THE COLLIMATED JET OF COMET 19P/BORRELLY: A STUDY OF THE DEEP SPACE 1 MICAS IMAGES AND GROUND BASED OBSERVATIONS

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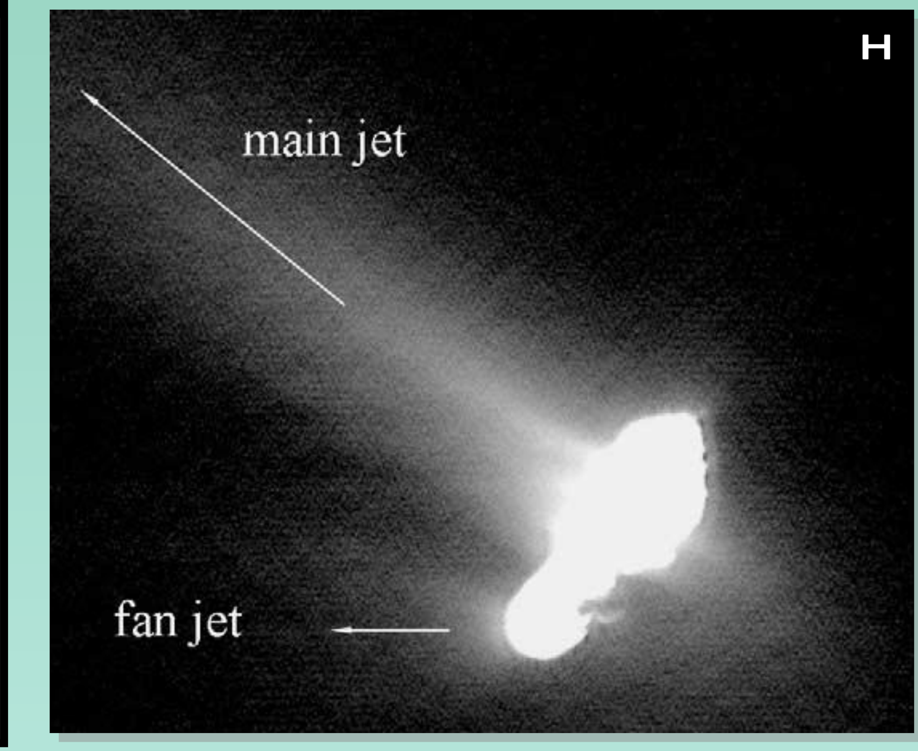


ABSTRACT

Presented on this Poster is a study of the Miniature Integrated Camera and Spectrometer (MICAS) Images and Ground Based Photometry found in the Planetary Data Systems: Small Bodies Node archives.

The images from the Deep Space 1 mission include a detailed view of the surface of comet 19P/Borrelly as well as two types of dust features: broad fans and narrow jets that suggest collimation. The goal of this research is to characterize the collimation of the jet, and study the expansion.

As a College Student Investigator for Planetary Data Systems, I will analyze the DS1 high-resolution images of 19P/Borrelly for the density distribution of the material contained in the jet, along with Ground Based Observations.

Stereo information will be assembled for different points along the spacecraft's flyby and a geometrical model will be created to help test the proposed models for the cometary mechanism below the surface.

INTRODUCTION

The Deep Space 1 (DS1) mission was intended to test and validate high-risk technologies that are important for future missions. In addition to this primary goal, the secondary objectives were to obtain images and spectra of the near-Earth asteroid 9969 Braille (1999 K2) and the comet 19P/Borrelly.

On September 22, 2001 at 22:30 UT Deep Space 1 flew by comet 19P/Borrelly near the south ecliptic pole. This was 8 days after perihelion, at a heliocentric distance of 1.36 AU and a geocentric distance of 1.48 AU. The closest approach during the flyby was 2171 km from the comets surface with a relative velocity of 16.58 km/sec.

The Miniature Integrated Camera and Spectrometer (MICAS) took both optical images (from 0.5 to 1.0 microns) and spectra (1.3 to 2.6 microns) during the approach.

