Failed supernovae may help understanding the Early Universe

The Outlook:

- Endpoint of Core Collapse: always SN or maybe not?
- The importance of assessing the fate of massive stars
- A phenomenological scenario for GC Formation
- JWST reveals more activity at z~5-16 than“expected”

Alvio Renzini, Padova, April 1, 2024

First Modern Supernova From Padova

LO SPETTRO DELLA SUPERNOVA (1960) IN NGC 4496

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SOMMARIO. — Sono descritti alcuni spettri della supernova (1960), apparsa in NGC 4496, ottenuti con lo spettrografo newtoniano al telescopio di 122 cm di Asiago. La supernova risulta di tipo I. Il suo sviluppo spettroscopico nei primi 41 giorni dopo il massimo appare identico a quello di altre supernovae dello stesso tipo. Seguono alcune brevi considerazioni generali sul fenomeno delle supernovae.

ABSTRACT. — Some spectra of supernova (1960) in NGC 4496, obtained with the newtonian spectrograph applied to the 122 cm reflector of Asiago, are here described. The spectra are characteristic of a supernova type I. They appear closely similar to the spectra of other supernovae at the same phase. General considerations on the outburst of supernovae follow.

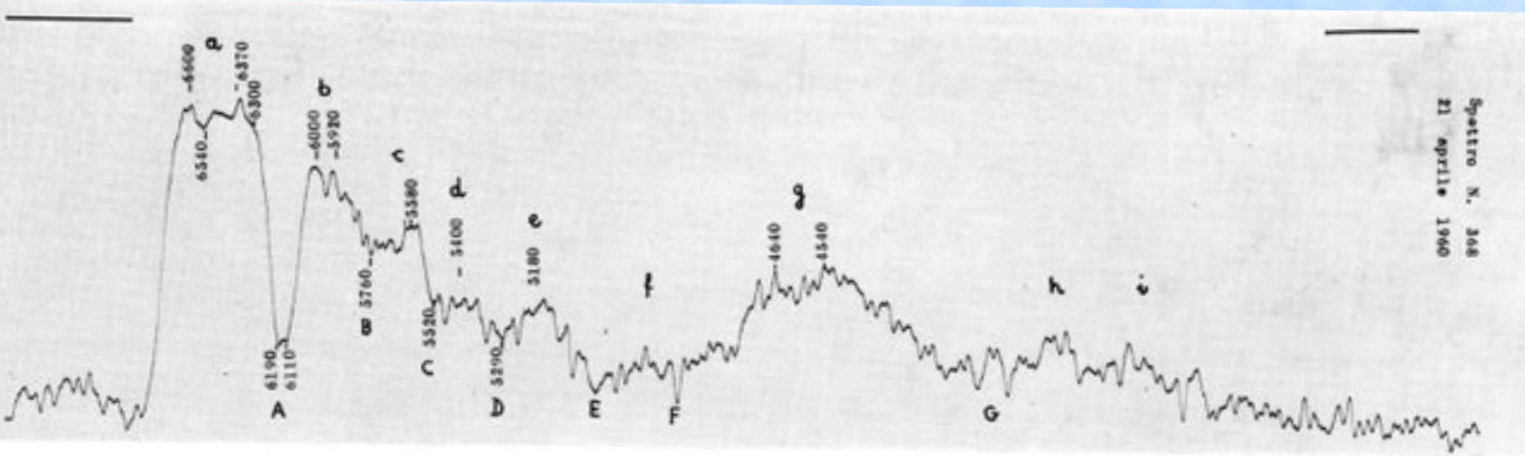
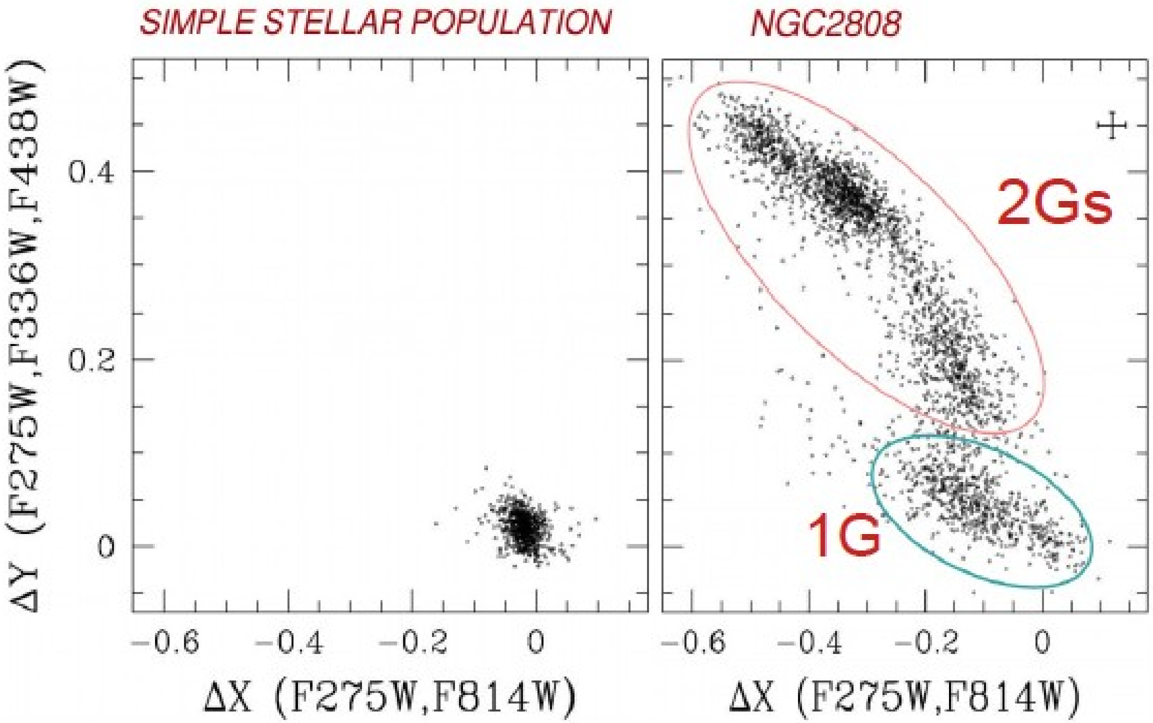


