METALLICITY DISTRIBUTION OF M DWARFS AND LOCAL GALACTIC EVOLUTION

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Photometric Metallicity Calibration

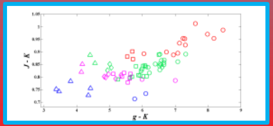
Based on a sample of 71 dwarfs, we developed an optical-NIR photometric calibration to estimate the metallicity of late-K and early-to-mid M dwarfs. The best fit is a 2nd order polynomial in SDSS *g* and 2MASS *JK* photometry, applicable for -0.73 ≤ [Fe/H] ≤ +0.30.

[Fe/H]	
[+0.15,+0.30]	red
[-0.10,+0.15]	green
[-0.40,-0.10]	magenta
[-0.73,-0.40]	blue

Color-coded Metallicities

Spectral Type	
[M0,K6]	△
[M2,M1]	◇
[M4,M3]	□
[M6,M5]	○

Symbol-coded Spectral Types



The (g-K)-(J-K) diagram for the 71 dwarfs in our calibration sample

Why M Dwarfs?

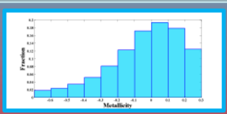
- Most numerous stars in the Milky Way
  - About 70% of all stars in the Galaxy by number
  - Nearly half the stellar mass of the Galaxy
- Main sequence lifetimes longer than the current age of the Universe: excellent tracers of Galactic evolution
- Providing stars with a wider range of ages than G and K dwarfs for representing the local metallicity distribution

Observation

We selected a sample of 1,312,000 M dwarfs from SDSS DR 9 and 2MASS catalogs with clean photometry and Galactic heights ≤ 2 kpc., meeting the following conditions:

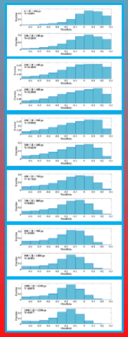
- Stars had $b \geq 50^{\circ}$ to minimize Galactic extinction
- Typical color ranges for late-K and M dwarfs: i-$z \geq 0.25$ and r-$i \geq 0.47$
- Metallicity color cuts: $3.37 \leq g$-$K \leq 8.46$ and $0.71 \leq J$-$K \leq 1.01$
- Removal of M giants with color cuts: J-$H > 0.8$, $0.15 < H$-$K < 0.3$
- Color range for the photometric parallax used to estimate distances: $0.50 < r$-$z < 4.53$

M-dwarf Metallicity Distribution



We applied the calibration to determine the metallicity of the M dwarfs in the large sample. Around 94% of these stars have H ≤ 1000 pc. The volume-corrected metallicity distribution has a peak around +0.05 dex, giving a mean metallicity of about -0.04 dex.

Age-Metallicity Relation



Dividing the stars into 100 pc thick bins to 1.2 kpc clearly shows that mean metallicity decreases with Galactic height. This can be attributed to the age-metallicity relation, i.e., stars which formed at earlier times in the Galaxy's history, on average, have lower metallicities. In addition, due to disk dynamical heating, stars dissipate from the Galactic plane, increasing their vertical distance from the plane in the course of time. As a result, the older stars are more likely to be found at larger Galactic heights.

Conclusion

Using a sample of dwarf stars, a photometric calibration to determine the metallicity of M dwarfs was presented. The calibration was applied to a large sample of over 1.3 million M dwarfs. Our results shows a decrease in metallicity as a function of Galactic height, indicating the age-metallicity relation. Several Galactic chemical models proposed to solve the G and K dwarf problems were examined through the observed metallicity distribution of M dwarfs. It was shown that these models could, to some extent, mitigate the M dwarf problem as well.

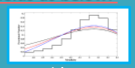
Galactic Chemical Evolution Models

The closed box model with initial metallicities and yields as below:

$Z_0 = 0$ (The Simple Closed Box Model, SCBM) and y = 0.022

$Z_0 = 0.002$ and y = 0.020

$Z_0 = 0.003$ and y = 0.019



The SCBM shows "the M dwarf problem (MDP)". The models with pre-enrichment mitigate MDP. All the yields above are larger than the value estimated for the solar neighborhood $y_{Sol} \approx 0.012$-0.014.

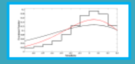
The exponential inflow model (EIM) with the assumptions as below:

1- Star formation rate = $dS/dt \propto G$: S ≡ star mass and G ≡ gas mass

2- Accretion rate $\propto \exp(-\alpha t)$: t ≡ time and α ≡ constant

The SCBM as above

The EIM with y = 0.022



The EIM mitigates the MDP but its yield is larger than y_{Sol}.

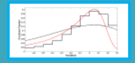
Clayton's models (CM) with the assumptions as below:

1- Star formation rate as above

2- Accretion rate = $\frac{k}{t+t_0}$ G: k is an integer and t_0 is arbitrary.

The SCBM as above

The CM with y = 0.016 and k = 7



The CM mitigates the PDM but a modification of this model for high- metallicity tail is needed. The yield value is rather consistent with y_{Sol}.

There have been many other models proposed to solve the G and K dwarf problems which need to be tested through M-dwarfs metallicity distributions as well.

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