Hydrodynamical simulations of the variable accretion on to Sgr A*

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Visualization credit: Manuel Behrendt (MERA+Paraview)


10” ~ 0.4 pc
Credit: ESO/S. Gillessen et al.

10” ~ 0.4 pc

Credit: EHT Collaboration

Credit: ESO/S. Gillessen et al.

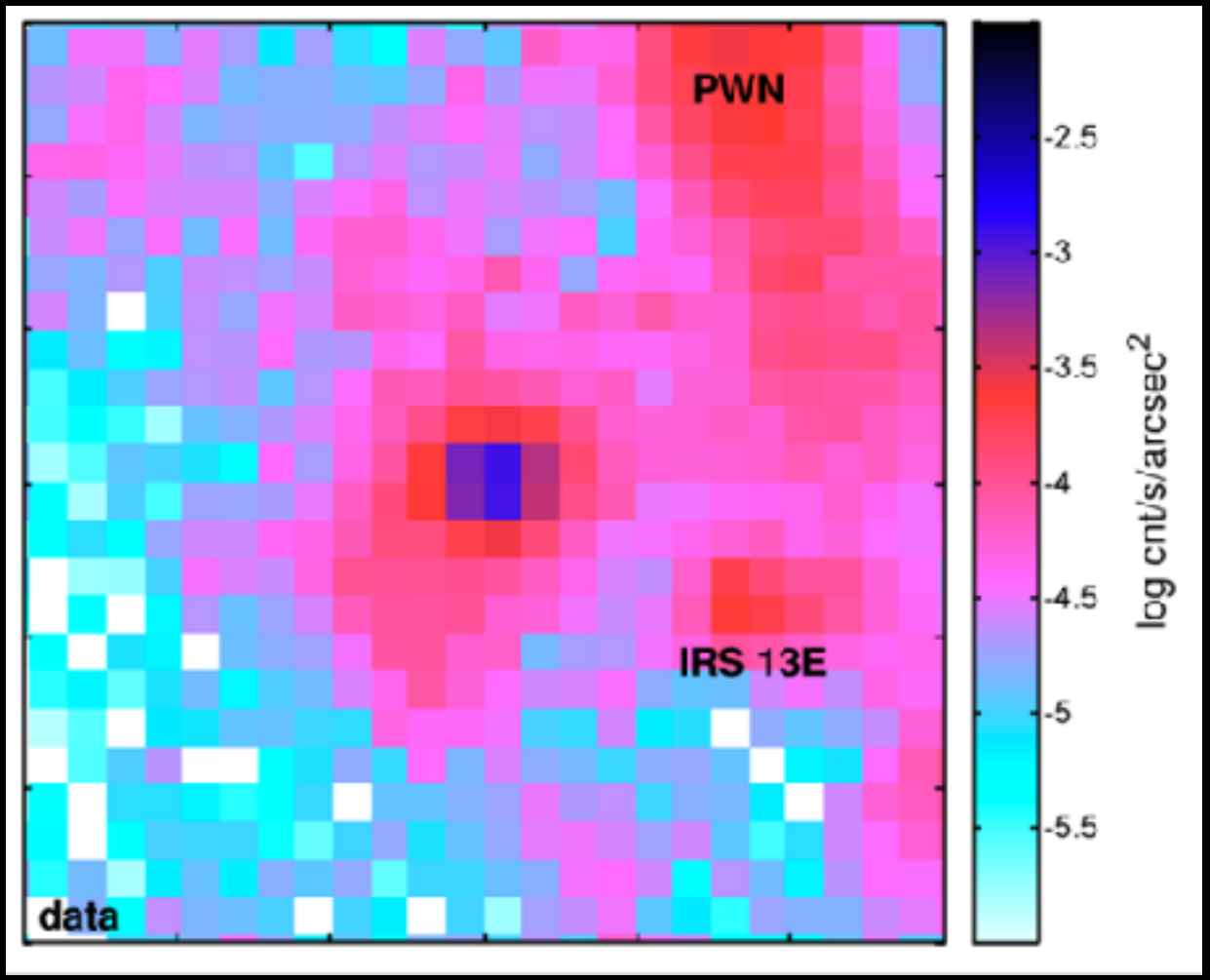
Stellar winds in the Galactic Centre

- Young, massive stars.
- Many of them are Wolf-Rayet → strong stellar winds
- Shocked winds should create hot plasma.

