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Bright Comet Project

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Abstract: A comet is an icy, small solar system body which, when passing close to the Sun heats up and spews dust and gases into a giant glowing head larger than most planets a process that is called outgassing They are frozen leftovers from the formation of the solar system and are composed of dust, rock, and ices. The dust and gases form a tail that stretches away from the sun for millions of kilometers. This work focus on mainly to compute the product ion rates of OH, NH, CN, C3 and C2 molecules of IP Halleys comet [1] using a Haser model [2], in addition to the Afρ parameter [3] to track the activity and the dust properties. I used the image of 1P/Halley comet obtained by Jet Propulsion Laboratory as tronomer Eleanor Helin with the 48 inch Schmidt telescope at Caltech's Palomar Observatory on Dec. 13, 1985, in DS9 software for data reduction. I first measured the photometry of the comet's coma, calibration of the images is quite critical. After calib rating, I derived a median radial profile for the image. I then removed the dust contamination in the gas radial profiles by subtracting a properly scaled dust profile. From the OH, NH, CN, C3, and C2 radial profiles I have derived production rates by adjusting a radial coma brightness model. The desired outputs of the different parameters computed using the Lowell Observatory site. I have derived the production rates from params provided input r in AU, Δ in AU, heliocentric velocity, v, in km/s, aperture radius in arcsec, and fluxes I used the Fluorescence efficiencies (also called g-factors) derived from David Schleicher’s website to convert fluxes into co lumn densities. I have used the Haser model to compute the gas production rates (Haser 1957). The desired outputs are mentioned in the report.

المستخلص: المذنب هو جسم جليدي صغير من النظام الشمسي ، عند مروره بالقرب من الشمس ، ترتفع درجة حرارته ويطلق الغبار والغازات في رأس متوهج عملاق أكبر من معظم الكواكب ، وهي عملية تسمى إطلاق الغازات. النظام وتتكون من الغبار والصخور والجليد. يشكل الغبار والغازات ذيلًا يمتد بعيدًا عن الشمس لملايين الكيلومترات. يركز هذا العمل بشكل أساسي على حساب معدلات أيون المنتج لجزيئات OH و NH و CN و C3 و C2 لمذنب [1 IP Halleys] باستخدام نموذج [2 Haser] ، بالإضافة إلى المعلمة [3 Afρ] لتتبع النشاط وخصائص الغبار. لقد استخدمت صورة المذنب 1P / Halley التي حصل عليها مختبر الدفع النفاث مثل Eleanor Helin مع تلسكوب 48 Schmidt بوصة في مرصد Palomar التابع لمعهد كاليفورنيا للتكنولوجيا في 13 ديسمبر 1985 ، في برنامج DS9 لتقليل البيانات. قمت أولاً بقياس قياس الضوء لغيبوبة المذنب ، وكانت معايرة الصور أمر بالغ الأهمية. وبعد تصنيف كاليب ، اشتقت ملف تعريف نصف قطري متوسط للصورة. بعد ذلك ، قمت بإزالة تلوث الغبار في الملامح الشعاعية للغاز عن طريق طرح ملف تعريف غبار تم تحجيمه بشكل صحيح. من الملامح الشعاعية OH و NH و CN و C3 و C2 ، اشتققت معدلات إنتاج عن طريق ضبط نموذج سطوع غيبوبة شعاعي. المخرجات المرغوبة للمعلمات المختلفة المحسوبة

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باستخدام موقع مرصد لويل. لقد اشتققت معدلات الإنتاج من المعلمات المقدمة r في AU ، في AU ، سرعة مركزية الشمس ، v ، بالكيلومتر / ثانية ، حيث أن نصف قطر الفتحة في قوس ثانية ، والتدفقات التي استخدمت في كفاءات الإسفار (تسمى أيضًا عوامل g-) المشتقة من ديفيد شلايشر لتحويل التدفقات إلى كثافات العمود المشترك. كما استخدمت نموذج Haser لحساب معدلات إنتاج الغاز (Haser 1957). تم ذكر المخرجات المطلوبة في التقرير.

1. Introduction

Comets are the most primitive objects in the Solar System. Many scientists think that they have kept a record of the physical and chemical processes that occurred during the early stages of the evolution of our Sun and Solar System. When a comet's orbit, brings it close to the sun, it heats up and spews dust and gases into a giant glowing head larger than most planets. The dust and gases form a tail that stretches away from the sun for millions of kilometres. This thesis focuses on to compute the production rates of OH, NH, CN, C3 and C2 molecules [1] using a Haser model [2], in addition to the Afρ parameter [3] to track the activity and the dust properties.

1.1 Research Problem

Despite the fact that, until the 1980s, the chemical makeup of comets was thought to be largely similar, subsequent discoveries have shown a number of exceptions. Comet P/Giacobini-Zinner, for example, has an abnormally high molecular abundance compared to other comets. Bobrovnikoff noted that this comet had an odd spectra, and he was correct (1927). Beaver et al. (1990) based their conclusions on observations made during this comet's 1985 apparition that both C2 and C3 were deficient relative to CN by a factor of 5 or more when compared to the average comets' abundance. The presence of NH2 is also shown to be under-abundant by a factor of three or more.

The comet Yanaka (1988r) was discovered more recently and its spectra clearly exhibited the NH2 band sequence and [Ol] lines, despite the fact that there were no obvious indications of either C2 or CN in the spectrum (Fink 1992). The comet is depleted in C(2) by at least a factor of 100 and in CN by a factor of 25 relative to typical comets. Another example is P/Wolf-Harrington, which similarly had an abnormally high molecular abundance, despite the fact that, it had no obvious indications of C2, C3, or NH2, but , it did have a CN feature in its spectrum, which indicated that it had an abnormally high molecular abundance (Schleicher et al. 1993).

