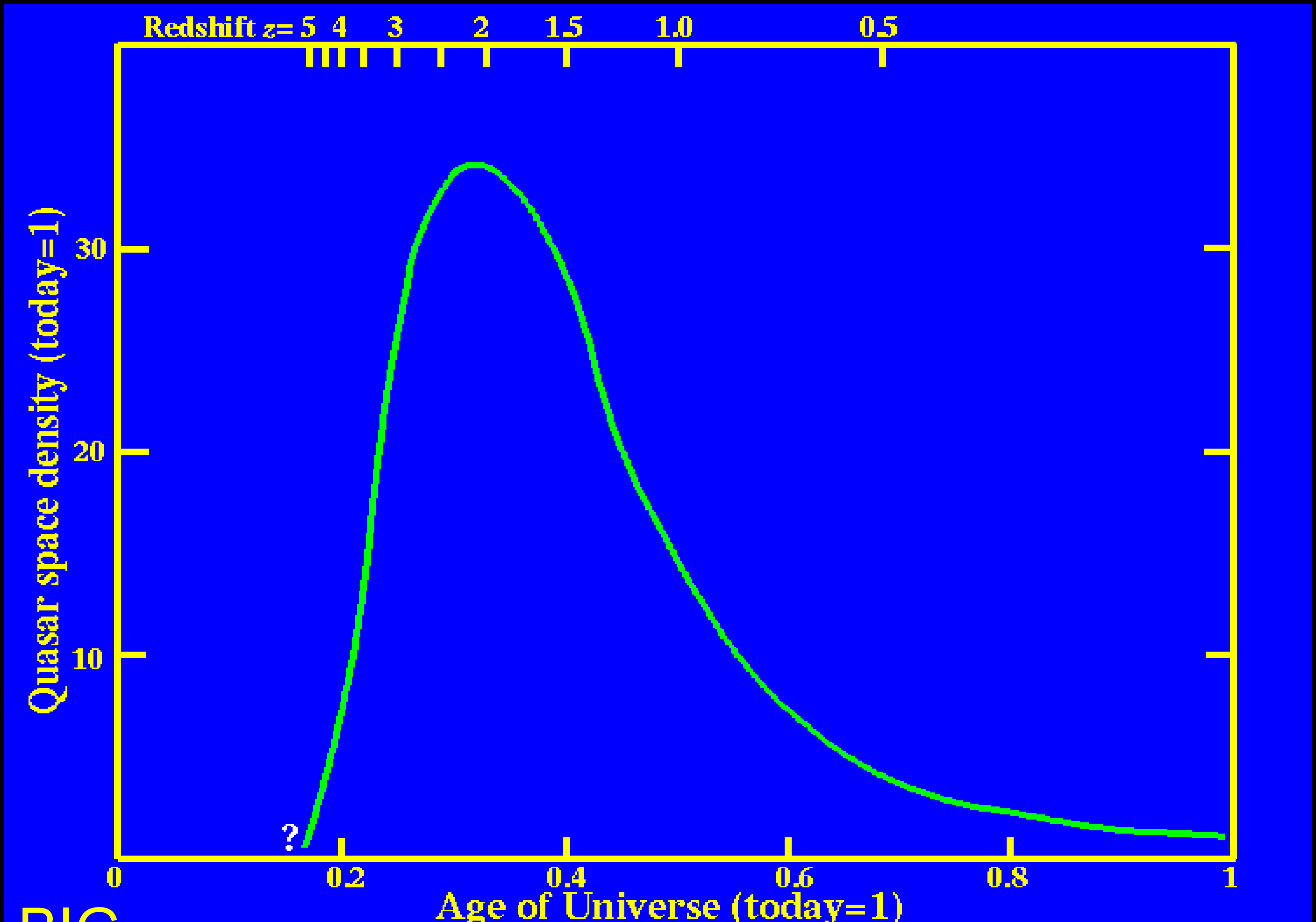
Observing quasars at high redshifts

⬄ distances of several Gpc

⬄ Look-back times of many billions of years

⬄ Universe was only a few billion years old!



