The Integrated Galaxy View

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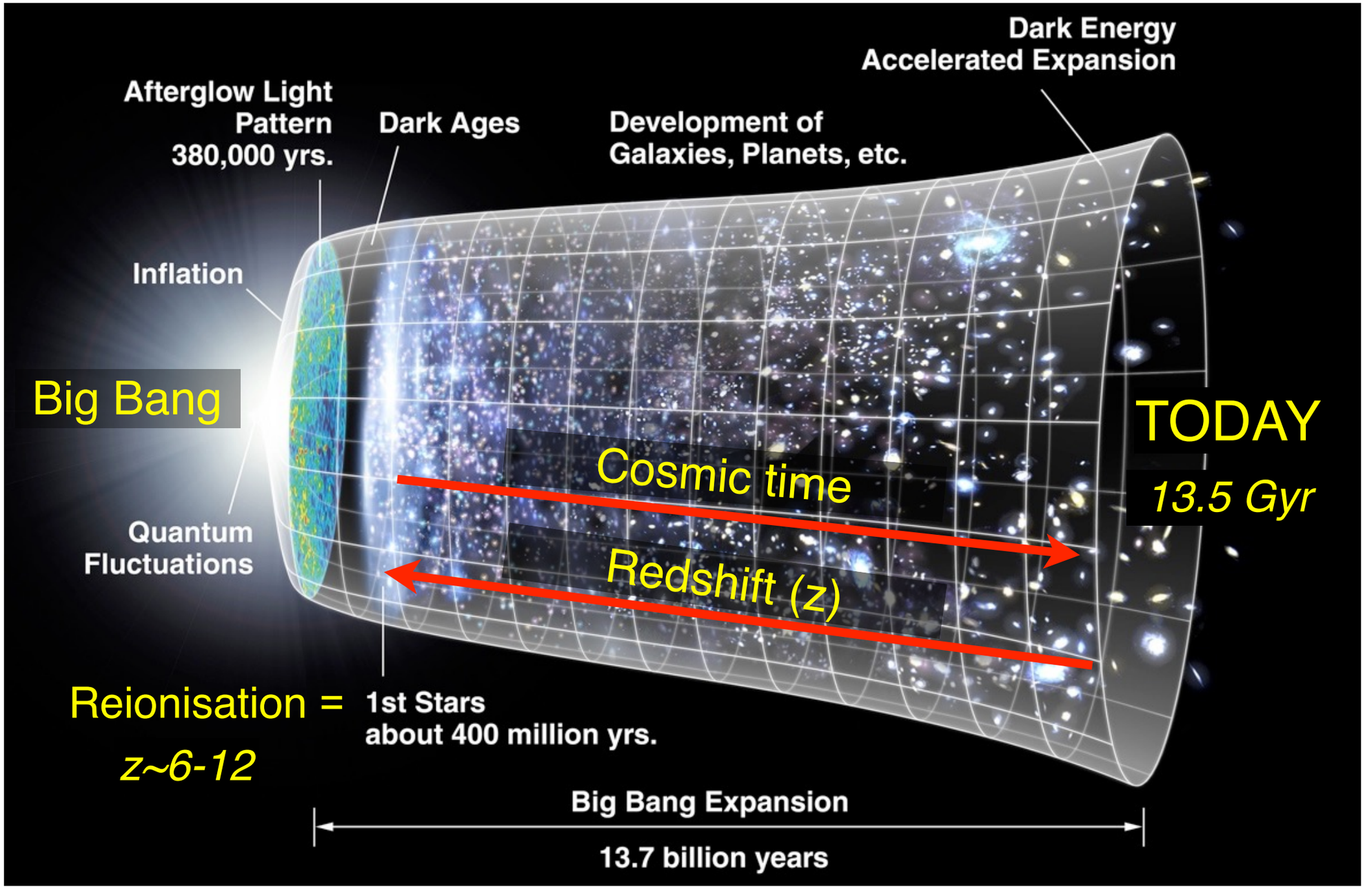
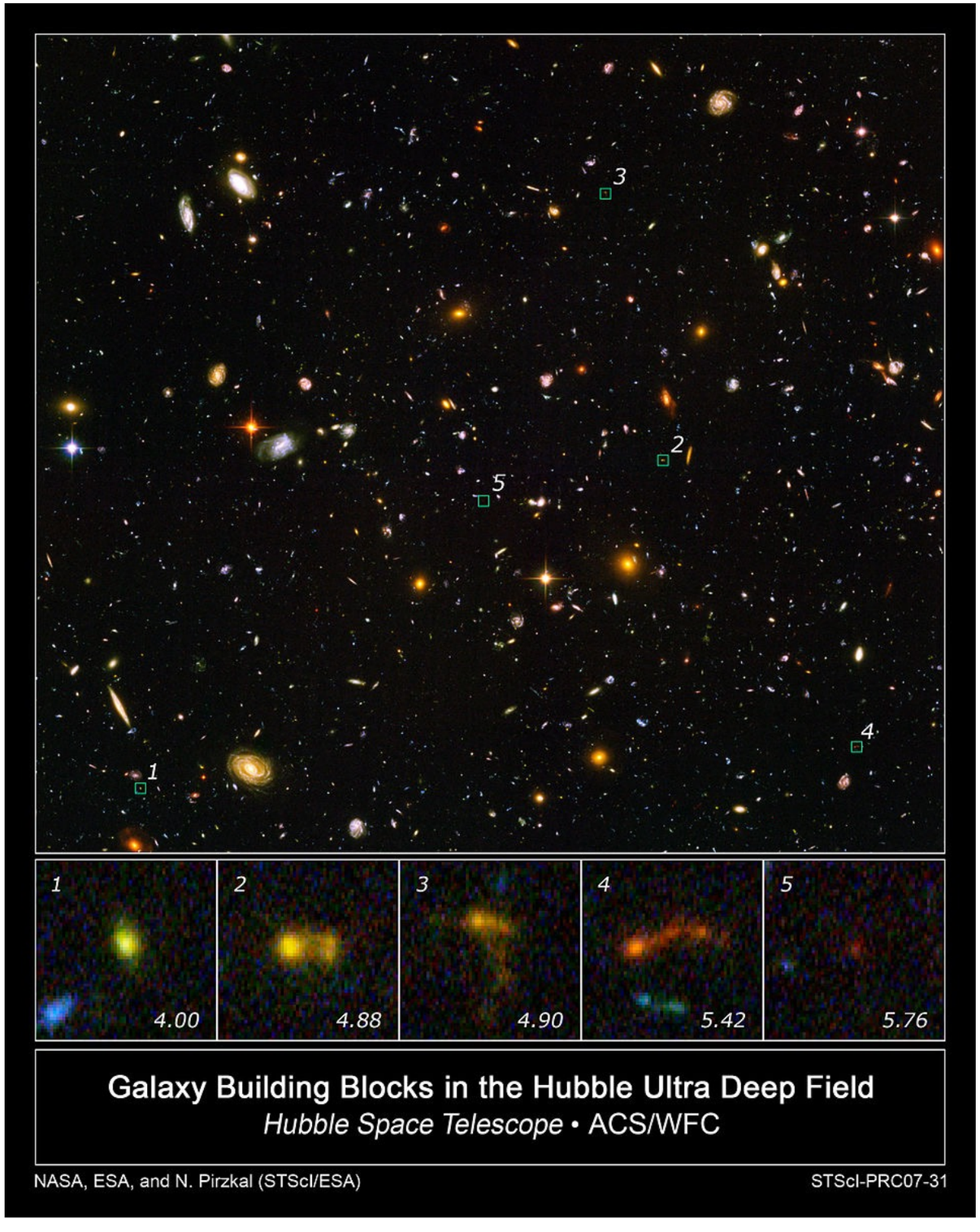
The Universe timeline