Fig. 4

“Chromosome Maps” of this kind now exists for 57 GCs

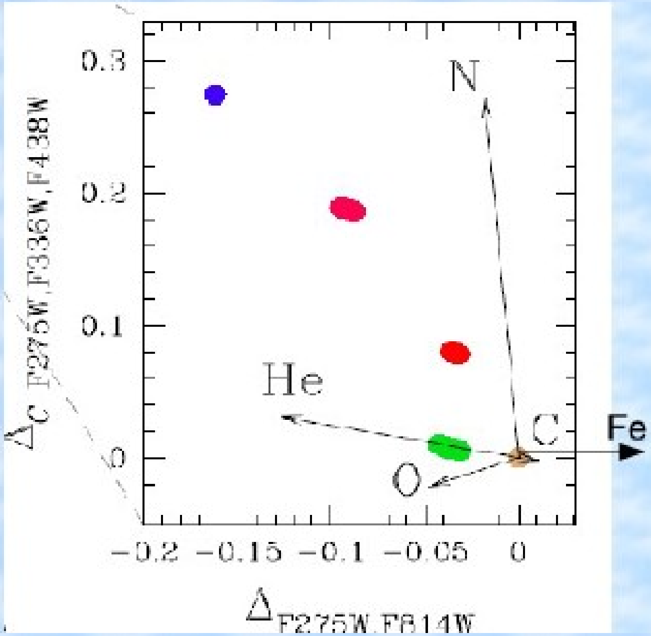
No extra Supernova products in 2G stars!



