High resolution spectroscopy of stars around Sgr A* with AO3k/NIR-WFS

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Abstract

We performed NIR, high-resolution spectroscopy of three *early*-type stars near Sgr A*, IRS 16CC, IRS 33N and 16SSW, using IRCS, NIR-WFS/AO3k. Analysis of He I lines and stellar evolutionary tracks revealed that they are B0.5–1.5I with masses of 25 – 37 $M_\odot$, and ages of 4.3 – 6.5 Myr. Our study provides one of the most precise age determination of stars around the SMBH of our Galaxy.
(Nishiyama et al. 2025, Universe)

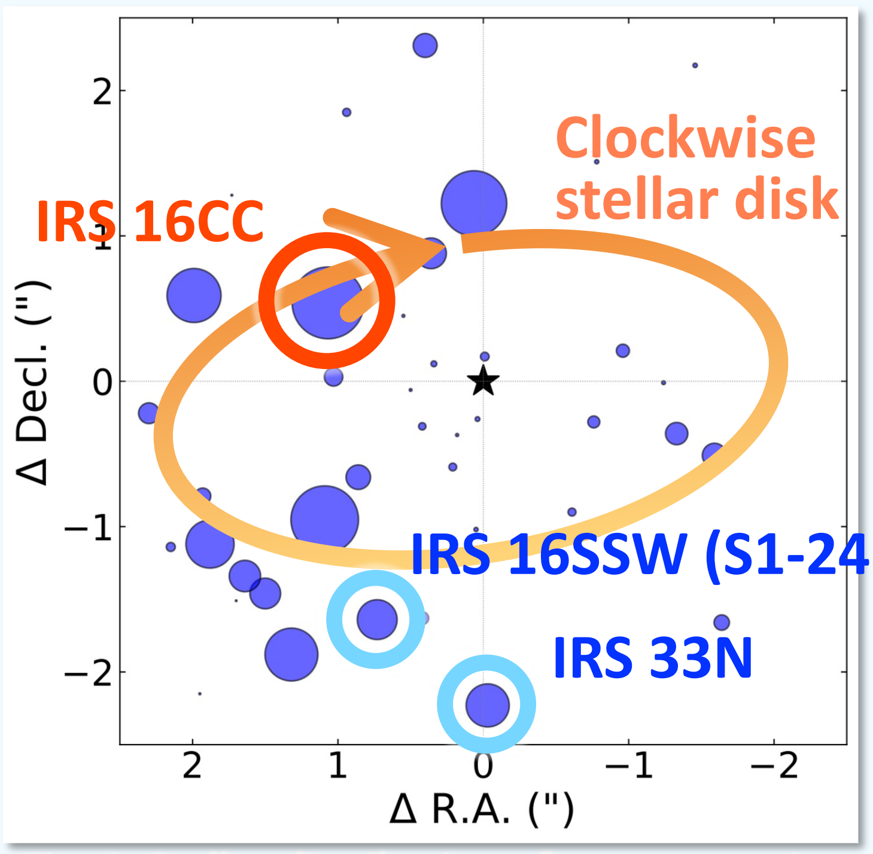

Fig. 1. Stellar distribution of young massive stars around Sgr A. IRS 16CC is a member of disk stars, but 16SSW and 33N are not.*

<Background> More than 100 *young massive* stars found around Sgr A*. However, Due to the tremendous tidal forces, standard SF should be suppressed around the SMBH. The coherent motion of the disk stars(1) may be indicative of "in situ" formation in a massive, gas disk around Sgr A*(2). How about the origin of other, non-disk member stars?
To investigate the origin of the massive stars, we performed NIR spectroscopy of a disk-member star IRS 16CC, and non-disk member stars IRS 33N and IRS 16SSW (S1-24) (Fig. 1).

<Methods> Two He I absorption lines (21,126/21,138 Å) are used to compare with model spectra and to derive T_{eff}, $\log g$, and $v \sin i$ (Fig. 2). With $\log(L/L_\odot)$, we used BONNSAI(4) to determine additional parameters of initial mass (M_{ini}) and age.