Galaxies in blank fields



We know many hundreds of thousands of galaxies in the Universe

but we can't resolve different regions in the vast majority of them

statistical treatment

↓

(mainly) galaxy evolution

Individual sources

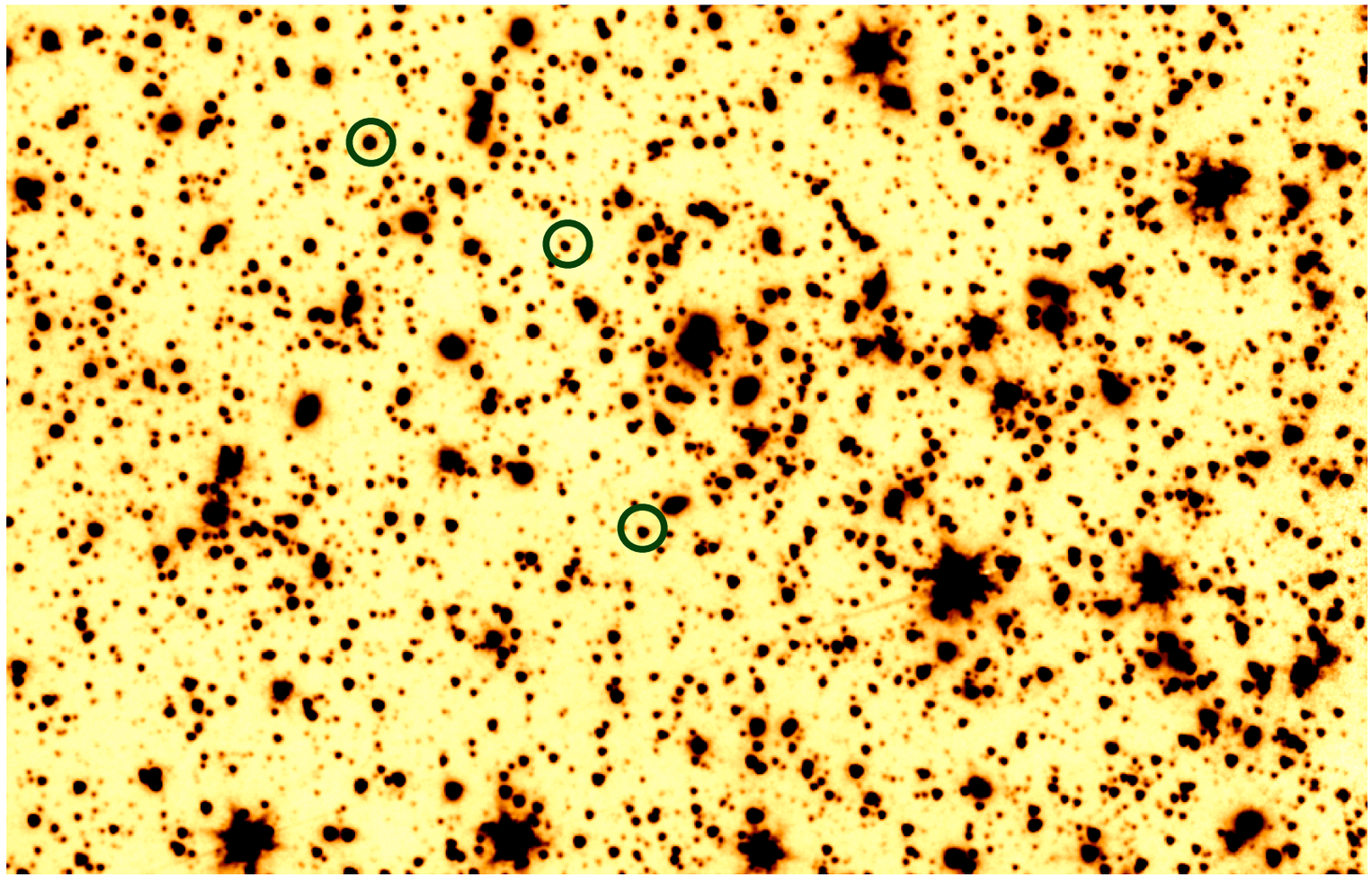
↓

galaxy physics

Problem: representativeness

Galaxy Physics from Photometric Measurements

Galaxy photometry



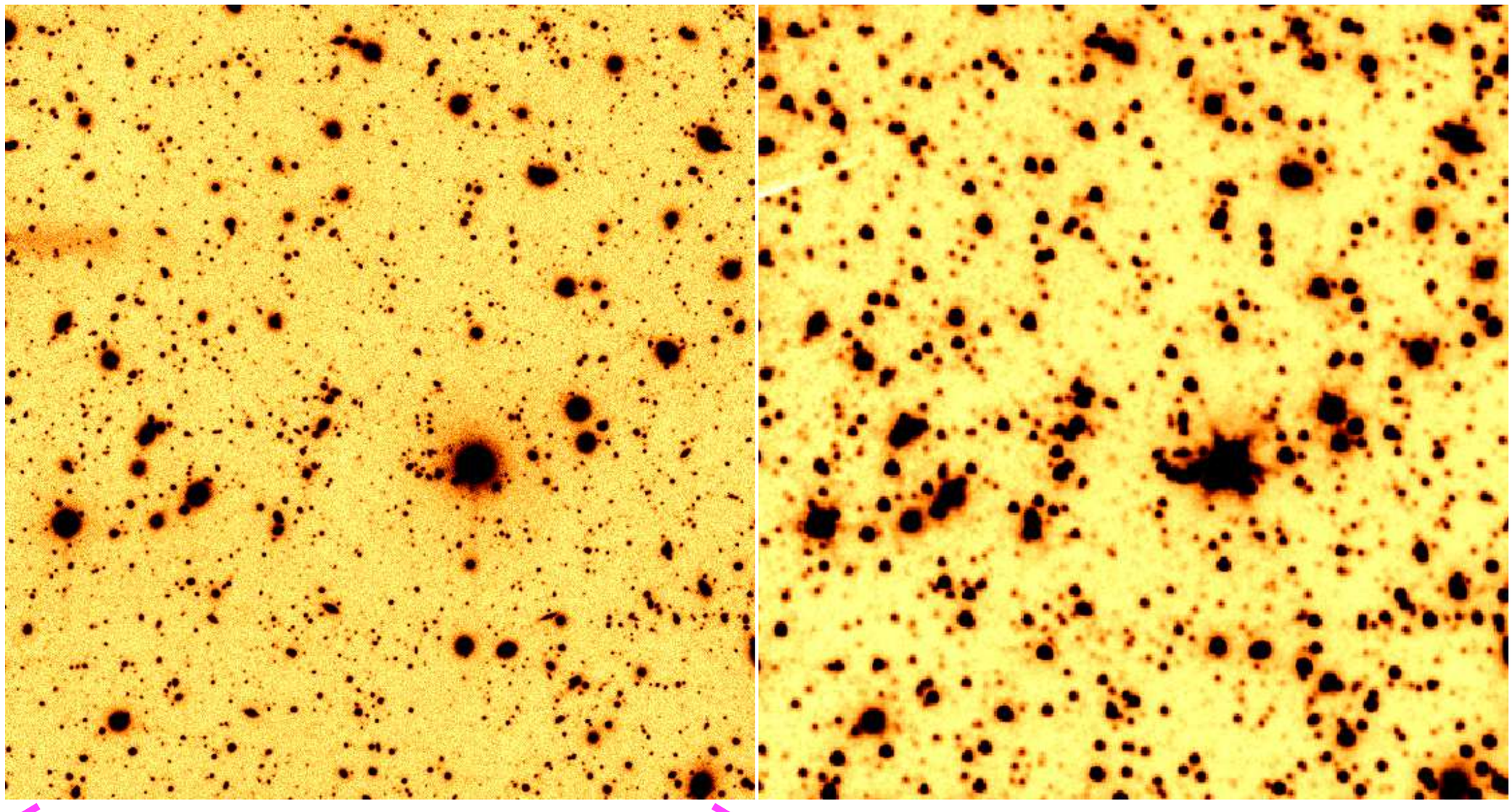
Measure all light encircled in an aperture
(and subtract background)

This can be done at different wavelength to measure light from different components (e.g., young stars, old stars, dust emission)

Dealing with images of different resolution

HKs - PSF FWHM~0.8 arscec

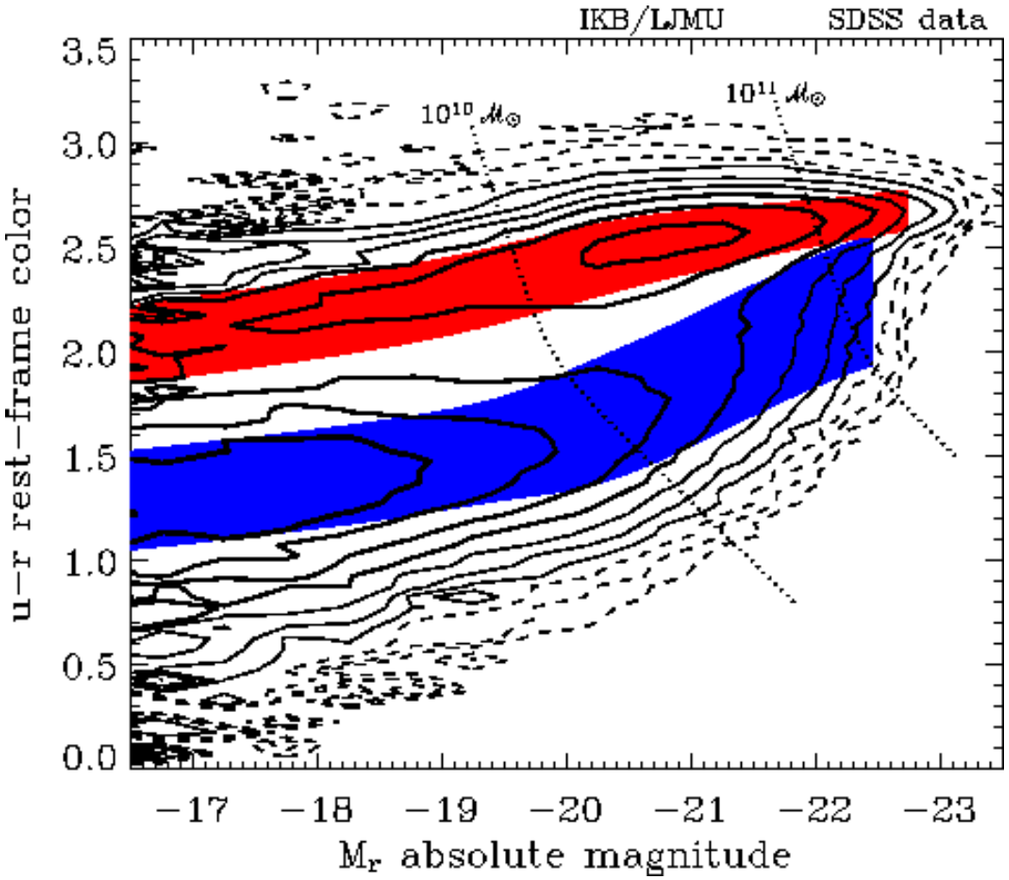
3.6 microns - PSF FWHM~1.9 arscec

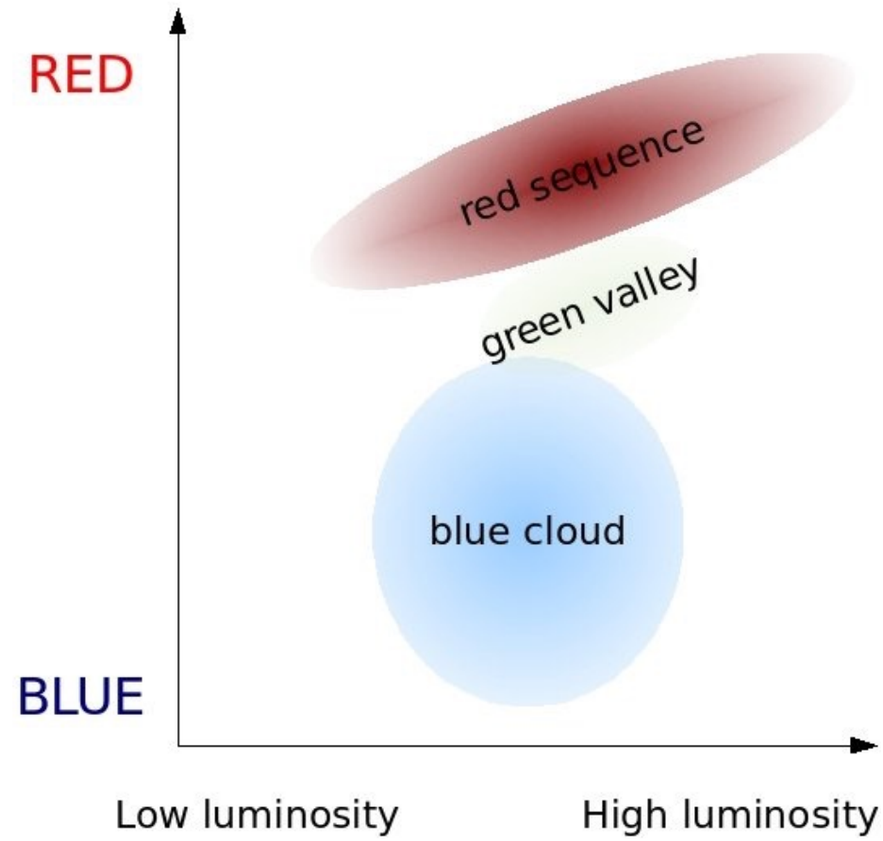


~4.5 arcmin

Galaxy colour-magnitude diagrams

z=0



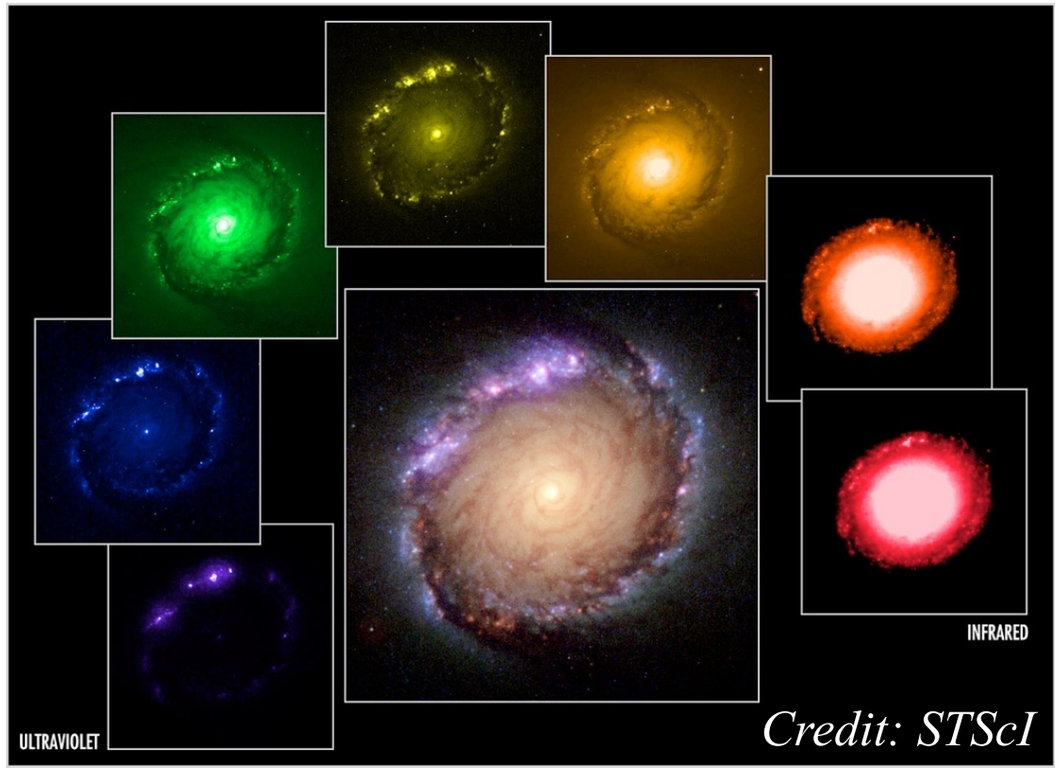


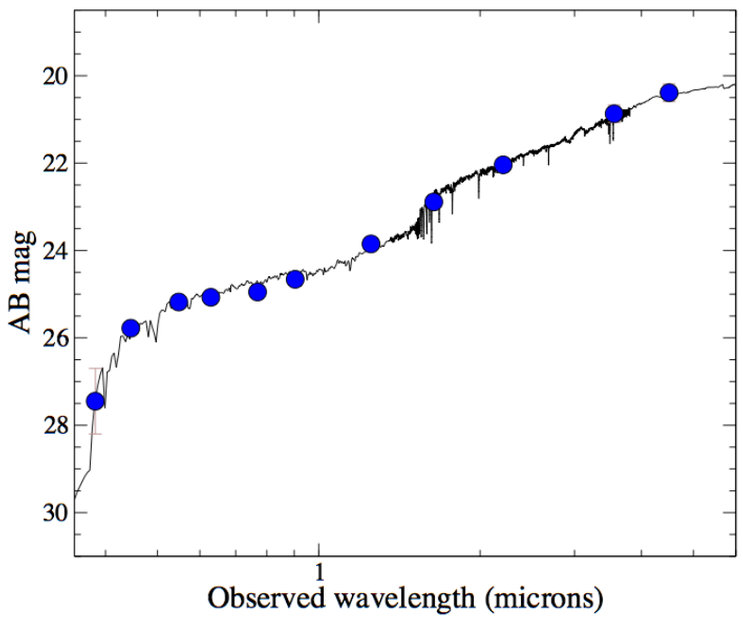
Credit: Baldry et al.