Comets exhibit a wide range of characteristics, not just in terms of chemical composition, but also in terms of other characteristics. A comet's gas-to-dust ratio exhibits a significant deal of variation. For example, the gas-to-dust ratio of the most gas-rich comets is 100 times greater than the value of the dustiest comets, indicating that the most gas-rich comets contain 100 times more gas than the dustiest comets.

1.2 Objectives of the Study

In this thesis, I aim to present the measured fluxes and column densities and compute production rates of OH, NH and C3 and C2 molecules [1] using the Haser model [2], as well as the Af parameter [3], in order to track the activity and dust features of the advective layer [4]. A bright comet was observed, and its various physical features were investigated in this investigation. It was a collaborative effort. As a result, the first step was to choose a comet, and I went with the most well-known of them all, the 1P/Halley comet. Then I have used the Lowell Observatory website to calculate the gas production rates.

1.3 Hypothesis of the Study

Despite the fact that many comets pass near to the Sun, only a small number of them are properly observed. One of these comets may have an unusual characteristic. The comets 1P/Halley and Hale-Bopp (C/199501), for example, have received a considerable deal of attention, and many thorough observations have been made of them.

2. Study Terminologies

2.1 Comet Description (1P/Halley)

Halley's Comet is the most renowned short-period comet, returns to the inner Solar System every 76 years like clockwork. Halley-type comets (also known as 'intermediate-period comets') have orbital periods of 20 to 200 years with orbits that can be strongly inclined to the ecliptic. They are named after this renowned precursor. Both of these findings point to a different origin for Halley-type comets than the Jupiter-family comets, which have shorter durations and lower inclinations. Jupiter-family comets are assumed to be small fragments of Kuiper Belt Objects that were thrown towards the Sun by Neptune's gravity and then disrupted by Jupiter's gravity. Halley-type comets, on the other hand, are thought to originate much further out in the Solar System, in the spherical Oort Cloud. A passing star or a massive molecular cloud may disturb the frozen bodies that make up the Oort Cloud, sending them on highly elliptical courses through the inner Solar System.

2.2 Name

Comets are usually named for their discoverer(s) or for the name of the observatory/telescope used in the discovery. Since Halley correctly predicted the return of this comet — the first such prediction — it is named for him to honor him. The letter "P" indicates that Halley is a "periodic" comet. Periodic comets have an orbital period of less than 200 years. Halley's Comet or Comet Halley, officially designated 1P/Halley, is a short period comet visible from Earth every 75–76 years. It is the only naked-eye comet that can appear twice in a human's lifetime. 1P/Halley is often called the most famous comet, because it marked the first time astronomers understood comets could be repeat visitors to our night skies. Astronomers have now linked the comet's appearances to observations dating back more than 2,000 years.

2.3 2.Orbit

Its orbit around the sun is highly elliptical, with an orbital eccentricity of 0.967. The perihelion, the point in the comet's orbit is just 0.6 AU , this is between the orbits of

Mercury and Venus. Its aphelion, is 35 AU . Unusual for an object in the Solar System, Halley's orbit is retrograde; it orbits the Sun in the opposite direction to the planets, or clockwise from above the Sun's North Pole. The orbit is inclined by 18° to the ecliptic, with much of it lies south of the ecliptic. (Because it is retrograde, the true inclination is 162°.). Owing to the retrograde orbit, it has one of the highest velocities relative to the earth of any object in the Solar System. The 1910 passage was at a relative velocity of 70.56 km/s (157,838 mph or 254,016 km/h). Each time Halley returns to the inner solar system and its nucleus sprays ice and rock into space. This debris stream results in two weak meteor showers each year the Eta Aquariids in early May, and the Orionids in late October. Halley is the parent body to the Orionids.

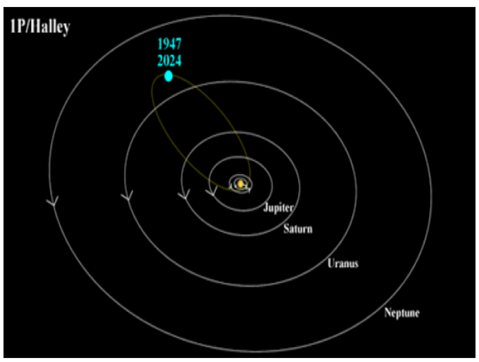

Fig. 1 Comet 1P/Halley is the prototypical Halley-type comet. It has a period of 76.2 years, aphelion of 35.3 AU, and its orbit is inclined at 162.3o to the ecliptic.

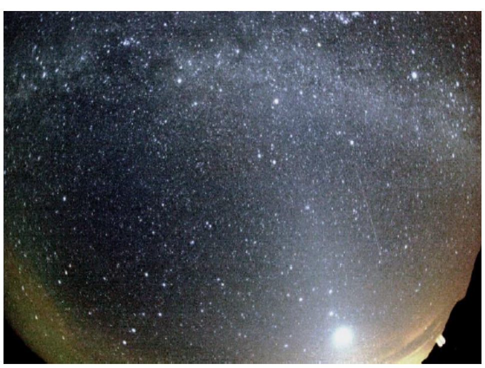

Fig. 2 : Orionid meteor originating from Halley's Comet streaking the sky below the Milky Way and to the right of Venus, By Brocken Inaglory, CC BY-SA 3.0

2.4 Size

Despite the vast size of its coma, Halley's dimensions of its nucleus are about 9.3 by 5 miles (15 kilometers by 8 kilometers). It is one of the darkest, or least reflective, objects in the solar system. It has an albedo of 0.03, which means that it reflects only 3% of the light that falls on it. Its mass is also relatively low (an estimated 2.2 × 1014 kg, or 242.5 billion tons) and its average density is about 0.6 g/cm3, indicating that it is made of a large number of small pieces held loosely together.

