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PERIHELION APPROACH OF COMET 67P/CG CARRYING PHILAE

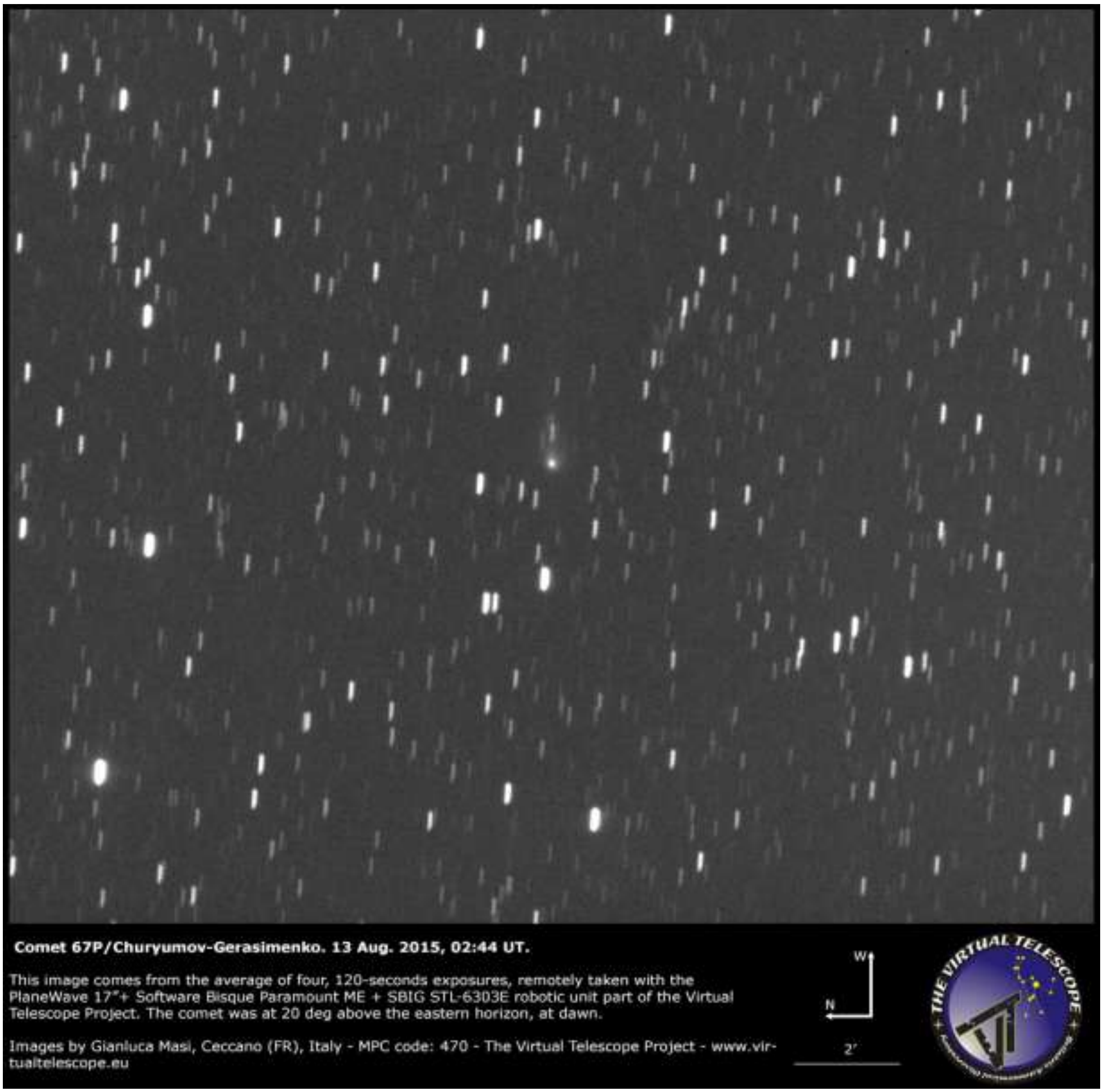

Image Description: Post-perihelion image of comet 67P/C-G taken by PACA member and Director of The Virtual Telescope, Dr. Gianluca Masi on 13th August 2015, at 02:44:13 UT.

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Letters

Proposal

Claudia J. Alexander (1959 - 2015)

Dr. Padma A. Yanamandra-Fisher, *Space Science Institute, Boulder, Colorado, USA.*
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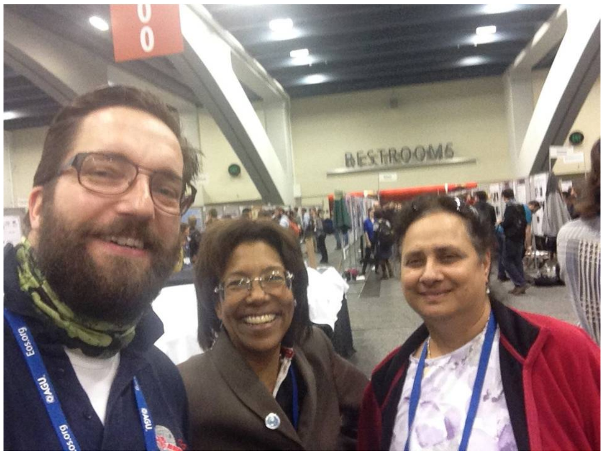
Comet 67P/Churyumov-Gerasimenko (CG), the final target of ESA mission Rosetta, was also the pinnacle of Dr. Claudia Alexanders extraordinary professional achievements. She lost her battle with breast cancer on 11 July 2015 and left behind a wonderful and multifaceted legacy from students to scientists. Although journalism was first choice for study, Claudia chose science as a compromise with her parents to attend school in California. With impressive credentials such as undergraduate degree from University of California, Berkeley; masters from University of California, Los Angeles (UCLA), Ph.D. from University of Michigan, Claudia was employed at NASA/Jet Propulsion Laboratory (JPL), as an engineer for NASA/Galileo mission to Jupiter. As she rose in her career at JPL, Claudia served as the last Project Scientist for Galileo mission, as the spacecraft was allowed to crash into the planet, Jupiter; served on NASA/ESA/Cassini mission to Saturn; and finally the US NASA Project Scientist for ESA/Rosetta mission to comet 67P/CG via several asteroid fly-bys. Claudia was always seeking to improve various procedures to enhance performance of the mission. Claudia was interested in the application and use of both social media and amateur astronomers in support of ESA/Rosetta mission to comet 67P/CG and instrumental for my role as US Rosetta Collaborator for Global Amateur Observations of Comet 67P since 2014. Thanks to her support and confidence (and supported by ESA/Rosetta Project Scientist, Dr. Matt Taylor), a global community of amateur observers was created on several social media, including Facebook, Flickr, Twitter, etc., with a joint JPL call for participation. At last count, nearly 250 amateur observers have signed up to participate in the 67P observing campaign!

On a personal level, Claudia was a remarkable, multi-faceted person; determined to achieve success, as a black woman in a field where there were few and a strong advocate for many important causes: from STEM-related causes to the inclusion of indigenous peoples (such as Native American and Hawaiian) to help broaden their languages to include astronomy in a balance with their cultural heritage. Claudia was a great writer, with several successful childrens books, with the latest book released recently. Claudia also was a strong advocate to ensure, as Project Scientist, there were proper and adequate resources for the US Teams for ESA/Rosetta mission to allow the US Teams to provide the required work products for the ESA/Rosetta mission. She had a vision of how to integrate and enhance the various components of such a large and ambitious mission and empower people to produce their best.



ESA/Rosetta Project Scientist, Matt Taylor (left), US Project Scientist for Rosetta, Claudia Alexander (center) and the authour, Padma A. Yanamandra-Fisher (right) at the 2014 American Geophysical Union (AGU) meeting in San Francisco, CA, USA.

Besides science, Claudia enjoyed life with her devotion to her family she was unmarried, but her family of parents, siblings, nieces and nephews was her solid foundation. With interests from dancing, writing, horse riding, tennis (she enjoyed watching Roger Federer) and journalism, Claudia had multi-circles of friends in all these fields. She impacted and left a legacy of knowledge, role models, and various activities to promote STEM-literacy amongst young girls.

Claudia Alexander was a true trailblazer for many generations to come. I hope she is watching from the heavens as comet 67P/CG goes through perihelion on 13 August 2015, with ESA/Rosetta spacecraft in orbit around the comet.

On the Difficulty of Finding New and Complex Molecules in Comets

Dr. Michael J. Mumma, *NASA Gaddard Space Flight Center,USA (Michael.J.Mumma_at_nasa.gov)*

Almost from the moment in 1970 when I first was exposed to discussions on the chemistry of comets, talk turned to methods for detecting the expected parent volatiles that could explain the observed free radical species seen in cometary comae (OH, CN, C_2, C_3, CO^+, etc.), and to the possible astrochemical implications of the native ices in cometary nuclei from which they derived. During the decadal 70s, I was strongly influenced by extended and continuing discussions with Armand Delsemme, Bertram Donn, William M. Jackson, and Fred Whipple during our attempts to define and achieve in situ exploration of comets, and through laboratory investigations to understand the molecular processes that might control their properties.