The blue and red galaxy sequences are clearly separated up to at least z~1

At higher z, red=passive is not valid any more due to increasing importance of dust extinction

Spectral energy distribution (SED) fitting





Photometric redshift → ***'cheap' alternative to spectroscopic redshifts***

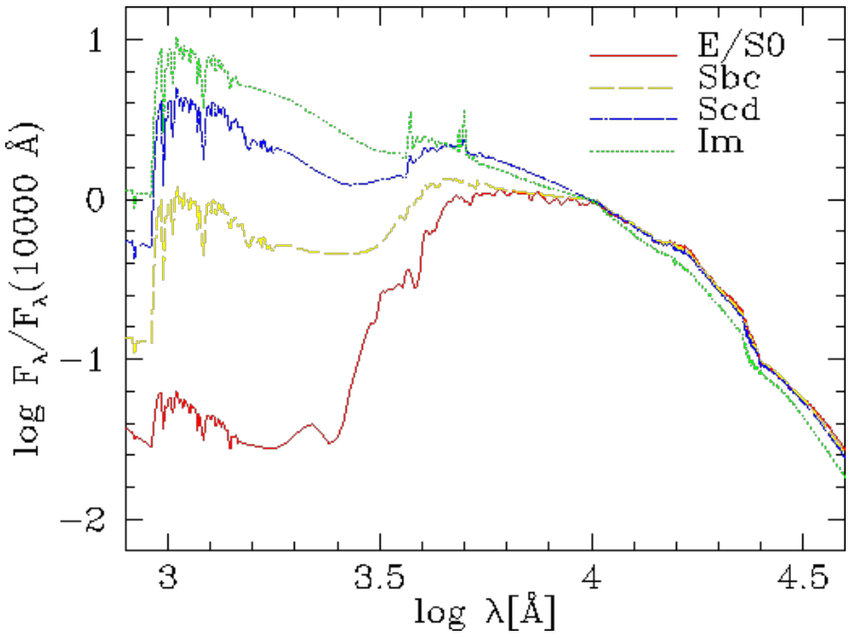
Age

Dust Extinction

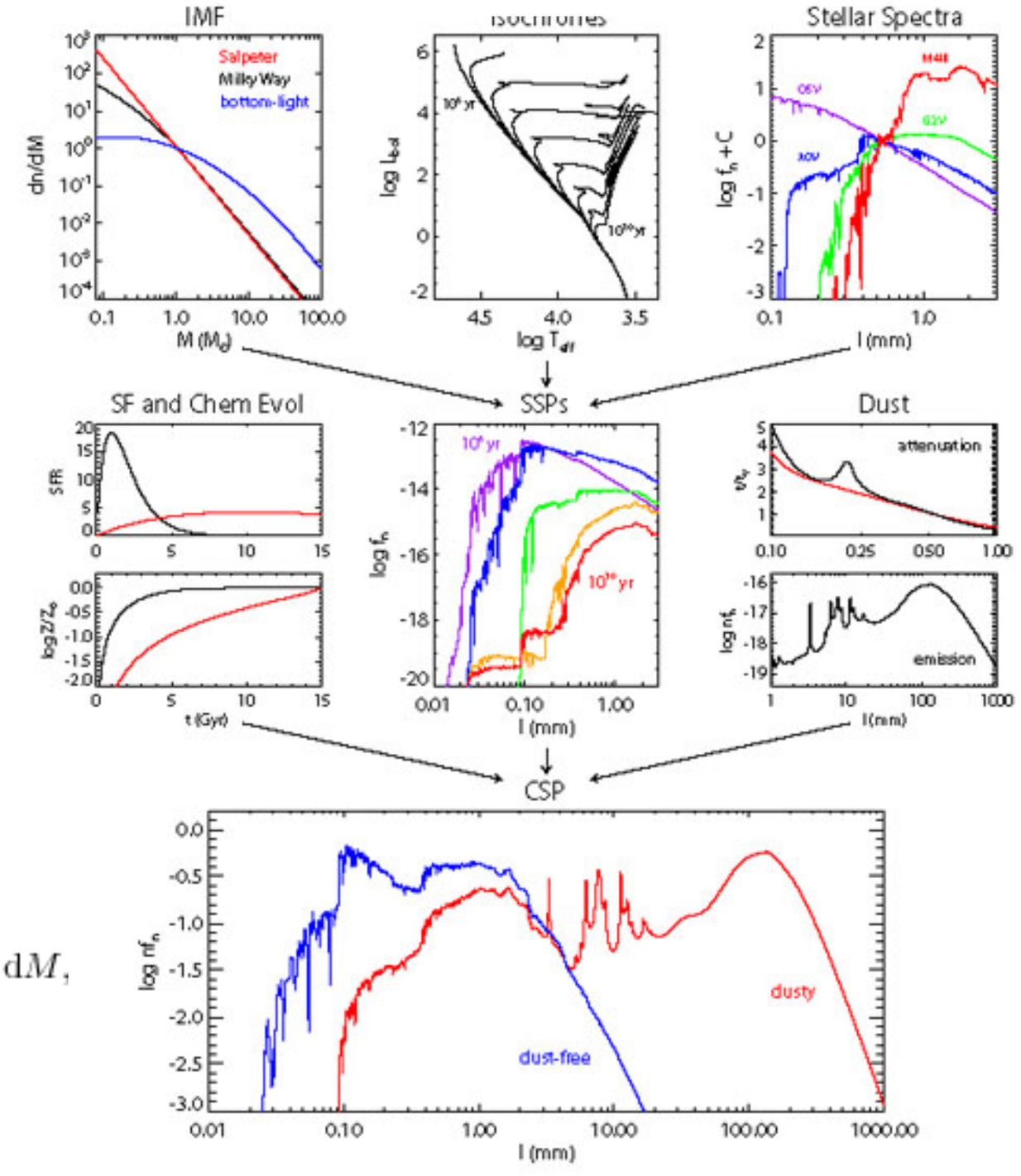
Stellar Mass

SED models

Empirical



Synthetic



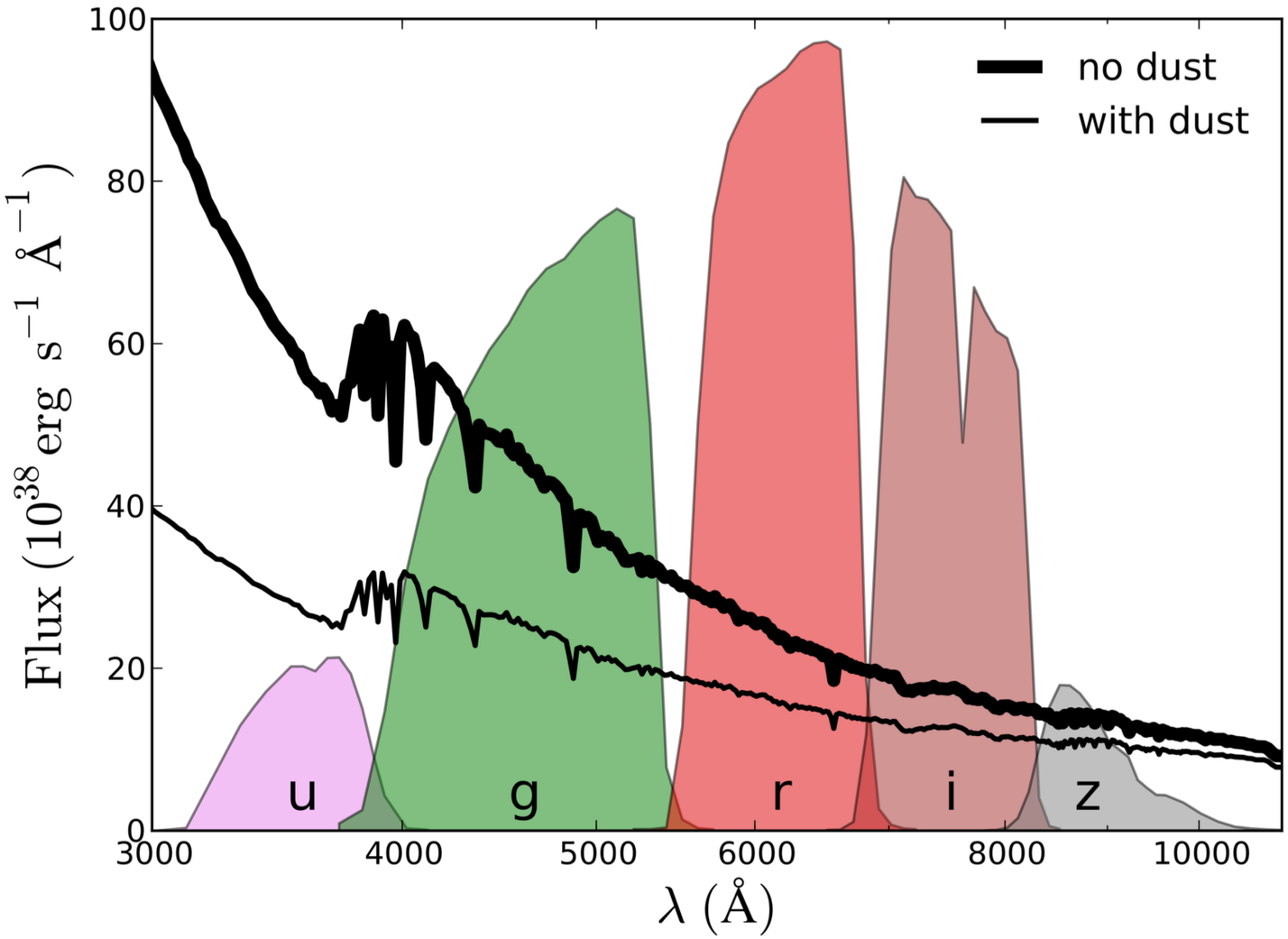
$$f_{\rm SSP}(t,Z) = \int_{m_{\rm lo}}^{m_{\rm up}(t)} f_{\rm star}\left[T_{\rm eff}(M), \log g(M) | t, Z\right] \Phi(M)\, {\rm d}M,$$

