Two puzzles about star formation in the Galactic centre

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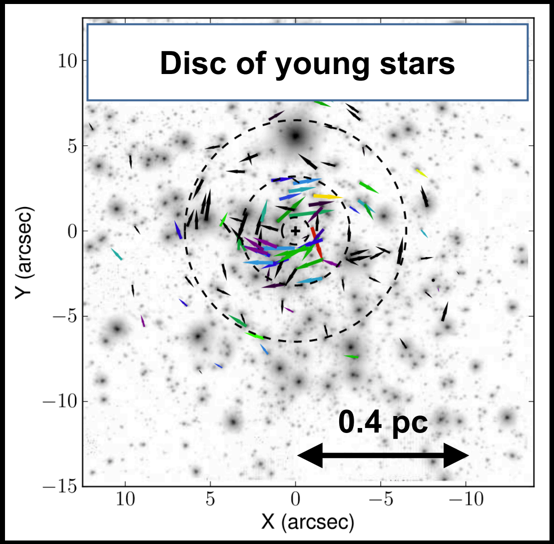
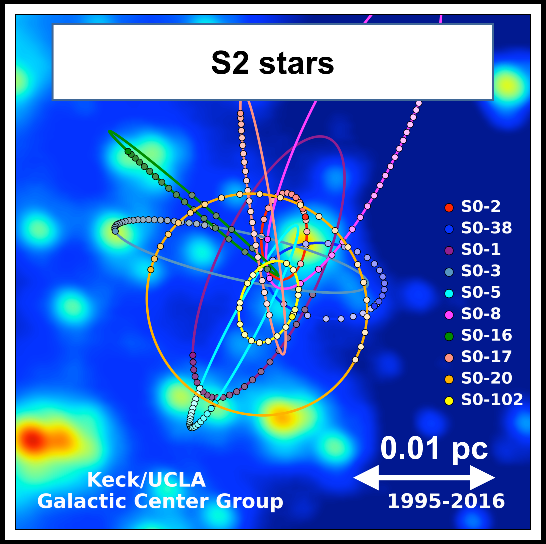
Puzzle 1

Why do stars form in the central 1 pc of the Milky Way despite huge tidal forces?

- The central 1 pc of the MW contains many (>100) massive young stars



Yelda et al. 2014



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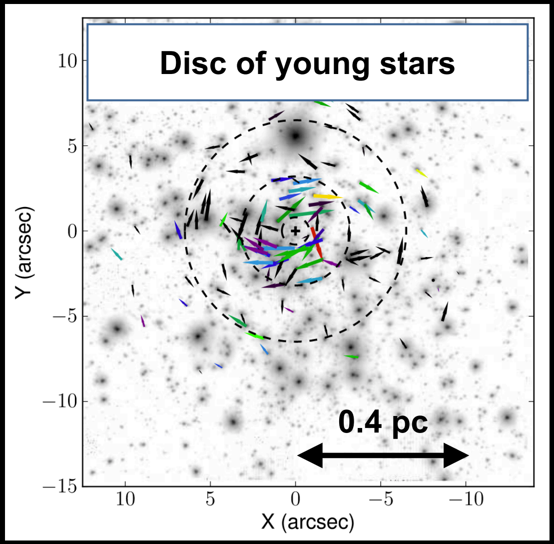

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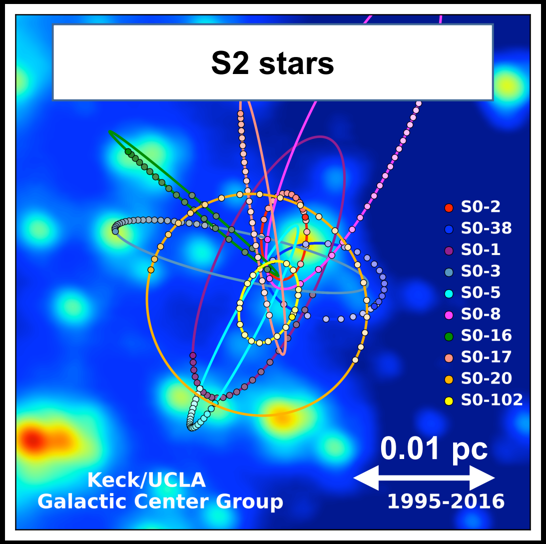