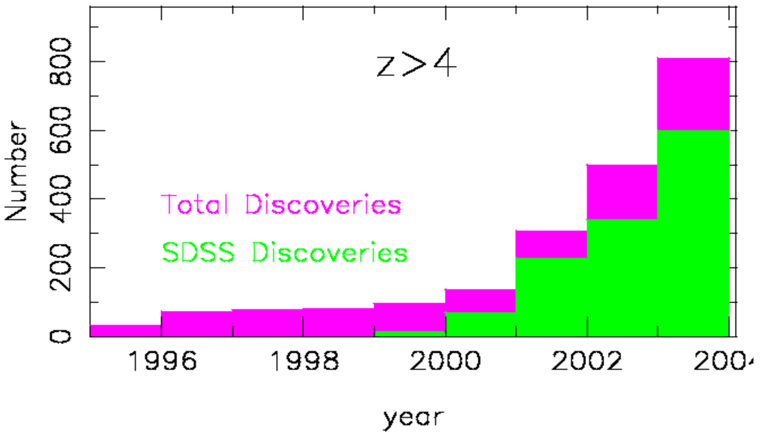
BIG-BANG

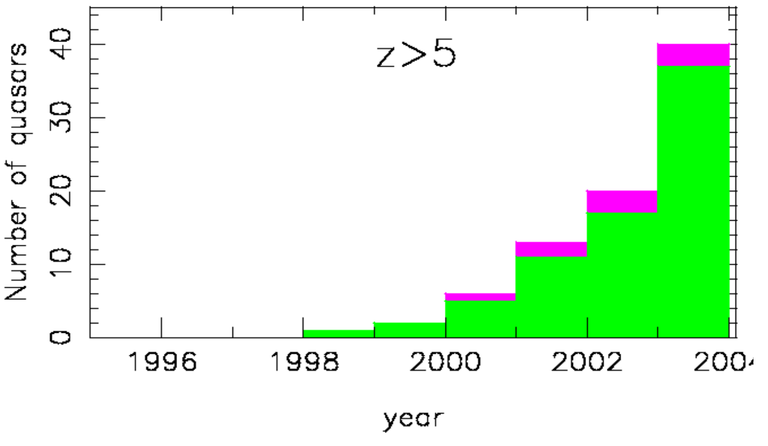
Today

ttp://www.astr.ua.edu/keel/galaxies/qsoevolve.html

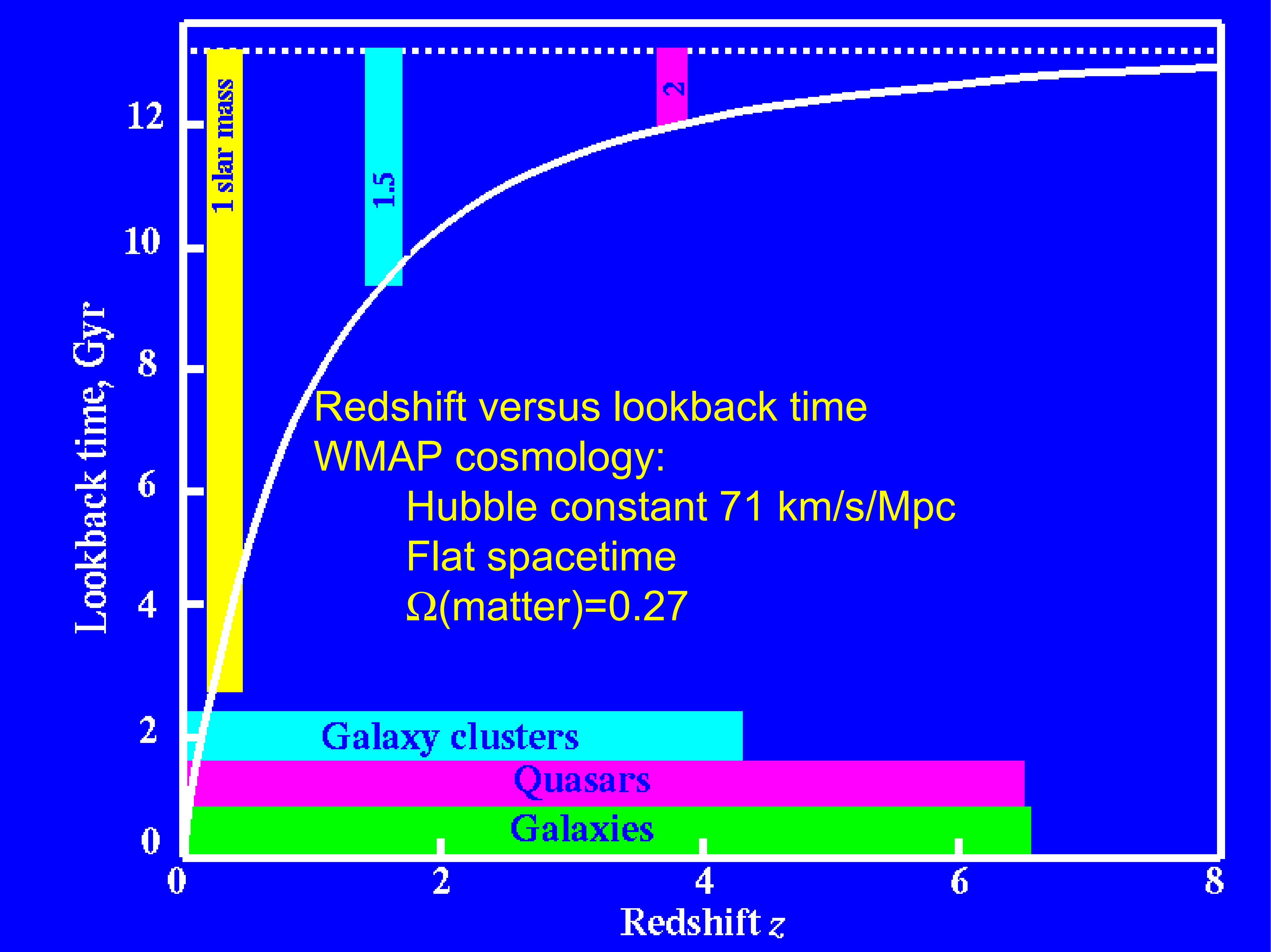
The Highest Redshift Quasars Today

- z>4: ~700 known
- z>5: ~30
- z>6: 7
- SDSS i-dropout Survey:
  - By Spring 2004: 6000 deg² at z_{AB}<20
  - Fourteen luminous quasars at z>5.7
- 20 – 40 at z~6 expected in the whole survey

