銀河系円盤の化学・力学進化と太陽

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「太陽物理学と恒星物理学の相互交流と将来的展望」
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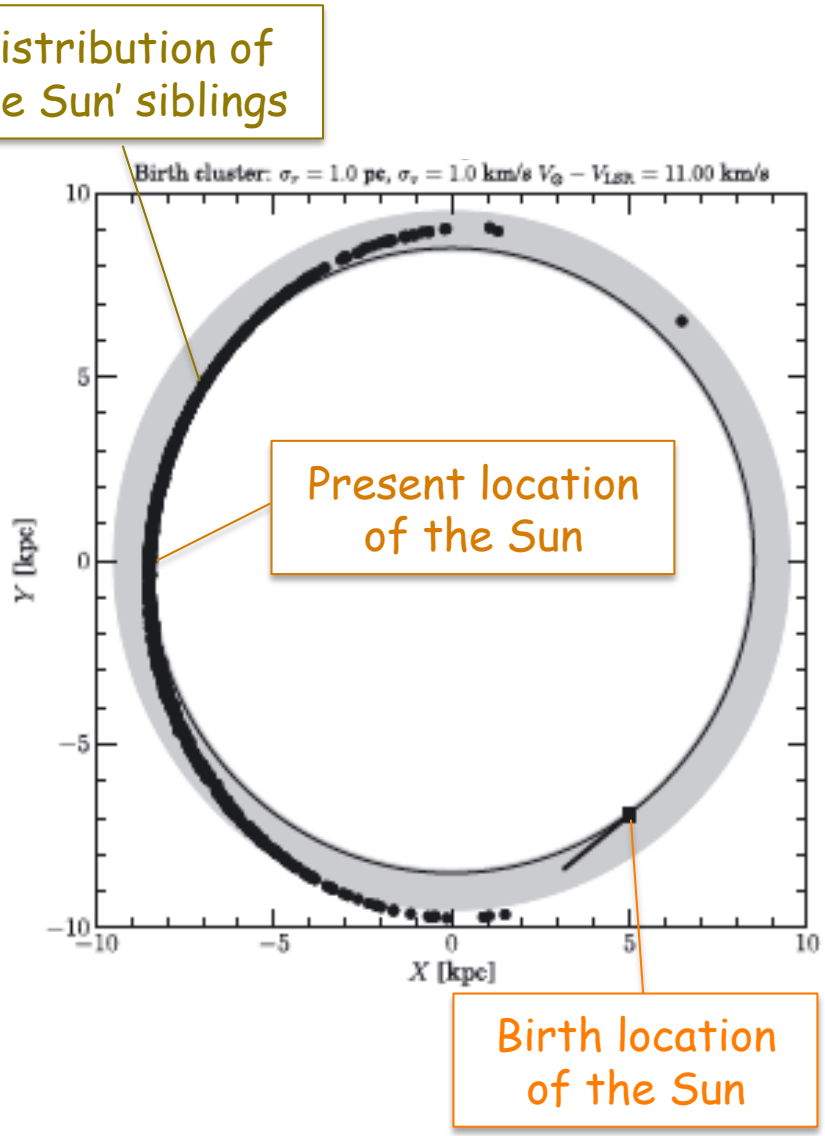
Outline

- Motivation
- The Sun and the MW disk system
- Formation and evolution of the MW disk system
  - Models for the disk formation & evolution
  - Observational constraints
- Where are the siblings of the Sun?

Motivation: Sun as a member of the MW disk system

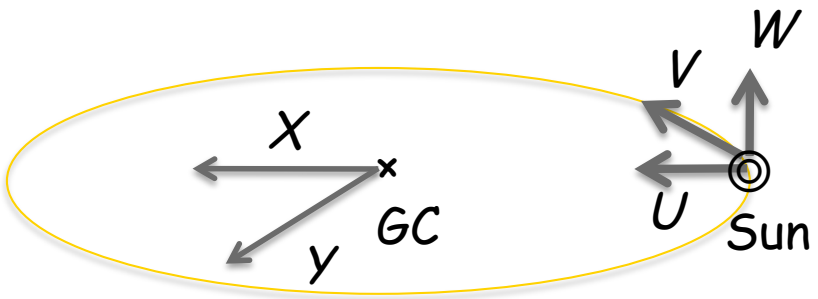
- Questions:
  - Why the Sun/Solar system has acquired the current properties?
- These are determined by…
  - Environment of the birthplace (stellar density, nearby SNe, etc)
  - Astrophysical impacts as it travels through the Galaxy
  - Properties (size, IMF, etc) / destruction process of the birth cluster
- Search for the Solar siblings (兄弟星)



