On the Distribution of Early-type Stars toward the Galactic Center

Preben Grosbøl, European Southern Observatory, Germany

Abstract

With the aim of studying the distribution young stars across the Sagittarius arm, a catalog of ~10k early-type candidate stars with B<14.5^m in a 100□° field toward the Galactic center was produced based on objective prism spectra from the ESO Schmidt telescope at La Silla, Chile (Grosbøl, 2016, A&A 585, A141). The spectra allowed to estimate extinctions and distances for the individual candidates indicating that the sample reaches distances of 2 kpc from the sun i.e. beyond the Sagittarius arm. The spatial distribution shows an increased extinction in the plane associated to the Sagittarius arm. Observations of radial velocities of a sub-sample of these candidates will allow to determine if any significant mass is associated to the Sagittarius arm (i.e. if it is a major arm or not).

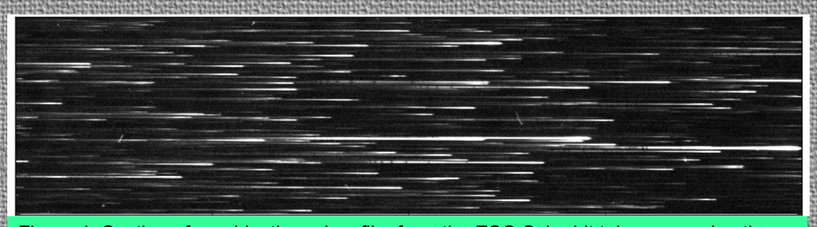

Figure 1: Section of an objective prism film from the ESO Schmidt telescope using the 4415 emulsion.

Introduction

Although young objects in the Galaxy outline a 4-armed structure (Russeil et al. 2007, Reid et al. 2014, Vallee 2014), it is unclear if all arms are massive or only 2 of them (i.e. Perseus and Scutum-Crux) as indicated by NIR observations (Drimmel 2000). One option to resolve this issue is to map the radial velocities of young stars across the Sagittarius arm toward the Galactic center since this direction minimizes the influence of the Galactic rotation and the radial variation would show if a significant mass is associated to this arm.

Statistical considerations suggest that a list of around 500 early-type candidates out to distances of 2kpc would be required. To achieve this, an area of ~100□° would need to be surveyed. The strong and variable extinction toward the Galactic center makes it very difficult to obtain reliable candidates from broad-band photometry, even in the NIR. An alternative is objective prism observations which yield clean candidate lists although crowding is an issue.

Data and Reductions

Several sets of plates were observed with the objective prism on the ESO Schmidt telescope at La Silla covering a field of 100□° using IIA-O, IIIA-J, and 4415 emulsions (see Fig. 1). Each plate was digitized with the ESO PDS machine in 4 sections and analyzed with ESO-MIDAS and Python script. Traces of early-type spectra are shown in Fig. 2 for the emulsions used showing their spectral range including transmission curves for Johnson and Strömgren filters. Almost 10k candidates with B<14.5^m were identified on the 4415 films by cross-correlation with such templates. The densities were converted to relative intensities through the characteristic function which was estimated by comparison with CCD photometry of the central field from the Max-Planck 2.2m telescope at La Silla. Magnitudes were transforms to the Johnson and Strömgren systems using common stars in Mermilliod (1991, Lausanne) and Hauck & Mermilliod (1998, AAS 129, 431) with typical errors of 0.2^m. In addition, the equivalence widths (EWs) of the Balmer and CaII lines were measured. Astrometric solutions were derived by using common Tycho-2 stars (Høg et al. 2000, AA 355, L27) which gave formal errors σ(α)≃0.9” and σ(δ)≃1.6” where the sensitivity cut-off were used in δ i.e. the dispersion direction (significant larger errors σ(δ)≃6” were found at the plate edges).

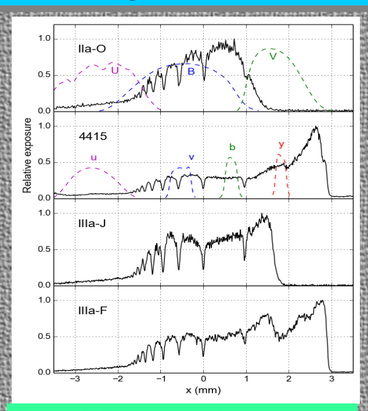

Figure 2: Traces of early-type spectra from the 4 different emulsions. Transmission curves for Johnson and Strömgren filters are plotted.