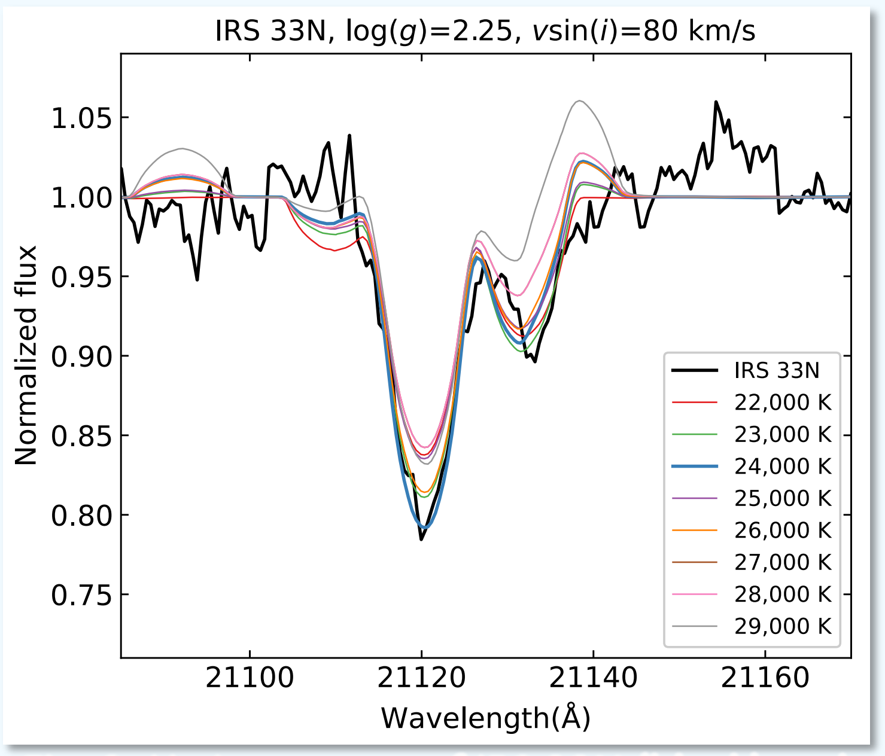

Fig. 2. He I spectrum of IRS 33N (black) and model spectra generated with TLUSTY and SYNSPEC(3).

