Spectroscopic and Imaging study of the first Interstellar comet 2I/Borisov from two Indian Observatories

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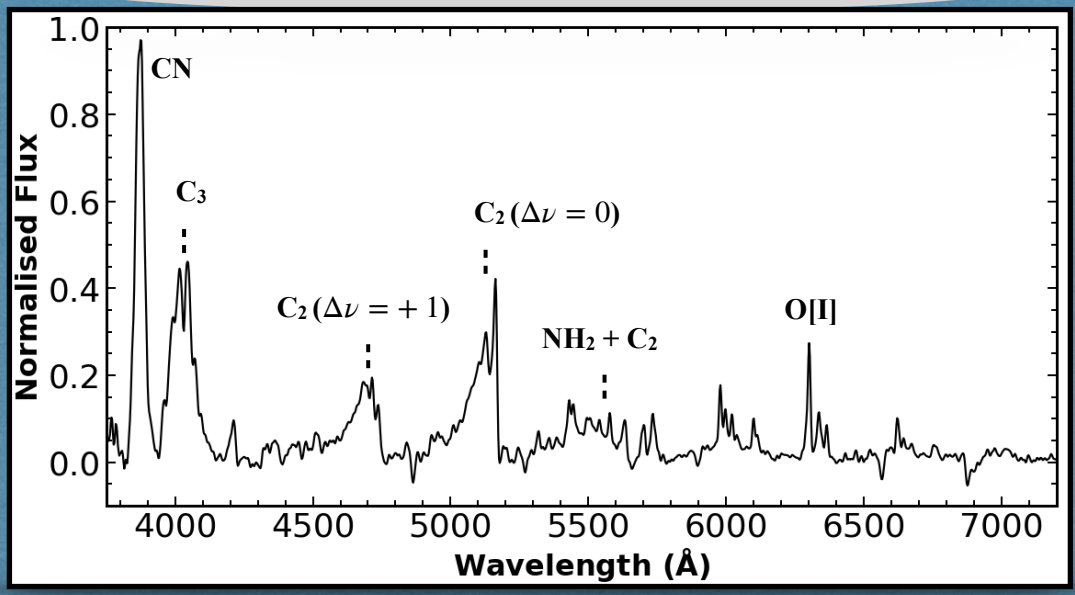
Introduction

Comets can be considered to be the time-capsules of the early Solar system since they spend larger part of their life away from the Sun. Studying various aspects of these minor bodies can help us gain insight into the conditions that prevailed during the formation of the Solar System since they are made up of pristine materials that comprised the proto-solar nebulae. Figure 1 depicts the low resolution optical spectrum of a typical solar system comet, containing emissions from the radicals like CN, C_2, C_3, NH_2 etc produced by the sublimation, photoionisation and photodissociation of various parent molecules present in the comet's nucleus as the comet comes closer to the Sun.

Figure 1 : Low resolution optical spectrum of short period comet 46P/Wirtanen



Background & Hypothesis

- McGlynn & Chapman (1989) explored the possibility of predicting the number of Interstellar comets that can be detected passing through inner solar system.
- Sen & Rana (1993) developed an acceptable theory predicting the number of interstellar comets to be detected as only 1 per 200 years.
- First interstellar comet 2I/Borisov was detected on August 30 2019 by Gennadiy Borisov using his own telescope.

