THE CHEMICAL EVOLUTION OF THE MILKY WAY GALAXY

Tejpreet Kaur, Sandeep Sahijpal
Department of Physics, Panjab University, Chandigarh, 16001, India
tejpreetkaur95@gmail.com

Galactic Chemical Evolution (GCE) Models

Galactic chemical evolution (GCE) models deal with understanding the origin of the distribution and gradual evolution of the elemental abundances along with other Galactic observables across the Galaxy over the Galactic time-scale.

Basic ingredients to build a chemical evolution model

1. Initial conditions (infall rate and chemical composition of the intergalactic gas) (Chiappini et al. 1997; Micali et al. 2013).
2. Star formation rate (SFR) as a function of distance from the galactic center (Kennicut 1998; Alibes 2001).
3. Initial mass function (IMF) (Salpeter 1955; Kroupa 1998).
4. Stellar yields from stars of different masses (Woosley & Weaver 1995; Karakas & Lattanzio 2007; Cristallo et al. 2015; Chieffi & Limongi 2018).

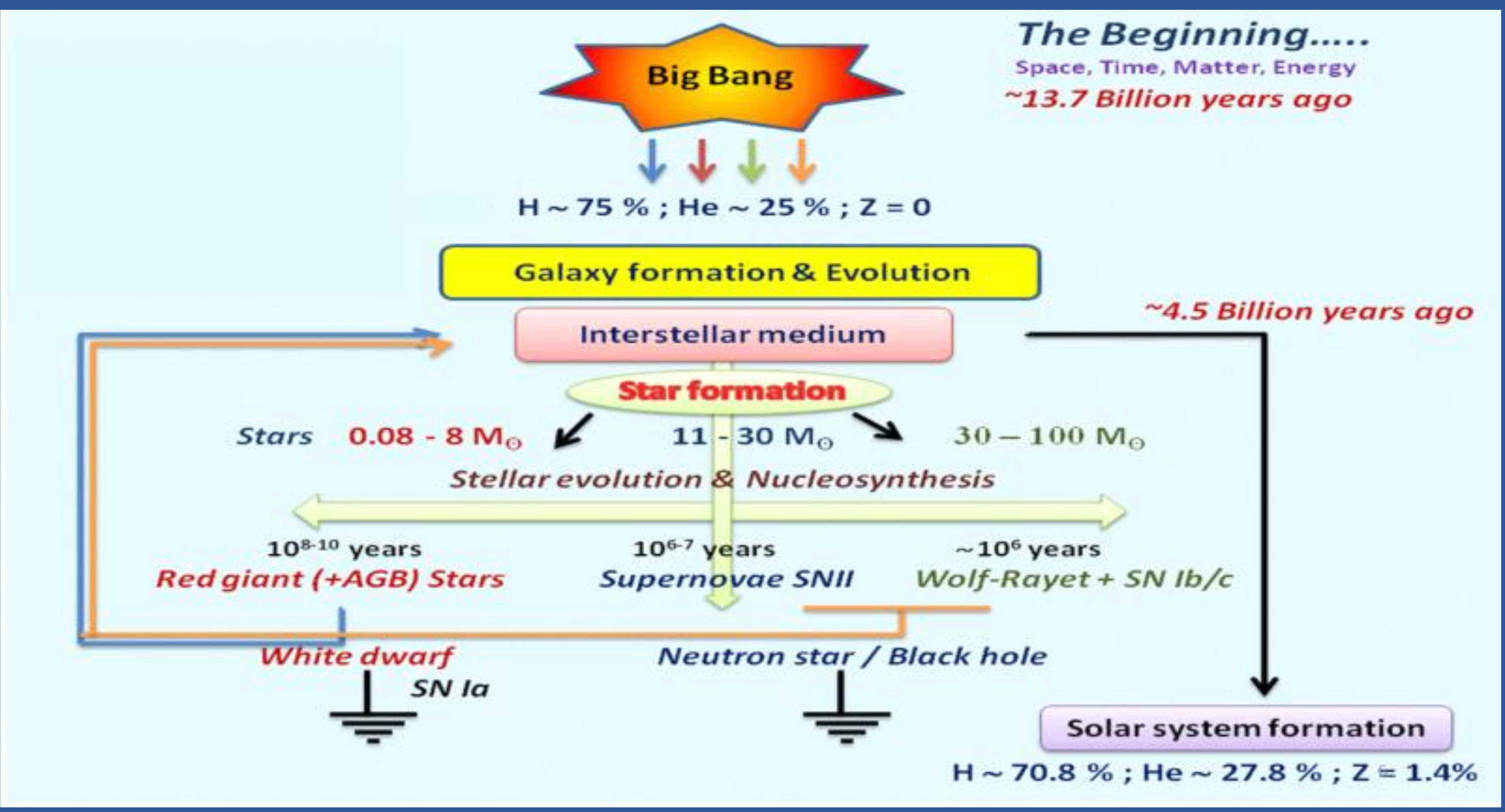


Fig 1. Sequence of events showing the formation of various generations of stars during the evolution of the Galaxy.