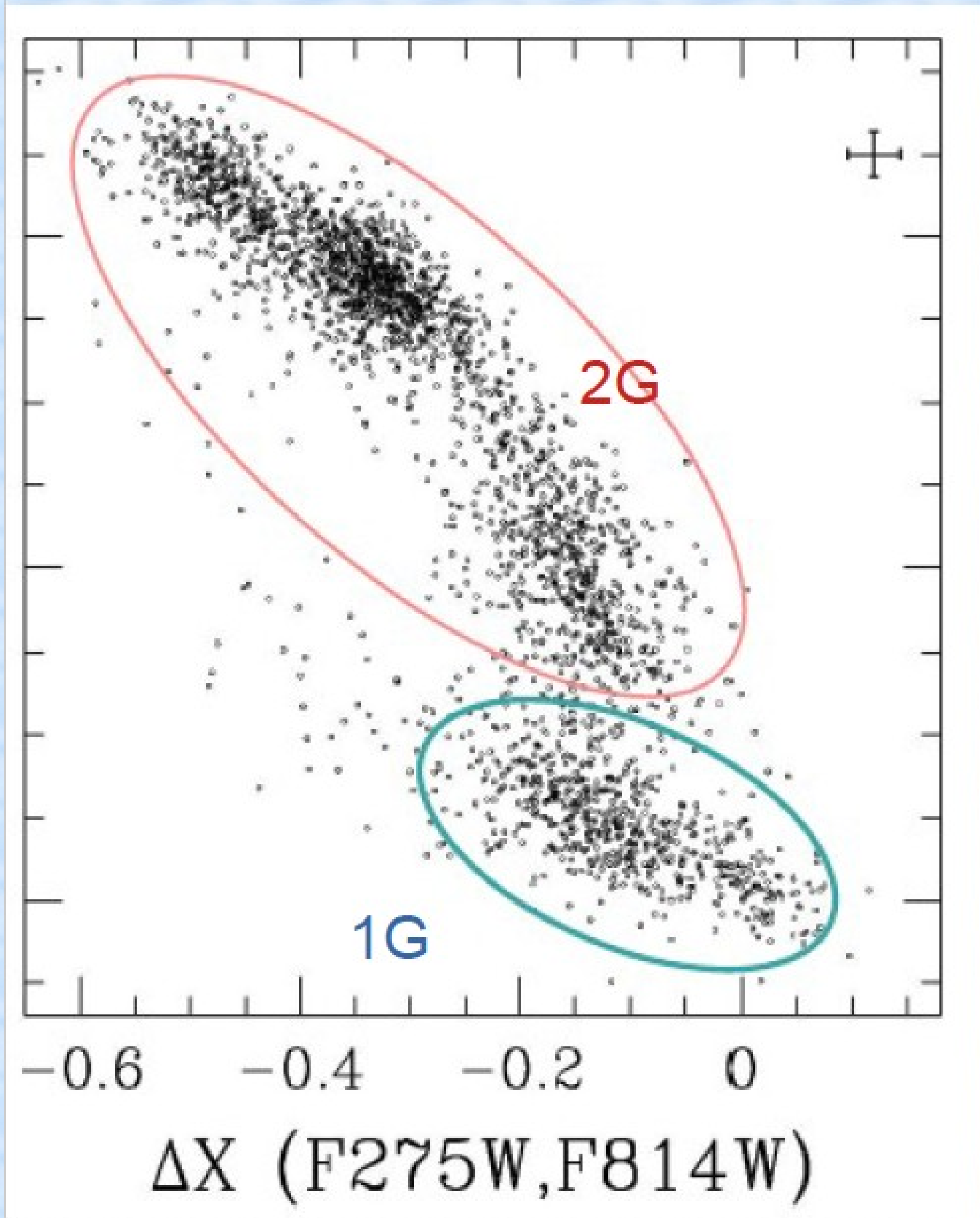
Courtesy of Tonino Milone

2G stars are enriched in Nitrogen, Helium, and Sodium and depleted in Carbon and Oxygen