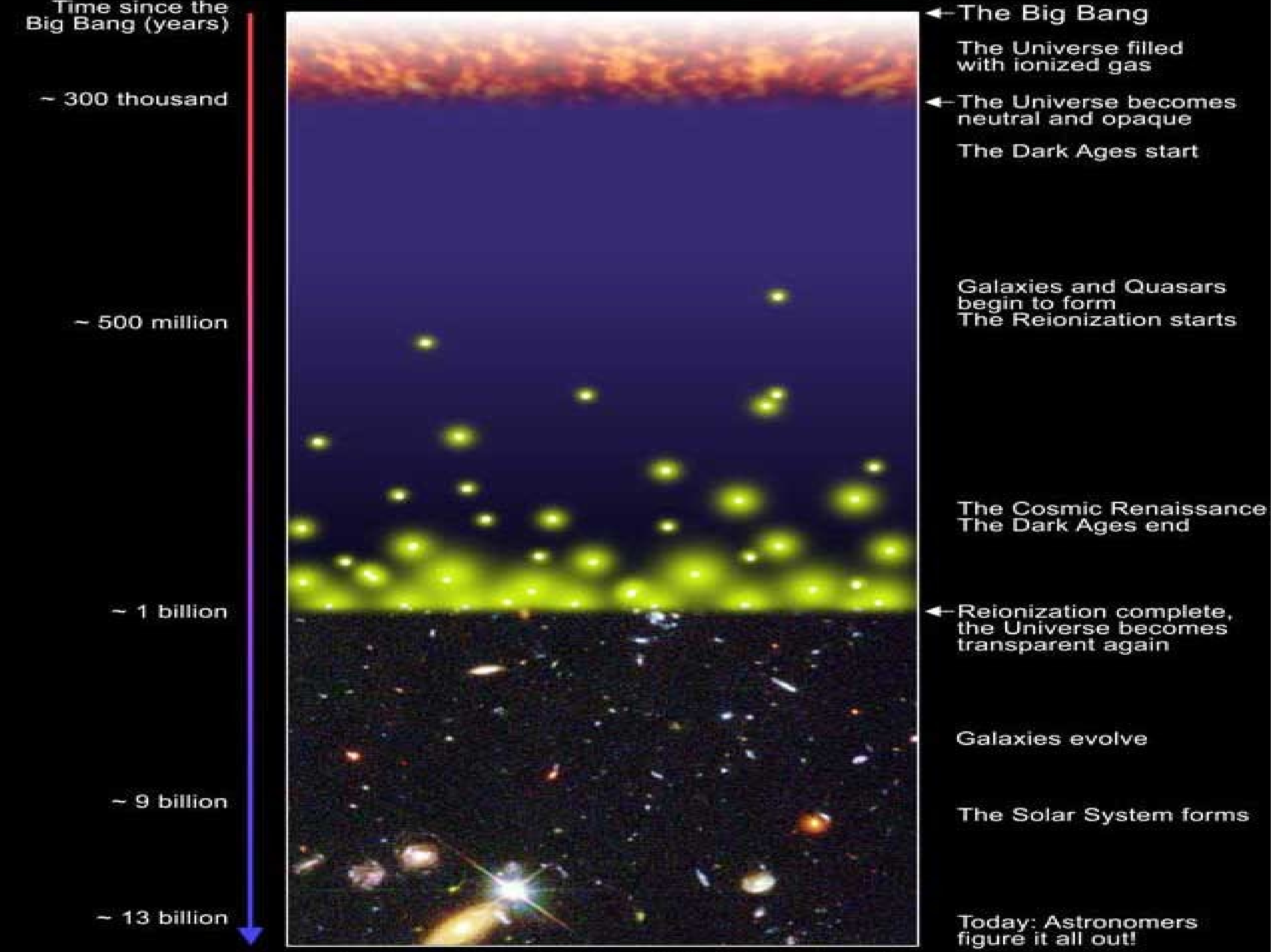




- **Quasars now seen to 0.5 Gyr <u>after</u> beginning,**
- **very common 10 Gyr ago (z=2)**