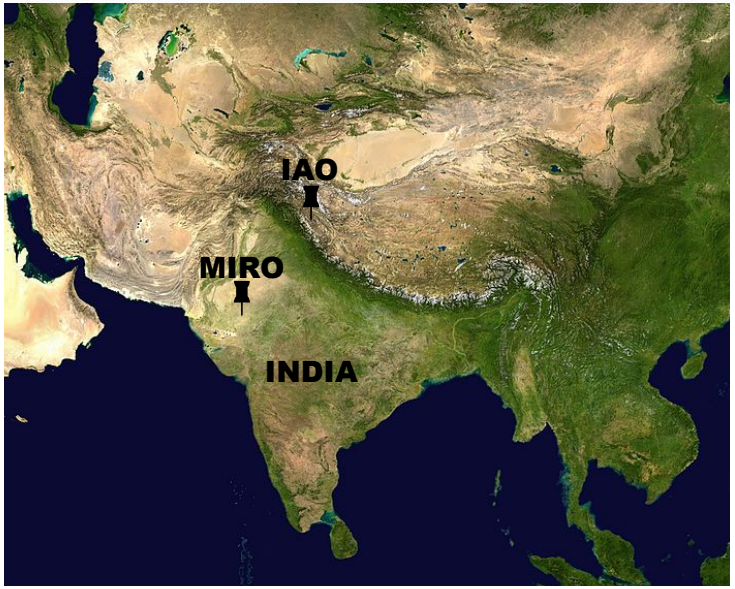
Objective

- Investigate the fluorescence emissions from the interstellar comet using spectroscopic observation.
- Study the gas compositions and hence compare their properties with those of Solar system comets.
- Use imaging mode to study the colours of the dust present in the comet's coma and compare its similarities/dissimilarities with the observed dust colours of solar system comets.

Research - Observational Facilities

Himalayan chandra Faint Object Spectrograph and Camera (HFOSC)

- ✓ Actively working on the 2-m Indian Astronomical Observatory (IAO), situated at Hanle, India.
- ✓ 2K x 4K CCD used as detector
  - Spectroscopy : 1.5K x 4K
  - Imaging : 2K x 2K
- ✓ A grism providing wavelength range of 3700 - 7500 Å with a resolution of R ~ 1300 was used for spectroscopy.
- ✓ Bessell's *BVRI* filters were used for imaging.
- ✓ Non-sidereal tracking was incorporated using the in-built keystone mode.



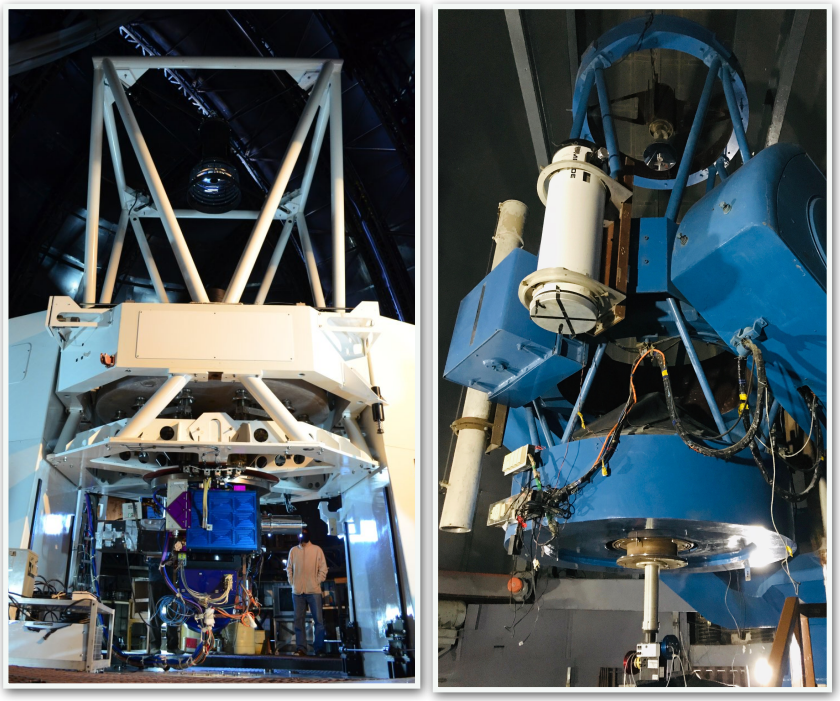


Figure 3 : 1.2 m, MIRO, Abu

EMCCD IMAGER

- ✓ Mounted on the Cassegrain focal plane of the 1.2-m telescope at the Mount Abu InfraRed Observatory (MIRO), situated at Mt.Abu, India.
- ✓ Consists of a 1K x 1K EMCCD and a filter wheel equipped with Bessells *BVRI* filters.
- ✓ Imaging observations were carried out in 2x2 on-chip-binning mode, using the *BVRI* filters.
- ✓ The non-sidereal track mode built into the in-house developed telescope software was used to track the fast moving comet during entire observation time.