Molecular bands of NH, OH, CN, CH, and H_2O tell the difference

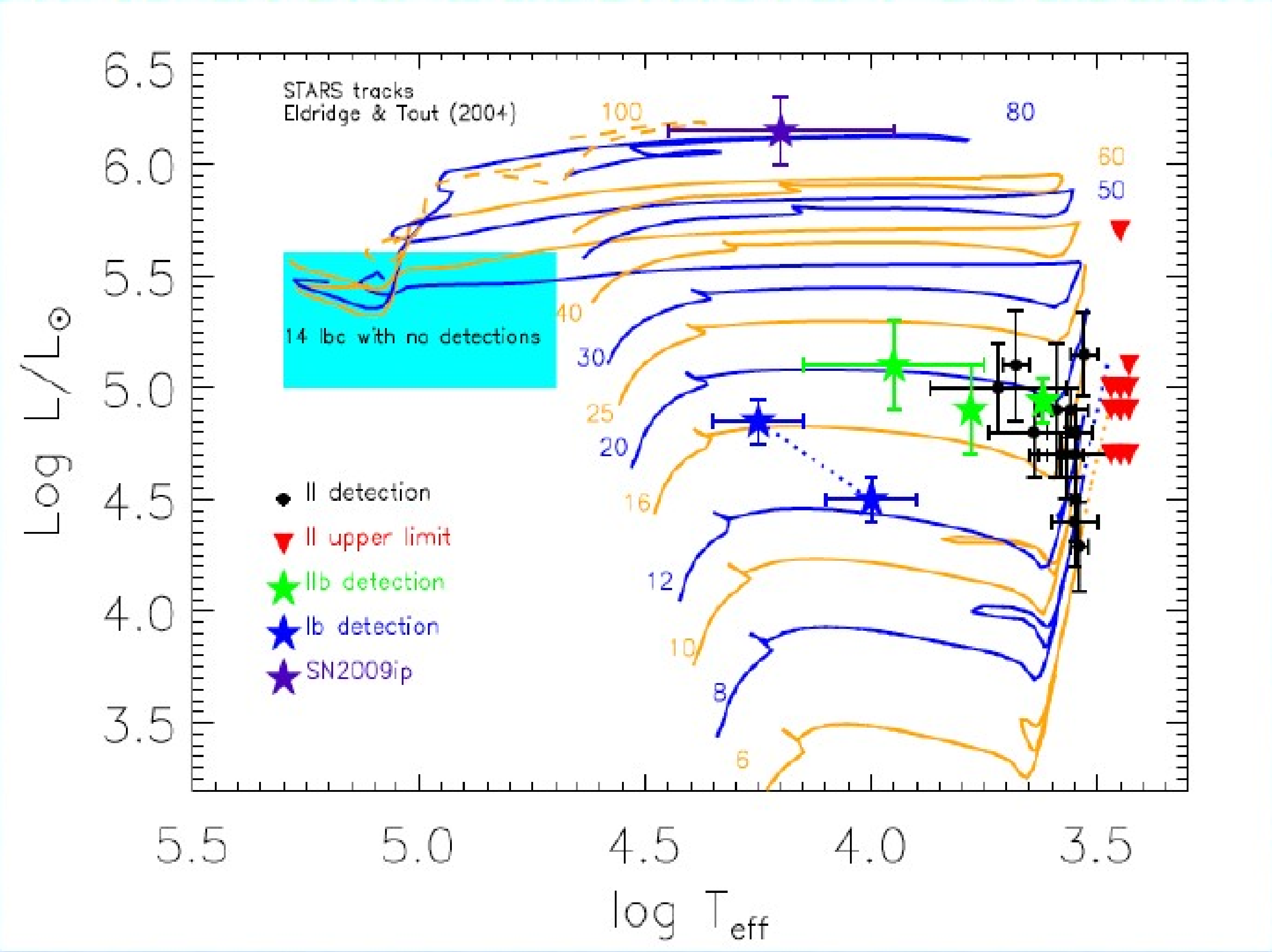


How to read the Chromosome Map



- The formation of the first generation did not prevent the formation of second generations
  ➡ There was no Negative Feedback!
- Stars kept forming out of gas with varying composition, but without supernova products
  ➡ No Feedback, No SN products
- No supernovae during 2G formation!

