The first stars in the Universe

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Presented in the Fourth Azarquiel School of Astronomy: a Bridge between East and West

Outline

- Numerical simulations of contemporary star formation
- Differences between primordial and contemporary star formations
- Characteristics of the first stars
- Future project proposition

Contemporary star formation

- Study the effect of the magnetic field on the star formation.
- Start with a gas density distribution.
- Incorporate all the desired physics
- Run the adequate 3-dimensional magnetohydrodynamics code.

Contemporary star formation

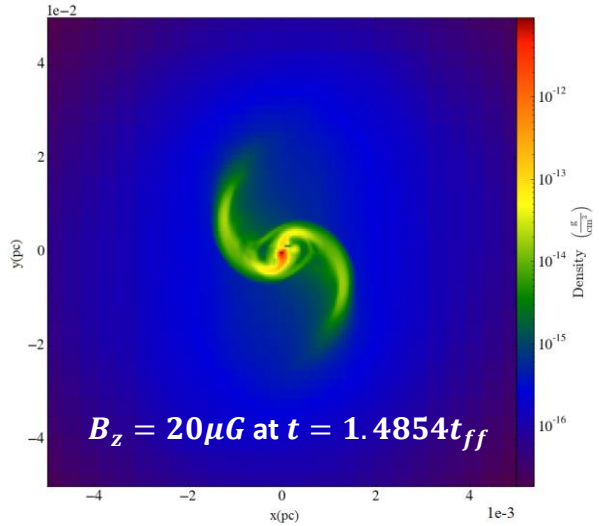
Model 1

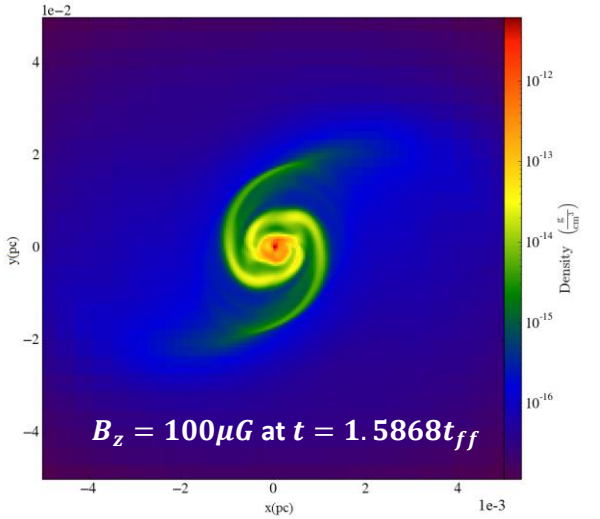
- Uniform initial density
  $\rho_0 = 1.44 \times 10^{-17} g.cm^{-3}$,
- Angular velocity:
  $\Omega_0 = 1.6 \times 10^{-12}\ rad.s^{-1}$,
- Magnetic field.