Modelling Approach

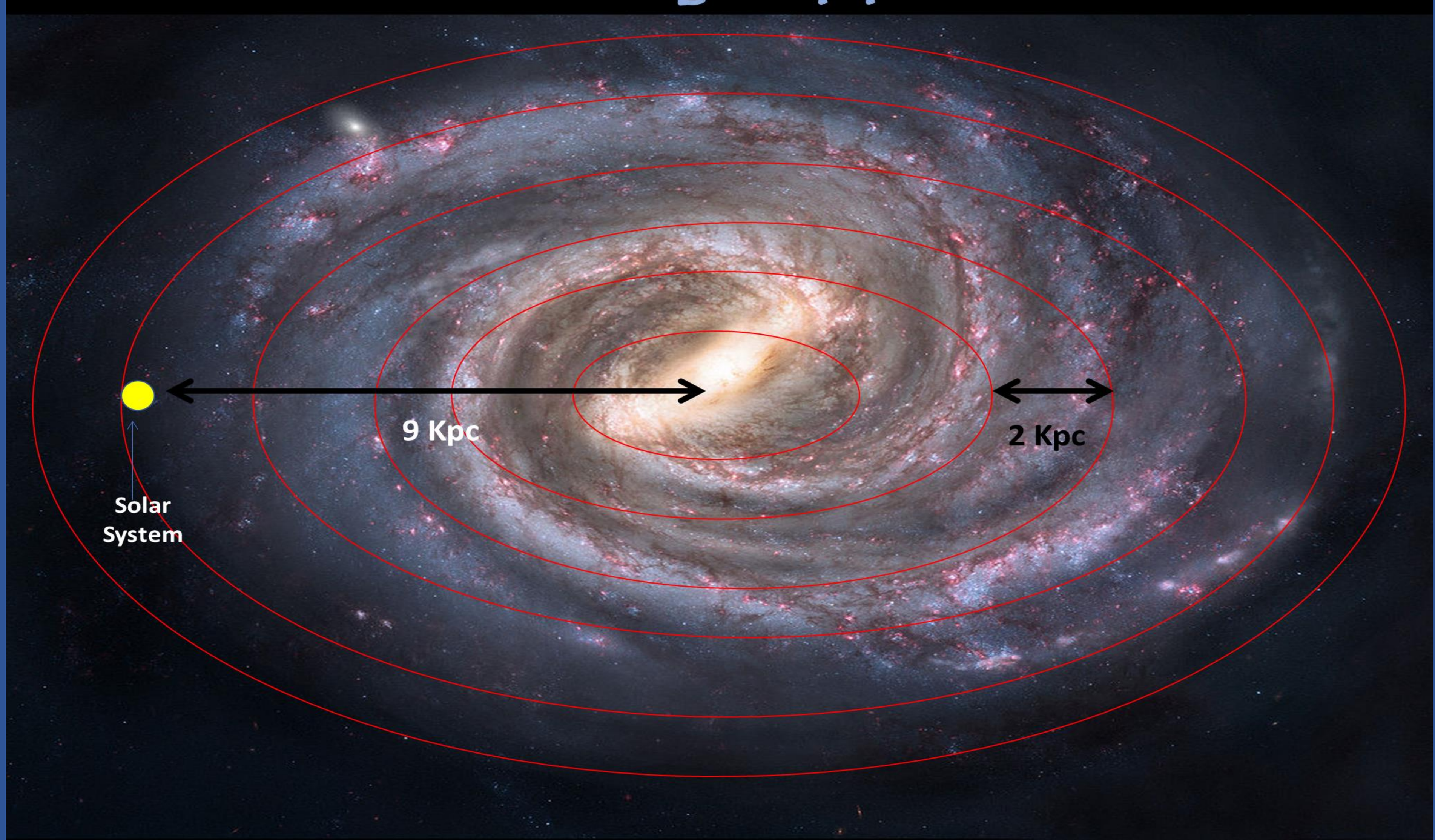


Fig 2. In our GCE model, the Milky Way Galaxy is divided into eight annular rings of 2 kpc width each, across the radial extent of 2 to 18 kpc from the center of the Galaxy. The evolution of these eight rings is studied over the Galactic timescale in terms of the evolution of various generations of stars in the mass range of 0.1 - 100 $M_\odot$. The solar system is located in the fourth ring at a distance of 8-10 kpc from the center. The value of the metallicity (Z) and [Fe/H] at the time of formation of solar system ~ 4.56 Gyr ago is assumed to be ~0.0143 ($Z_\odot$; Asplund et al. 2009) and 0, respectively. Various model parameters are discussed in detail in Sahijpal & Kaur (2018) and Kaur & Sahijpal (2019).