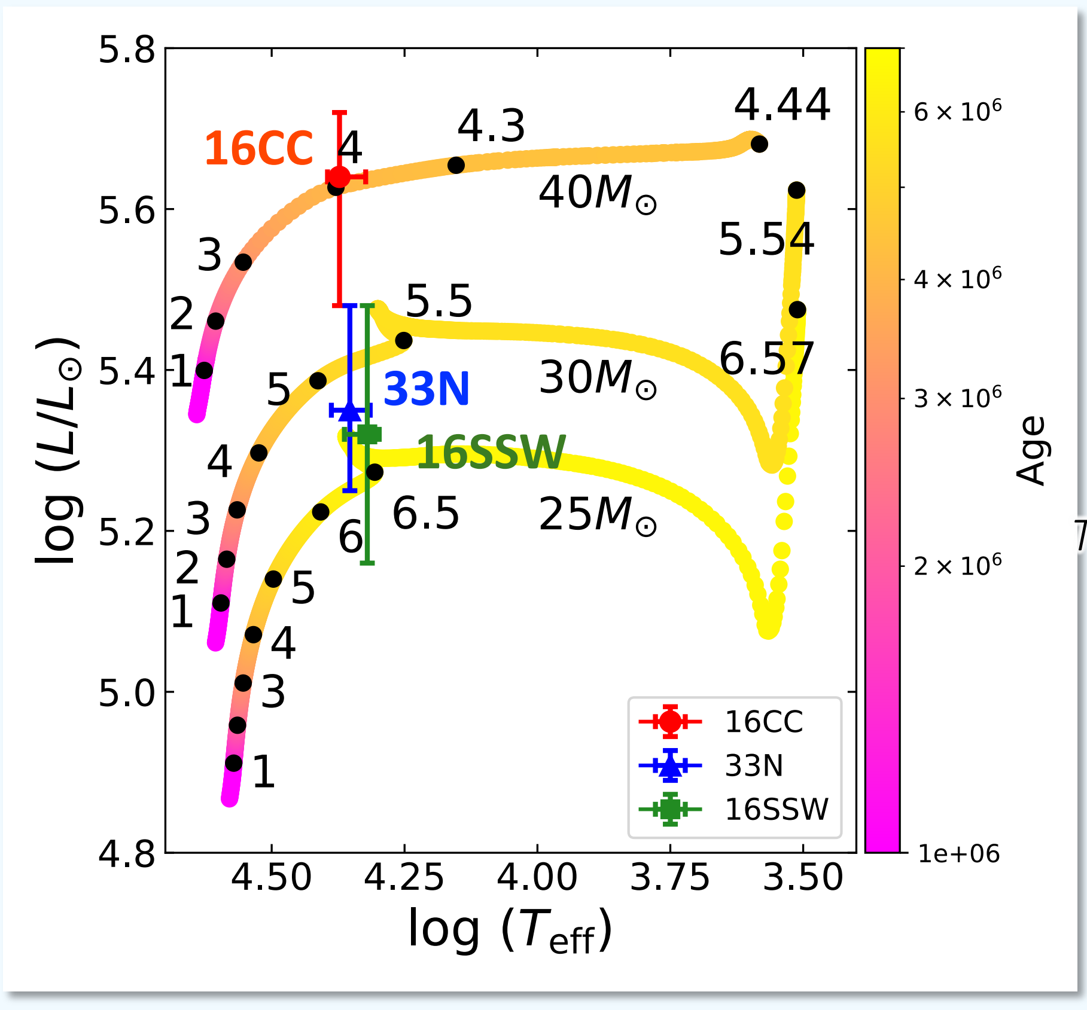

Fig. 3. HR diagram and The stellar evolutionary tracks for 25, 30, and 40$M_\odot$ with the Galactic composition(5). The results of three IRS stars are also shown.

Table 1. Results of stellar parameters from BONNSAI

	16CC	33N	16SSW
T_{eff} (kK)	23 ± 2	22 ± 2	21 ± 2
$\log g$	2.7 ± 0.2	2.8 ± 0.2	2.8 ± 0.2
$\log(L/L_\odot)$	5.7 ± 0.2	5.4 ± 0.1	5.4 ± 0.1
M_{ini} ($M_\odot$)	37 ± 8	29 ± 5	25 ± 5
Age (Myr)	4.3 ± 0.8	5.1 ± 1.0	6.5 ± 1.2

<Results and Discussions>
The stellar parameters (Table 1) suggests that they are B0.5-1.5 supergiants with initial masses from 25 $M_\odot$ to 37 $M_\odot$, consistent with previous studies(6,7). As shown in HR diagram (Fig. 3), Their ages are from 4.3 to 6.5 Myr. Within uncertainties (0.8 – 1.2 Myr), the ages are consistent with each other. This is one of the most precise age determination for Early-type stars in this region.

The probability of 33N and 16SSW being a member of the clock-wise disk is very low(8), while the membership of 16CC has been confirmed. IRS 33N and 16SSW might belong to a recently proposed "Outer filament 2", which might be an outer warp of the clock-wise disk(9). Despite their different dynamical properties, they likely formed in the same SF event.

The rotating stellar disk and NSC exert mutual torques, affecting the disk's structure. Simulations(10) show that NSC rotation scatters outer disk stars while aligning inner ones, making a warped disk. Analytical estimates give a resonant friction timescale of ~2.5 Myr, consistent with simulations and stellar ages. The different dynamical properties among 16CC, 33N, and 16SSW may produced through this phenomena.