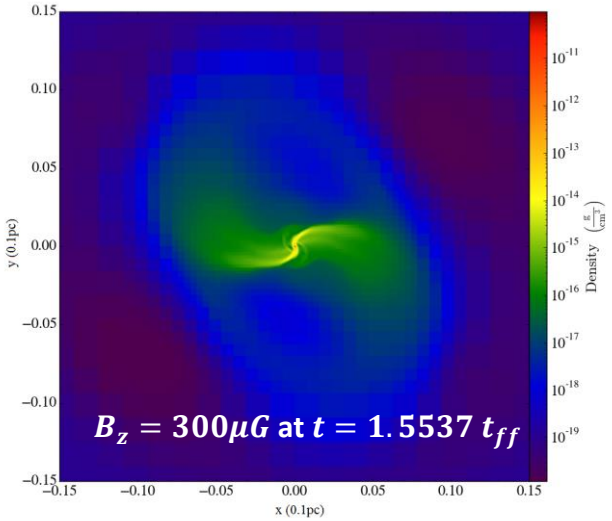
Model 2

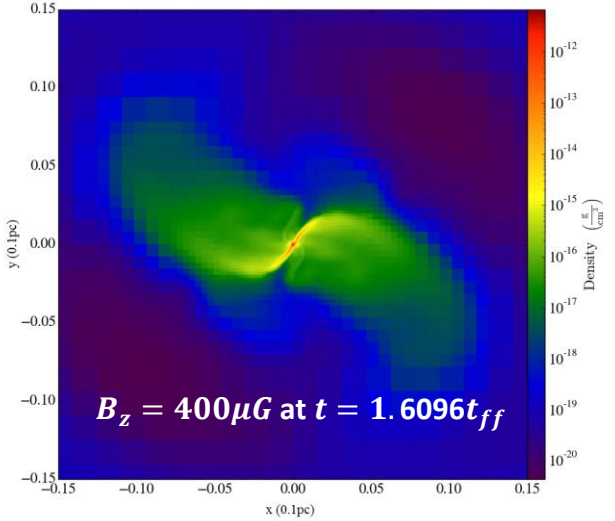
- Non uniform initial density
  $$\rho_i = \frac{\rho_0}{1 + \left(\frac{3r}{R}\right)^2}$$
  $\rho_0 = 1.8 \times 10^{-18} g.cm^{-3}$,
- Angular velocity:
  $\Omega_0 = 2.9 \times 10^{-15}\ rad.s^{-1}$,
- Magnetic field.

