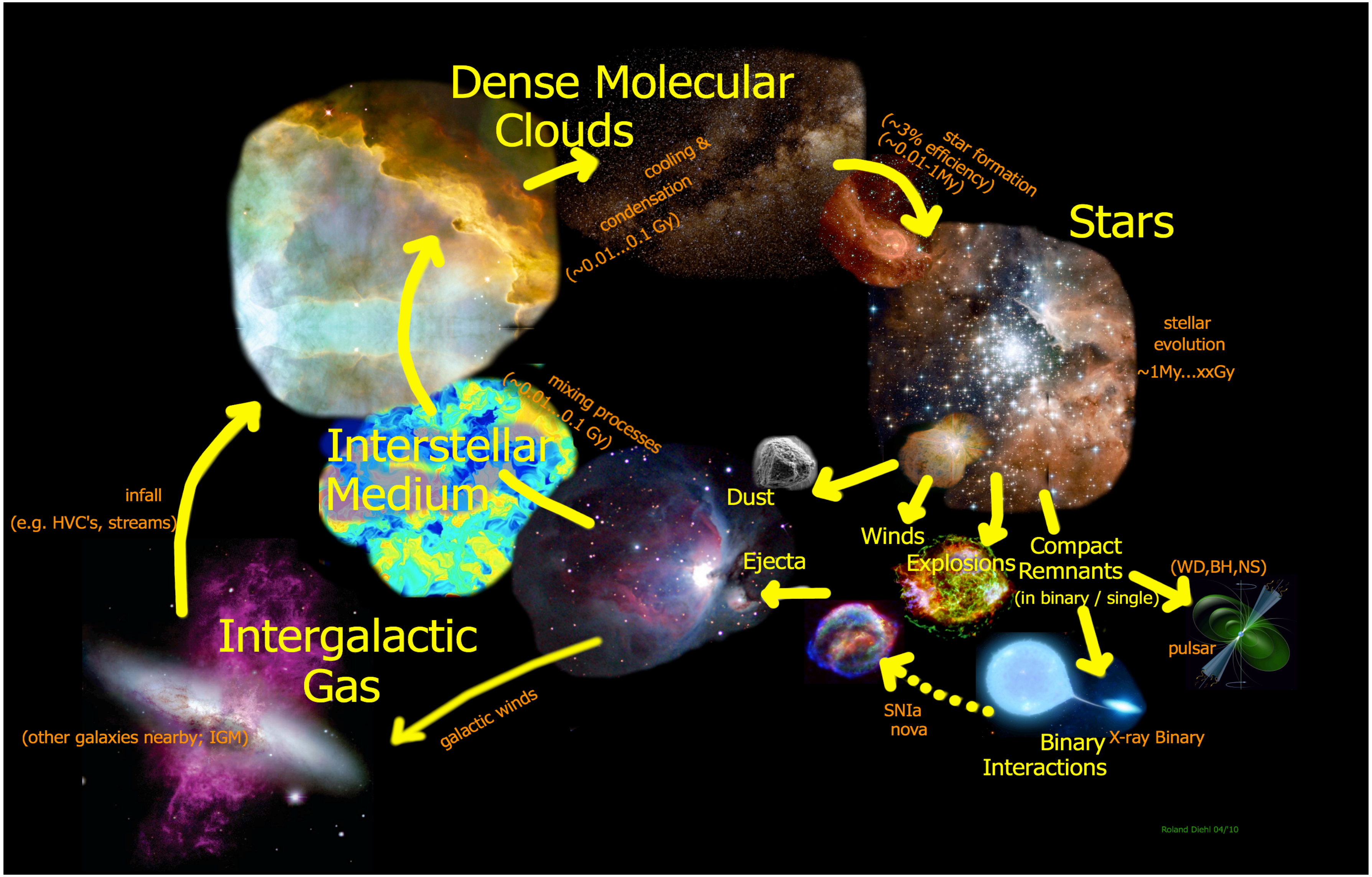
Observations and Galactic Chemical Evolution

