

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

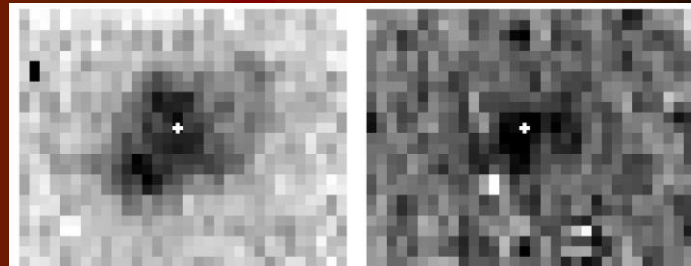
# Обзор KMOS-3D: $z=0.7-2.7$ , панорамная спектроскопия на VLT



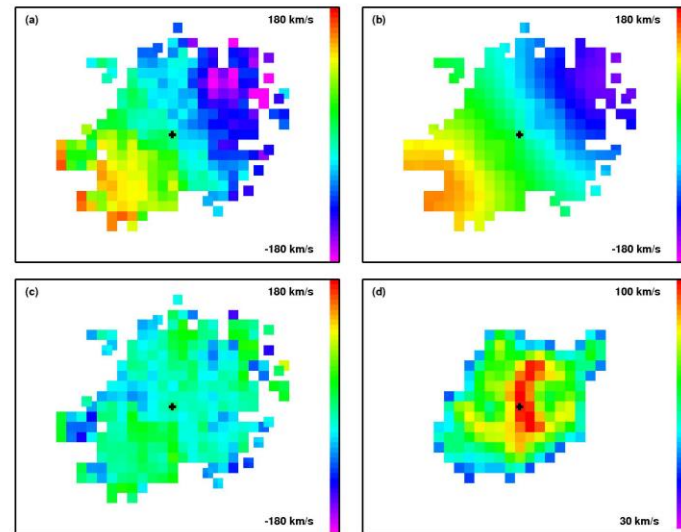
# Как оказалось, все клочки участвуют в едином вращении:



**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.

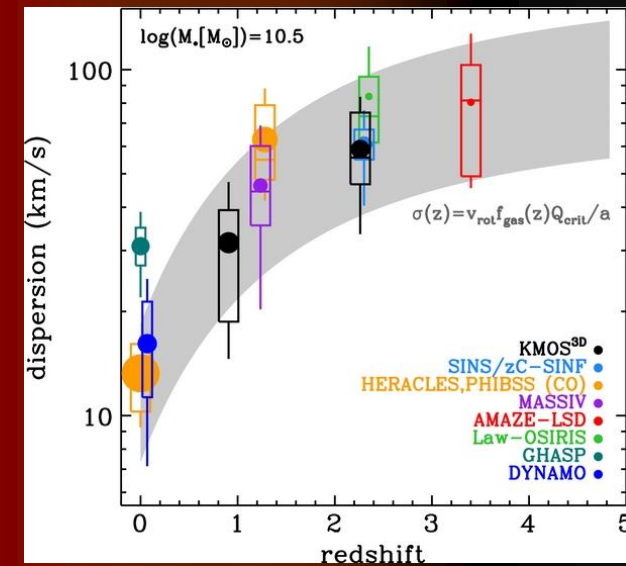
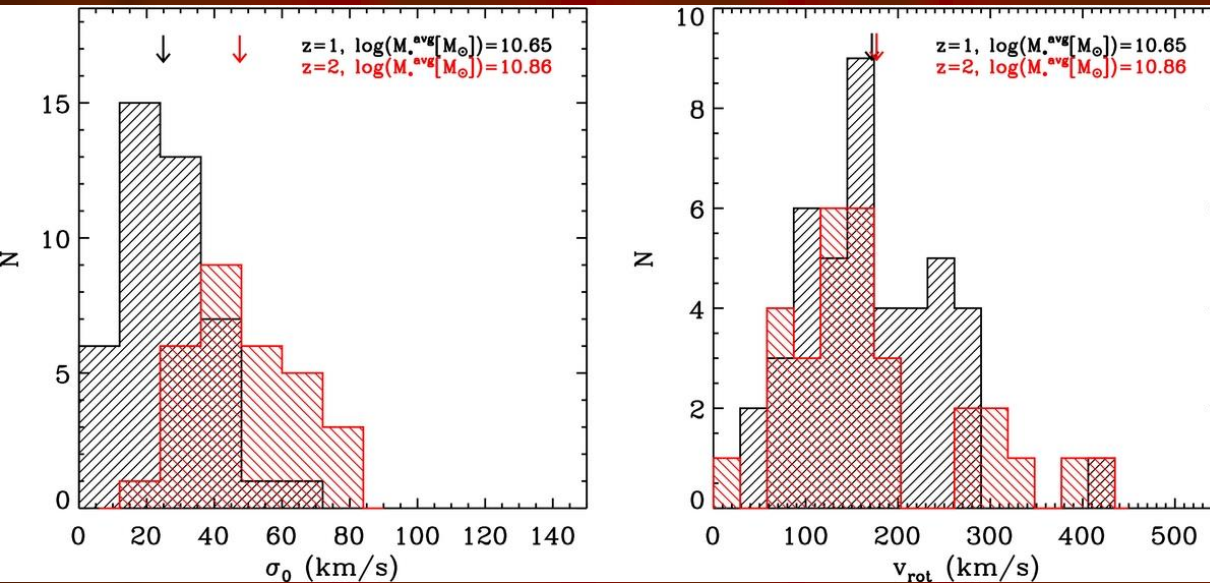