Fred Whipple envisioned the cometary nucleus as an icy conglomerate composed of refractory (meteoritic) dust and native (primary) ices, whose sublimation upon warming created the visible coma and tails so familiar to ground-based observers (Whipple 1950). In so doing, he adopted and extended Pol Swings suggestion that the nucleus of comet Encke contained polyatomic molecular ices, whose release and dissociation produced the free radical species observed at optical wavelengths (Swings 1948a, 1948b). Whipple and Swings suggested that the polyatomic molecules stored in the nucleus were of interstellar origin, and thus of primary importance for understanding planetary origins. Whipple further proposed that water ice was dominant, with ices of methane, ammonia, and other species present in smaller amounts.

Whipples proposal triggered a decades-long effort to detect the proposed primary (parent) volatiles through astrophysical spectroscopy that in 1985 produced the first definite detections of primary volatiles in a cometary coma: hydrogen cyanide and water vapor were detected in comet 1P/Halley using ground-based radio and airborne infrared observatories (HCN: Despois et al. 1986, Schloerb et al. 1986; H_2O: Mumma et al. 1986, Weaver et al. 1986). In 1986, in situ spacecraft measurements confirmed these discoveries, added ten more species to the suite of known primary volatiles, and acquired images of a cometary nucleus for the first time (Praderie Grewing 1987, Eberhardt 1999). The combined results decisively confirmed the Whipple-Swings model of the icy conglomerate nucleus.

Today, we recognize that the composition of cometary ices can sometimes reflect changes induced by thermal and radiation processing, so their identities and abundances can provide central clues to those aspects of planetary heritage. Yet, extending the ground-based detections of cometary H_2O and HCN to more complex species has proven difficult and was/is strongly dependent on advances in both theoretical and observational capabilities. I will use my own experience as an example, keeping in mind that my experiences are certainly not unique in struggling to achieve new ends.

My initial foray was an attempt to detect infrared emission from NH_3 (2, 10 microns band) in comet C/1973x Kohoutek, using a laser heterodyne spectrometer that utilized a then-developmental lead-salt laser as a local oscillator. Working day and night for 3 months, my team built the spectrometer, mated it to a telescope, and acquired astronomical data but the comet fizzled and ammonia could not be detected (Mumma et al. 1975). We next decided to use CO_2 lasers as local oscillators, building our own since commercial devices were not well suited to astrophysical needs. After perfecting the spectrometer, in 1976 we emplaced it at the McMath Telescope at Kitt Peak National Observatory, and then in 1981 moved it to the NASA IRTF on Mauna Kea. During this period, we studied CO_2 non-thermal emission on Mars and Venus, trace gases in Earths atmosphere, and NH_3 in stellar atmospheres and in Jupiter.

We searched for NH_3 whenever a suitable target comet appeared, but repeated failures showed that our approach was fundamentally flawed. Our stellar work revealed that the gases there were rotationally relaxed but vibrationally hot, owing to the collisionally impoverished low-density atmosphere. The eureka moment came when I realized that the cometary atmosphere was both very cold and collisionally impoverished, suggesting that radiative decay from solar-pumped excited states would compete favorably against collisional quenching, thereby permitting intense ro-vibrational emission lines characterized by low rotational temperatures. The optimum wavelength domain for detections would also depend on the specifics of the process and the molecule in question. I immediately embarked on intense consideration of the physics involved, and presented first thoughts at a conference in 1981 (Mumma 1982). Hal Weaver joined me as a post-doctoral fellow that year, and our greatly expanded version of this idea was submitted for publication on 8 March and accepted on 28 June 1983 (Weaver and Mumma 1984). Our models assumed fluorescence equilibrium. Unknown to us, Crovisier and Encrenaz were developing the idea in parallel, but they emphasized LTE rotational populations at 300K so then-available molecular databases could be used for simulations; their paper was submitted on 12 March and accepted on 26 April 1983 (Crovisier and Encrenaz 1983). These two papers form the basis for the now-widely accepted observational approach of solar-pumped infrared fluorescence, for detection of primary volatiles in comets. Many subsequent papers established the methodology for vibrational band systems of molecules having up to 8 atoms (C_2H_6).

This work demonstrated that the prime wavelength region for ground-based detections was in the near infrared (3-5 micron), not the mid-infrared as first conceived. It further showed that high spectral resolution was needed, and that a Doppler shift (to avoid extinction) was needed for volatiles that had terrestrial counterparts. Moreover, only low rotational temperatures were expected. Together, these constraints drove the initial search strategies, leading to detection of water (the 2.7 micron fundamental band, 3) in comet 1P/Halley using the University of Arizonas infrared Fourier Transform Spectrometer (FTS) on NASA's Kuiper Airborne Observatory, on 22 and 24 December 1985. Water detections followed in comets C/1987 P1 (Wilson) (in 1987) and 23P/Brorsen-Metcalf (in 1989), but a new approach was mandated by sensitivity needs. The team attempted detections of methane in comets Halley and Wilson, without success, and the large optical bandwidth of the FTS presented large stochastic noise to the detection system. However, the airborne detections of water vapor in three comets confirmed the theoretical predictions of solar-pumped infrared fluorescence from primary volatiles, and the importance of high resolution spectroscopy for detecting them.

Even before 1986, it was clear that grating spectroscopy with array detectors offered a possible solution to the sensitivity question. In 1987, these instruments were barely emerging, and the first was commissioned at the NASA IRTF on Mauna Kea, Hawaii. CGAS featured a simple 32 element linear array behind a cryogenic grating that narrowed the optical bandwidth per pixel, thereby reducing shot noise from the optical background dramatically. The first proposed use for cometary detections was proposed independently by two teams that then merged for a Target-of-Opportunity campaign on C/1987 P1 (Bradfield) (Brooke et al. 1990). By 1989, 2-D array-based (58x62 and 128x128) cryogenic grating spectrometers were available at KPNO and UKIRT, and my Team extended the CGAS findings to other comets with these more powerful instruments. We also teamed with John Lacys team to search for OCS and CO near 4.7 and 5.0 m in comets C/1990 Levy (DiSanti et al. 1992).

After 1992, ground-based capabilities expanded rapidly. CSHELL at IRTF enabled a major breakthrough by coupling high resolving power with a 256x256 array detector. With CSHELL, my team detected an emission line of H_2O near 2 micron in C/1991 T2 (Shoemaker-Levy). CSHELLs upgrade to an InSb detector array in 1995 permitted detection of H_2O in comet 6P/dArrest (Mumma et al. 1995). These detections of H_2O emission in two comets were the first definite detections of cometary water from ground-based observatories.

The planned de-commissioning of the KAO in 1995 emphasized the critical need to develop a new method for detecting cometary water from ground-based observatories. The problem can be stated succinctly: how can we make Earths atmospheric water disappear, so as not to absorb the water lines emitted by an extraterrestrial source. The successful strategy seems obvious once explained and so it is but it was not so obvious before the strategy was conceived, and then demonstrated!

The breakthrough was dependent on recognizing that fluorescent emission from solar-pumped excited quantum states could penetrate to the ground if the transition terminated on an excited rovibrational level that was not populated at atmospheric temperatures. It was rooted in the discovery of hot-band emission in 1P/Halley that was identified in spectra acquired on the KAO; 3 unidentified emission lines were seen in March 1986. I had brought a copy of the H_2O spectral atlas of Flaud Camy-Peyret to New Zealand for the March flights, and searched the atlas for these lines. Comparison of the new lines revealed that they belonged to the 3 011-010 hot band that emitted in the 2.7 micron region. Several years later when considering ways to make terrestrial water vapor disappear, I realized that fluorescent transitions that terminated on more highly excited states would be transmitted to the ground, permitting detection of H2O from ground-based observatories.

In 1990, Michael DiSanti (then my postdoctoral associate) and I considered possible band systems and identified the 111-100 hot-band near 2.0 micron as a favorable candidate. In 1992, we targeted its detection in C/1991 A1 (Shoemaker-Levy) with CSHELL/IRTF and in 1995 targeted it in 6P/d'Arrest - detecting water in these two comets confirmed the strategy. In 1996, we targeted water in newly discovered C/1996 B2 Hyakutake, detecting many lines of this band and using the resulting water production rate as the comparator for trace gases CO, CH_4, HCN and C_2H_6 detected in this comet (Mumma et al. 1996; Dello Russo et al 2002). Since then this approach has been extended to more than 10 water hot bands that span the 1-5 m region, providing a means to quantify the dominant volatile in comets simultaneously with individual trace species. CSHELL also cleared the path for detections of many primary volatiles in comets Hyakutake and C/1995 O1 (Hale-Bopp) at 3-5 micron (L- and M-bands). In 1999, we extended the strategy to prompt emission of highly excited OH produced by water photolysis (an outgrowth of my Ph.D. dissertation on dissociative excitation of small molecules) and later comets providing a second approach for direct measurements of water in comets.