The most distinguishable feature in the images of Borrelly is the large jet projecting radially outward in the sunward direction. This is present in the MICAS images as well as the Ground Based Photometry.

The difference in pressure between the subsurface gases and the vacuum of space causes the gas and dust to be expelled from the subsurface cavities and outward. The gas and dust is then decoupled due to the rapid drop in density as the gas and dust expand out of the nucleus, and the dust is allowed to continue in a collimated beam into space. (Yelle et al, 2004)

The major jet of comet Borrelly is located on the comet's spin axis, which allows us to easily measure the collimation and neglect any effects do to rotation. This shows that Borrelly is the ideal test case for evaluating the models for this cometary mechanism.

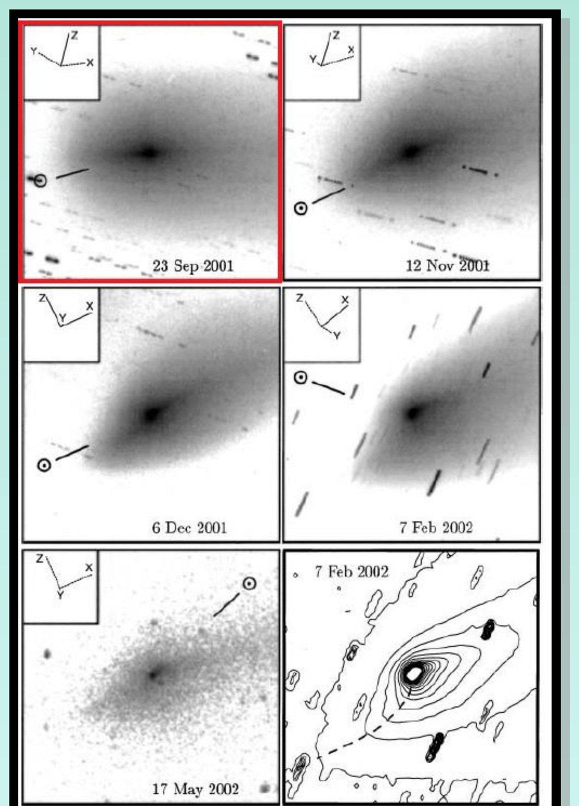
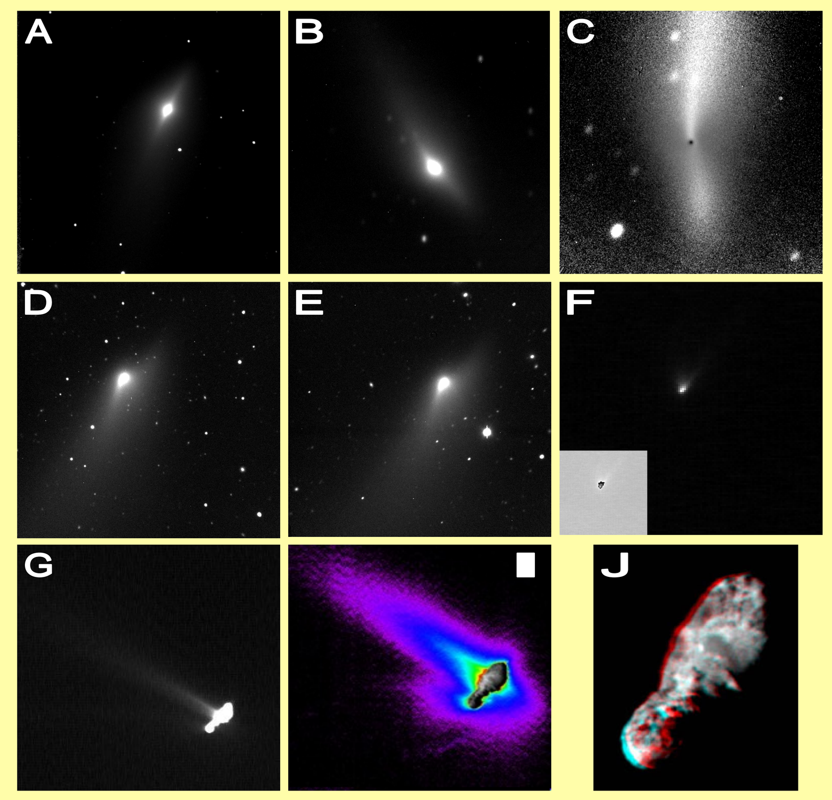