**Fig. 5.** a. H $\alpha$  line map. b. [N II] $\lambda$ 6583 line map. Image size is again 3" times 4" and the images have been rotated so that east is to the top and north is to the right. The white crosses mark again the (K band) center (here determined from the PSF star positions).



**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.

# 83% -Массивные, быстро вращающиеся диски, но ТОЛСТЫЕ И ГОРЯЧИЕ динамически



Wisnioski et al. 2015

# Кривые вращения

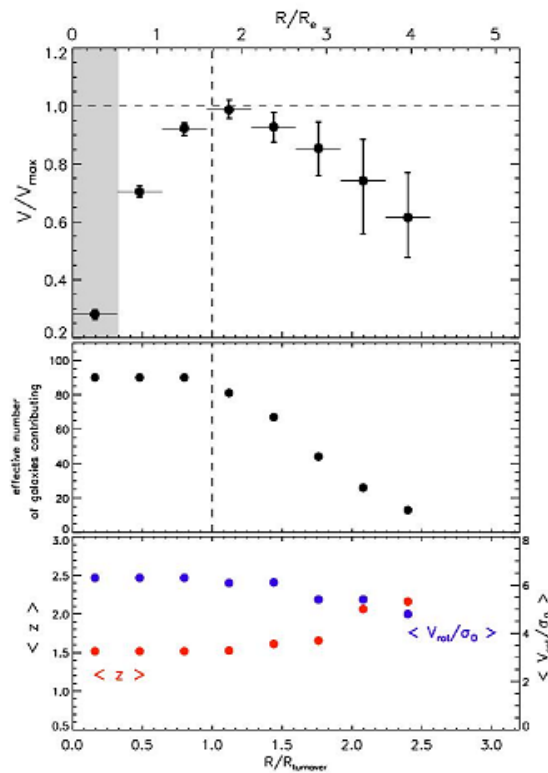
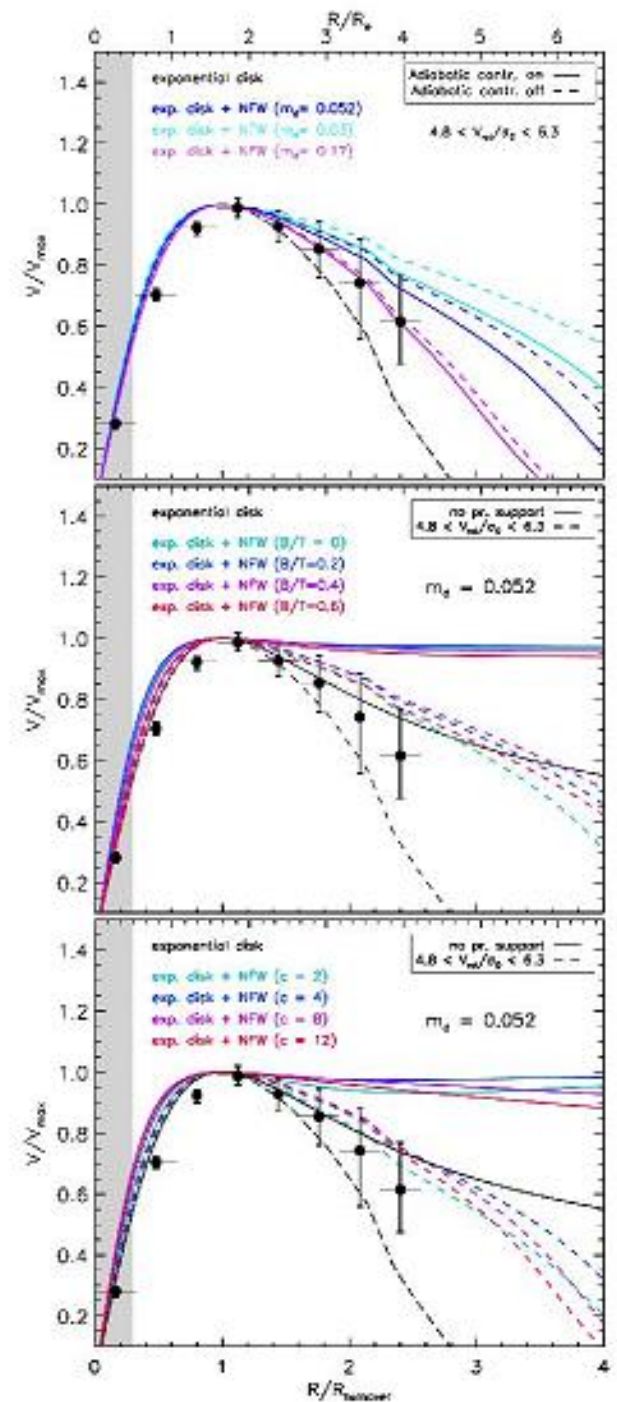
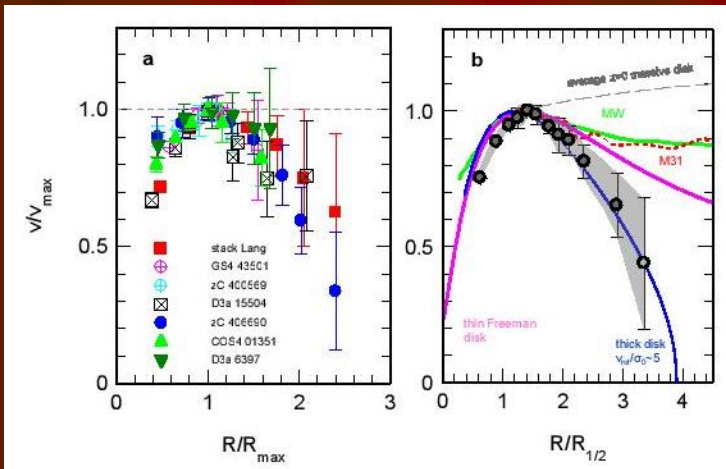


Figure 5. Top: Stacked rotation curve (black dots) plotted in units of normalized velocity ( $V/V_{max}$ ), normalized radius ( $R/R_{turner}$ ), and intrinsic effective radius ( $R/R_c$ ). The error bars are derived from bootstrapping and include both sample variance as well as RMS noise in the spectra. The shaded area marks the half-light beam size of the average PSF observed for our sample. Middle: Effective number of galaxies contributing to the stack, accounting for masking out noisy pixels in the pv diagrams. The decrease in the number of contributing galaxies with increasing radius is driven by FOV limitations. Bottom: Median redshift and  $V_{rot}/\sigma_0$  of contributing galaxies for a given radial bin.