2.5 Lifetime

With each orbit around the Sun, a comet is the size of Halley loses an estimated 3 to 10 feet (1 to 3 meters) of material from the surface of its nucleus. Thus, like a comet age, it eventually dims in appearance and may lose all the ices in its nucleus. The tails disappear at that stage, and the comet finally evolves into a dark mass of rocky material or perhaps dissipates into dust.

Fig. 3: Image of 1P/Halley taken by the European spacecraft Giotto.
Image Credit: Halley Multicolor Camera Team, Giotto Project, ESA

2.6 Description

The apparition of Halley's Comet in 1986, which was the comet's most recent appearance, was much anticipated. Using the 200-inch Hale Telescope at Palomar Observatory in California, astronomers captured the first photograph of comet Halley on October 16, 1982, when it was still beyond the orbit of Saturn at 11.0 AU (1.65 billion kilometers [1 billion miles]) from the Sun. It passed at perihelion on February 9, 1986, at a distance of 0.587 AU (88 million kilometers [55 million miles]) from the Sun, and came closest to Earth on April 10, 1986, at a distance of 0.417 AU (62 million km [39 million miles]).

Fig. 4: Halley's Comet crossing the Milky Way Galaxy, as observed from the Kuiper Airborne Observatory on April 8–9, 1986. The disconnection of the narrow bluish ion tail can be seen to the left of the comet's head.Image Credit: Kuiper Airborne Observatory/NASA

There were five interplanetary probes that passed by the comet in March 1986: two Japanese spacecraft (the Sakigake and the Suisei), two Soviet spacecraft (the Vegas 1 and Vegas 2), and a European Space Agency spacecraft (the Giotto), which passed within 596 kilometres (370 miles) of the comet's nucleus. Imagery of the nucleus collected by Giotto revealed a dark potato-shaped object with dimensions of around 15 km (8 miles) in diameter and a radius of approximately 9 km (5 miles).

Fig. 5: Composite image of the nucleus of Comet Halley produced from 68 photographs taken on March 13–14, 1986, by the Halley Multicolor Camera onboard the Giotto spacecraft. Image Credit: Courtesy of H.U. Keller; copyright Max-Planck-Institut für Aeronomie, Lindau, Ger., 1986

It is important to emphasize that prior to the spacecraft encounters with Comet 1P/Halley in 1986, the existence of a nucleus was merely inferred from coarse observations.

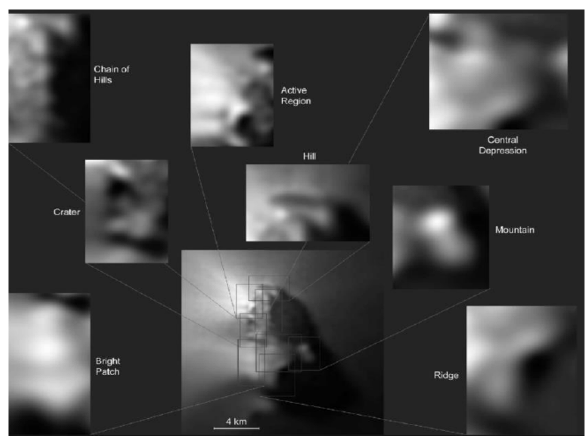

Fig.6: Features on the surface of the nucleus of Comet 1P/Halley. Sections of the composite image (centre bottom) are extracted and expanded by a factor of 3 to show, in detail, notable features on the nucleus. Nonlinear enhancement has been applied to provide improved contrast. From Keller et al. (1988).

While the idea that a single, small, solid body was at the center of a comet's activity (Whipple, 1950) was widely accepted by the scientific community. It was only with the arrival of the Russian Vega 1 and 2 and European Space Agency's Giotto spacecraft at Comet Halley in 1986 that this could be confirmed and other concepts [e.g., the "sandbank" model of Lyttleton (1953)] could finally be rejected. It was to be 15 years before another image of a cometary nucleus would be acquired, when NASA's Deep Space 1 (DS1), a technology development mission, successfully imaged the nucleus of Comet 19P/Borrelly in September 2001. Remarkably, the two nuclei observed by these missions were extremely similar (H.U Keller)

3. Methodology

A periodic comet, 1P/Halley comes to its perihelion (closest distance to the sun) once every 76 years, and it is an once-in-a-lifetime opportunity to see it up close. The passage of the comet 1P/Halley in 1910 was particularly impressive since the comet went by Earth at a distance of around 13.9 million miles (22.4 million kilometres), which is almost one-fifth the distance between Earth and the sun. On that occasion, Halley's Comet was photographed for the first time in its whole history. Halley's Comet goes around the Sun once every 76 years – roughly a human lifetime. Upon its return to the inner solar system in 1986, it was met by a small flotilla of spacecraft, including ESA's Giotto, Japan’s Sakigake and Suisei, and Russia’s twin Vega probes.