CSHELL reigned supreme until 1999, when NIRSPEC at Keck-2 was commissioned - the first cryogenic cross-dispersed high resolution grating spectrometer at a high altitude site. During the commissioning run, 7 primary volatiles and OH* (prompt emission) were detected in C/1999 H1 (Lee) (Mumma et al. 2001). Up to 12 primary volatiles have been detected in a given comet with NIRSPEC, and all simultaneously with water. Subsequent instrumental advances included higher resolving power (80,000) and the use of four 1K x 1K InSb arrays (CRIRES/VLT) (but single spectral order) and the imminent commissioning of iSHELL/IRTF, equipped with a Hawaii-2RG HgCdTe 2K x 2K detector array, cross-dispersion, and ultra high spectral resolution (approx 80,000). An upgrade for CRIRES is now in progress that will provide similar capability for VLT, with cross-dispersion and with three 2K x 2K Hawaii-2RG detector arrays. These facilities will provide higher sensitivity, greater spectral grasp, and improved specificity (higher spectral resolving power), and will enable detections of new and more complex volatile species, along woth isotopologues of the more abundant species.

The ever higher spectral resolving power (now approaching resolution of 3 km/s) required similar expansion of laboratory data on molecular band systems, along with advanced quantum mechanical band models hundreds of papers have reported these new findings and their application to fluorescence models for comets and other astrophysical sources.

Today, many primary volatile are measured routinely in a moderately active comet (cf. Mumma and Charnley 2011). Improvements in sensitivity now permit measurement of primary volatiles at abundances as small as 100 ppm (relative to H_2O). To date, more than 20 comets have been characterized in this way, and we now can build an emerging taxonomy based on cosmogonic parameters such as composition, isotopic fractionation, and nuclear spin temperatures of primary volatiles, along with dust signatures such as crystallinity and mineralogy. The number of detected species has advanced as the observational capabilities expanded (Figure 1), and is even now undergoing a revolution with the emergence of IRAM-EMIR and ALMA at radio wavelengths, and of next-generation powerful high resolution cryogenic spectrometers at infrared wavelengths (iSHELL/IRTF and CRIRES+/VLT). This trend will expand with the commissioning of iSHELL/IRTF, CRIRES+/VLT, and the near IR high resolution and massively parallel spectrometers at 30-m class telescopes (E-ELT, TMT, GMT).

While local processing can affect the abundance ratio of bulk species in comets, the abundance ratios of isotopologues are more robust because few mechanisms exist to modify one isotopologue more efficiently than another within the nucleus. For this reason, D/H in water and HCN, 14N/15N in nitriles (CN and HCN), and 12C/13C in organics (CN and C_2) have assumed high importance. Compared

with terrestrial values, cometary values for 12C/13C are consistent in CN and C_2, but 14N/15N is much lower in CN (15N is enriched), and D/H varies strongly in water and hydrogen cyanide. Most comets show water more enriched in deuterium compared with Earths oceans, but the enrichment in 103P/Hartley 2 was exactly consistent with that in ocean water (VSMOW), showing that comets of this type could have contributed water to Earth.

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However, care must be taken when interpreting such limited measurements, especially when the context is unknown. For example, ROSINA reported the D/H ratio in coma water to be enriched to 3 VSMOW while 67P/Churyumov-Gerasimenko was still far from the Sun (3.7 AU), where water is not yet fully activated (Altwegg et al. 2015). The surface layer was likely enriched in HDO by fractionation of water emplaced during the last retreat from perihelion (the vapor pressure of HDO is lower than that of H_2O), and so an enriched value should be seen as the comet becomes active again on its next return to perihelion. The test will come when water is fully activated and both isotopologues are subliming fully, perhaps during the near-perihelion passage. The emerging compositional and isotopic taxonomies are crucial for extrapolating in-depth analytical information obtained from the few comets sampled directly, such as 67P, to the many that are sampled only remotely.

The composition and structure of cometary nuclei hold vital clues to understanding the formation and evolution of matter in the early Solar System (Mumma, Weissman Stern 1993; Irvine et al. 2000; Bockele-Morvan et al. 2004; Mumma and Charnley 2011). Relating the sampled comets to the diverse populations of icy planetesimals is a critical step when testing models of the evolution of material from the natal interstellar cloud core through entry into the protoplanetary disk, possible processing in the disk, formation of the nal icy bodies, and injection into their cosmic reservoirs. With the aid of dynamical models, the emerging taxonomies will also help to assess the signicance of each cometary class for exogenous delivery of organics and water to terrestrial planets.

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Rosetta: Perihelion approach and Beyond

Dr. Matt Taylor, *Scientific Support Office, Rosetta Mission (mtaylor_at_cosmos.esa.int)*

A lot has happened in the world of Rosetta in the last months. We have been orbiting the Sun along side Comet Churyumov Gerasimenko for a year and on 13th August we will reach perihelion.

In the last year we have become more and more familiar with out target, a dual lobed comet, which we affectionately refer to as duck-shaped. This frozen body of dust and ices is around 4 km across and its outer atmosphere or coma currently stretches well over 100, 000 km into a tail, based on estimations from ground based observations. Ground based observations are very important to Rosetta, and on top of professional observations, we have a very active amateur connection, coordinated by Padma A. Yanamandra-Fisher a Senior Research Scientist at the Space Science Institute, USA.

On 11 July Rosetta lost a dear colleague, Dr Claudia Alexander, the US project scientist who passed away suddenly. Claudia worked for NASA at JPL. She was an eminent planetary scientist and was deeply involved with the Rosetta Mission as US Rosetta project scientist. She was passionate about outreach, including engaging amateur astronomers through the ground-based observing campaign of Rosettas target comet, 67P/ChuryumovGerasimenko. Claudia was also very well known for her role in NASAs Galileo and Cassini projects. She will be greatly missed. Last month you heard from Alan Stern and New Horizons. We have some connection there, as Alan is Rosetta colleague also as PI of the Alice instrument. In fact, we actually pointed Rosetta at Pluto when New Horizons was doing its fly by!

In July, we released the first results of Philae, from the surface of the comet. The results indicated the surface of the comet to by covered by a thin dust layer with a very hard subsurface. We detected a number of organics molecules, some of which are key in playing a role in pre-biotic synthesis of amino acids, sugars and nuclebases: the ingredients of life. It is important to stress that we do not see life itself though. Only the building blocks. The existence of such complex molecules in a comet, a relic of the early Solar System, imply that chemical processes at work during that time could have played a key role in fostering the formation of prebiotic material. We found little evidence of an intrinsic magnetic field indicating that magnetic field would have had little role to play in the aggregation processes as the comet was formed. We are beginning to see significant activity at the comet, so Perihelion is going to be an exciting time., as one can see from recent images.

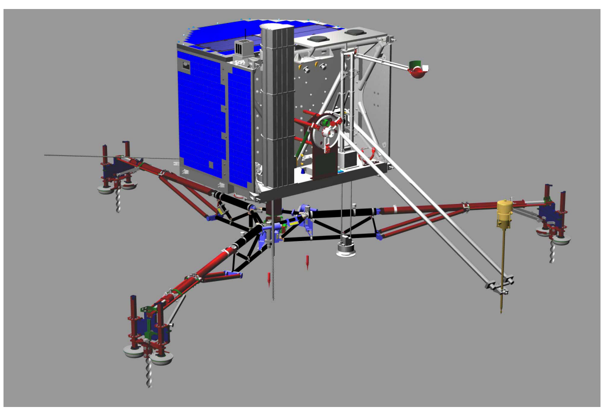
Following this month, the mission will continue through to September 2016, where we will de-orbit the Rosetta spacecraft into the comet, landing for a 4th time!

Rosetta Lander Philae: First Data from the surface of a Comet

Dr. Stephan Ulamec, *German Aerospace Center, DLR, 51147 Cologne. (Stephan.Ulamec_at_dlr.de)*

November 12th, 2014, when Philae landed on comet 67P/Churyumov-Gerasimenko, this was the first time in history, when in-situ investigation of a cometary nucleus became possible.

Comets are believed to be 'left overs' from the time of the formation of the solar system, about 4,6 billion years ago. In addition they are believed to contain organic material, possibly triggering the formation of life on Earth.



CAD model of the Philae Lander, with instruments deployed

Philae is part of the ESA (European Space Agency) Rosetta mission, and was provided by an international consortium, led by the German Aerospace Center, DLR, with large contributions from MPS, CNES, ASI and other partners. It was attached to the mother spacecraft during its ten years of cruise. Only, when Rosetta arrived at the target comet, in August 2014, it became possible to characterize the nucleus with orbiter instruments and to select an appropriate landing site.

