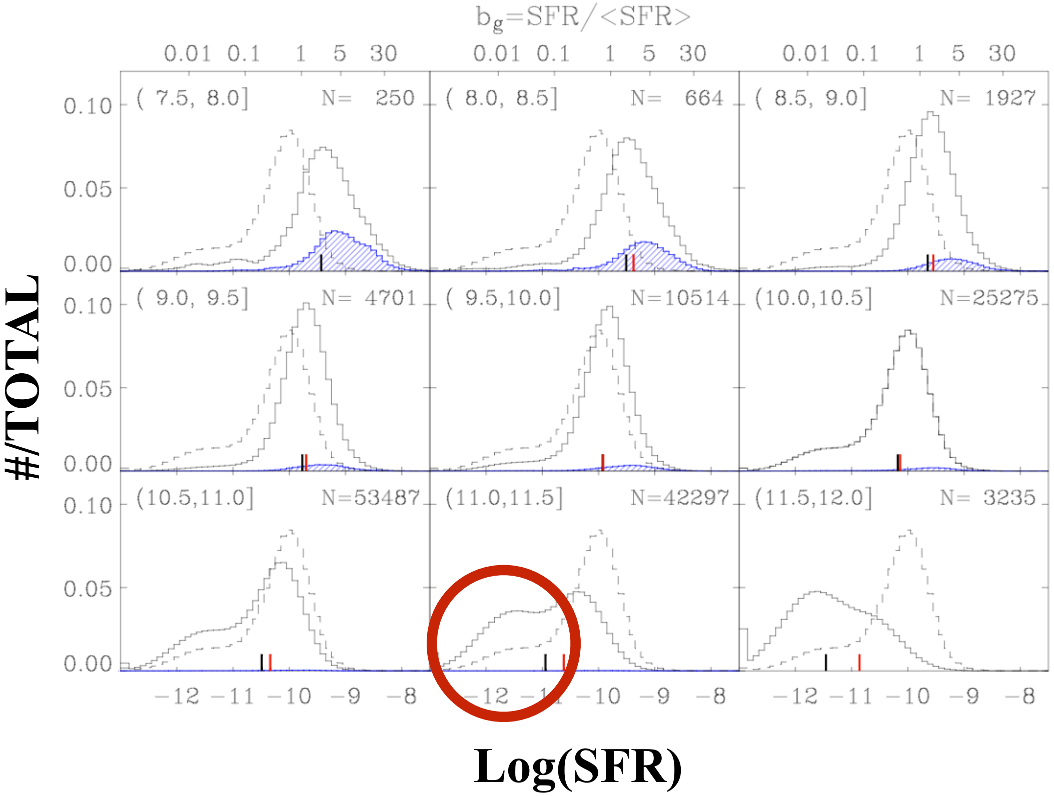
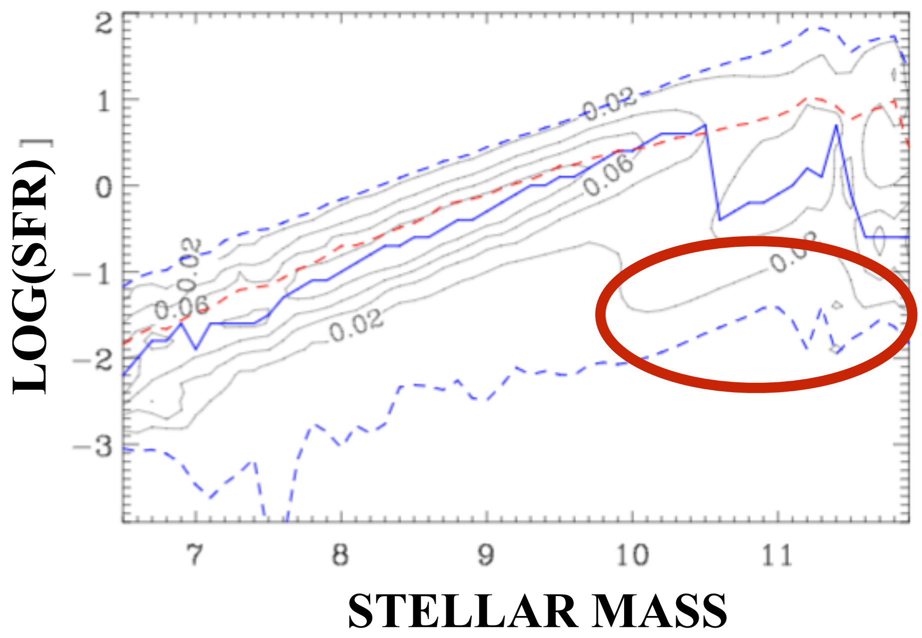
QUENCHING OF GALAXY STAR FORMATION

