ASTRONOMY AND SPACE SCIENCE
eds. M.K. Tsvetkov, L.G. Filipov, M.S. Dimitrijević, L.Č. Popović,
Heron Press Ltd, Sofia 2007

# Photometry of the split comet 73P/Schwassmann-Wachmann 3 from November 2005 to April 2006*

**T. Bonev**[1], **B. Bilkina**[1], **G. Borisov**[1], **Z. Donchev**[1], **Al. Ivanova**[1], **V. Ivanova**[1], **Kl. Jockers**[2], **A. Kostov**[1], **Vl. Krumov**[1], **E. Ovcharov**[3]

[1]Institute of Astronomy, Bulgarian Academy of Sciences

[2]Max-Planck-Institute for Solar System Research, Germany

[3]Department of Astronomy, Sofia University

**Abstract.**

In 1995, two perihelion passages ago, comet 73P/Schwassmann-Wachmann 3 split into at least 3 fragments. In May 2006 the comet will approach the Earth to only 0.08 AU. This will give an unique opportunity to observe the dust and gas environment of the particular fragments with high spatial resolution. In preparation for this event we conducted CCD imaging photometry observations of the fragments of comet 73P/Schwassmann-Wachmann 3.

## 1 Introduction

Analysis of the phenomena ralated to split comets provides valuable information on the internal structure and chemistry of the cometary nucleus [2]. Comet Schwassmann-Wachmann 3 takes a special place in the family of split comets. It was in the list of potential targets of the ROSETTA mission when first disruptions of its nucleus were registered [3]. Sekanina [5] uses the data on observed outbursts of the comet to derive the momenta of splitting and the properties of the particular subnuclei. His study is an excellent illustration of the close link between photometric behaviour of the comet and the fragmentation events.

Our monitoring of comet 73P/Schwassmann-Wachmann 3 started on November 7, 2005, when the comet was at 2.6 AU from the Sun. The observations were conducted with the 2m telescope of the National Astronomical Observatory (NAO), Rozhen. Two modes of observations were used: (1) high spatial resolution imaging (0.26 arcsec/px), directly in the RC focus, and (2) low spatial resolution imaging (0.89 arcsec/px) with the 2-channel focal reducer (FoReRo2),

*Based on observations obtained with the 2m telescope of NAO, Rozhen

attached to the telescope. FoReRo2 makes the system faster, and gives the opportunity to obtain images in two spectral ranges simultaneously.

We present the results of our CCD imaging photometry and discuss possible correlations between the increase of activity with decreasing heliocentric distance. We show that the subnuclei of comet 73P/Schwassmann-Wachmann 3 proceed to experience subfragmentation, and consider morphological changes in the coma caused by the existence of subfragments.

## 2 The First Images of Fragment C: November 2005

Fragment C is considered the main fragment of the split comet Schwassmann-Wachmann 3. It was recovered by Hergenrother on Oct 22, 2005 [4]. We observed this fragment on November 8, 2005. The surface brightness of fragment C, derived from these observations is presented in Figure 1. At that time the comet showed already a well developed coma, extending to more than $10^4$ km in tailward direction and to about $5 \times 10^3$ km sunwards and in lateral directions. The total magnitude of fragment C, calculated from the brightness integrated above $1 - \sigma$ of the sky background, amounted to $R_{tot} = 17.8$.

The image shown in Figure 1 is a composite with a total exposure of 660 sec (11 exposures $\times 60$ sec). The particular images were obtained with R-filter in the RC-focus of the 2-m telescope in NAO Rozhen. The 11 images were first shifted to bring the comet to the same reference position with subpixel accuracy, then stacked in a 3D data cube, and finally the composite was created taking the median along the 3-d dimension. The surface brightness is expressed in mag/arcsec$^2$. The images were acquired during twilight what causes the relatively bright background.

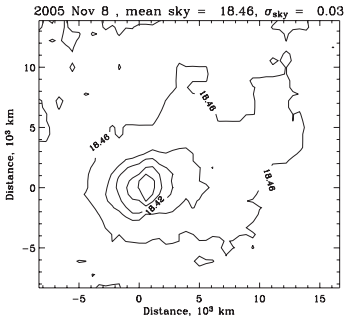


Figure 1. Surface brightness of fragment C as observed on November 8, 2005.