The Lander was separated from Rosetta at an altitude of about 22 km and touched ground after seven hours of ballistic descent. It was intended to be anchored by two harpoons, but, unfortunately those failed to fire, so Philae was bouncing off and landed after several ground contacts about 1km from the original site in an area now called 'Abydos'

Scientific data were gained during descent, the bounces and at Abydos. All of the ten scientific instruments aboard the Lander could be operated at least once, until the batteries depleted after about 64 hours after separation. Unfortunately, Philae is now at a spot which is poorly illuminated and after the first scientific sequence in November, it took eight months till 67P (and Philae) were close enough to the sun, and the Lander could again establish radio contact with the mother spacecraft.

The terrain is characterized by rough rock-like structures. (Note that the material is not expected to be rock, but sintered, porous ice-dust agglomerate with high organic content.) The instrument MUPUS, attempting to hammer a penetrator into ground indicated a surprisingly high crushing strength of at least 4MPa!

Two mass spectrometers on board the Lander, COSAC and Ptolemy, delivered spectra immediately after the first touch-down. While COSAC identified 16 molecule species, including amines, amides and alcohols (some of which are of prebiotic relevance), Ptolemy found clear indication for organic polymers in the cometary material.

CONSERT, a radar tomographer allowed insight into the global internal structure of the comet nucleus, indicating a rather homogeneous interior, with a permittivity of $\in = 1.27$ corresponding to a porosity of 75 to 85 percent.

ROMAP, a fluxgate magnetometer identified a lack of remnant magnetization of the comet surface, which is interpreted that there was no significant magnetic field in the planetary disc, when 67P formed.

The camera ROLIS, looking 'downward' provided fascinating images of the first touch-down site with a resolution op to 1cm. The terrain is characterized by coarse regolith and embedded boulder-like features.

The teams will continue to work on possibilities to command Philae, so that more scientific data can be obtained until the heliocentric distance will become too large again to power the Lander (probably end October 2015).

Philae provided unique science on structure and composition of a cometary nucleus. Part of these results will enhance the planning for future missions to comets, particularly those foreseeing landing or sampling.

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PACA Rosetta67P: Leveraging Amateur Astronomers and Social Media in Support of ESA/Rosetta Mission to Comet 67P/Churyumov-Gerasimenko (CG)

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Rosetta Mission to Comet 67P/CG and Need for Ground-based Observational Support:

The European Space Agency (ESA) Rosetta mission (with 18 European partners and NASA), launched in 2004, is an ambitious engineering and science mission. The spacecraft consists of an orbiter (Rosetta) and lander (Philae), with a combined suite of 21 instruments to rendezvous with a comet, drop a lander on the comet to study it in situ, orbit the comet and escort it into the inner solar system to its perihelion, all the while learning about the composition, the initiation and sustaining of activity of the comet. After encountering two asteroids, an earth swing-by, the Rosetta spacecraft exit from a near-3 year hibernation on 20 January 2014 to resume its journey to its final destination, comet 67P/Churyumov-Gerasimenko (67P). The key milestones for the mission are: (a) encounter with its final target, comet 67P/Churyumov-Gerasimenko (or 67P), in May 2014; (b) orbit insertion in August 2014 and mapping of 67P; (c) release of lander, Philae, in November 2014; and (d) escort 67P on its journey to perihelion in August 2015. The target for the Rosetta mission, 67P/Churyumov-Gerasimenko (67P), discovered by Klim Churyumov and Svetlana Gerasimenko in 1969, is a short-period comet, low orbital inclination, and influenced by Jupiters gravity field. Such comets are know as Jupiter Family comets (JFC) and considered to originate in the Kuiper Belt, just outside the orbit of Neptune. Since its discovery in 1969, the comet has been observed on six apparitions, with an orbit of 6.45 years. From past apparitions, it is known that the comet becomes active about a month before perihelion, with at least three active jets and a long tail that persists months after its perihelion passage seasonal changes of the comet. Rosettas close-up views of the comet nucleus and the observations of the initiation of the comets activity indicate the nucleus is bi-lobed or rubber ducky shaped, very dark and has an orbital period of 12 hours; with the narrow/neck part of the nucleus exhibiting the first jet activity was observed. Global observations from Earth are still necessary, to compare with previous apparitions and relate observed changes with the varying activity level. Therefore, the Rosetta mission sought ground-based observational support from both professional and amateur astronomers worldwide. The advantages of professional facilities allows the use of large telescopes to be able to acquire data of the comet; however, since the comet is expected to be faint (around magnitude 12) even at closest approach, a dedicated global international network of amateur astronomers is necessary to be able to observe the comet whenever it is available at their particular location and build a temporal and spatial data base of observations. The ground-based observations consist of two networks: (i) professional observers and (ii) amateur astronomers, each with a coordinator, to ensure the best observations are acquired in support of the mission and to liase with the mission science teams. As part of the support for ESA/Rosetta mission, a complementary two-pronged ground-based observational program was initiated late 2013: a professional observer component, overseen by Dr. Colin Snodgrass, Open University, England and an amateur observer component, overseen by Dr. Padma A. Yanamandra-Fisher, Space Science Institute, USA. As Global coordinator for amateur observations, Dr. Yanamandra-Fisher initiated a core network of amateur observers, based on the legacy of her work with the NASA/CIOC and the equivalent social, amateur observer networks for Comets C/2012 S1 (ISON) and C/2013 R1 (Siding Spring). The resulting network of observers is the basis of the Facebook group, PACA Rosetta67P, including members of the media, educators, Rosetta mission managers and team members in addition to the observer network. Formed in January 2014, the observer network has imaged comet 67P/CG from March 2014, when the comet was just detectable by amateurs, at a magnitude of 19-20 and available in the southern latitudes, with Peter Lake, of iTelescope.net in Siding Spring, Australia, being one of the first observers. Since then, regular contributions by other PACA observers such as Efrain Morales (Puerto Rico, USA), Andres Chapman (Argentina, South America), Rolando Ligustri (Italy), have formed the basic timeline of the comets changing magnitude with time or its light curve. As the comet became available at other latitudes, other PACA members/imagers have joined the campaign, with observers as far north as Essex, England (Dave Eagle, Peter Carson, Nick James) contributing data.

Leveraging Amateurs and Social Media:

The availability and access to various forms of social media with the immediate dissemination of observations and results, while being able to engage with other professional and amateur colleagues globally. Perceiving a need for an organized connection between the Pro-Am observer communities, I created The PACA Project from my earlier Pro-Am efforts in support of NASA Comet Observing campaigns (CIOC) for comets C/2012 S1 (ISON) in 2013, which dramatically disintegrated on its perihelion day of 28 November 2013 and C/2014 A1 (Siding Spring), which flew by very close to Mars on 19 October 2014. Currently, The PACA Project is involved in the Ground-based Amateur campaign to observer ESA/Rosetta missions target, 67P/Churyumov-Gerasimenko (CG) that is en route to its perihelion on 13 August 2015. Since the formation of its Facebook group, PACA Rosetta67P, in January 2014, the group consists of a core group of amateur astronomers, (their locations shown as red dots in Figure 1), professional observers and members of the mission teams, including the two project scientists (Drs. Matt Taylor/ESA and Claudia Alexander/NASA/JPL).

The various social media, creative logos, bookmarks illustrating the Egyptian theme used by Rosetta to name the various regions of the comet nucleus and the landing site for Philae lander; and appropriate QR codes relating to the social media are shown, created by various members of the Facebook group, PACA Rosetta67P.

JPL/PACA Call for Participation:

Since November 2014, the comet was behind the sun or conjunction, and therefore not visible to observers on ground. Following the first recovery detection

CIOC/PACA logos for various comet observing campaigns, designed by R. Kaufman, (Australia), G. Conzo (Italy); T. Greiner (U.S.A.) and A. Vossinakis (Greece).

of the comet of magnitude 16.9, post-conjunction by three French amateur observers (Maury, Bosch and Soulier) using a remote observatory in Chile on 12/13 April 2015, JPL issued a call for participation to the amateur community (link can be found at:

http://rosetta.jpl.nasa.gov/rosetta-science-blog/be-part-excitement

with mirror coverage at ESA Rosetta blog site found at:

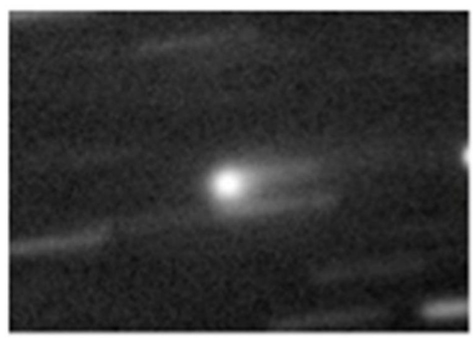
http://blogs.esa.int/rosetta/2015/04/16/

to announce the recovery of the comet and to encourage both professionals and amateurs to observe and characterize the comet through perihelion and several months post-perihelion, when the comets southern hemisphere (currently dark due to lack of insolation) will become very bright for a short time, even as the Rosetta spacecraft continues it high resolution spatial images of the comet exhibiting increasing jet activity over its surface, simultaneously providing two unique views : close in to the nucleus and the far-field global image of the comets coma and tail.