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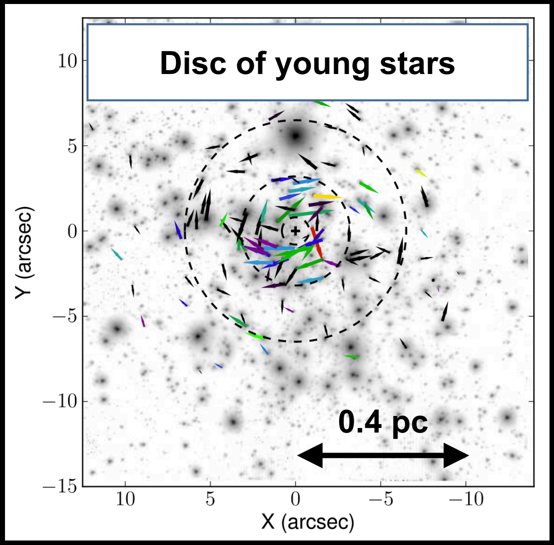

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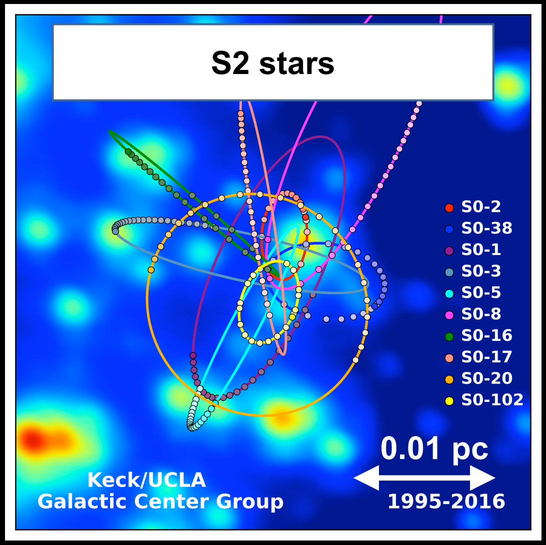
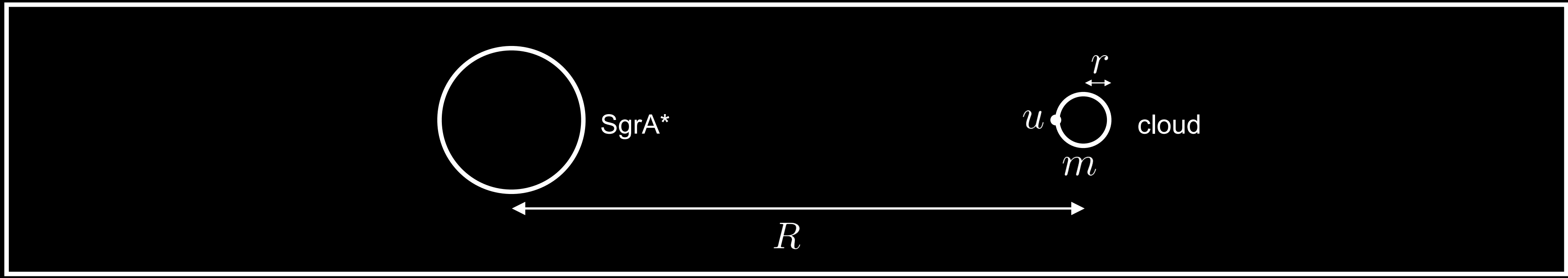


- However, for gravitational collapse to occur in the presence of tidal forces from the black hole, the gas cloud must be denser than the **Roche density:**

$$n_{\rm roche}(R) \approx 6 \times 10^{10}\,{\rm cm}^{-3} \left(\frac{R}{0.1\,{\rm pc}}\right)^3$$



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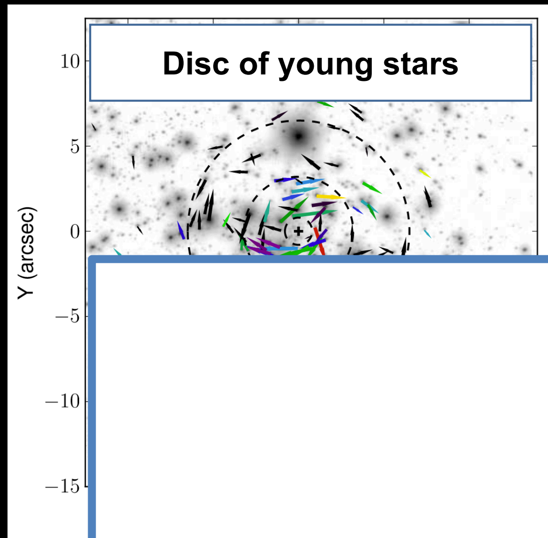

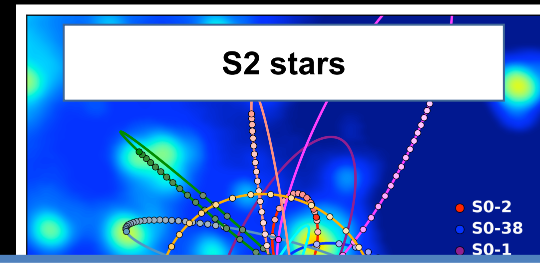

Why do stars form??