Table 1: List of Halley's Comet Explorers

Explorer	Country (Agency)	Launch	Encounter	Closest Distance
VEGA-1	USSR (Intercosmos)	December 15, 1984	March 6, 1986	10,000km
VEGA-2	USSR (Intercosmos)	December 21, 1984	March 9, 1986	8000km
GIOTTO	Europe (ESA)	July 2, 1985	March 14, 1986	500km
SAKIGAKE	Japan (former ISAS)	January 7, 1985	March 11, 1986	7,000,000km
SUISEI	Japan (former ISAS)	August 18, 1985	March 8, 1986	150,000km
ICE	U.S.A. (NASA)	August 12, 1978	(Approached comet Giacobini-Zinner in September 1985)	

3.1 Specification of the Observing Comet

There is a certain peculiarity to comet observation compared to that of other celestial objects. As a one-dimensional object in space, the comet must be monitored as it travels through the sky. To monitor the comet with precision, the orbital characteristics of the comet are therefore extremely critical. Spacecraft observations have shown that the gases ejected from the nucleus were 80% H_2O vapor, 17% carbon monoxide(CO) and (3–4)% carbon dioxide(CO_2), with traces of hydrocarbons (although more-recent sources give a value of 10% for carbon monoxide and also include traces of methane and ammonia). The dust particles found have a mixture of carbon-hydrogen–oxygen-nitrogen (CHON) compounds – which are common in the outer Solar System, and silicates, like those found in terrestrial rocks.

At one time, it was thought that Halley could have delivered water to Earth in the distant past – based on the ratio of deuterium to hydrogen found in the comet's water which is chemically similar to the Earth's oceans. However, subsequent observations have indicated that this is unlikely. A large number of filters are utilized to gather the desired information about a comet. To acquire the different photometry in the different filters, it is necessary to conduct a large number of observations of a single item.
To observe the light from the sun that is reflected by the dust, the filters GC, RC, and BC are utilised, among others. The light released by the fluorescence of the chemical elements that compose the comet is measured using different filters such as C2, CN, and so on. The 1P/Halley comet is a periodic comet that comes to its perihelion (closest distance to the sun) every 76 years, making it a once-in-a-lifetime experience. A large number of observations of the 1P/Halley comet were made in 1986, and a great deal of research has been done on it since then. Different filters like as C2, CN, GC, and RC have been observed to have 1P/Halley (etc.). In this paper, I will use a Haser model to compute the production rates of OH, NH, CN, C3 and C2 molecules, as well as the Af parameter to track the activity and the dust qualities, among other things.

3.2 The Observing Elements Description

Halley's Comet approaches the Sun, and as it gets closer, it emits jets of sublimating gases from its surface, which cause it to deviate very slightly off its orbital course. Due to this process, the comet develops two distinct tails: a bright one formed of ionised gas and a dim one composed of dust grains. In addition to volatiles like as methane, water, ammonia, and carbon dioxide, the ion tail is surrounded by a coma that can reach up to 100,000 kilometers across the sky. With the exception of Comet Encke and Comet Holmes, all of the periodic comets are less active than Halley. Others, such as Comet Encke and Comet Holmes, are one to two orders of magnitude less active. In comparison to the nightside, the dayside (the side that faces the Sun) is much more active.
Halley develops its own environment. Sublimating ices such as water, carbon monoxide, and carbon dioxide ice generate a "atmosphere" that can be as large as 100,000 km across when the comet approaches the Sun, which is astounding considering the nucleus is only around 15 km long, 8 km wide, and 8 km thick. The solar wind blows away much of this atmosphere, leaving a tail that can be as long as 10 million kilometers. Comet construction was first demonstrated by Giotto, who provided the first evidence in support of Fred Whipple's "dirty snowball" hypothesis. Whipple proposed that comets are icy objects warmed by the Sun as they approach the inner Solar System, causing ices on their surfaces to sublimate (change directly from a solid to a gas) and jets of volatile material to burst outward, resulting in the coma. With some minor tweaks, Giotto demonstrated that this model was in general correct. To give an example, Halley's albedo is approximately 4 percent, which means that it reflects only 4 percent of the sunlight that hits it; this is roughly what would be expected for coal. The result is that Halley's Comet seems bright

white to watchers on the Earth, although it is actually completely dark. At higher albedo, the surface temperature of evaporating "dirty ice" varies from 170 K (103 °C) to 220 K (53 °C); Vega 1 discovered that Halley's surface temperature ranged between 300 and 400 K (27–127 °C) when the planet was discovered. This indicated that barely ten percent of Halley's surface was active, and that significant sections of it were blanketed in a coating of dark dust that retained warmth. Together, these results suggested that Halley was primarily formed of non-volatile elements, and so more closely resembled a "snowy dirtball" rather than a "dirty snowball" in appearance.

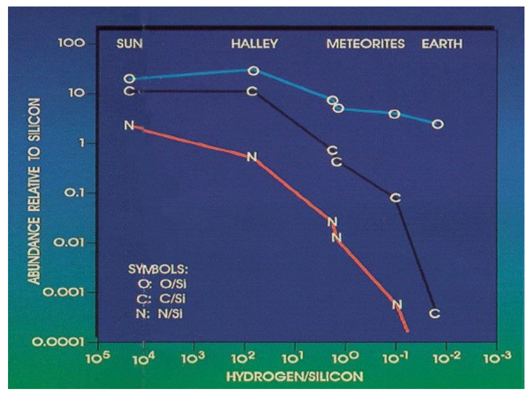

Fig.7: Date: 03 May 1986, Satellite: Giotto,Depicts: Plot of relative abundances for different solar system objects

In the solar system, Halley has the highest velocity in relation to the Earth. Because the comet orbits the Sun in the opposite direction as the planets, it moves faster than any other body in the solar system in relation to the Earth's rotation around the Sun. The comet was measured moving at 70.56 km/sec relative to the Earth during its transit in 1910, translating to a speed of 254,016 km/h (157,838 mph).