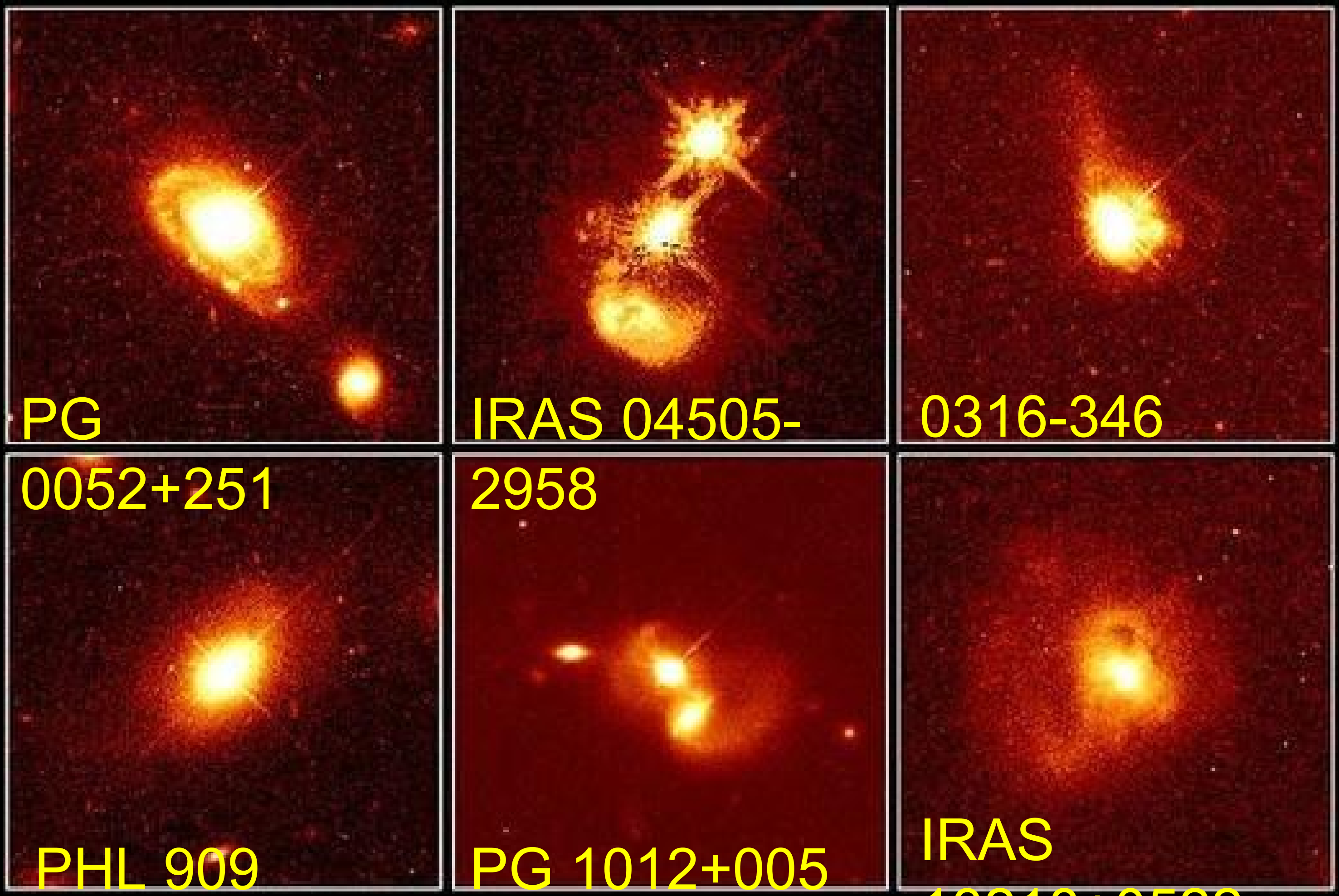


Redshift versus lookback time
WMAP cosmology:
Hubble constant 71 km/s/Mpc
Flat spacetime
Ω(matter)=0.27
1 solar mass
1.5
2
Galaxy clusters
Quasars
Galaxies
Lookback time, Gyr
Redshift z
0
2
4
6
8
10
12


Time since the Big Bang (years)
~ 300 thousand
~ 500 million
~ 1 billion
~ 9 billion
~ 13 billion
The Big Bang
The Universe filled with ionized gas
The Universe becomes neutral and opaque
The Dark Ages start
Galaxies and Quasars begin to form
The Reionization starts
The Cosmic Renaissance
The Dark Ages end
Reionization complete, the Universe becomes transparent again
Galaxies evolve
The Solar System forms
Today: Astronomers figure it all out!

Quasar Host Galaxies

Elliptical galaxies; often merging / interacting galaxies

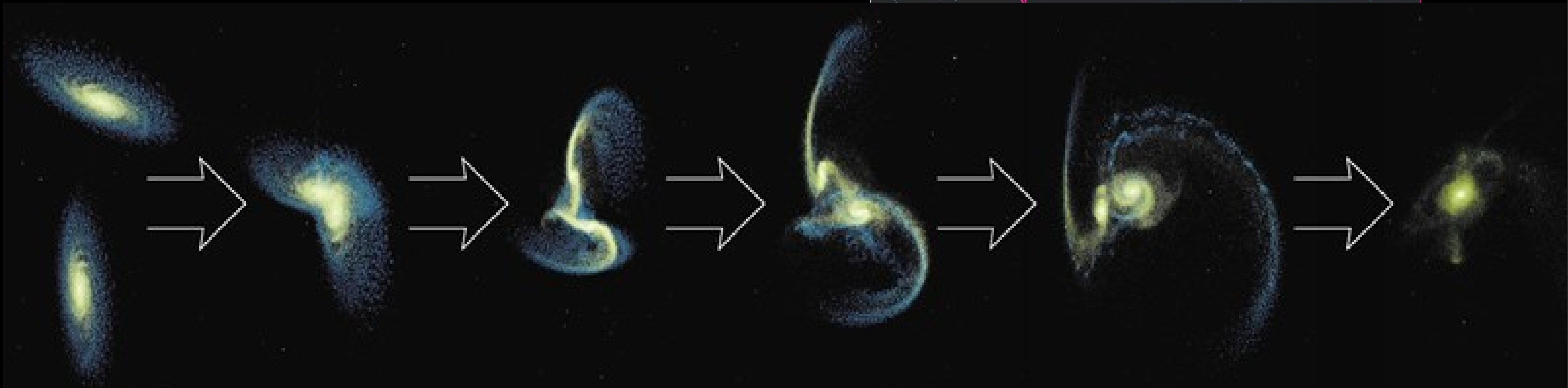


Galactic Collisions

The typical size of galaxies is usually not much smaller than the typical distance between galaxies – For example, the distance of Andromeda is about *30* times that of the size of the Milky Way.

While the distance between stars is 10 Millionen fach the size of the stars.

⇒Collision between stars are much rarer…



Two simulated spiral galaxies approach each other on a collision course.

