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Stellar populations and chemical abundance ratios in the bulge of M31

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IAU

IAU Symposium 395: Stellar populations in the Milky Way and beyond

An event sponsored by the IAU | November 17-22, 2024

LAYOUT

- Why the bulge of M31?
- The bulge of M31 with OSIRIS@GTC (optical)
- The bulge of M31 with LUCI@LBT (NIR)

ETGs and bulges: unresolved stellar populations (SPs)

ETGs and bulges include >75% stellar mass in the local universe (Renzini 2006)

Unresolved SPs, even with JWST (resolution of turn-off stars <4Mpc; Brown+2011)

Key properties

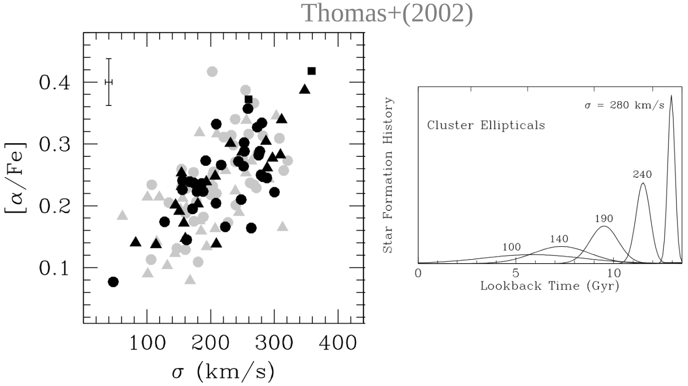
- ages/metallicities
- abundance ratios
- stellar IMF

- the stellar IMF (high-mass) drives abundance ratios
- abundances affect IMF-sensitive absorption features

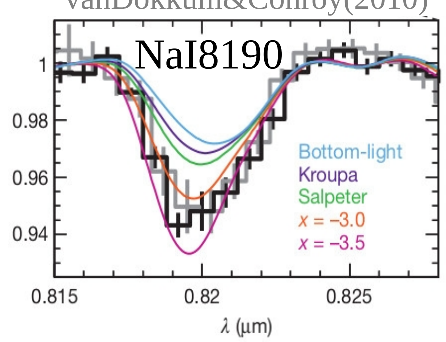
SF timescale decreases with galaxy mass

Non-universal (bottom-heavy) IMF in massive ETGs

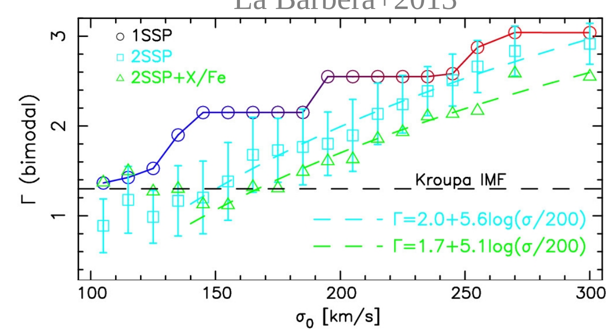
Thomas+(2002)



vanDokkum&Conroy(2010)



La Barbera+2013



Why the bulge of M31?

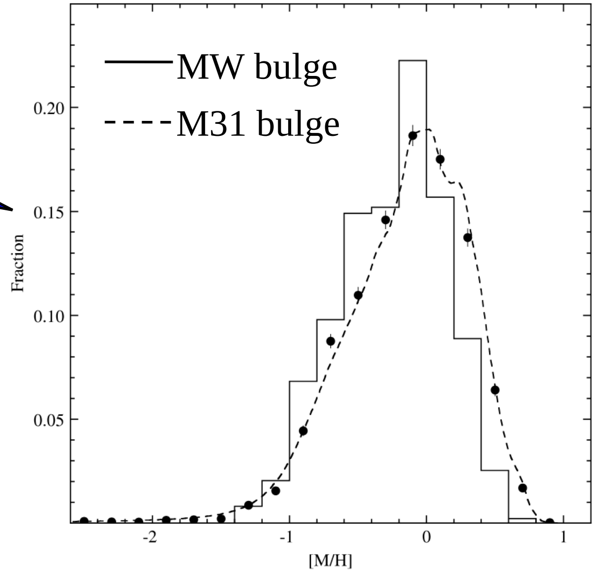
- low velocity dispersion (150km/s), implying tight constraints on the M/L (consistent with a Kroupa-like IMF)