Gemini Observatory/François Rigaut

Hot Gas in the Galactic Centre

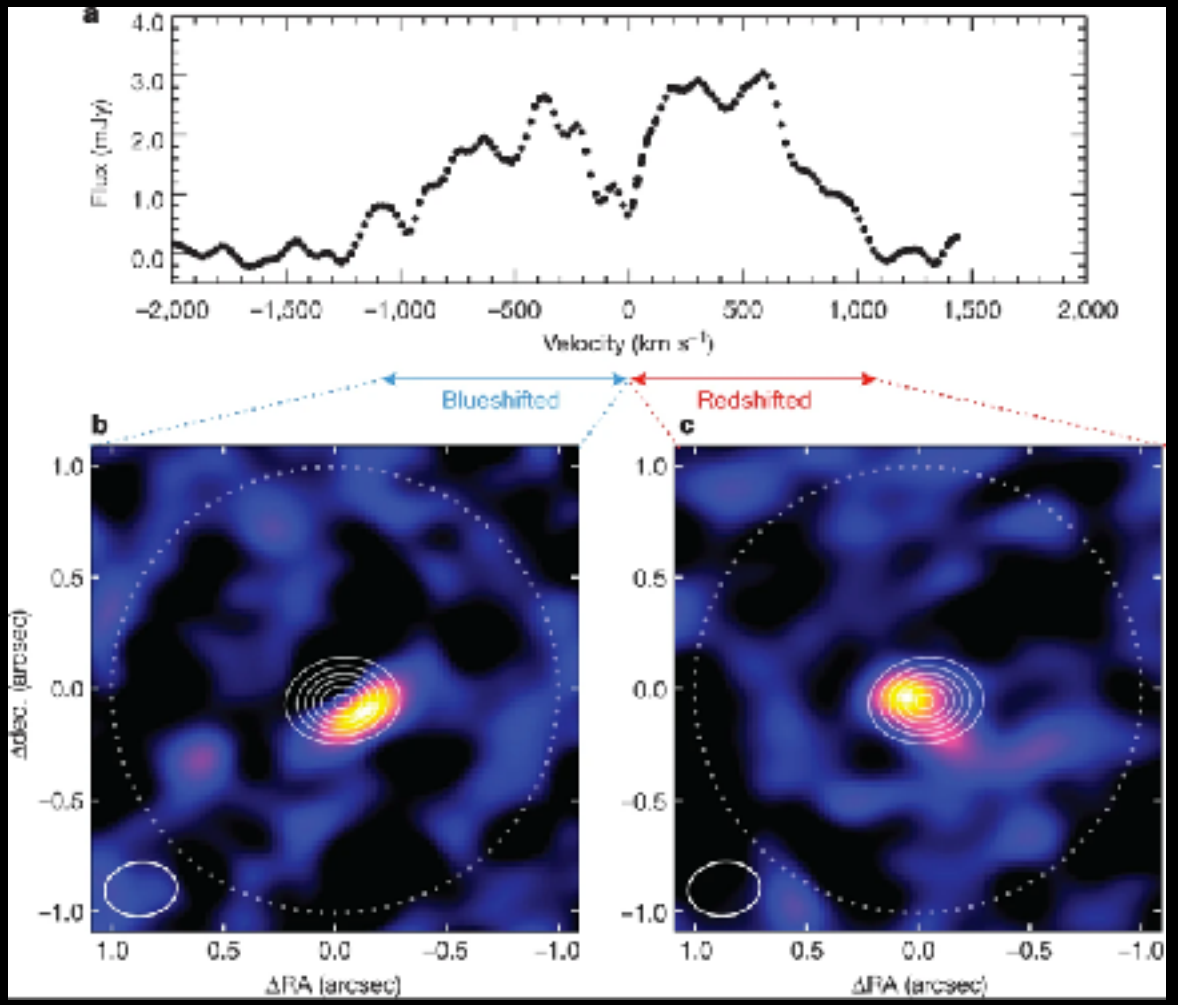
12” ~ 0.41 pc



Chandra 4-9 keV image, consistent with ~10^7 K plasma
(Wang et al. 2013, Russell et al. 2017)

A cold, disc-like structure around Sgr A, but no standard-disc accretion*

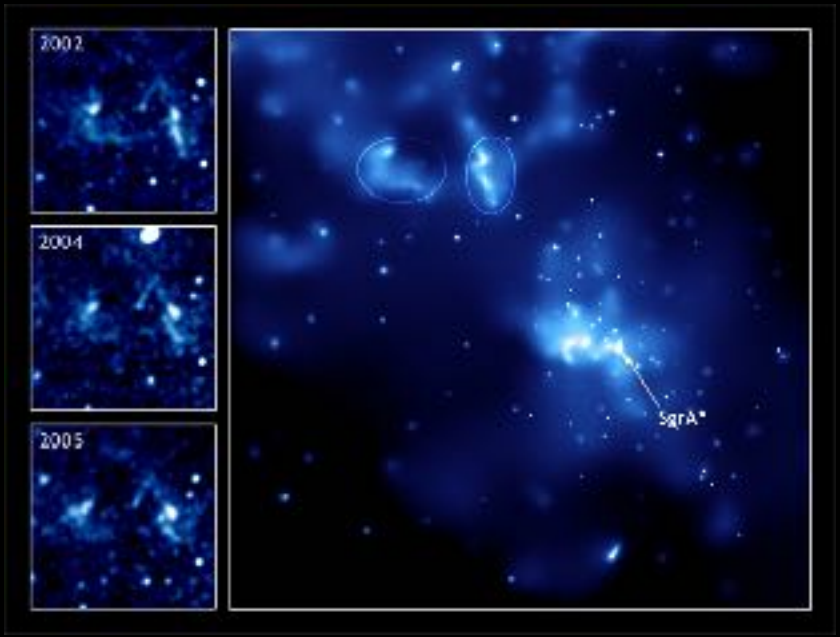
2” ~ 0.08 pc



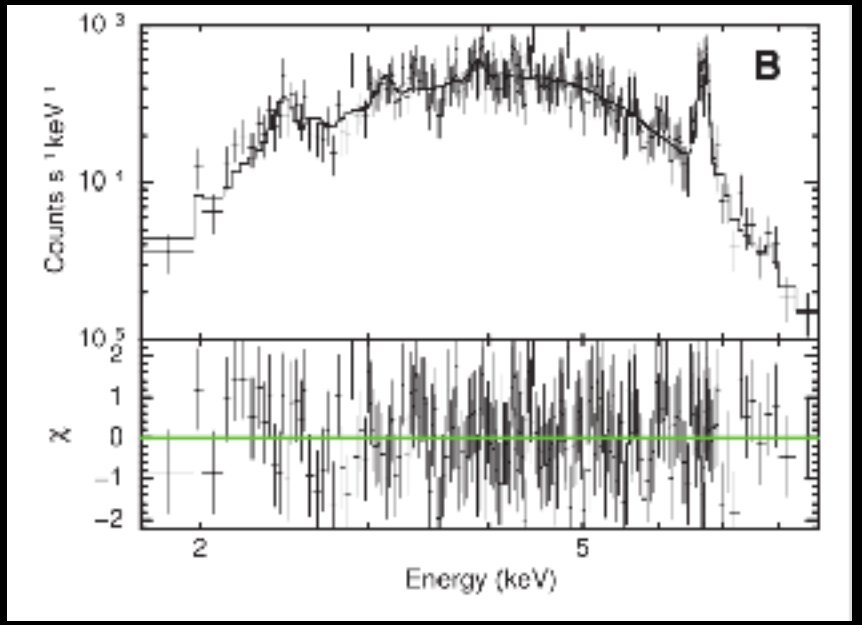
ALMA spectrum of the H30α line integrated around ~0.01 pc of Sgr A*
(Murchikova et al. 2019).