The amateur observers data will be collected and crowd sourced by both professionals and amateurs to characterize the comet and model it activity. The data will also be archived in ESA/Planetary Science Archive (PSA) for its legacy value too. While the spacecraft, Rosetta, in orbit around 67P/CG nucleus since August 2014, provides high resolution and multi-spectral images of the comet and its activity; maps the location and detection of various chemical species, etc., the ground-based observations (both professional and amateur) provide a complementary perspective of the evolution of the comets coma and tail. Figures below indicate the evolution of the comet and its tail, from magnitude of 16 to 13, as expected by the observations of its previous apparitions.

Latest image from 12 August 2015, a day before perihelion:

As we await eagerly the perihelion passage of the comet and images/data from Rosetta spacecraft, here is one of the latest images of comet 67P/CG, sent in by the amateur astronomer, Jean-Gabriel Bosch, imaged from the Space Observatory (Chile), showing a bright nucleus and a faint dust tail.



Comet 67P/CG imaged on 12 August 2015, one day before its perihelion passage, by amateur observer Jean-Gabriel Bosch, from the Space Observatory, Chile. The magnitude of the comet is estimated to be 12.8, and a distinct dust tail is observed.

This historic moment in cometary observations will be upon us in a few hours on 13 August 2015, as comet 67P/CG goes through its perihelion passage:

with a spacecraft in orbit around the cometary nucleus and characterize the activity with several different instruments to determine the nature of activity, abundance of chemical species through perihelion passage while ground-based professional and amateur observations will provide a timeline/reference for the Rosetta observations. The ground-based observations will provide another important resource: a bridge between legacy data sets of previous apparitions and future apparitions as the comet returns next in approximately 2021/22. A new chapter in the cometary physics is being written with ESA/Rosetta mission. Congratulations to the ESA and NASA teams for a great engineering marvel that has provided both new perspectives on cometary activity and engaged several generations of audiences globally.

Finally, this article is a tribute to the dedicated work of the late Dr. Claudia Alexander, the US NASA Project Scientist, who passed away on 11 July 2015, on the eve of the pinnacle of both ESA/Rosetta mission and her professional career.

For more images of comet 67P/CG from PACA network:
`https://www.flickr.com/photos/pro-amastronomy/sets/72157641578093805`

Spectroscopic study of Comet Lovejoy

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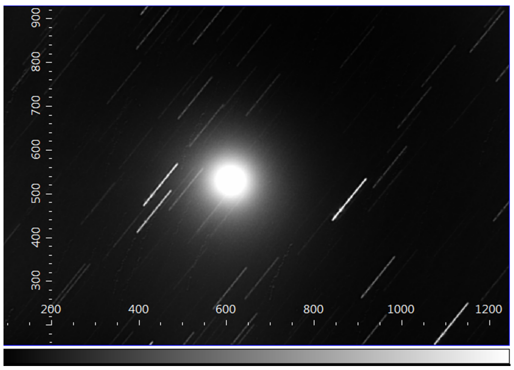
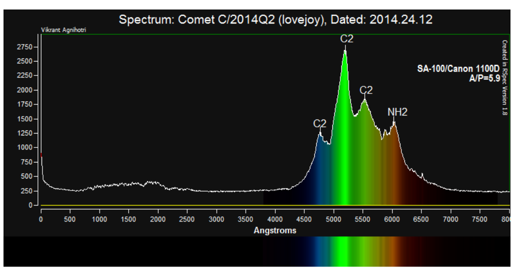
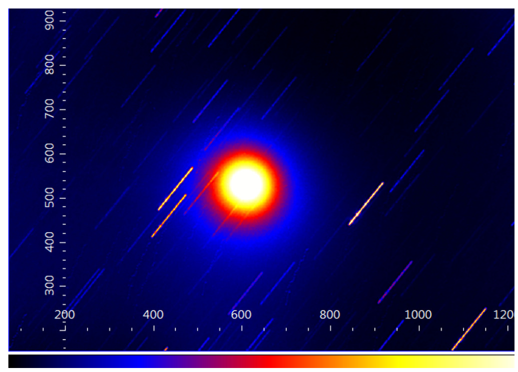




We carried out the imaging/spectroscopy of comet C2014Q2 Lovejoy as on 24.12.2014, UT: 18:47:06. The comet imaged at sloan g'2 band (400nm-550nm) wavelength, also the spectrum captured using star analyzer grating (SA-100) within filter wheel fixed with 0.2m SCT telescope mounted on sky-watcher NEQ6 mount.



The spectral image captured over sensor KAF8300 (Atik383L+ cooled monochrome CCD) coupled with filter wheel assembly The comet image manually guided over the field of view of CCD using double cross view application of APT- Astro Photography Tool. The telescope mount was commanded using EQ-direct (ASCOM platform supported) + Starrynight (SN7). The 50 imaged are stacked in maximDL and false color imaged created in DS9. The spectral image files processed in RSpec spectroscopy software.

We examined the dia-atomic carbon (C_2) and NH_2 predominantly in comet.

Study of Cometary Atmospheres

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Comets are regarded as the most pristine objects of the solar system, which preserve the information on the primitive solar nebula because they have not undergone much thermal evolution (except for the outer irradiation mantle). Comets are usually inert at large heliocentric distances, but develop a coma and tail when they come close to the Sun as the gas sublimes and evolves off the surface and dust is also dragged along. Initially, the solar wind permeates the thin comet atmosphere formed from sublimation, until the size and plasma pressure of the ionized atmosphere define its boundaries. Water (H_2O) ice is the most dominant volatile in most comets. In addition to this, cometary ices also consist of CO_2 and CO molecules and modest amounts of molecules like CH_4, NH_3, H_2CO and CH_3OH, probably contained within complex organic compounds.

The chemical composition of the comets is mostly assessed by remote sensing - spectroscopic observations. In the case of H_2O, the infrared emissions are difficult to observe from ground because of strong attenuation by the terrestrial atmosphere. Water does not have any spectroscopic transitions in UV or visible regions of solar spectrum. Hence, the emissions of the dissociative products of H_2O (OH, O and H) is studied to understand the production and spatial distribution of H_2O in comets (e.g. Furusho et al. 2006). The primary products of dissociation of H_2O molecule are H and OH. A small fraction is O and H_2. The [OI] lines (green (5577 A°) and red-doublet (6300, 6364 °) lines) are prompt emissions of metastable oxygen atoms that have been observed in several comets, and the value of the intensity ratio of green to red-doublet (G/R ratio) has been used to identify the whether the parent source of these lines is H_2O or CO_2/CO in the coma of comets (Bhardwaj and Raghuram, 2012). The H_2O production rates in comets are also derived by observing the emissions from its dissociative products, like OH (18-cm, 3080 A°), O (6300 A°) and H (Lyman-alpha). Recently, Decock et al (2015) studied the G/R ratio in four comets and found that the ratio varies as a function of nucleocentric projected distance due to the collisional quenching of O(1S) and O(1D) by water molecules in the inner coma. It was also found that that the main parent species producing O(1S) and O(1D) in the inner coma is not always the same. They also discovered that the [OI] line emissions may be used to estimate the CO_2 relative abundance in comets (Decock et al., 2015). Similarly, the CO_2 production rate in comets has been derived using Cameron-band emission of CO molecules, assuming that photodissociative excitation of CO_2 is the main production mechanism of CO in the metastable state (Weaver et al., 1997). However, model calculations by Bhardwaj and Raghuram (2011) showed that photoelectron impact excitation of CO is also significant for the Cameron band emission, together with dissociative excitation of CO_2.

Apart from remote-sensing, information on the composition of comets is obtained from in situ mass spectrometry, for instance comet Halley was observed with the mass spectrometers of VEGA and Giotto. The more recent Rosetta spacecraft had three mass spectrometers, capable of studying the atmospheric composition: ROSINA (on the orbiter), Ptolemy and COSAC (both on the Philae Lander) and a suite of plasma analysers. Using the Rosetta Plasma Consortium ion composition analyzer, Nilsson et al (2015) studied the evolution of water ions on the Jupiter family comet 67P/Churyumov-Gerasimenko. The first in situ measurement of N_2 on comet 67P/Churyumov-Gerasimenko was made by the ROSINA mass spectrometer aboard the Rosetta spacecraft. Actually, though molecular nitrogen (N_2) is considered to be the most abundant form of nitrogen in the protosolar nebula, N_2 was not detected previously in comets (Rubin et al., 2015). The ROSINA, being a Double Focusing Mass Spectrometer (DFMS) has a high mass resolution of m/m about 3000 at 1 percent at atomic mass per unit charge 28 m/q, allowing the separation of N_2 from CO (Rubin et al., 2015). Very recently, Goesmann et al (2015) reported the presence of a suite of 16 organic compounds, including many nitrogen bearing species and four compounds methyl isocyanate, acetone, propionaldehyde and acetamyde on comet 67P/Churyumov-Gerasimenko, that had not been previously reported in comets. The measurements were from COSAC (COmetary Sampling And Composition) mass spectrometer, and the spectrum was obtained 25 minutes after Philaes initial touchdown. These new observations would definitely lead to new insights regarding the chemical composition of comets, the production of volatiles in comets and about the formation of cometary grains from protosolar nebula.