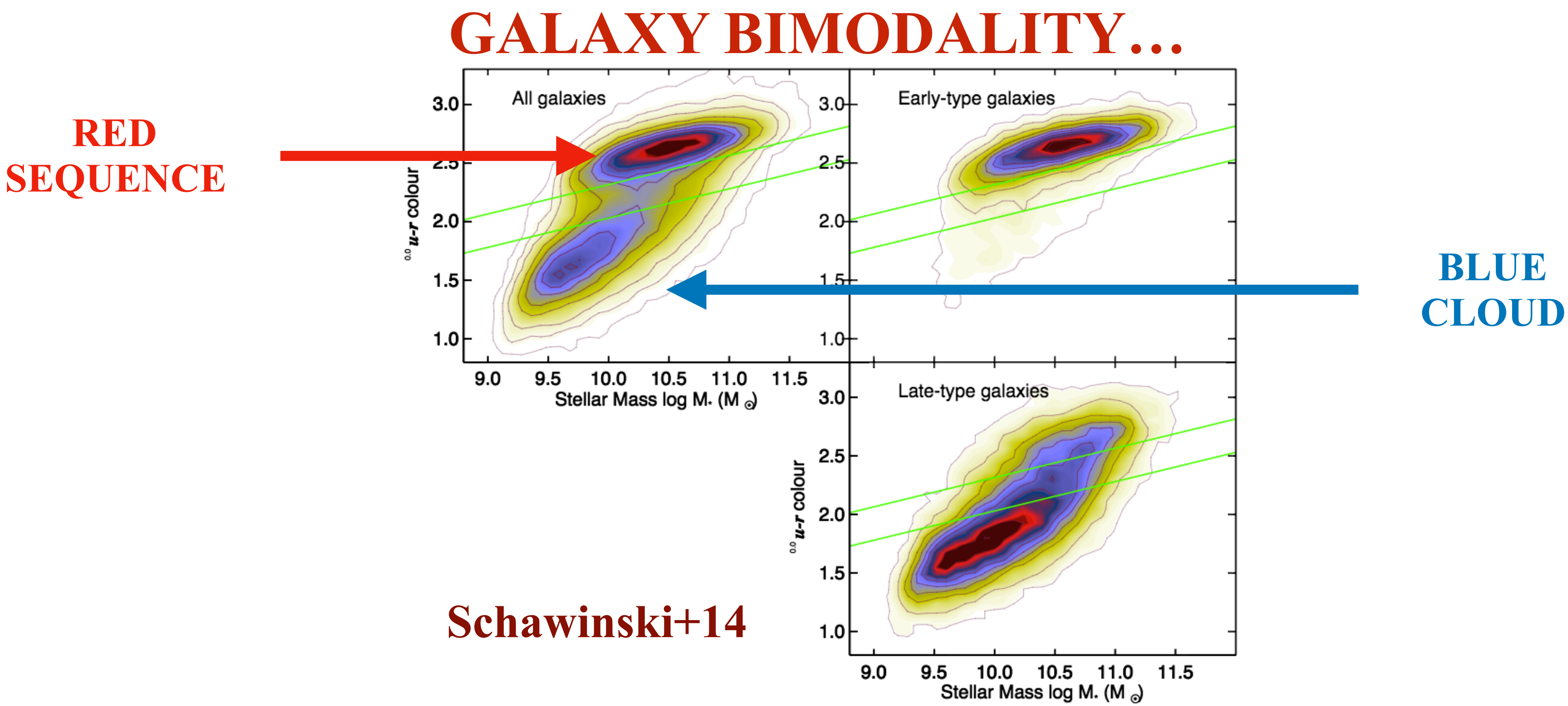
GALAXY BIMODALITY IN STAR FORMATION





Brinchmann+04

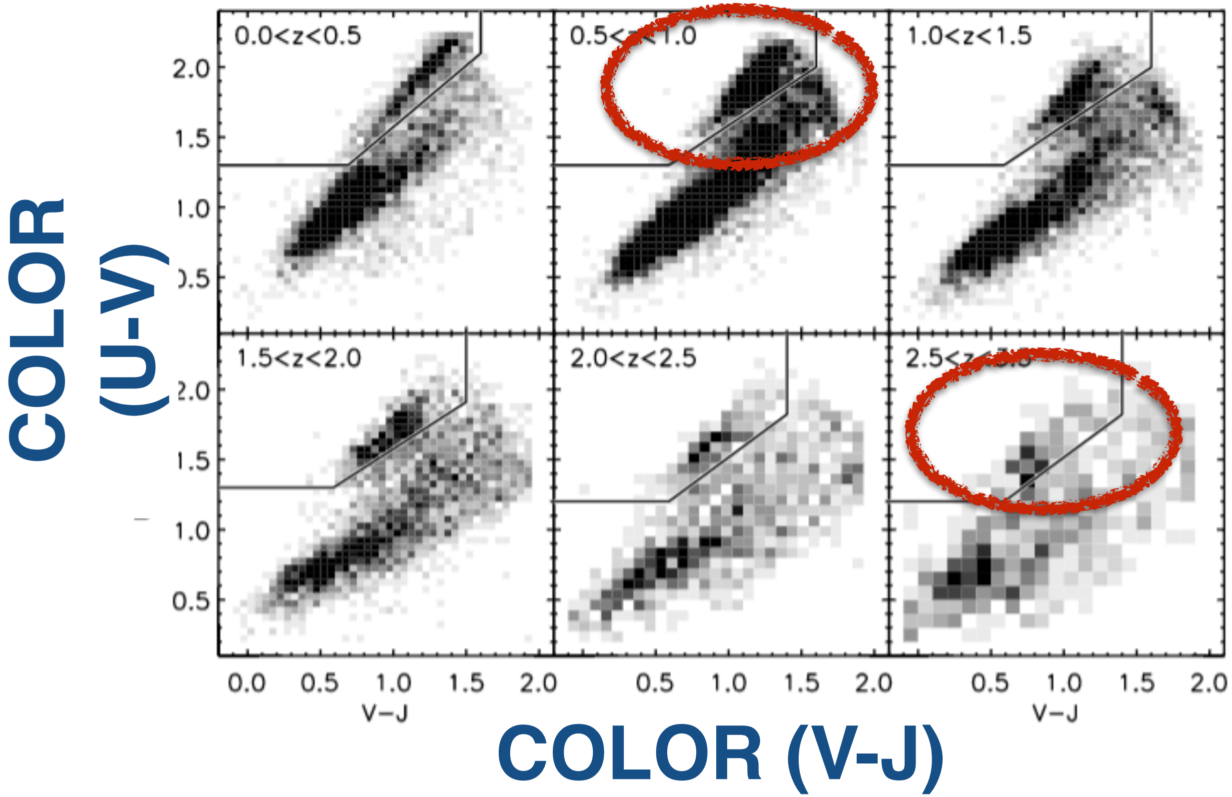
GALAXY BIMODALITY IN STAR FORMATION



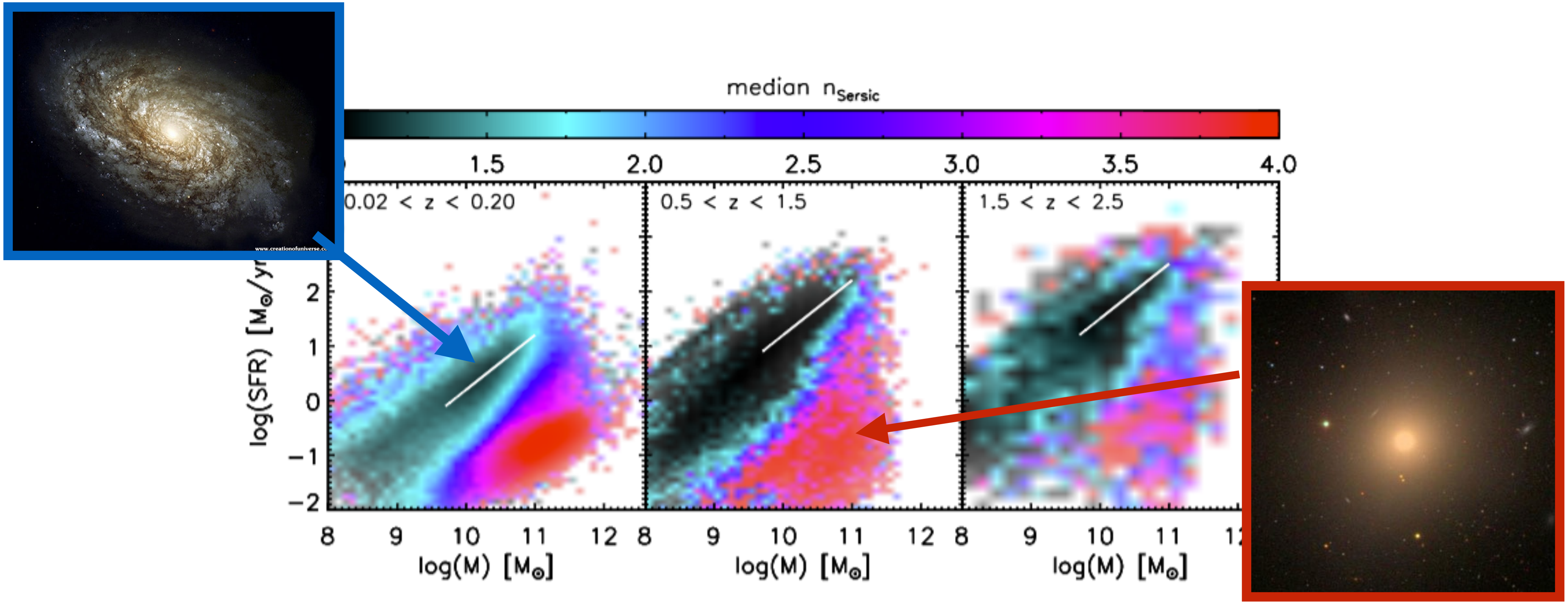
ALSO SEEN IN COLOR

GALAXY BIMODALITY FROM z~3 (AT LEAST)!