Sgr A* is currently inactive, but…

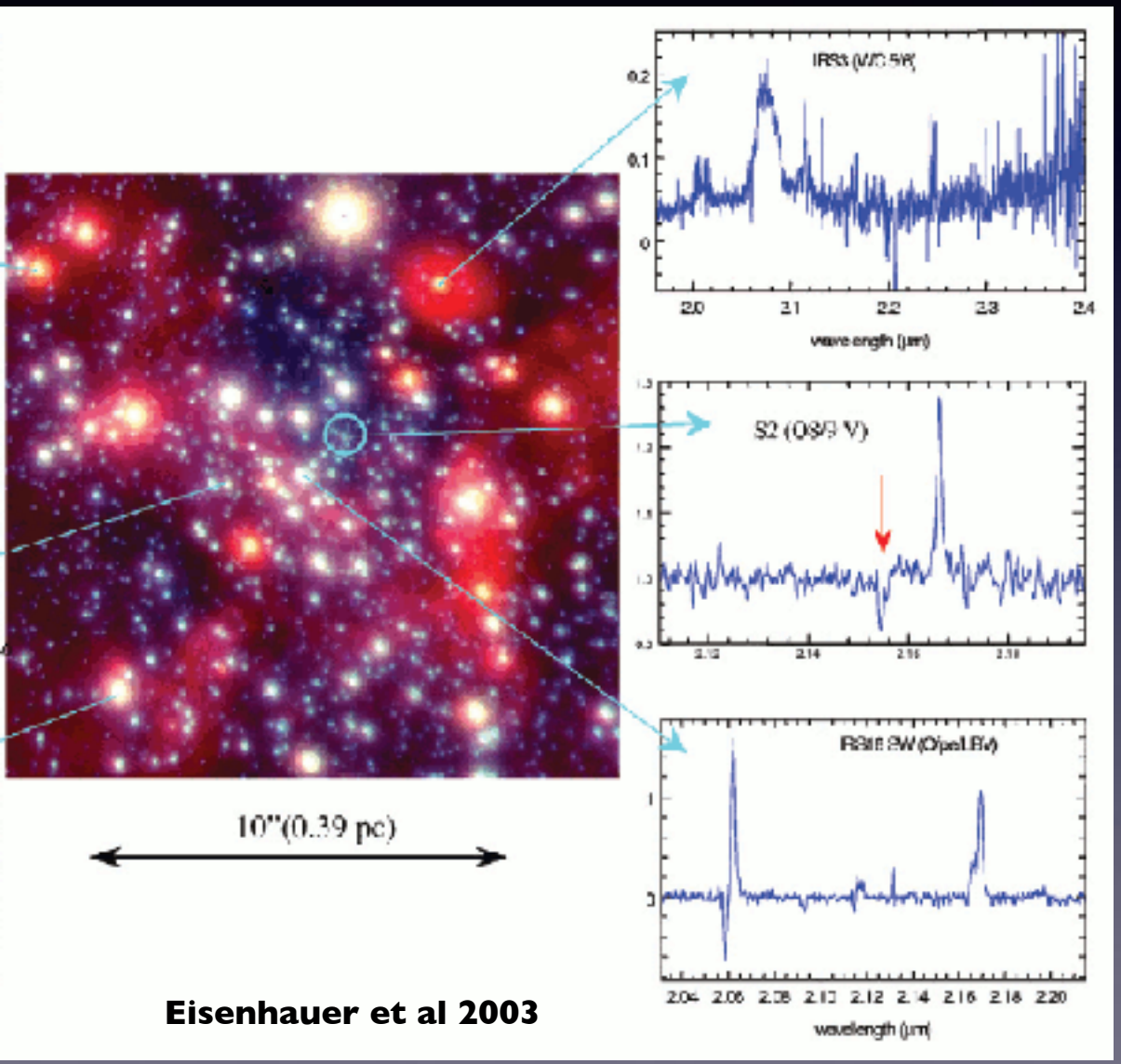
X-ray echoes suggest a more active past of Sgr A*
(eg, Sunyaev et al. 1993, Muno et al. 2007, Ponti et al. 2010, Marin et al 2023)



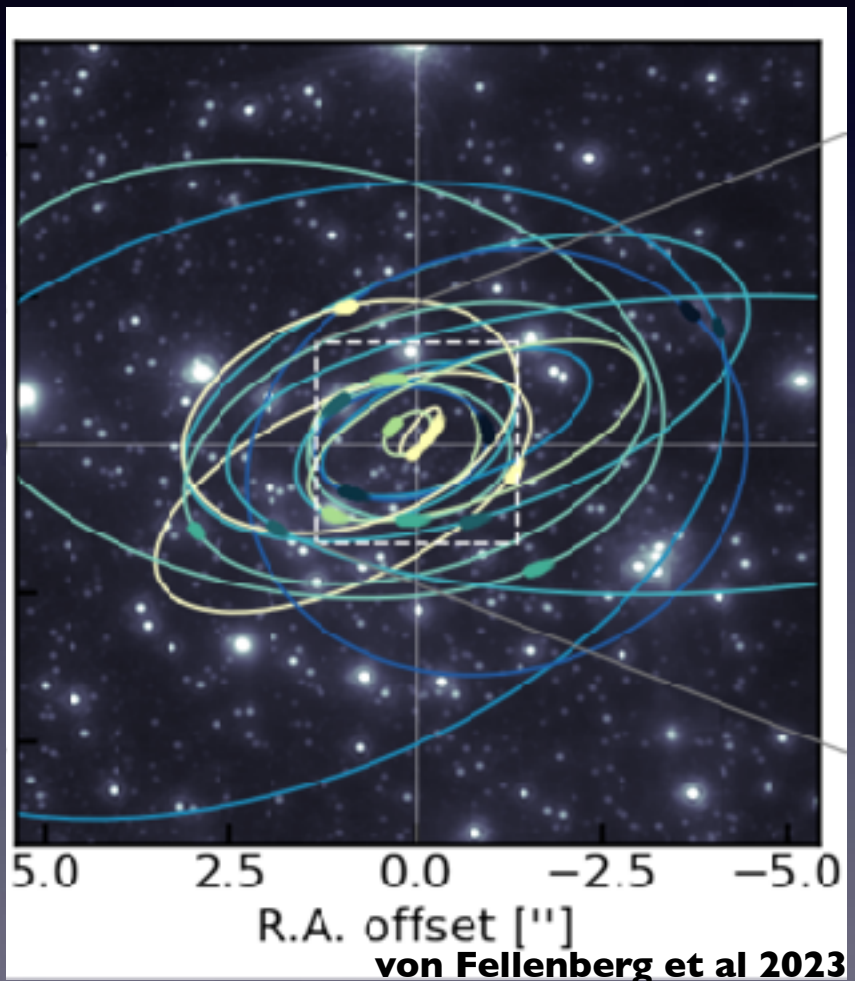
X-ray spectrum is well reproduced by an accretion flow model with an outflow
(Wang et al. 2013, Russell et al 2017)