Discussion

Cycling of Matter: Interstellar Gas through Stars



Conceptual View: Cosmic Abundance Evolution

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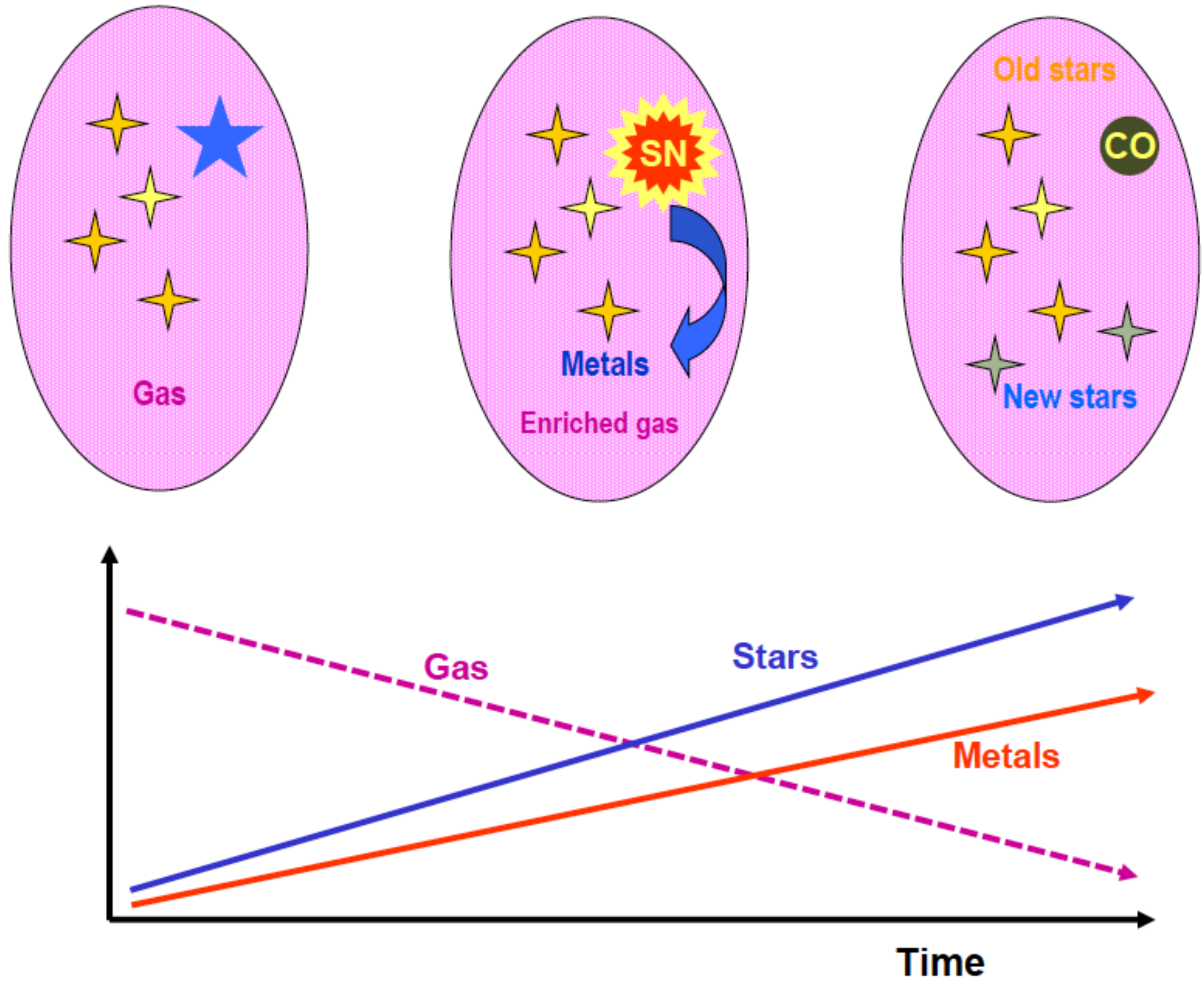
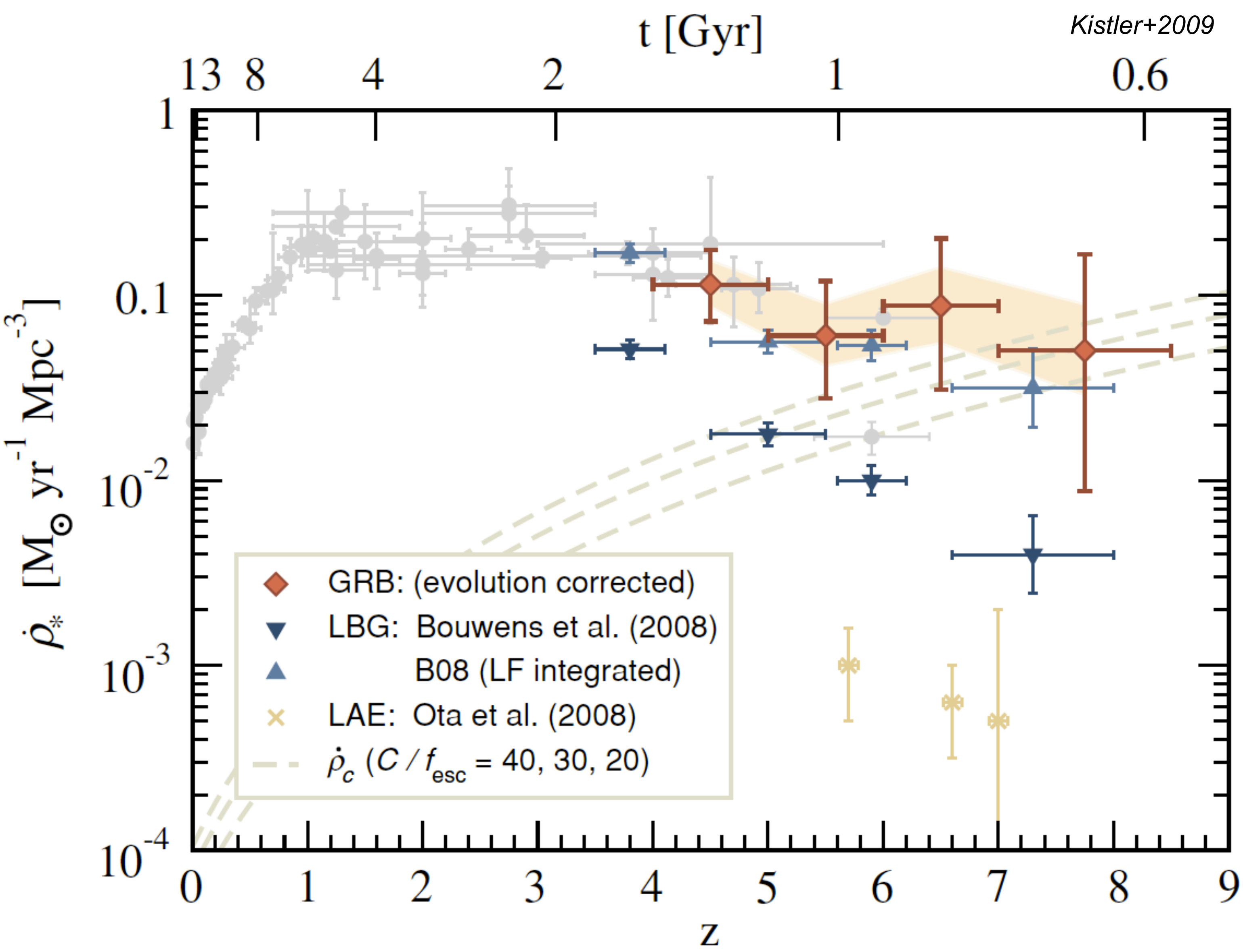