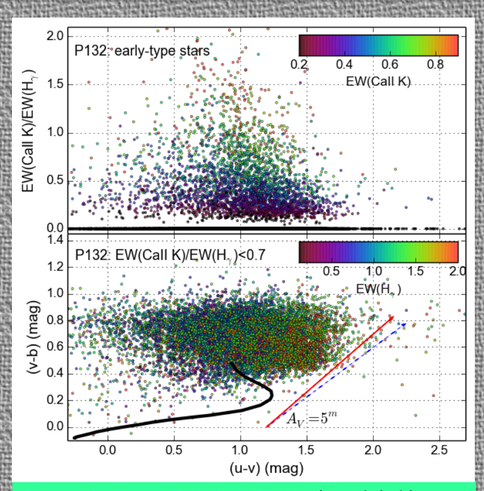

Figure 3: Ratio EW(CaII)/EW(Hγ) and (v-b) as a function of the Strömgren (u-b) index. The black line indicates the ZAMS while the arrow show standard reddening vectors.

Extinctions and Distances

Although the 4415 spectra include all Strömgren filters, the accuracy of the synthetic photometric was not sufficient for estimating the extinction of individual sources. However, since the EWs of CaII and Hγ were computed from the spectra, it was possible to separate early- and late-type stars and thereby use the (u-v)-(v-b) diagram to evaluate the extinctions as shown in Fig. 3. The absolute magnitudes M_B for the early-type candidates were derived from the models of Munari et al. (2005, AA 442, 1127) providing the dependency on Hγ, T_{eff}, and logG. Fig. 4 shows T_{eff}, B, and distance as a function of the visual extinction A_V estimated for the candidates. The extinction increases with distance although with significant scatter due to the patch nature of the interstellar medium. The stars with high extinctions are generally hotter (i.e. intrinsic brighter) and apparent fainter than nearby stars with low absorption due the the limiting magnitude of the sample.

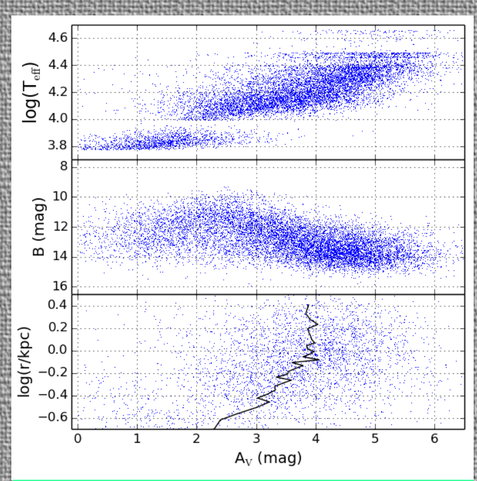

Figure 4: T_{eff}, B, and distance as a function of visual extinction A_V for early-type candidates.

Distribution of early-type stars

Although the list of early-type candidates is far from complete, due the varying extinction and crowding, their spatial distribution still suggests the general properties of the early-type stellar population in the direction of the Galactic center as shown in Fig. 5 where the density of sources projected on the Galactic plane and perpendicular to it is given. The increased extinction in the plane due to the Sagittarius arm is clearly seen at a distance of ~0.8 kpc from the Sun. The asymmetric of the distribution perpendicular to the plane indicates that the Sun is located ~10pc above the plane in agreement with Joshi (2007, MNRAS 378, 768). This is better seen in Fig. 6 where densities of candidates in radial bins are displayed as a function of their distance from the plane. Already in the bin r=0.5-0.8kpc, an increase of absorption is visible.

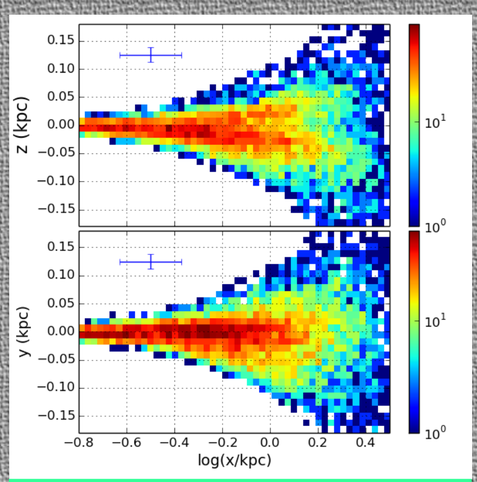

Figure 5: Number density of early-type candidate as a function of distance from the Sun. Z is perpendicular to the plane while Y is in the longitudinal direction.

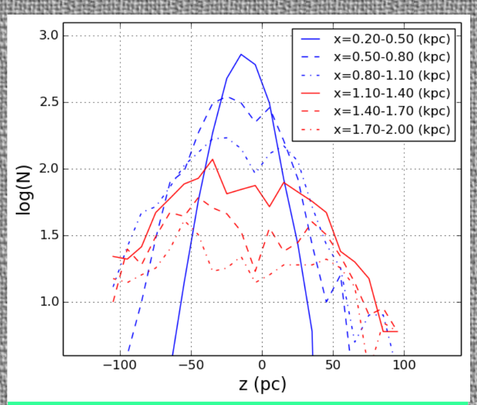

Figure 6: Number of early-type candidates in radial bins as a function of distance z perpendicular to the plane.