How can we explain all this?
use stellar data to model hydrodynamics

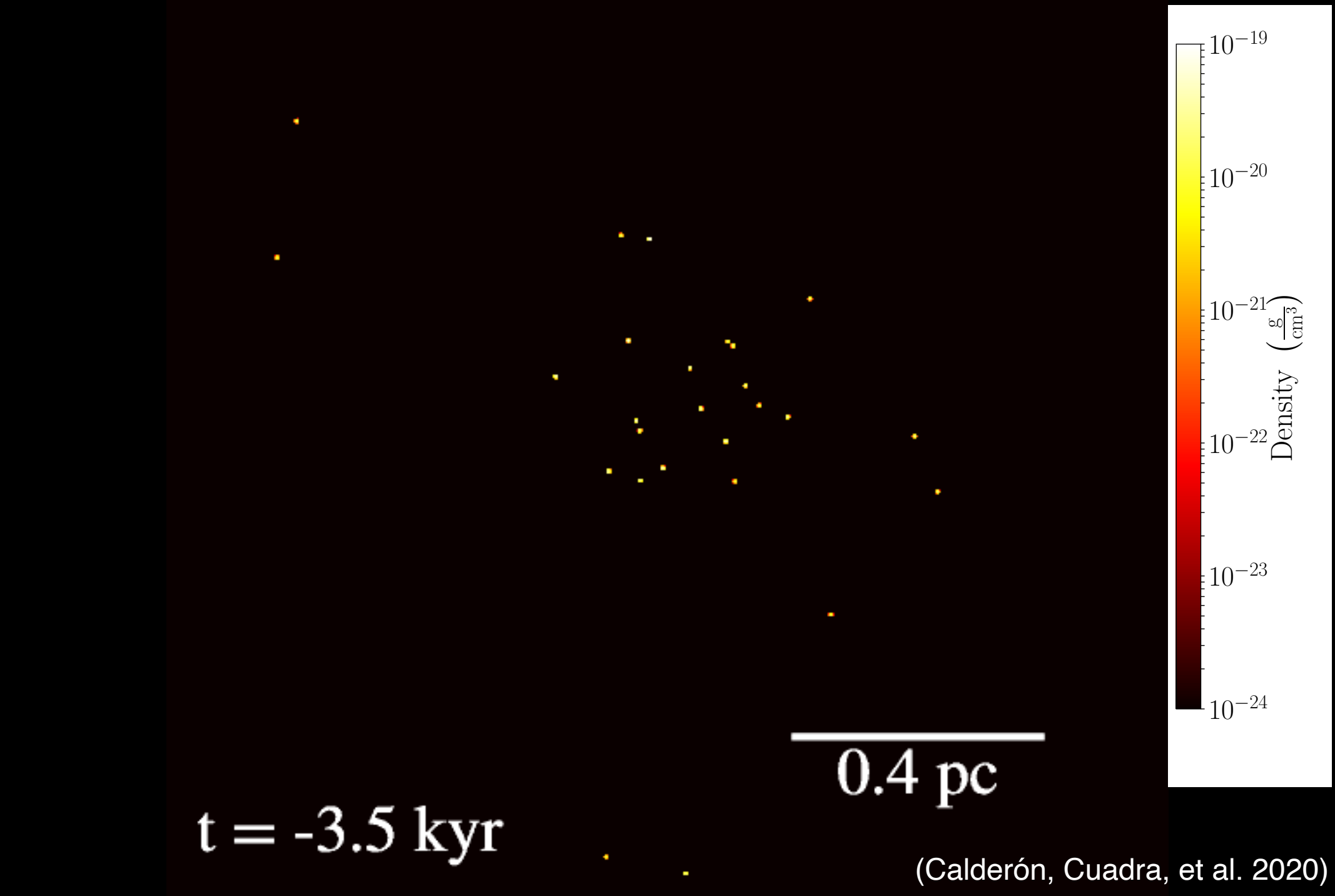


Eisenhauer et al 2003

