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OBSERVATIONS OF THE COMET C/2007 N3 (Lulin) DURING ITS CLOSEST APPROACH TO THE EARTH

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Abstract. In this the results from the observations of the comet C/2007 N3 (Lulin) were presented. The comet was observed at 23 and 24 February 2009, when it was at its closest approach to the Earth (at geocentric distance $\Delta = 0.411$ A.U.). For the observations the 2m Ritchey-Chretien-Coude Telescope at the Bulgarian National Astronomical Observatory Rozhen equipped with 2-channel focal reducer and a set of narrow-band filters and grisms were used. This combination was used for obtaining narrow band images and low dispersion spectra of the comet's coma. The images were investigated for jet-like structures with radial image enhancement filter and significant structures were detected.

1. INTRODUCTION

Spectra of comets offer an opportunity to examine chemical composition of their comae in great details. The first spectra of comets was made by Huggins, W. (1881) on photographic plates 120 years ago. Comets are very good "laboratories" to study transitions in atoms and molecules that cannot be observed on Earth. From analysis of comets continuum (which is caused by the reflected sunlight from dust particles in the coma) we can go by what is the nature of the comets dust.

Different kind of structures are observed in the comets' coma. These structures are caused by an anisotropic emission from active region over the rotating nucleus. Their shape depends on the orientation of the spin axes, the coordinates of the active region over the nucleus and the aspect of the observations (Larson and Sekanina 1984).

2. OBSERVATIONS

The observational material was obtained with the 2m RCC telescope at NAO–Rozhen. The focal length of the RC–focus is 16 000 mm. The 2-channel focal reducer (FoReRo2) was used to transform the focal length to 5 600 mm. The FoReRo2 gives opportunity for observations at two different wavelengths simultaneously (*red* and *blue* channel). Detailed description of the FoReRo2 is given in Jockers, *et al.* (2000).

A CCD – cameras Photometrics, CE200A-SITe, comprising $1024 \times 1024\,\mathrm{px}^2$ and VersArray 512B, comprising $512 \times 512\,\mathrm{px}^2$ were used respectively on the blue and the

Table 1: Grisms parameters

Lines/mm	Wavelength straight pass, nm	Dispersion Å/px	Range nm
600	392	2.6	355 – 460
300	530	5.2	480 – 750

Table 2: Conditions during the observations

Date	r	Δ	S-T-O	PsAng	PsAMV
23 Feb 2009	1.392	0.411	10.03	292.7	111.5
24 Feb 2009	1.399	0.412	5.67	292.5	111.1

red channel. Both CCD cameras have pixel size of $24\,\mu m$ With these cameras and the described optical system the spatial scale is $0.89\,''$/px.

Two filters for comet observation centered at clean continuum windows (BC and RC) and two filters centered at characteristic cometary emissions (CN and C_2,) were used in both channels.

The FoReRo2 gives an opportunity to observe in two spectral regions: 3500Å–4500Åand 4500Å– 7000Å, simultaneously.

The spectral mode of the ***FoReRo2*** is realized with two grisms placed in the blue and red channel, respectively. Their parameters are presented in table 1.

The comet was observed in two consecutive nights when it was at its closest approach to the Earth. In table 2 the heliocentric and geocentric distances, apparent phase angle, the position angles of the extended Sun–target radius vector (PsAng) and the negative of the target's heliocentric velocity vector (PsAMV) orientations are presented.

3. DATA REDUCTION

3. 1. ABSOLUTE CALIBRATION

The atmospheric extinction was obtained from narrowband photometry of standard star in all filters. For correction of differential extinction within the spectrum the extinction was fitted at those three wavelengths and then extrapolated over the wavelength range using λ^{-4} law. This comes from Rayleigh scattering in the atmosphere, which is the main source of loosing the light from the object.

For flux calibration of spectra to fluxes standard star HD100889 from the catalog of Hamuy *et al.* (1992, 1994) was used.

For spectral observations a part of star image is blocked. We estimate the coming trough the slit fraction to be 31%. It was calculated by obtaining signals without grisms from the images of the star with and without slit. This number was used to obtain the whole signal from the star, which corresponds to the fluxes in the catalog.