Whitaker+11

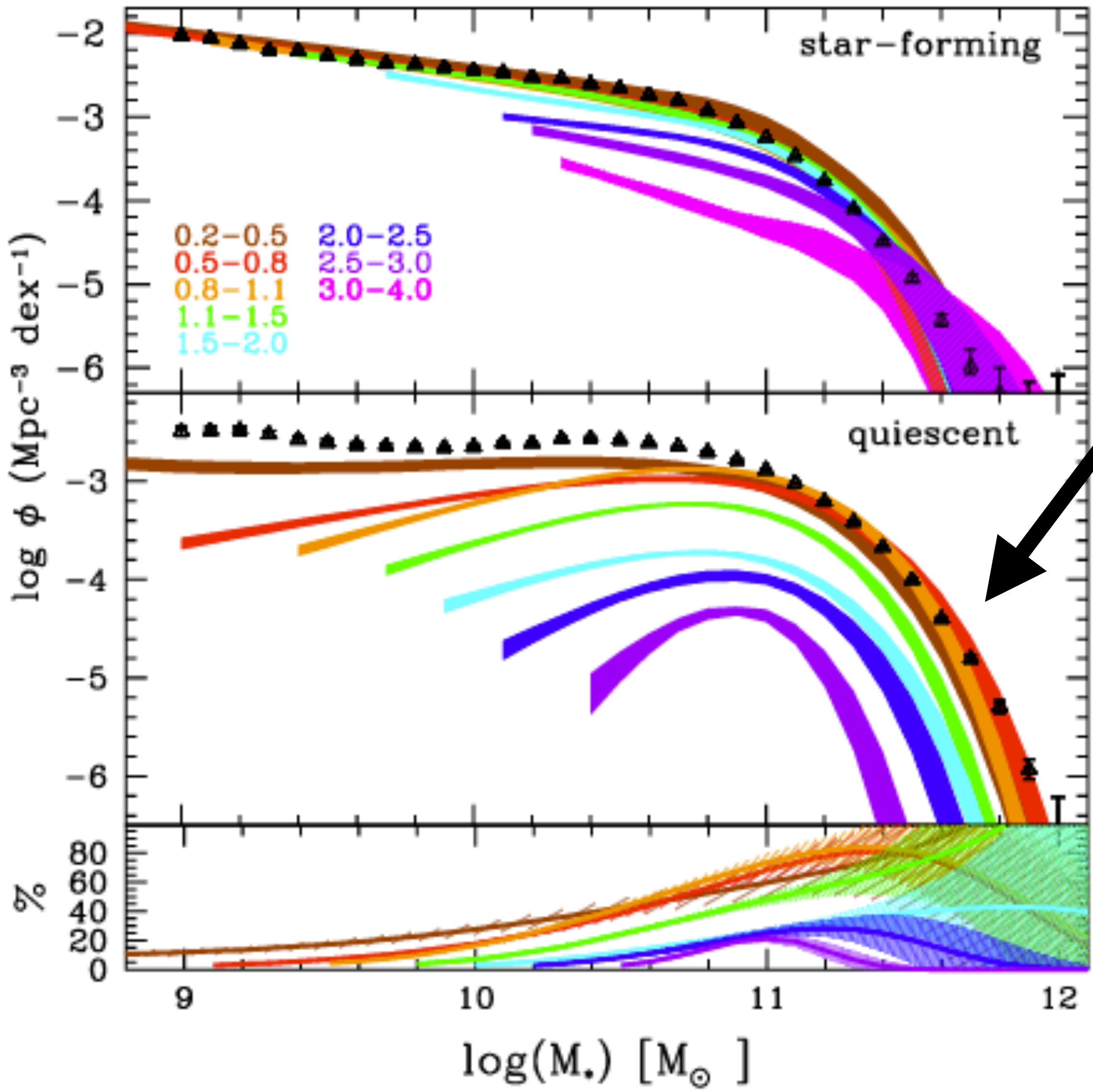


SF AND MORPHOLOGY BIMODALITY TRACK EACH OTHER



Wuyts+11

Quenched/SF galaxies have different morphologies

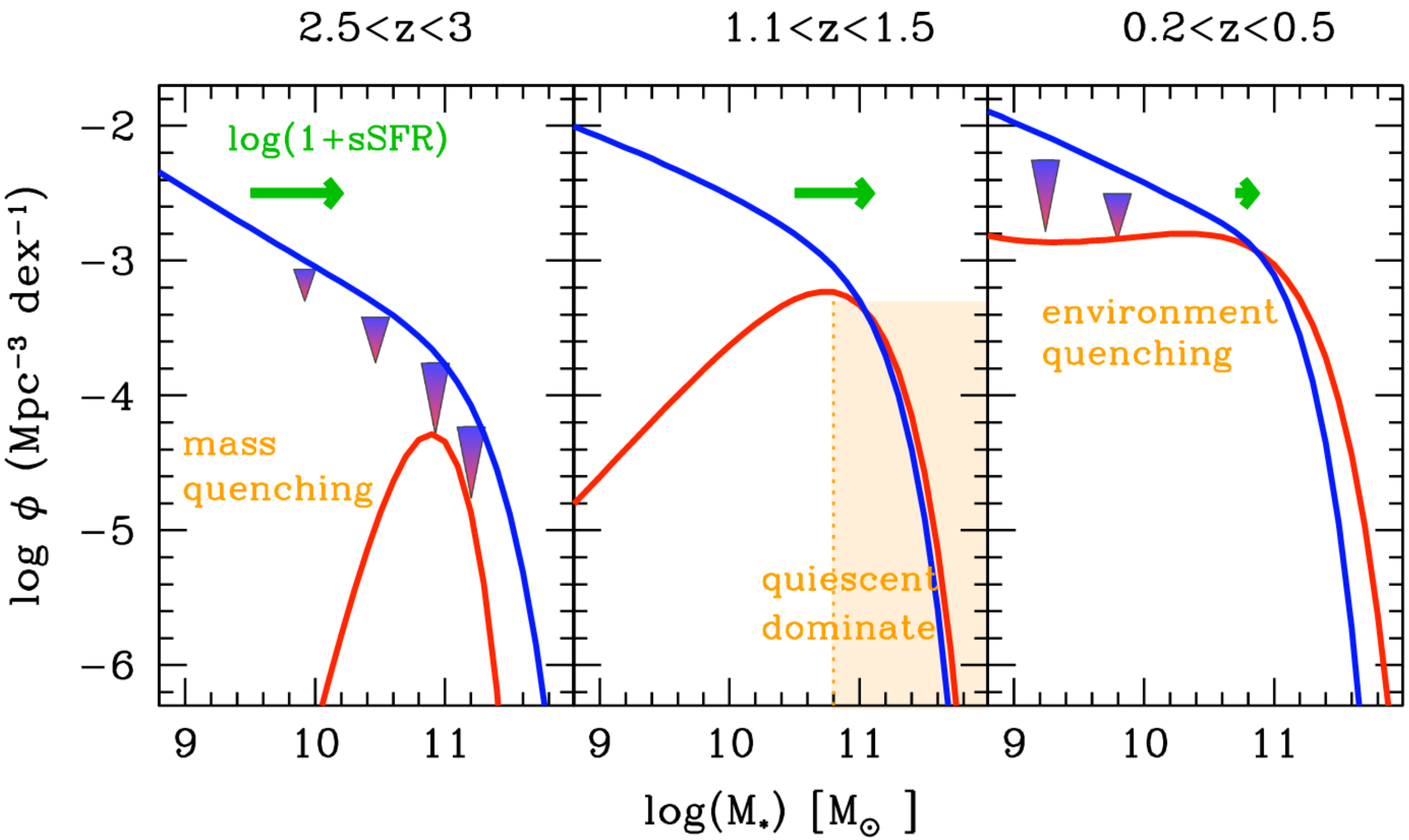


INCREASING ABUNDANCE OF THE QUENCHED FRACTION

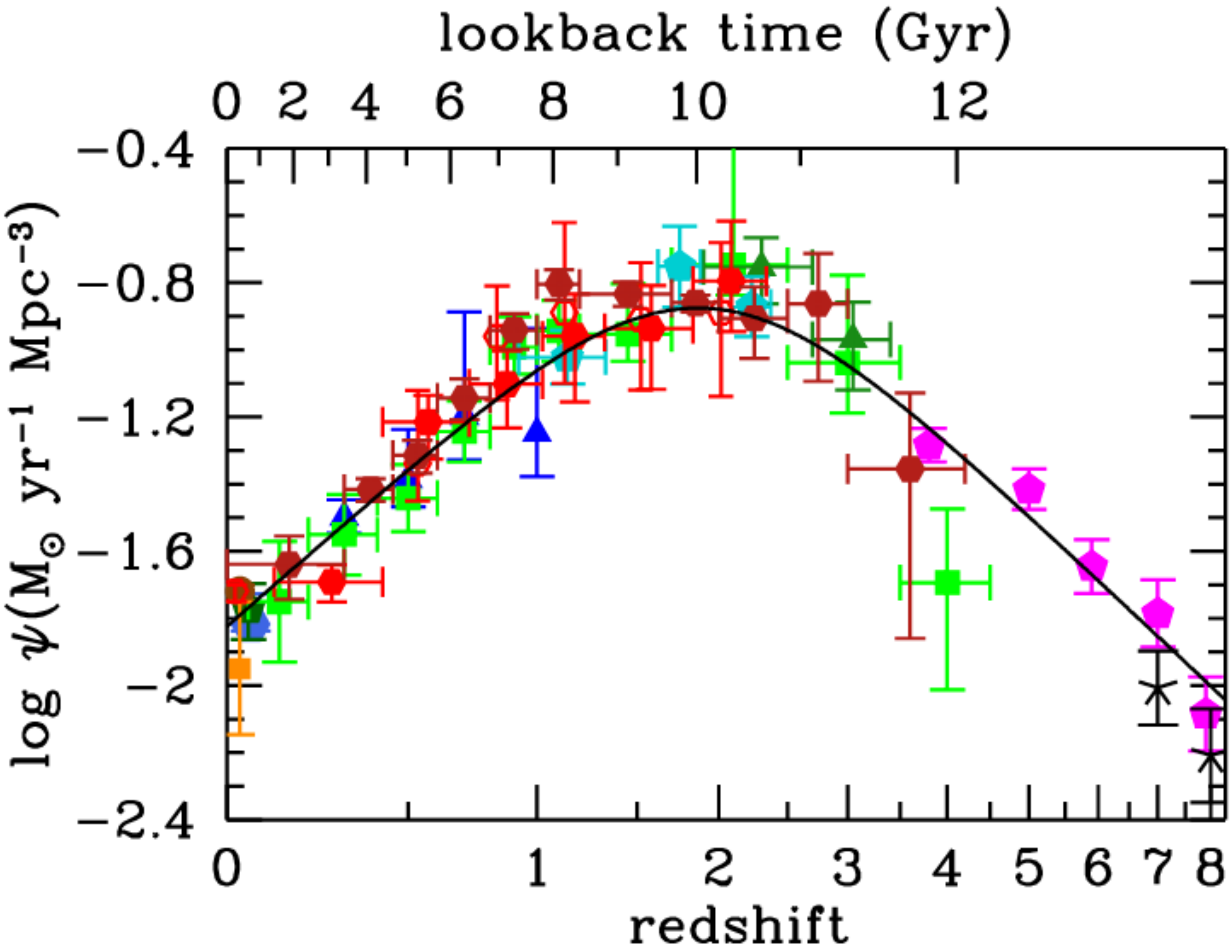
Ilbert+13

A CARTOONISH / EMPIRICAL VIEW

Ilbert+13

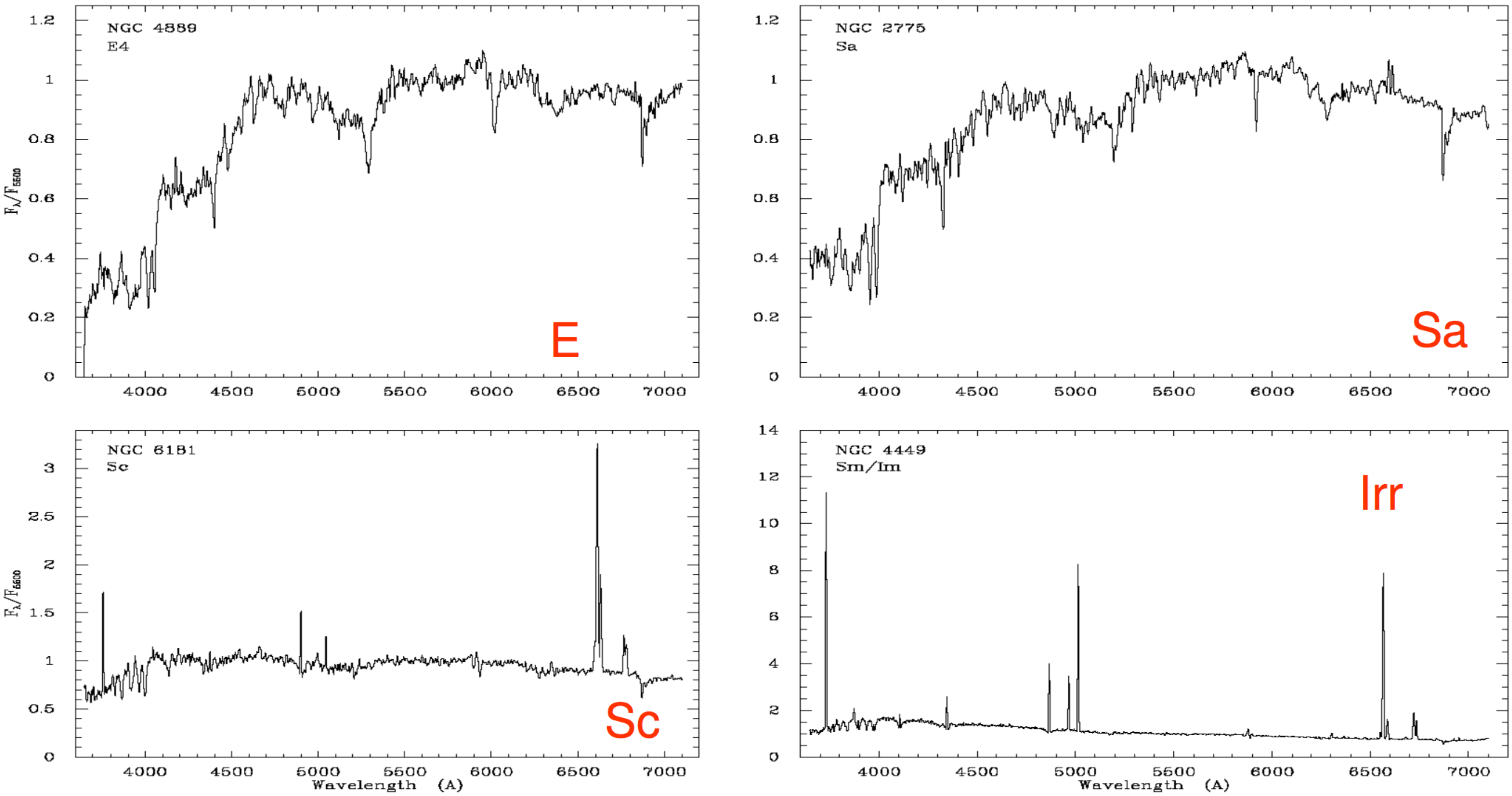


<u>Quenching:</u> a key event in a galaxy's life and a fundamental property of our universe?