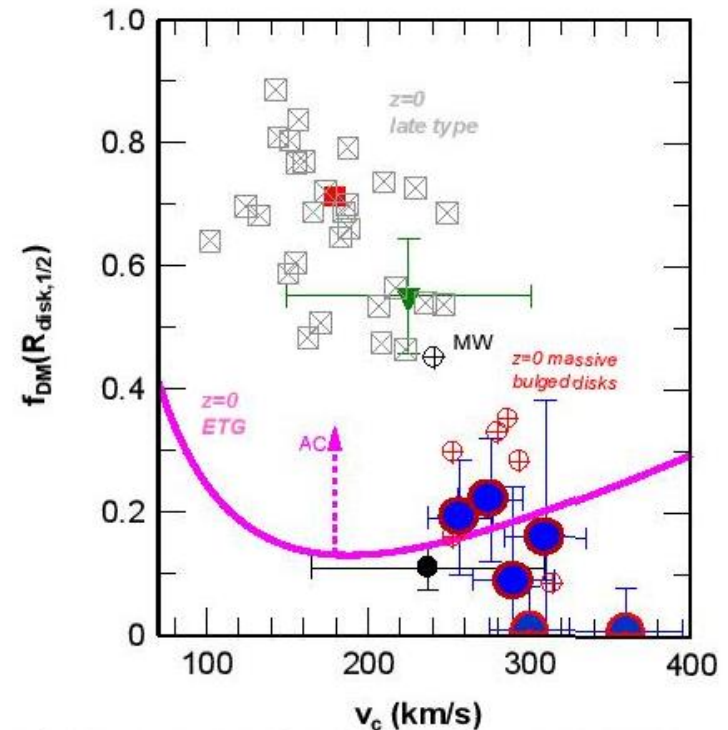




# Главный результат: отсутствие темной материи – признак раннего типа галактики?

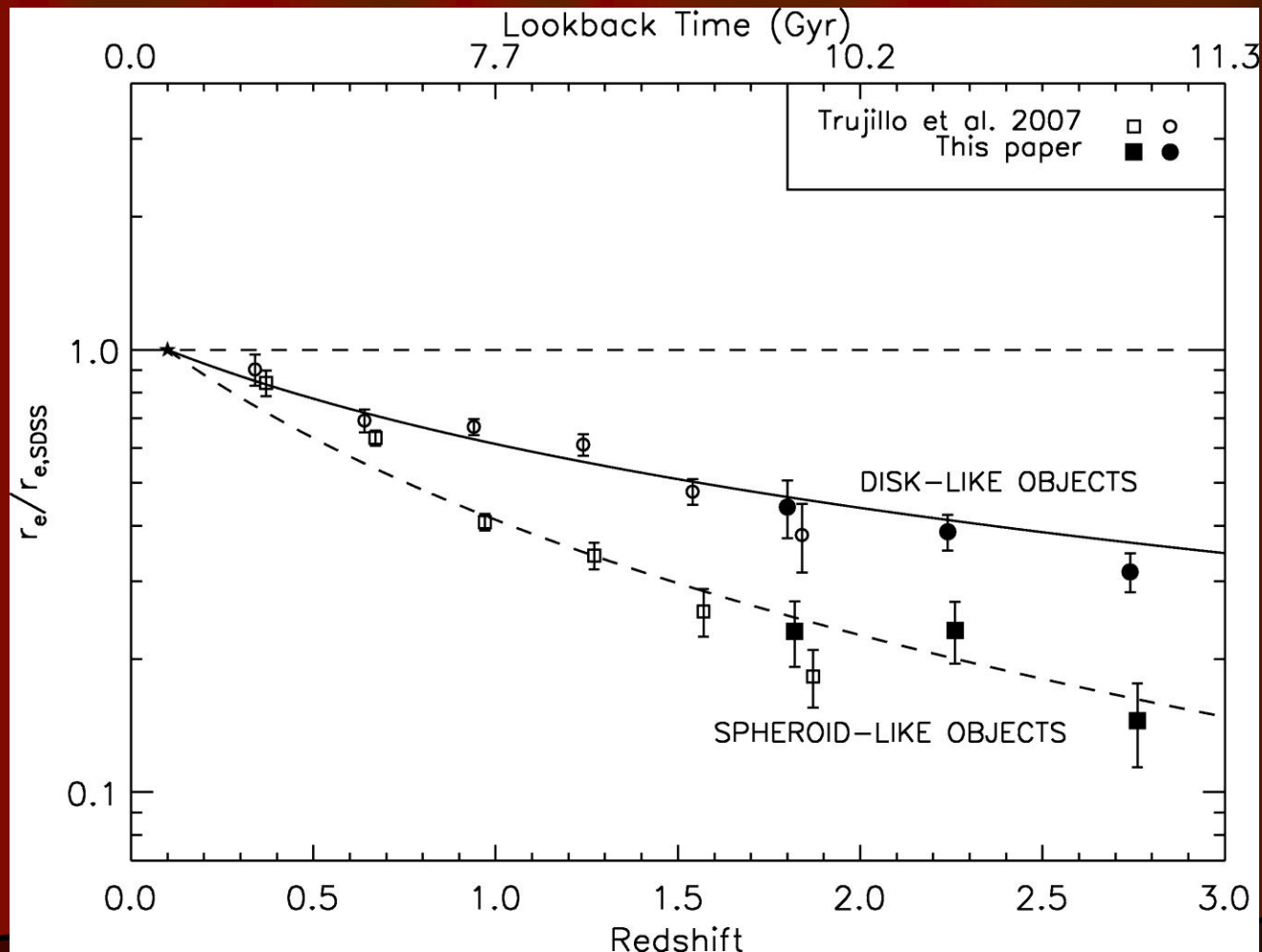


**Figure 2. Normalized rotation curves.** (a): The various symbols denote the folded and binned rotation curve data for the six galaxies in Figure 1, combined with the stacked rotation curve of 97  $z=0.6-2.6$  star-forming galaxies<sup>18</sup> (Methods). For all rotation curves we averaged data points located symmetrically on either side of the dynamical centres, and plot the rotation velocities and radii normalized to their maximum values. Error bars are  $\pm 1$  rms. (b): The black data points