Brown et al. 2010

The Solar system in the MW disk

- Position
  - ~7.5-8.5 kpc from the Galactic center
- Kinematics
  - $(U, V, W)_{\odot}$=(11.10, 12.24, 7.25) km/s (Schönrich+ 10), relative to V_{LSR}=220 km/s
- Chemical abundance
  - More metal-rich than other stars around the Sun

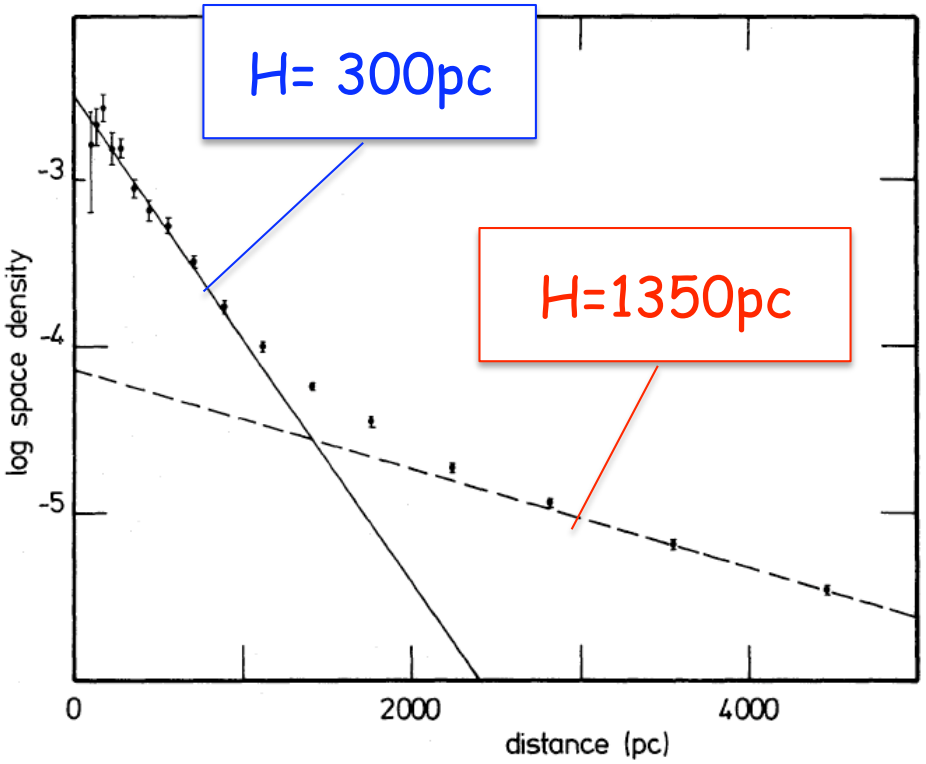


The Milky Way disk system

- Thin disk
  - ρ∝exp(-Z/H), H ~ 300 pc
  - metal-rich: [Fe/H]~0.0
  - Rotational velocity

    V_φ~220-240 km/s
  - low [α/Fe]
- Thick disk
  - H ~ 1 kpc
  - metal-poor: [Fe/H]<-0.5
  - V_φ~160-180 km/s
  - high [α/Fe]

Stellar density distribution
(Gilmore & Reid 1983)