Model 1: Differences in spiral arm shapes

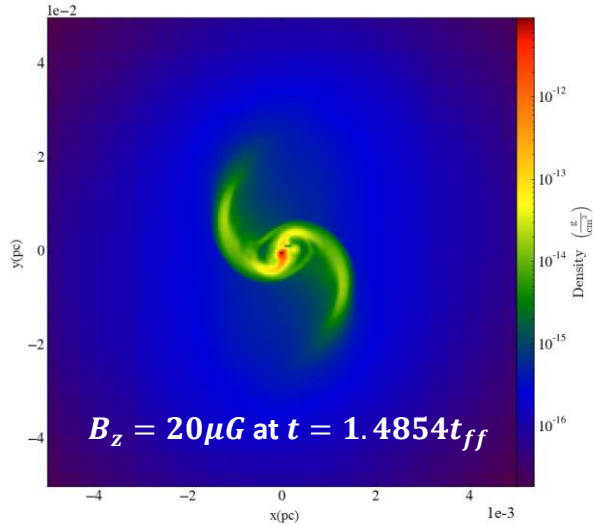


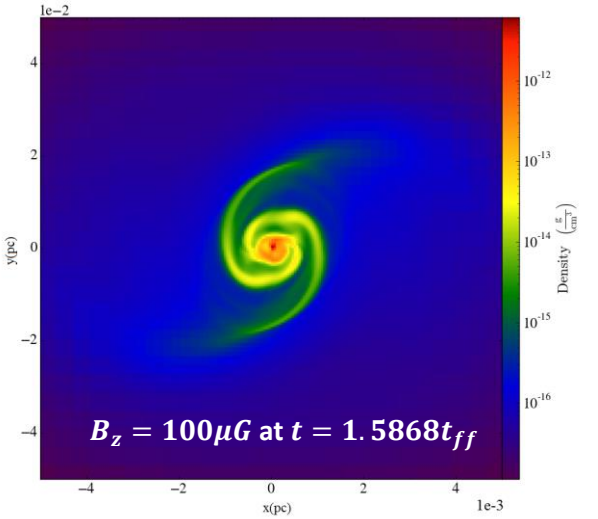




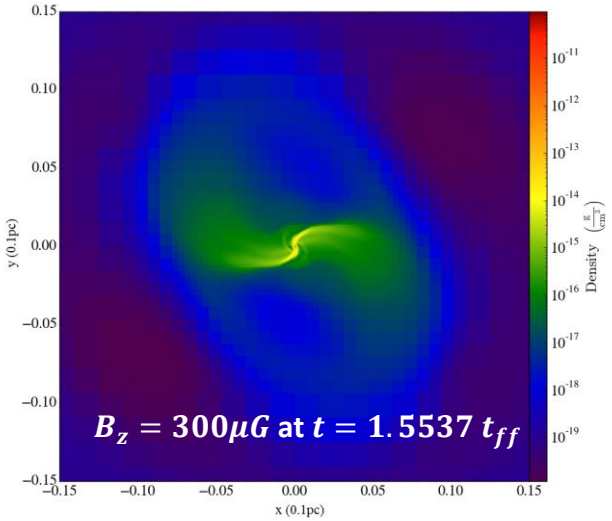


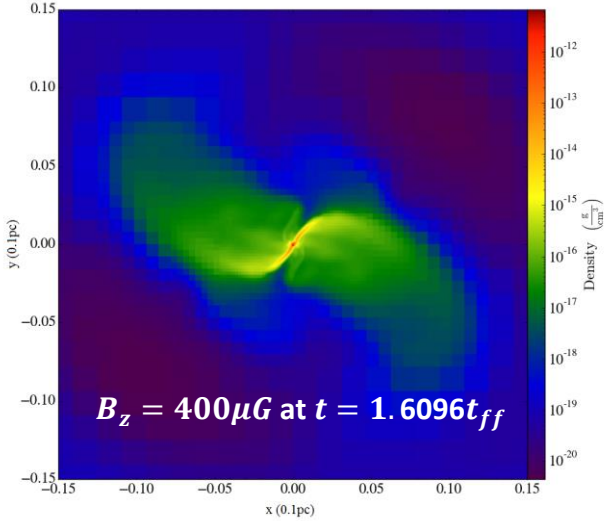
Model 1: Effect of the magnetic field





