Concluding remarks
Major progress in our understanding of galaxy formation thanks to the recent generation “MOS” facilities and surveys...

Also... many more new questions have been opened...
Evolu0n\tof	BPT
at high-z

Why?
N/O
Ionization parameter
Harder spectra (low-Z+binaries)
Pressure/density
Shocks
AGNs
DIG

... very likely
not a single origin:
different effects play
different roles in
different galaxies
Additional warning: be also aware of aperture effects.

(Belfiore+16)
Evolution of the ISM properties, Mass-Metallicity relation and of the FMR: a Tower of Babel?

Different diagnostics
Different calibrations
Different assumptions
Different approaches
Different samples
Neglect/account environment

Mannucci, Sanders Vilchez, Calabro’, Sanchez-Almeida Shapley, Siana, Puglisi
Evolution of the ISM properties, Mass-Metallicity relation and of the FMR: a Tower of Babel?

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[OIII]/[OII]

Metallicity tracer

Ionization parameter tracer

Both metallicity and ionization parameter dependence
... but used to trace f(esc)
Evolution of the ISM properties, Mass-Metallicity relation and of the FMR: a Tower of Babel?

Different diagnostics
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Attempt to homogenize low-z and high-z
Mannucci

Yet, see Siana’s dwarf high metallicity targets... as well as Puglisi’s
Can the metallicity strong line diagnostics be applied at high-z?

Te – Direct metallicity calibrations/checks at high-z

At z~1 is ~ok

But still low statistics (and mostly at intermediate-z)

Need to recalibrate strong-line diagnostics at high-z

Curti+17

z=0 high-z (JWST/ELT)
Metal abundance ratios (esp. secondary elements) -> much more stable tracers of galaxy evolutionary stage

Metallicity sensitive to inflow/outflows

Perez-Montero
Masters
Shapley
Strom

Amorin+12

Steidel+12
Metallicity gradients at high-z

Major progress, but still far from achieving the statistics and clear-cut results obtained locally

Yet, main issue is that high-z galaxies are simply “messy” in terms of metallicity structure ... do not get fixated in trying to extract radial, azimuthally averaged gradients...

(z=0 from Manga, Belfiore+17)

(all of this convolved with diagnostic uncertainties)

Independent measurement in each pixel!
Modelling nebular lines and stellar spectra

Feltre
Gomes
Vidal-Garcia
Wilkins
Ferrara
Hirschmann
Curtis-Lake

Beagle
FADO
Mega
HCm
...

Combined with cosmological simulations

- Impressive progress!
- Key new insights!
- Next step:
  Check consistency with other direct diagnostics?
  (e.g. Te for metallicities,
   X-ray for AGNs, ...)

Important warning
- degeneracies especially at high-z

Need to expand to a broader range of diagnostics & combine with photometry

Stark
Pentericci
Maseda
Curtis-Lake

\[
\frac{\log([\text{OIII}]\lambda1666/\text{He II} \lambda1640)}{\log([\text{NII}]\lambda6584/\text{H}\alpha)}
\]

\[
\begin{align*}
\epsilon_{\text{gr}} = 0.3 \\
Z = 0.001, 0.004, 0.008, 0.017, 0.03, 0.04
\end{align*}
\]

\[
\begin{align*}
\eta_{(\text{AGN})} &= 10^3 \text{ cm}^{-3} \\
\epsilon_{(\text{SF})} &= 10^2 \text{ cm}^{-3}
\end{align*}
\]
Limits of current models...

Interesting new physics?
Dust extinction
Dust attenuation curves
Stellar/nebular relative attenuation

Reddy
Siana
Ferrara

- Different from local
- New recipes for stellar/nebular dust correction
- New insights on the relative distribution of dust and stars
- New insights on the dust properties and stellar population

Next step -> exploit Paschen and Brackett lines
Momcheva

Where do stars form? Where star formation is suppressed

- Look at stacks on, above and below the star-forming sequence
- Elevated (suppressed) at all radii above (below) the SF sequence
- e.g., no evidence for central starbursts
\( f_{esc}(\text{ion}), \xi_{ion}, f_{esc}(\text{Ly}\alpha) \) and reionization sources

A lot of progress being made despite the technical difficulties.

- Schauerer
- Reddy
- Stark
- Nakajima
- Marchi
- Fletcher
- Sobral
- Matthee
- Maseda
- Castellano
- Bowler

Connection between reionization and overdensities
Kinematics

Gas Kinematics (star forming galaxies):
- Higher velocity dispersion at high-z
- Lower $V_{\text{rot}}/\sigma$ at high-z

(Progenitor bias fully under control?)

Stellar Kinematics:
- probing (also) passive galaxies
Evolution of the Tully-Fisher relation?

Major problem: sample selection?
Some of the kinematic studies warnings:

- Constraining dark matter content
  -> need to reach larger radii
  (JWST, ELT, SKA2)

- Angular resolution
  (JWST, ELT)

- Non-uniform gas distribution
  (van der Wel)

[Images of kinematic studies results]
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[Images and graphs with credit to Ubler+17, Genzel+17, Williams+14, S. Kassin]
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Courtesy S. Kassin

Ubler+17
Genzel+17

HST H-band
Williams+14
Clumps (in-situ/ex-situ) and role of merging

Clumps: evidence for both
- in-situ formation (instabilities) and long survival times
- accreted clumps (minor merger)

Merger scenario vs “smooth” accretion... really alternative scenarios? (accreting flows are clumpy and form stars along the stream)
Probing cold flow accretion with 3D wide field spectroscopy

Great prospects for “tomography”

(Hammer)
Cosmological constraints using high-z HIIG

Terlevich

Constraints on IMF

“Any change in the slope of the IMF between $z \sim 0$ and $z \sim 2.5$ has to be less than $\sim 0.06$ at 1-$\sigma$ level.”
Next generation facilities: a sudden big leap in discovery space

DESI, 4MOST, WAVE, PFS, MOONS, Euclid, WFIRST: “SDSS-like” surveys at high-z

ELT/TMT: Will couple Sensitivity with angular resolution (Kassn)
Emission Line Galaxies with MOS:
from cosmic noon to the reionization era
18-22 September 2017, Kavli Institute for Cosmology, Cambridge, UK

Thank you!