Halley is the most remarkable target for a cometary mission among the more than 1000 known comets since; it is the only comet with a well-known orbit and a high gas and dust generation rate similar to that of new comets. A voyage to Halley takes very little launch energy and the comet can also be monitored from the Earth during the flybys. Halley is the most well-known comet due to its predictability and brightness. Halley was chosen as the destination for the first cometary mission for all of these reasons. The ion tail is the result of ultraviolet radiation ejecting electrons off particles. It spans up to 100,000 km across and consists of volatiles such as methane, water, ammonia, and carbon dioxide.

4. Observations and Results

4.1 Data Processing-Measures

4.1.1 Data Reduction

For Data Reduction, I used DS9 software. And I opened image of 1P/Halley comet obtained by Jet Propulsion Laboratory astronomer Eleanor Helin with the 48-inch Schmidt telescope at Caltech's Palomar Observatory on Dec. 13, 1985, in DS9 software I selected the coma region using "region option". After that I get statistic by clicking statistics from the menu.

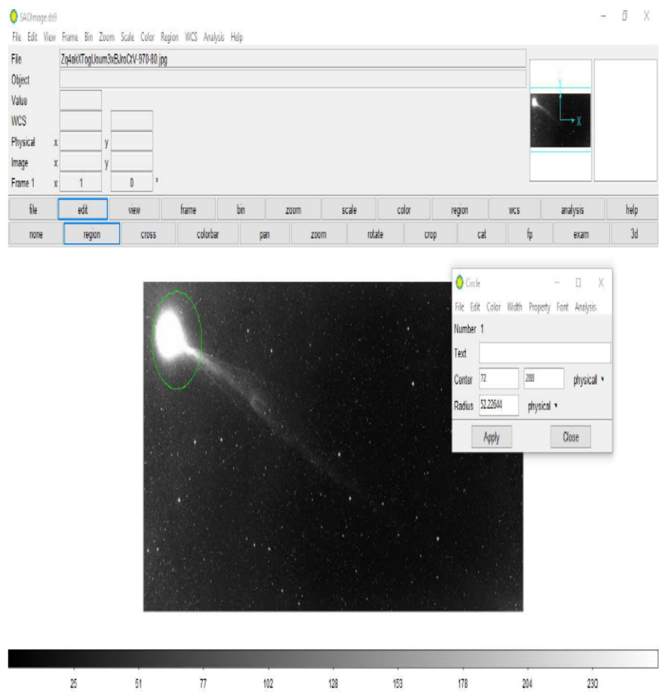

Fig. 8: DS9 Software

Now to use fluxes to find the production rate of different species, first I have converted them to physical unit erg/cm2/s/Å using the equation given below.

$Fc = F0 \text{ x F x } 100.4(K\ X\ am-25+zp)$

With F the measured comet flux (in ADU/s), am the air mass, F0 the flux of a zero-magnitude star (in erg/cm2 s o A), K the extinction coefficient and ZP the zero point of the filter. After changing the unit, I ended up with the following results (in erg/cm2/s/˚A)

4.2 Gases Production Rate

The Haser Model is frequently employed in order to gain an estimate of the rate at which the gas species detected on the comet are produced. Based on some simplifying hypotheses, the Haser model was developed. In the first place, it is believed that the cores of comets have a spherically symmetrical configuration. This results in a uniform distribution of the gas species across the entire spectrum of directions. The model also includes the generation of secondary species (also known as daughter molecules) as a result of the photo dissociation of a parent molecule, which is the final step in the process. In the following step, the secondary molecule is destroyed by light. Photo metrically calibrated spectra of comet 1P/Halley(1986III) were recorded between 1985 September 12-1986 June 10 using the Ohio State University Image Dissector Scanner on the Perkins Inch telescope at the Lowell Observatory. Column densities of CN,C3,CH,C2 and NH2 were calculated from measured fluxes in these spectra, and molecular-scale lengths were deduced from the radial distribution of CN.C3,C2 and NH2. Production rates were computed using the new scale lengths and a Haser model analysis. Continum emission at 4260 angstrom was used to derive gas-to-dust ratios.

Due to the fact that I want to measure very precisely the amount of material ejected by the comet, and in order to do so, I must first measure the photometry of the comet's coma, calibration of the images is quite critical. . After calibrating, I derived a median radial profile for the image. I then removed the dust contamination in the gas radial profiles by subtracting a properly scaled dust profile. From the OH, NH, CN, C3, and C2 radial profiles I have derived production rates by adjusting a radial coma brightness model. Calculating the size of the coma on the photographs is the first step. I predict that the coma will extend up to 10.000 kilometres from the nucleus of the star. To avoid point spread function (PSF) and seeing effects around the optocenter. at larger nucleocentric distances, the signal usually becomes fainter, especially in the OH filter for which the signal to-noise ratio is lower.

I used the Fluorescence efficiencies (also called g-factors) derived from David Schleicher’s website to convert fluxes into column densities. C2 g-factors only consider the C2 in triplet state (A’Hearn et al. 1985) and C3 g-factors are from A’Hearn (1982). CN and NH fluorescence efficiencies vary with both of the heliocentric distance, velocity are respectively taken from Schleicher (2010) and from Meier et al. (1998). For OH g-factors, which also vary with the heliocentric velocity, we considered unquenched values of the ground state (Schleicher & A’Hearn 1988).