FIG. 1. A sequence of 5 R-band images of Comet Borrelly, showing the evolution of the coma, and a contour plot of the February data. In each frame, north is at the top, east is to the left, and the field of view is 2.5×10^5 km. The inset for each image depicts an inertial coordinate system relative to the comet's orbit, where the X axis extends in the antisolar direction at perihelion, the Y axis is the velocity vector at perihelion, and the Z axis is parallel to the orbital angular momentum vector. The length of the axis in the inset indicates the amount of foreshortening, with solid lines extending toward the Earth and dotted lines extending away.

OTHER IMAGES USED IN ANALYSIS

A = McDonald Ground Based Observation taken at 2001-11-12 T 11:22:31.25
B = McDonald Ground Based Observation taken at 2001-12-05 T 11:29:26.79
C = Image 'B' after Rotation and OneOverRho Image Enhancement Routines have been Performed
D = McDonald Ground Based Observation taken at 2002-02-07 T 08:57:23.83
E = McDonald Ground Based Observation taken at 2002-02-08 T 09:47:05.06
F = MICAS Image take just prior to spacecraft flyby at 2001-09-22 T 12:23:56.819
G = MICAS "near_ccd" Image Taken during the spacecraft flyby at 2001-09-22 T 22:16:31.819
H = Expanded Version of the MICAS "near_ccd" Image 'G' with Jets Labeled
I = Composite Image, Purple = 1/1000, Blue = 1/100, and Red = 1/10 the Brightness of the Nucleus
J = Stereo Image, Two frames taken a few seconds apart by Deep Space 1 as it swept past Comet Borrelly

IMAGES (A B D E K) ARE PROCESSED THE SAME WAY AS THE IMAGE SHOWN ON THE LEFT OF THE POSTER AND THEN COMBINED TO CREATE STEREO INFORMATION ON THE JET



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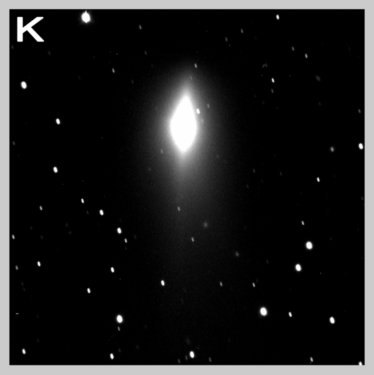