Magnetic braking: Slowing down of high density rotation, and transfer of angular momentum to low density region.





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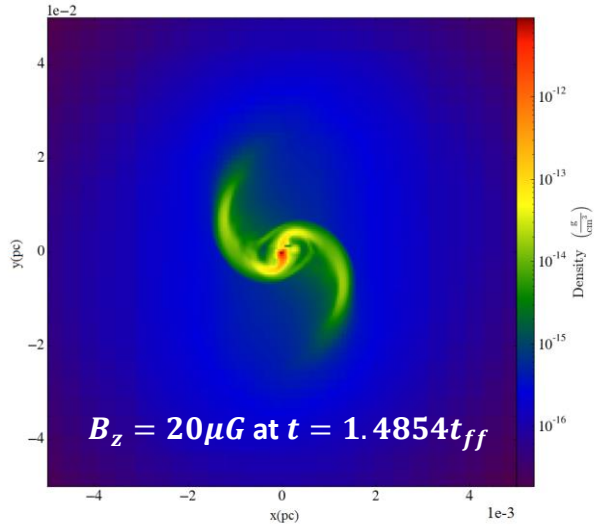
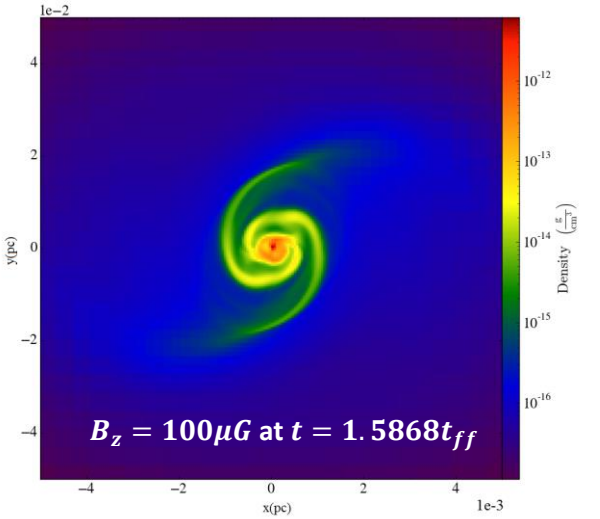
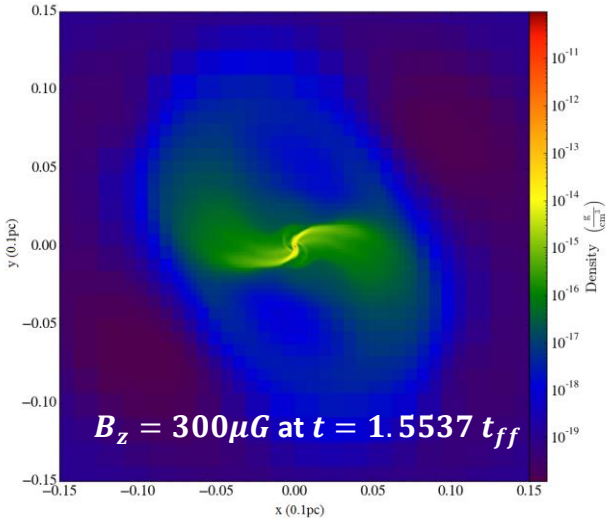
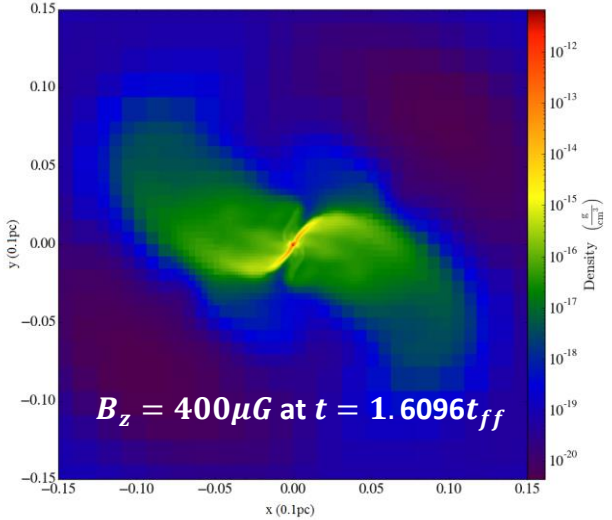