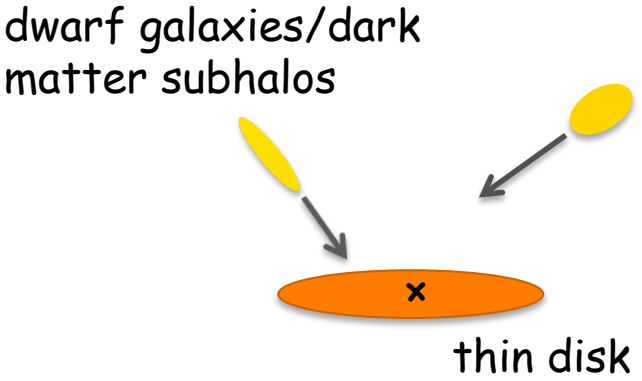


(Distance from the Galactic plane)

* [α/Fe]=average of [Mg/Fe], [Si/Fe], [Ca/Fe] and [Ti/Fe]

Formation/evolution of the MW disk system

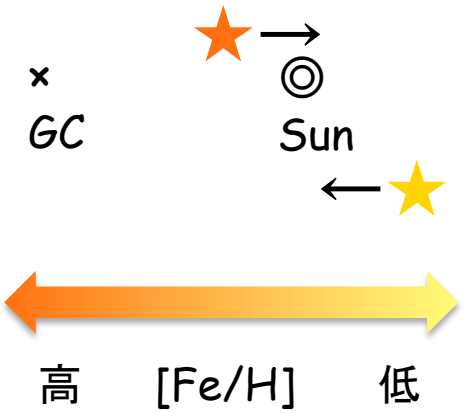
- Violent process
  - Accretion of dwarf galaxies
  - Dynamical heating via minor mergers of dwarf galaxies/dark matter subhalos
  - Gas-rich mergers at the early phase