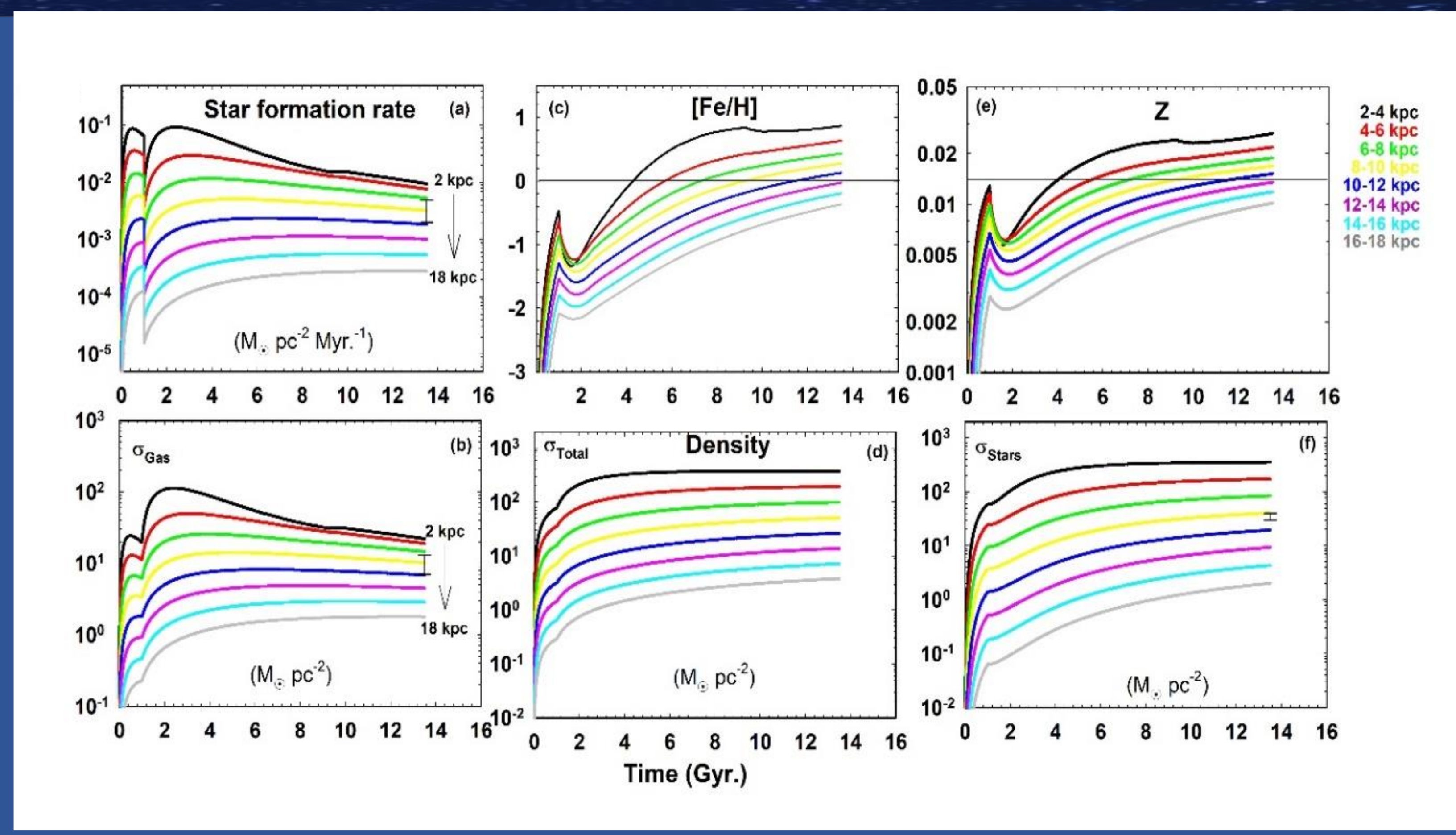