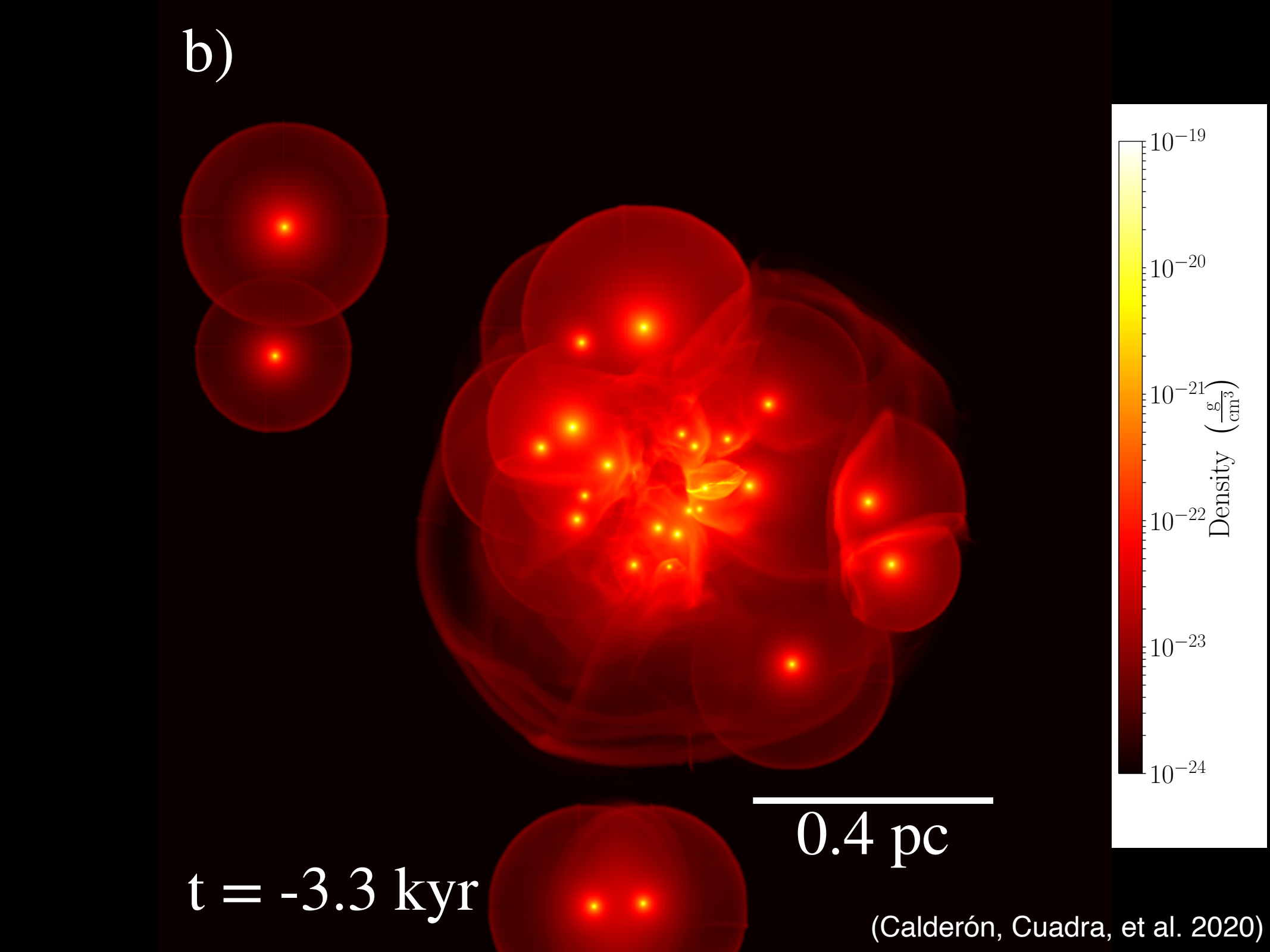


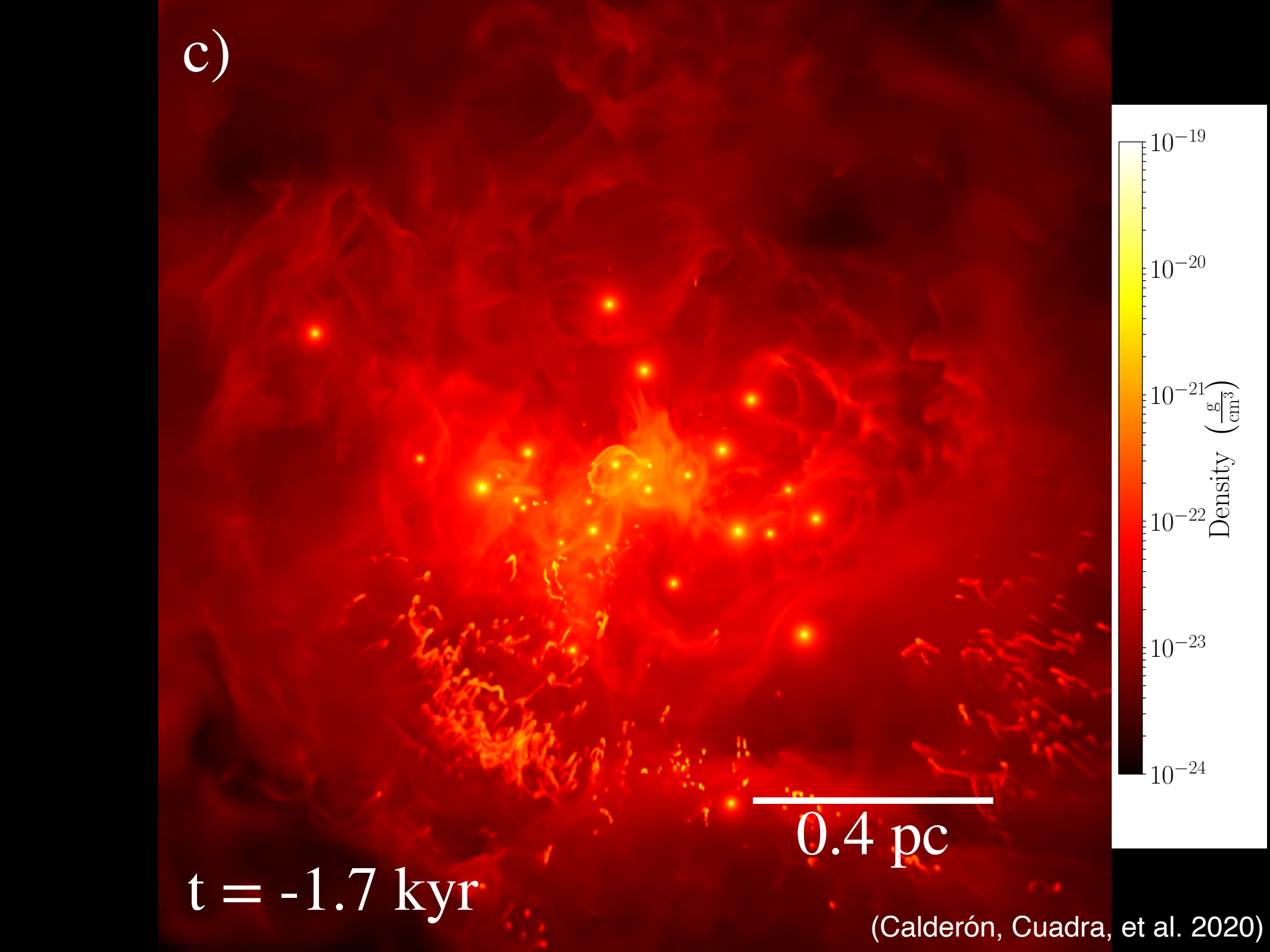
von Fellenberg et al 2023

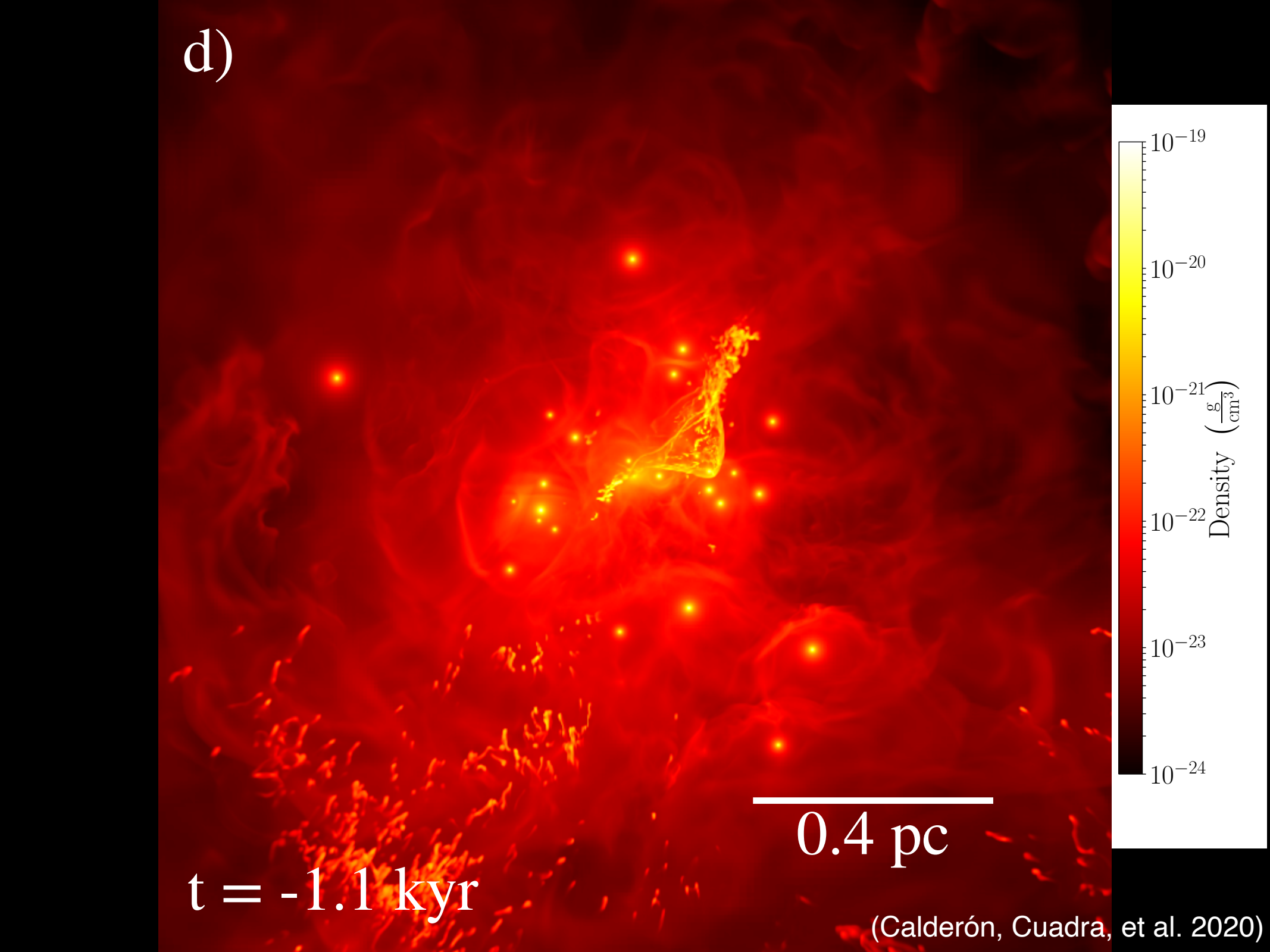