stellar spectrum

IMF

Credit: J. Walcher

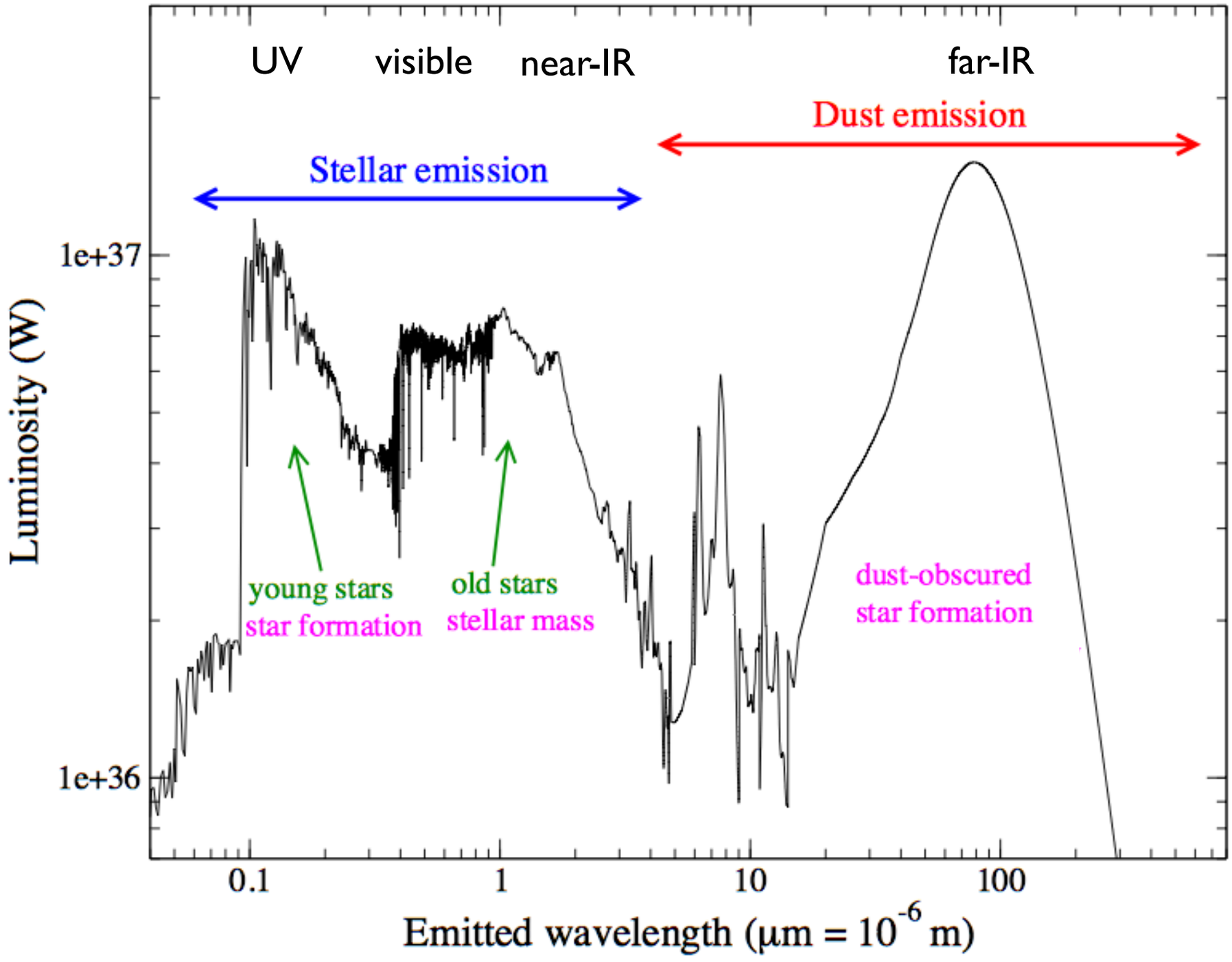
Expected photometry from templates



Credit: TAO - Bernyk et al.

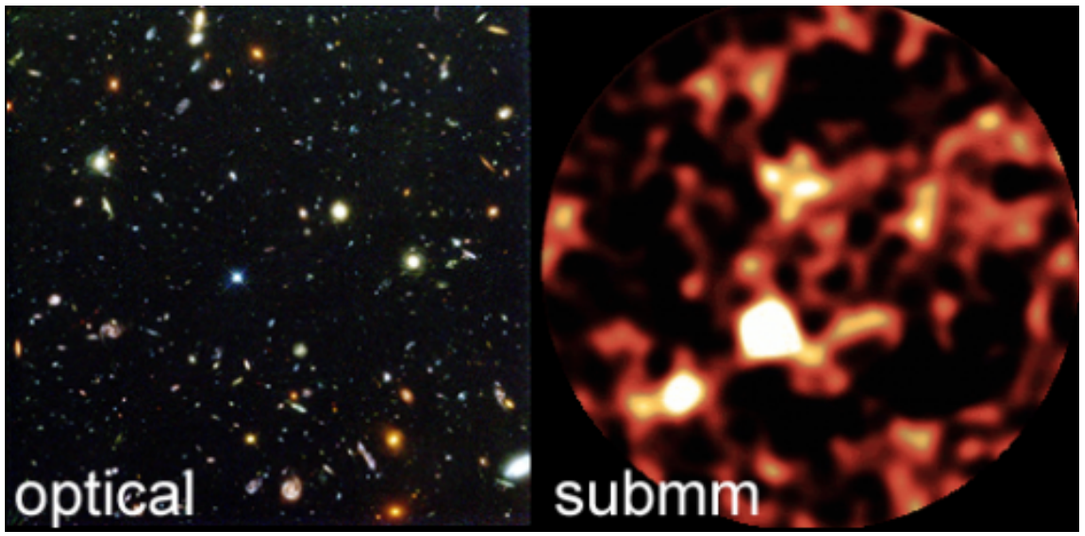
$$f_\nu^{band}(\lambda) = \frac{\int_0^\infty f_\nu(\lambda) T(\lambda) d\lambda}{\int_0^\infty T(\lambda) d\lambda}$$

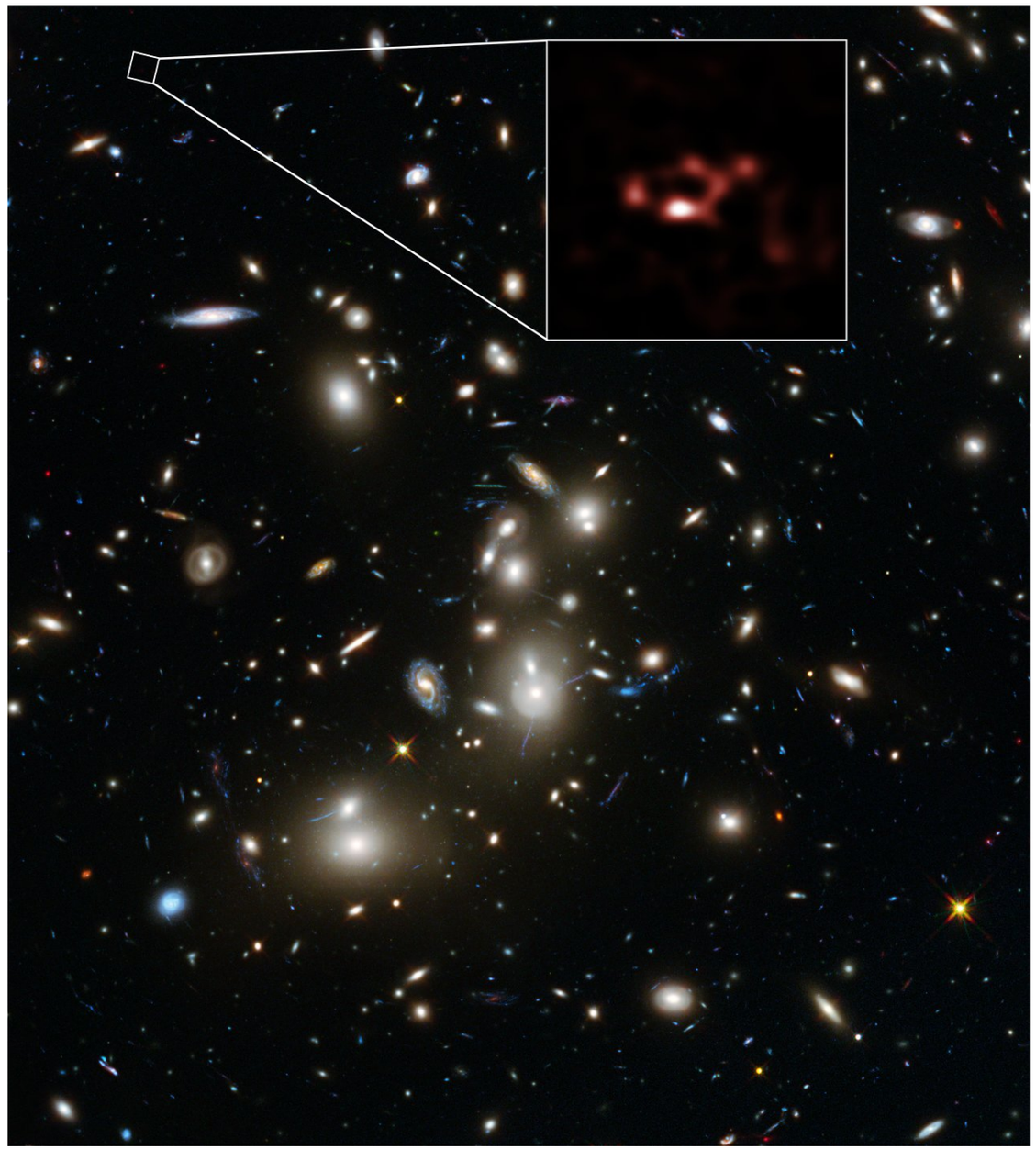
The typical SEDs of star forming galaxies



Dusty Galaxies

Dust in galaxies is relatively unimportant in the present day, but it was much more important in the cosmic past