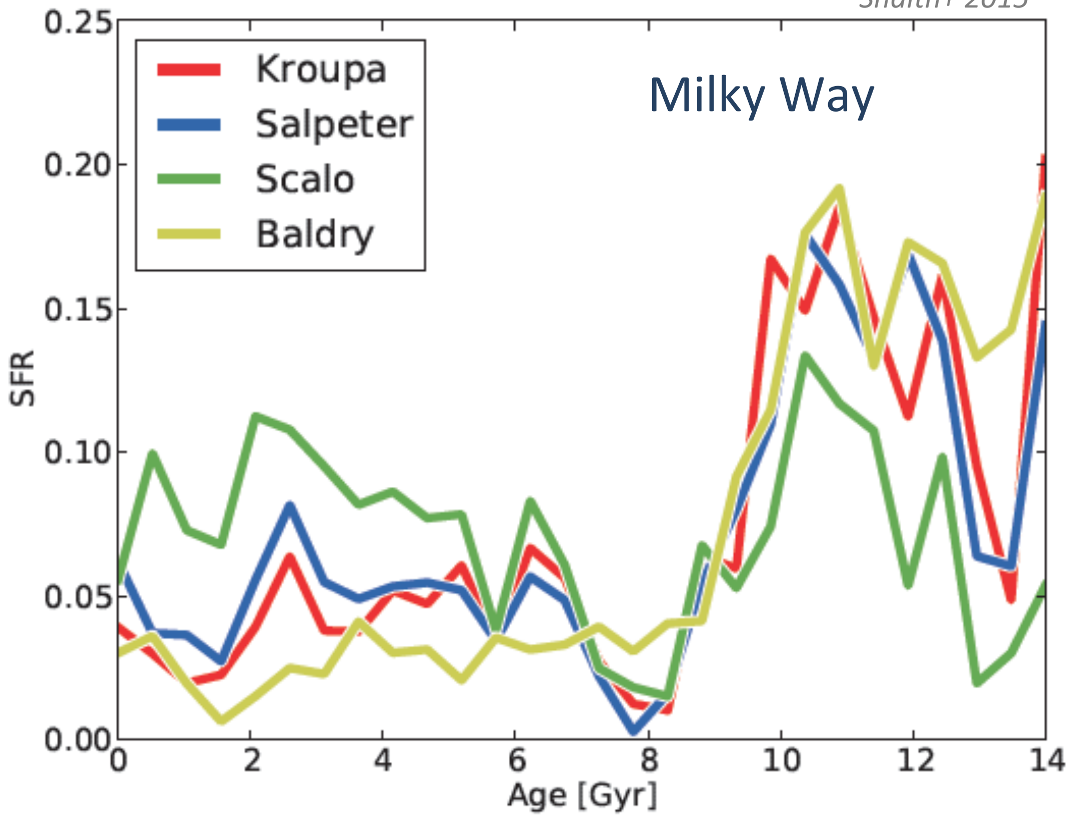
Cosmic Star Formation History



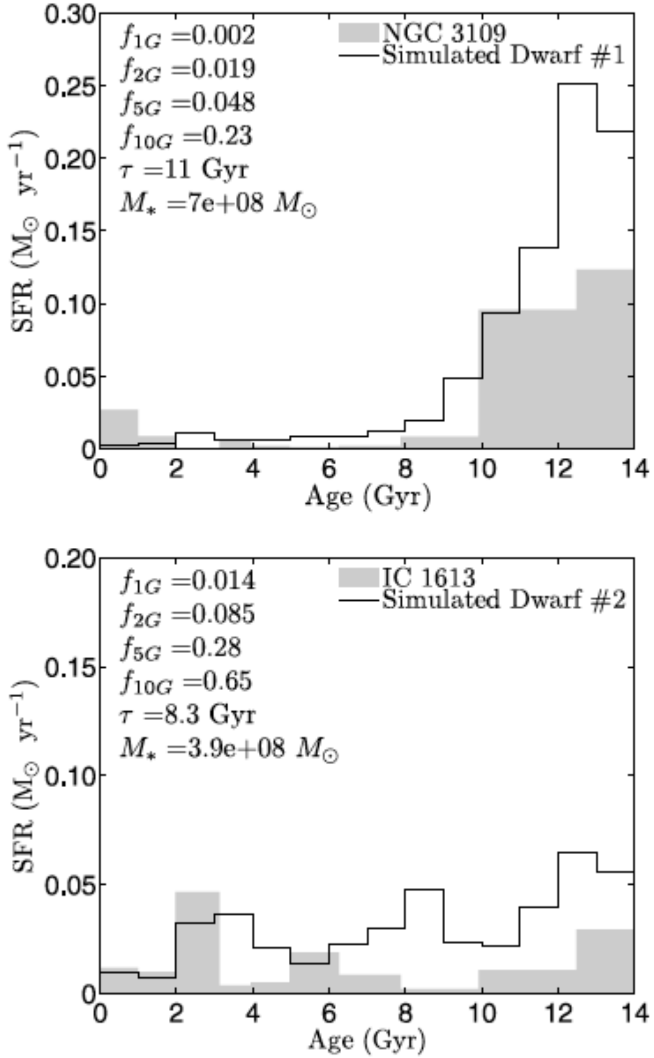
- no peak?
- SFR sufficient for reionization

Star Formation Histories

- Different for different galaxies:



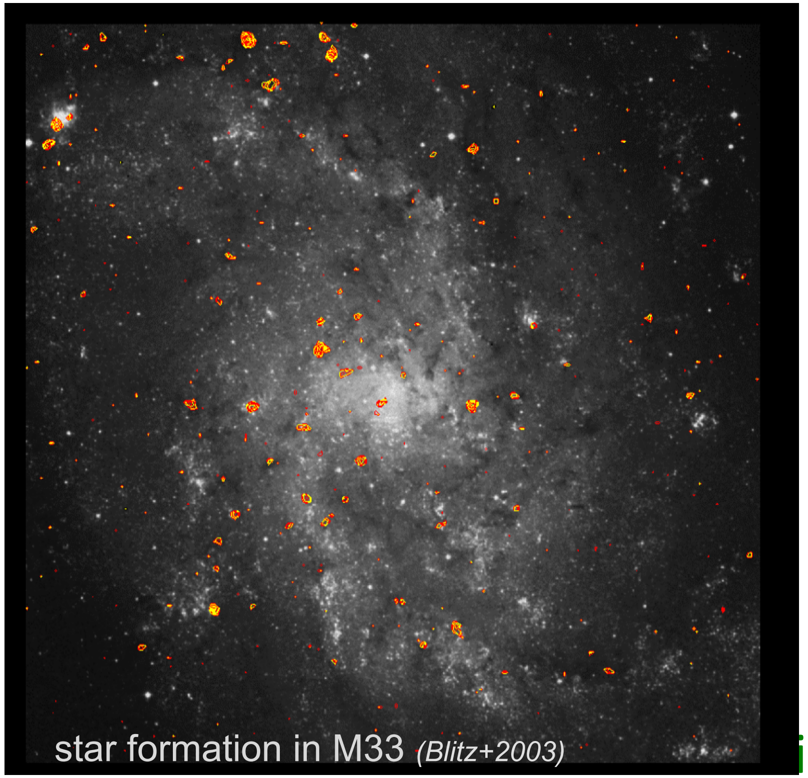
Dwarf Galaxies

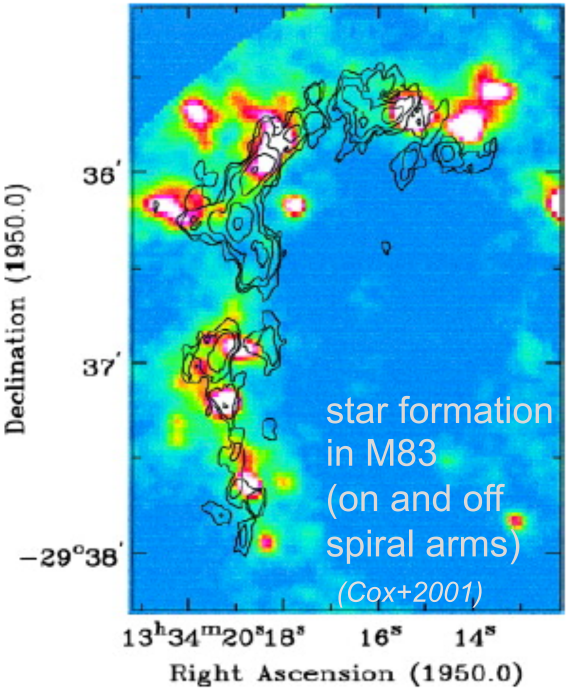


Orban+ 2008

How do stars form?

- Star formation is essentially a LOCAL process, which is influenced by large-scale environmental parameters





CO - Hβ

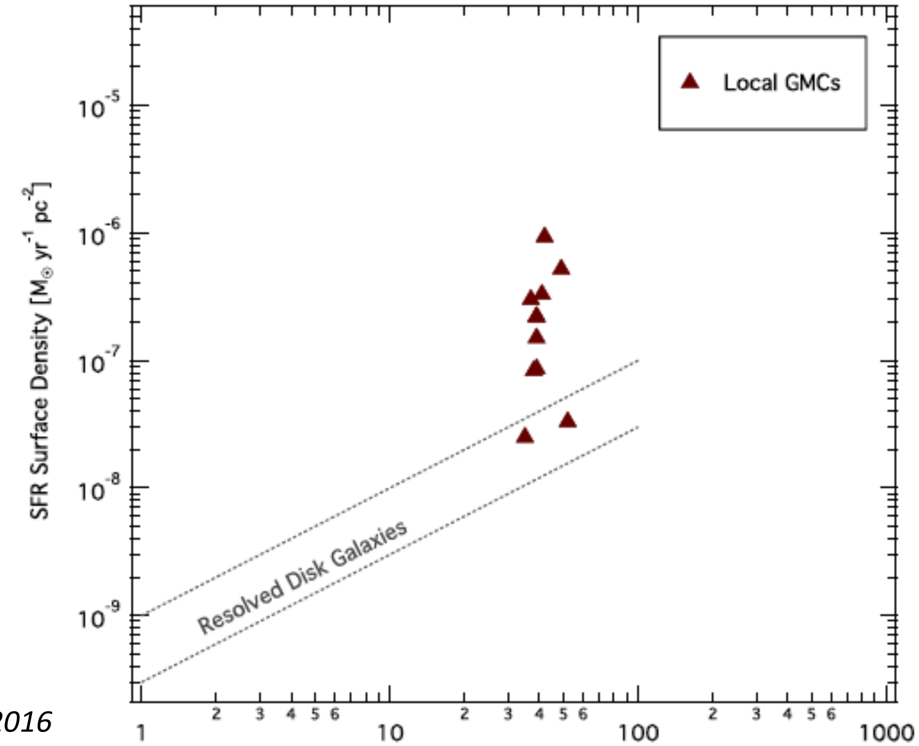
galactic rotation
and internal thermal energy
vs. gravity

$$2\pi Gk\left(\frac{\Sigma_g}{\kappa^2+k^2c_s^2}+\frac{\Sigma_*}{\kappa^2+k^2\sigma_*^2}\right)\equiv Q^{-1}>1$$

Star Formation versus Observations: Where and How Many?