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The Diverse Science of Sungrazing Comets

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October 2015 marked the 50th anniversary of the spectacular perihelion passage of one of the most celebrated comets in modern astronomy. Discovered September 18, 1965, comet C/1965 S1 (Ikeya-Seki) passed a mere 468,000 km from the solar surface on October 21, 1965, attaining a peak estimated brightness of magnitude -10, and being visible to the naked eye in broad daylight. Comet Ikeya-Seki was a Sungrazing comet and a member of an extended population of comets known as the Kreutz group, whose origin dates back to an unidentified parent object that fragmented millennia ago. Ikeya-Seki was the seventh observed member of the Kreutz group, with an added eighth being observed in 1970, yet despite these observations, little was known of the Kreutz population. Kresak (1966) hypothesized a dense meteor stream in the Kreutz orbit, but the nature of the objects rendered ground-based imaging of all but the brightest members an impossibility. In 1979, the SOLWIND coronagraph on the USAF P78-1 satellite made the first space-based detection of a Kreutz-group comet (Marsden, 1981, Michels et al. 1982). Several more detections followed from SOLWIND and the later Solar Maximum Mission (SMM), leaving a known population of around twenty Kreutz objects by the late 1980s.

In 1995, the launch of the joint ESA/NASA Solar and Heliospheric Observatory (SOHO) heralded the dawn of a new era of comet observations. The coronagraph telescopes aboard the spacecraft - designed to block direct sunlight and observe the Suns corona in visible in light - yielded not only unprecedented views of solar phenomena such as coronal mass ejections, but also a wealth of detections of small, previously unknown sungrazing and sunskirting comets. Since routine operations began in 1996, SOHO has discovered over 3,000 comets.

Approximately 85 percent of these objects are Kreutz sungrazers, with the remaining 15 percent belonging primarily to one of four new families of comets identified solely by SOHO. The launch of the twin NASA Solar Terrestrial Relations Observatory (STEREO) in 2006 added two additional coronagraphs and their unique Heliospheric Imagers (HI) to image the near-Sun environment with unprecedented sensitivity and viewing circumstances very different from SOHO. These instruments have yielded extraordinary views of comet tails interacting with the solar wind, as well as discovering over fifty new comets.

The wealth of observations and discoveries of near-Sun and sungrazing comets now offered to us by the SOHO and STEREO heliospheric observatories present myriad opportunities for studying the many unique aspects of these objects. We can broadly separate these focus areas into three categories - evolution, dynamics, and physical properties - though overlap clearly exists between all three.

Regarding evolution, we can perhaps fundamentally look back to the progenitor of the Kreutz-group, which at some unknown time, and for unknown reasons, fragmented into some unknown number of child objects. The objects subsequently fragmented and, via a process referred to as cascading fragmentation (Sekanina Chodas, 2007), led to the present day scenario in which around two-hundred small Kreutz objects are discovered each year. This fragmentation process is not unique to the Kreutz group, or sungrazing comets. The so-called Marsden and Kracht populations of near-Sun object, first identified by SOHO, are related families with orbital periods of around five years. This short orbital period has enabled SOHO to observe repeat passages of certain individual objects, including one object observed to return as a pair of objects at the next apparition (Marsden et al., 2005), giving us indirect observation of an ongoing cascading fragmentation process. The Marsden and Kracht populations follow different orbital paths, but it has been well demonstrated (Ohtsuka et al, 2003, Sekanina Chodas, 2005) that they once were part of the same system, which itself has direct ties to comet 96P/Machholz, the Quadrantid and Daytime Arietid meteor streams, and perhaps asteroid 2003 EH1 (Jenniskens, 2004). Thus through discovery and observation of near-Sun and sungrazing populations, including other newly recognized families such as the Meyer and Kracht II groups (Marsden, 2005), and numerous individual pairs of objects observed by SOHO and STEREO, we can begin to describe and understand the complex evolution of inner solar system objects.

Such studies of comet family evolution naturally lead us to the question of dynamics. What is happening to these objects as they fragment? How do seemingly diverse bodies and populations relate to one-another, and over what time-scales have the apparent changes occurred? In many cases we can look to gravitational interactions - specifically and most obviously with Jupiter - as a primary driver of the dynamic evolution of cometary orbits. However, comets also experience non-gravitational forces - a result of the physical activity of the comet leading to a jet effect whereby sublimation of water ice from the comets surface creates a momentum transfer that gradually alters an objects orbit over time. These effects are described by empirical laws first derived by Marsden et al (1973), and remain routinely adopted to describe cometary orbits. Recent studies of sungrazing comets, however, are beginning to question the extent to which these laws can be applied to comets undergoing the extreme sublimation we expect in the near-Sun environment. In the case of C/2012 S1 (ISON), for example, numerous observers reported significant deviations of the comet from its nominal and well-described orbit in the days preceding perihelion (e.g., Cordiner et al. 2014). Similar effects were observed in C/2011 W3 (Lovejoy), and have been theorized for most of SOHOs small Kreutz-group comets. Regarding comet ISON, it is firmly established that by the last few days of its existence, the comet had undergone at least one major fragmentation event, and was likely experiencing ongoing and catastrophic events until it finally vaporized (Knight Battams, 2014, Sekanina Kracht, 2014, Combi et al. 2014). Sekanina Kracht (2014) demonstrated that the deviations in comet ISONs orbit could best be explained by extreme momentum transfer driven by sublimation of sodium and not water, as typically assumed in the standard model of non-gravitational forces (Sekanina Kracht, 2015).

When we consider the concept of extreme sublimation we must also consider the physical (and chemical) properties. Comets have been remotely observed spectroscopically for decades, and we now have the ESA Rosetta mission, for example, performing very detailed in situ studies of the physical and chemical properties of comet 67P/Churyumov-Gerasimenko. It is reasonable to assume that many of the properties of comets like 67P transfer to sungrazing comets, but particularly in the days and hours surrounding perihelion we can argue that sungrazers become their own distinct class of comet, complete with properties we may not ordinarily assign to classical comets. Cometary activity is driven by solar radiation, with various ices sublimating at different distances from the Sun. However, when we consider sungrazing comets, we can no longer assume an object that sublimates typical cometary volatiles. Studies looking at the sublimation distances of inner solar system dust (Mann et al. 2004) show that once inside approximately 14 solar radii (approx. 0.07 AU), non-volatiles such as olivines and pyroxenes begin sublimating, and are ultimately followed by much harder materials such as quartz. For sungrazing comets, there comes a point at which the entire surface of a comet is unstable, regardless of composition. The physical and chemical processes at this stage are both complex and poorly understood, but collectively lead to the ultimate destruction of most sungrazing comets. Mechanisms for this destruction mostly center on continual breakup of the object into small pieces, but the physical mechanism for that initial breakup itself is not well understood. Tidal (gravitational) forces only become relevant within approximately 2 solar radii from the Sun (Knight Walsh, 2013), however, the overwhelming majority of Sungrazing comets are vaporized or entirely fragmented before they reach this close to the Sun (Biesecker et al. 2002, Knight et al. 2010). Processes such as sublimation pressure (Steckloff et al. 2015) have been proposed as an alternative to simple sublimation-driven mass loss models, but these remain theoretical with little to no direct observational support.

The wealth of observations, and the unique nature of sungrazing comets, offer rare insight beyond just studies of comets. The solar physics community has, in recent years in particular, embraced comets as unique and valuable probes of the solar wind and the near-Sun environment.

The solar wind was first theorized due to the presence and direction of comet tails. Today, with instruments such as the Heliospheric Imager (HI) on the STEREO mission, we are able to observe comet tails in extreme proximity to the Sun, and see their interaction with both the solar wind and coronal mass ejections (CMEs). In 2007, STEREO-HI witnessed a CME completely rip the tail from comet 2P/Encke (Vourlidas et al. 2007). The STEREO-HI instrument has subsequently observed several comet tails strongly interacting with the solar wind, enabling unique measurements of the speed (Ramanjooloo et al. 2014) and turbulence (DeForest et al. 2015) of the solar wind, and addressing critical questions in solar and space weather studies. Data returned by the Ultraviolet Coronal Spectrometer (UVCS) instrument on SOHO has similarly yielded unique insights into the solar wind properties near the Sun (Giordano et al. 2015).