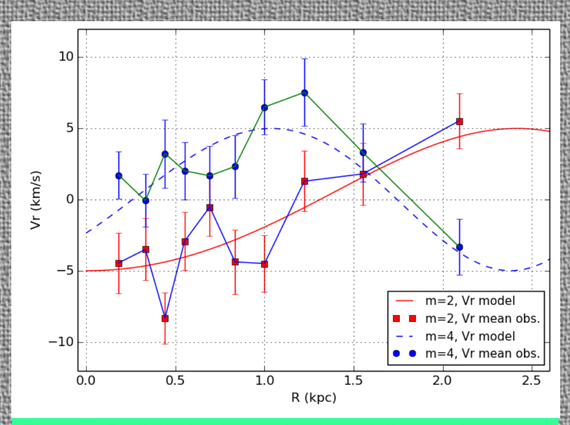

Figure 7: Radial velocity as a function of distance from the Sun for models with either a 2- or 4-armed spiral pattern in the Galaxy.

Radial Velocities and the Sagittarius Arm

The mean radial velocities of early-type stars toward the Galactic Center as a function of their distance from the Sun are well suited to determine the nature of the Sagittarius arm since they are affected by Galactic rotation and will indicate if a significant mass is associated to the arm. Models of the radial velocity variation for a 2- and 4-armed spiral pattern are shown in Fig. 7 where also simulated observations of a sample of 500 early-type stars are displayed assuming a velocity dispersion of 15 km/s for the population.

The candidate list was cross-identified with 2MASS stars using both positions and colors in order to obtain accurate NIR colors and coordinates. An observing program to obtain radial velocities using FLAMES at the ESO VLT was started where the first spectra are shown in Fig. 8. This demonstrates that the candidate list is very reliable. By fitting to synthetic spectra, it is possible to estimate both T_{eff} and logG which in turn allow to derive intrinsic colors and photometric distances to the stars.

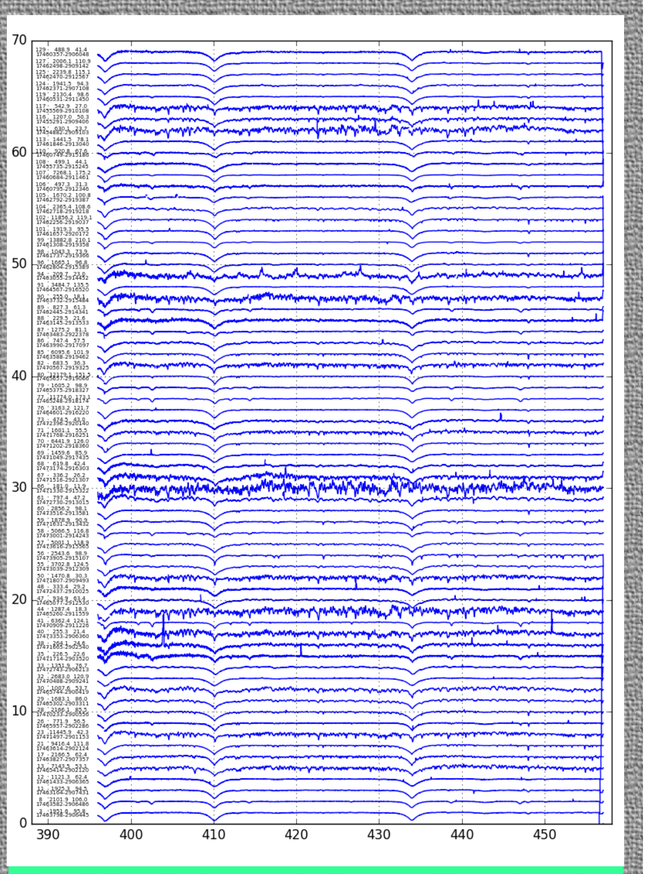

Figure 8: Normalized spectra of early-type candidates observed with FLAMES/VLT as a function of wavelength in nm.

Conclusions

A candidate list of ~10k early-type stars in a 100□° field toward the Galactic center with B<14.5^m was obtained from objective prism observations performed at the ESO Schmidt telescope at La Silla. Extinctions and distances for the individual candidates could be estimated using intermediate-band magnitudes and EWs of Balmer and CaII lines derived from the spectra. The spatial distribution of the sample clearly shows the increase extinction in the plane associated to the Sagittarius arm confirming that the candidates extend beyond this arm.

Radial velocities of ~500 stars from this list, evenly distributed in distance and reaching beyond the Sagittarius arm, will allow to determine if any significant mass is associated to it. Cross-identification with 2MASS sources provides a well defined list of candidates with accurate NIR magnitudes and positions. An observing program at FLAMES/VLT has been started to obtain the radial velocities. First observations show that the candidate list of early-type stars is very reliable and will make it possible to estimate individual distances to the stars in addition to the radial velocities.