## 3 Fragment C in January, 2006

On January 21, 2006, we observed fragment C with FoReRo 2. The use of FoReRo 2 allowed to acquire simultaneously images in the blue and red spectral regions. The derived B-band and R-band surface brightness is presented in Figure 2. The data processing of these images is identical to this described in the previous section.

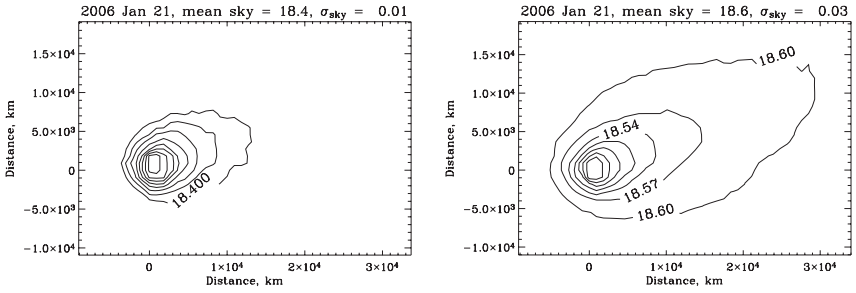


Figure 2. Surface brightness of fragment C, derived from images obtained on Jan 21, 2005 with FoReRo 2. Left: a composite B-band image, obtained in the blue channel of the focal reducer. Right: a composite R-band image, obtained in the red arm of FoReRo 2, simulataneously with the B-band images.

The R-image shows that, in comparison to November 2005, the coma is more extended, it reaches now $3 \times 10^4$ km in tailward direction. The total magnitudes amount to $R_{tot}$ = 14.7 and $B_{tot}$ = 15.9. The color index B–R is equal to 1.2. This value is very close to the color of the Sun (1.17, [1]), which is an indication that the main contribution to the brightness in both spectral regions comes from solar light, scattered by the cometary dust particles. There is a minor difference in the shape of the surface brightness in both spectral regions, the R-image is more elongated in comparison to the B-image. Most probably this difference is caused by additional contribution of neutral molecules to the coma of the B-image. There are two arguments in support of this explanation. First, the neutrals are more symmetrically distributed around the nucleus which masks the more elongated dust distribution. And second, the B-band is characterized by the presense of more molecular emissions.

## 4 A New Fragment, 'G': March and April, 2006

Tucker *et al.* [7] reported the discovery of a new fragment, on Feb. 20.4 and 22.4 UT. As this fragment was not likely to be 'E' or 'F' [7], it was denoted 'G'. Our first observations of fragment 'G' were conducted on March 30 with FoReRo 2. The surface brightness maps in the B and R spectral regions are presented in Figure 3. In the B-image, in the very inner region, we see indications for further splitting of this fragment. The shape of the R-image is unusually elongated in the sunward direction, what suggests the presence of subfragments around fragment 'G'. The B and R total magnitudes were $B_{tot}$ = 17.5 and $R_{tot}$ = 15.8, and the color index B–R = 1.7, redder than the Sun.

The additional subfragments, suspected from the surface brightness maps on March 30, were resolved in the R-band image, obtained 2 days later and shown in Figure 4. Most probably, the fragment at coordinates (0,0) is that one, which

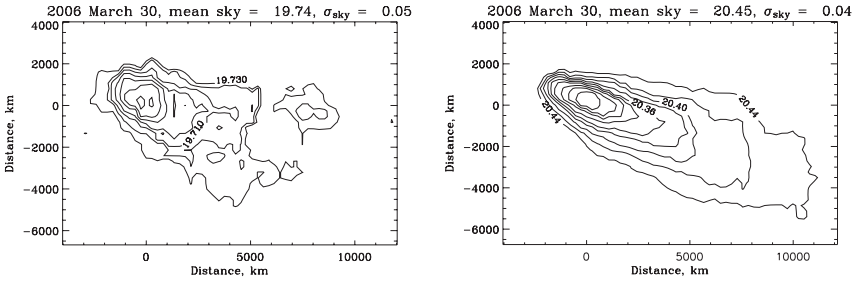


Figure 3. Surface brightness maps of the fragment 'G' coma, derived from images obtained on March 30, 2006. Left: B-band. Right: R-band. The images in both spectral ranges are obtained with FoReRo 2, simultaneously.

causes the sunward elongation of the coma in Figure 3. Now it is strongly condensed and more active than the original fragment 'G', which is seen at approximately $2 \times 10^3$ km tailwards. The total magnitude of both components is $R_{tot} = 15.1$.