Sungrazing comets that survive to near or beyond perihelion enable detailed studies of the solar corona and its complex magnetic fields. In July 2011, the NASA Solar Dynamics Observatory (SDO) witness the complete destruction of comet C/2011 N3 (SOHO) in extreme ultraviolet (EUV) observations of the solar corona. (Schrijver et al. 2012). Later that same year, comet C/2011 W3 (Lovejoy) made a spectacular passage through the corona, with observations from SDO and both of the EUV imagers on STEREO showing a complex striated tail pattern behind the comet. It was found that sublimated material released from the comet was being rapidly ionized to a state strongly preferred by EUV imagers, and was seen to illuminate the solar magnetic field lines in the inner corona (Bryans Pesnell, 2012). These one-of-a-kind observations enabled unique studies of the Suns field lines, and temperatures and electron densities of the solar corona, and allowed models of the environment to be validated against direct observation of a well-defined probe in that region (Raymond et al. 2014).

Thus near-Sun and sungrazing comets act as wind-socks and probes of a largely unexplored environment, and offer insights that go far beyond studies of comets. Advances in both cometary and solar physics have been enabled directly by the past and ongoing detections and observations of comets by heliospheric observatories. The planned ESA Solar Orbiter and NASA Solar Probe Plus missions hold future promise with their high-resolution heliospheric imager instruments that will study the near-Sun region as the spacecraft evolve on orbits that will ultimately take them to within 12 solar radii of the Sun and operate in the same domain as the comets we have been studying. The SDO and SOHO spacecraft, and one of the STEREO spacecraft, currently continue routine operations, with the author acting as liaison to the operation teams to inform them of potential comets of interest, perhaps requiring special observing sequences. The NASA-funded Sungrazer Project, led by the author, continues to enable citizen science discoveries of sungrazing comets on a daily basis.

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Electron Irradiation of Cometary Ice Analogs - N_2O - CS_2 ice mixtures

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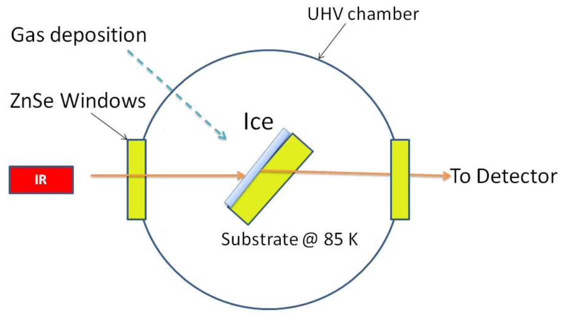

Figure1: Schematic of the Experimental setup housed at PRL, Ahmedabad used to record the Infrared spectra of Astrochemical ices containing a Zinc Selenide (ZnSe) substrate cooled to 85 K in an Ultrahigh Vacuum chamber with a pressure less than 10^{-9} torr.

Introduction

The first identification of Carbon monosulfide (CS) in the InterStellar Medium (ISM) in 1971 with column density 1014 molecules cm^{-2} in Orion A, W51, IRC+10216 and DR21 (Penzias 1971) and in the NGC 2264 cluster in 1972 (Zuckerman 1972) and on Comet West in 1980 (Smith 1980) started the quest to trace its parent molecule CS_2 in the ISM and comets. CS_2 was first detected on Comet 122P/de Vico in 1995 by comparing the unidentified spectral lines of the comet in the visible and ultraviolet region with the experimental spectra of supersonically cooled CS_2 (Jackson, Scodinu et al. 2004). Recently (Sivaraman 2016) has confirmed the presence of CS_2 in the cold traps of Lunar South Pole. Extensive experimental studies have been made on this simple molecule CS_2 but its reaction with other ice mixtures in interstellar condition is still least explored.

Nitrous oxide (N_2O) was also detected in the Interstellar medium (ISM) in SgrB2(M) in the year 1994 which was the third molecule found in space to have N-O bond (Ziurys 1994). N_2O is yet to be discovered on comets. CO_2 has been detected on comets (Combes, Moroz et al. 1986) and the recent results from ESAs Rosetta mission revealed the presence of molecular Nitrogen in the coma of comet 67P/ ChuryumovGerasimenko. Rich nitrogen and carbon dioxide in planetary environment produces N_2O. N_2O can be formed on extraterrestrial ices when molecular nitrogen and carbon dioxide ice mixtures are irradiated with 5 KeV and 10 KeV electrons (Corey, Chris et al. 2005). Experiments show that solid nitrogen oxides when bombarded by Argon atoms and ions at 4 KeV produce ozone which is not possible in gas phase (Jim Liang 1984). Ozone is a biomarker to trace the existence of extraterrestrial life. N_2O also plays an important role in the catalytic destruction of ozone in Earths stratosphere (Portmann,

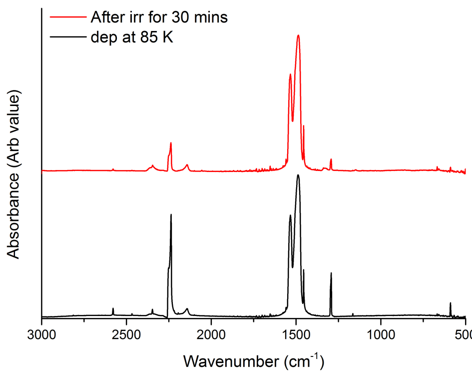

Figure 2: Infrared spectra of CS_2 N_2O ice mixture after deposition at 85 K (black) and spectra after irradiating the ice mixture for 30 minutes (red).

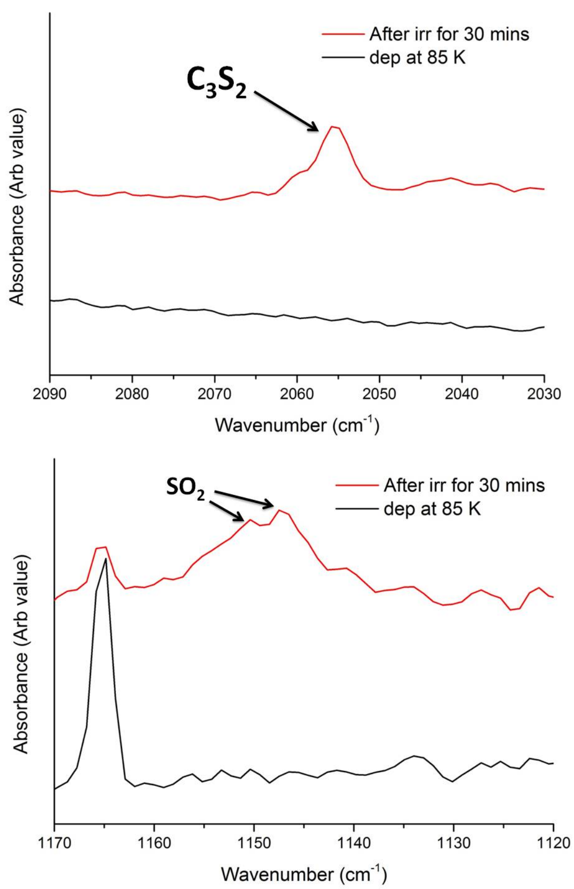

Figure 3: Infrared spectra of the ice mixture before and after irradiation (a) C_3S_2 observed after irradiation at 2055 cm^{-1} and (b) SO_2 after irradiation at 1150 and 1154 cm^{-1}

Daniel et al. 2012). Chemical processing of solid N_2O at 25 K by 1 KeV electrons produced ozone and oxides of nitrogen like N_2O_2, N_2O_3, N_2O_4 and N_2O_5 with NO, NO_2 and O_2 as intermediates (Sivaraman, Ptasinska et al. 2008). Therefore studying the reaction of N_2O with CS_2 in the ISM and on planetary bodies will refine our knowledge towards the formation of simple to complex molecules bearing carbon, sulphur and nitrogen.

Experiment

Experiments were carried out in the experimental chamber housed in the laboratory for low temperature Astrochemistry at Physical Research Laboratory (PRL), India. An UltraHigh Vacuum (UHV) chamber, that can reach base pressures up to 10^{-10} mbar, containing a cold head with Zinc Selenide (ZnSe) substrate cooled to 85 K. An all metal leak valve was used to introduce gases to form molecular ices on to the cooled ZnSe substrate at 85 K.

Pure CS_2 molecules were let into the gas line after two freeze-pump-thaw cycles at liquid nitrogen temperature. The gaseous N_2O molecules were also let into the gas line to mix with CS_2 molecules and then the gas mixture was let into the chamber and was made to condense on the ZnSe substrate kept at 85 K, and monitored using the Fourier Transform Infrared Spectrometer operating in the Mid-IR region (4000 500 cm^{-1}) with a resolution of 2 cm^{-1}. After recording a spectrum at 85 K, the ice mixtures were irradiated with 1 keV electrons at 10 microA to initiate the chemical reaction.