Adaptive Mesh Refinement simulation using Ramses (Teyssier 2002)

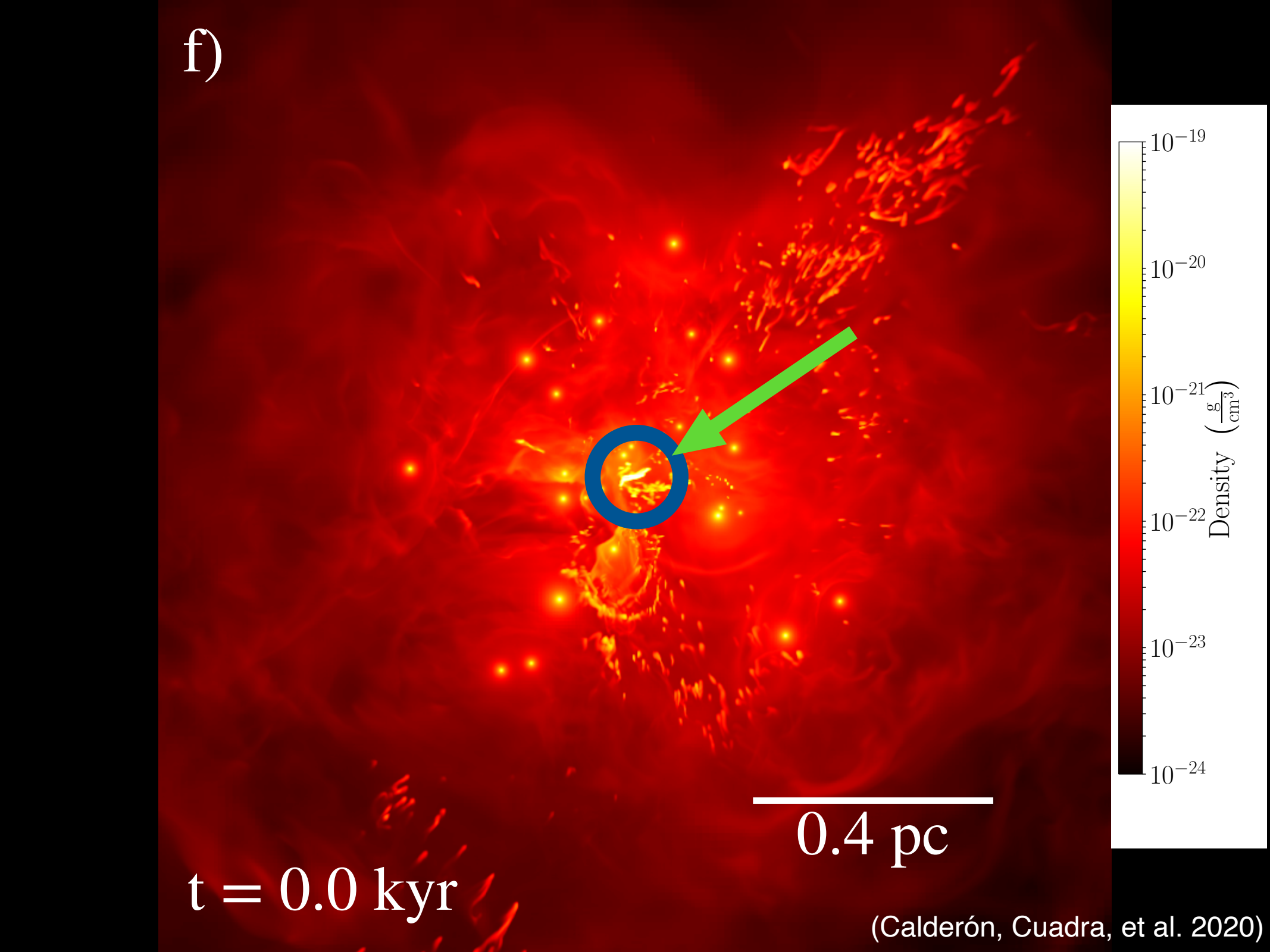


(Calderón, Cuadra, et al. 2020)