How to avoid Supernova Feedback & products



Smartt 2015: no SN precursor more massive than ~18 $M_\odot$

Limong & Chieffi 2018 Recommend no SNe above ~25$M_\odot$

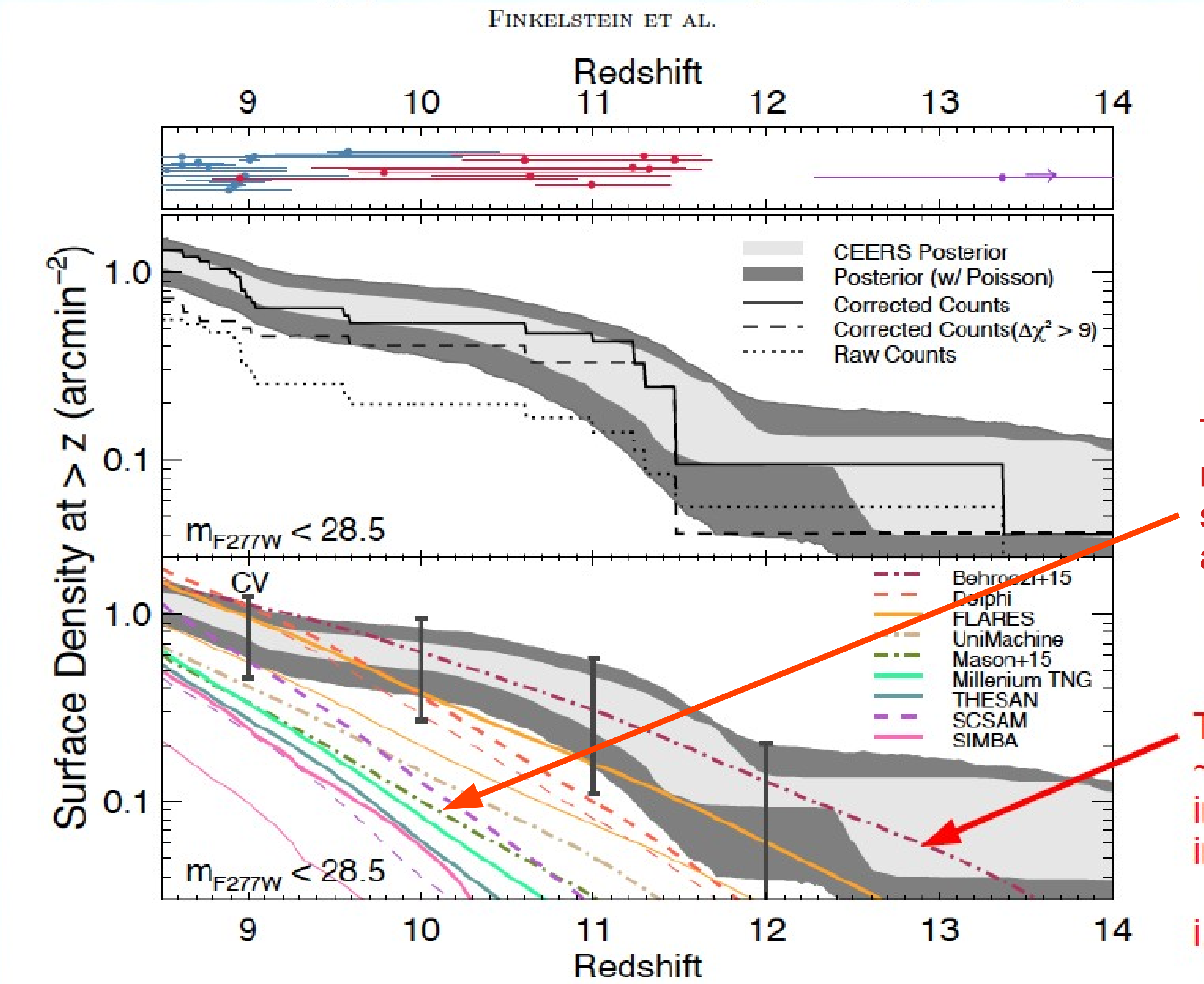
Independent supporting arguments in Smartt 2015; Li+2023; Sukhbold+2016; Adams+2017; Eldridge & Stanway 2022, ARAA

If so, supernova feedback is delayd ~10 Myr after a burst of star formation!

What if stars >~20 $M_{\odot}$ fail to explode?

- A 10 Myr Delayed FEEDBAK/transient overcooling
- will facilitate local burstiness in star formation
- may facilitate the formation of giant clumps
- may help to form extreme baryon Concentrations... such as GCs, very compact galaxies and early seeds to form SMBHs