- The spatial scale of averaging determines the observed "star formation efficiency"

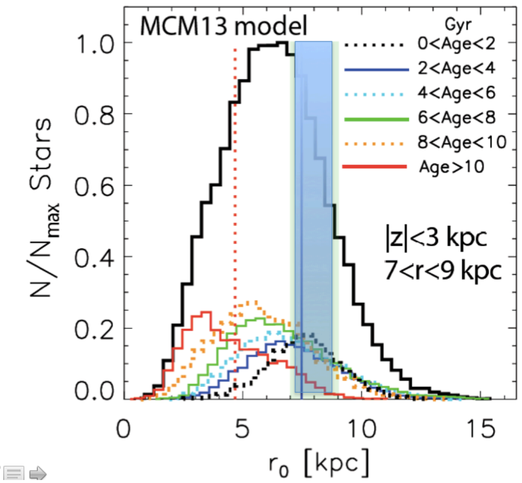
Lada+2013 *Schruba+2011*



- Stars are not born where observed, in general

Martig+2016 Stars today at Solar Vicinity are a Mosaic of stars born at different $R_{initial}$ at different times

New Approach: Chemodynamical model of the MW (Minchev, Chiappini, Martig 2013, 2014)



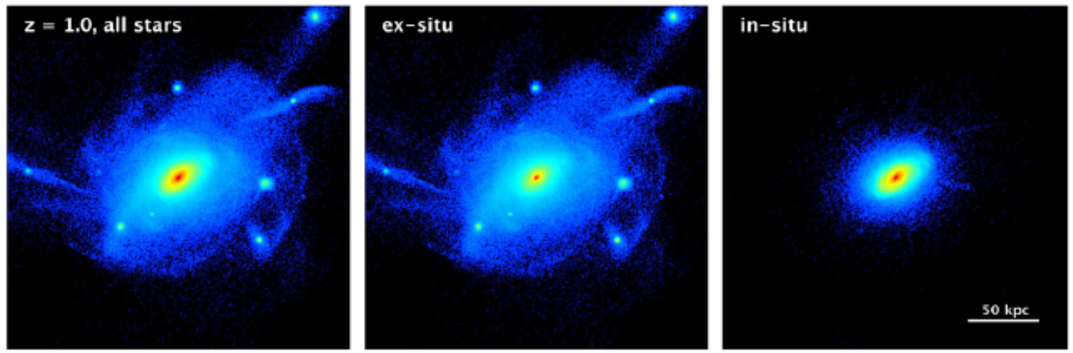
r_0 = Birth Radii in kpc

Input chemistry:
Thin disk only

Self-consistent dynamics:

N-body simulation in cosmological framework:
early mergers,
gas infall,
bar,
spirals,
radial migration

Pillepich+2016



Contributions of Stars to Abundance Enrichments

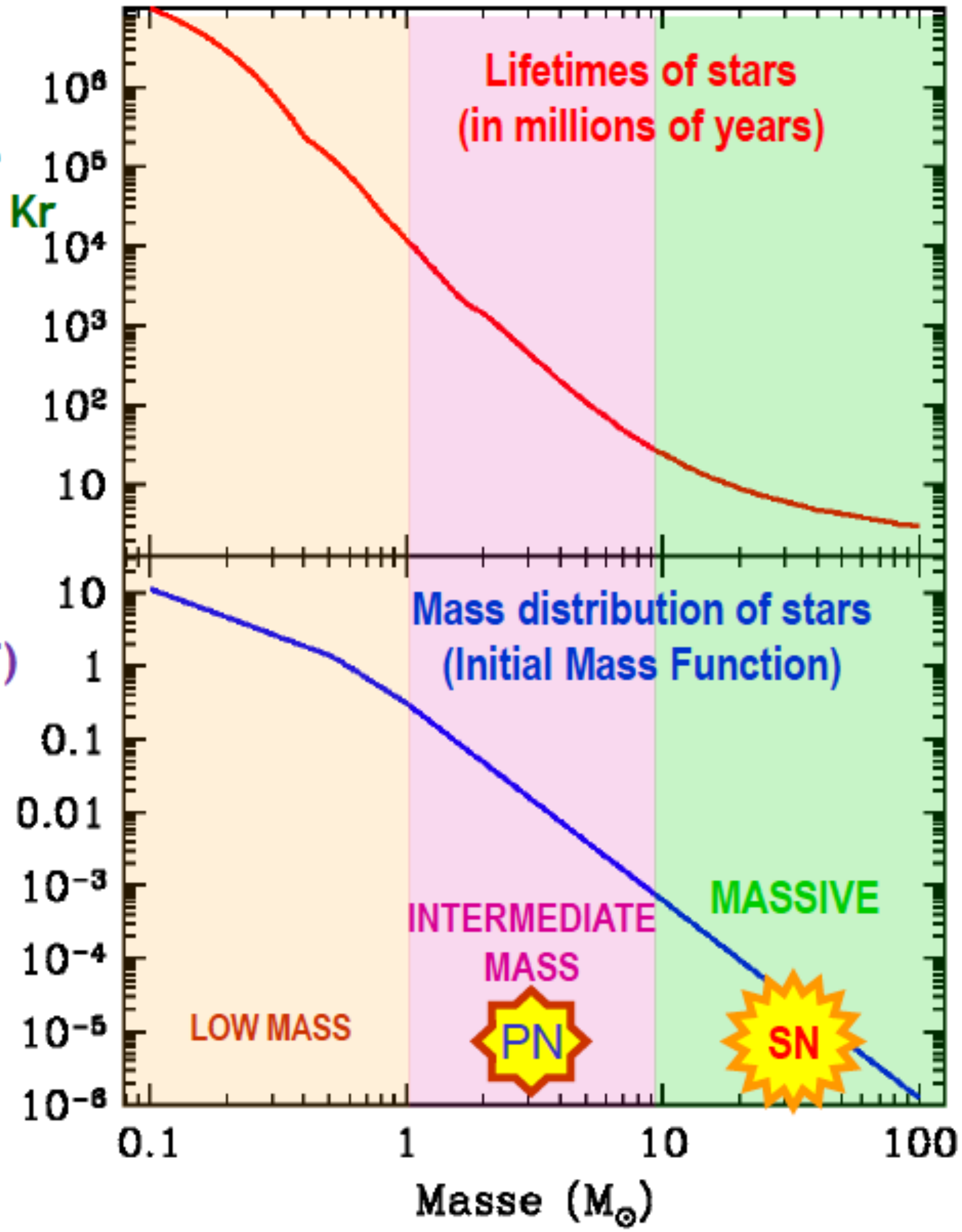
courtesy Nikos Prantzos

Massive stars (M > 10 MΘ) contribute almost all of the nuclei between C and Kr and neutron-rich (r-) nuclei

Intermediate mass stars (1<M/MΘ<10) produce s-nuclei and *part of* He3, He4, N14, C12, C13, O17, F19

and are more efficient (because of IMF) in *astrating* fragile elements (e.g. D)