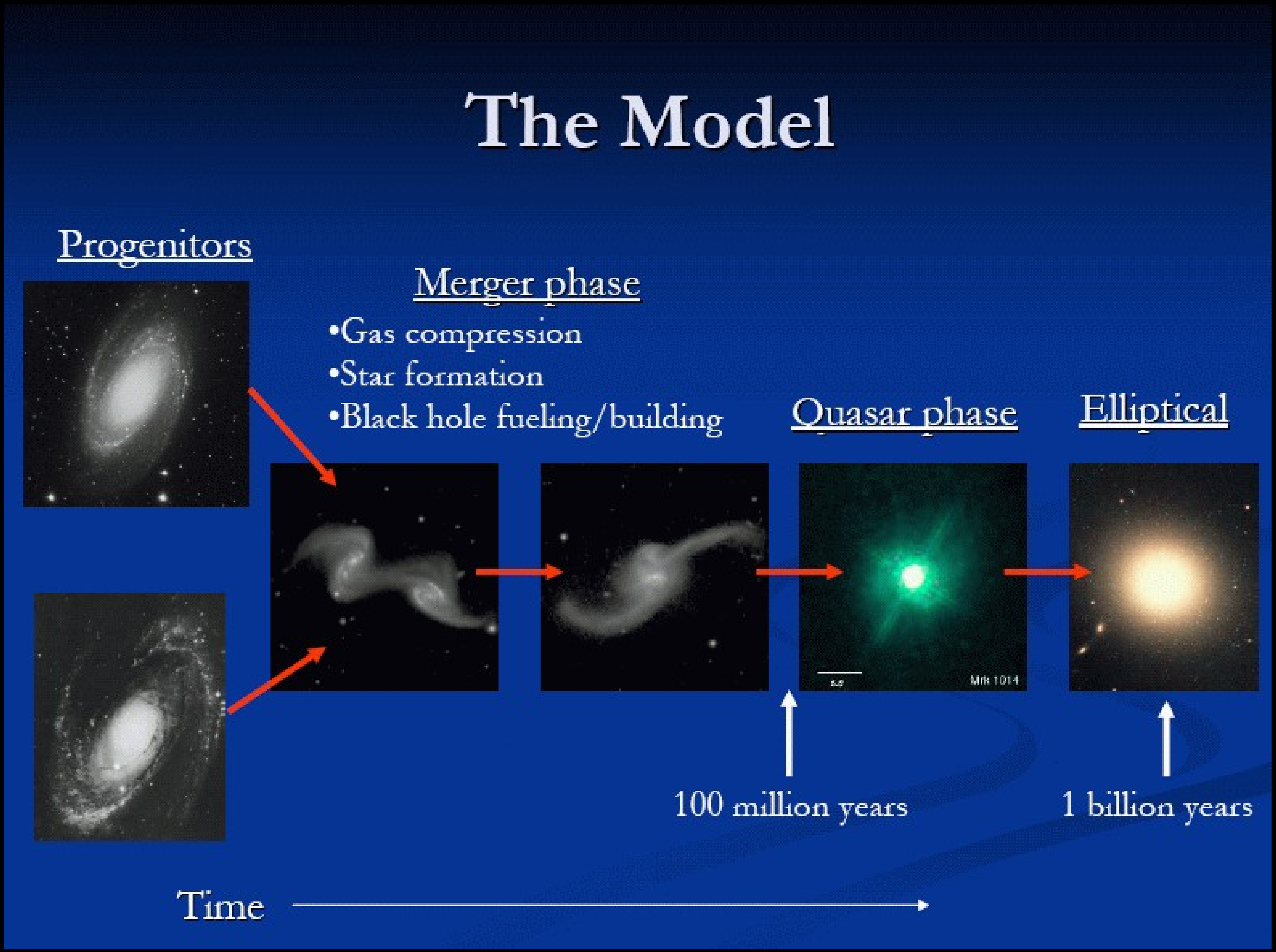
The first encounter begins to disrupt the two galaxies and sends them into orbit around each other.

As the collision continues, much of the gas in the disk of each galaxy collapses toward the center.

Gravitational forces between the two galaxies tear out long streamers of stars called tidal tails.

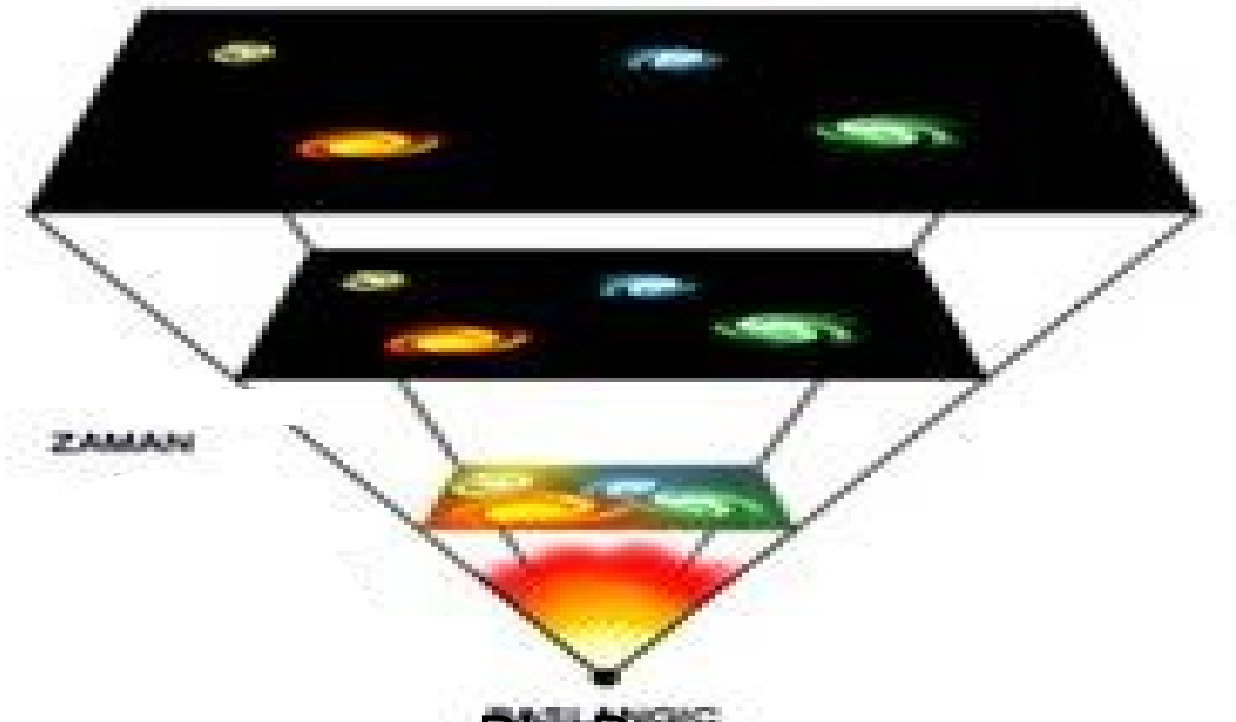
The centers of the two galaxies approach each other and begin to merge.