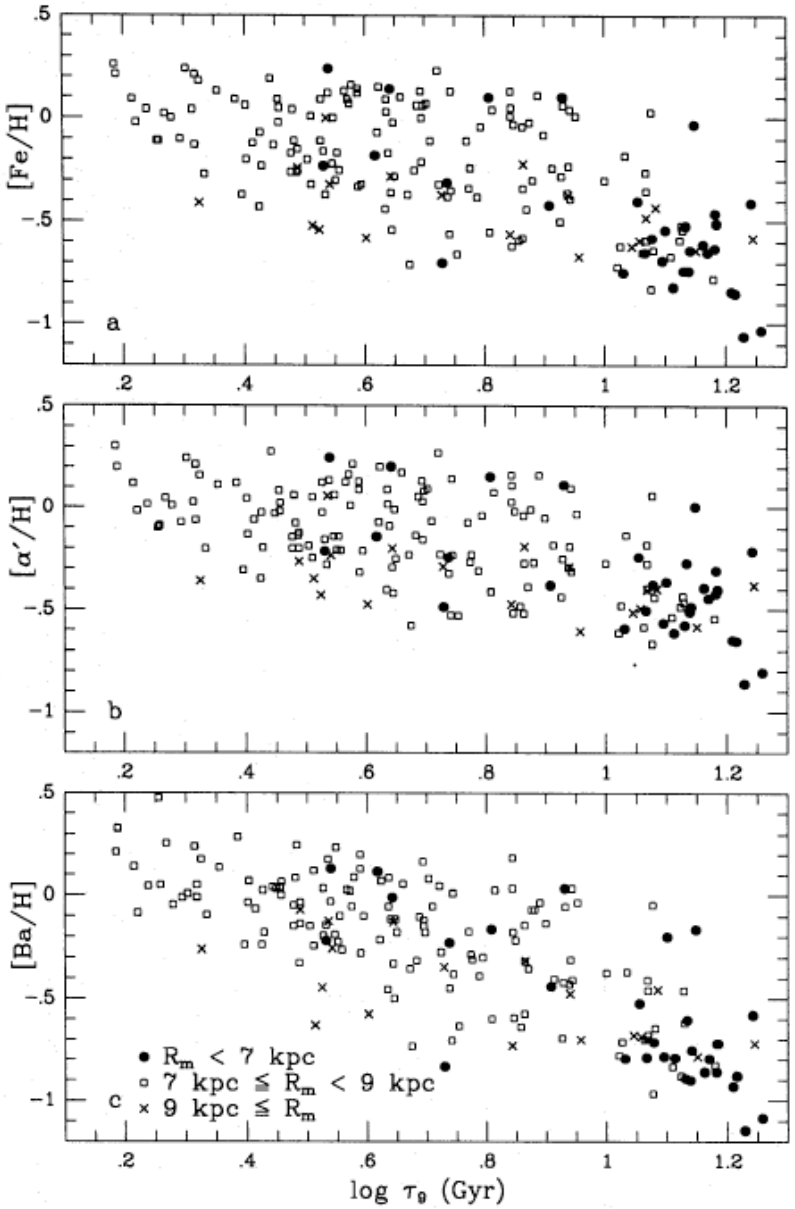
- Secular process

Scattering of disk stars by the bar, spiral arms and/or giant molecular clouds cause…

  - Radial migration
  - Increase in velocity dispersion



Age-metallicity relation

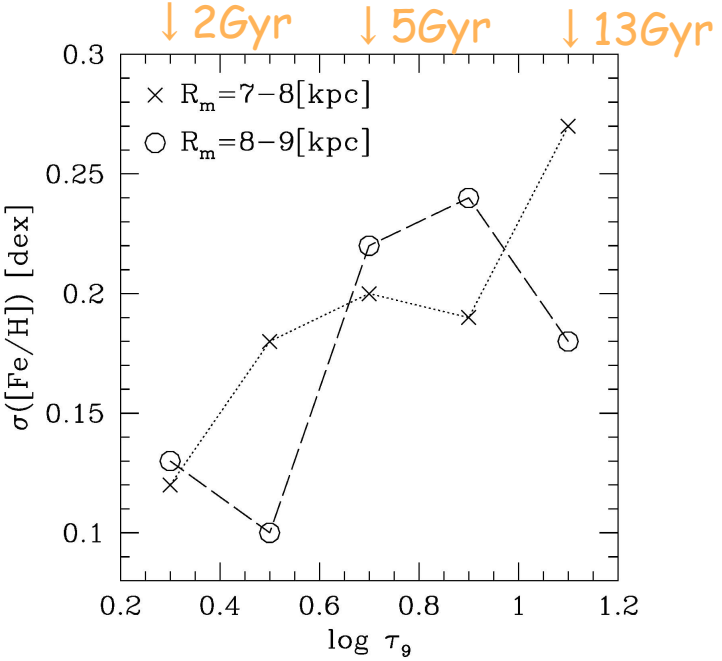


Edvardsson et al. 1993

- Scatter in log τ_9-[Fe/H] relation is larger than the observational errors.