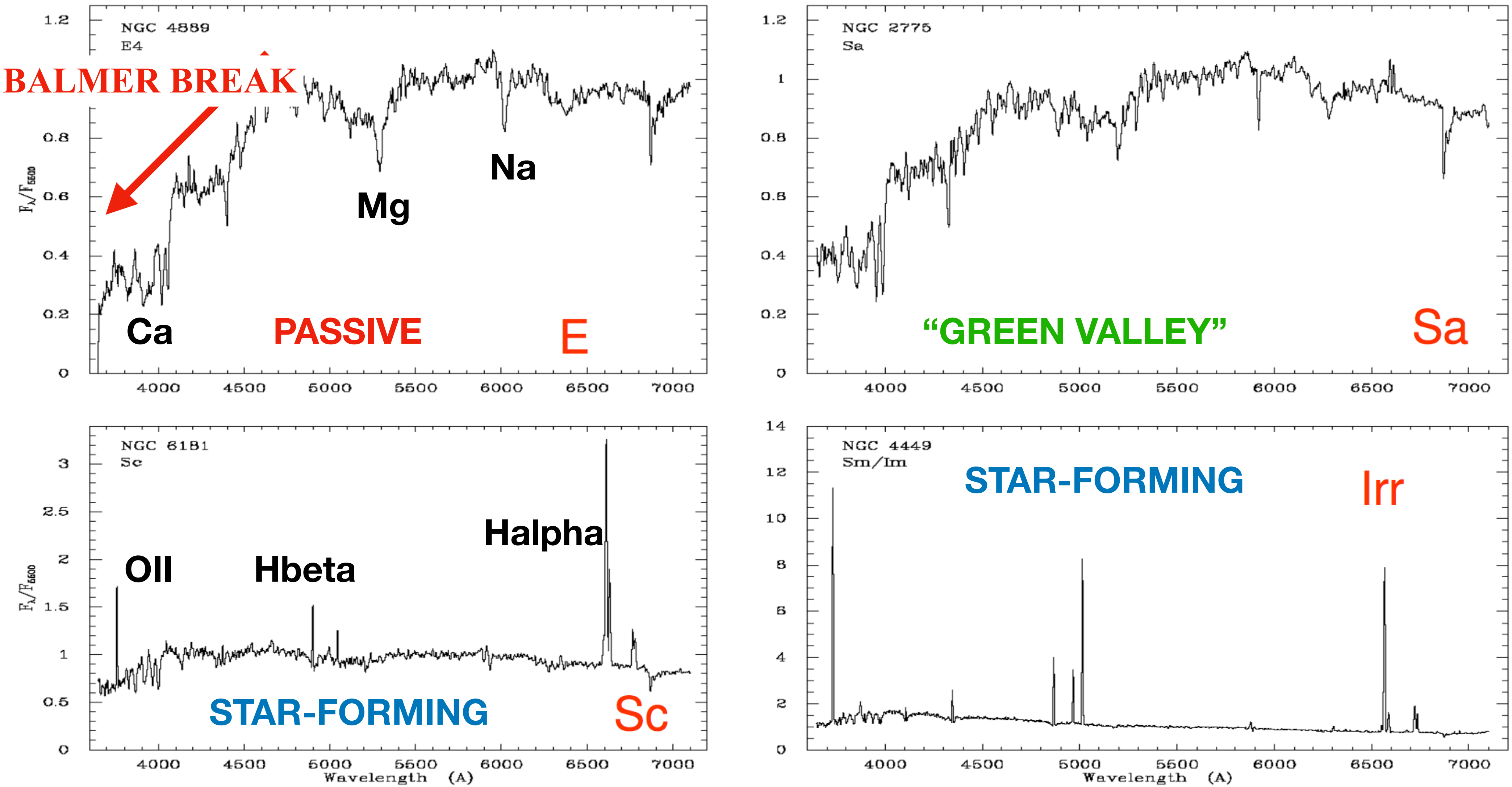
Madau&Dickinson+14

PASSIVE AND STAR-FORMING GALAXIES….



KENNICUT92

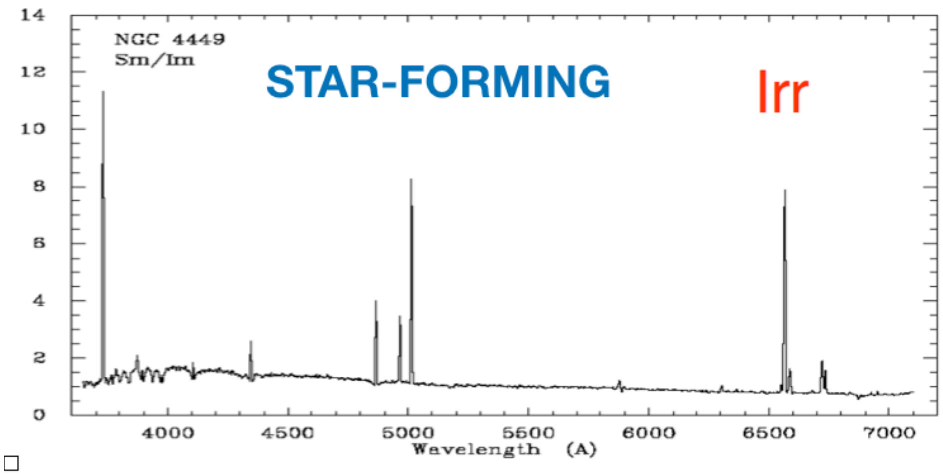
STELLAR ABSORPTION LINES



NEBULAR EMISSION LINES

KENNICUT92

ESTIMATING STELLAR MASSES AND SFRs



OBSERVATION
(COMBINED LIGHT OF STARS + NB EMISSION)

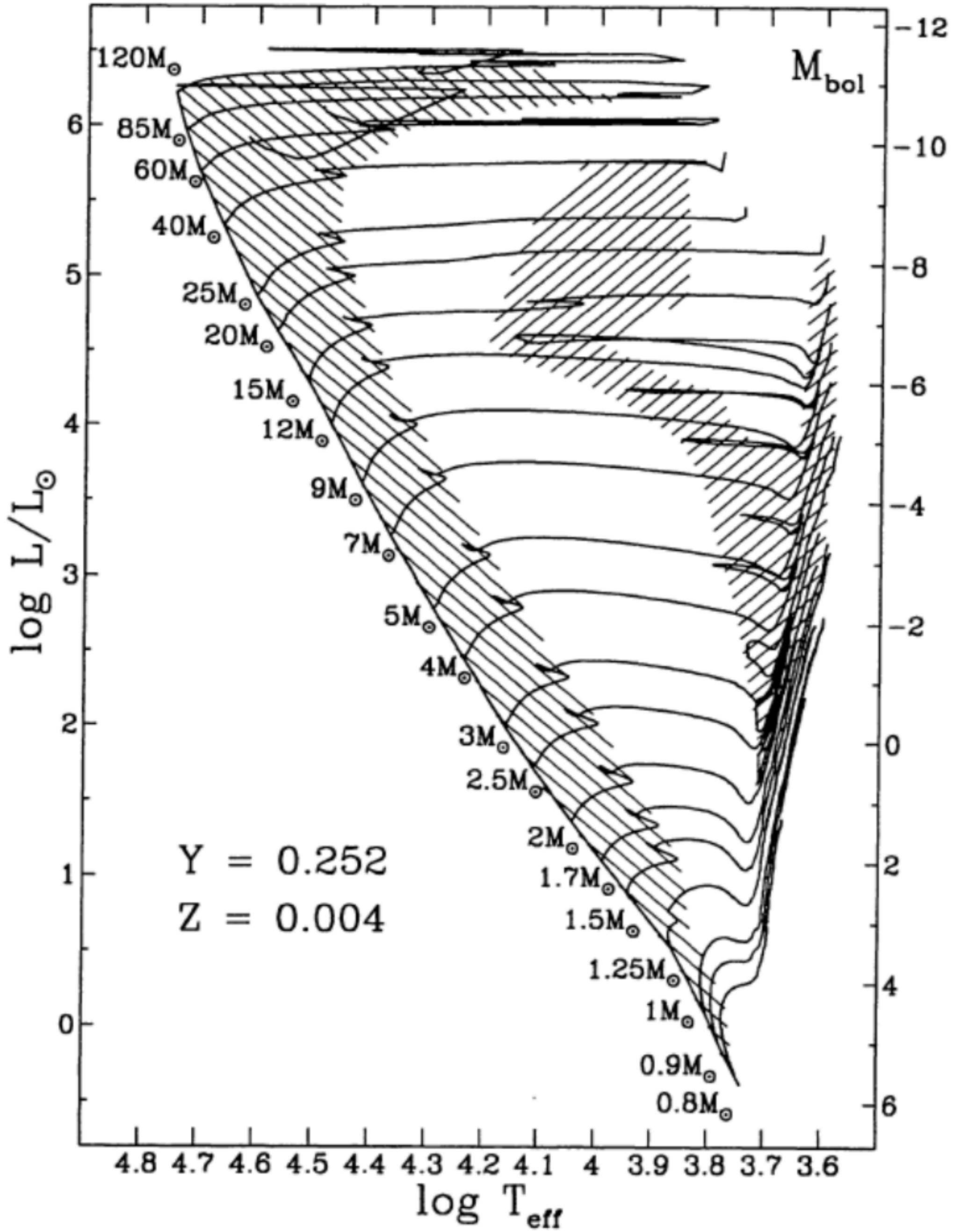
SFR
MASS
Metallicities
etc..

ESTIMATING STELLAR MASSES AND SFRs

EVOLUTIONARY SYNTHESIS MODELS

INGREDIENTS:

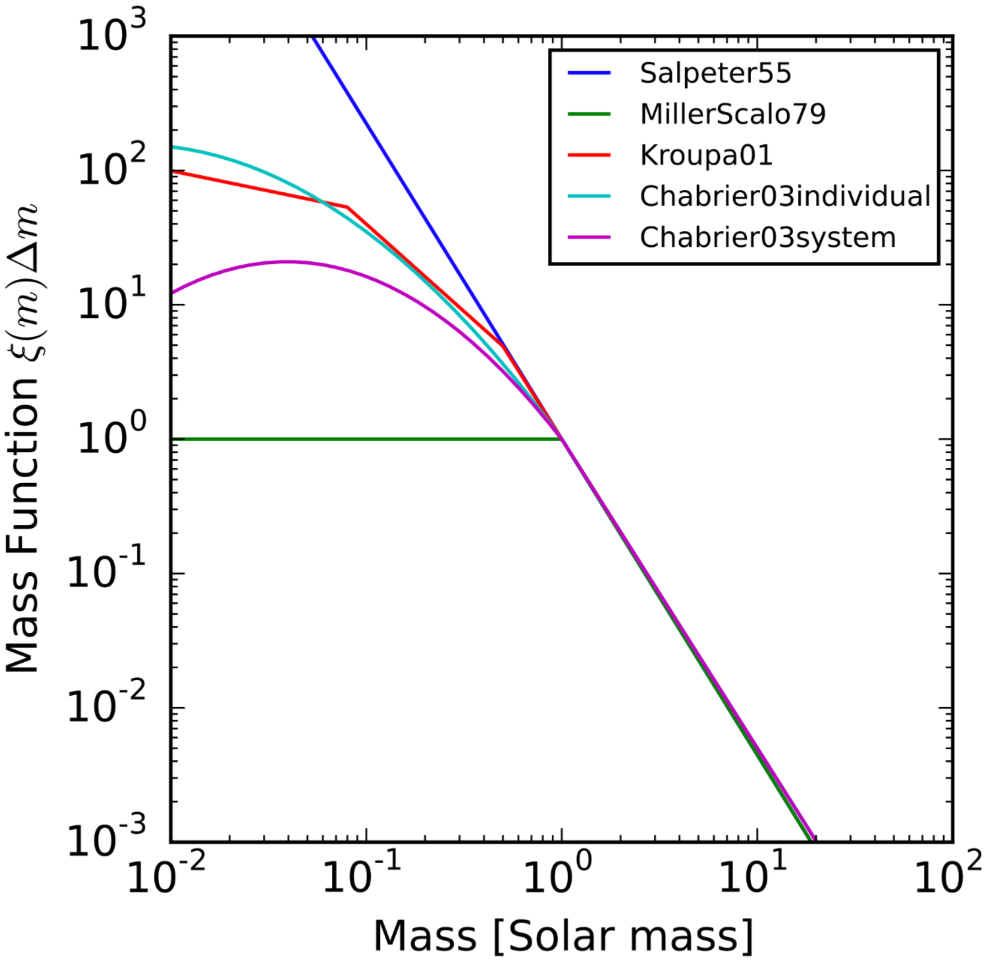
- **STELLAR EVOLUTION TRACKS**
- **INITIAL MASS FUNCTION (IMF)**
- **STAR FORMATION HISTORY**



