The Evolution of Resolved Kinematics and Metallicity from $z=2.7$ to $0.7$ with LUCI, SINS and KMOS$^{3D}$

Eva Wuyts

Redshift Evolution of Velocity Dispersion

- overall decrease from z~4 to the present day
- driven by the evolution of gas fractions in near-critical disks

Wisnioski et al. 2014, to be submitted soon

Tracing Metallicity with the [NII]/Hα ratio

- consistent study over large redshift range 0.7 < z < 2.7
- MZR shows a constant slope at the low mass end -> redshift evolution fully described by the evolution of the characteristic turnover mass
- no correlation between [NII]/Hα and SFR at fixed mass and redshift

THE KMOS$^{3D}$ SAMPLE

223 targets - 80% detection rate

Stellar Mass vs. SFR

0.7<z<1.1

1.9<z<2.7

SFR vs. Stellar Mass

0.7<z<1.1

1.9<z<2.7

U-V vs. Stellar Mass

0.7<z<1.1

1.9<z<2.7
\(\sigma = 20\ \text{km/s}\)

\(v_{\text{obs}} = 110\ \text{km/s}\)

\(v_{\text{obs}} = 115\ \text{km/s}\)

\(v_{\text{obs}} = 108\ \text{km/s}\)

\(v_{\text{obs}} = 136\ \text{km/s}\)

\(\sigma = 26\ \text{km/s}\)

\(\sigma = 62\ \text{km/s}\)

\(\sigma = 57\ \text{km/s}\)

\(\langle \sigma \rangle = 25\ \text{km/s}\)

\(\langle \sigma \rangle = 55\ \text{km/s}\)
averages from low-z surveys
Wisnioski et al. (in prep), also see Kassin et al. 2012, 2014
Toomre stability criterion

\[
\frac{v_{\text{rot}}}{\sigma_0} = \frac{a}{f_{\text{gas}}(z)Q_{\text{crit}}}
\]

Genzel et al. 2008
DISPERSION EVOLUTION

Toomre stability criterium

\[ \frac{v_{\text{rot}}}{\sigma_0} = \frac{a}{f_{\text{gas}}(z) Q_{\text{crit}}} \]

Genzel et al. 2008

\[ \sigma_0(z) = \frac{1}{\sqrt{2}} v_{\text{rot}} f_{\text{gas}}(z) \]

Wisnioski et al. (in prep)

averages from low-z surveys

18x(1+z)
averages from low-z surveys

dispersion evolution
dependence of sample extracted from the COLD GASS catalog, revealing an increase of disks as a function of redshift. Several studies have now reported for which a CO-based measurement of Figure 11. The Astrophysical Journal (A color version of this figure is available in the online journal.)

redshift at $z = 2$, and may even be reversing. These three secure measurements are reproduced in.

As the PHIBSS sample extends to $z > 2$, and may even be reversing. As explained in Section 2, these secure measurements are reproduced in Geach et al. (2010a) to correct for sample incompleteness. As the sample of systems found in Geach et al. (2013) is compiled, CO measurements for several galaxies, accounting for this bias raises the mean gas fraction lensed galaxies with $0 < z < 8$. We then apply the methodology of Tacconi et al. (2013) to correct for sample incompleteness. As the sample of systems found in Geach et al. (2013) is compiled, CO measurements for several galaxies, accounting for this bias raises the mean gas fraction lensed galaxies with $0 < z < 8$. We then apply the methodology of Tacconi et al. (2013) to correct for sample incompleteness.

To correct for sample incompleteness, we combine all $f_{\text{gas}} = \frac{1}{1 + (t_{\text{dep}}sSFR)^{-1}}$

Wisnioski et al. (in prep)

Tacconi et al. 2013

Wisnioski et al. (in prep)
Dependence of disk gas fraction on redshift. Several studies have reported increasing gas fraction with redshift, but the extension beyond the MS galaxies in lensed and comparison samples above redshift intervals from the lensed and comparison samples as well as from PHIBSS, and corrects for sample incompleteness. On the left plot, the gray shaded region is the expected redshift flattening because of the shallower evolution of gas.

\[
f_{\text{gas}} = \frac{1}{1 + (t_{\text{dep}}sSFR)^{-1}},
\]

\[
t_{\text{dep}}(z) = 1.5(1 + z)^\alpha \text{[Gyr]},
\]

[Tacconi et al. 2013]

\[
sSFR(M_*, z) =
\begin{cases}
0.07 \left( \frac{M_*}{10^{10.5} M_\odot} \right)^{-0.1} (1 + z)^3 & \text{if } z < 2 \\
0.30 \left( \frac{M_*}{10^{10.5} M_\odot} \right)^{-0.1} (1 + z)^{5/3} & \text{if } z > 2.
\end{cases}
\]