Apparent excess of massive galaxies at high z over theoretical simulations



The pre-JWST models adopted strong feedback to avoid overcooling

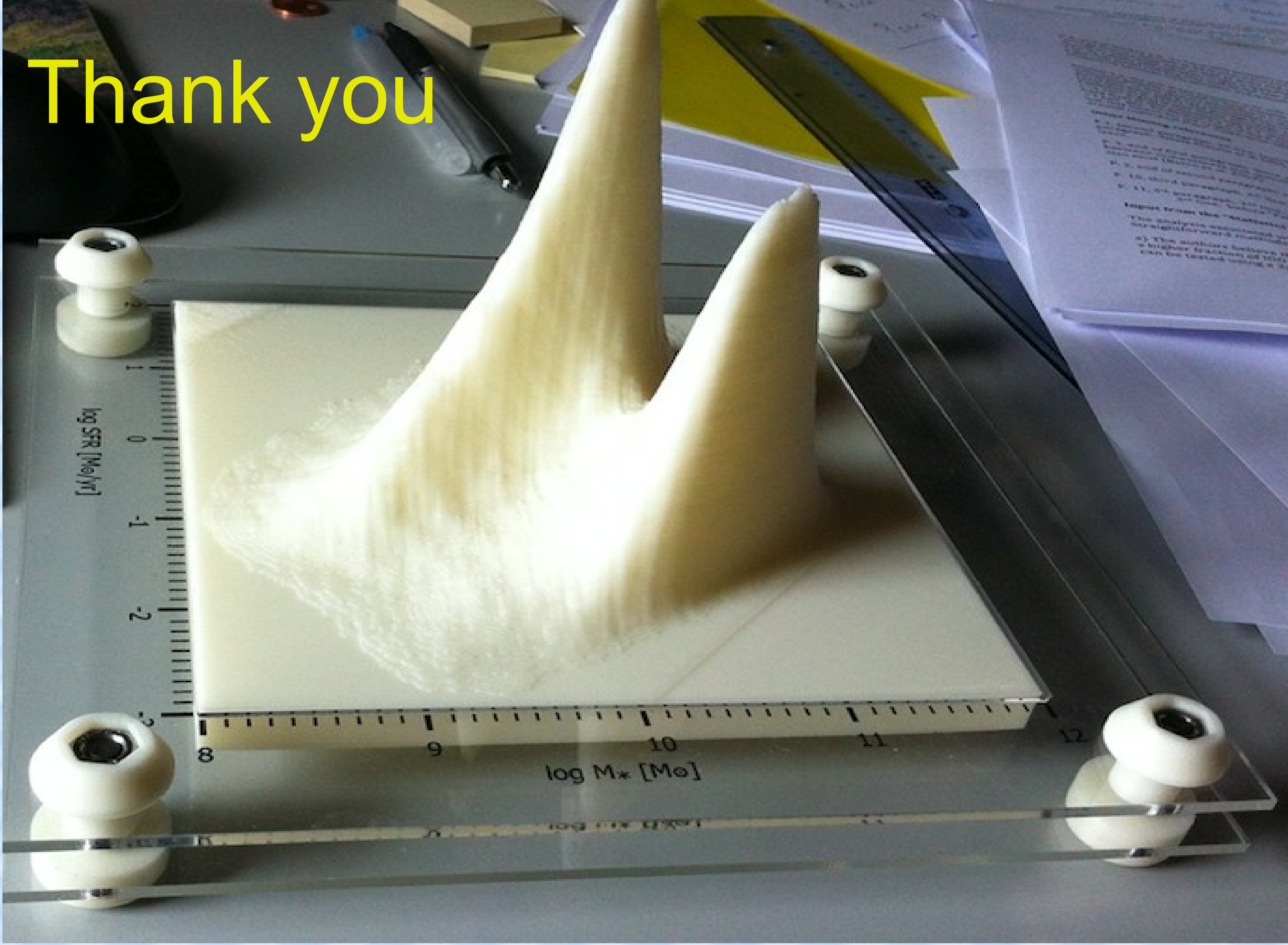
This assumes ~100% efficiency in converting gas into stars

i.e., overcooling

Establishing the mass ranges for successful and failed supernovae resulting from the core collapse of massive stars is of paramount importance:

- In itself
- For understanding the formation of globular clusters
- For the formation of extreme baryon concentrations in the early Universe (compact galaxies, SMBHs, ...)
- Euclid wide-field imaging may settle the issue, by identifying large numbers of successful/failed SN precursors (a` la Smartt-2015)

Thank you



The densest baryon concentrations we know of:
Globular Clusters, Nuclear Star Clusters, SMBHs

- ☻ Formed easily in the early Universe

- ☻ Apparently, not much SN feedback was contrasting a tendence of Baryons to cool, sink and reach extreme densities while deepening potential wells.

➤ Understanding how globular clusters formed may help to understand z=9-16 galaxies and early SMBH formation as revealed by JWST