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A high spectral resolution catalog of emission lines in the visible spectrum of comet C/2020 F3 (NEOWISE)

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Abstract

Comets are primitive bodies left over from the formation of the Solar System. Formed at large distance from the Sun, comets have been preserved at low temperatures since their birth. Therefore, the study of comets offers a unique opportunity to investigate the physical and chemical processes that occurred during the early stages of the formation and evolution of our Sun and Solar System. Most of the species in the coma are the products of physical and chemical processes acting on the parent molecules in the nucleus or in the inner coma. The study of their emission lines could then provide a large information on the physical phenomena occurring in the coma and on the composition of the nucleus. Comet C/2020 F3 (NEOWISE) is considered as the brightest comet in the northern hemisphere since comet C/2005 O1 (Hale-Bopp) in 1997. From Earth, comet NEOWISE was observable within elongations less than 20 degrees from the Sun between 11 June and 9 July, 2020. The perihelion occurred on 3 July, 2020, at a small heliocentric distance of 0.29 AU. Observations from the Comet OBServation Database (COBS)[1] of the Minor Planet Center (MPC)[2] show that comet NEOWISE had brightened from a visual magnitude of about 8 at the beginning of June to 0 early July.

[1] https://cobs.si/

[2] https://minorplanetcenter.net//

1. Observation and emission line identification

We obtained two high resolution optical spectra of comet NEOWISE on 26 July and 5 August, 2020, by using the High Accuracy Radial velocity Planet Searcher (HARPS-North) echelle spectrograph installed on the 360-cm Telescopio Nazionale Galileo (TNG). This instrument covers the wavelength range between 383 and 693 nm, with a resolving power of 115000. The unique passage and brightness of comet NEOWISE yielded spectra with a large number of emission lines, providing information on the coma composition and the physical and chemical processes occurring on the nucleus. The spectra have been used to generate a catalog of emission lines to be used for future studies of comets, since there are no catalogs in the literature with this spectral resolution. The spectral extraction has been performed automatically by the HARPS-N Data Reduction Pipeline. To compile the high-resolution catalog, we collected and digitized several laboratory molecular line lists covering the same wavelength range of our spectra. Once the molecular line lists were collected, we analyzed our spectra with the aim of finding wavelength coincidences of emission lines in the line lists and emission features in our spectra. We included all catalog lines matching our observed emissions within the spectral resolution, i.e. +/- $\Delta\lambda = \lambda/R$, where R is the resolving power. To verify the reliability of our identification, we used spectra from both nights. Finally, to further validate the final identification, we compared our catalog with other atlas resulting from the spectral analysis of other comets [1,2,3,4,5,6,7,8,9,10,11,12].

2. Results

We catalogued more than 4000 comet emissions. We found cometary lines due to C2, C3, CH, CN, CO+, H_2O+, N2+ ,NaI, NH2, and [OI]. In particular, we found 82 CN lines, some of which belong to the violet system ($B^2\Sigma^+$ --> $X^2\Sigma^+$ band). The spectral resolution of our spectra allows to reveal definite structure of the 3883 Å sequence of the CN bands, and the P-branch is resolved into individual lines. Our spectra also reveal the presence of sodium. The identified emissions belong to the sodium doublet at 5889.95 and 5895.92 Å. We identified the emission of the forbidden green oxygen line at 5577.31 Å, and the strong red doublet emission of [OI] at 6300.31 and 6363.78 Å. C2 and C3 neutral radicals are also present in the spectra of comet NEOWISE. In particular, we found C3 emission lines in the 4050-Å Group both in the spectrum of 26 July, and in the spectrum of 5 August, 2020.We also identified NH2 and CH emissions, and observed three ionic species (H_2O+, N2+, and CO+).

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