[Lilly et al. 2013]

Wisnioski et al. (in prep)
**DISPERSION EVOLUTION**

Toomre stability criterium

\[
\frac{v_{\text{rot}}}{\sigma_0} = \frac{a}{f_{\text{gas}}(z) Q_{\text{crit}}}
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\sigma_0(z) = \frac{1}{\sqrt{2}} v_{\text{rot}} f_{\text{gas}}(z)
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THE COMBINED SINS + LUCI + KMOS\textsuperscript{3D} SAMPLE

222 SFGs @ \( z=0.9-2.3 \)

- SINS/zC-SINF
  - 12 SFGs @ \( z=1.5 \)
  - 49 SFGs @ \( z=2.3 \)

- LUCI
  - 14 SFGs @ \( z=1.5 \)
  - 38 SFGs @ \( z=2.3 \)

- KMOS\textsuperscript{3D}
  - 62 SFGs @ \( z=0.9 \)
  - 47 SFGs @ \( z=2.3 \)

Wuyts+2014
THE MASS-METALLICITY RELATION

AGN = classic indicators X-ray, radio, IRAC colours, rest-frame UV spectra (18)

broad AGN-driven outflows
Genzel+2014 (20)

-> 17% contamination

83% detection rate of [NII]

Wuyts+2014
THE MASS-METALLICITY RELATION

$\frac{[\text{NII}]}{H\alpha}$ vs $\log(M_*/M_\odot)$

Comparison with different models:
- $z=0.08$ (KE08)
- $z=0.08$ (Z13)
- $z=1.6$ (Z13)
- $z=2.2$ (E06)
- $z=2.3$ (S14)

Wuyts+2014
FITTING THE MASS-METALLICITY RELATION

\[ 12 + \log(O/H) = Z_0 + \log \left[ 1 - \exp \left( - \left[ \frac{M_*}{M_0} \right]^{\gamma} \right) \right] \]

Zahid+2014

<table>
<thead>
<tr>
<th>Reference</th>
<th>Redshift</th>
<th>(Z_0) (\pm 0.01)</th>
<th>(\log(M_0/M_\odot)) (\pm 0.02)</th>
<th>(\gamma) (\pm 0.01)</th>
<th>(\log(M_{0\text{fixed}}/M_\odot)) (\pm 0.05)</th>
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<tbody>
<tr>
<td>Z13</td>
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<td>9.02 (\pm 0.02)</td>
<td>0.40 (\pm 0.01)</td>
<td>8.95 (\pm 0.05)</td>
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<tr>
<td>This work</td>
<td>0.90</td>
<td>8.8 (\pm 0.4)</td>
<td>10.2 (\pm 0.9)</td>
<td>0.4 (\pm 0.6)</td>
<td>9.78 (\pm 0.11)</td>
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<td>8.7 (\pm 0.3)</td>
<td>10.5 (\pm 0.5)</td>
<td>0.5 (\pm 0.2)</td>
<td>10.36 (\pm 0.06)</td>
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Fitting the Mass-Metallicity Relation

$12 + \log(O/H) = Z_0 + \log \left[ 1 - \exp \left( -\frac{M_*}{M_0} \right)^\gamma \right]$

Zahid+2014

Constant asymptotic metallicity $Z_0 = 8.7$

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FITTING THE MASS-METALLICITY RELATION

\[ 12 + \log(O/H) = Z_0 + \log \left[ 1 - \exp \left( -\left( \frac{M_*}{M_\odot} \right)^\gamma \right) \right] \]

\[ \gamma = 0.4 \]

Constant slope

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The redshift evolution of the MZR can be described fully in terms of the evolution of the characteristic turnover mass

$$
\log(M_0/M_\odot) = (8.86 \pm 0.05) + (2.92 \pm 0.16) \log(1 + z).
$$
CORRELATION WITH STAR FORMATION RATE

Wuyts+2014
No correlation between $\text{[NII]}$/H$\alpha$ and SFR at fixed redshift and stellar mass.

The redshift evolutions of metallicity and SFR might not be causally related.
METALLICITY GRADIENTS

![Graphs showing metallicity gradients with various parameters](image-url)
METALLICITY GRADIENTS

we need to understand beam-smearing

Yuan+2013

Förster Schreiber (in prep.)
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extra
CORRELATION WITH STAR FORMATION RATE

162 galaxies, FMOS, z=1.6

Zahid et al. 2013
CORRELATION WITH STAR FORMATION RATE

SFR\textsubscript{UV+IR} and SFR\textsubscript{Ha}

162 galaxies, FMOS, z=1.6

Zahid et al. 2013