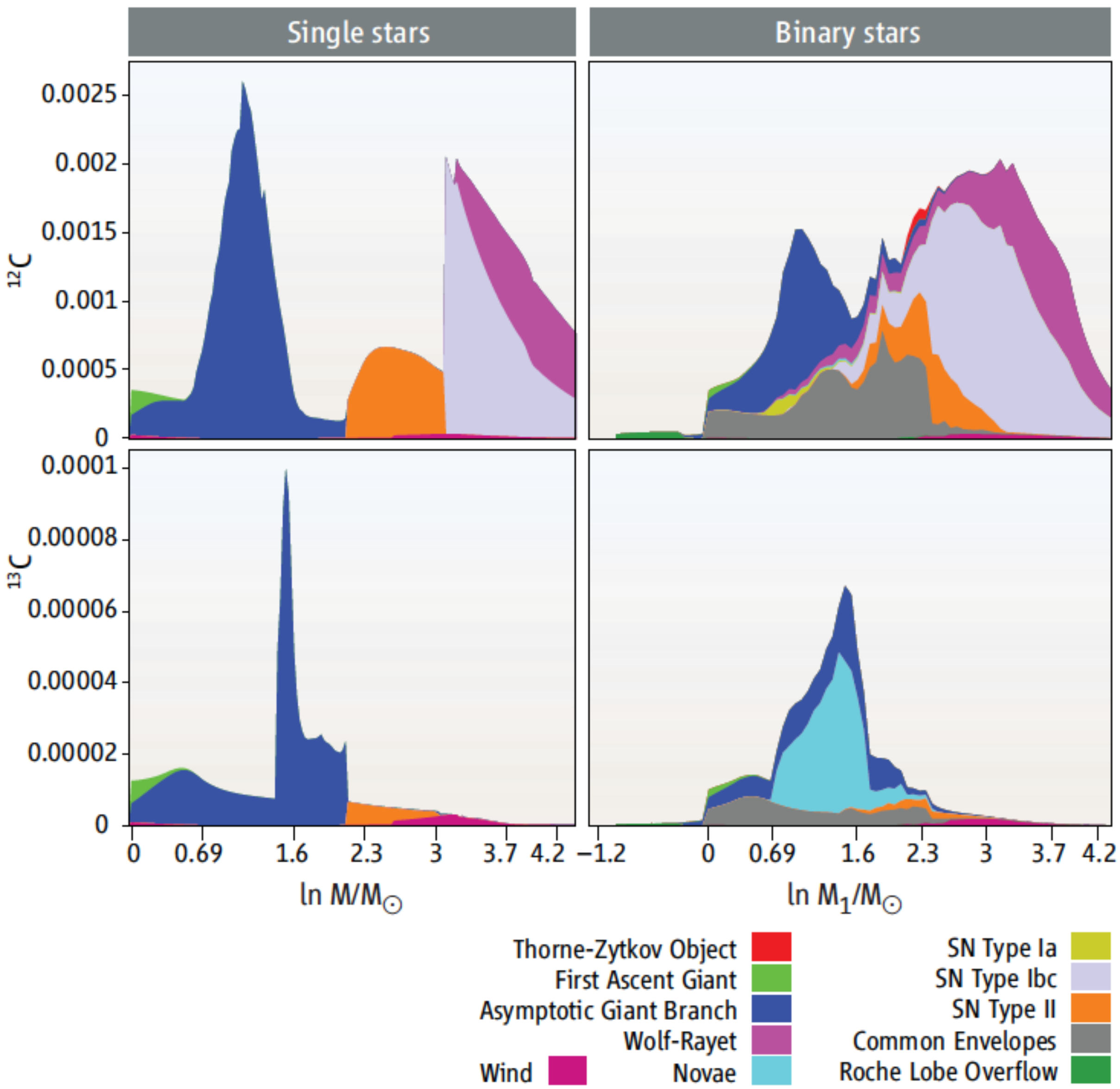
Low mass stars (M < 1 MΘ) are "eternal" and just block gas, removing it from circulation



Cosmic Carbon: The Role of Binaries

- Low-mass and WR-C stars (not SNe) are prominent Carbon producers
- The role of binaries became apparent when investigating
  – Low-metallicity stars: high fraction of "Carbon stars", relatively little Fe
  – Globular clusters: Also here, not as much Fe as should be (from massive stars)

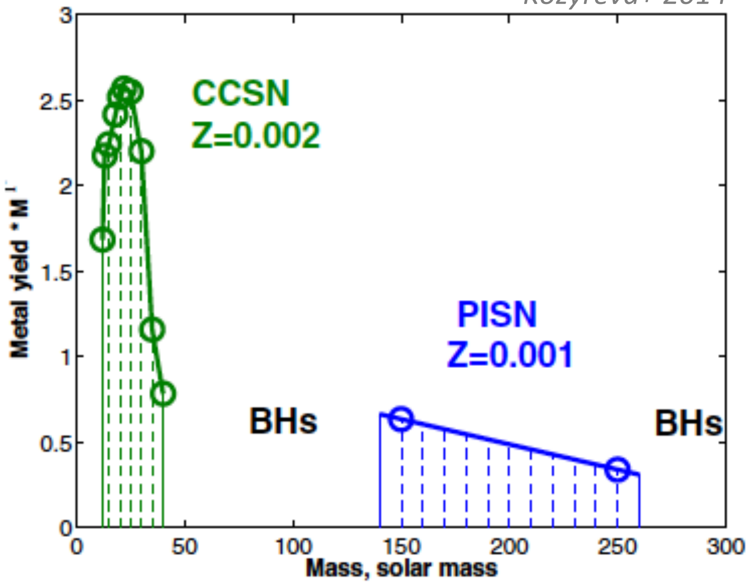
Jeffery+2006



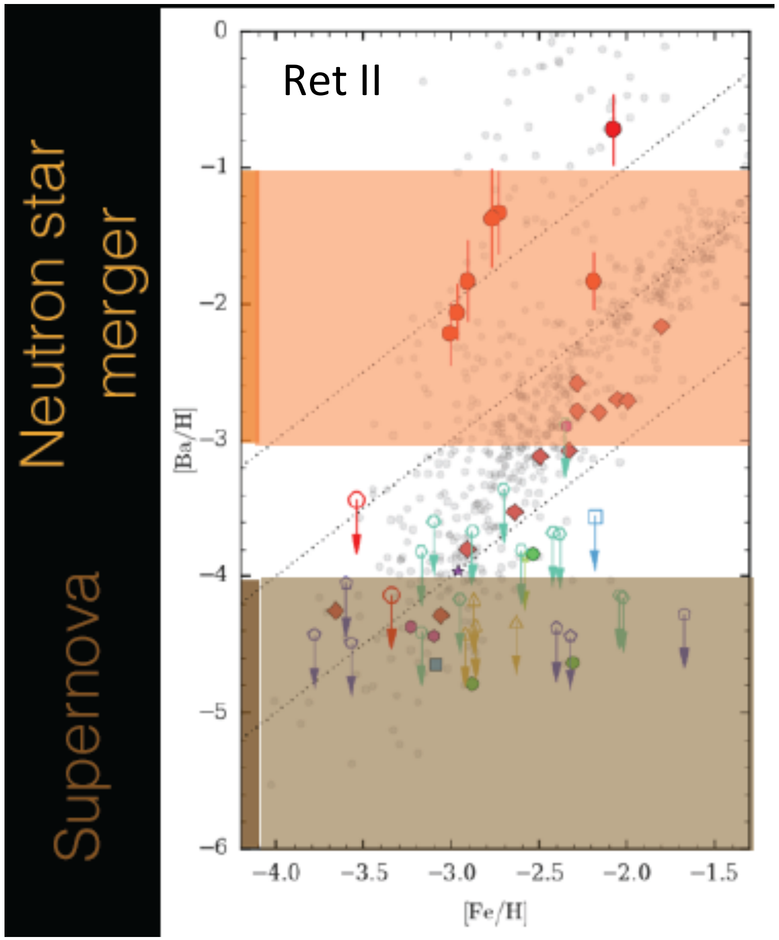
Role of extremes

- Nucleosynthesis contributions may be important from sources that are hard to observe as they occur
  - Pair instability supernovae