The single galaxy resulting from the collision and merger is an elliptical galaxy surrounded by debris.



www.ess.sunysb.edu/aevans/talks-pdf/hayden022403.pdf tidal forces induced by interactions cause the gas in the galaxies to lose its angular momentum, and to fall to the centres of the galaxies, where it may ignite a firestorm of star birth. Finally, some of this gas may be accreted onto the central supermassive black hole, and this will trigger activity in the nucleus of the galaxy.

Local Universe



Big-Bang

After the initial phase of galaxy formation,galaxies collided and merged

As the universe expanded, galaxies became more separated and merger rarer.

Dormant Black Holes in Nearby Normal Galaxies

Qu: Given that the density of QSOs was higher in the past, & that QSOs built up black holes with masses on the order of $10^{7\text{-}9}$ M_{sun}, where are these dead QSOs?

An: Perhaps these dormant QSOs are in the nuclear regions of nearby normal galaxies. The implication of this is that almost every massive galaxy has gone through an active galactic phase.

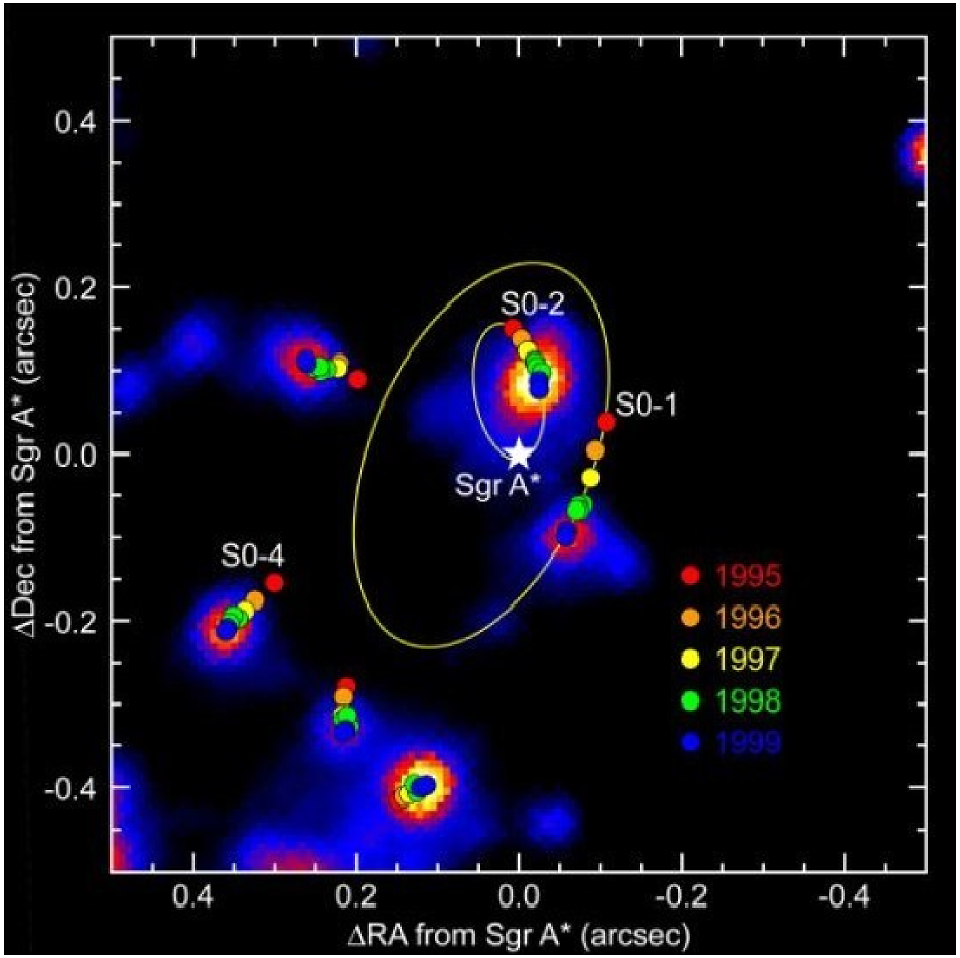
Qu: Why aren't present day, nearly normal galaxies active?

An: Because they're not being fed. "[Quasars] can live forever, but they must fed."

Evidence for Mass of Central Black Holes in Nearby Galaxies

- If dead quasars are in the nuclear regions of nearby normal galaxies, how might we infer their presence?
- By their gravitational effect on stars & gas in the nuclear regions of galaxies

