

ATTOSECOND TRANSIENT ABSORPTION SPECTROSCOPY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of
Philosophy in the Graduate School of The Ohio State University

By

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ABSTRACT

The Antarctic Impulsive Transient Antenna (ANITA) is a NASA long-duration balloon experiment with the primary goal of detecting ultra-high-energy ($> 10^{18}$ eV) neutrinos via the Askaryan Effect. In the fourth ANITA mission, the Tunable Universal Filter Frontend (TUFF) boards were deployed for mitigation of narrow-band, anthropogenic noise with tunable, switchable notch filters. They contributed to a factor of 2.8 higher total instrument livetime in ANITA-4 compared to ANITA-3. A search for a diffuse flux of ultra-high-energy neutrinos was conducted using the data collected during the ANITA-3 flight with a new approach where the Antarctic ice area is sectioned off into bins and a search is performed with different thresholds in different bins. The binned analysis methods were extended to the development of a search for neutrinos from Gamma Ray Bursts, implementing constraints in time, and for the first time, in direction. Lower analysis thresholds were achieved in a feasibility search even when extending the search to include longer afterglow periods.

Dedicated to coffee

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I thank the National Aeronautics and Space Administration and the National Science Foundation for supporting the research presented in this thesis. My work was also supported by collaborative visits funded by the Cosmology and Astroparticle Student and Postdoc Exchange Network (CASPER). Sincerest thanks to the astronomy department at OSU for their generous support through teaching assistantships during my Ph.D. candidacy and defense. Thanks to my home department, physics, for all the support that allowed me to find the best fit for a research group for my Ph.D. Many thanks to the Ohio Supercomputer Center - what would I do without you, Oakley.

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I am deeply grateful to Mauricio Bustamante for all his help in learning about Gamma Ray Burst theories and for letting me include in this thesis a previously unpublished, beautiful figure he made. Thanks a ton to Mat Page for sharing many useful insights on observing

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Special thanks to my teachers and mentors at South Point School and High School back in Kolkata. Many, many teachers there have made me who I am - I will specially mention my high school physics teacher Partha Pratim Roy (the famous PPR) - thank you, Sir.

I am extremely grateful for a wonderful undergraduate experience at NC State. Thank you to everyone there for not only welcoming me to school but to the United States! Special thanks to my amazing professors there: John Blondin, Stephen Reynolds, David Haase, Carla Frohlich, among others. Last but not least, I thank my first research advisor, Leslie Sombers, for giving me a chance to work in her lab as a freshman. That's where I got to be a scientist for the first time!

I thank my family - Ma, Baba, Dada, Mark, and Fuji, for everything. Now, we can move on with our lives. Thank you to my friends, especially, my best friend Twameka Kumar for being there for me since Nursery. Love you all lots.

VITA

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Publications

“Constraints on the Diffuse High-Energy Neutrino Flux from the Third Flight of ANITA”, P. W. Gorham, P. Allison, **O. Banerjee** *et al.*, Physical Review D. I am a lead author and contributor of the new binned analysis presented, which is one of the three complementary analyses in the paper. [Link to electronic version](#).

“Dynamic tunable notch filters for the Antarctic Impulsive Transient Antenna (ANITA)”, P. Allison, **O. Banerjee** *et al.*, Nuclear Instruments and Methods A. I led this paper and served as **corresponding author**. This paper is on the filters that I played a lead role in commissioning for ANITA-4, that helped to triple the livetime of the experiment. [Link to electronic version](#).

I am also a co-author on all ANITA publications (6 total) since Jan 2016.

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Chapter 1

INTRODUCTION

1.1 Exciting astrophysics happen far, far away

We live in a boring part of the Universe. This allows life and the life sciences to thrive here. However, everything that is interesting in astrophysics takes place far, far away. For example, most [Gamma Ray Bursts \(GRBs\)](#) take place about 1 Gpc ?? away from us. That is over three billion light years away!