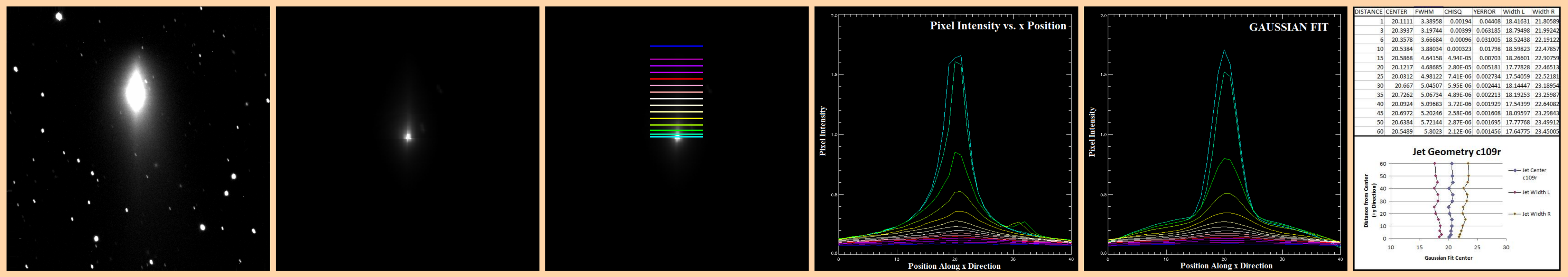
IMAGE WAS TAKE AT THE MCDONALD OBSERVATORY 2.7 M HARLAN J SMITH TELESCOPE

EXPOSURE DURATION = 120.00 sec
RIGHT ASCENSION = 118.992 DEG
DECLINATION = 20.897 DEG
AIRMASS = 1.616

2001-09-23
10:54:03.64 UT

THIS IS THE ORIGINAL IMAGE THAT ALL FURTHER ANALYSIS WILL REFER TO

2)



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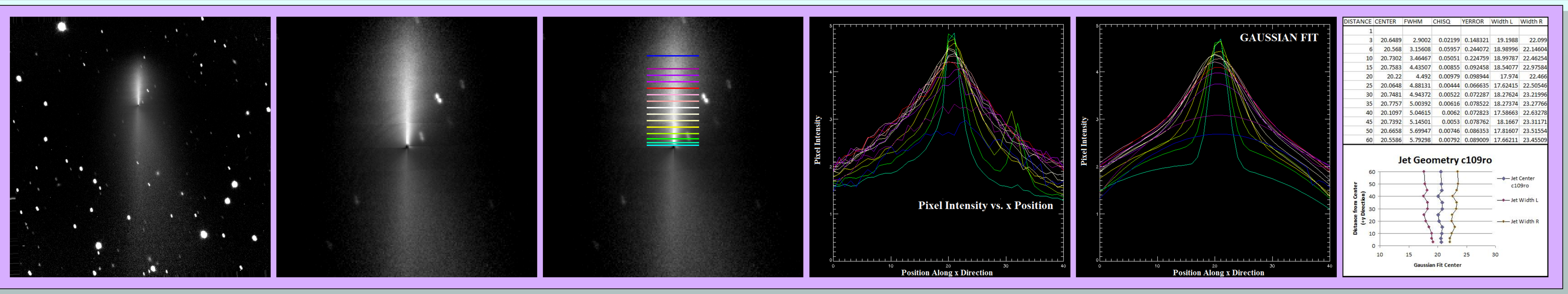

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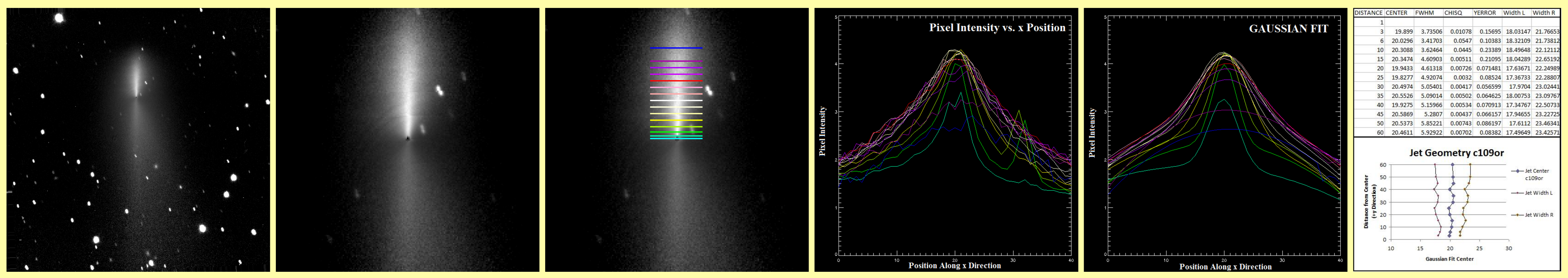