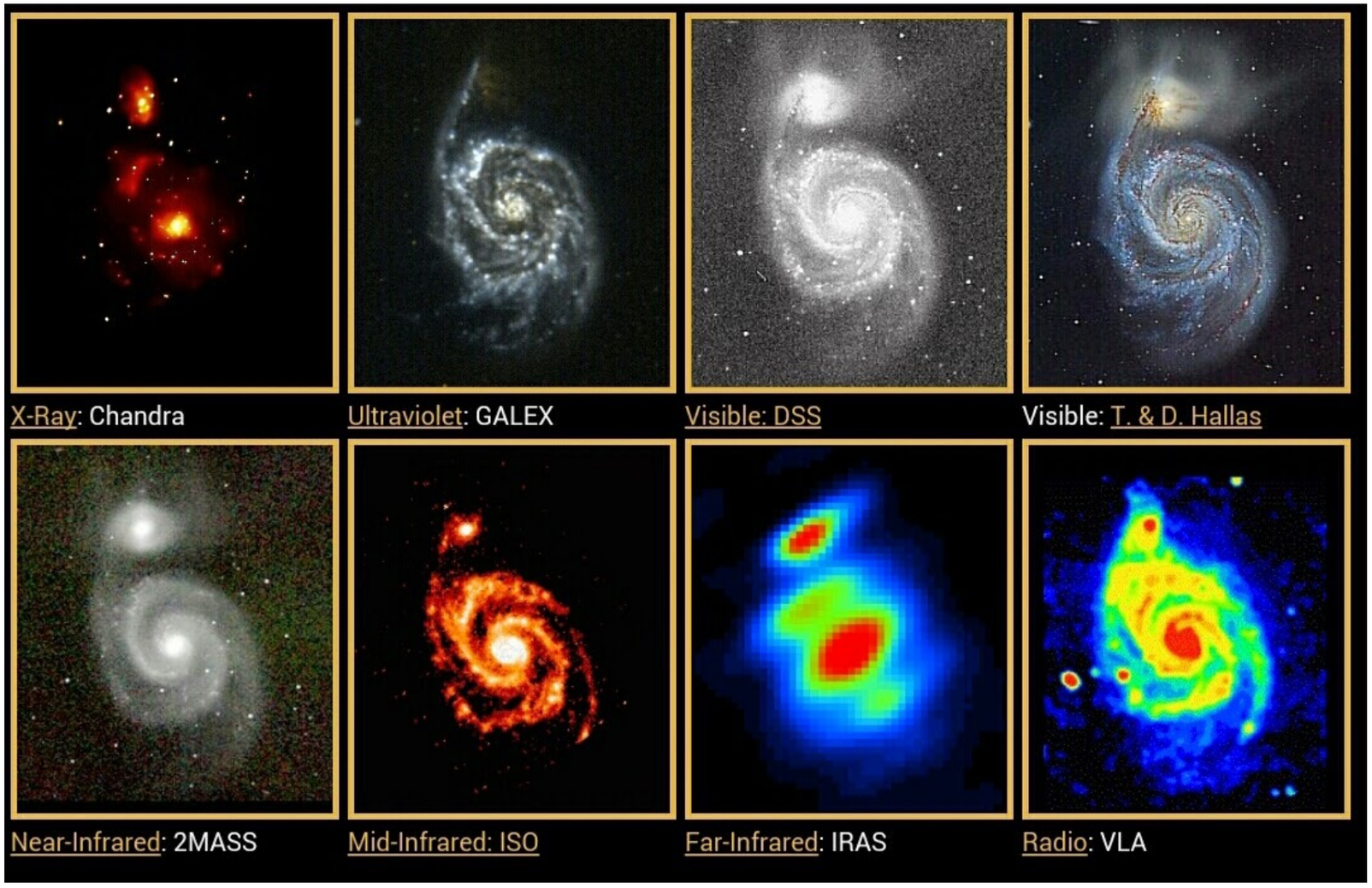


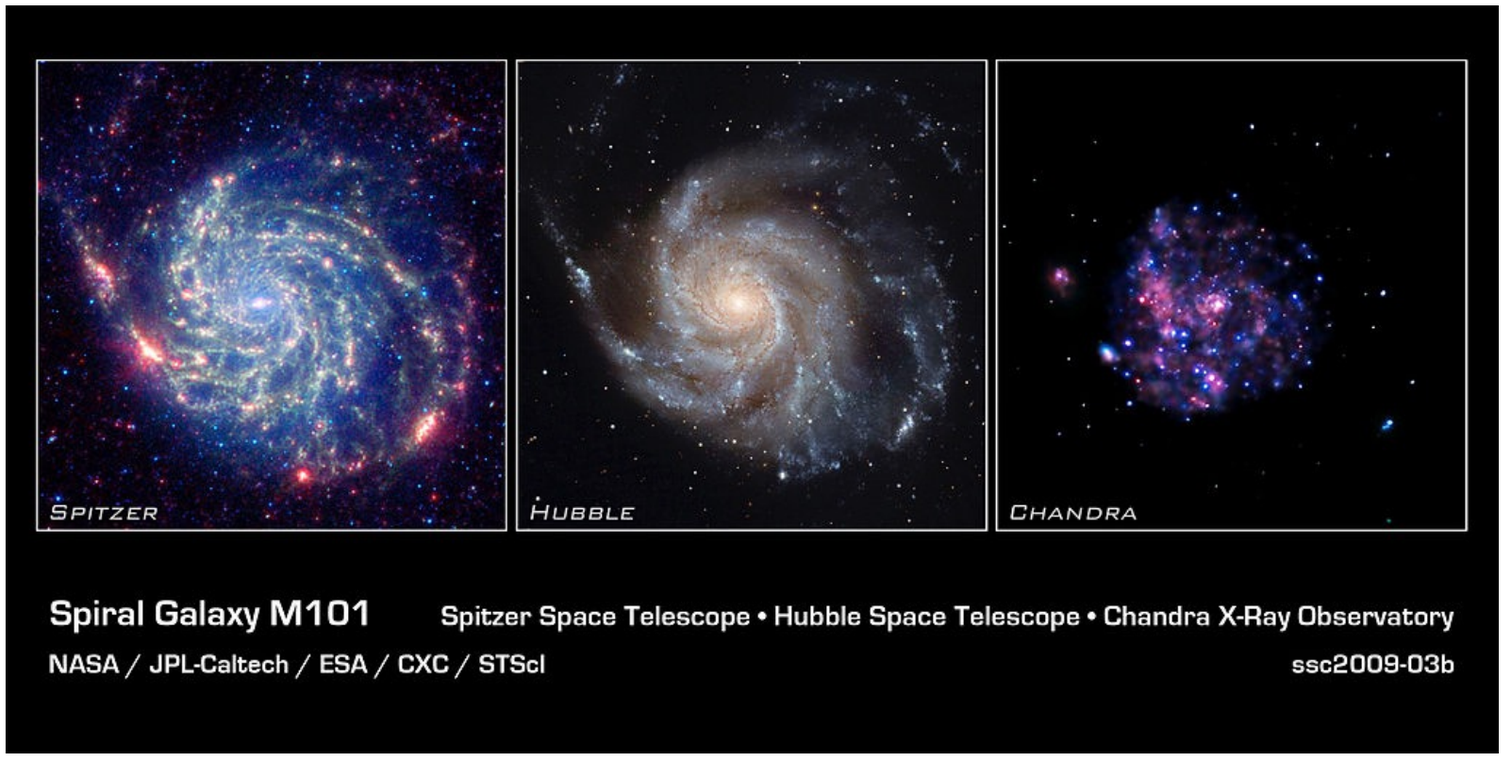


Credit: ALMA/ESO/ESA - Coe et al.

X-rays

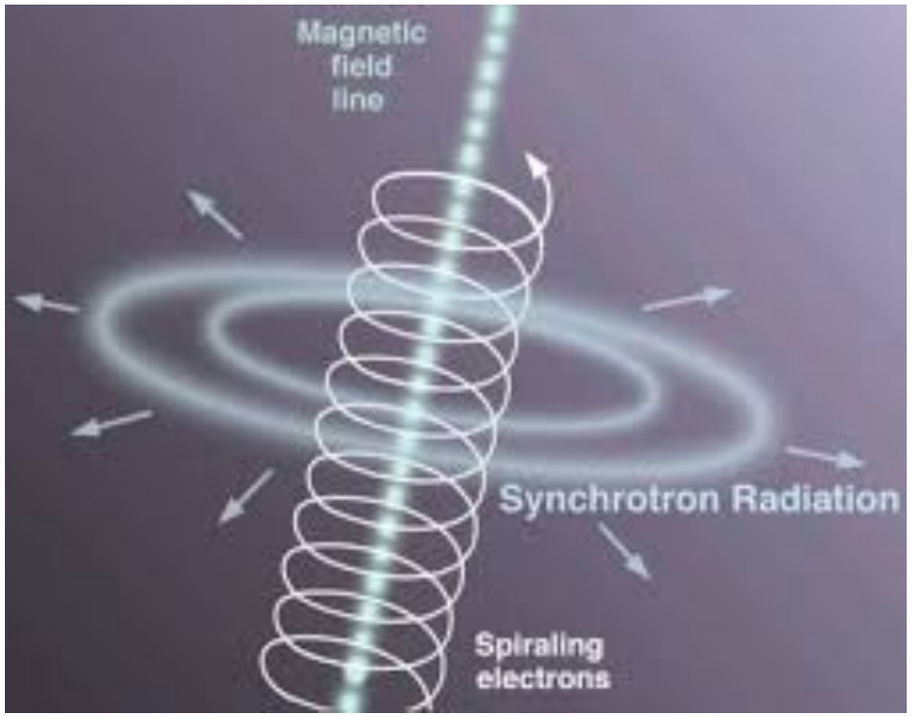
Chandra X-ray Observatory

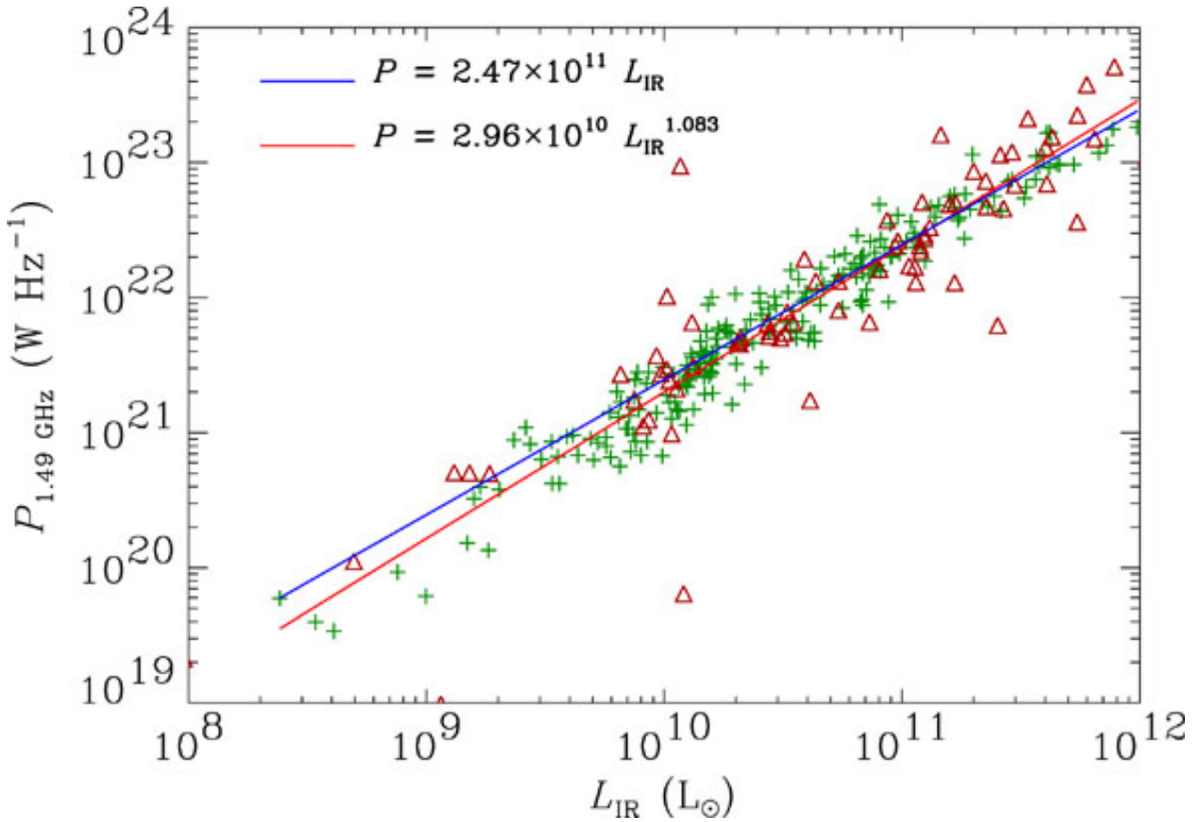




Emission at different wavelengths does not necessarily come from the same part of the galaxy

Radio





e.g. Condon et al.

Very Large Array (VLA)