- However, for g s from the black hole, the

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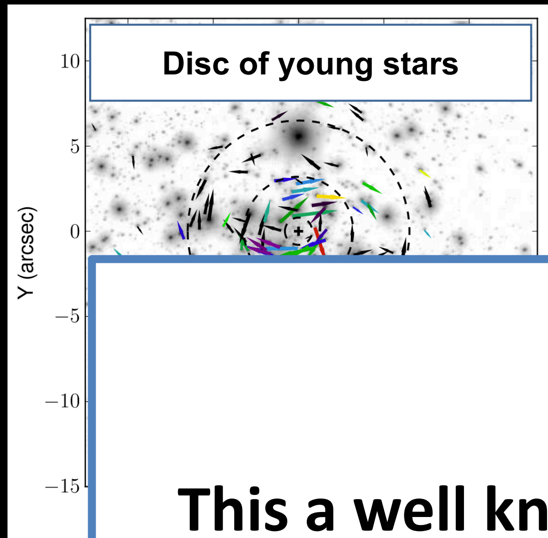

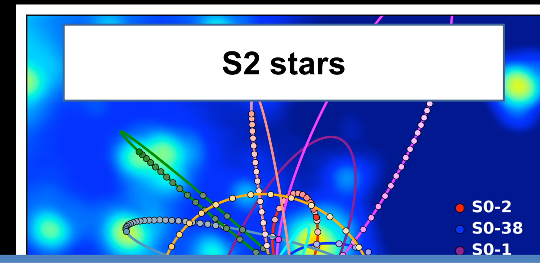

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This a well known puzzle (“Paradox of youth”, e.g. Morris 1993, Ghez 2003, Genzel 2010)

Solution 1: there is actually no black hole

(1992)

The case against a massive black hole at the Galactic Centre

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MANY of the compact near-infrared sources observed in the central parsec of our Galaxy have been shown to be very massive, luminous blue stars with strong helium lines and fast winds, perhaps similar to Wolf–Rayet stars[1–3]; and the complex near-infrared source IRS16, which appears to be the central concentration of such sources, has now been shown[3] to consist of about 20 luminous blue stars, not 100 main-sequence stars, as had been suggested earlier[4]. These young blue stars, rather than any object associated with the nearby compact radio source SgrA* (ref. 8), may be the predominant source of ionizing radiation[1] and hydrodynamic activity[5–7] in the inner two parsecs of the Galaxy. An earlier argument[4] that the distribution of IRS16 components precludes the existence of a million-solar-mass black hole at or near SgrA* remains valid even if there are fewer than two dozen stars in IRS16. Here I argue further that the presence of young stars in this region is incompatible with the presence of a giant black hole or any other centrally condensed mass, because tidal forces would have inhibited star formation.

Solution 2: the gas density was much higher in the past

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However, this sounds “ad-hoc” and only convincing “a-posteriori”

- Should we really believe the Roche criterion?
  - It makes a number of simplifying assumptions (circular orbit, spherical cloud, zero velocities, …)
  - ISM is turbulent. Can random motions compress clouds enough to overcome tidal force and trigger collapse?
- Is there a simulation that actually tests whether the Roche criterion works?
- Is the presence of young stars in the central 1 pc a (another) hint that there is something wrong in the “standard” picture of star formation as collapse of an isolated core/cloud?