- STELLAR EVOLUTION TRACKS

INITIAL MASS FUNCTION

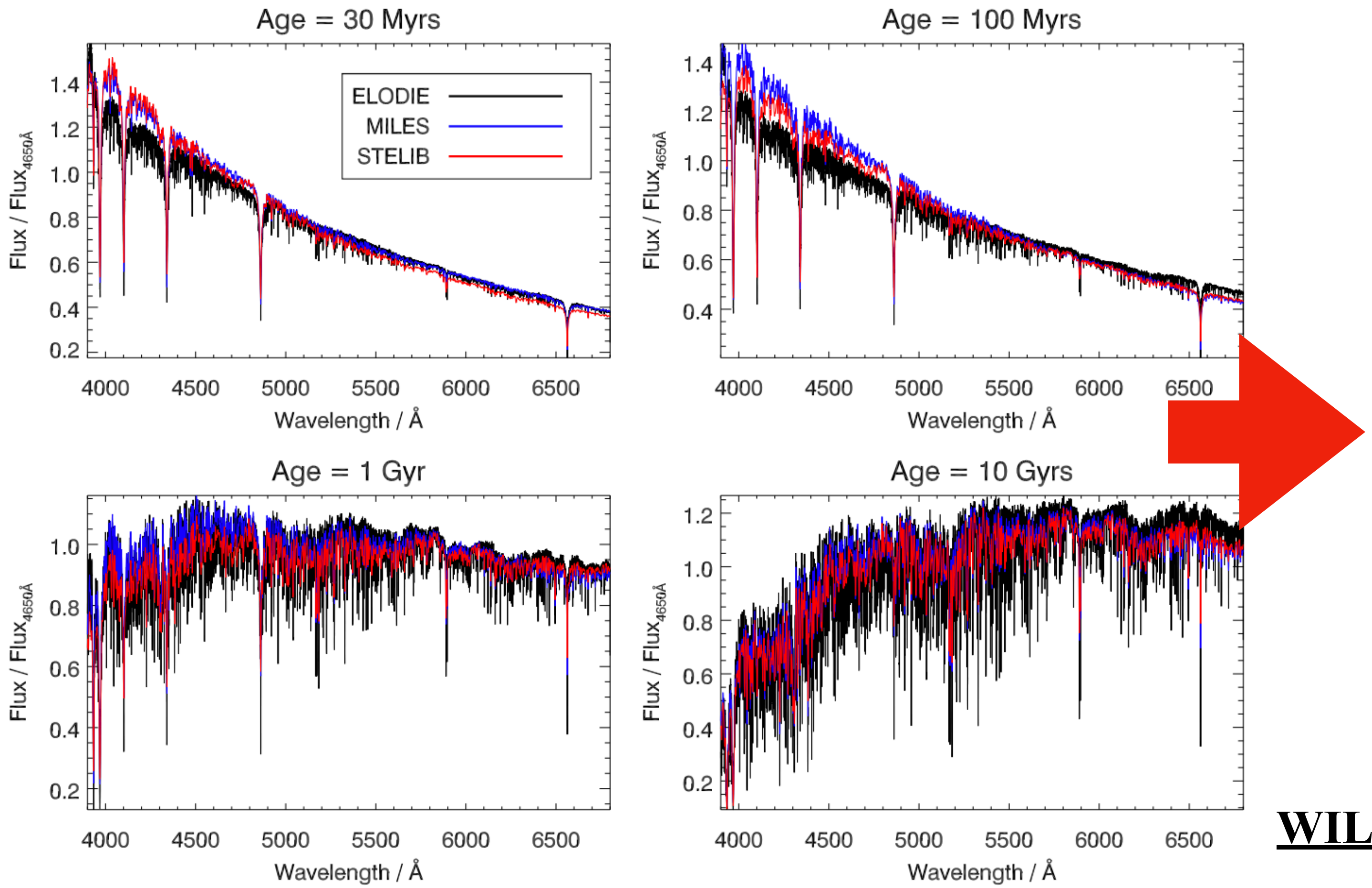
IMF == NUMBER OF STARS OF A GIVEN MASS CREATED PER UNIT VOLUME



USED TO CONVERT TO STELLAR MASS

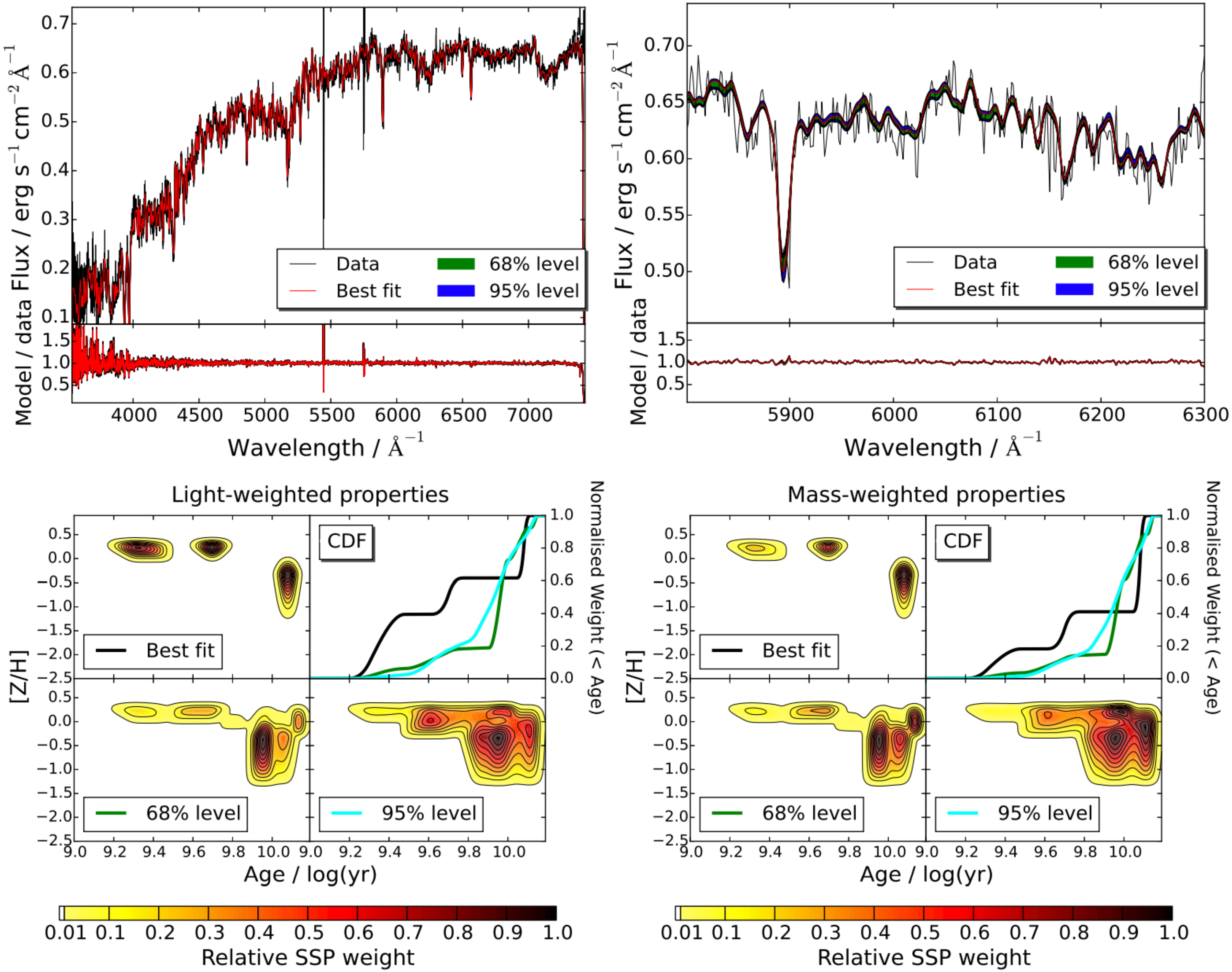
SYNTHESIS MODELS