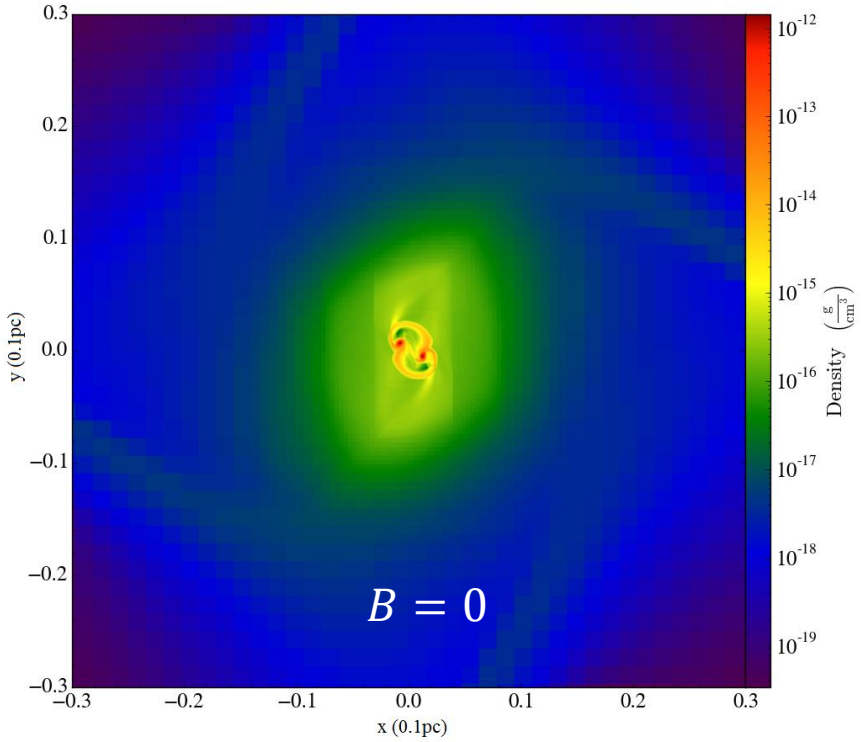


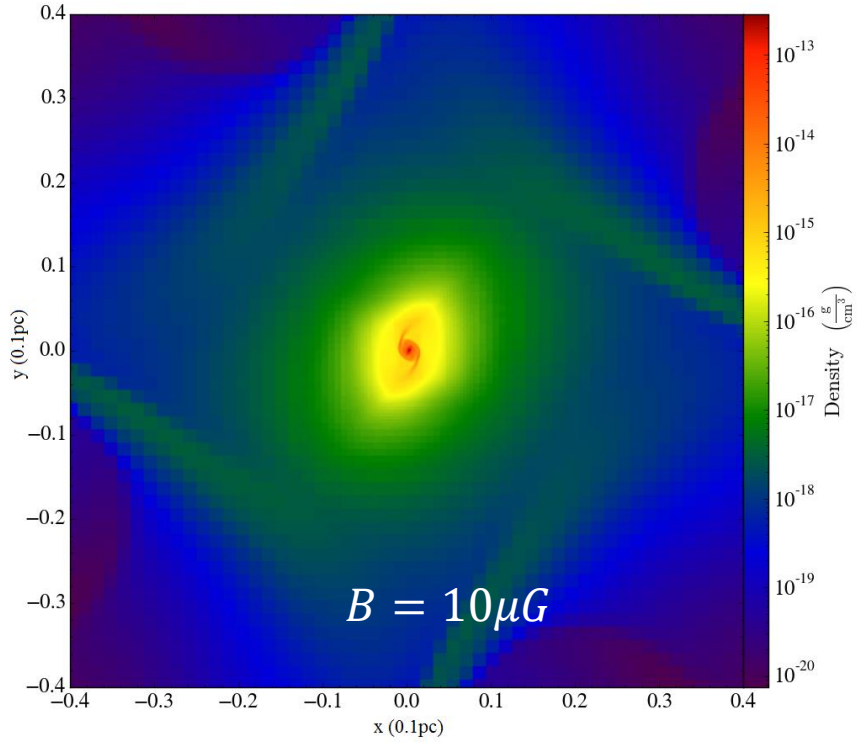
⇒ more accentuated spiral arms with increasing magnetic field