- high metallicity in the center (<10''), solar metallicity outwards, and [α/Fe]~0.2, as in massive ETGs

- independent constraints on SP paramaters from resolved SP studies

testing workbench of
SP models and unresolved SP studies

Sarajedini&Jablonka(2005)

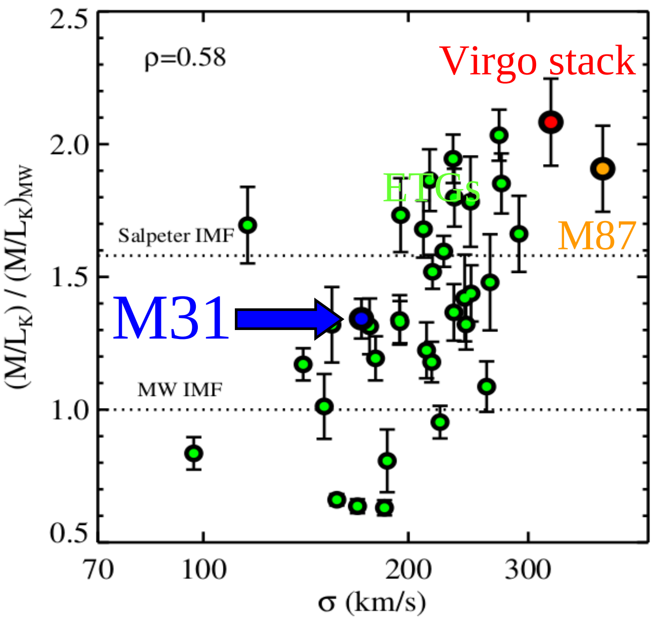


[Na/Fe]-enhanced, top- or bottom-heavy?

strong NaI8200
(Spinrad&Taylor 1971; O'Connell 1976) → dwarf-dominated IMF (M/L=44)

weak FeH0.99 and strong CO2.30
(e.g. Faber 1972; Whitford 1977; Cohen et al. 1978) → MW-like or giants-enhanced IMF

Conrov&vanDokkum(2012b)



→ IMF normalization between MW and Salpeter
(within the innermost 10'')

→ [Na/Fe]~1dex (!!), while [Na/Fe]<0.3dex in the MW bulge (Bensby+2017; but see Barbuy+2023 and refs therein).

Zieleniewski et al.(2015)

V12 models → bottom-heavy IMF at all radii   CvD models → lighter IMF, but high [Na/Fe]

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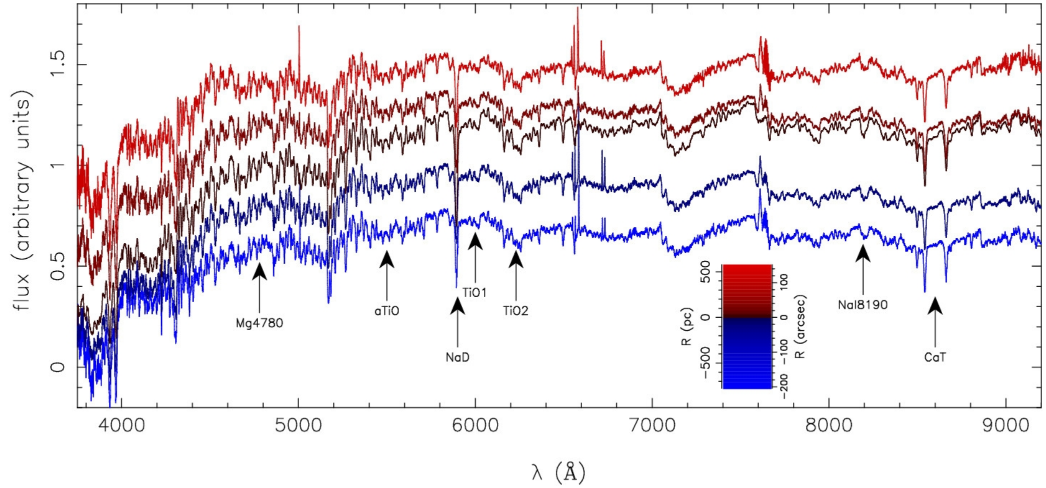
New M31 spectroscopy with 10m telescopes