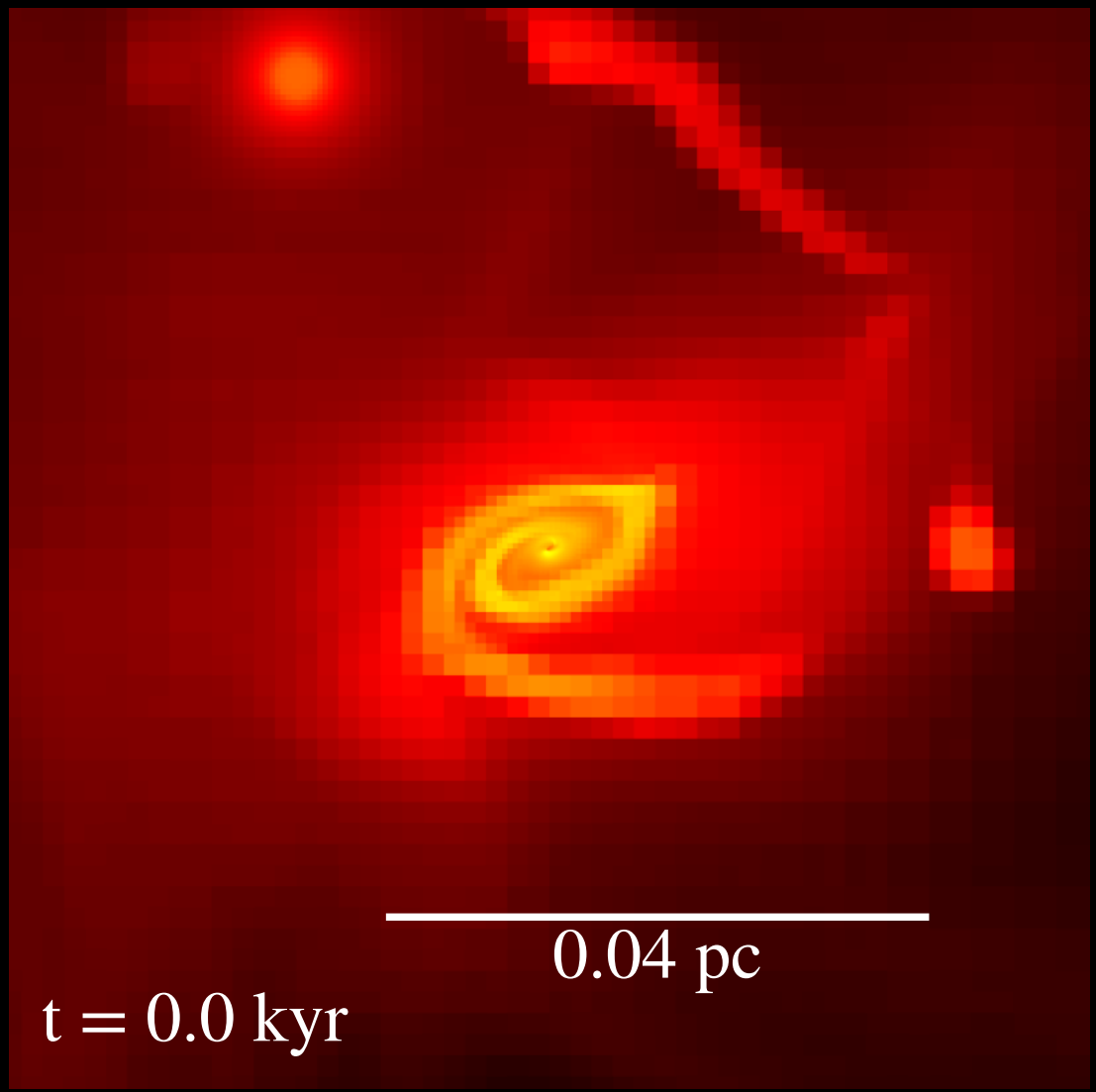

b)
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
Density $\left(\frac{g}{cm^3}\right)$
0.4 pc
t = -3.3 kyr
(Calderón, Cuadra, et al. 2020)


c)
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
Density $\left(\frac{g}{cm^3}\right)$
0.4 pc
t = -1.7 kyr
(Calderón, Cuadra, et al. 2020)


d)
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
Density $\left(\frac{g}{cm^3}\right)$
0.4 pc
t = -1.1 kyr
(Calderón, Cuadra, et al. 2020)