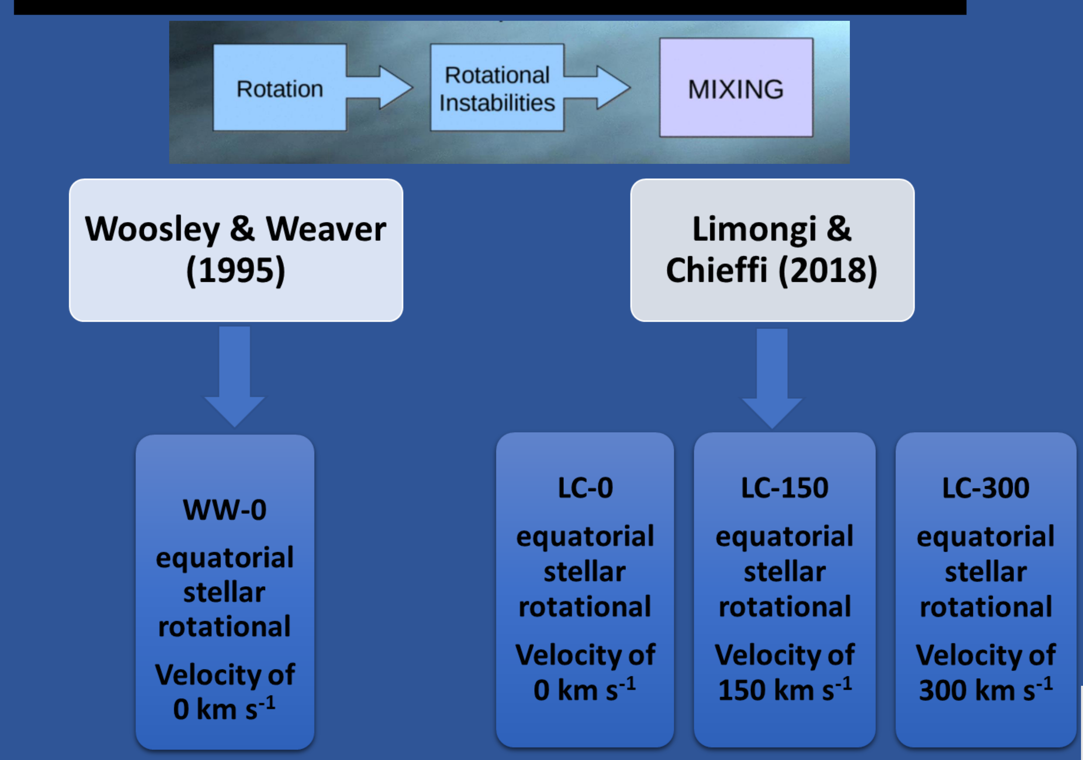