I have computed the appropriate fluorescence efficiencies (g-factors) and Haser fractions needed to take a molecular flux measurement for a comet and derive a resulting production rate using five optical/near- UV species as listed below using the David Schleicher’s website five primary molecular species are included along with the respective narrowband filters

- OH — 0-0 band at 3090 Å
- NH — Δv=0 band sequence at 3360 Å
- CN — Δv=0 band sequence at 3870 Å
- C3 — band complex center at 4060 Å but with wings extending from 3300 Å to 4400 Å
- C2 — Δv=0 band sequence at 5140 Å

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       R (AU) =  0.587
   Delta (AU) =  0.42
     V (km/s) =  55.00
 Aper rad (") =  52.2
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Fig. 10: Lowell output. These are the desired outputs of the different parameters computed using the Lowell Observatory site. I have derived the production rates from params provided input r in AU, Δ in AU, heliocentric velocity, v, in km/s, aperture radius in arcsec, and fluxes

By using David Schleicher's website, which provided measured fluxes for the appropriate molecular emission bands, I have derived the production rates from params provided input r in AU, Δ in AU, heliocentric velocity, v, in km/s, aperture radius in arcsec, and fluxes. ρ, log ρ, area (cm2), L/N, M(ρ), log M(ρ), N(&rho), log N(ρ), XP, xd, H-frac, M(tot), log M(tot), Q, log Q.

1- The L/N (g-factors) is calculated by interpolating from look-up tables scaled to 1AU, then scaled by r-2.

2- The number of molecules within the observing aperture: M(ρ) = 2.812E27 * Δ * Δ * Flux / L/N, where the constant term is 4 * pi * AU-to-cm squared unit conversion.

3- Column density within the observing aperture: N(ρ) = M(ρ) / Area of aperture projected to the comet.

4- Haser-fraction (what fraction of the total coma is within the observing aperture): using the table of Haser parent and daughter scale lengths, and parent and daughter r-dependencies. Then using these values, plus r, Δ, and aperture radius in a Haser model calculation.

5- M(total) is calculated by: extrapolating to the total number of molecules in the entire coma by taking M(ρ) and dividing by the Haser fraction.

6- Daughter lifetime: Extracting from the table for 1 AU and scale by r2.

7- Production rate (Q): Dividing the total number of molecules M(total), by daughter lifetimes. This yields the destruction rate which, for static equilibrium, must be equal to the production rate.

4.3 Relative Abundances

The relative abundances of most of the molecular trace species have not yet been accurately determined in the ice components of either comet nuclei or interstellar grains. Of the above trace species only C02, CO, CH4, and H2CO have been directly observed spectroscopically in comets (Feldman 1983; Weaver, Mumma, and Larson 1990; Snyder et al. 1989), although the ions of N2 and C02 have long been observed in ground-based spectra (e.g., Wyckoff 1982). Only CO is known to vary significantly in abundance among comets (Feldman 1983).

In comparison to the solar photosphere, the elemental nitrogen quantity in the ice component of the nucleus is 75 times lower. The total (dust -h gas) elemental nitrogen abundance in comet Halley is decreased by a factor of 6 relative to the Sun for a mass ratio of dust/gas 2. A correction to the nitrogen inventory for undiscovered species (e.g., ammonium salts and polymers) would only lower the nitrogen shortfall in the comet gases by a factor of two at most, and would have no effect on the total nitrogen inventory in the comet (gas + dust). The fact that most of the nitrogen-bearing chemicals in comet Halley are found in the dust component suggests that the volatile and refractory solids in the nucleus had separate evolutionary histories and did not form as a result of a straightforward condensation event in the solar nebula.

If N2 was the most abundant nitrogen-containing species in the early protosolar cloud, nitrogen depletion in the comet's gas coma relative to the Sun can most likely be explained by physical fractionation of N2 during the condensation process, as proposed by Geiss, or by subsequent preferential diffusion of molecular nitrogen from the cometary ices, or both. If, on the other hand, comet Halley's low nitrogen abundance reflects the real nitrogen content of gas and dust in the comet-forming region, the

nucleus must be made up of material with a different nucleosynthesis history than the rest of the solar system. The lack of elemental nitrogen in the comet ices suggests that chemical partitioning of N2 into NH3 and other nitrogen compounds during the genesis of the solar nebula cannot fully explain the comet's low abundance ratio, N2/NH3 0.1.
Furthermore, the low and consistent ammonia/water abundance ratios seen in a limited sample of comets suggest that comet nuclei were not subjected to large episodic accretion of NH3-rich material from big planet sub-nebulae. They propose that the comet Halley's low N2/NH3 ratio could be explained simply by physical fractionation, thermal diffusion, or both.

Table 2: Relative abundances of different species

Gases	Values
Q(OH)/Q(OH)	1
Q(NH)/Q(OH)	9.38 x 10^-3
Q(CN)/Q(OH)	2.05 x 10^-3

4.4 Afrho Parameter

When the albedo "A" (grain reflectivity) is multiplied by the filling factor "f" and multiplied by the letter "rho," the result is the radius of the coma (often measured in kilometres) under examination. Specifically, the filling factor "f" is a parameter that is related to the optical density of the coma, and it is defined as the amount by which the total cross section of grains fills the field of view. It is defined as the relationship between the total area of dust filled in the considered field of view and the total area of the field of view. It is the ratio between the total area filled by dust in the considered field of view and the area of the field of view itself. The "Afp" product value (the difference in power between the albedo and the filling factor) reaches its greatest close to the nucleus and then gradually decreases toward the outside margins if the dust reflectivity remains constant.
The *Afρ* parameter of A'Hearn et al (1984) is based on the observations of the idealized cometary dust comae. It is proportional to the observed flux density within a circular aperture. The quantity is the product of dust albedo, dust filling factor, and the radius of

the aperture at the distance of the comet. It carries the units of ρ (length), and under certain assumptions is proportional to the dust production rate of the comet:
The afrho quantity is related to the total cross section of the grains and is a useful way to investigate the dust production rate. The Afrho parameter can be calculated with the following formula:
$Af p$ = $(2\Delta r)2p\ FcFsun$
The $\varepsilon f\rho$ parameter is the thermal emission counterpart to $Af\rho$, replacing albedo with IR emissivity, ε, and the solar spectrum with the Planck function, B: εfρ=Fc(Δ)^2/πρB(Tc), where Tc is the spectral temperature of the continuum (Kelley et al. 2013).
With Δ the geocentric distance (in cm) and r the heliocentric distance (in Au). It is calculated by doing the product of A, the albedo, f (the filling factor) and rho (the radius of the coma, in km) as showed in the figure given below. Fc is the dust flux measured in erg/cm2 sA˚ and $FSun$ is the solar flux at 1 Au in the filter used for the observation (also in erg/cm2 sA˚ and $FSun$). A schematic representation of the afrho parameter is observable on the figure given below.