(La Barbera, F., Vazdekis, A., Ferreras, I., Pasquali, A., 2021, MNRAS, 505, 415)

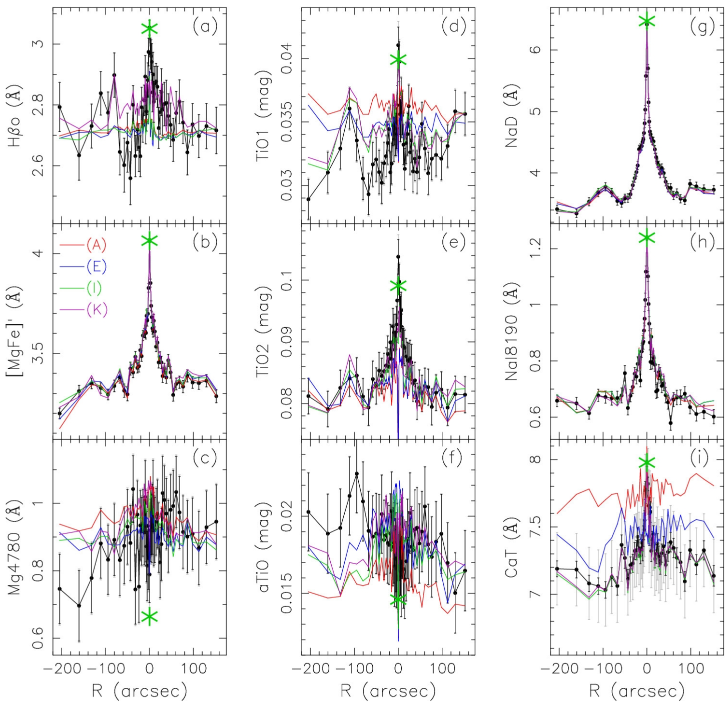
OSIRIS-GTC longslit spectroscopy along the bulge major axis

(GTC39-17A; PI: A. Vazdekis)

- Radially binned spectra, S/N>100Å^{-1}
- UVRI grisms (350-1000nm; R~3400)



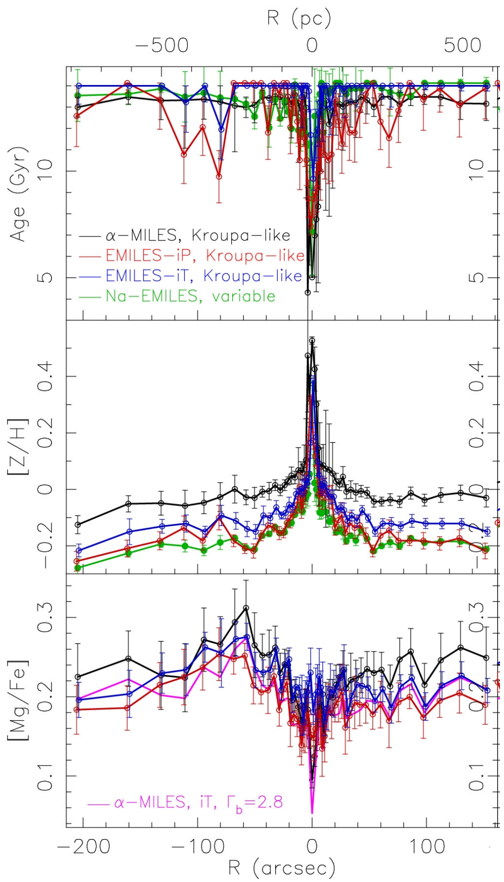
We fit a large set of line-strengths, simultaneously:
Hb, Hg, [MgFe]', Mgb5177, Mg1, Mg2, C4668, CN2, Fe4531 Mg4780, TiO1, TiO2, aTiO, NaD, NaI8190, Ca1, Ca2, CaT, aTiO with varying age, [M/H], [X/Fe]'s, and IMF