Fig 3. Various galactic Observables predicted by GCE model for the Milky Way Galaxy. The present observables in the solar neighborhood (8-10 kpc) are compared with the marked observational values as a bar. **a)** The star formation rate (SFR) ($M_\odot$ pc^{-2} Myr^{-1}) compared with the observational data of (2-5)×10^{-3} $M_\odot$ pc^{-2} Myr^{-1} (Güsten and Mezger 1982), **b)** The surface mass density of the gas, σ_{Gas} ($M_\odot$ pc^{-2}) with the observational values of 7-13 $M_\odot$ pc^{-2} in the solar neighborhood (Bovy and Rix 2013). **c)** [Fe/H], **d)** The total surface mass density (stars + stellar remnants + interstellar gas), σ_{Total} ($M_\odot$ pc^{-2}) agrees with the observed value of 51 ± 4 $M_\odot$ pc^{-2} (Bovy and Rix 2013), **e)** metallicity Z with the horizontal line represents the adopted metallicity value of ~0.143 at the time of formation of the solar system (Asplund et al. 2009), **f)** surface mass density of 'live' stars in the Galaxy, σ_{Stars} ($M_\odot$ pc^{-2}) Observations in the solar neighborhood, marked as a bar is in the range of 30-40 $M_\odot$ pc^{-2} (Gilmore, Wyse and Kuijen 1989).

Rotation in Massive stars (>11 $M_\odot$)