USING AN IMF + STELLAR EVOLUTION TRACKS ONE CAN GENERATE SYNTHETIC SPECTRA



THIS IS A SINGLE STELLAR POPULATION

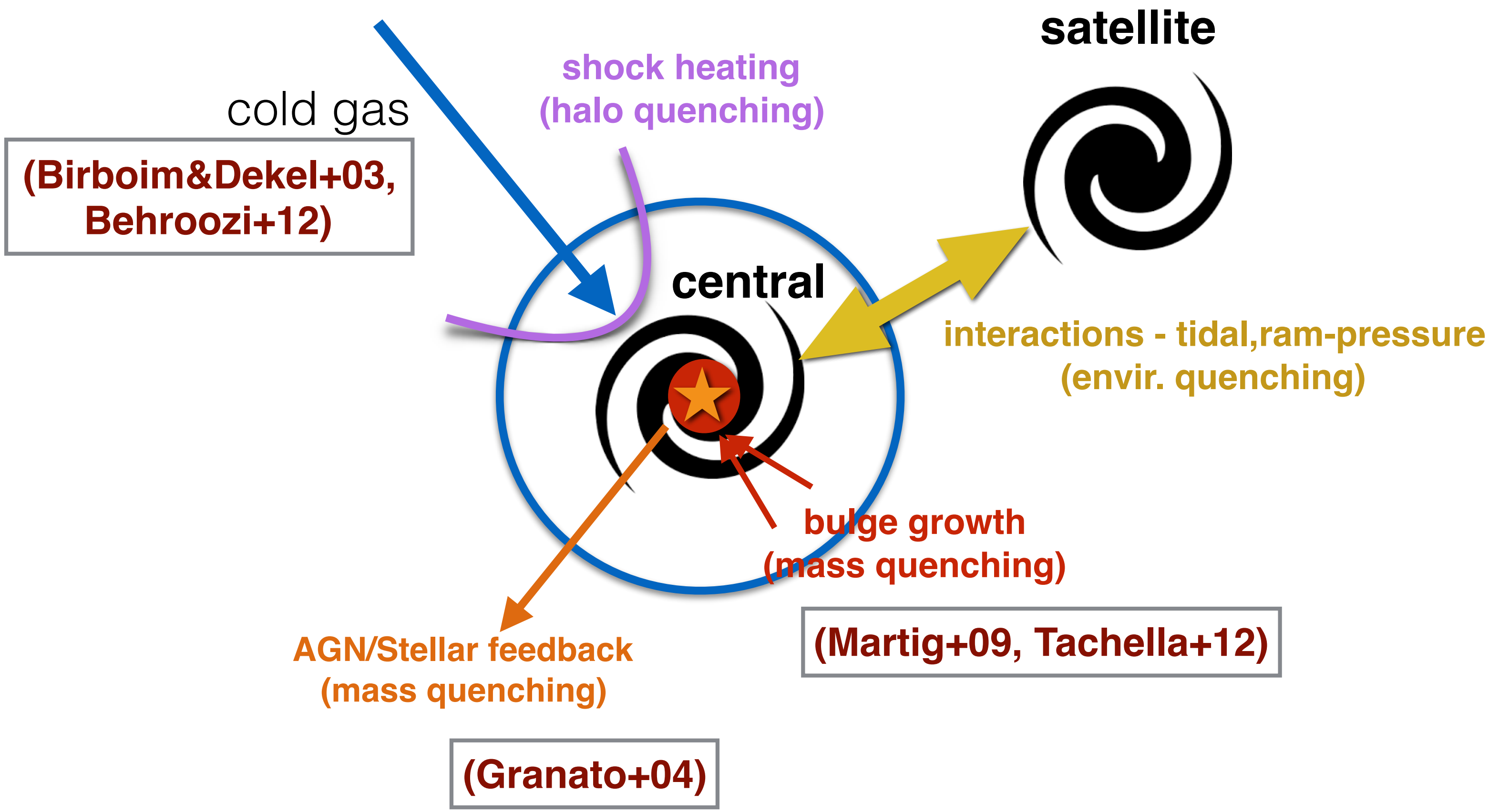
WILKINSON+17



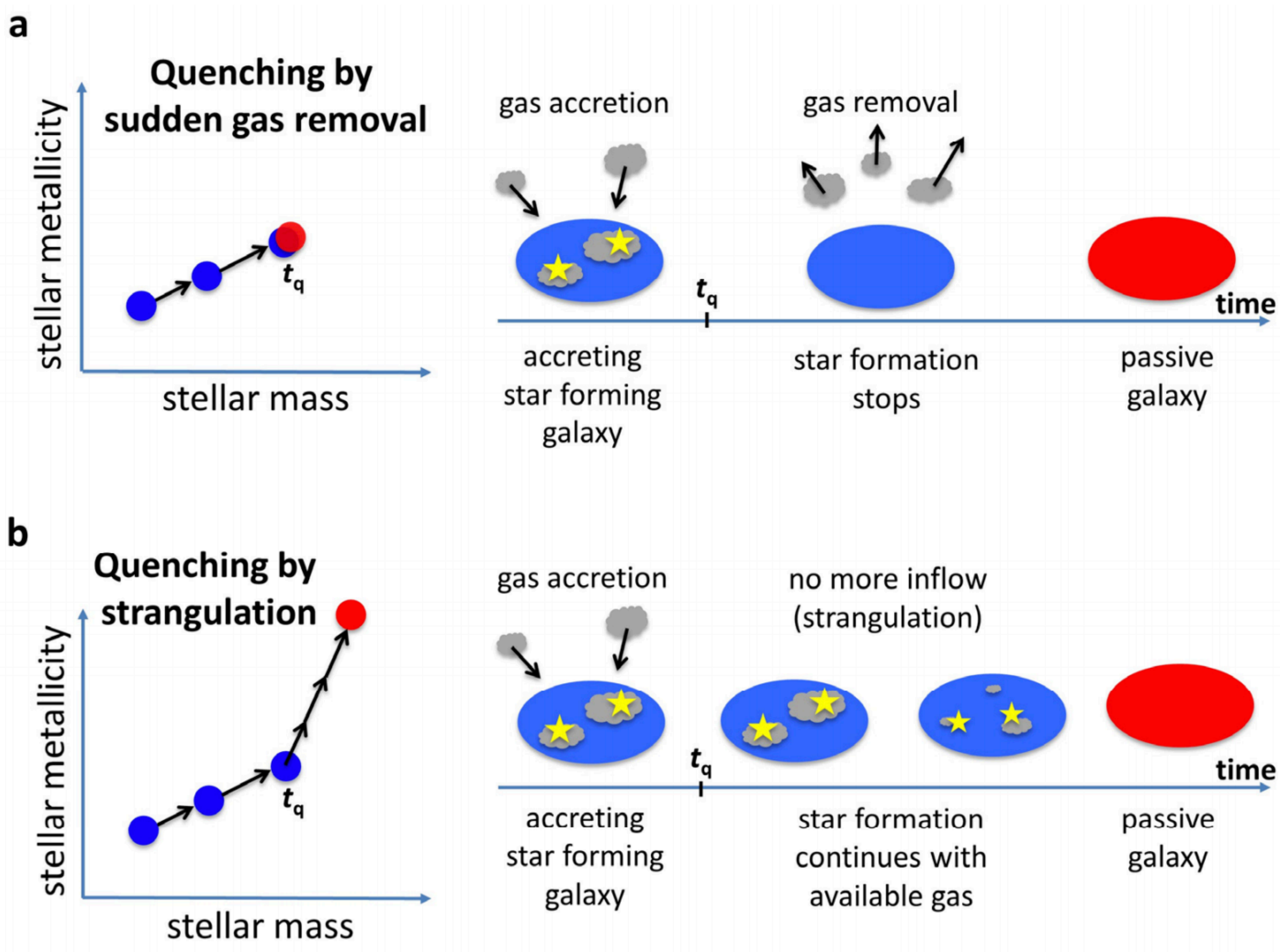
WILKINSON+17

How to stop forming stars?
(quench)