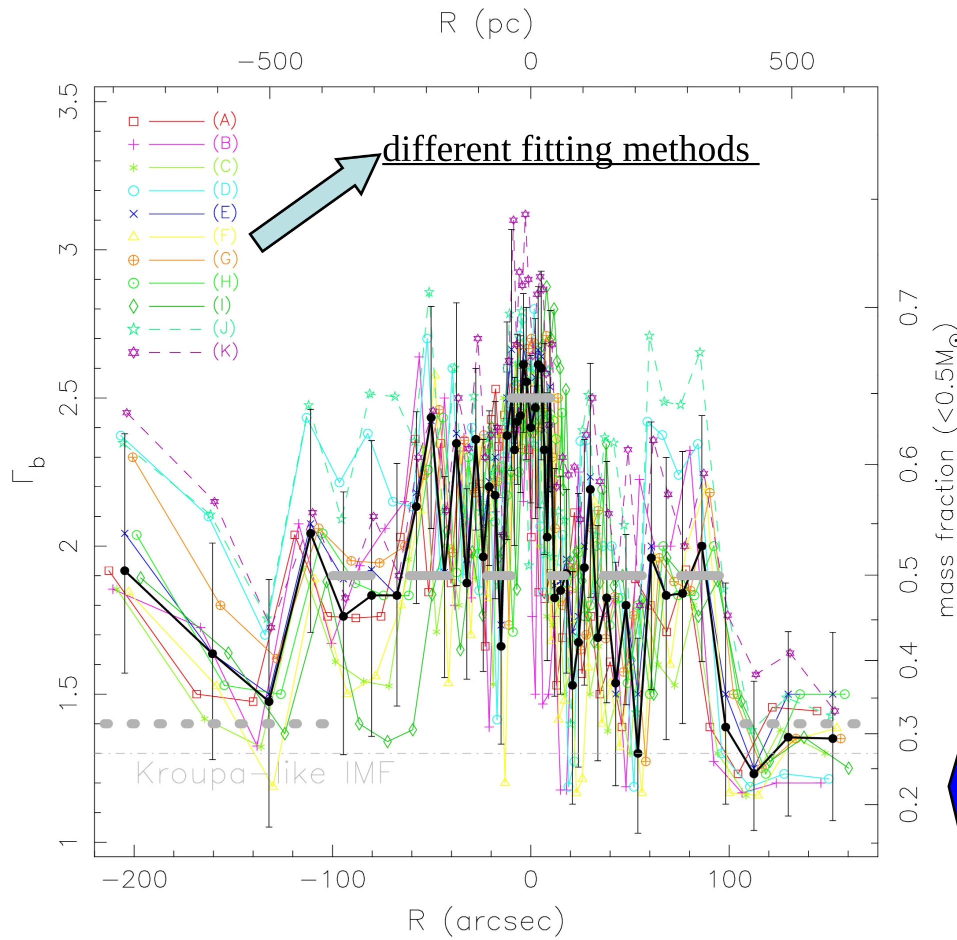


Na-enhanced EMILES models (Vazdekis+2015; La Barbera+2019)