Table 3: ADU to FLUX coefficients

Filter	CN	BC	C_2	RC
$\frac{F_\lambda^*}{S_\lambda^*}\ 10^{-15}[\frac{erg\,cm^{-1}\,s^{-1}\,\mathring{A}^{-1}}{ADU\,s^{-1}}]$	9.145	4.282	4.015	1.945

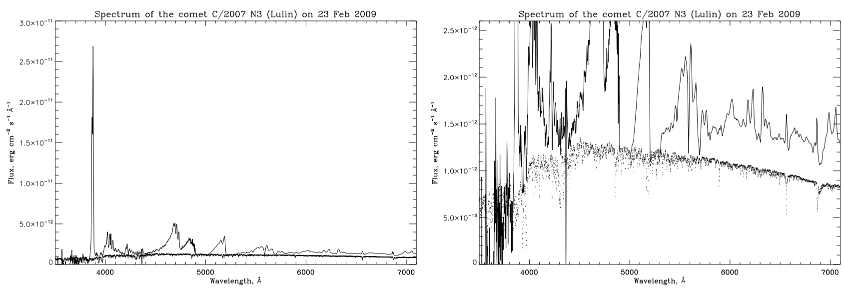

Figure 1: The flux calibrated comets spectrum compared with solar one (left panel), and continuum zone (right panel).

Finally the flux calibration was performed by applying following equation to the comet images and spectra spectrum as well.

$$F_\lambda^{com} = S_\lambda^{com} \frac{F_\lambda^*}{S_\lambda^*} \tag{1}$$

The ADU to FLUX coefficients ($\frac{F_\lambda^*}{S_\lambda^*}$) are presented in table 3.

3. 2. WAVELENGTH CALIBRATION

The wavelength calibration was performed by using information contained in the spectra themselves. For the standard star the Ballmer absorption lines and for the comet the night sky emission lines were used. The obtained linear dispersions in Å/px are given in table 1.

4. RESULTS

4. 1. MEAN RADIAL FLUX AND INTENSITY DISTRIBUTION

In 1984 A'Hearn *et al.* define the quantity $Af\rho$ and the calculated values are 663 cm and 824 cm in BC and RC respectively

4. 2. SPECTRUM

The flux calibrated spectrum of the comet C/2007 N3 (Lulin) is presented in the figures 1. The main cometary emissions: CN, C_3, C_2, NH_2 and O[I], are well discernible.

The solar spectrum was equalized to the clear continuum zone at 443 nm of the comet spectrum. The other good clear continuum zone is at 642 nm, where the comet

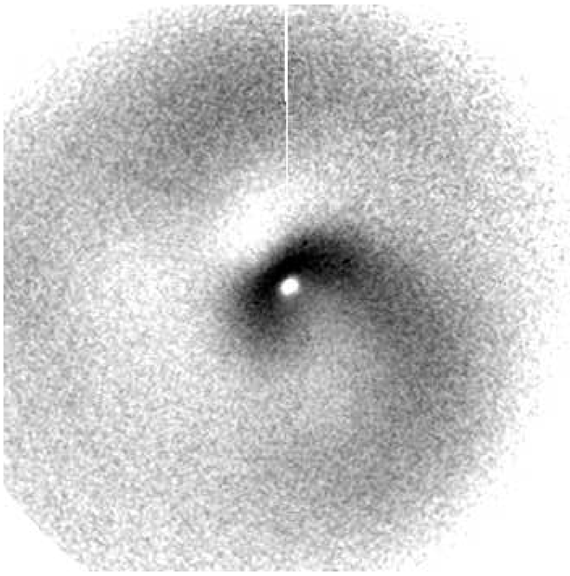

Figure 2: Enhanced jet-like structure in the image of the CN coma.

spectrum is brighter than the solar one (see Fig. 1 right panel). From this difference the normalized spectral gradient of the cometary dust (the color of the continuum) is calculated by the following relation:

$$C_{\lambda_1,\lambda_2} = \frac{1}{\bar{F}} \frac{\partial F}{\partial \lambda} \tag{2}$$

where $\bar{F}$ is the mean flux between λ_1 and λ_2 (Jewitt and Meech 1986).

The reddening of the cometary dust (C_{λ_1,λ_2}) was calculated to be 4% per 1000Å.

4. 3. JET-LIKE STRUCTURES

Not a single combination of parameteres of Haser's model (Haser 1957) gave satisfying results of matching model and observations. So it was found out that the raw images of the neutral coma show irregularity. After applying a numerical filter for enhancement coma structures, the results presented at Fig. 2 are obtained. Knight and Schleicher, (2009) obtained and analyzed extensive CN narrowband images of comet C/2007 N3 (Lulin) on eleven nights. They also found side-on gas jets and a nucleus rotation period of 42 hours.

5. CONCLUSIONS

1. Observations of the spectrum, dust and neutral coma of comet C/2007 N3 (Lulin) are obtained.
2. The dust coma is characterized with presence of discrete structures.

3. The images are absolutely calibrated and $Af\rho$ values are calculated.
4. The spectrum is absolutely calibrated.
5. The observed structures are enhanced from the ambient dust coma with application of suitable numerical radial filter.

6. FUTURE WORK

In the future this work will be continued by extracting physical parameters of neutral molecules from comet spectrum and applying better unstationary model for neutral coma images.

Acknowledgments

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