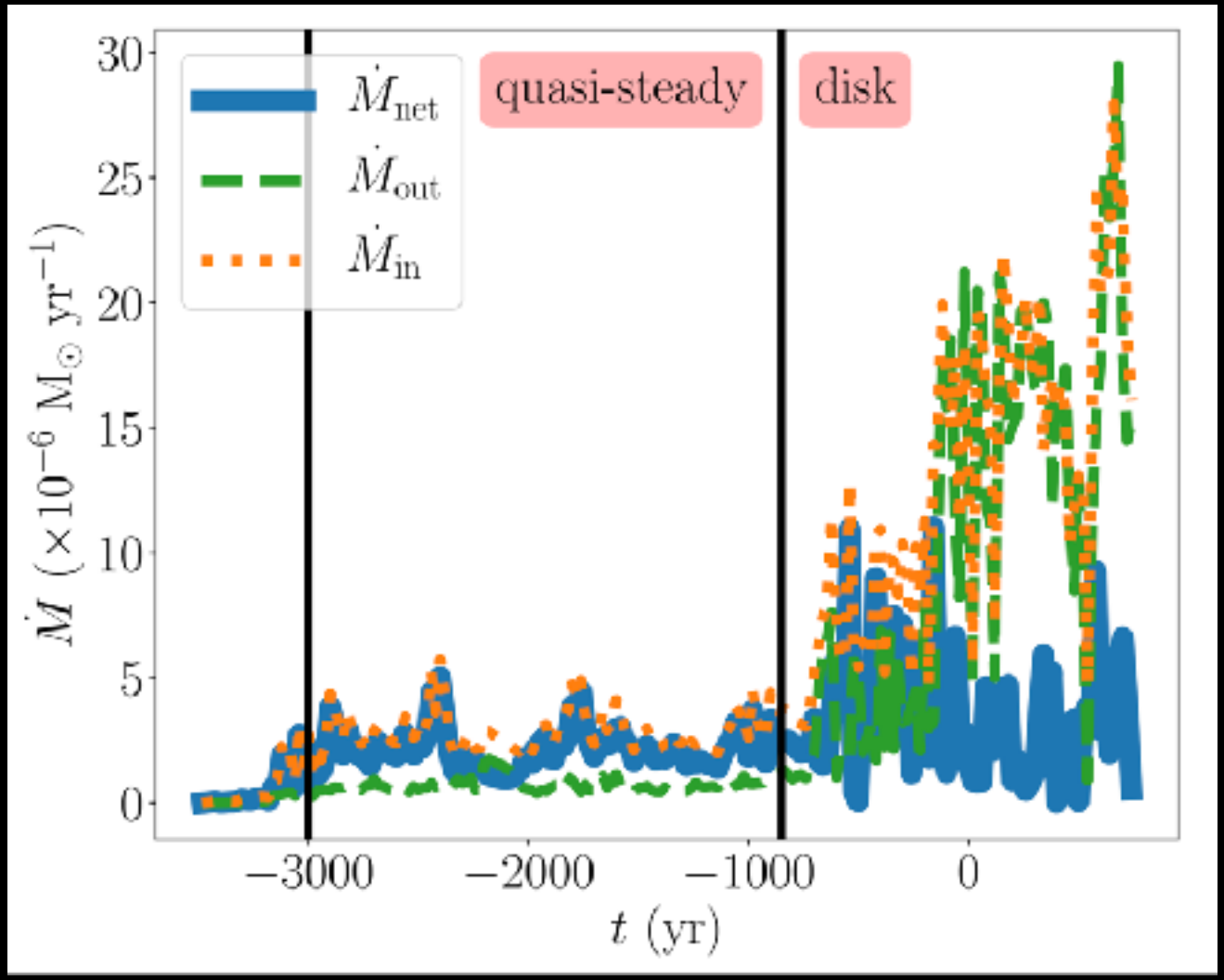

f)
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
Density $\left(\frac{g}{cm^3}\right)$
0.4 pc
t = 0.0 kyr
(Calderón, Cuadra, et al. 2020)

A disc appears!
Roughly aligned to main stellar disc



(Calderón, Cuadra, et al. in prep)

Disc increases the accretion rate, maintaining variability



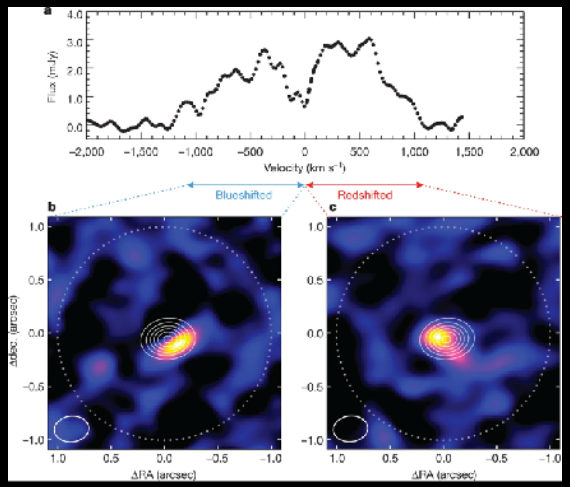
Measured at r = 5x10^{-4} pc (disc inner radius).

(Calderón, Cuadra, et al. 2020)

***i)* Cold material accumulates as a disc around Sgr A*, if modelled for long enough (≳2500 yr).**

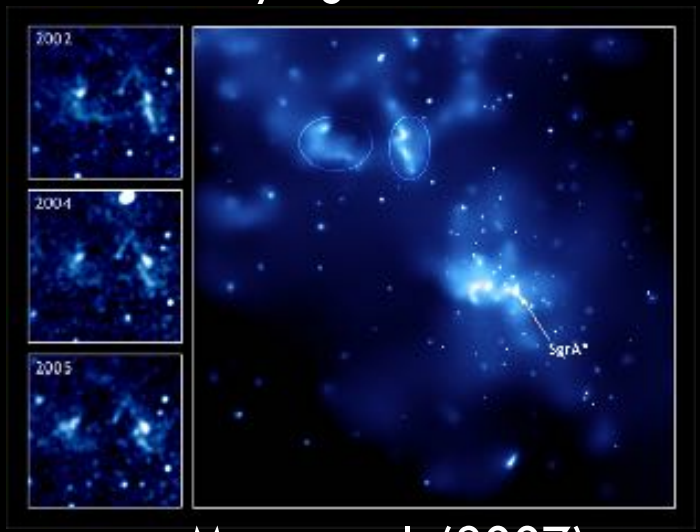
***ii)* Given the ~10^5 yr duration of the WR phase, <u>this likely already happened!</u>**

Disc-like structure



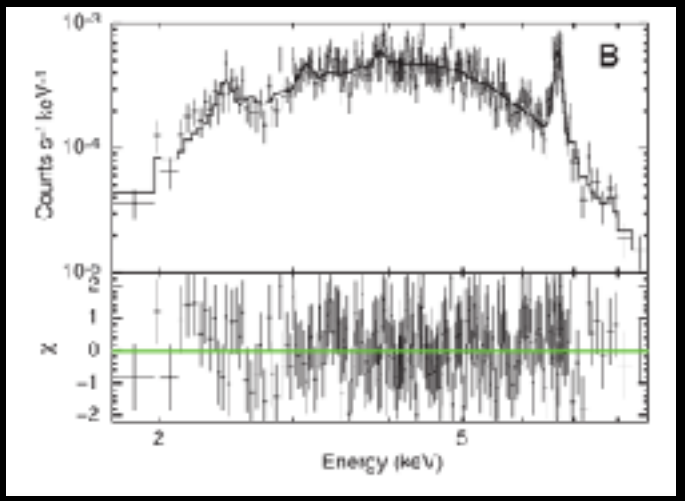
Murchikova et al. (2019)

X-ray light echoes



Muno et al. (2007)

Inflow / outflow



Wang et al. (2013)

***iii)* Large amplitude variation in accretion rate could have produced high x-ray luminosity and outflows.**

(Calderón, Cuadra, et al. 2020)

Summary

- The Galactic centre provides a unique opportunity to model and observe the material feeding a SMBH.
- Models show that accretion rate is low, but variable at different time-scales.
- Stellar winds on their own can potentially explain past higher activity and current outflow.
- Sgr A* as a potential analogue for changing-look AGN.