Galaxy Physics from Spectroscopy

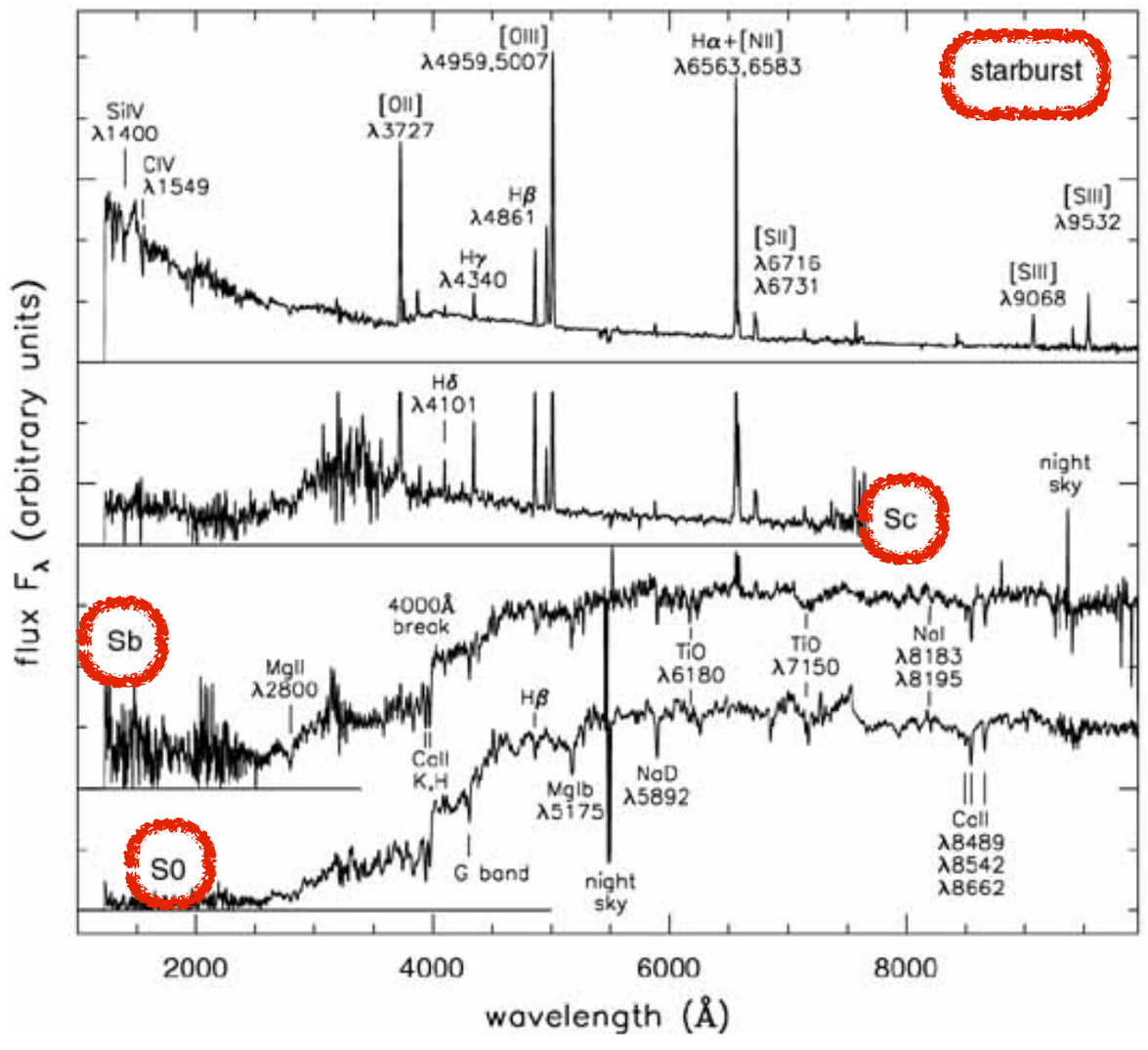
Spectra of star forming galaxies

the spectra of star-forming galaxies are characterised
by the presence of emission lines

Disc galaxies looks as you might expect given their colours:

early-type spirals have older stars and few if any emission lines from star-formation regions

late-type spirals have younger stars and emission lines from star-formation regions



Spectra of passive galaxies

the spectra of ‘passive’ galaxies only has absorption lines

due to negligible level of on-going star formation

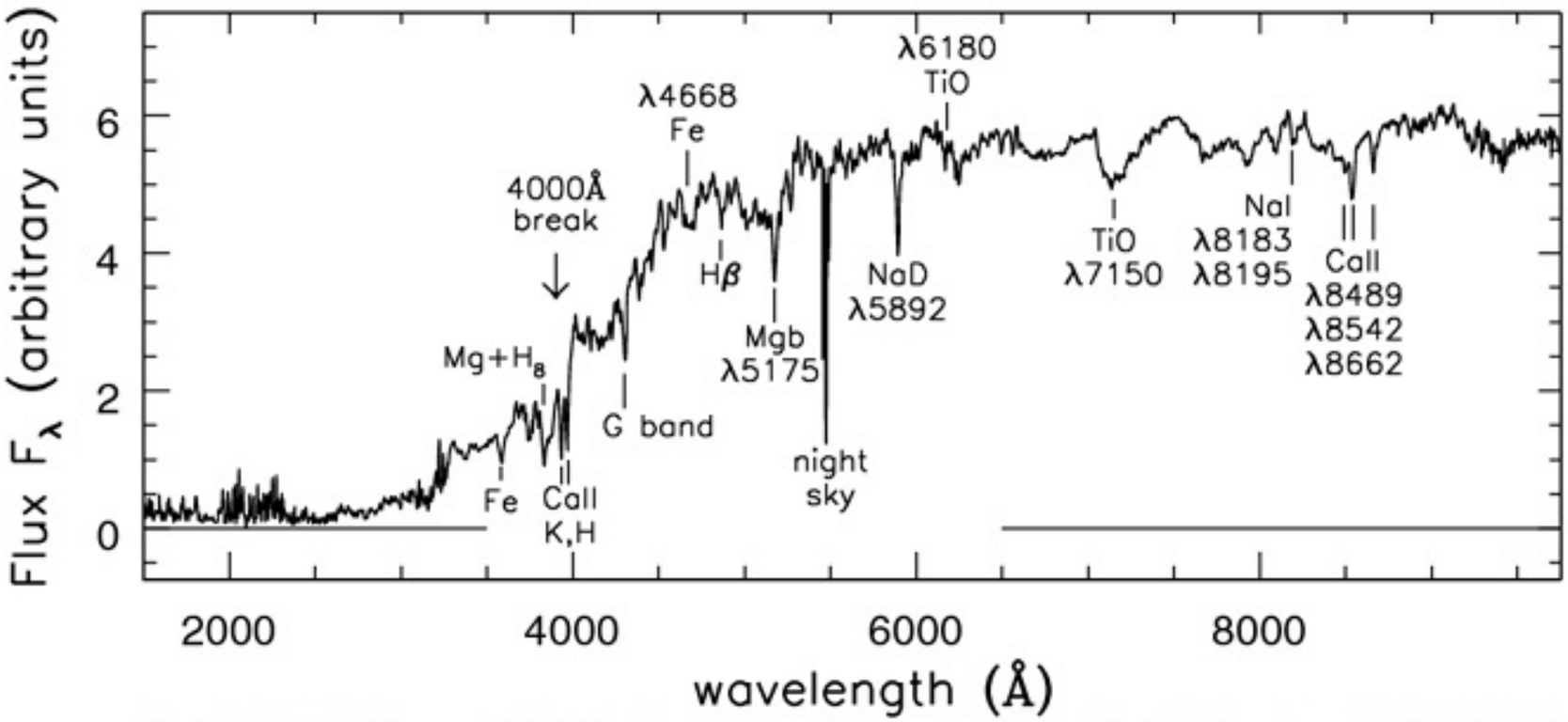
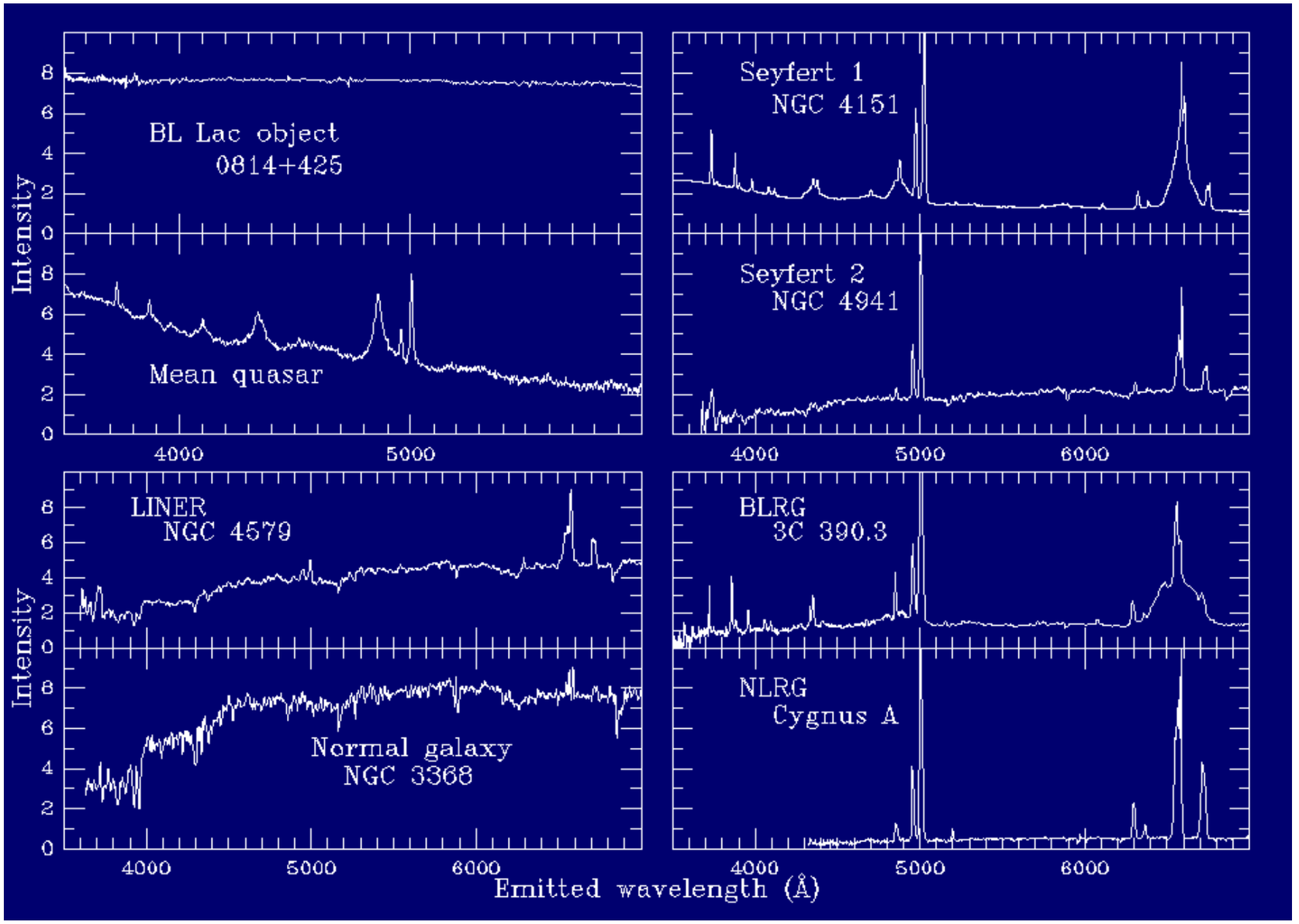


Fig 6.17 (A. Kinney) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

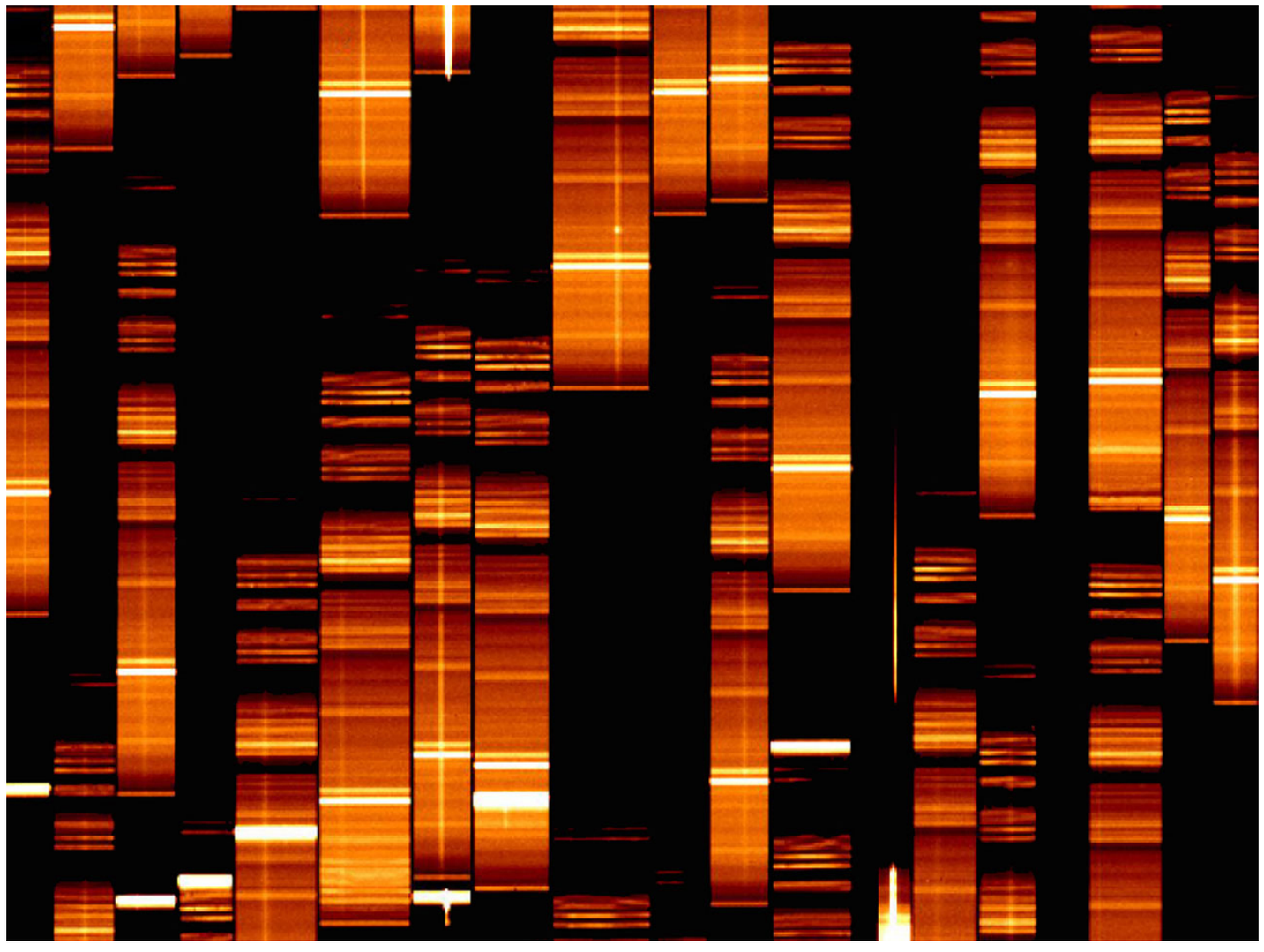
AGN spectra


BL Lac object
0814+425
Mean quasar
Seyfert 1
NGC 4151
Seyfert 2
NGC 4941
LINER
NGC 4579
Normal galaxy
NGC 3368
BLRG
3C 390.3
NLRG
Cygnus A
Intensity
Emitted wavelength (Å)
0
2
4
6
8
4000
5000
6000