Sgr A*



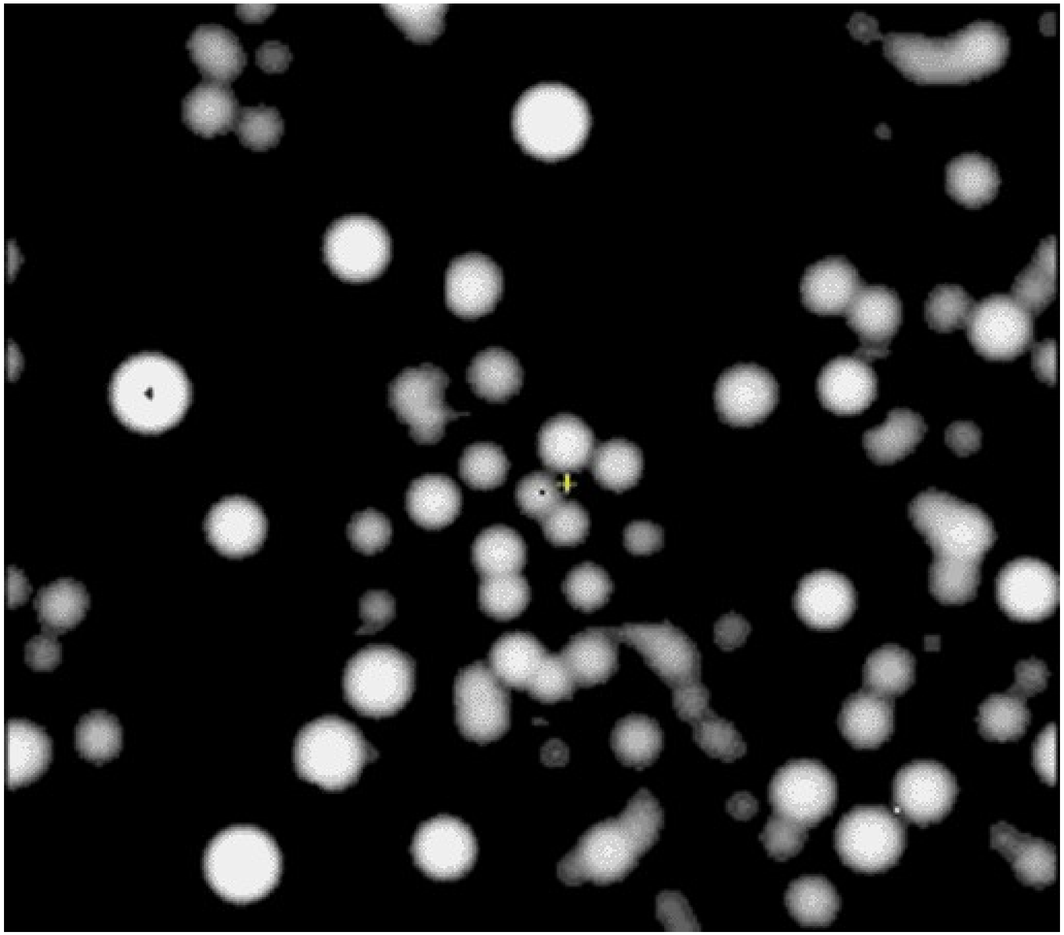
The case of Sgr A* is unique. Thanks to direct measurements of several stellar orbits it is possible to get a very precise value for the mass of the central object.

Also, there are very strict limits on the size of the central object. This is very important taking into account alternatives to a BH.

The star SO-2 has the orbital period 15.2 yrs and the semimajor axis about 0.005 pc.