Results and Discussion

The N_2O and CS_2 molecules were mixed in the gasline and deposited on the ZnSe

substrate at 85 K. An IR spectrum was recorded at 85 K. The IR band assignments of N_2O and CS_2 obtained are presented in Table 1. The ice mixtures were irradiated with 1 KeV electrons for 30 minutes and another IR spectrum was recorded as shown in Figure 2. The main products found to appear after irradiation were C_3S_2 at 2055 cm^{-1} and SO_2 at 1150 and 1154 cm^{-1} as shown in Figure 3.

Table 1: *Infrared bands of solid Nitrous oxide (N_2O) and Carbon disulfide (CS_2) assigned according to (Łapiński, Spanget-Larsen et al. 2001) and (Maity, Kim et al. 2013) respectively:*

Nitrous oxide (N_2O)		Carbon disulfide (CS_2)	
Mode	Wavenumber, cm^{-1}	Mode	Wavenumber, cm^{-1}
$2\upsilon_2$	1164.8	$2\upsilon_2 + \upsilon_3$	2286.9
υ_1	1292.2	$2\upsilon_2 + \upsilon_3$	2219.1
$\upsilon_1 + \upsilon_2$	1887.9	$\upsilon_1 + \upsilon_3$ (C=S stretching)	2145.1
υ_3	2237.0	$\upsilon_1 + \upsilon_3$ (C=S stretching)	2100.7
$\upsilon_1 + 2\upsilon_2$	2468.7	υ_3 (C-S symm. stretching)	1508.1
$2\upsilon_1$	2580.2	υ_3 (C-S symm. stretching)	1455.9
$\upsilon_2 + \upsilon_3$	2813.6		
$2\upsilon_2 + \upsilon_3$	3379.5		
$\upsilon_1 + \upsilon_3$	3508.0		
$3\upsilon_1$	3861.0		

SO_2 can be formed by the following reaction (a), (b) and (c); C_3S_2 can be formed by reaction (d):

$$CS_2 \longrightarrow CS + S \text{ (Maity, Kim et al. 2013)}$$

$$S + O \longrightarrow SO\ (+O) \longrightarrow SO_2$$

$$S + O_2 \longrightarrow SO_2$$

$$3\ CS_2 \longrightarrow C_3S_2 + 4\ S \text{ (Sivaraman 2015)}$$

Conclusion

The N_2O and CS_2 ice mixture, kept at 85 K, upon electron irradiation was found to synthesis C_3S_2 and SO_2. From the experiments carried out we could clearly see that carbon and sulphur bearing molecules were synthesized in larger amounts. The available S atoms from the CS_2 and O atoms from N_2O were found to react readily in synthesizing SO_2. Therefore, we propose SO_2 to be one of the largely available molecules on cometary nucleus rich in CS_2 and oxygen bearing simple molecules.

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Concept for a comet chaser/flyby mission

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Mars Orbiter Mission (MOM) showcased ISRO's potential in deep space navigation with a great success in the maiden venture. The technology has been demonstrated and now is the time for Indian scientists to take advantage of the capabilities. One of the key areas that need to be addressed with a dedicated space mission is that of long period comets. Long period comets are supposed to be relatively less affected by weathering due to lesser number of close perihelion passes. Hence their study would allow us better understanding of the pristine building blocks at the early stages of Solar System evolution.

So far, all the missions to comets, starting with International Cometary Explorer (ICE) to the current Rosetta/Philae, have targeted short period comets where the orbits are relatively well known, understood and predictable with reasonable accuracy. The recent encounter of Comet C/2013 A1 (Siding Spring) with Mars is a unique case where spacecraft meant for Mars observations (including MOM) were able to contribute to study of the comet.

Thus a comprehensive mission with a suite of instruments must be designed, built and kept on standby for launch to a long period comet that would make a suitable pass through the inner Solar system. Long period comets such as the massive Comet C/1995 O1 (Hale-Bopp) are discovered when they are sufficiently far enough away. Hence they provide for a sufficient lead time for computing and setting a deep space course for a suitable flyby of the comet. Again taking the case of Hale-Bopp, the comet was discovered on 23rd July 1995 at a distance of over 7AU and approached perihelion (distance of 0.9AU) on 1st April 1997. Generally long period comets are in orbits with very different inclination angles with the ecliptic and getting spacecraft to follow those orbits would be quite demanding in terms of power for trajectory mapping and corrections. It would be a very rare orbit that would allow us to accompany the comet as being done by the Rosetta spacecraft. Hence a precisely timed flyby would be most appropriate to sample the comet. It is here that ISRO's recently demonstrated potential for cheap, low gestation missions can make a unique mark in planetary exploration on an international scale.

Spectroscopy and Chemical Synthesis of Interstellar Ice Analogues (Thesis Abstract)

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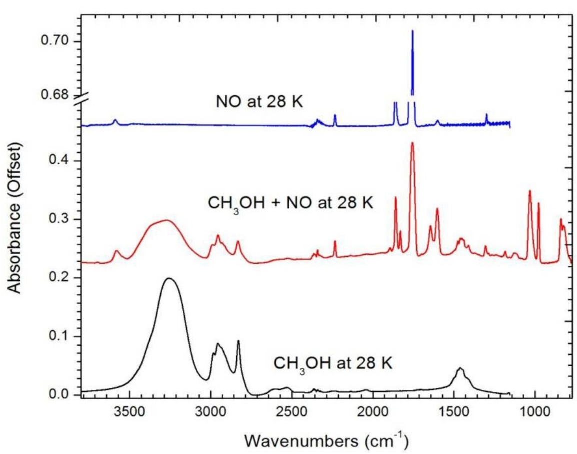

Absorption spectra of pure NO ice, CH_3OH+NO [1:1] ice mixture and, pure CH_3OH ice at deposited at 28 K.

Molecular synthesis and chemical evolution in the interstellar medium has been studied under laboratory conditions. The method of preparation and energetic processing of interstellar ice analogues on surfaces, spectroscopic principles for monitoring chemistry and morphology of these ice analogues and analysis methodologies are discussed in detail.

The modification of a portable, ultra-high vacuum (UHV) system for electron irradiation, vacuum ultraviolet (VUV) spectroscopy and temperature programmed desorption (TPD) of interstellar ice analogues are described in this thesis. Experimental procedures to grow interstellar ice analogues of pure molecules and mixtures are described. The results from the various experiments discussed in this thesis are classified into four main parts: VUV spectroscopy, electron irradiation of interstellar (IS) ice analogues, simultaneous irradiation and generation of IS ice analogues and temperature programmed desorption of interstellar ice analogues.

Temperature dependent vacuum ultraviolet (VUV) photo-absorption spectra of pure molecular ices such as $HCONH_2$, HCOOH, $HCOOCH_3$, CH_2CHCH_2OH CH_3COOCH_3, CH_3CH_2COOH, C_6H_6 and O_3 have been measured on the UV1 beamline of the ASTRID Synchrotron at the University of Aarhus in Denmark and UV A1 beamline at NSRRC, Taiwan. These spectra and photo-absorption cross-sections in the condensed phase are also presented. In particular, temperature dependent VUV photo-absorption characteristics of condensed ice films of O3 are measured for the first time. Electron induced molecular synthesis in pure organic ice films of $HCONH_2$, $HCOOCH_3$, CH_3COOH, NO and binary ice mixtures of CH_3OH+NO (1:1) are also reported. Newly identified pathways of molecular synthesis and results of electron destruction cross-sections are discussed. Molecular synthesis during simultaneous electron irradiation and physisorption of a binary mixture of CH_3OH+NH_3 (1:1)

is studied for the first time. Simultaneous irradiation-deposition has shown very interesting behaviour in terms of efficiency of formation of radical species such as OCN^-, NH_4^+ etc and biologically important complex organic species such as $HCONH_2$, $HCOOCH_3$, CH_3COOH, CH_3OCH_3, CH_2CHCHO etc. Simultaneous irradiation-deposition closely simulate the effect of cosmic ray irradiation in a dense molecular cloud and reveal new pathways of formation with higher efficiencies even at lower column densities of reactants. Finally preliminary results of a temperature programmed desorption study of pure NO ice films are also presented along with the future challenges and strategies.

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   http://as.wiley.com/WileyCDA/WileyTitle/productCd-3527412816,subjectCd-ES12.html

ASTROPROJECT

Captured on 14/12/2013.

Location: Mount Abu Infrared observatory, Mt Abu, Rajasthan, India.

Comet C/2013 R1 (Lovejoy) photographed by Rakesh Rao rising over the light polluted Abu valley. Also seen is a sporadic meteor burning up in the Earth atmosphere.

The sharp line near the horizon marks the edge of the boundary layer of the atmosphere frequently seen in winter at Mt Abu.

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