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Abstract

Objectives

This project seeks to characterize the chemical composition of Oort cloud comet C/2022 E3 (ZTF) by collecting spectra of its coma, identifying emission lines from a catalog, and comparing its emission features to those of other long-period comets. We hypothesize that C/2022 E3 (ZTF) will be rich in carbon-based molecules, but due to its extremely long orbital period, it will exhibit several unusual emission features.

Methods

Using a low-resolution (R~1000) slit spectroscope, Schmidt-Cassegrain telescope, and monochrome CMOS camera, we recorded 7 spectra of the outer coma and 15 spectra of the inner coma of C/2022 E3 (ZTF) on February 9, 2023. On the same night, we also captured neon-argon calibration spectra, incandescent flat frames, and spectra of an A-type reference star, HIP24160. During data reduction, we preprocessed and wavelength calibrated the cometary spectra, created an instrument response curve from the A-type star, and cropped the spectra to the visible domain. When analyzing the spectra, we subtracted a synthetic dust continuum and identified chemical emission lines from the spectral catalog by Brown et al. (1996). Finally, we compared the emission lines of C/2022 E3 (ZTF) to those found in six other Oort cloud comets: C/1996 B2 (Hyakutake), C/2000 WM1 (LINEAR), C/2014 Q2 (Lovejoy), C/2016 R2 (PanSTARRS), C/2019 Y4 (ATLAS), and C/2020 F3 (NEOWISE).

Results

The species C_2, C_3, CN, and NH_2 were found in all comets except C/2016 (PanSTARRS) within the wavelength domains 4600-6200Å, 3950-4100Å, 3800-4200Å, and 5150-6400Å, respectively. CH was detected in C/2014 Q2 (Lovejoy), C/2016 R2 (PanSTARRS), C/2019 Y4 (ATLAS), C/2020 F3 (NEOWISE), and C/2022 E3 (ZTF) around 4300Å. CH^+ and H_2O^+ were tentatively identified in C/2022 E3 (ZTF) and C/2000

WM1 (LINEAR) at 4240Å and 6200Å, respectively. [O I] lines at 5577Å, 6300Å, 6364Å were detected in every comet, with a rudimentary G/R ratio of 0.42 calculated for the outer coma and 0.23 calculated for the inner coma of C/2022 E3 (ZTF). According to the JPL Solar System Dynamics ephemeris database, only C/2000 WM1 (LINEAR) and C/2022 E3 (ZTF) exhibited hyperbolic orbits.

Conclusion

The spectral emissions of C_2, C_3, CN, NH_2, and [O I] strongly indicate that C/2022 E3 (ZTF) is a chemically average Oort cloud comet. However, the detection of CH and CH^+ suggests that C/2022 E3 (ZTF) contains a slightly higher concentration of methane, the parent molecule for CH and CH+, than average. Additionally, the lack of CO and CO^+ detected in C/2022 E3 (ZTF) contradicts its relatively high G/R ratios (Opitom et al. 2019), which is unsurprising given that the relative intensities of the [O I] emissions were uncorrected for Doppler shifting and line blending. Lastly, even though C/2022 E3 (ZTF) and C/2000 WM1 (LINEAR) share similar spectral features and orbital eccentricities, no other trends between orbital period and chemical composition were identified. Thus, our original hypothesis remains inconclusive.

Research Plan

Rationale

Comet C/2022 E3 (ZTF) is the visually brightest long-period comet in several years, making it one of few trans-Neptunian objects accessible to amateur astronomers. Long-period comets almost exclusively originate from the Oort cloud, a spheroidal body of frozen planetesimals which were ejected from the early solar system but remained gravitationally bound to the sun. Oort cloud comets therefore pose a unique opportunity to study the early chemical composition of the solar system, which is important in understanding how the solar system has evolved over billions of years. Specifically, Oort cloud objects are known to possess high concentrations of carbon-chain molecules, water, and nitrogen, species which are critical to biological life. Additionally, Oort cloud objects can help us understand the compositions of other stellar systems. By comparing the compositions of proto-stars and young stars to Oort cloud comets, we can reveal patterns in stellar formation and search for habitable extrasolar systems. Thus, identifying the chemical compositions of Oort cloud comets is the first step towards understanding our world and countless other planetary systems.

Questions and Hypothesis

In order to characterize the spectrum and chemical composition C/2022 E3 (ZTF), we will need to first research typical and abnormal chemical emission features among Oort cloud comets. Afterwards, we will investigate the most prominent chemical emission features in C/2022 E3 (ZTF) in order to determine how the features of C/2022 E3 (ZTF) compare to those of other Oort cloud comets. Knowing that C/2022 E3 (ZTF) has an inbound orbital period of 50,000 years, we are also curious about the comet's origin from within the Oort cloud and whether there is a correlation between its extremely long orbital period and chemical composition. Thus, we hypothesize that C/2022 E3 (ZTF) will be rich in carbon-based molecules, but due to its extremely long orbital period, it will exhibit several unusual emission features.

Procedure

In early February, we will record the inner and outer coma of C/2022 E3 (ZTF) using a Shelyak LISA low-resolution (R~1000) slit spectroscope, Schmidt-Cassegrain telescope, and monochrome CMOS camera. The comet will be high in the night sky during this time of year, which will allow us to record spectra for many hours. In order to obtain a sufficient signal-to-noise ratio in our spectra, we will record at least an hour's worth of spectra for both components of the coma. To properly calibrate the wavelength of our spectra, we will capture neon-argon calibration frames and incandescent flat frames immediately after recording each component. To account for atmospheric turbulence and the instrument response of the optical system, we will record spectra of a reference A-type star at a similar altitude as the comet. To compensate for cometary dust scattering the solar continuum, we will record a solar spectrum, multiply it by the dust continuum, and subtract it from the cometary spectra.

When analyzing the cometary spectra for emission lines, we will employ a catalog of known cometary emission lines. Afterwards, we will quantitatively compare the observed emission features of C/2022 E3 (ZTF) to those found in several other long-period Oort cloud comets in order to discover trends in Oort cloud cometary compositions. Finally, using the Jet Propulsion Laboratory Solar System Dynamics ephemeris database, we will compare the eccentricities and period lengths of the various comets in order to discover any correlations between cometary motion and chemical composition.