Expel, heat or prevent gas to cool…

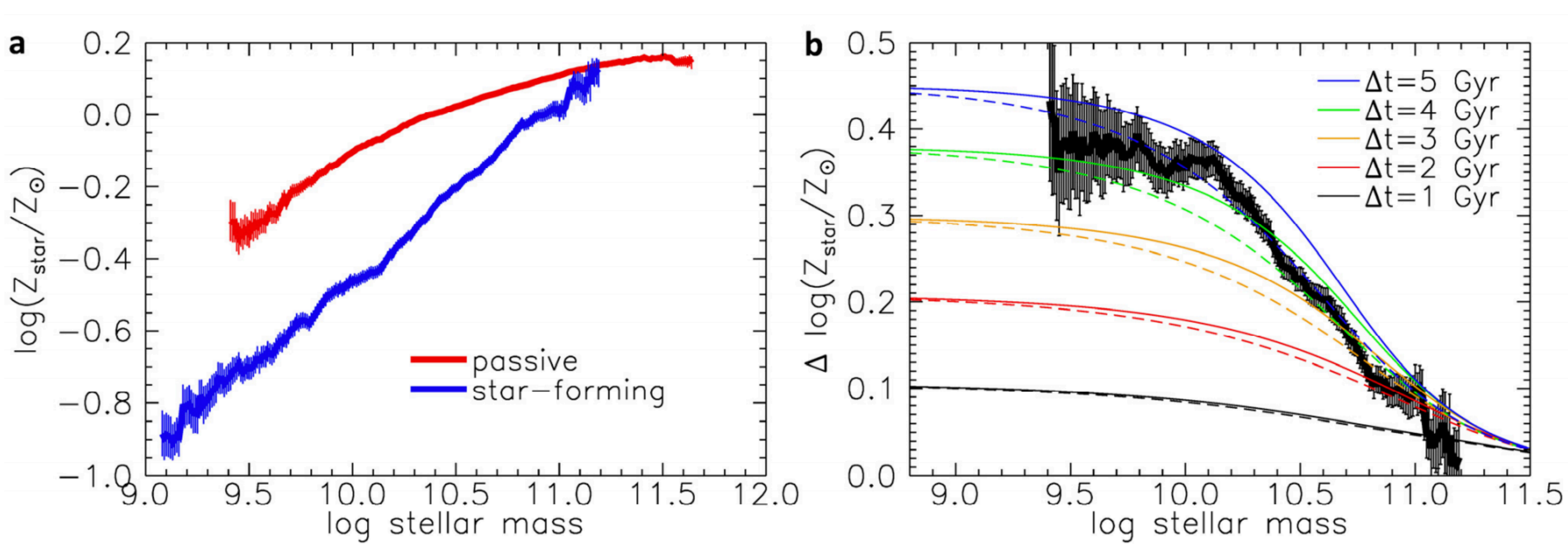


See also Lilly+13

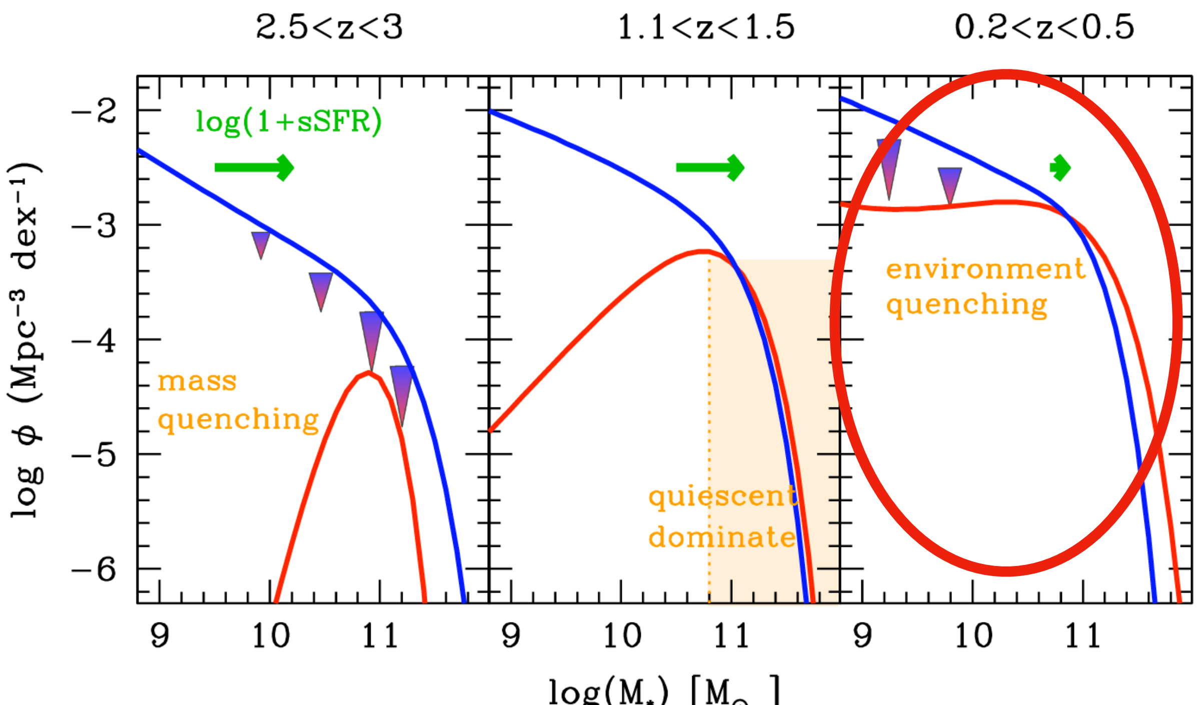

a
Quenching by sudden gas removal
stellar metallicity
stellar mass
t_q
gas accretion
gas removal
time
accreting star forming galaxy
star formation stops
passive galaxy
b
Quenching by strangulation
stellar metallicity
stellar mass
t_q
gas accretion
no more inflow (strangulation)
time
accreting star forming galaxy
star formation continues with available gas
passive galaxy

Peng+15

STRANGULATION MIGHT BE IMPORTANT FOR SATELLITE GALAXIES



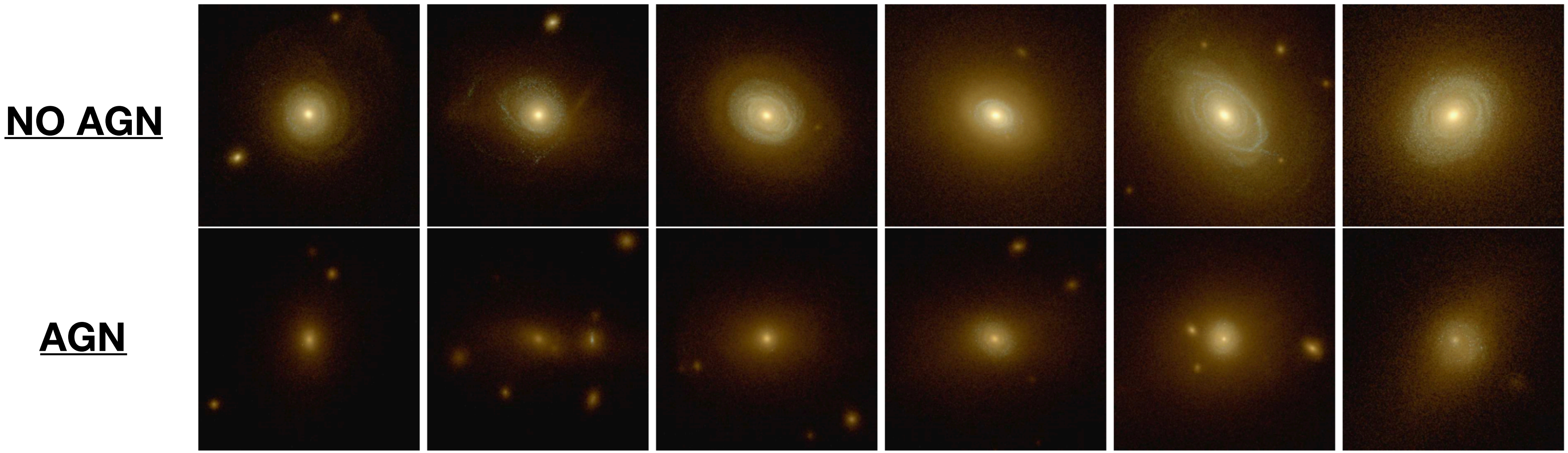
Peng+15



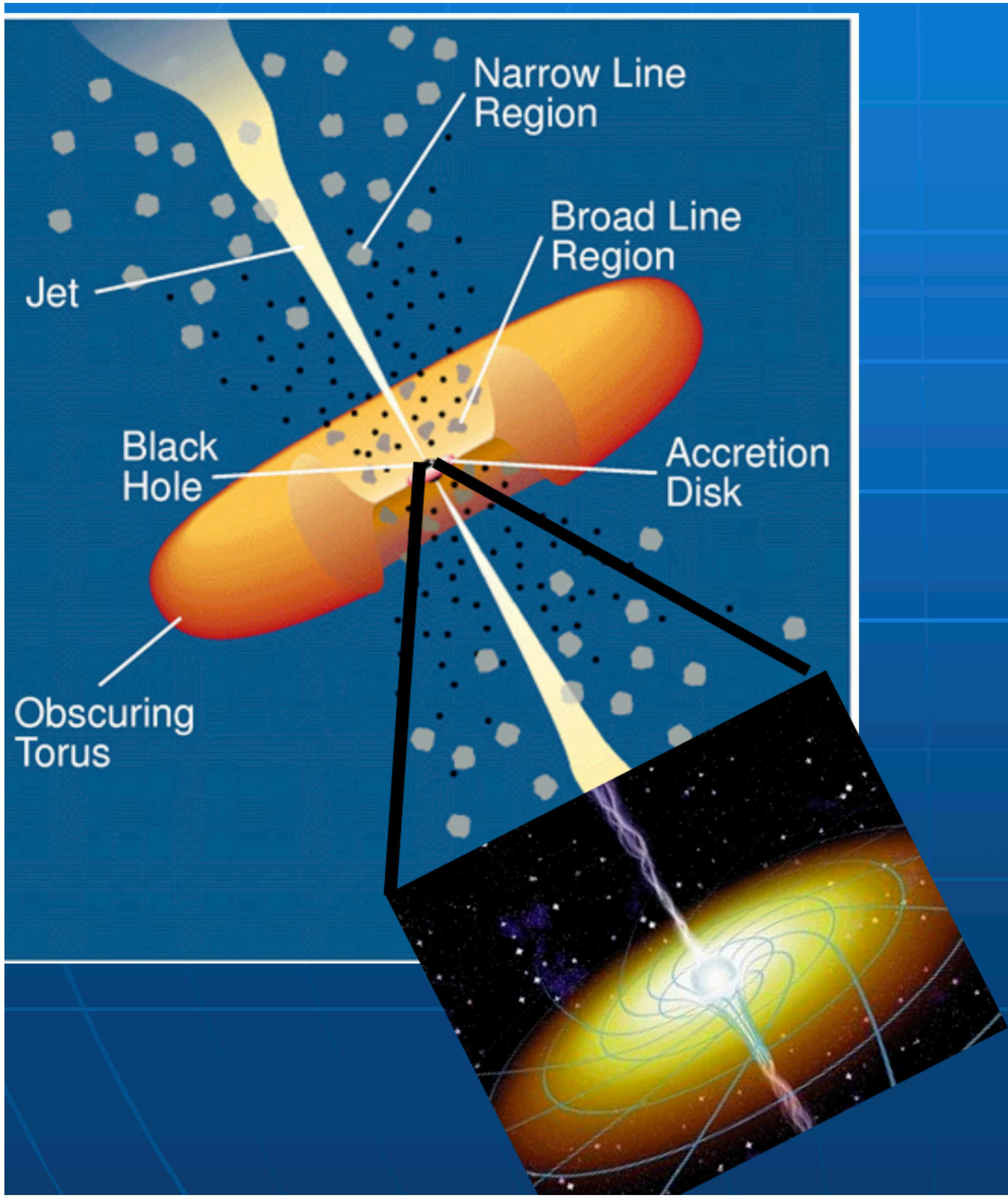
Ilbert+1

QUENCHING IN CENTRAL GALAXIES…

BLACK HOLES HAVE CLEARLY SOMETHING TO DO….



DUBOIS+13



- **What are black holes?**
  - **GR analog to point masses**
  - **Two numbers to characterize them**
    - **Mass M_{BH}**
    - **Spin (or not)**
  - **"Size of the black hole" Schwarzschild Radius**

$$R_S = \frac{2GM_{BH}}{c^2}$$

$\frac{M}{M_\odot}$	R_S
10^6	$10^{-7}pc$
10^8	$10^{-5}pc$
10^9	$30^{-4}pc$

- As material moves to the black hole, its potential energy is converted into kinetic energy.