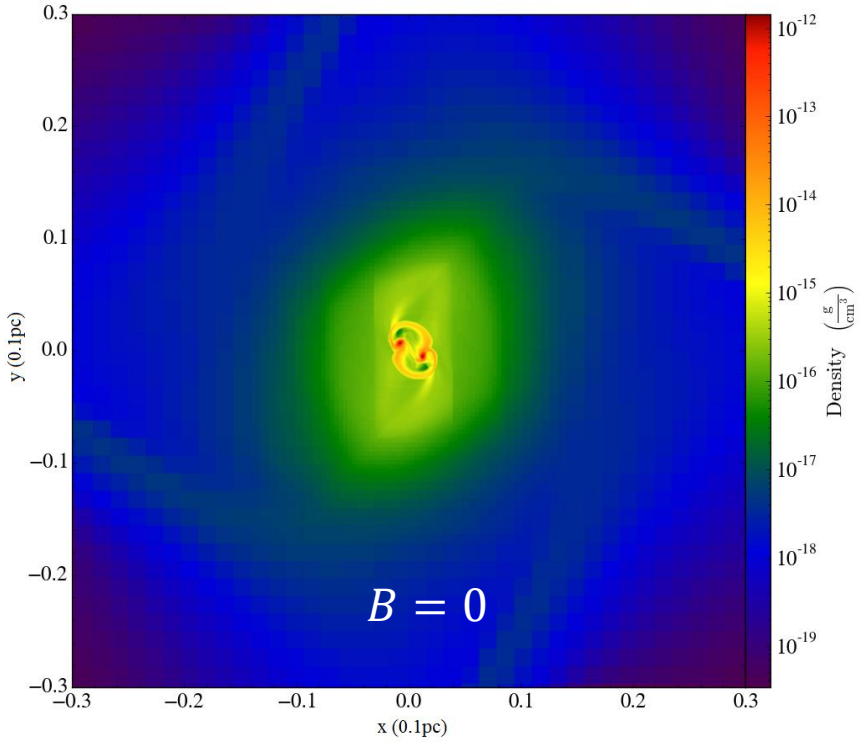
Model 2: Effect of magnetic field

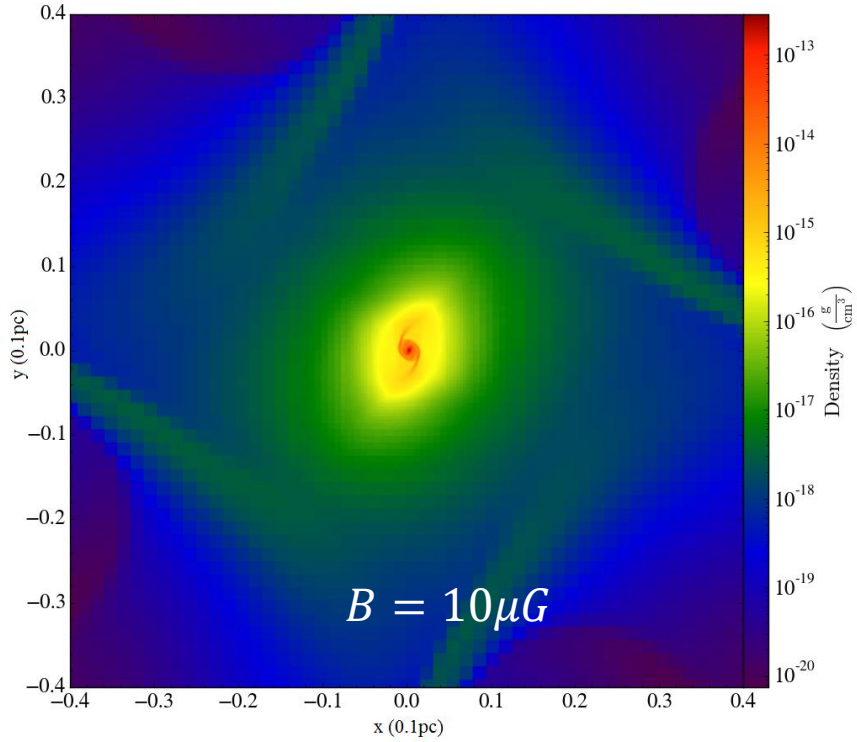




Model 2: Effect of magnetic field

Inhibiting the formation of binary systems





Primordial and contemporary star formation

- Contemporary physics :
  Gravity, magnetic field, astro-chemistry, radiative transfer, interstellar feedback, observational initial conditions.