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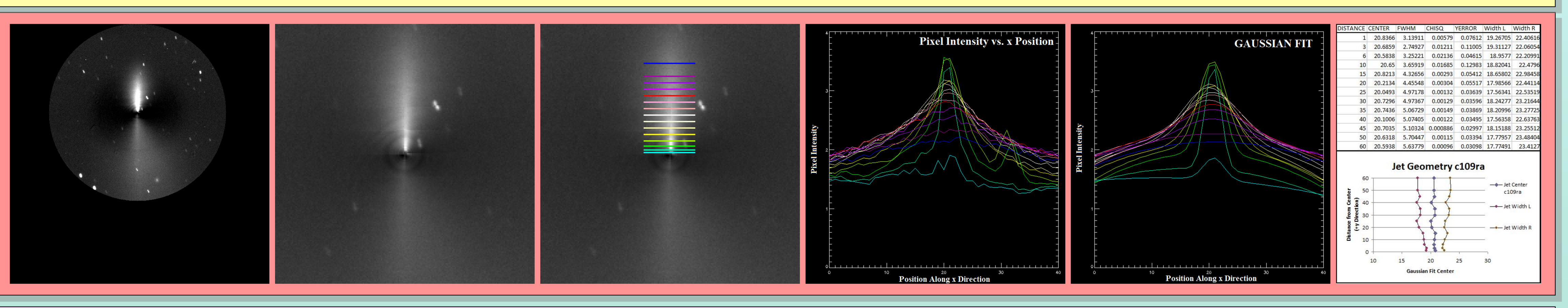

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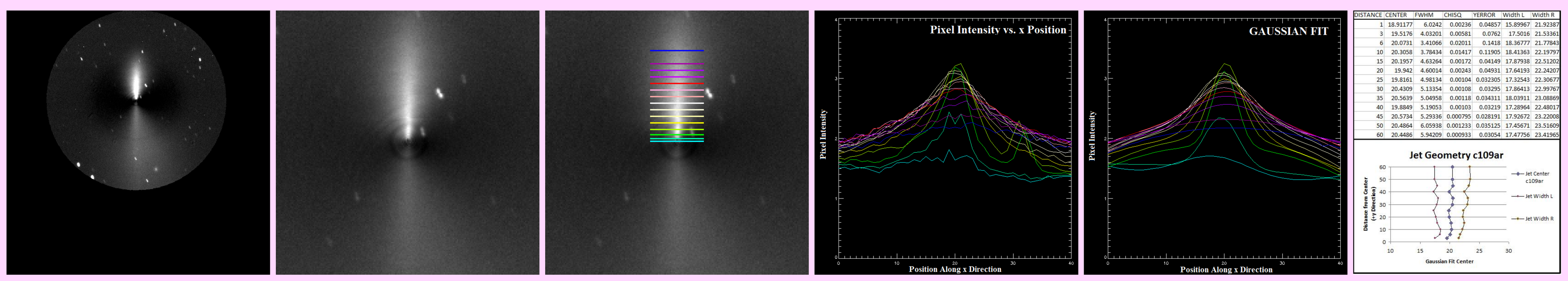


7)

DISTANCE	CENTER	FWHM	CHISQ	YERROR	Width L	Width R
1	19.95316	4.184297	0.003363	0.056257	17.86101	22.04531
3	20.22902	3.322796	0.010936	0.110941	18.56762	21.89042
6	20.32246	3.380564	0.03134	0.113371	18.63218	22.01274
10	20.50664	3.682636	0.025271	0.145102	18.66532	22.34796
15	20.5419	4.528976	0.003672	0.08121	18.27741	22.80639
20	20.08808	4.56953	0.00451	0.056017	17.80332	22.37285
25	19.95782	4.947278	0.002001	0.044661	17.48418	22.43146
30	20.6146	5.030002	0.002353	0.040047	18.0996	23.1296
35	20.6724	5.055654	0.002771	0.043672	18.14457	23.20023
40	20.02302	5.113444	0.002759	0.042561	17.4663	22.57974
45	20.66004	5.204954	0.002271	0.040938	18.05756	23.26252
50	20.59194	5.807394	0.003455	0.048662	17.68824	23.49564
60	20.5222	5.820876	0.003367	0.047161	17.61176	23.43264