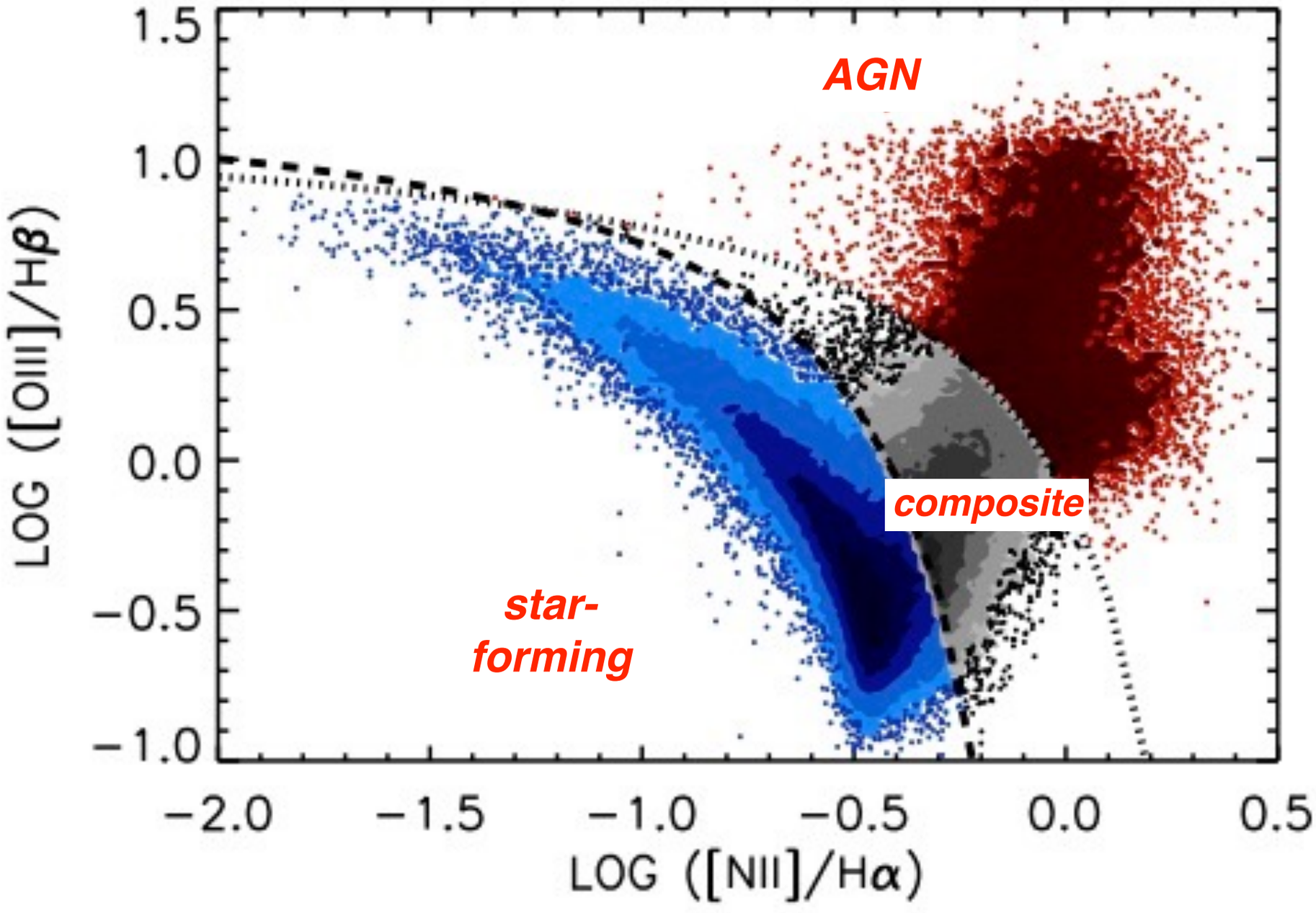
Multi-object spectroscopy

traditionally with slits or fibres

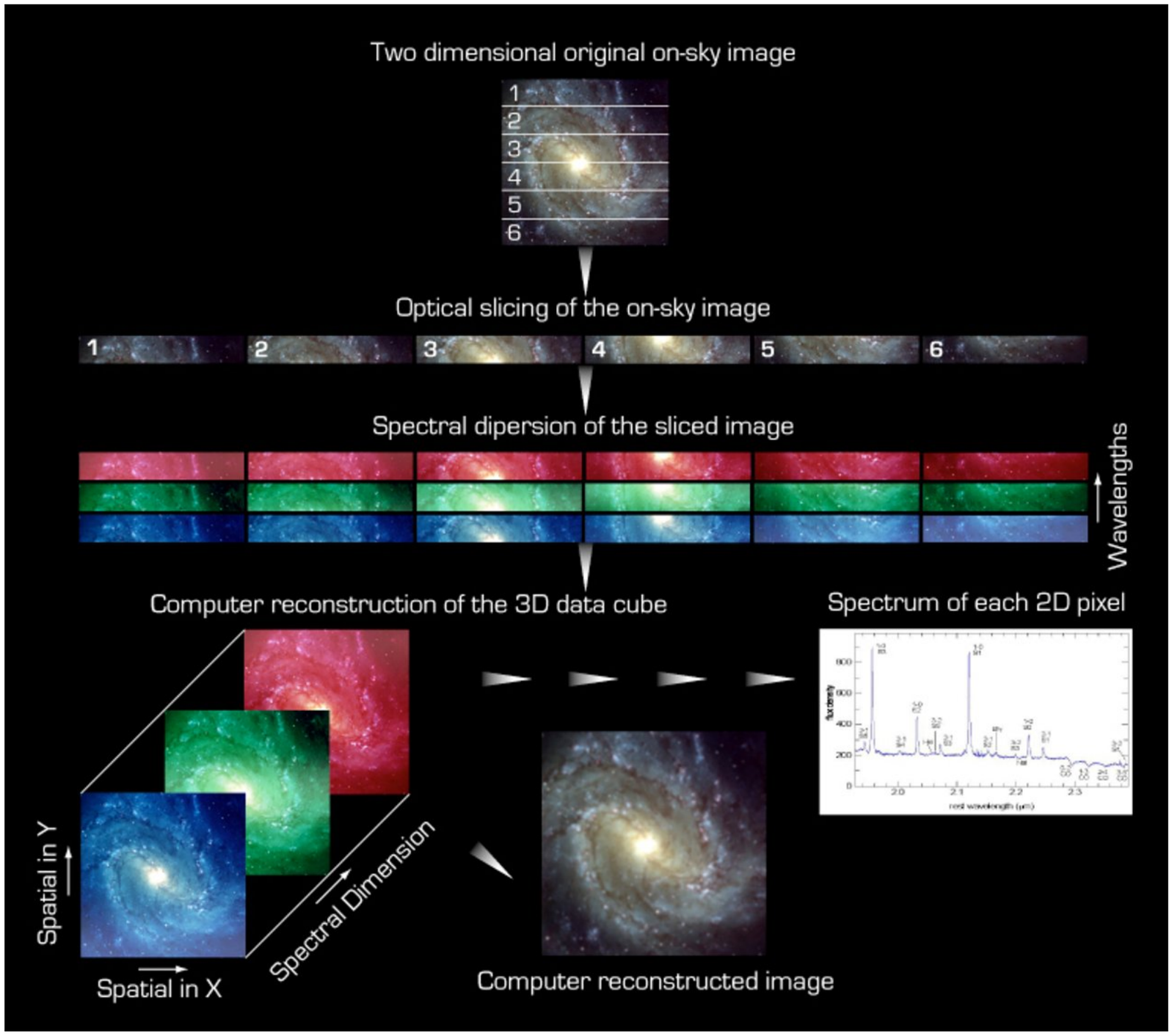
- ✓ calibrate zphot
- ✓ provide backbone for LSS studies
- ✓ study of physical properties (e.g. metallicities)