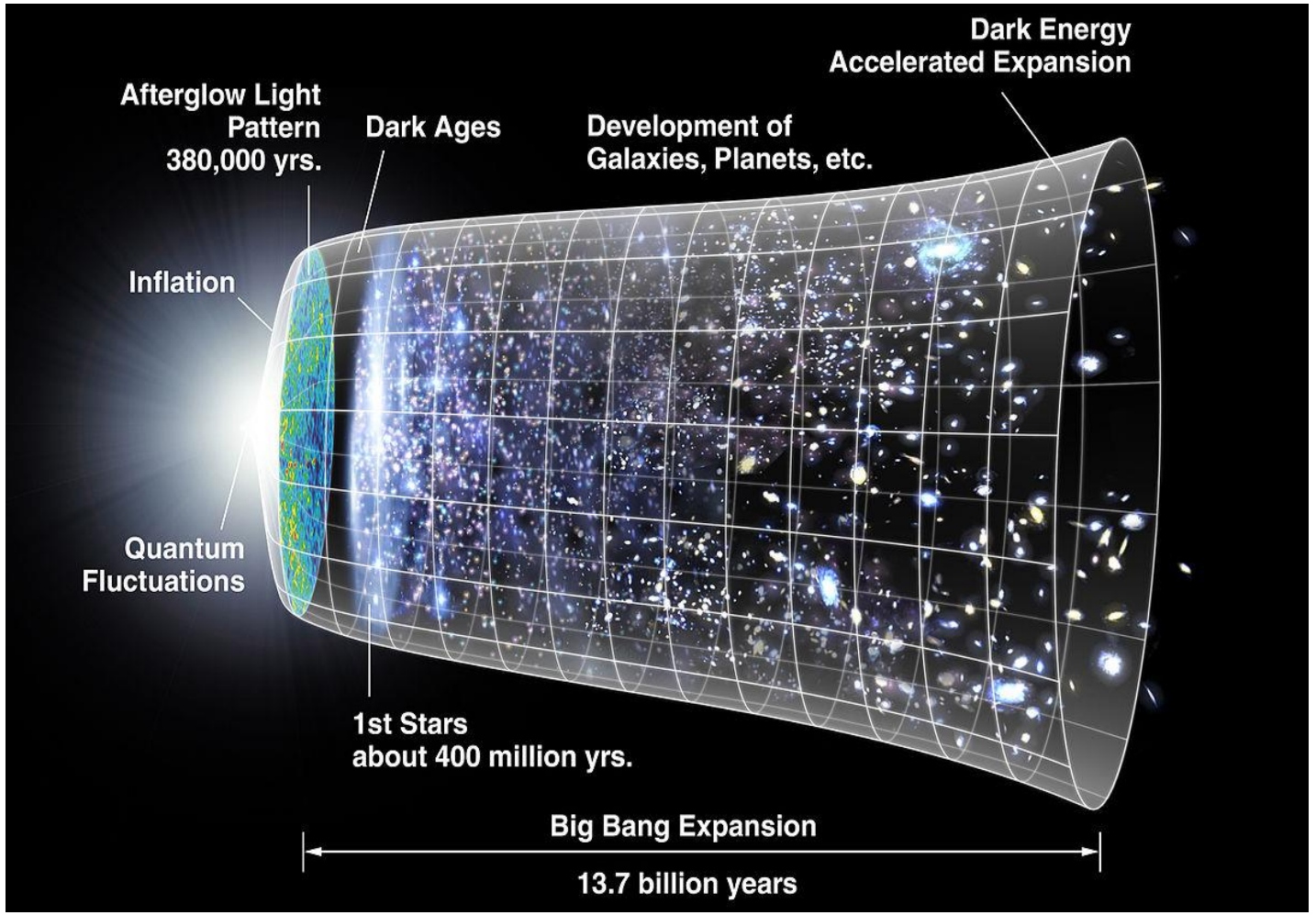
- Primordial physics:
  Dark matter, gravity, magnetic field (maybe?), simpler chemistry network, radiative transfer, no interstellar feedback, theoretical initial conditions.

Primordial star formation

- To understand the formation of the first stars, two basic ingredients are to be considered:
  - The evolution of the dark matter component, and the related formation history of dark matter halos,
  - The thermal evolution of the primordial, pure H/He gas that falls into those halos.

The first stars

- They are called the Population III stars.
- They formed 380 million years after the Big Bang.
- Their formation signaled the end of the cosmological Dark Ages.
- They re-ionized the Universe.