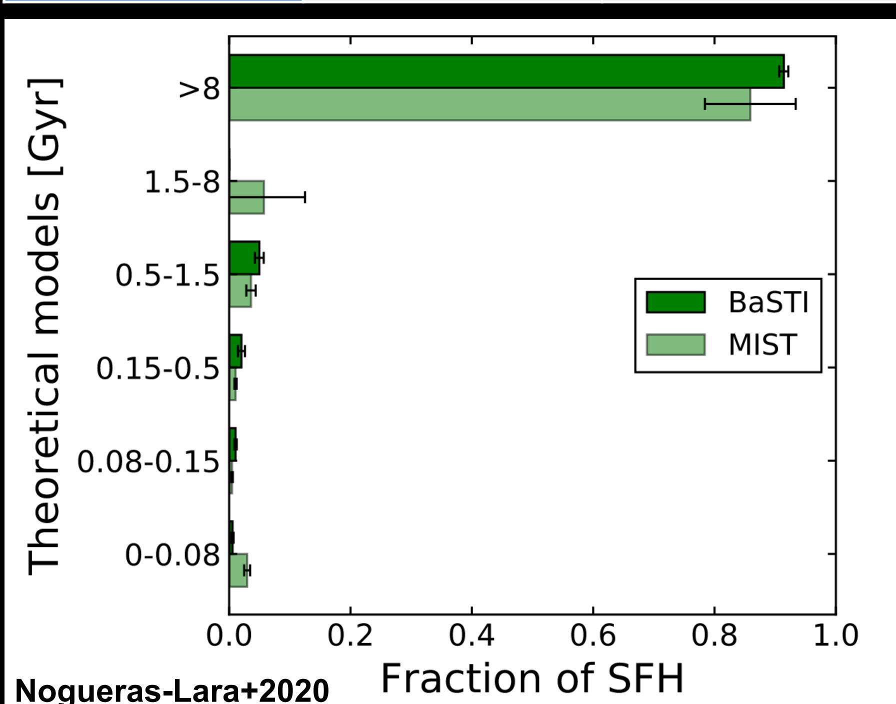
Puzzle 2

Does star formation in the centre of barred galaxies proceed in a series of intermittent episodic bursts, and what drives them?

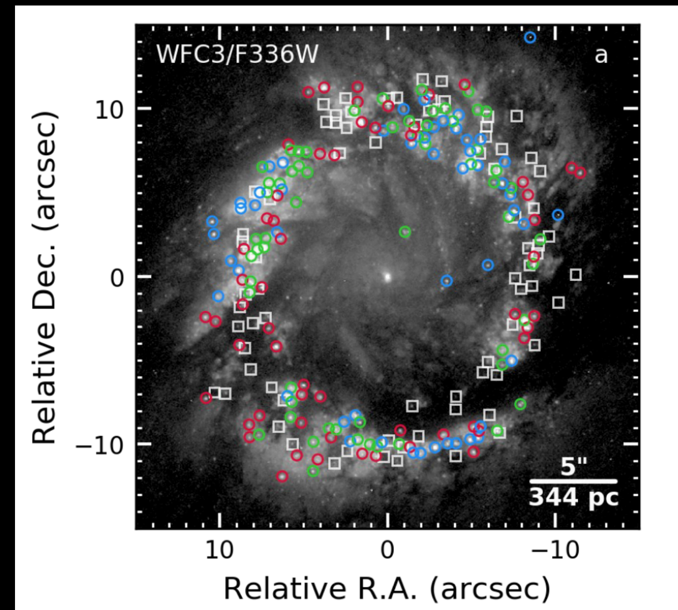
There is observational evidence for variable star formation in galactic centres

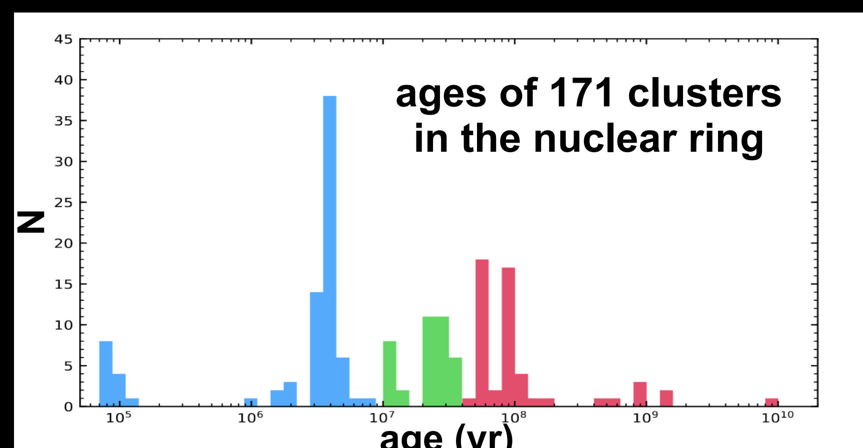
Milky Way's central molecular zone

	SFR [Msun/yr]	Source
past 5 Myr	0.09±0.02	Barnes+2017
past 30 Myr	0.2-0.8	Nogueras-Lara+2020