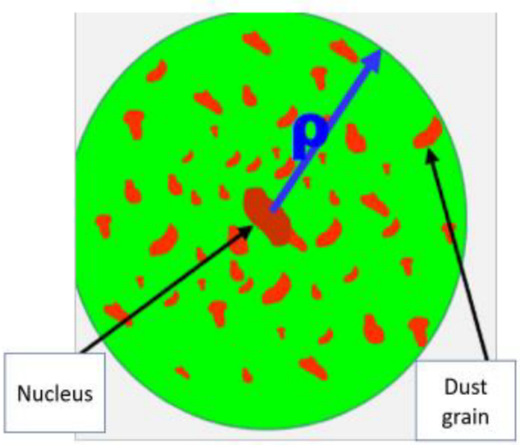

Fig. 11: Afp parameter

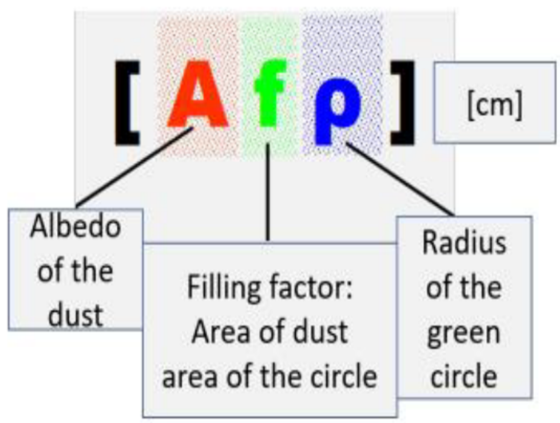

Fig. 12: Schematic representation of the Afp parameter

The afrho parameter can be related directly to the dust production rate at the nucleus. The calculated Afrho parameter of 1P/Halley comet is in the table given below.

Table 3: Afrho parameter

Filters	Afrho (cm)
C2	1050
C3	5353
CN	1257
NH	1375
OH	6856

4.5 Coma Morphology

The nucleus of Halley's Comet is quite small in comparison to the rest of the comet: It is just 15 kilometers long, 8 kilometers wide, and possibly 8 kilometers thick. Its shape is similar to that of a peanut shell, to some extent. A rubble pile is a structure made up of many small pieces that are held together very loosely, resulting in a mass that is relatively low (approximately 2.2 x 1014 kg) and an average density of about 0.6 g/cm3, indicating that it is composed of a large number of small pieces that are held together very loosely to form a structure known as a rubble pile.

Fig. 13: Comet Halley as seen in March 1986. NASA International Halley Watch, by Bill Liller.

Halley's rotation period was estimated to be approximately 7.4 days based on the ground-based studies of coma brightness. In accordance with images taken by the numerous spacecraft, as well as observations of the jets and shell, a time period of 52 hours was suggested. It is conceivable that Halley's rotation will be complicated because of the uneven form of the nucleus. Despite the fact that only 25 percent of Halley's surface was imaged in detail during the flyby missions, the images revealed a topography that was extremely varied, with hills, mountains, ridges, depressions, and at least one crater. Halley's surface was imaged in detail because of the limited time available during the flyby missions.

4.5.1 Gas Features and CHON Particles

Understanding the physics behind the gas features is helpful, but the gas can also be utilised to confine morphological research without it. The gas can be employed in the same way as dust jets, regardless of how they are made, and they have their own advantages in the analysis. Because the structures in the gas flow emerge at greater distances from the nucleus due to the higher velocities, gas features often have more detail than dust features, especially in low resolution situations. This makes them more measurable as well as easier to analyse and model.

4.5.2 Magnetic Field Observations in Comet Halley's Coma

The Giotto spacecraft collided with comet Halley in March 1986, coming within 600 kilometres of its nucleus. The inner coma contains a mixture of cometary neutral gas and dust, thermal ions and electrons, fast cometary pick-up ions, decelerated solar-wind ions and electrons, as well as fast neutrals1 produced by charge exchange between pick-up ions and cold neutrals, according to the results of this encounter. In his work, (P.Chaizy et al 1991) reported the discovery of a new component of comet Halley's inner coma: Negatively charged cometary ions. At a distance of 2,300 km from the nucleus, these ions are seen in three broad mass peaks at 7–19, 22–65, and 85–110 AMU, with densities reaching 1, 5, and 4x10-2cm-3, respectively.

O-, OH-, C-, CH-, CN-, and heavier complex CHO molecular ions are among the ion species expected to be present. Because solar radiation easily destroys negative ions at 1 AU (ref. 2), an effective manufacturing mechanism, as yet unknown, is required to account for the observed concentrations. Negative ions were detected in the coma about 1 AU, implying that negative ions might be found in similar neutral gas and dust environments farther away from the Sun (for example, in Jupiter's or Saturn's magnetospheres3). If negative-ion densities are great enough, it is projected that they will play a key role in physical processes such as radiative transmission and charge exchange.