CvD models to compute responses to varying [X/Fe]'s

Radial gradients of age, [Z/H], [Mg/Fe], and IMF slope

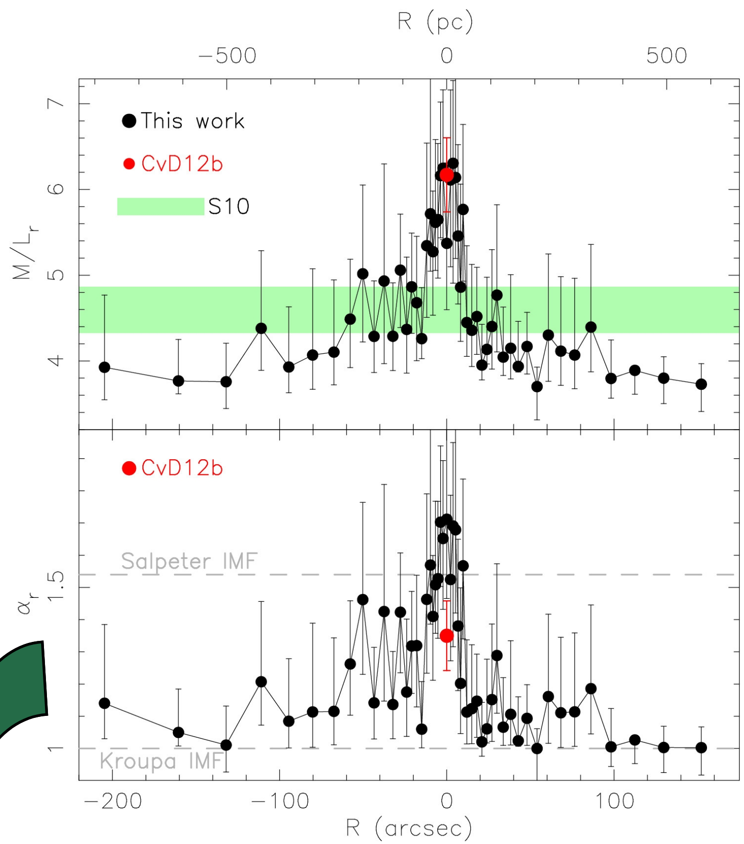


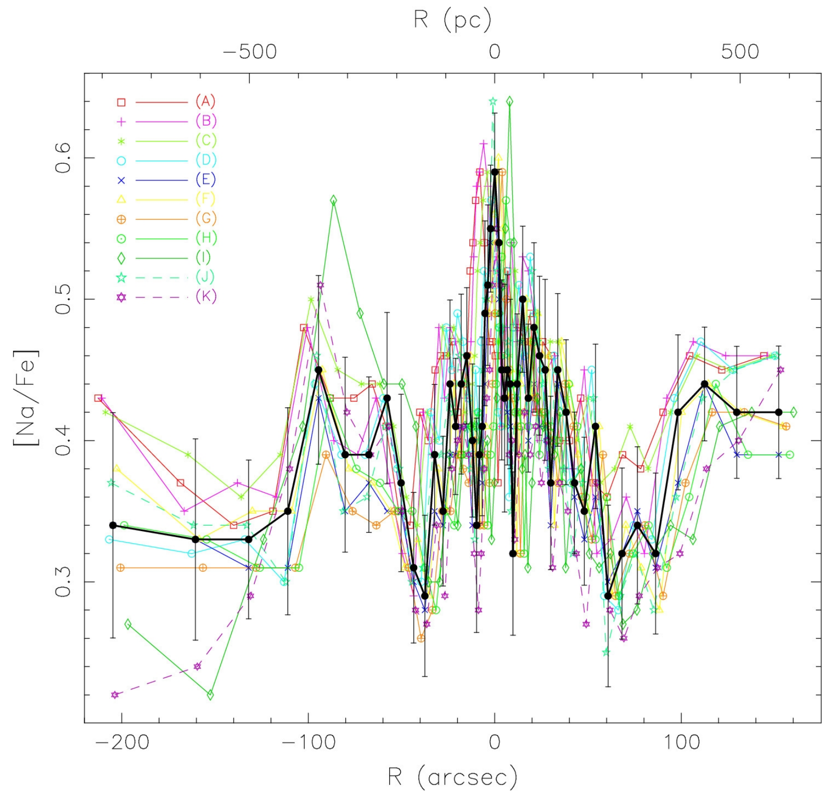


Age, [M/H], and [α/Fe] radial trends consistent with previous works (e.g. Saglia et al. 2010, 2018). [M/H] is consistent with resolved SP studies (Sarajedini&Jablonka 2005).

Radial IMF gradient, with a (mildly) bottom-heavy distribution only in the inner bulge (<10’’)

Radial gradients of M_*/L and [Na/Fe]





- M/L_r consistent with Salpeter-like IMF only in the center (in agreement with CvD12).
- Average M/L_r consistent with a MW-like IMF (in agreement with Saglia+2010)

- Radial [Na/Fe] gradient, with “low” [Na/Fe] (~0.3-0.5dex; as for ETGs)

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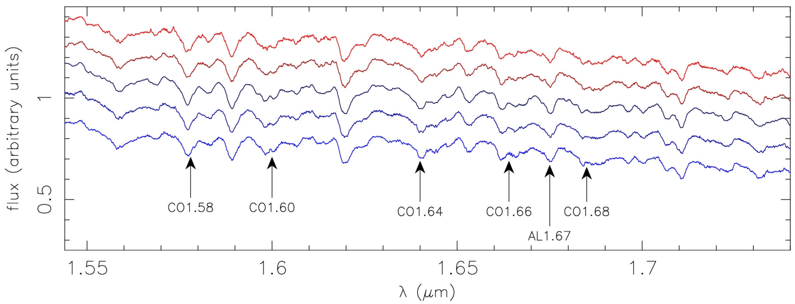
Radial trends of CO features in the bulge of M31

