THE EFFECTS OF AGING ON THE MORPHOLOGY OF THE DUST COMAE OF PERIODIC AND NON-PERIODIC COMETS WITH REGARDS TO THE FORMATION OF JETS

Kristine Genelli Ayson
Institute for Astronomy
University of Hawai‘i at Mānoa
Honolulu, HI 96822

ABSTRACT

Comets are kilometer-sized mixtures of ice and cosmic dust. When they approach the sun, the solar energy becomes sufficient to allow for sublimation of water, which in the low gravity of the nucleus drags the small dust from the comet into a cloud, which we call a coma. This project looks for the evidence that comets develop a thick dusty mantle on the surface by searching for evidence of uneven sublimation in the form of jets in the dust comae of both periodic and non-periodic comets. Thirteen different comets were observed so far, which yields a total of 136 comet images. An image processing software called IRAF was used to observe the images, using the shift, smooth, rotate and unsharp masking techniques to look for features. Out of the thirteen comets, only comet Hale-Bopp showed obvious features. At the time the picture was taken, the comet was very close to the sun. This provides some evidence that jets do form when the comet is “active,” which means that the comet is close to the sun and its ice is undergoing sublimation. More comets are expected to come soon to be added on the list, which can provide more evidence in the aging process of the morphology of the dust comae of comets.

INTRODUCTION

For millennia, observers have pondered the appearances of comets in the night sky. The concepts developed to explain these mysterious apparitions have a long and intriguing history. During medieval times, comets were considered as atmospheric phenomena, or signs, sent by an angry God to warn the sinful people of Earth to repent. In other words, it was considered as a bad omen. As a matter of fact, most comet appearances in the past were linked to many historical tragedies, such as King Harold’s death in the battle of Hasting shortly after comet Halley’s appearance. It wasn’t until the early nineteenth century that specific tools became available to define the physical nature of comets.

1. What are comets?

A comet is a small body composed mainly of ice and dust in an elliptical orbit around the sun. They originated from the cold outer reaches of the solar system. In the comet’s pristine state, its surface consists of amorphous ice, dust and other volatiles. Comets have many different parts, as illustrated in Figure 1. Most comets are composed of the nucleus, coma, tail and a hydrogen envelope. The nucleus, typically about 10 kilometers across, is composed mostly of dust and ices of carbon dioxide, water, ammonia and methane. The coma is a dense cloud of gas
and dust particles around the nucleus. This can extend to 35,000 miles and it is formed as the comet gets close to the sun. There are two kinds of cometary tails. The ion tail of the comet is formed when the gas in the coma is ionized by sunlight. The dust tail is formed by tiny dust particles blown by the solar wind. The hydrogen envelope is a clear area that surrounds the coma and grows as it gets closer to the sun. Comets have been valuable in space exploration because they help us understand the evolution of our solar system as well as the origin of life. They represent relics of early solar system processes, and can give us clues to the chemistry and physical conditions when the solar system was forming.

There are two types of comets: periodic and non-periodic comets. Periodic comets have a period that is less than 200 years. That means that it takes less than 200 years for it to go around the sun. These comets originated from the kuiper belt and orbits around the sun in a regular schedule. Their names usually start with a P, or a number followed by a P. Non-periodic comets on the other hand, have a period greater than 200 years. They originated from the oort cloud and takes thousands of years to orbit around the sun. Their names usually start with a C, followed by a year.

2. The Aging Process

Although most comets have been stored in the cold outer reaches of the solar system since their formation 4.5 billion years ago, there are many processes, which have affected them since that time. Aging of the cometary nuclei refers to the effects since the time of its formation that have chemically or physically altered the nucleus. While stored in the oort cloud, it undergoes many different chemical alterations, including a possible crystalline core. As the comet approaches the sun, the aging process accelerates. The solar energy becomes sufficient to sublimate the amorphous ice and releases the gas trapped inside. The released gas causes the dust grains to flow away from the nucleus and the low gravity drags it into a cloud to form the coma. This process starts near 5-6 AU, but doesn’t drag much dust until 3 AU. When gases inside the nucleus expand under the heat of the sun, they often shoot out through holes or weak spots in the crust of the nucleus. The expanding dust and gas escape as jets, which has the same effect as thrusters in a spacecraft.