NGC 1097

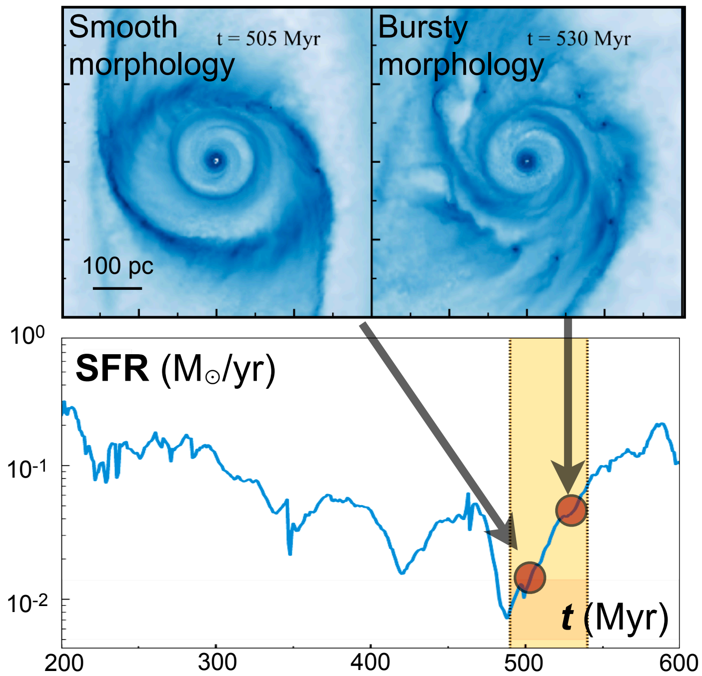




What drives the bursts?

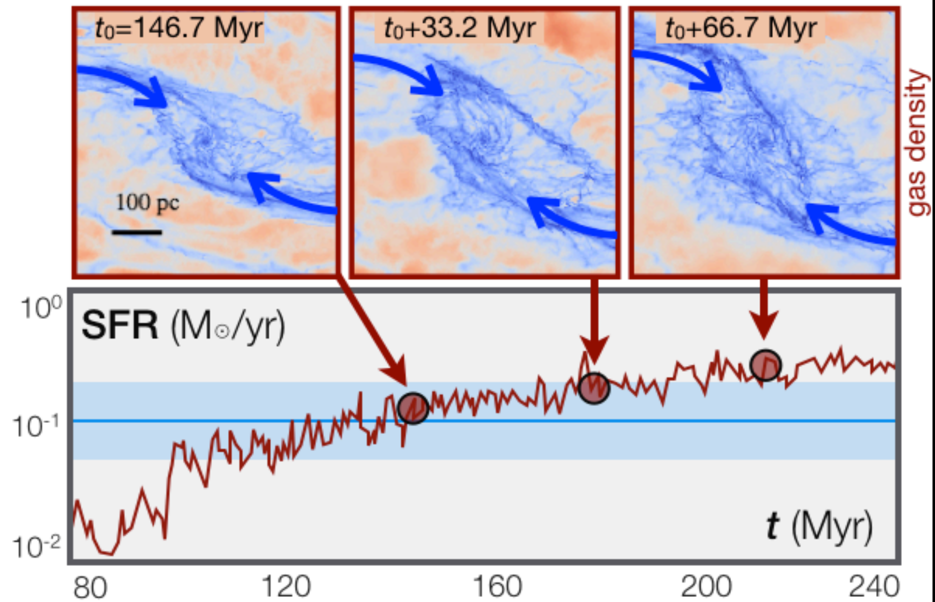
Models reach different conclusions

Internally driven
(Krumholz+2017, Armillotta+2019)



Armillotta et al. (2020)

Externally driven
(Sormani+2020,Moon+2021)



Sormani et al. (2020)

Difference between simulations

Armillotta et al. 2019

- Type: global
- Code: Gizmo
- Resolution: 200-2000 Msun/cell
- Feedback: SN feedback + simple photoionisation heating

Sormani et al. 2020

- Type: global
- Code: Arepo
- Resolution: 2 Msun/ cell (~0.2-0.3pc)
- Feedback: SN feedback

Moon et al. 2021

- Type: semi-global
- Code: Athena
- Resolution: 2-4 pc
- Feedback: SN feedback

- Why do similar simulations show different results? Is it a resolution problem, or a difference in the feedback recipes?

- What drives the bursts: recurrent cycles of SF feedback (internal), changes in the mass inflow rate and external perturbations (external), or a combination of both?