Abstract

We performed NIR spectroscopy of 12 *late*-type giants within 0.1 pc from Sgr A* to investigate their origin. The mean metallicity is [M/H] ≈ 0.1, with values ranging widely from −0.6 to +0.6, providing the innermost data point for the metallicity measurements in our Galaxy. Notably, one low-metallicity star, S0-6, exhibits dwarf-galaxy-like abundances, suggesting a distinct chemical evolution from its neighbors.
(Nishiyama, et al. 2024, Proceedings of Japan Academy B)

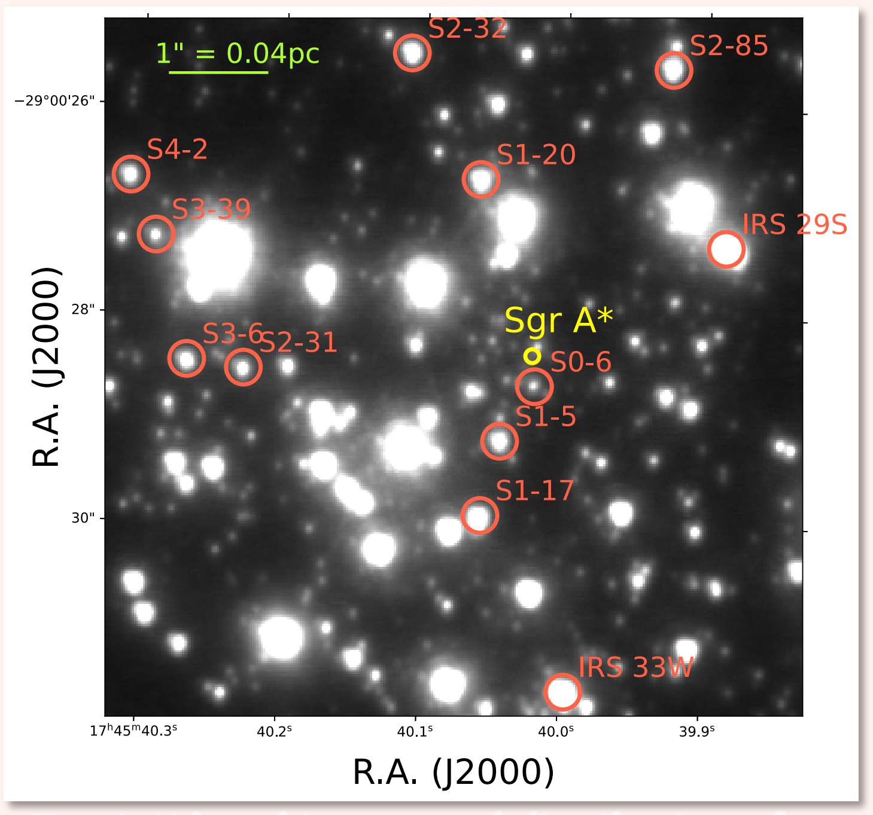

Fig. 4. K-band image and distribution of stars whose metallicity were measured (red circles).

<Background> Since standard star formation should be suppressed around the SMBH, the origin of *late*-type stars around Sgr A* remains unclear. Most of them are old (>~10^8 yr), and this life-time is long enough to migrate from the outside of the center to the central pc. The long life-time also implies that they have already lost their memory of the initial dynamical conditions. In this case, the metal abundances are crucial for understanding their origin. We therefore have conducted spectroscopy of 12 late-type stars (Fig. 4) within 0.1 pc from Sgr A*.

<Methods and results> We used *K*-band spectra to determine stellar parameters. Starkit(11) is used to estimate T_{eff}, $\log g$, and [M/H]. We confirmed the reliability of T_{eff} with the Sc method(12). SME(13) was employed to estimate element abundances such as [Fe/H] and [Mg/Fe].

Fig. 5 shows metal distributions of NSC stars(14) and our targets. Although the sample size is small, our results already show wide range of metal abundances, from [M/H] = −0.6 to +0.6. Fig. 6 presents a radial profile of [M/H], suggesting a higher metallicity toward Sgr A*(14). Our study provides the *innermost* data point in the radial profile.