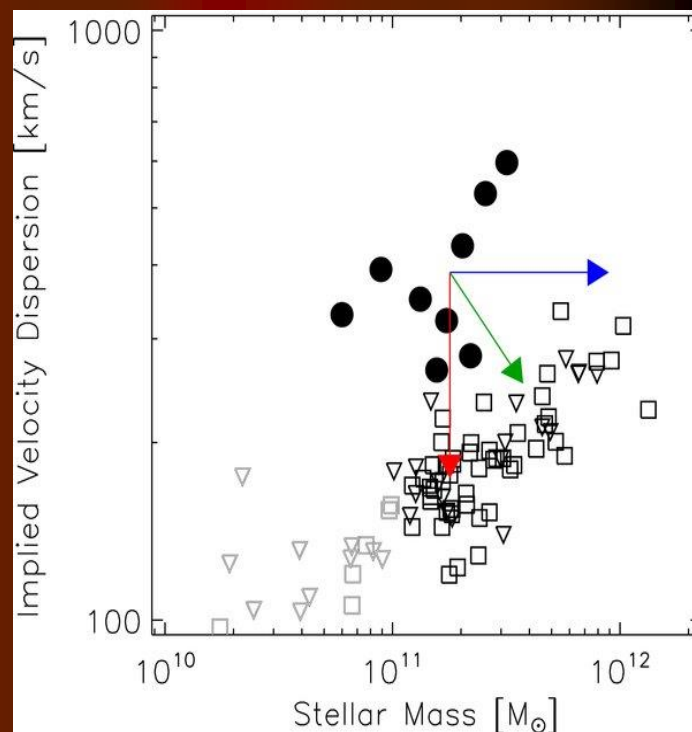
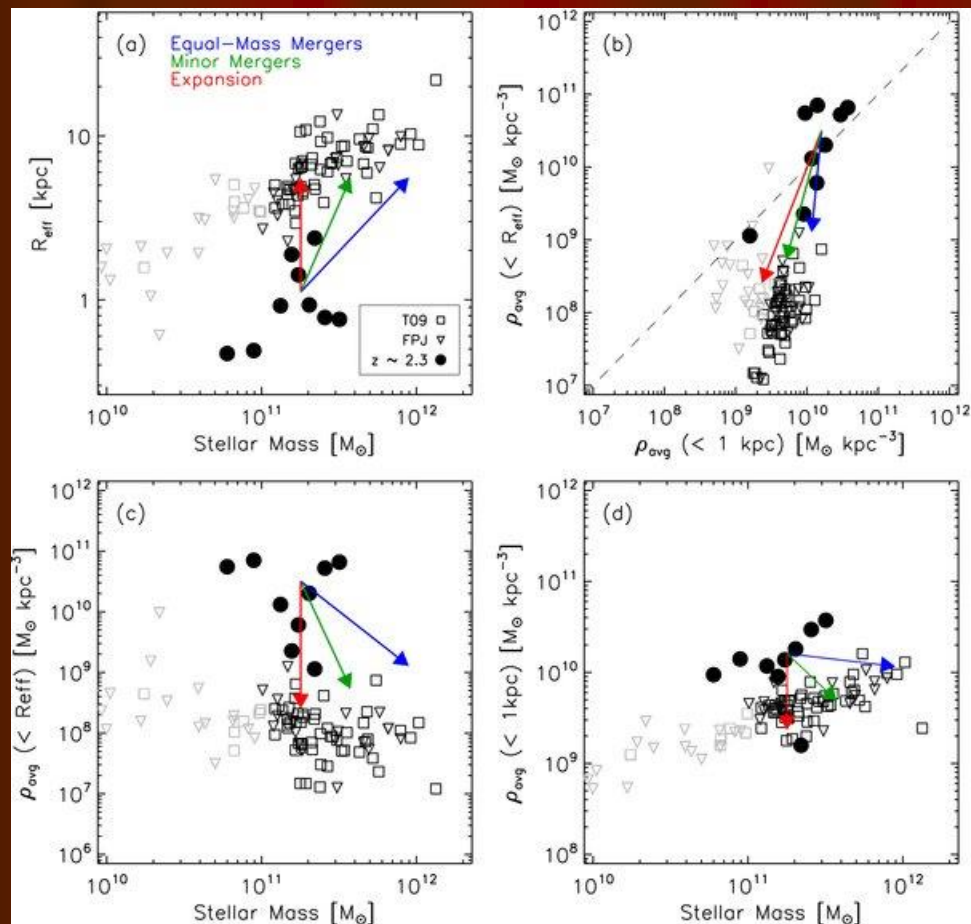


**Figure 3. Dark matter fractions.** Dark matter fractions from different methods are listed as a function of the circular velocity of the disk, at the half mass/light radius of the disk, for galaxies in the current Universe and  $\sim 10$  Gyr ago. The large blue circles with red outlines indicate the dark matter fractions derived from the outer-disk rotation curves of the six high- $z$  disks presented in this paper (Table 1), along with the  $\pm 2$  rms

# Эволюция размеров: особенно сильная у сфероидов



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



# Все-таки много малых слияний

## Development of Massive Elliptical Galaxies