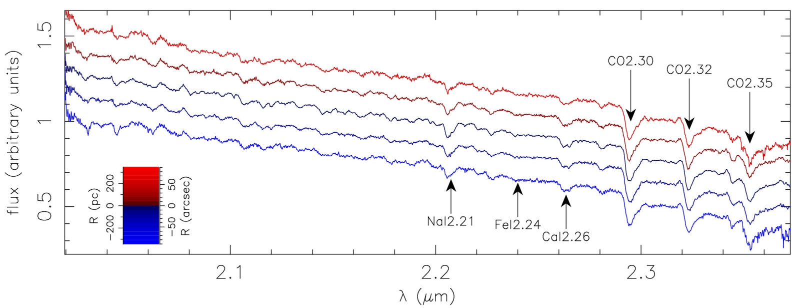
(La Barbera, F., et al., 2024, A&A, 687, 156)

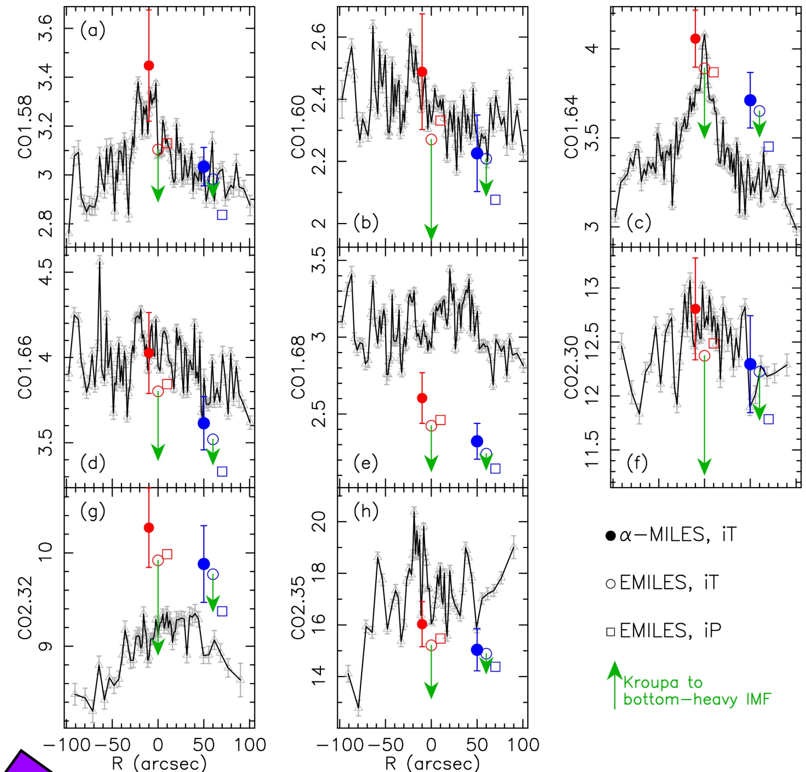
New NIR spectroscopy with LUCI@LBT along the bulge major axis

(LBTB 2019+2021,P.I.: A. Pasquali; IT-2021B-017, P.I.: F. La Barbera)

- (J)HK grisms (990-2370nm; R~3300)
- Radially binned spectra with S/N>200 A^{-1}