Kozyreva+ 2014

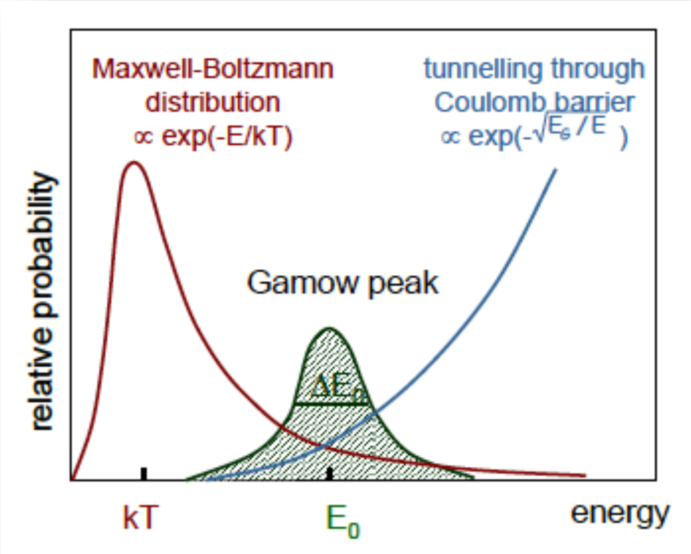


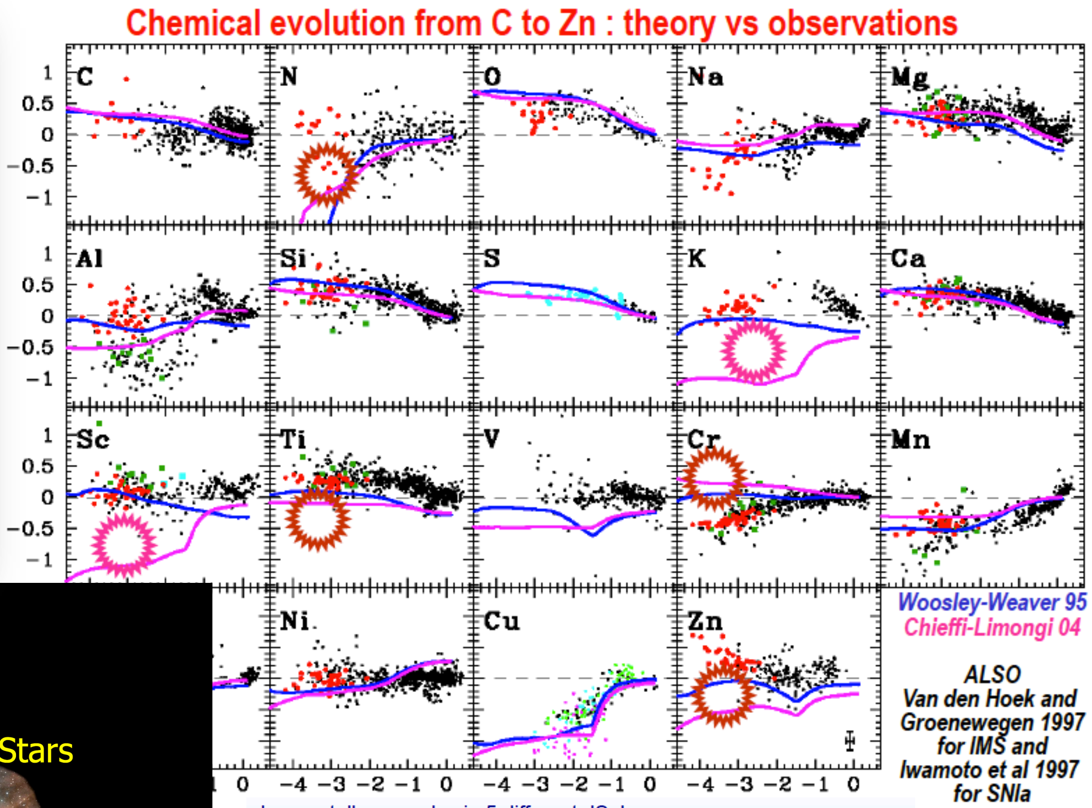
Ji+ 2016

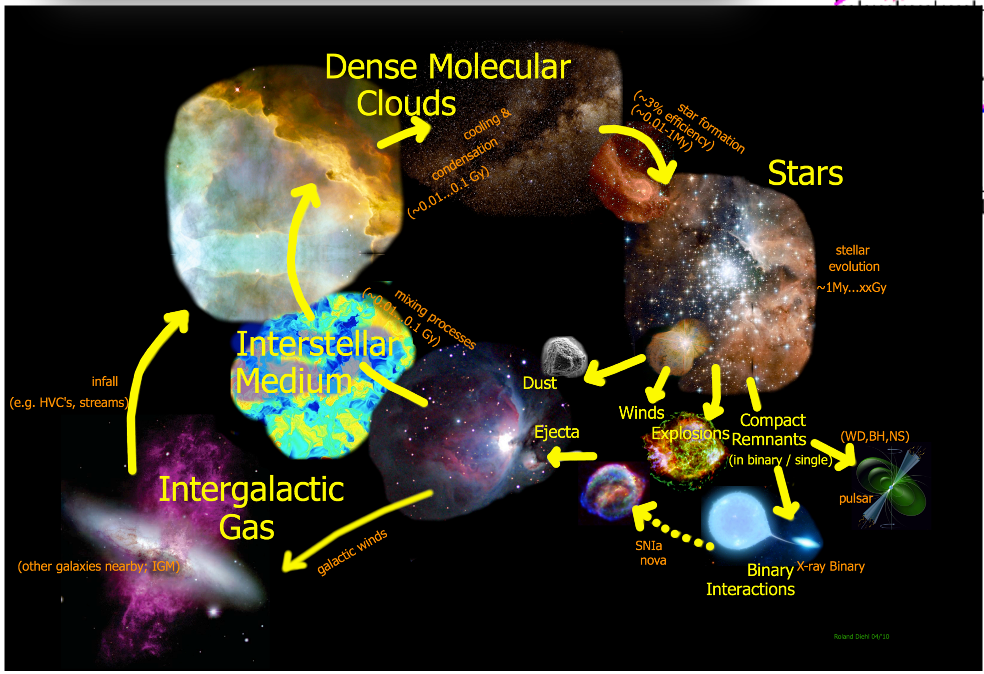


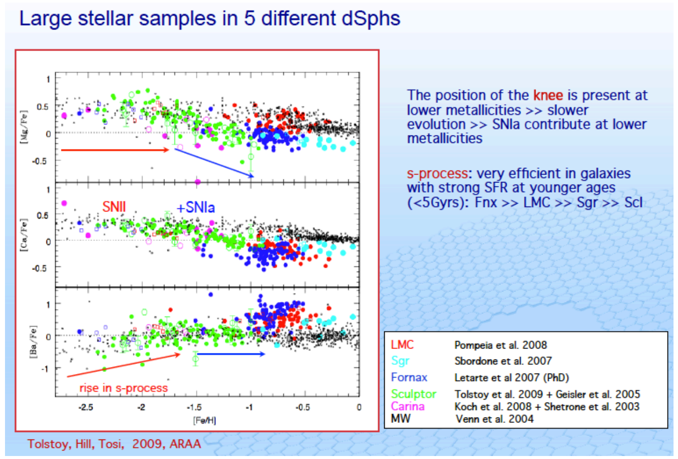
  - Neutron star mergers

Testing Compositional Evolution Description against Observations







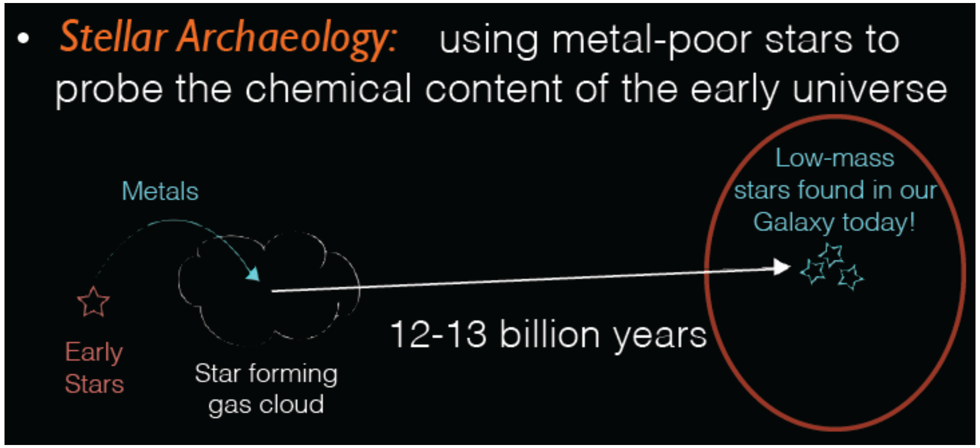


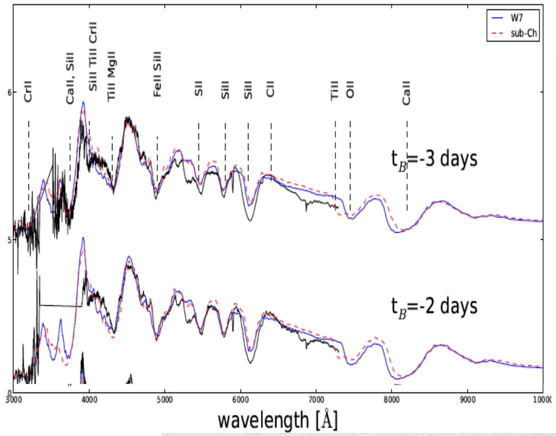
Observational Constraints

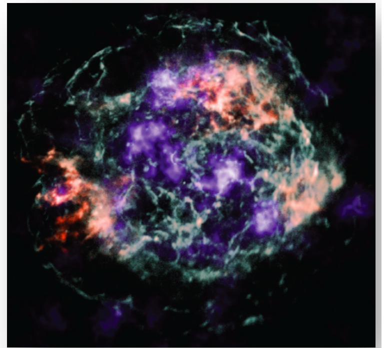
- Photospheric abundances
  - Stars nearby
  - Stars across metallicity, galaxy ‘components’

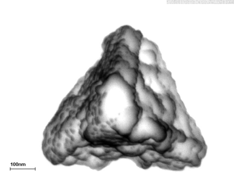
  complemented by
  - Asteroseismology
  - ISM abundances
- Nucleosynthesis events
  - Spectroscopy
  - Indirect constraints (e.g. LCs)

  for supernovae, type I XRBs, ..
- Composite systems
  - Indirect: galaxy properties, absorption lines (QSO, GRB), …
- Specific samples/probes
  - ESS material, cosmic rays, oceancrust, lunar, presolar grains









How to learn

- Modeling of sources
  - Explore the variety of parameters that may occur
  - Understand systematic uncertainties of modeling approaches
  - We “expect” … (not “we know”)
  - Guidance for observational efforts and data analysis
- Modeling of galaxy evolution on all scales
  - Assemble a global description
  - Enable and verify subgrid models
- Observations, observations, ..
  - Understand observational biases and limitations

- **Discussion AMONG theorists and observers**

Towards an Evolutionary Model: Questions and Issues

- How do stars form, evolve, and explode?
  - Environment, from which material, how efficient?
  - Variations with time, location, and environment?
- What are the yields?
  - From stars (rotation, mixing), from supernovae (Ia w subtypes, EC, ccSN), from extremes (HN, NSM, GRBs, PISN), from binaries?
- How are new nuclei mixed and recycled?
  - Ejecta flows, feedback, gas flows, fountains, blow-out?
- How detailed must a chemical-evolution description be?
  - Bottom-up physics, subgrid models, stochasticity?
- How can we assemble adequate observations?
  - Stellar migration, stellar atmosphere uncertainties?
  - Gas abundances (hot, cold), dust & presolar grains, ESS?

