The ionized gas in the Galactic Center Radio Arc

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The Radio Arc is one of the most prominent radio continuum features in the Galactic center region. It is composed by long and thin filaments that emit non-thermal radiation (Non-Thermal Filaments; NTFs) and indicate the presence of a strong component of the magnetic field perpendicular to the Galactic plane. The Arc is apparently connected to Sgr A by a “bridge” of arched filaments that emit thermal radio continuum (Thermal Filaments). There are two other thermal sources in the vicinity of the NTFs: the Sickle and the Pistol Nebula.

The origin of the ionization of those thermal features has been a subject of great interest in the last years. It was first thought that they were the surfaces of molecular clouds ionized by collisions with the relativistic particles that illuminate the NTFs. However, with the discovery of the outstanding clusters of young stars known as the Quintuplet and the Arches clusters, the effect of UV radiation on the ionization of the thermal features has been revised. There is increasing evidence that the Sickle and the Pistol Nebula are ionized by the Quintuplet and that the Arches cluster could account for the ionization of the Thermal Filaments (see Rodríguez-Fernández et al. 2001, A&A 377, 631 —hereafter RF01— and references therein).

Here, we present the first large scale study of the ionization structure in the Radio Arc region. We have analyzed fine structure lines observations made by the Infrared Space Observatory (ISO) toward the sources shown in the left panel of Fig. 1 with filled squares.

Figure 1. Dust and ionized gas in the Radio Arc region (see text).

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The right panel of Fig. 1 shows, with thick contours, a map of the N\textsc{iii} 57 µm to N\textsc{ii} 122 µm lines ratio (hereafter N\textsc{iii}/N\textsc{ii} ratio). The map shows two clear gradients, one pointing to the Quintuple (in the southern part of the map) and other pointing to the Arches cluster (indicated by a star).

From the O\textsc{iii} 52/88 µm line ratio we derive an electron density ($n_e$) of $\sim 200$ cm$^{-3}$ for all the sources. However, photoionization modeling shows that the interstellar medium (ISM) in this region cannot have an average density of $\sim 200$ cm$^{-3}$ in order to explain the size of the ionized region, which is larger than 30 pc. Instead, the ISM should be rather inhomogeneous. Thus, we have considered the sources as independent clouds with a density of 200 cm$^{-3}$ located at a distance to the clusters equal to their projected distance. We have found that the trend of the N\textsc{iii}/N\textsc{ii} ratio with the distance from the Quintuplet cluster is consistent with the flux of Lyman continuum photons ($Q$) estimated from the stellar content of the cluster ($Q \sim 10^{50.9}$ s$^{-1}$) and effective temperatures ($T_{\text{eff}}$) of $\sim 33000$ K (see RF01). For the sources that are clearly influenced by the Arches cluster, the trend of the N\textsc{iii}/N\textsc{ii} ratio with the distance to the cluster is also consistent with the cluster parameters ($Q \sim 10^{51.4}$ s$^{-1}$) for $T_{\text{eff}} \sim 33000$ K (RF01).

Since those $T_{\text{eff}}$ are rather similar for both clusters, to estimate the combined effect of the clusters we have used a very simple model in terms of a total ionization parameter ($U$) defined as the sum of the ionization parameters due to the Quintuplet and the Arches clusters. Thus, for a cloud located at distances $D_Q$ and $D_A$ from the Quintuplet and the Arches clusters, respectively, $U$ will be given by:

$$U = \frac{Q_Q}{4\pi D_Q^2 n_e c} + \frac{Q_A}{4\pi D_A^2 n_e c},$$

where $c$ is the velocity of light. The right panel of Fig. 1 shows as dashed lines some contours of equal $U$ assuming $n_e = 10^{2.2}$ cm$^{-3}$, $Q_Q = 10^{50.9}$ s$^{-1}$ and $Q_A = 10^{51.4}$ s$^{-1}$. The agreement of the iso-$U$ curves with the N\textsc{iii}/N\textsc{ii} map is very good taking into account the simplicity of the model. Furthermore, this simple model also reproduces the distribution of warm dust as observed by MSX (the background image of Fig. 1 is the $\sim 20$ µm MSX image).

We conclude that the large scale ionization and the heating of the dust in the Radio Arc region are dominated by the combined effect of the Quintuplet and the Arches clusters. They ionize a large region of more than $30 \times 30$ pc$^2$. Any other possible ionization mechanism as interaction with magnetic fields or more hot stars must play a minor role.