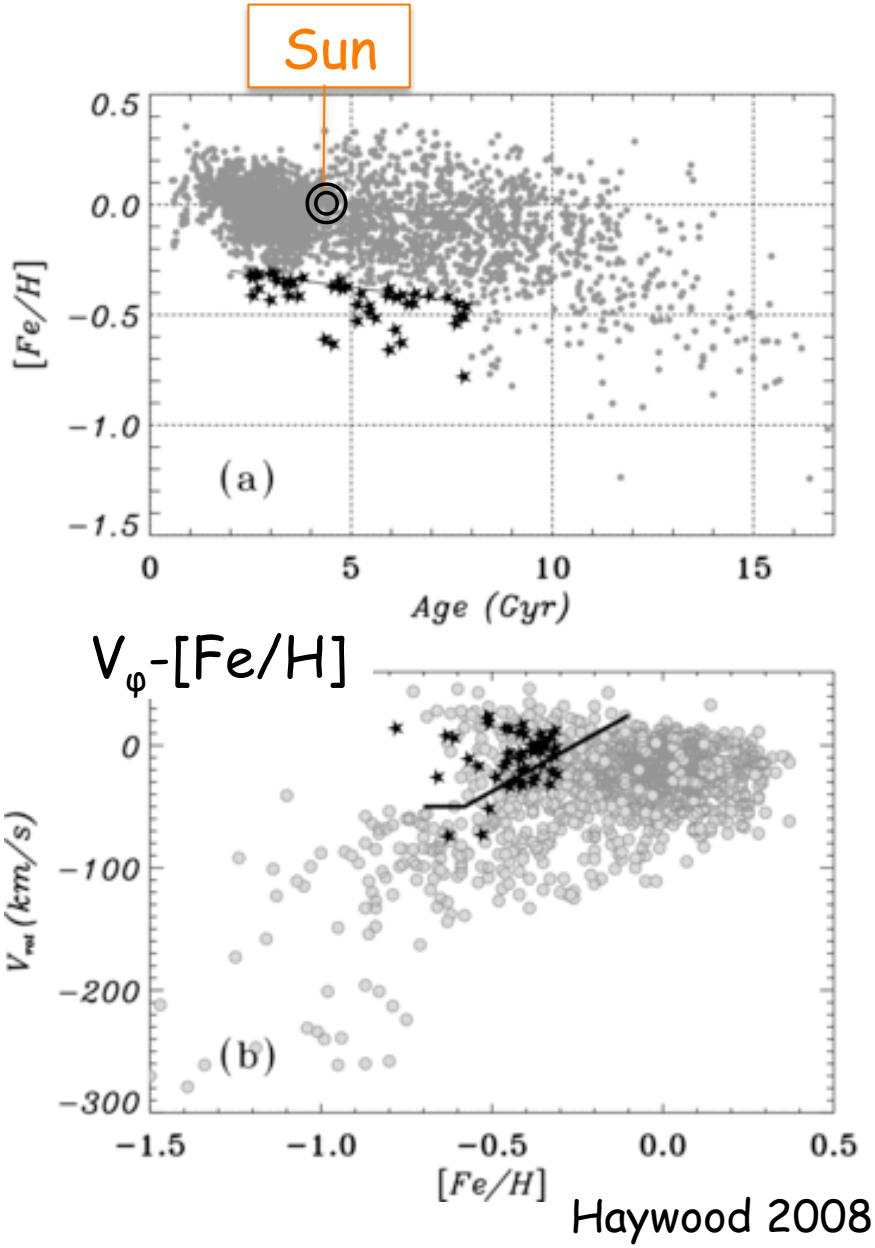
  ※ τ_9: Age of a star in unit of 10^9 yr

- The scatter, σ([Fe/H]), is larger for older stars



Data from Table 15 of Edvardsson+93

Evidences of the radial migration: Rotational velocity (V_φ)-[Fe/H]