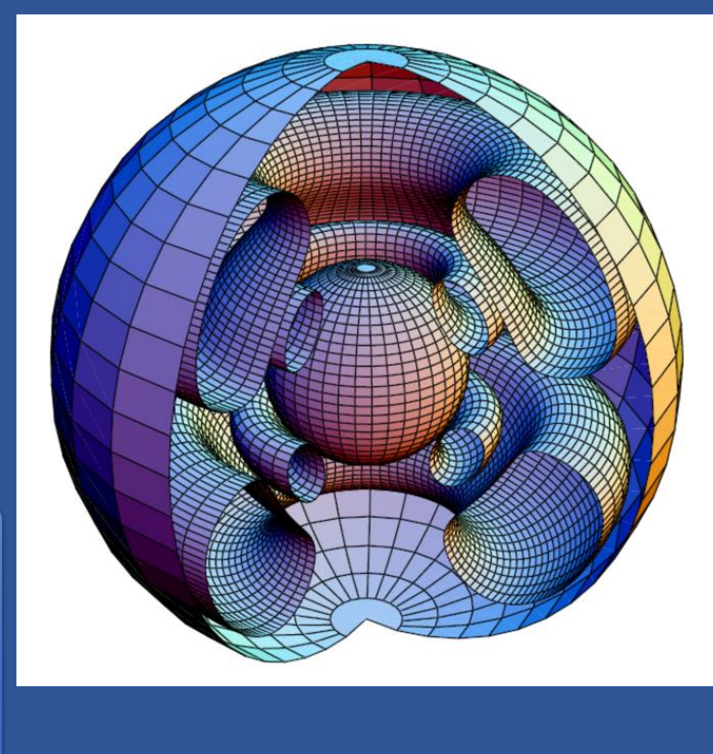
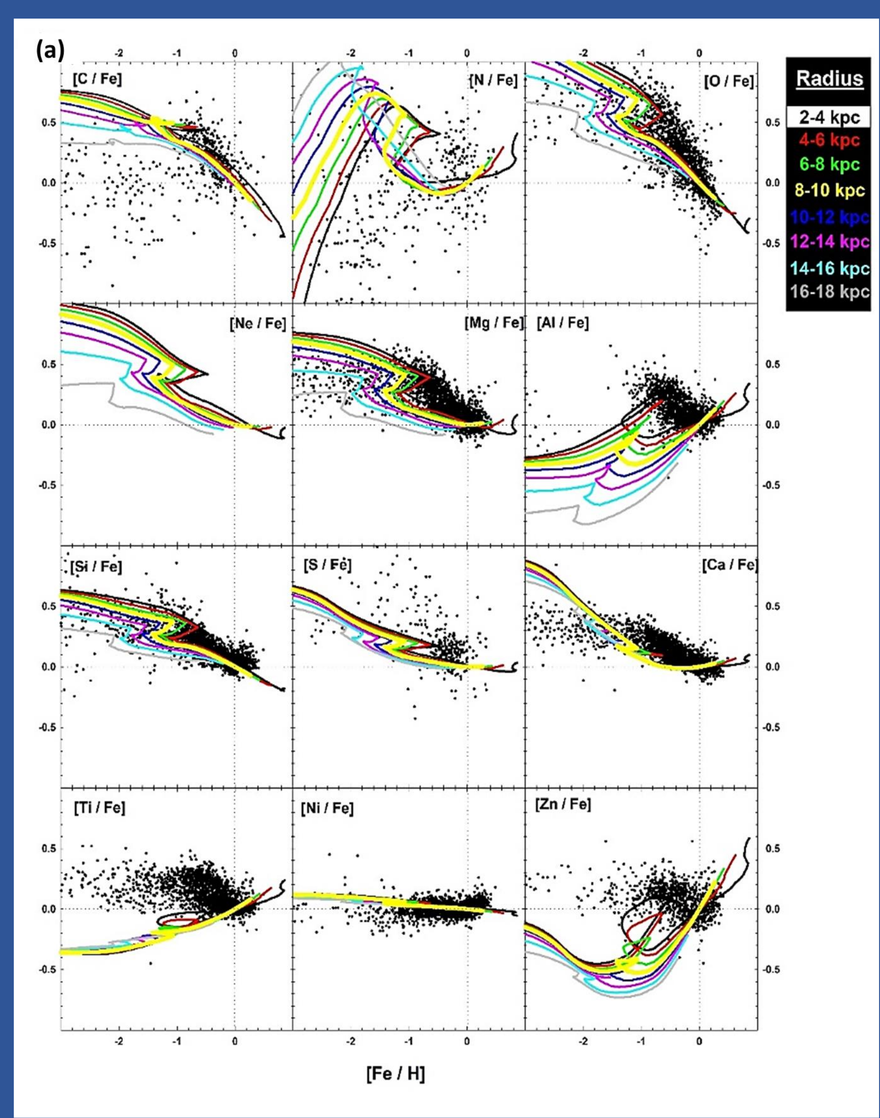


Fig 4. The stellar rotation can influence the internal mixing of elements due to convection inside the star (Meynet & Maeder 2002).