Twenty days later, on April 24, we again obtained R-band images of fragment 'G'. It was still active and brightened to $R_{tot} = 13.6$. The surface brightness distribution of fragment 'G' on April 23 is shown in Figure 5.

Sekanina [6] points out that recent reports of a duplicity of fragment 'G' confirm advancing fragmentation of the comet. He estimated that the subnuclei of 'G' should have separated from their parent around Mar 6. Our image from Apr 2, 2006 (Figure 4) shows an example of cascading fragmentation. Boehnhardt [2] gives a mean value of $2.7 \pm 2.3$ m/s for the separation velocity for the fragments

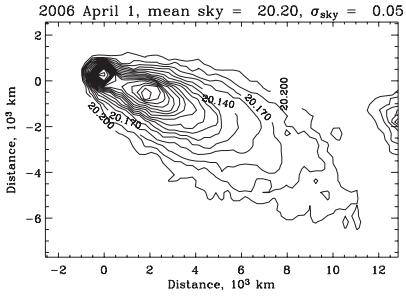


Figure 4. R-band surface brightness map of the fragment 'G' coma on April 2, 2006. Note the component at about $2 \times 10^3$ km tailward. This is the original fragment 'G', which is now fainter then the subfragment placed at coordinates (0,0).

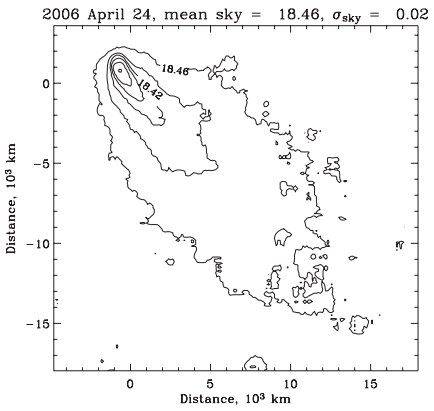


Figure 5. R-band surface brightness around fragment 'G', on April 24, 2006.

of split short-period comets. Using this value and the distance between the two fragments seen in Figure 4 we can conclude that they have separated about less than 10 days before the time of observation. This confirmes are previous suspicion that unresolved subfragments cause the elongated shape of the coma, observed on Mar 30 (Figure 3). Obviously, these subfragments are different from those which have appeared after the fragmentation event on Mar 6. [6].

## 5 Conclusions

We presented a sequence of photometrically calibrated CCD images of comet Schwassmann-Wachmann 3., obtained in the period Nov 2005 – Apr 2006. The variations of the surface brightness of fragments 'C' and 'G' with heliocentric distance are followed up. Cascading fragmentation of fragment 'G' caused morphological changes in the coma. A subfragment is resolved at 2000 km from fragment 'G' on Apr 2, 2006. The mean color of the coma varied from neutral to about 0.5 magnitude redder then the Sun.

Will the process of cascading fragmentation continue? Are the physical properties of the different fragments different? In order to look for answers of these questions we plan to observe comet 73P/Schwassmann-Wachmann 3 during its closest approach to Earth in the first half of May, 2006.

## References

[1] C.W. Allen (1973) *Astrophysical quantities*, The Athlone Press, University of London.

[2] H. Boehnhardt (2004) *Comets II*, eds. M.C. Festou, H.U. Keller, H.A. Weaver, The University of Arizona Press, p. 301.

[3] J. Crovisier, D. Bockelee-Morvan, E. Gerard, H. Rauer, N. Biver, P. Colom, and L. Jorda (1996) *A&A* **310** p. L17–L20.

[4] C.W. Hergenrother (2005) *IAUC* **8623**.

[5] Z. Sekanina (2005) *Int. Com. Quarterly* **27** p. 225–240.

[6] Z. Sekanina (2006) *CBET* **464**.

[7] R.A. Tucker, E.J. Christensen, and Z. Sekanina (2006) *IAUC* **8679**.