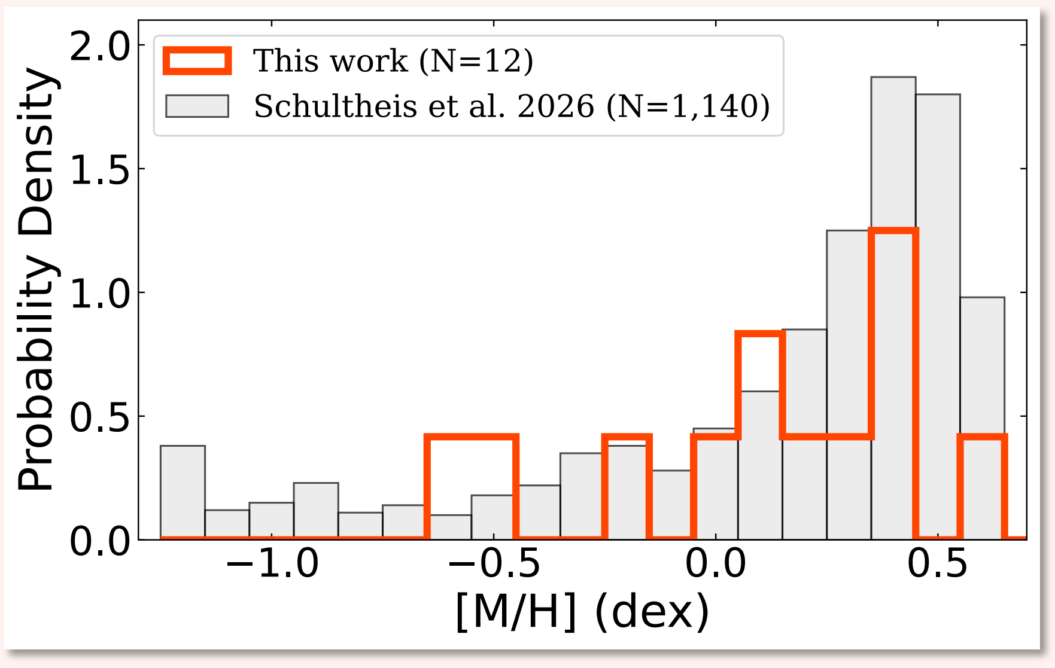

Fig. 5. Metal probability distribution function for NSC stars(14) (grey) and late-type stars within 0.1 pc (red). The NSC stars show two components with means of +0.26 and -0.76 dex.

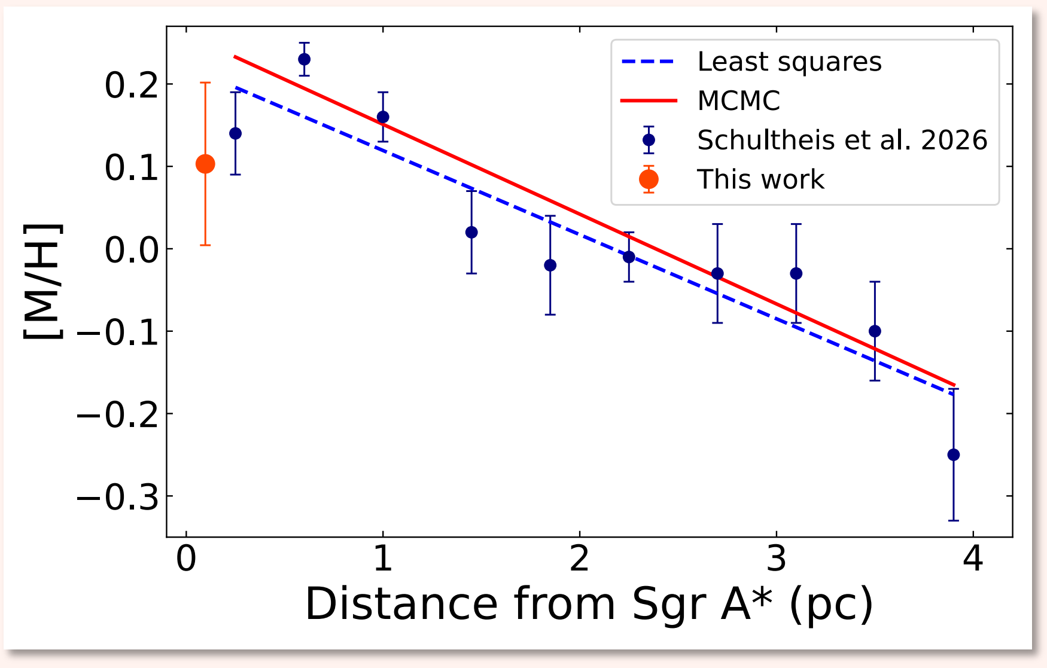

Fig. 6. Mean metallicity as a function of the distance from Sgr A, for NSC stars(14) (black dots) and late-type stars within 0.1 pc (red). The error bars indicate the standard error of the mean.*