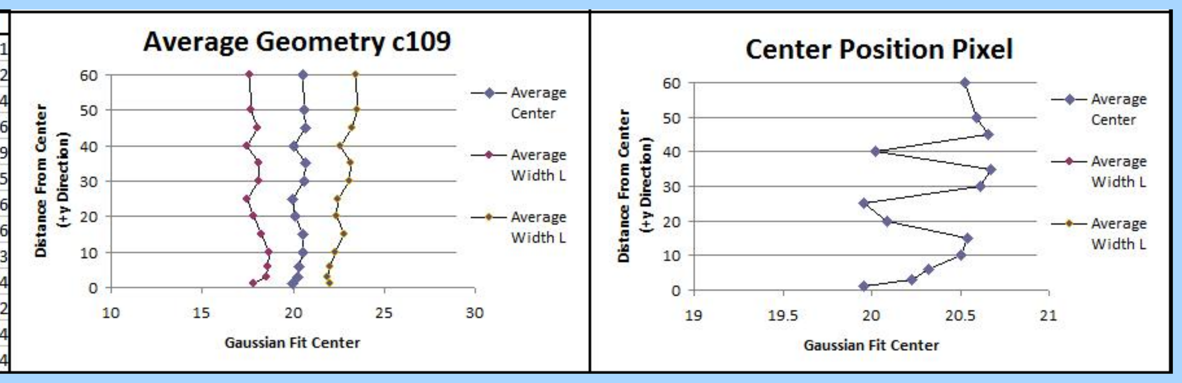


IMAGE ENHANCEMENT PROCESS

To the Left of the Poster, there are five different "image enhanced" versions of the same original image, which can be found in the Grey Box 1). Each Row includes 3 images that have been returned after a series of Interactive Data Language (IDL) routines have been performed. There are also 3 plots associated with these images.

Box 1) [Grey] displays the original image "ut010923_109c.fit" from the Ground Based Dataset of the PDSSBN archives.

Box 2) [Orange] displays the same images as above, only after a rotation command has been run on the image. After calculating an approximate rotation angle of 3.15 degrees counterclockwise, the program was performed, and an image was returned with the preferred orientation of the jet, which in this case is in the +y direction. The image was rotated with the center of rotation placed directly on the nucleus of the comet.

Box 3) [Purple] takes the rotated image and then runs a OneOverRho (oor) routine on the image where the function is still centered on the nucleus of the comet. The OOR routine takes the image and divides out a 1/rho profile.

Box 4) [Yellow] is the reverse order of previous steps. In order to measure the amount and severity of the artifacts that are introduced due to the manipulation of data, this image first divides a OOR profile of the very first image in BOX 1) [Grey], and then performs the rotation of the same angle. The Images in Box 3) and Box 4) do show slight differences in the jet close to the nucleus.

Box 5) [Red] takes the rotated image and then divides out an Azimuthal Average AZAV, instead of the OOR routine, with the center of the function, on the nucleus.

Box 6) [Pink] does the reverse process for AZAV as well, for the same reason. After the two images are compared there is a noticeable difference close to the nucleus.

In each case it seems that when the image was rotated first, and then subjected to an image enhancement routine, there were much more noticeable artifacts introduced due to the enhancement.

For each type of image enhancement process there is a total of three images. The second image along the row is an extracted Version of the first image, with the center of the nucleus now placed at the center pixel of the image. Each of the "extracted" images displayed on this poster is 201x201 with the center at 100,100. The final image for each row is the same, only now the image includes a line from 80:120 in the x direction, and a changing value in the +y direction, and the color depends on the distance from the center pixel, or nucleus.

The Intensity values each cut along this image was then plotted vs. the x pixel value, and the resulting Graph is display in Column 4 of each Box. The colored lines from image relate to the same color of the Intensity line on the following plots.

These peaks were fit to a Gaussian distribution, and resulting equation for each line was also plotted on a separate Graph. This was used to find the Center pixel according to the Gaussian Fit.