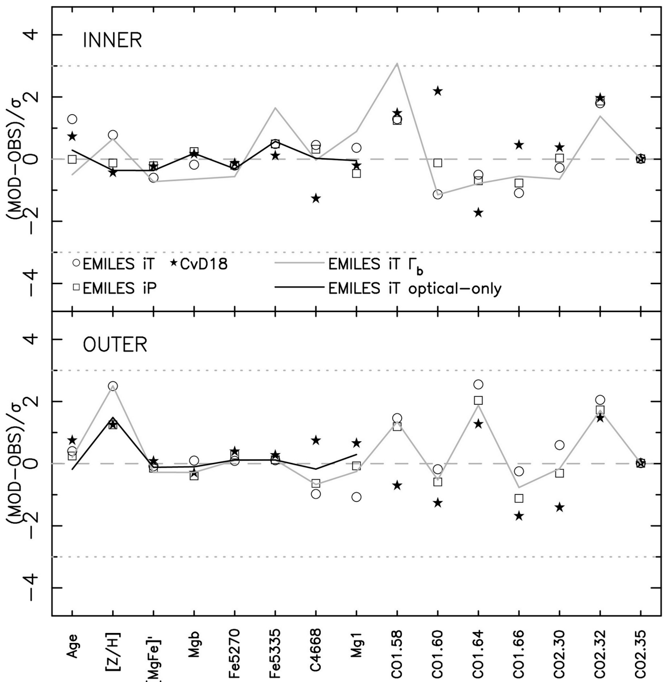
In contrast to the optical (e.g. $C_2$4668), CO radial trends in H/K band are mostly flat (but for CO1.64).

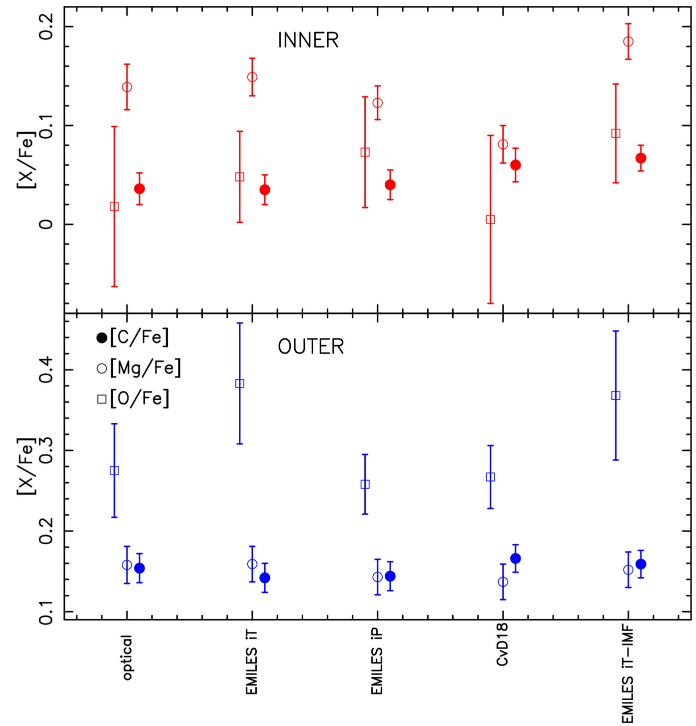
1SSP model predictions, based on results from the optical, are close to the data

Fitting optical+CO features for the M31 bulge

(La Barbera, F., et al., 2024, A&A, 687, 156)

Difference of observed and best-fitting indices.





Best-fitting C, Mg, O abundance ratios.

- We match, simultaneously, optical + all CO indices with age, [Z/H], C, Mg, and O abundances as free fitting parameters.