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Discussed

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Q 1

Q 2

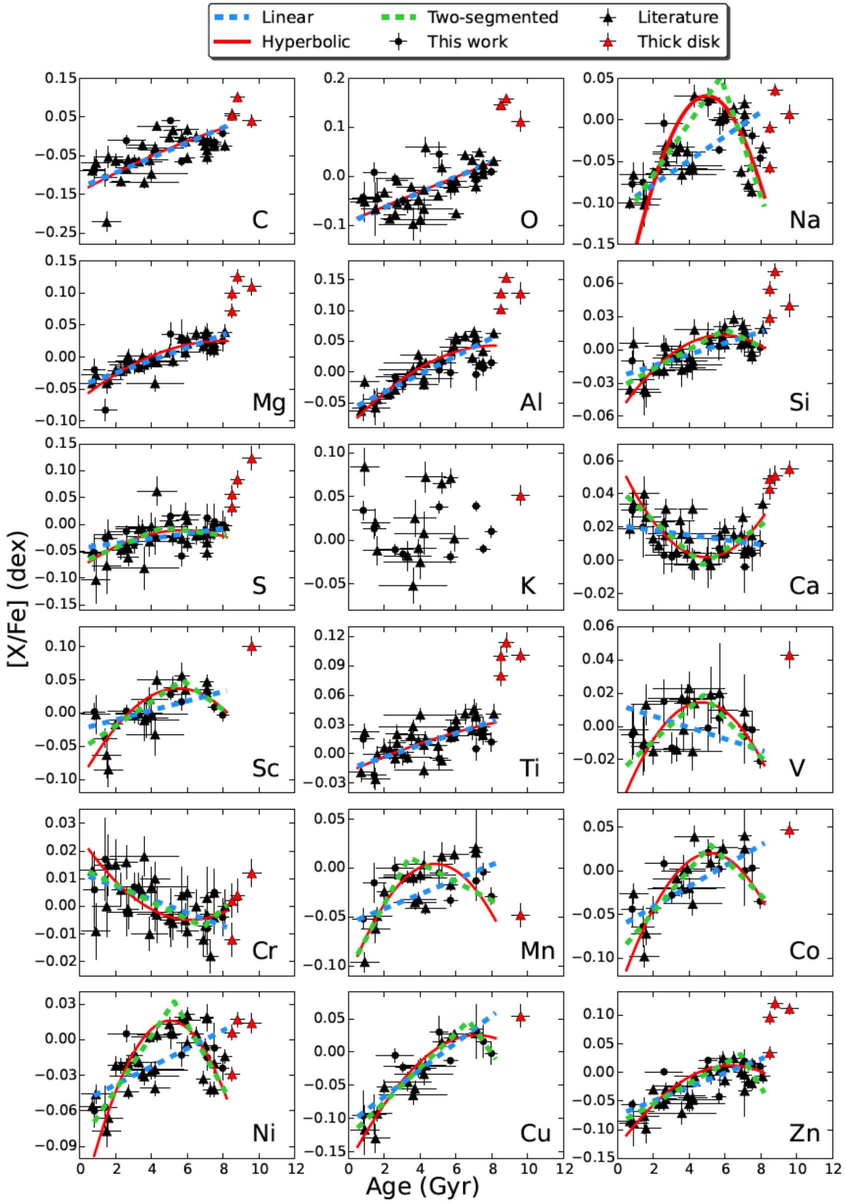
Q 3

Reducing systematic uncertainties

- Solar twins → age-metallicity

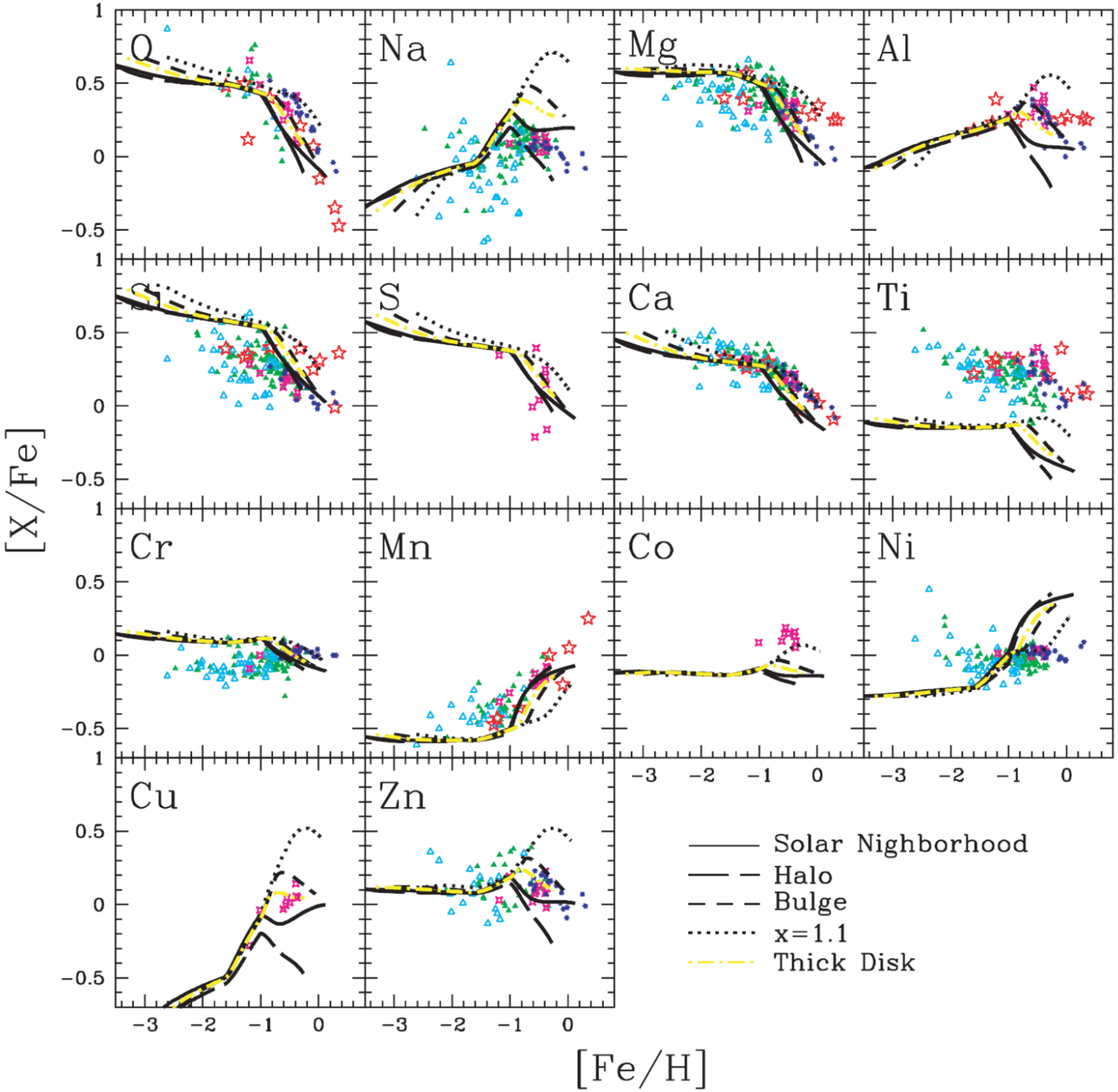
- Photosphere models in 3D

Spina+2016



Chemical Evolution of the Galaxy and its Components

- SNIa-Produced Fe Sets in at [Fe/H]~-1.1
- α-Elements Co-Evolve (cc-SNe)
- Zn (& Co) Have Major Contributions from Hypernovae
- Age of Components Determines Evolution History (Bulge→ thick disk → thin disk)



Chemodynamical Modeling with Radial Migration

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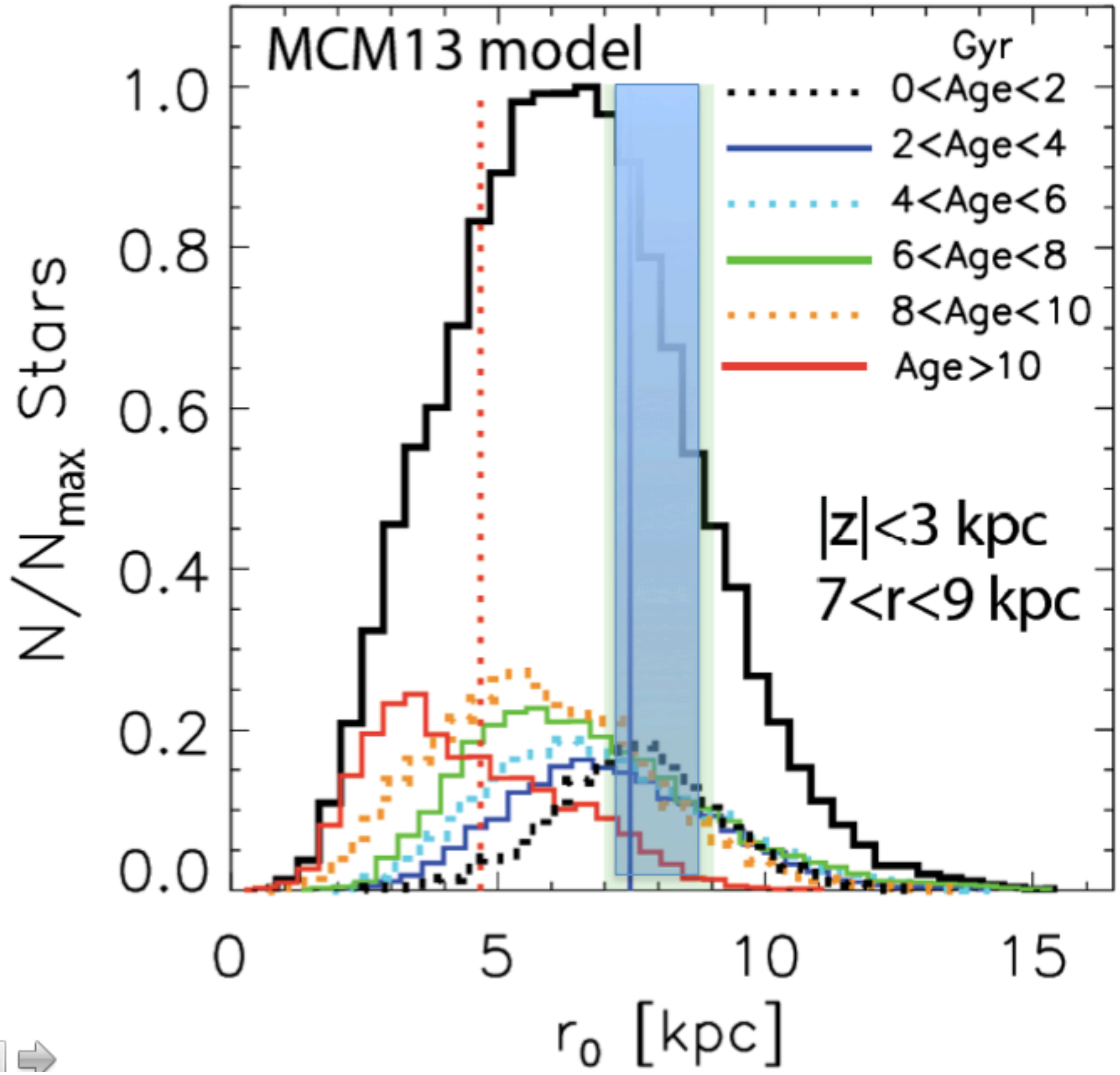

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