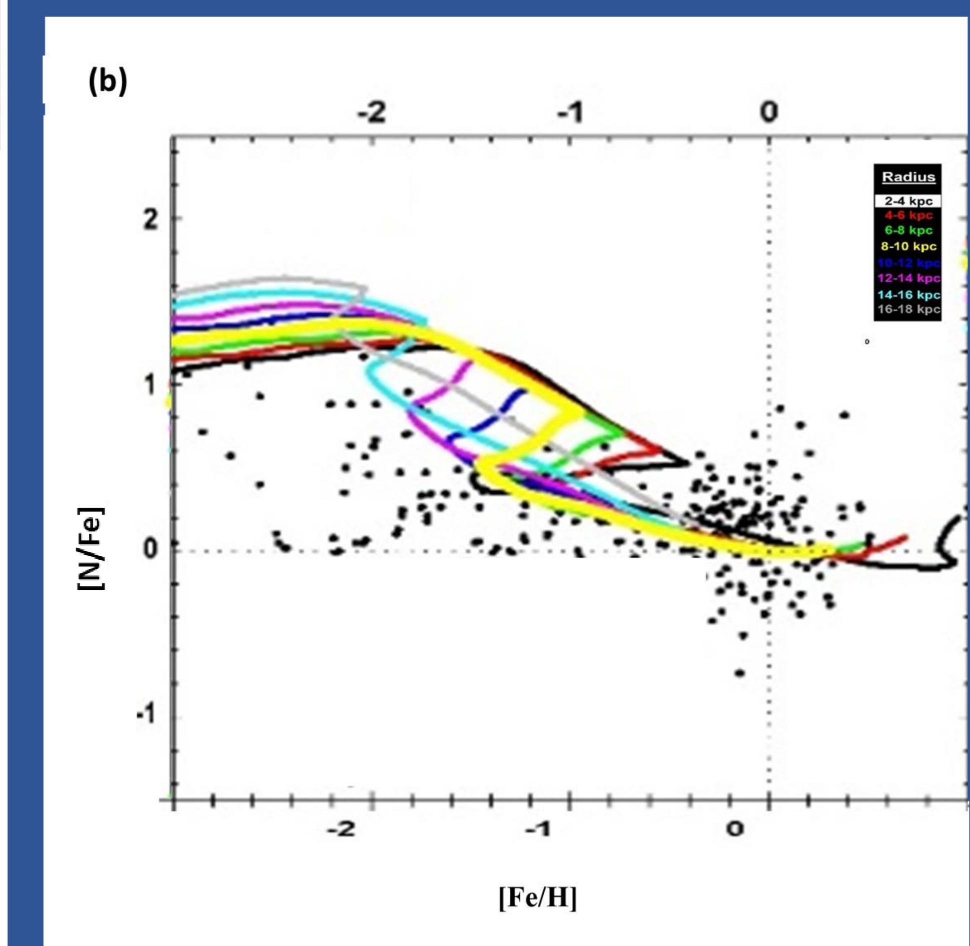


Fig 5 **(a)**. The normalized predicted trends of [X/Fe] vs. [Fe/H] for elements, C, N, O, Ne,Mg, Al, Si, S, Ca, Ti, Ni, and Zn, in case of the model LC-0 (Nucleosynthetic yields of non-rotating massive stars) for all the Galactic annular rings from 2-18 kpc. The thick yellow curve presents the [X/Fe] vs. [Fe/H] trends in the solar annular ring (8-10 kpc). The results are compared with the observational data details of which are presented in Sahijpal & Kaur (2018),

(b) The [N/H] vs. [Fe/H] trend for the LC-300 model (Nucleosynthetic yields of massive stars with rotation velocity of 300 kms^{-1}). Here it is evident from [N/Fe] vs [Fe/H] evolutionary trend that Nitrogen exhibits a primary behaviour with incorporation of massive stars rotational yields.

Summary: 1. We have developed GCE models to predict the galactic observables for the 2-18 kpc of the Milky Way Galaxy.

2. The GCE models with various rotational nucleosynthetic yields are studied to understand the influence of the massive stars on the evolution of the Galaxy.

3. The [N/Fe] vs [Fe/H] evolutionary trends exhibit a primary behaviour for Nitrogen in case of the GCE models with rotational massive stars yields.

References: (1). Kaur, T. and Sahijpal, S. (2019). Heterogeneous evolution of the Galaxy and the origin of the short-lived nuclides in the early solar system. Monthly Notices of the Royal Astronomical Society, 490(2), 1620-1637.
(2). Sahijpal, S. and Kaur, T. (2018). A Monte Carlo based simulation of the Galactic chemical evolution of the Milky Way Galaxy. Monthly Notices of the Royal Astronomical Society, 481(4), 5350-5369.
Note: for all other references mentioned above, please check our papers 1 and 2.

Star Clusters: the Gaia Revolution, 7 October 2021