Haywood 2008

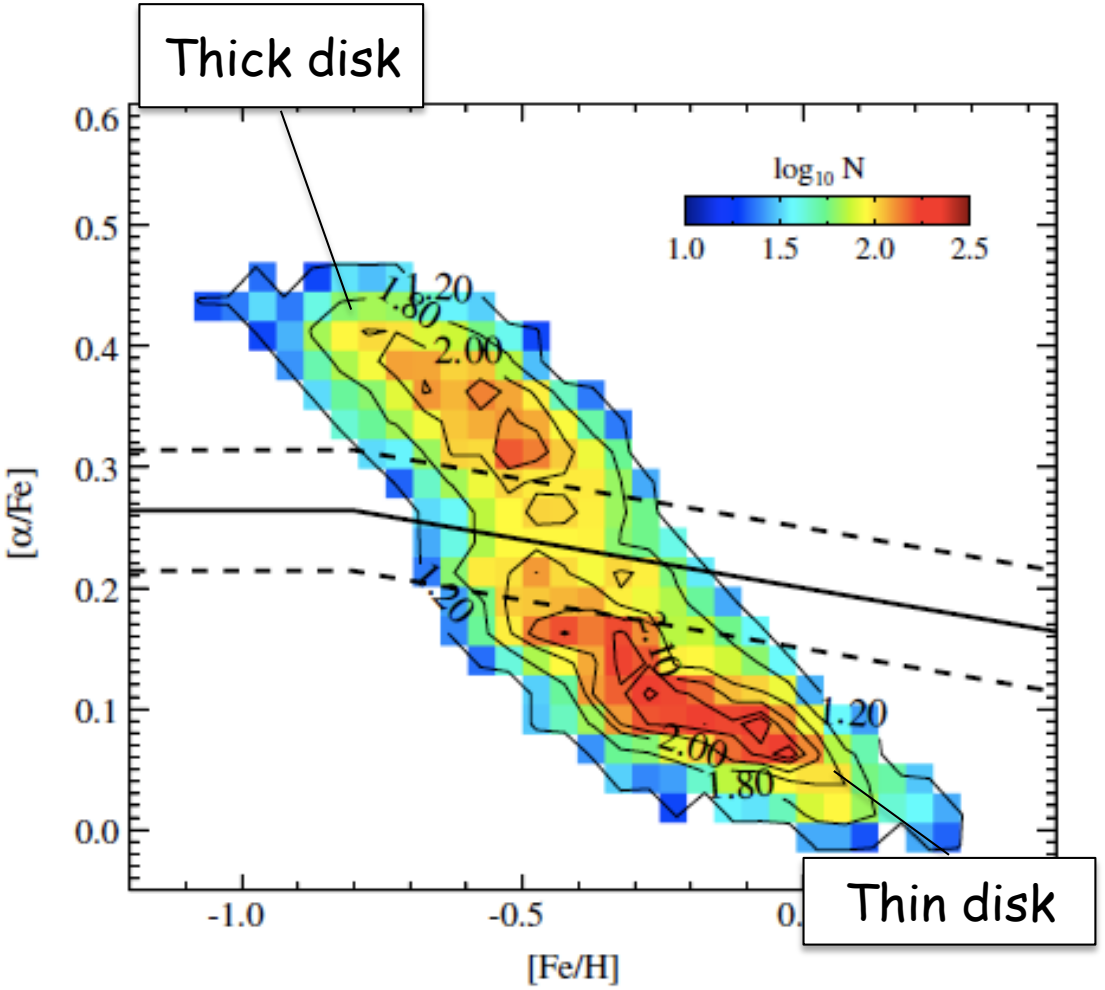
- Local metal-poor disk stars preferentially have high rotational velocity

  ⇒ Consistent with that these