See astro-ph/0309716 for some details

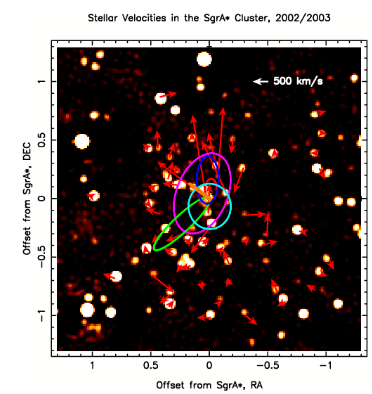
Stellar dynamics around Sgr A*

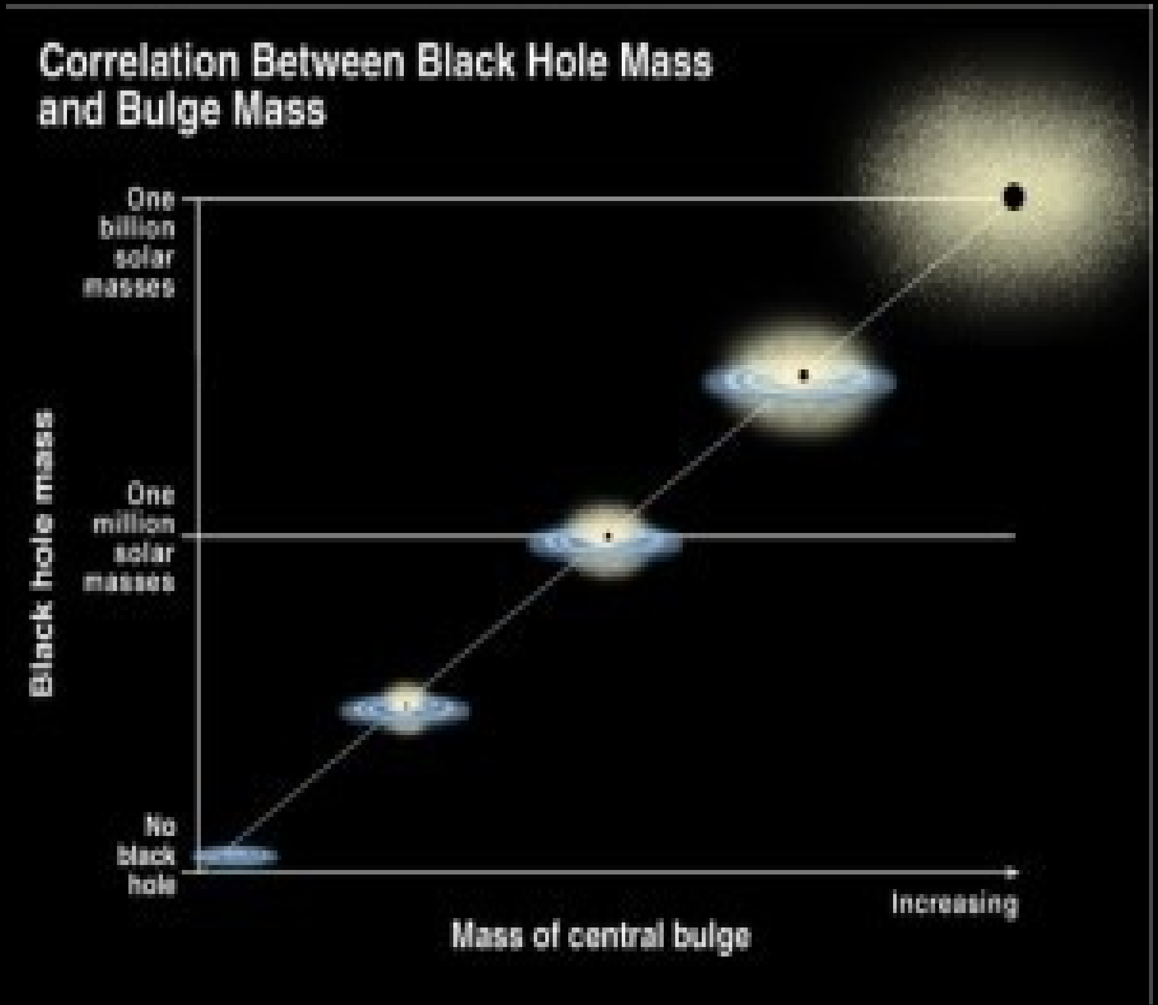


A. Eckart   R. Genzel

With high precision we know stellar dynamics inside the central arcsecond (astro-ph/0306214)

The BH mass estimate is (2-4) $10^6\,M_0$

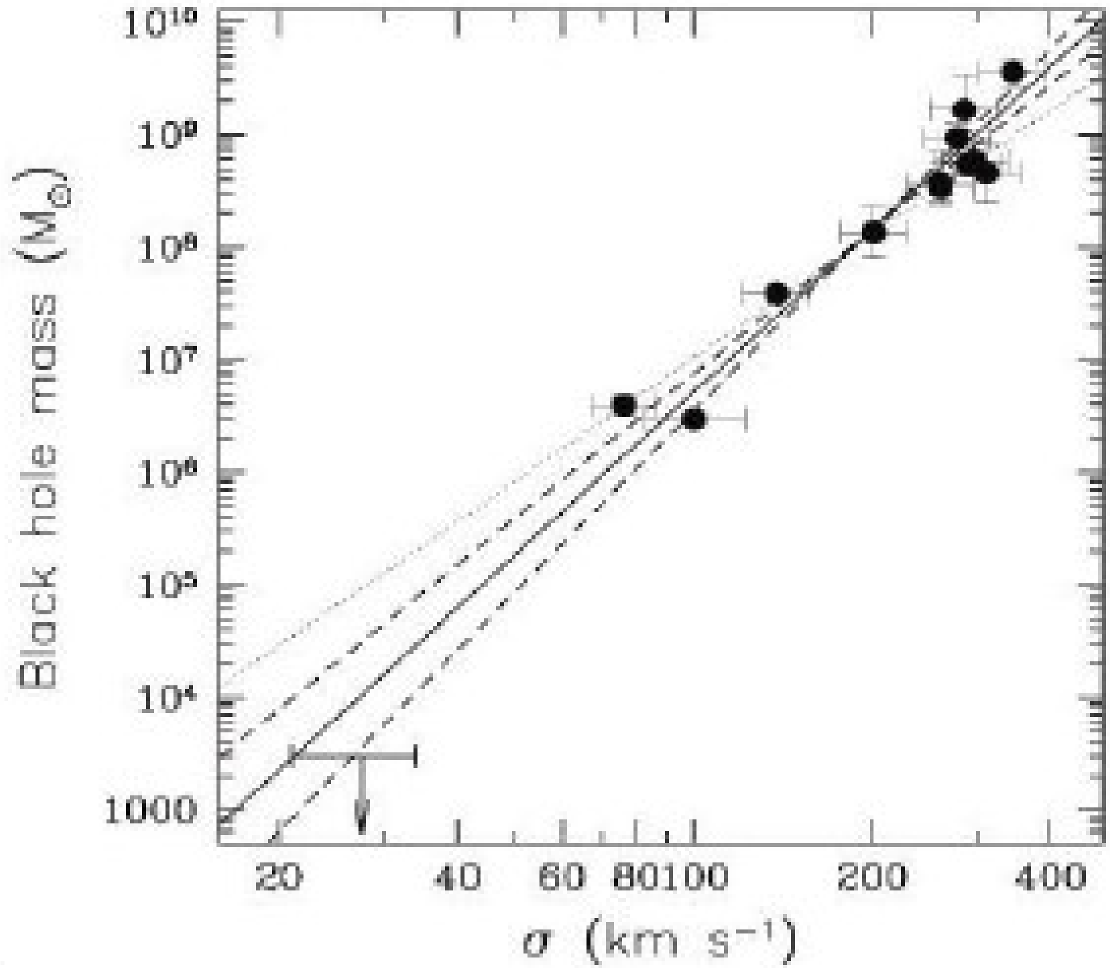




Kauffmann et al.2004

www.mpa-garching.mpg.de/.../hl2004-7-en.html

Nearby Galaxy with no Black Hole: M 33



Disk Galaxy – Negligible Bulge

Figure 4. The thick solid line represents the $M_\bullet - \sigma$ relation as derived by Ferrarese & Merritt (14), with 1$-\sigma$ confidence limits on the slope shown by the dashed lines. The upper limit for the black hole mass in M33 (shown by the arrow) is consistent with this relation but inconsistent with the shallower relation advocated by Gebhardt et al. (15) and shown by the thin dotted line.

(e.g., Merritt, Ferrarese, & Joseph 2001, Science, 293, 1116)