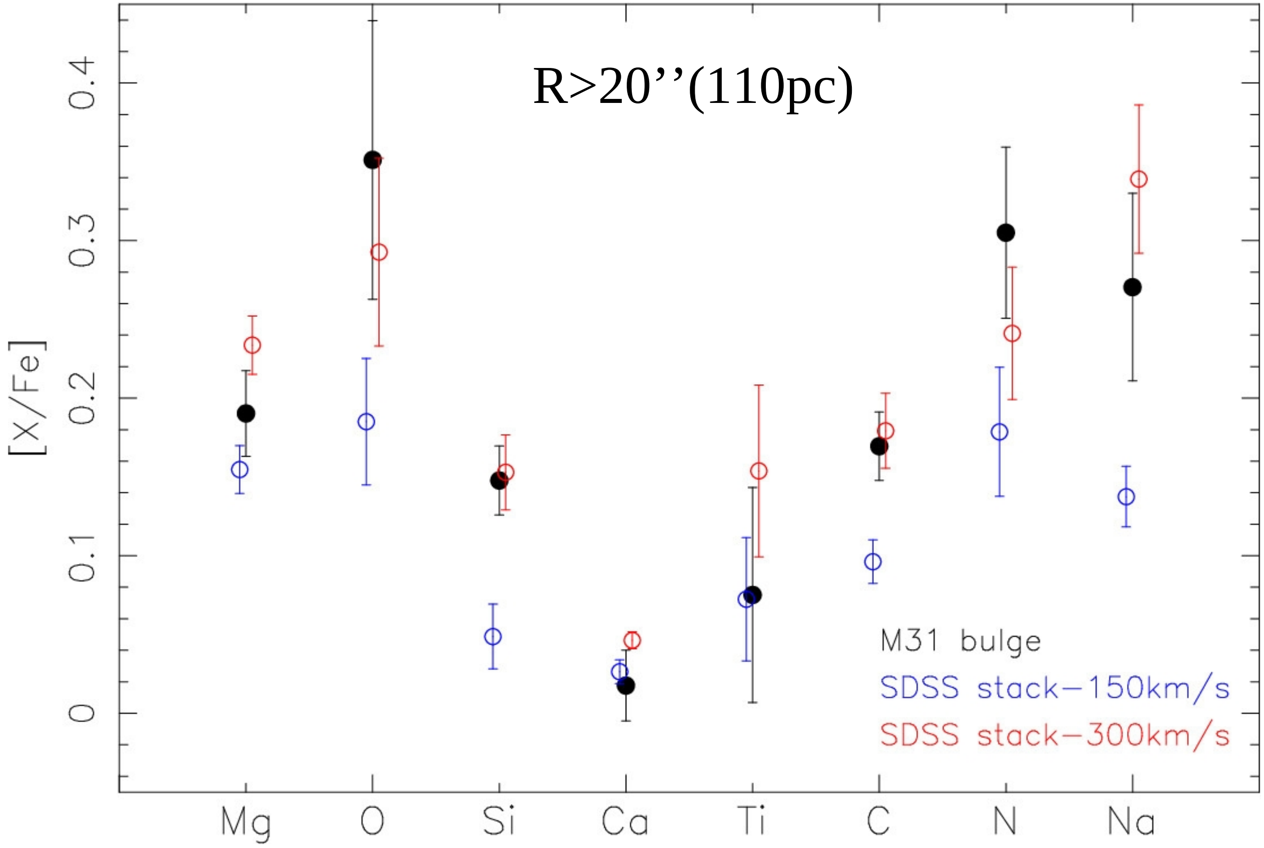
- For the bulk of the bulge: [Mg/Fe]~0.15dex, [O/Fe]>[Mg/Fe] (by ~0.1 dex), and [C/Fe]~[Mg/Fe] (qualitatively consistent with chemical evolution models, see Marcon-Uchida+2015).
  - M31 bulge seems more enhanced in C and O than the MW bulge, while similarly enhanced in Mg (Bensby+2017, 2021; see Barbuy+2018 and refs therein).

- In the central few arcsec, we still find an enhancement of Mg, but significantly lower [C/Fe]

Individual abundance ratios for the bulge of M31

(La Barbera, F., et al., 2024c, A&A, in prep)

Abundance ratios are estimated through full spectral fitting and full index fitting (Martín-Navarro+2019), using response functions from CvD18, and averaging results for EMILES and CvD18 models.



- Mg, C, O, and Na abundances agree with those estimated from line-strengths.
- O, N, Na are strongly enhanced (~0.3dex), followed by C, Mg, Si (0.15-0.2dex), and then Ti, Ca (tracking Fe).
- All abundances are similar to those of very massive ETGs.

Summary

*Take home message

- A *mildly* bottom-heavy IMF is found in the center (<10'') of M31, with a MW-like distribution at larger distances. The overall bulge M/L is close to that for a MW-like IMF.

- We find [Na/Fe] ~0.3-0.5dex, significantly lower than previously claimed.

- For the bulk of the bulge ($\gtrsim$100pc), O, N, Na are strongly enhanced (~0.3dex), followed by C, Mg, Si (0.15-0.2dex), and then Ti, Ca (tracking Fe), as in most massive ETGs.

- H and K-band CO line-strengths do not show significant radial gradients in the M31 bulge, and are matched with state-of-the-art SSP models.

- The abundances of C, O, and Mg from the NIR CO's are consistent with those from the optical.