stars came from the outer disk

- Radial migration timescale: 1.5-3.7 kpc /Gyr

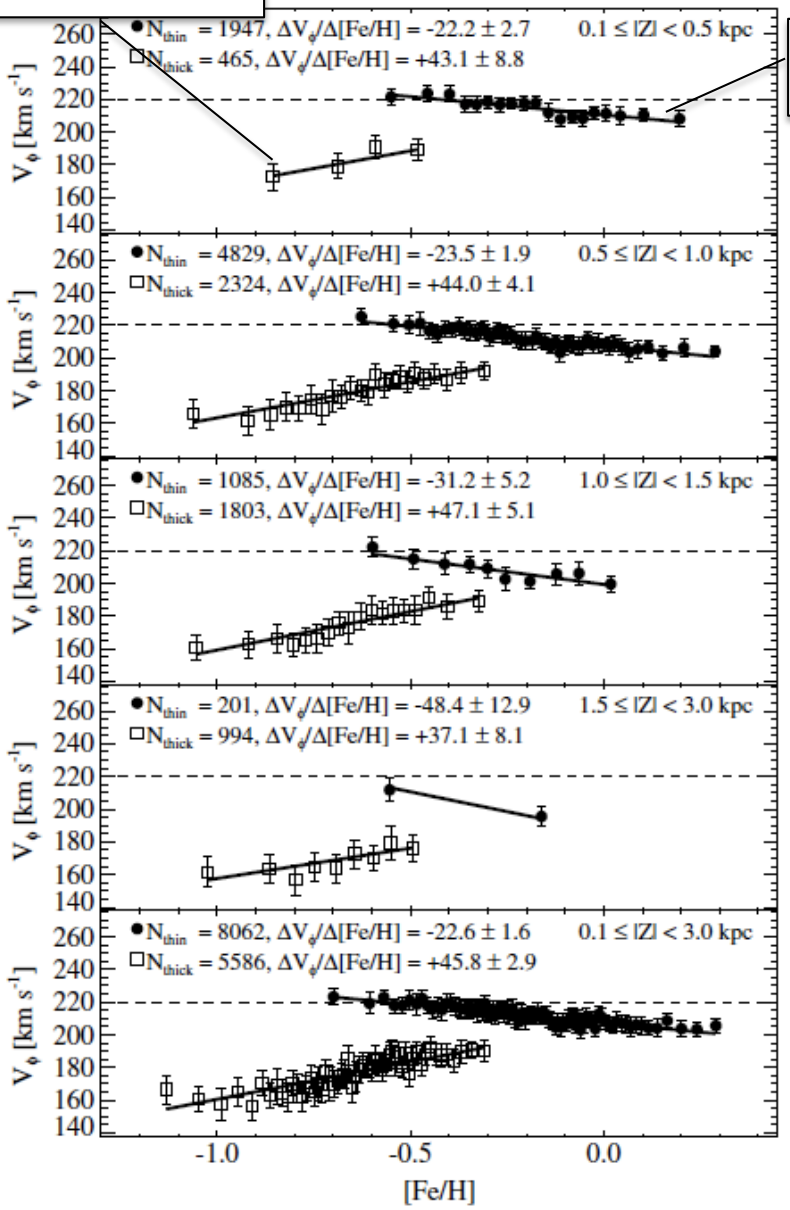
Thin/Thick disk division using [α/Fe]