Results

Following the successful spectroscopic and imaging observation of the first interstellar comet 2I/Borisov, the following results were obtained :

- Similar to the solar system comets (Figure. 1), the optical spectrum of 2I/Borisov also exhibits fluorescence emissions from CN, C_2, C_3 radicals at 3870 Å, 5160 Å and 4050 Å respectively (see Figure. 4).
- The comet was observed on two different epochs and all the above mentioned emissions, were detected, as shown in Figure. 5.
- With systematic reduction, sky correction and production rate (molecules/s) computation, it has been found that the comet is depleted in carbon chain molecules, as per the classification criterion defined by A'Hearn et al. (1995).
- From imaging study (magnitude and colour computation), it was deduced that the various dust colours are redder than solar, similar to the mean colours of Long Period Comets (LPC) [Jewitt (2017)] of our solar system and also similar to the colours of 1I/`Oumuamua [Jewitt et al. (2017)], the first interstellar object to be detected.

Figure 4 :Low resolution optical spectrum of 2I/Borisov with an RGB image as inset

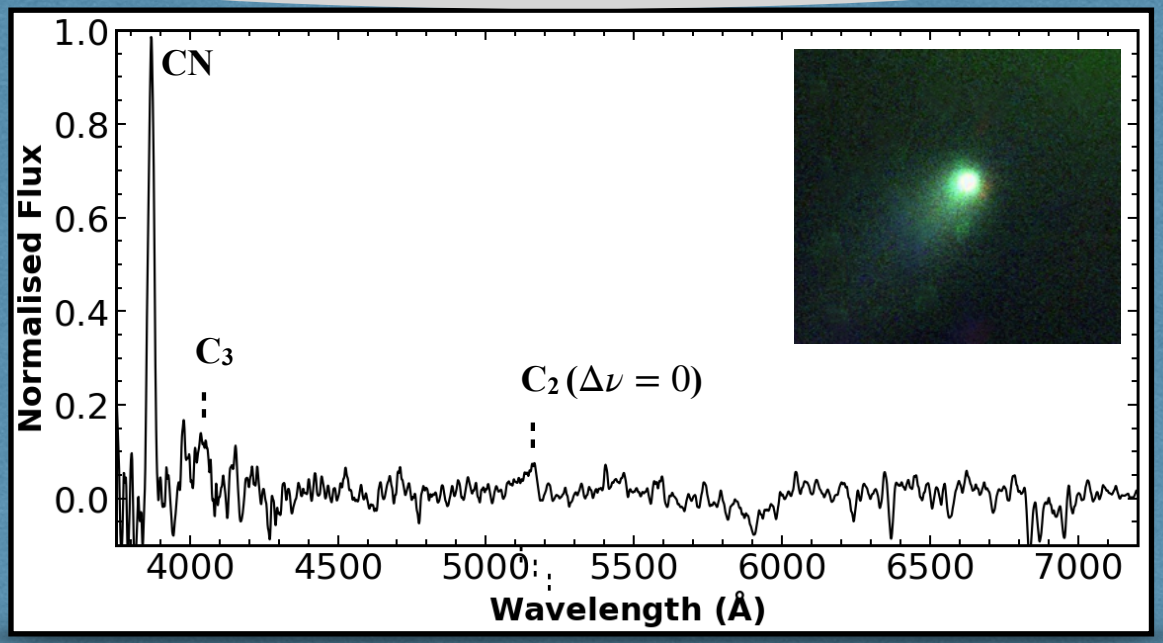
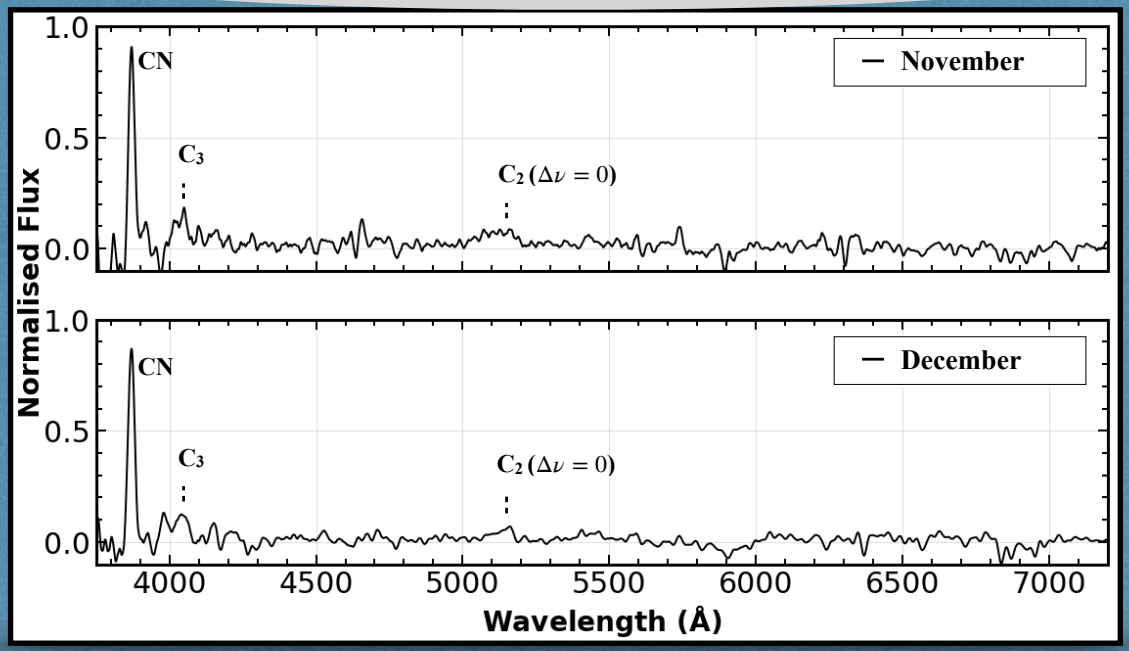