<S0-6, a low-metal star>
One of the closest late-type star to Sgr A* is S0-6 (Fig. 4). We measured S0-6's abundances (Fig. 7): [Fe/H] = −0.40, [α/Fe] = −0.20, [Mg/Fe] = −0.30, [Ca/Fe] = +0.10, and [Ti/Fe] = −0.40. Given its old age (≳ 10 Gyr) and proper motion nearly perpendicular to the Galactic plane, we suggest that S0-6 has experienced a different chemical evolution from other stars around Sgr A*. Since isolated stars cannot migrate to center on their own, there may be accompanying stars around Sgr A* that share the same origin as S0-6.

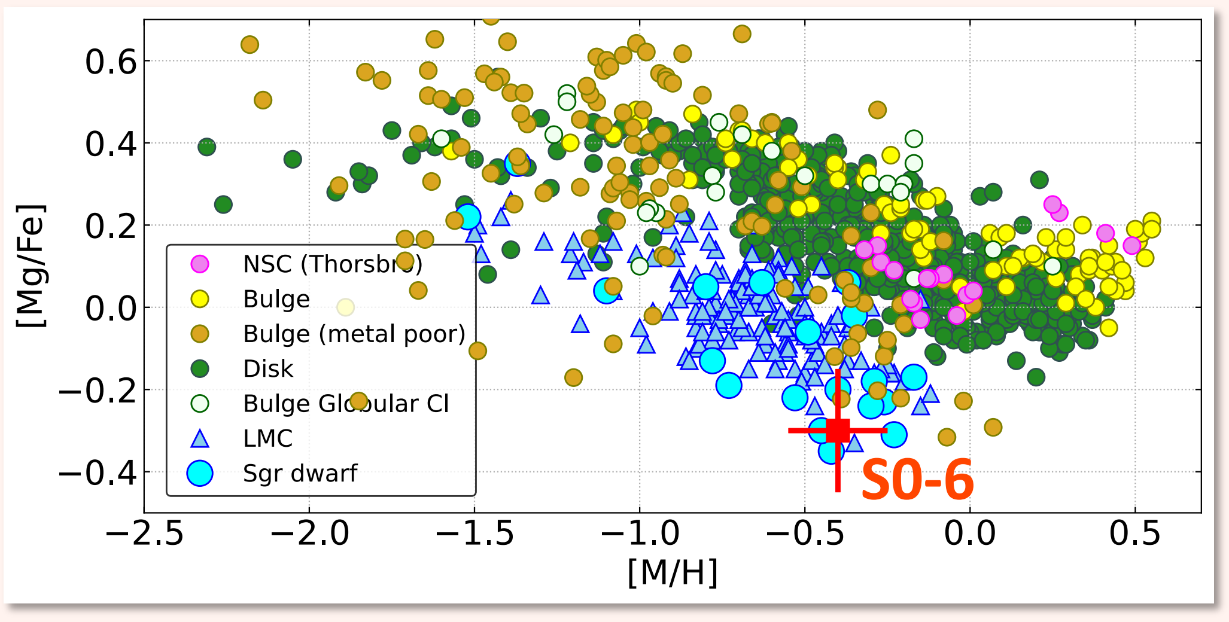

Fig. 7. [Mg/Fe] vs [M/H] for stars in MW(15 - 20) and nearby dwarf galaxies (LMC(21) and Sgr dSph(22)). The position of S0-6 is indicated by red rectangle. The [Mg/Fe] of S0-6 is lower than MW disk/bulge stars, and comparable to stars in dwarf galaxies. While it could originate from metal poor Bulge stars, its proper motion is nearly perpendicular to the Galactic plane, which is inconsistent with a Bulge origin.

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