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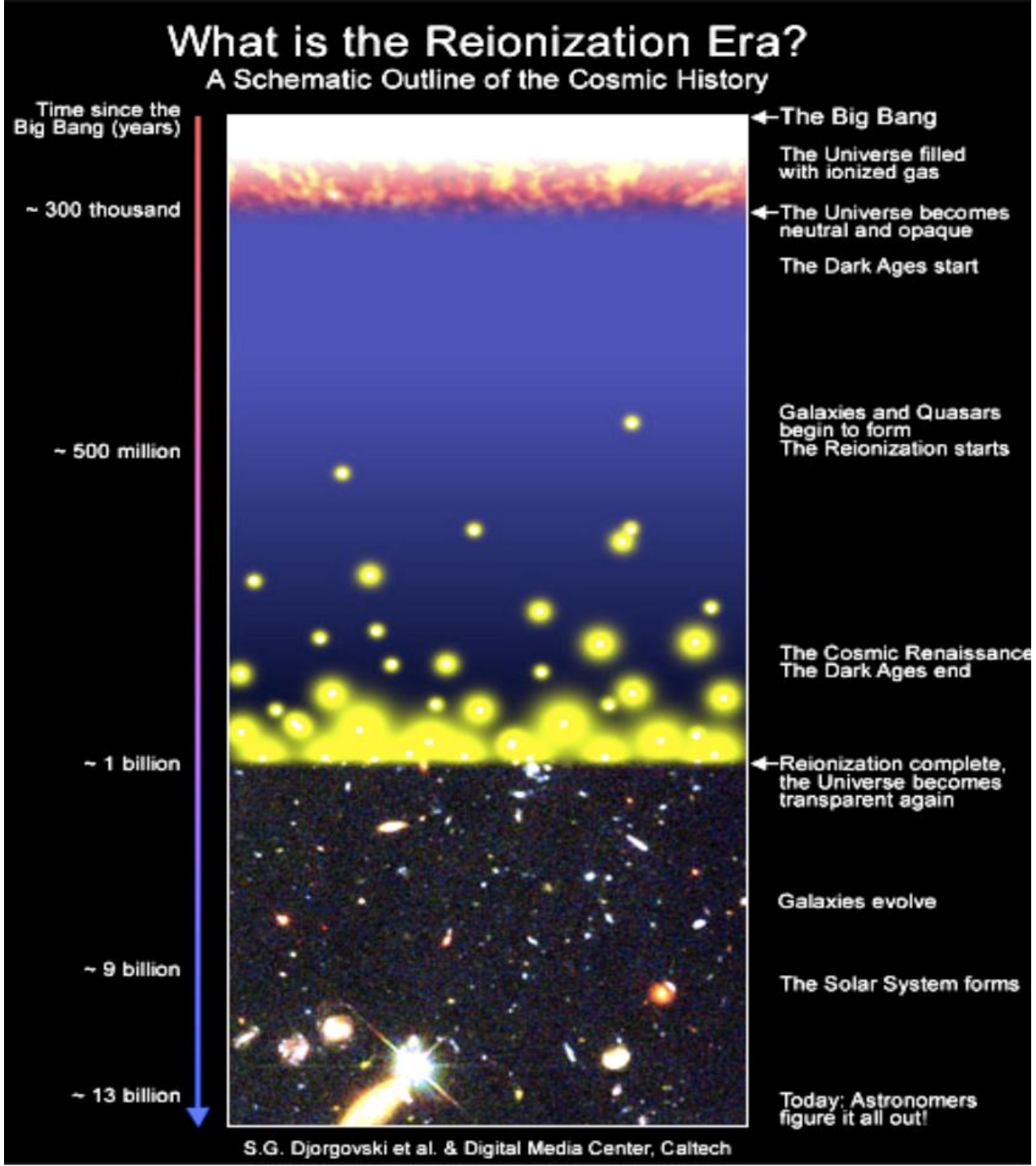

The first stars

- They are composed entirely of primordial gas : Hydrogen, Helium and very small amounts of lithium and beryllium
- They have extremely low metallicity.
- They produced the metals observed in Pop II stars and initiate the gradual increase in metallicity across subsequent generations of stars.
- They were the sites where magnetic fields reached dynamically significant levels for the first time in cosmic history.

Initial conditions in primordial star formation

- Simulations of the primordial star formation are of cosmological nature.
- Their initial conditions are inferred from the ΛCDM model (cold dark matter with cosmological constant).
- The type of parameters to specify:
  - Cosmological parameters: Omega baryon, omega CDM, omega matter, omega lambda, Hubble constant, initial and final redshift, maximum expansion rate.
  - Power spectrum parameters: Type, σ_8, primordial index.
  - The species involved in the chemistry .

Future projects

- Study the effect of different chemistry on the formation of the first stars: do small traces of deuterium affect the star formation outcome?
- Examine the mass range of the first stars: how massive were they and is it possible that some of them have survived until now?
- Investigate the multiplicity of the first stars: are binary systems a rare event?

Thank you

Questions?