- SDSS SEGUE sample:
  - d< 3kpc, 7<R<10 kpc
  - 17,300 dwarf stars
  - R~2000
  - T_{eff}, logg, [Fe/H], [α/Fe]



Lee et al. 2011

Vφ - [Fe/H] trends

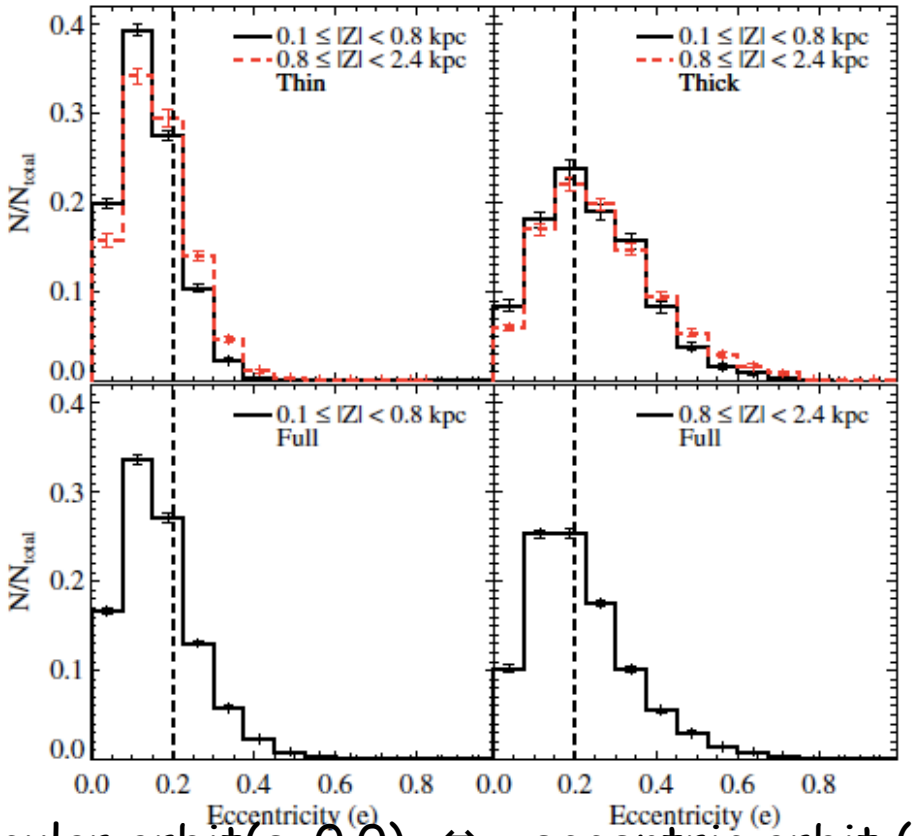


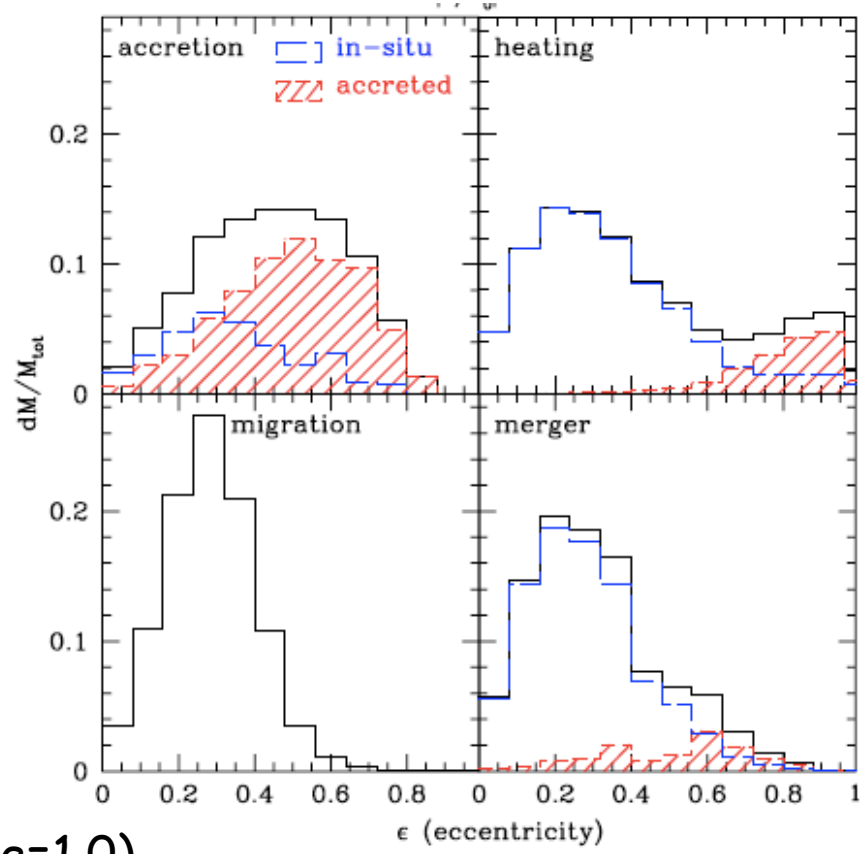
- Thin disk
  - Metal-poor stars have higher Vφ
  - Consistent with the migration model (metal-rich stars come from inner disk, metal-poor stars come from outer disk)
- Thick disk
  - Inconsistent with the migration model

Lee et al. 2011

e（軌道離心率）分布

Lee et al. 2011





circular orbit(e=0.0) ⇔ eccentric orbit (e=1.0)

- Thin disk: migration model
- Thick disk: heating model または gas-rich merger model

Implications on the formation and evolution of the MW disk(s)

- Radial migration have played a significant roll on the evolution of the thin disk
  - Spread in age-[Fe/H] relation
  - Vφ -[Fe/H] relation
- Violent process (heating/gas-rich mergers) are needed for the formation of the thick disk.
  - Vφ - [Fe/H] relation
  - e distribution

⇒ The Sun/Solar system has also experienced dynamical processes due to the disk evolution during its history

Can we find Solar siblings ?

- In a simplified simulation, ~10-60 Sun's siblings is expected within 100pc (Portegies Zwart 09)
- Currently available data (etc. Hipparcos) is not sufficient to find even 1 sibling (Brown+ 10).
- Dynamical evolution of the disk stars (violent/secular) further complicate the search through positions and kinematics alone.
- Combination of precise astrometry data (*GAIA*, etc) + detailed chemical abundance patterns are necessary