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Deep Spectroscopy of the Very Extended Ionized Gas of NGC 4388

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Abstract.

We report here the results of deep optical spectroscopy of the very extended emission-line region (VEELR) found serendipitously around the Seyfert 2 galaxy NGC 4388 in the Virgo cluster. The Hα recession velocities of most of the filaments of the region observed are highly blue-shifted with respect to the systemic velocity of the galaxy. The velocity field is complicated, and there seem to be several streams of filaments ranging from ~ -100 km s^{-1} to ~ -700 km s^{-1} with respect to the systemic velocity of the galaxy. The emission-line ratios of the VEELR filaments are well explained by power-law photoionization models with solar abundances. In addition to photoionization, shock heating probably contributes to the ionization of the gas. We conclude that the VEELR was formerly the disk gas of NGC 4388, which has been stripped by ram pressure due to the interaction between the hot intra-cluster medium (ICM) and the galaxy.

1. Introduction

Recently, Yoshida et al. (2002) found a very large region of ionized gas extending around a Seyfert 2 galaxy in the Virgo cluster, NGC 4388. This very extended emission-line region (the "VEELR") has a size of ≈ 35 kpc and is located preferentially toward the northeastern side of the galaxy. The region consists of many filaments or clouds, with a typical size of ~ 100 pc. The total ionized gas mass of the VEELR is $\sim 10^5$ M$_\odot$. Yoshida et al. (2002) proposed two possible hypotheses concerning the origin of the VEELR gas: (1) the tidal debris of a past minor merger or (2) ram pressure-stripped gas. In either case, such a large gas flow outside the galaxy disk must be closely related to the evolution of NGC 4388 and the surrounding ICM.

2. Observations

We performed a deep spectroscopy of the VEELR to reveal the nature and the origin of the ionized gas. The observations were made with FOCAS of the

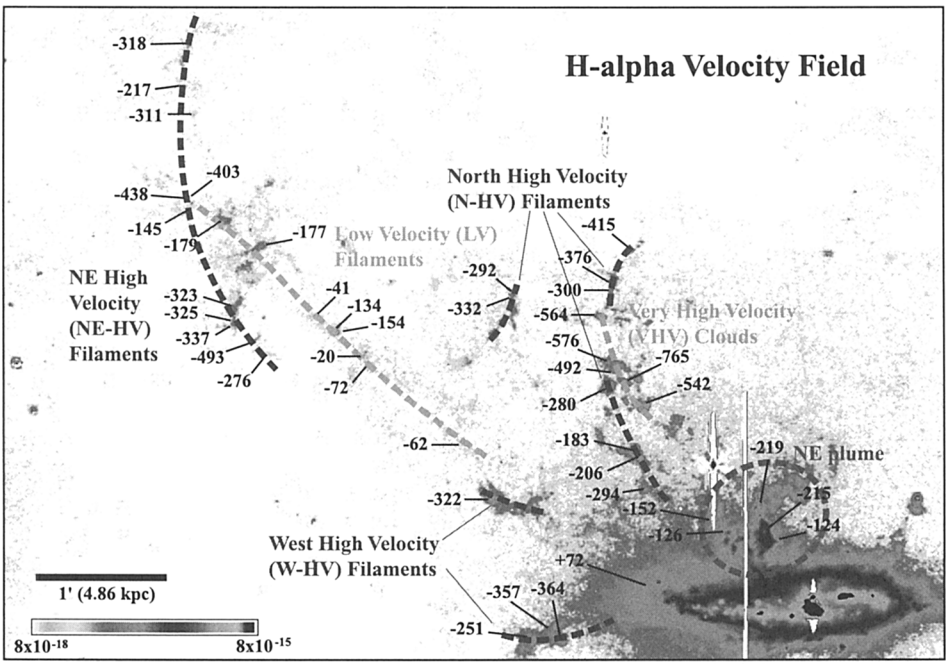

Figure 1. The velocity field of the VEELR of NGC 4388.

Subaru Telescope on 2002 March 11. We used the multi-slit spectroscopy mode of FOCAS to obtain the spectra of as many of the bright filaments of the VEELR as possible, given their complicated spatial distribution. We obtained 40 optical ($\lambda\lambda$4700Å–7500Å) spectra of the VEELR filaments with R$\approx$ 650.

3. Results and Discussion

The velocity field of the VEELR is shown in Figure 1. The velocities of almost all the filaments measured are blue-shifted relative to the systemic velocity of the galaxy. The velocities show a very wide range ($\sim$ 700 km s^{-1}) from ~ -50 km s^{-1} to over -700 km s^{-1}. The overall velocity field of the VEELR is quite complicated and could be dominated by significant turbulent motion. There is no smooth velocity gradient across the region. Although we measured only a fraction of the filaments in the region, several kinematic groups seem to be represented (see Figure 1).

The velocity field of the VEELR can be interpreted in the context of the ram pressure stripping scenario. NGC 4388 is moving in the Virgo cluster ICM with a line-of-sight velocity of $\approx$ 1500 km s^{-1} relative to the ICM. Hence, the blue-shifted velocity field of the VEELR can be explained naturally: the collision between the galaxy and the hot ICM strips the disk gas and the gas is blown in the direction opposite to the motion of the galaxy. The turbulent nature of the velocity field of the VEELR can also be explained by a high speed collision

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between the galaxy and the hot ICM. Strong ram pressure from the ICM should induce turbulent motion in the stripped gas stream.

References

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