- If that kinetic energy is converted into thermal energy (dissipation) then it will be radiated away

$$\boxed{L_{Acc} \simeq \frac{1}{16}\dot{m}c^2} \quad 1g \rightarrow 10^6\ kWh$$

efficiency of hydrogen burning is:

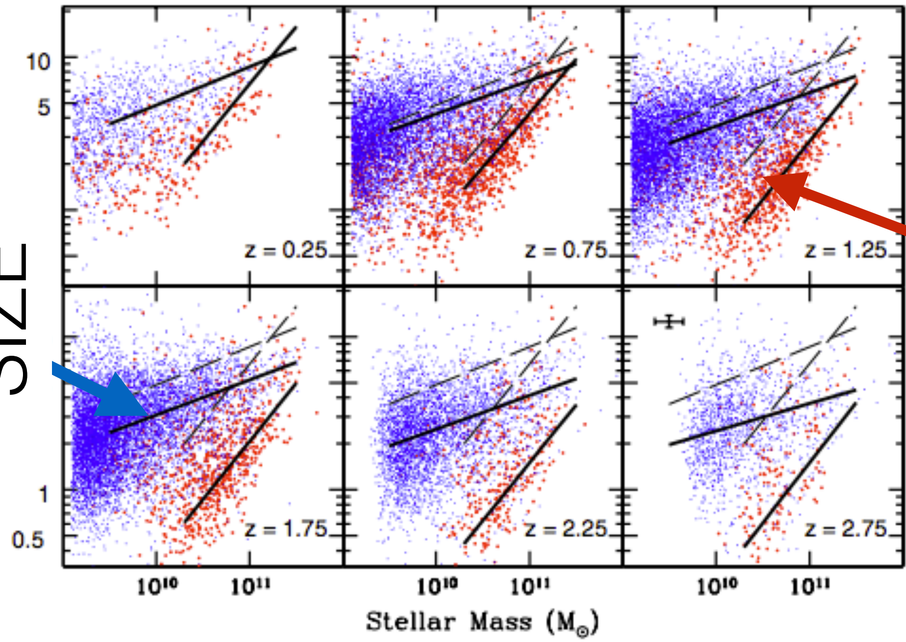
$$\boxed{L_{H-burn} \simeq 0.007\dot{m}c^2}$$

- Such luminous accretion of an ionized plasma has a natural upper limit, the Eddington limit:
  - Gravitational pull on proton > radiation pressure on electron (Thompson cross section)

$$L_{Edd} = \frac{4\pi c G M_{BH} m_p}{\sigma_{Te^-}}$$

Structure/morphology as tracer of past history…

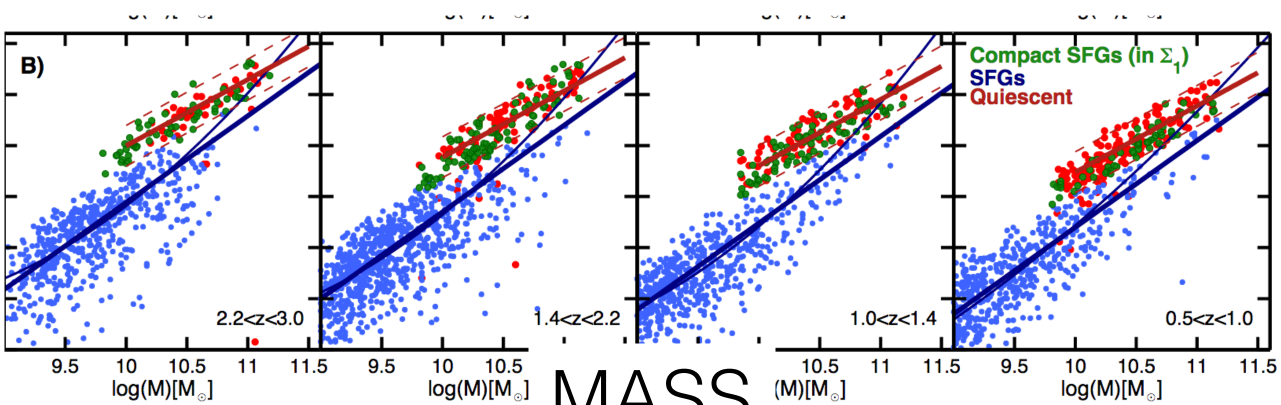
SIZE



van der Wel+13

Barro+15

CENTRAL DENSITY



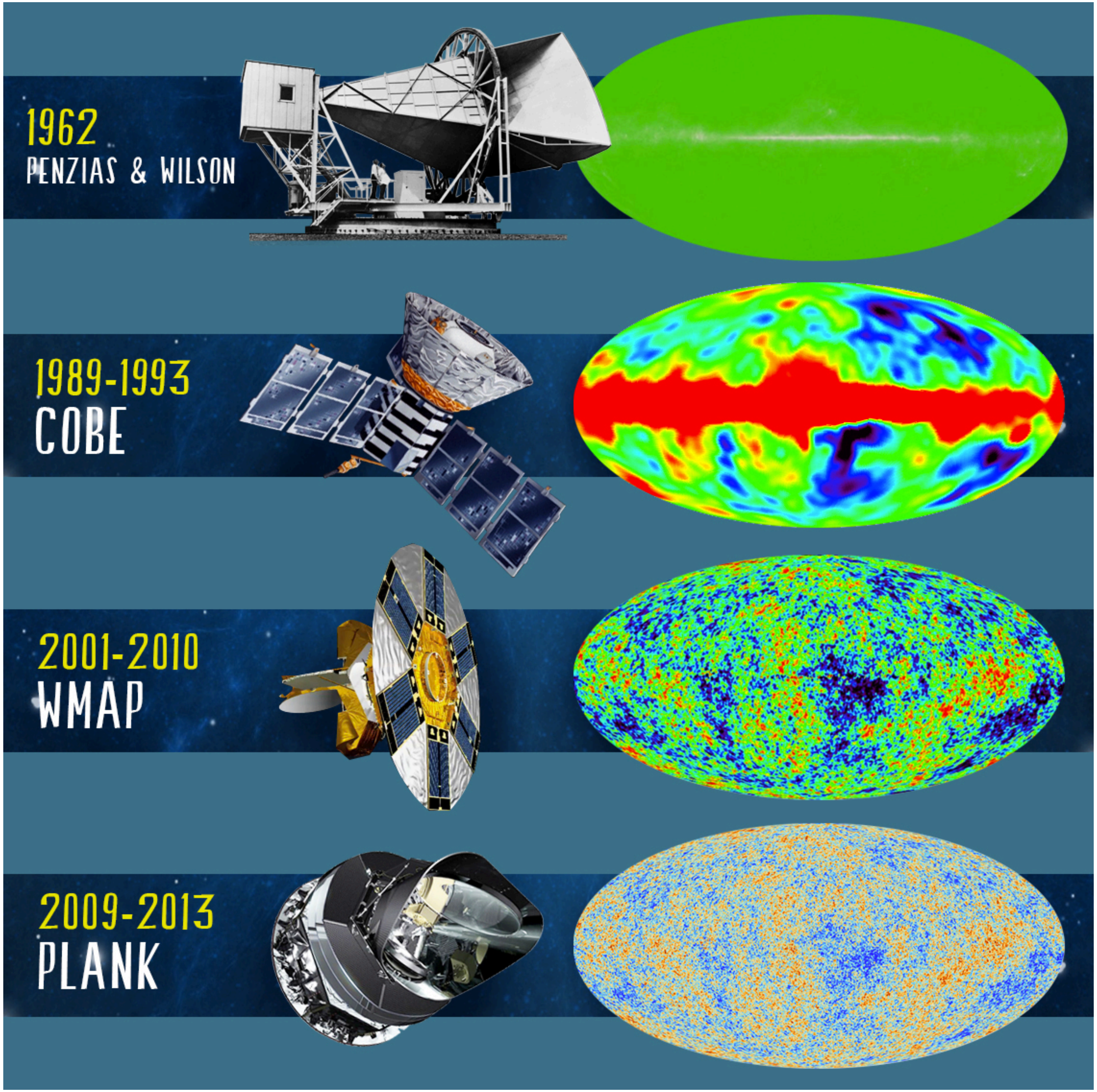
MASS

Imprint in the central 1Kpc!

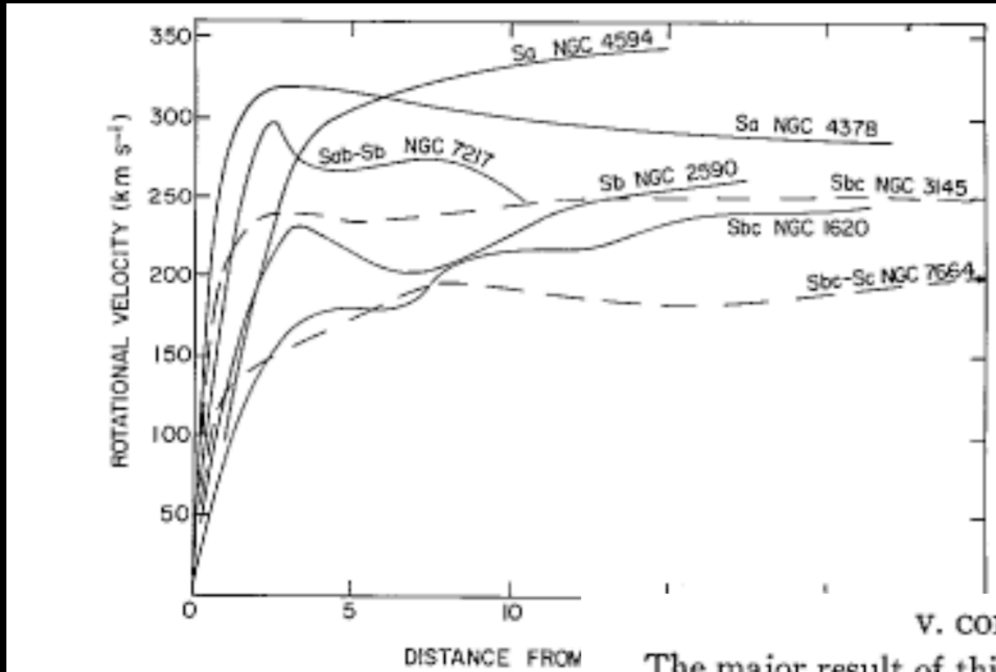
KEY HISTORICAL LANDMARKS IN GALAXY EVOLUTION

- DISCOVERY OF GALAXIES (SEE JAIRO'S)
- COSMIC MICROWAVE BACKGROUND —> BIG-BANG
- DISCOVERY OF DARK MATTER
- REALIZATION THAT GALAXIES EVOLVE
- DARK MATTER MASS FUNCTIONS != GALAXY MASS FUNCTION —> FEEDBACK

- COSMIC MICROWAVE BACKGROUND



• DISCOVERY OF DARK MATTER



Rubin et al. 1978

V. CONCLUSIONS

The major result of this work is the observation that rotation curves of high-luminosity spiral galaxies are flat, at nuclear distances as great as $r = 50$ kpc. Roberts and his collaborators (Roberts 1976) deserve credit for first calling attention to flat rotation curves. Recent 21 cm observations by Krumm and Salpeter (1976, 1977) have strengthened this conclusion. These results take on added importance in conjunction with the suggestion of Einasto, Kaasik, and Saar (1974), and Ostriker, Peebles, and Yahil (1974) that galaxies contain massive halos extending to large r. Such models imply that the galaxy mass increases significantly with increasing r which in turn requires that rotational velocities remain high for large r. The observations presented here are thus a necessary but not sufficient condition for massive halos. As shown above, mass distributions from disk models or spherical models

• GALAXIES EVOLVE - THE HST LEGACY