Spectral classification - the BPT diagram

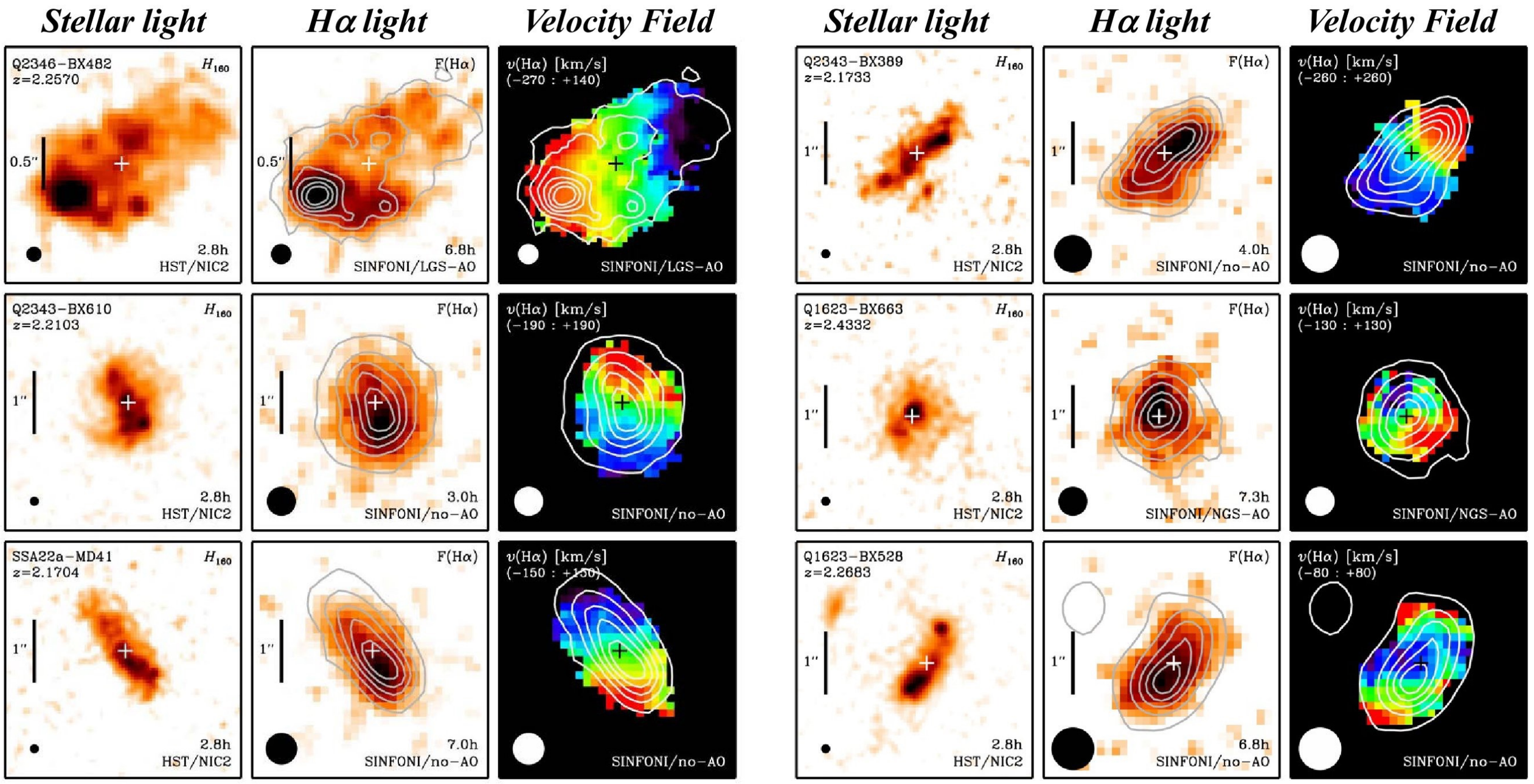


Integral Field Spectroscopy



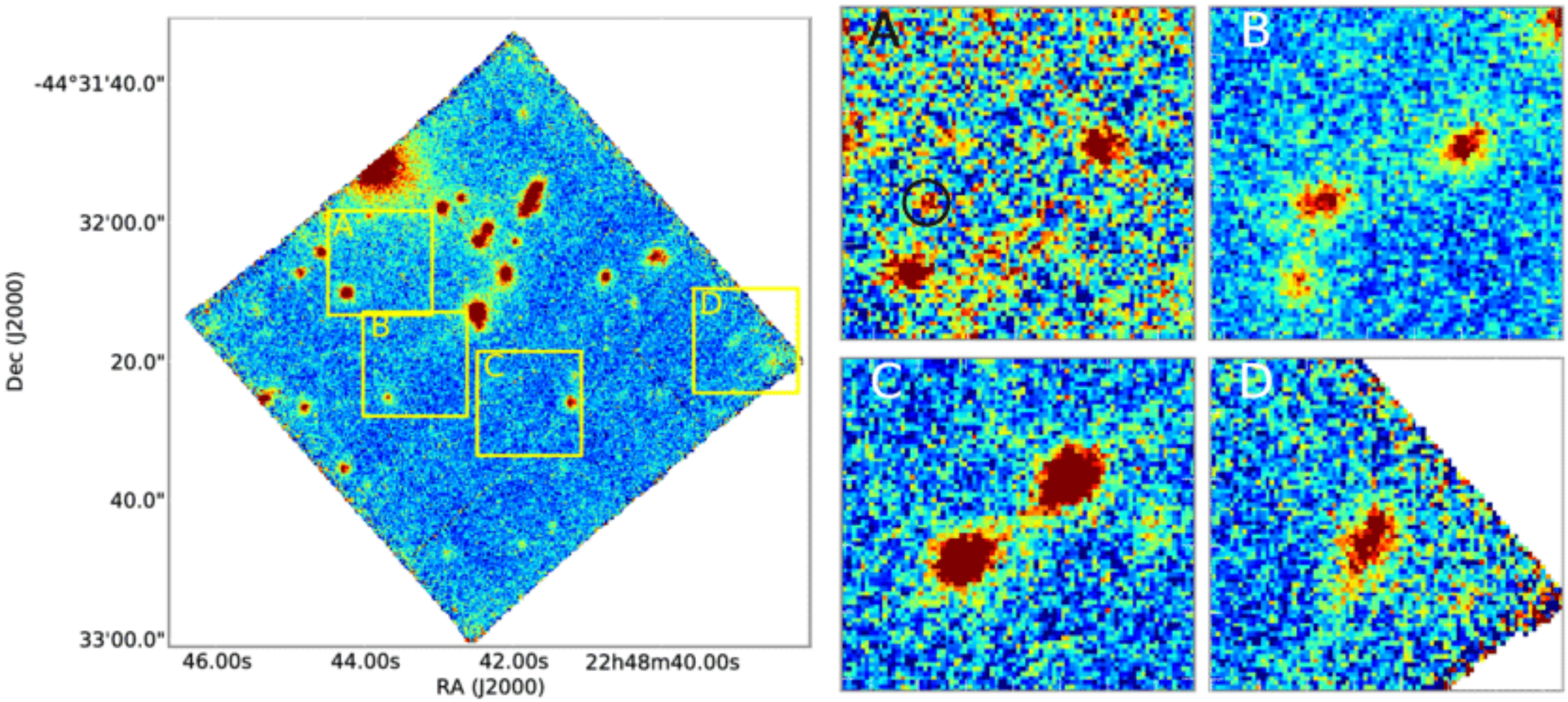
Credit: ESO

Galaxy spectral maps



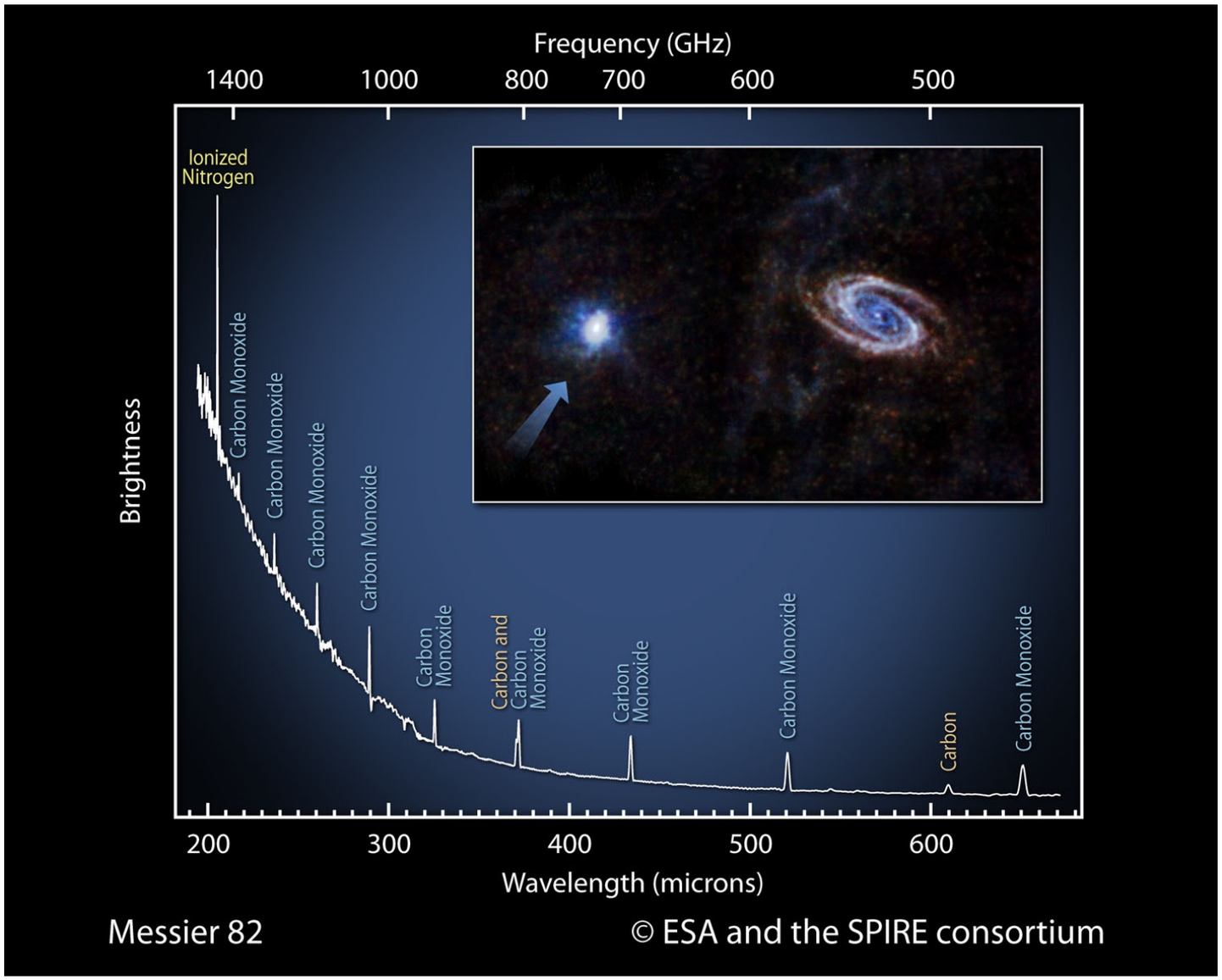
Foerster-Schreiber et al.

Galaxy spectral maps II - VLT/MUSE

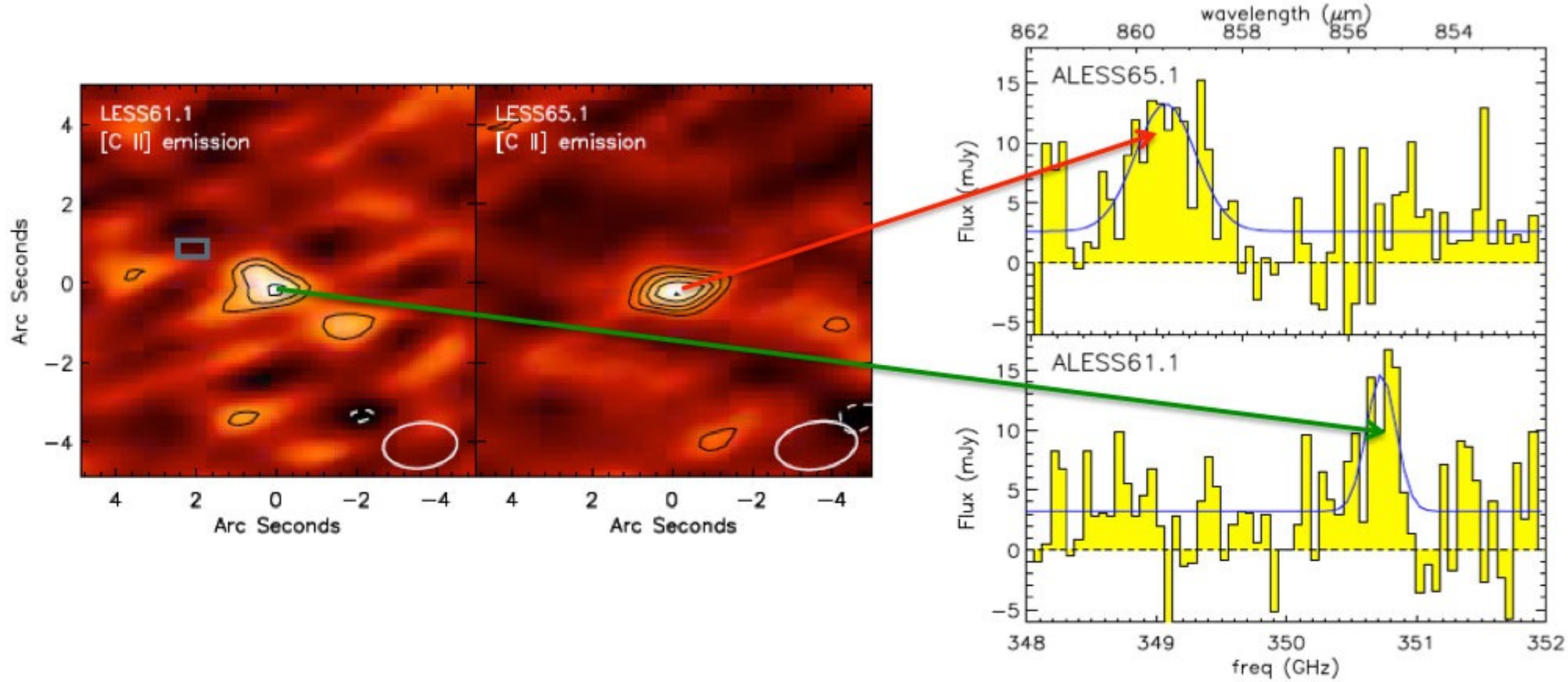


Karman, KC et al.

Far-infrared spectra of dusty galaxies



Gas in the ISM



Swinbank et al.