Theoretically, we know that the aging process must occur, but we don’t have abundant evidence of the details. In order to understand how representative these samples are of the earliest era of our history, we need to understand its process of aging. This project will look for evidence that comets do develop a thick dusty mantle on the surface. Doing this includes searching for
evidence of uneven sublimation in the form of jets in the dust comae of both periodic and non-periodic comets. This will provide evidence on whether the development of a coma as comets age is correlated with the appearance of jets. Understanding where the most primordial material is can lead to a better understanding of life’s origins.

METHODS

The computer used to analyze the comet pictures is run by the Solaris system. Because of this, learning UNIX was essential to perform the necessary tasks of the project. An online program called Ephemerides was used to make the observing plans for the comet pictures needed. This program provides the exact coordinates of a comet at any given time from a specific location (website: ssd.jpl.nasa.gov). After obtaining the pictures, an image-processing program called IRAF was used to analyze the pictures and look for the presence of jets. Four different techniques were used to analyze the pictures: the shift, smooth, rotate, and unsharp masking techniques. In the shifting technique, the pictures were shifted a certain number of pixels and then subtracted from the original. In the smoothing and unsharp masking techniques, the pictures were smoothed and subtracted from the original. In the rotating technique, the pictures were rotated at their center and subtracted from the original.

EXPERIMENTAL RESULTS

About 14 non-periodic comets and 9 periodic comets were collected and analyzed, which yields a total of about 250 comet pictures. The four IRAF techniques described were used to search for the presence of jets in these pictures. Out of the 23 comets, only comet Hale-Bopp showed obvious features. Figure 3 illustrates the shifting technique used in a comet that did not have features. This comet is called 78P/Gehrels. The picture above is the original picture. After shifting and subtracting it from the original, the picture below is what it would look like. In this case, the picture was shifted vertically. No jets were present in this comet at the time the picture was taken.

Figure 3: Image of 78P/Gehrels using the shifting technique
Figure 4 illustrates the shifting technique used on comet Hale-Bopp, which showed obvious features. The picture above is the original picture of comet Hale-Bopp. After applying the shifting technique, the picture below is what it would look like. Any of the four techniques yields the same result. The lines that appear to be like water ripples are the features on the comet’s surface. That means that this comet has a lot of active zones (jets) on its nucleus. The comet was about 1.4 AU from the sun when the picture was taken, which explains the presence of features. The comet has become very active due to the sublimation of amorphous ice and the abundant expansion of gases in the nucleus, which are released as jets as they shoot out from inside the nucleus.

**Figure 4: Image of comet Hale Bopp showing features after the application of the IRAF techniques**

**ANALYSIS AND DISCUSSION**

The techniques used can be tricky as each comet requires a different number of pixels to be used for a certain technique to work. In other words, if one comet showed features by shifting it 5 pixels vertically, it might not work for the next comet. Therefore, there isn’t a set procedure to use for each comet for analysis. Most of the time, trial and error and the process of elimination are applied to determine what works and what doesn’t.

Out of all the comets collected, only one had features in it. All of these comets are expected more or less to have features because all of them had a distance of 2 AU and below when the picture was taken. That distance should have been sufficient to heat up the comet and produce jets. However, certain factors can be considered to explain why no features were found. The jets could be on the other side of the comet that is not facing our direction. The picture taken could have been the side that is not active yet. In addition, it is possible that the comet produced jets maybe an hour, a day, or a week after the picture has been taken. In other words, just because the picture does not have jets does not imply that the comet does not have features at all. This is why it is very important to try to take pictures as often as possible.

Some things make it difficult for pictures to be taken, one of them, being our dependence on weather. If the weather is bad (i.e. cloudy, rainy), we cannot take pictures. In addition, the use of the telescope is not available all the time. The telescope time has to be reserved in advance. So that makes it difficult, especially when the night reserved for a person turns out to be a cloudy or a rainy night.

The person’s technique could also be a factor on why there are no features present. If the technique is not executed correctly, especially with the big range of possible pixel combinations to choose from, the comet will not show features. But this error would have to be very big for it to be the main cause. To prove that, a pixel combination that is far from the one that works for
Hale-Bopp was used and even then, some features are still present, or if not features, it certainly looks like a clue that something is there. Due to these factors, more pictures should be taken and analyzed.

**CONCLUSION**

Comet pictures were taken and analyzed using the IRAF program. Four different techniques were used to observe the pictures and search for the presence of features in the form of jets. Comet Hale-Bopp showed obvious features using any of the four techniques out of all the 23 different comets (about 250 comet pictures) taken.

Future improvements for this project would be to take more pictures of the same comets, or even new ones to search for jets. Doing so will make it more possible for features to be found due to the dependency of the analysis/results to when the comet will produce active zones.

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