At the end of each Box there is a table with values including Distance from Center (+y direction), Jet Center value for each line, the Full Width Half Maximum for each fitted line, the Chi Squared value of the Gaussian Fit for each line, and Y error associated with the Gaussian Fit. The FWHM was also used to calculate the width of the jet on the Left and Right sides. The values of Jet Center, and FWHM, are shown in the 'white' graph at the end of each Box. They are plotted with respect to their distance from the center in the +y direction). These 'white' graphs clearly show the geometry of the jet, and the rate of expansion.

The graphs for each of the 5 boxes were then Averaged, only to get a clear look at the geography of the jet. In practice only the OOR plots are combined with other OOR plots from other original images, after Stereo information is taken into account. A 3-D model of the jet will require jet geometry information for several points along the spacecraft's flyby and ground based photometry, and then will lead to a better understanding the cometary mechanism.

Box 7) [Blue] Finally the average center pixel position of the jet was blown up to see the variation as the lines increase in the +y direction. Future analysis will require a loop that will analyze every line in the + direction, and possible fractional cuts as well.

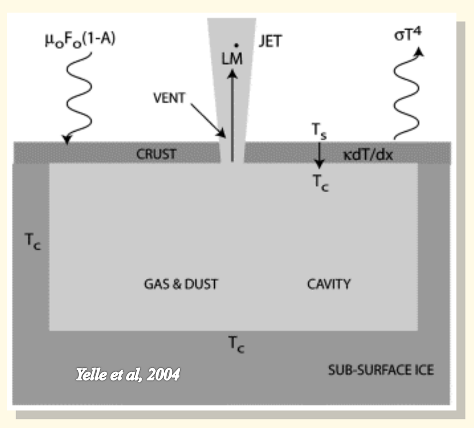
TESTING PROPOSED MODELS

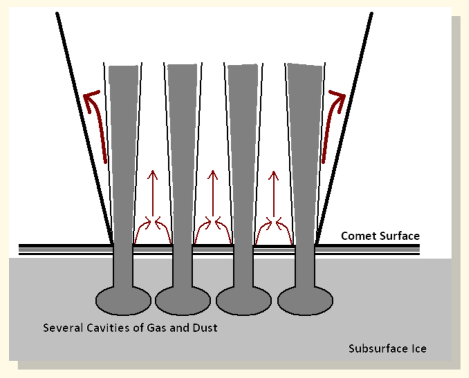
There have been many mechanisms proposed to explain the collimation process, including ones that discuss the topography of the surface of the comet, or theories of trenches, craters, or cavities below the surface. The "Yelle et al, 2004" model is shown in the top figure to the Right.

This is the first extensive testing done to explain the process behind the collimation, but there is much information available from the images of 19P/Borrelly to suggest that the observational data can be reproduced.

If the surface material is diffuse allowing gas and dust through a wider area, or if there is a large number of smaller pores, then all vents can contribute to the single jet. The smaller columns of gas and dust behave in the same manner, except that when the gas expands outward in all directions, it is met with equal and opposite force from the gas pressure of the surrounding columns. As shown in the bottom figure to the Right.

The jet characterization will provide constraints on the model that will help others learn more about this cometary mechanism. It may also be possible to apply the same limitations to jets on other comets.





REFERENCES

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- Thomas, N., A'Hearn, M. F. et al. Jet morphology in the inner coma of Comet 19P/Borrelly observed by the Deep Space One MICAS imaging System. Bulletin of the American Astronomical Society, 33, 1074.

PDSSBN ARCHIVES

All Raw Images and Data found in this Research Report can be found at the Planetary Data Systems: Small Bodes Node Archive Website located at:

http://pdssbn.astro.umd.edu/

under ear-c-igi-3-edr-borrelly-v1.0 for the McDonald Observatory Images of 19P/Borrelly 1, and under ds1-c-micas-2-edr-visccd-borrelly-v1.0 for the Deep Space 1 MICAS, FITS Files

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Planetary Data System