Figure 5 : Optical spectrum of 2I/Borisov as observed on two different epochs



Conclusions

Possible conclusions regarding the first interstellar comet, 2I/Borisov, based upon the previously described results are as mentioned below :

- ★ The gaseous composition (coma) of the comet resembles that of the Solar system comets with a depletion in the carbon chain molecules.
- ★ Similar carbon chain depletion is also observed in the long period and short period comets of the Solar system, with larger fraction of the depleted comets belonging to the Jupiter Family Comets (JFC).
- ★ This similarity in depletion can imply that the formation scenario which occurred in 2I/Borisov's parent star system maybe similar to that of our solar system.
- ★ A variation in the ratio of flux of various molecular emission is observed as the comet approaches the Sun.
- ★ Since the ratio of flux of various molecules does not vary significantly with minimal change in the heliocentric distance [A'Hearn et al.(1995)], this maybe an indicator that the comet nucleus is very heterogenous or the volatility of the pristine materials in 2I/Borisov is different from what is observed in solar system comets.

Acknowledgment

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References

1) McGlynn, T. A. & Chapman, R. D. 1989, On the Nondetection of Extrasolar Comets, ApJ, 346, L105
2) Sen, A. K. & Rana, N. C. 1993, On the missing interstellar comets, A&A, 275, 298
3) Bannister, M. T., Opitom, C., Fitzsimmons, A., et al. 2020, Interstellar comet 2I/Borisov as seen by MUSE: C2, NH2 and red CN detections
4) Jewitt, D. & Luu, J. 2019, Initial Characterization of Interstellar Comet 2I/2019 Q4 (Borisov), ApJ, 886, L29
5) Kareta, T., Andrews, J., Noonan, J. W., et al. 2020, Carbon Chain Depletion of 2I/Borisov, ApJ, 889, L38
6) Lin, H. W., Lee, C.-H., Gerdes, D. W., et al. 2020, Detection of Diatomic Carbon in 2I/Borisov, ApJ, 889, L30
7) Opitom, C., Fitzsimmons, A., Jehin, E., et al. 2019, 2I/Borisov: A C2-depleted interstellar comet, A&A, 631, L8
8) de León, J., et al., Monthly Notices of the Royal Astronomical Society 495.2 (2020): 2053-2062.
9) A'Hearn, M. F., Millis, R. C., Schleicher, D. O., Osip, D. J., & Birch, P. V. 1995, Icarus, 118, 223
10) Jewitt, David, et al., The Astrophysical Journal Letters 850.2 (2017): L36.