4.5.3 Dust in comet P/Halley from VEGA Observations

The SP-2 dust particle detector, which consists of a series of acoustic and impact plasma sensors, was used on the Vega mission to make direct measurements of the dust particle spatial and mass distributions in comet Halley over the mass range 10-16 - 10-6g. The position and properties of the dust coma's limits, as well as a significantly noticeable angular directivity of dust emission from the cometary nucleus, were revealed by these data. It was discovered that there was an unusually high concentration of small dust particles with masses below 10-14g, as well as large regular fluctuations in the shape of the particle mass distribution as a function of distance from the cometary nucleus. The nucleus's average dust generation rate has been estimated at (10 - 13)106g s-1 (Vega 1) and (5 - 7)106g s-1 (Vega 2). (Vega 2).(by E.P. Mazets et al 1987).

4.5.4 Ion flow at commet Halley

The interaction between protons and – the particles in the solar wind and positive ions from comet Halley was studied using the Giotto spacecraft's three-dimensional positive ion analyser. Although the overall shape gives the impression that the plasma flow evolves smoothly as the nucleus approaches, on both the inbound and outgoing legs of the trajectory, three rapid changes of very minor amplitude can be seen. At 106 kilometres from the core, the outermost one looks to represent a repeated crossing of a weak bow shock. At 80,000 kilometres, the innermost one is when the flowing plasma becomes depleted. The turbulence caused by the interaction between the two ion populations reaches a distance of several million kilometres from the nucleus on a microscopic scale. The plasma created around Giotto by dust and gas hits was far more energetic than expected at its closest approach to the nucleus.(Johnstone et al. 1986).

4.5.5 Information From in-Situ Measurements

Although there are a few particles near the end-point compositions, practically all silicates contain a CHON component, and all CHON particles have minor peaks of magnesium, silicon, and iron. There is a range of compositions available (Lawler and Brownlee, 1992). It is obvious that the average Halley dust composition is similar to that of chondritic elemental composition (with the exception of increased carbon and nitrogen), and that carbonaceous and silicate materials are typically combined at the submicron level.

Table 4: Relative atomic abundances in gas and dust at comet Halley

	Geiss (1988)	*Grün and Jessberger (1990)*	*Solar system*
H/Mg	39	31	25,200
C/Mg	12	11.3	11.3
N/Mg	0.4–0.8	0.7	2.3
O/Mg	22.3	15	18.5
N/C	0.03–0.06	0.06	0.2
O/C	1.8	1.3	1.6

Carbon and nitrogen have substantial abundances, indicating that these elements are extensively transported in dust at comet Halley. When dust and gas are combined, the overall composition is remarkably solar in terms of condensable components.

Halley dust's mineralogical makeup is a bit confusing (Schulze and Kissel, 1992). The ratios of iron, magnesium and silicon in the highest-quality mass spectra indicate a wide range of values that do not appear to be influenced by mineralogical compositions (Figure 15). There are no obvious correlation lines connected with major silicates. Mg/Si ratios fluctuate over two orders of magnitude, while Fe/Si ratios fluctuate over nearly four orders of magnitude. In comparison, studies of identical microvolumes of the Orgueil CI chondrite (Lawler et al., 1989) reveal tightly controlled Mg/Si ratios and limited Fe/Si ratios.

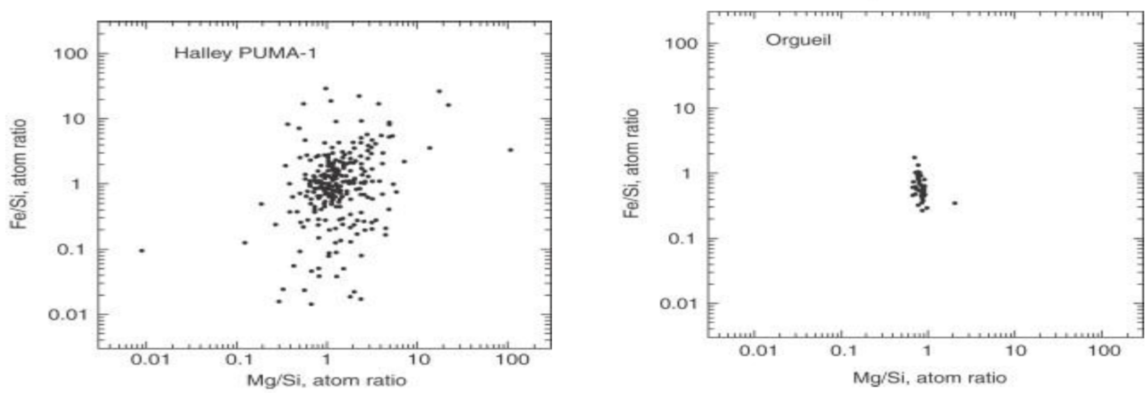

Fig. 14: Fe/Si and Mg/Si ratios for micron-sized particles from comet Halley compared with analysis of similar sized volumes of the Orgueil CI chondrite. The vast scatter in the Halley data does not show evidence for mineralogical control of compositions. The tight highly constrained range of Mg/Si in Orgueil is common for phyllosilicate dominated chondrites. Source: Lawler et al. (1989).

5. Conclusion and Recommendation

The flux estimates of different gas species produced by the comet 1P/Halley that I measured appear to be in agreement with the literature. I observed a difference in the pace of formation of different gas species, which I believe is due to the size of the molecules of the different gas species' relative gas species' molecules. The 1P/Halley comet appears to have a higher rate of OH and NH generation than other gas species, according to observations. This work has provided me with a deeper understanding of comets, the significance of multispectral observations, and how one may remotely examine the structure of comets using only images taken from the Earth's surface.

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