1.2 Astrophysical messengers

Traditional astrophysical messengers are not able to completely probe physics that take place at the farthest distances and at the highest energies. Since the beginning of astronomy, we have relied on optical light to study objects in the sky. In the last few decades, we have started utilizing light of other wavelengths such as X-rays and gamma rays. However, light

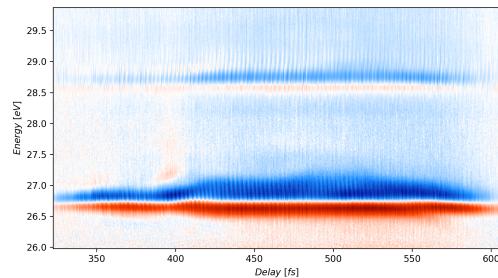


Figure 1.1: Depiction of a GRB. Picture Credit: NASA E/PO, Sonoma State University, Aurore Simonnet.

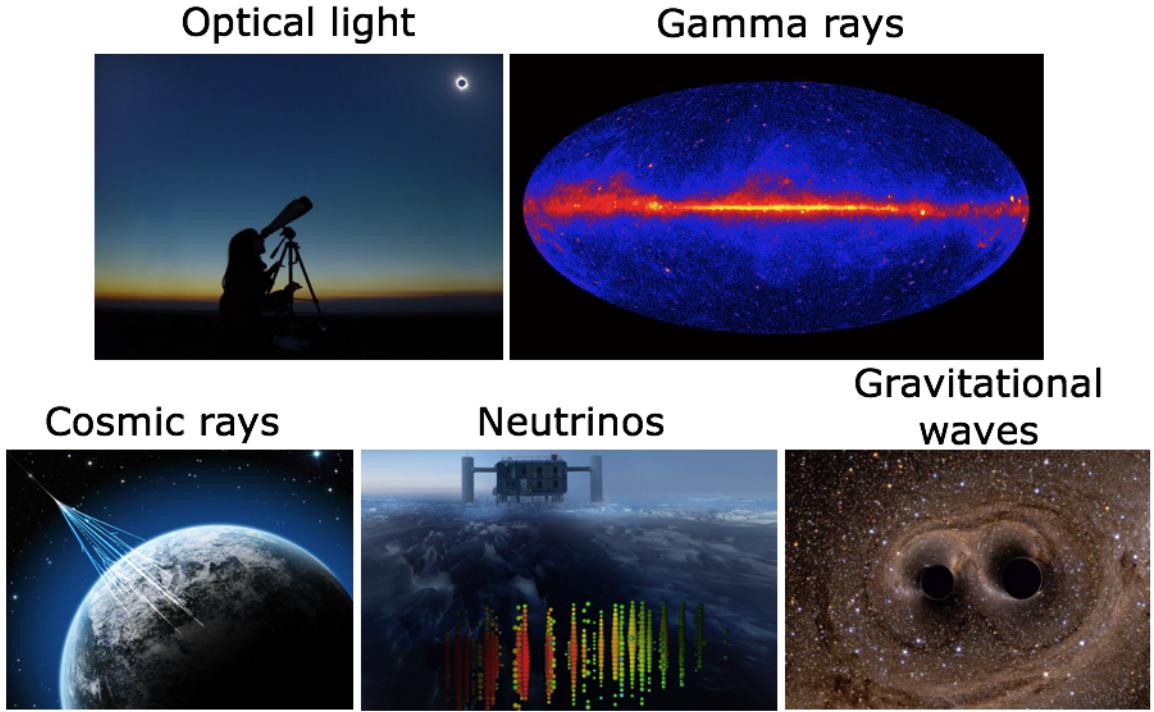


Figure 1.2: Astrophysical messengers. Pictures are all borrowed from Fermi, IceCube and LIGO collaborations, and the Internet.

of energy 1 MeV and above can undergo pair production. Light of energy 13.6 eV gets absorbed by Hydrogen atoms, the most abundant element in the Universe, while light at other wavelengths gets absorbed by other atoms and molecules. Light is the astronomer's best friend, but there is an inevitable need for complementary messengers.

Fortunately, in the last century, we have opened up multiple new windows to

1.3 Neutrinos as astrophysical messengers

Neutrinos are potentially perfect candidates for carrying information about distant particle accelerators all the way to us. Due to being neutral and weakly interacting, neutrinos would remain unattenuated and point straight back to their source. In this way, they would have a definite advantage over messengers such as cosmic rays. Neutrinos are the side product of almost every nuclear reaction and can carry versatile information about particle physics taking place at cosmic distances. Their

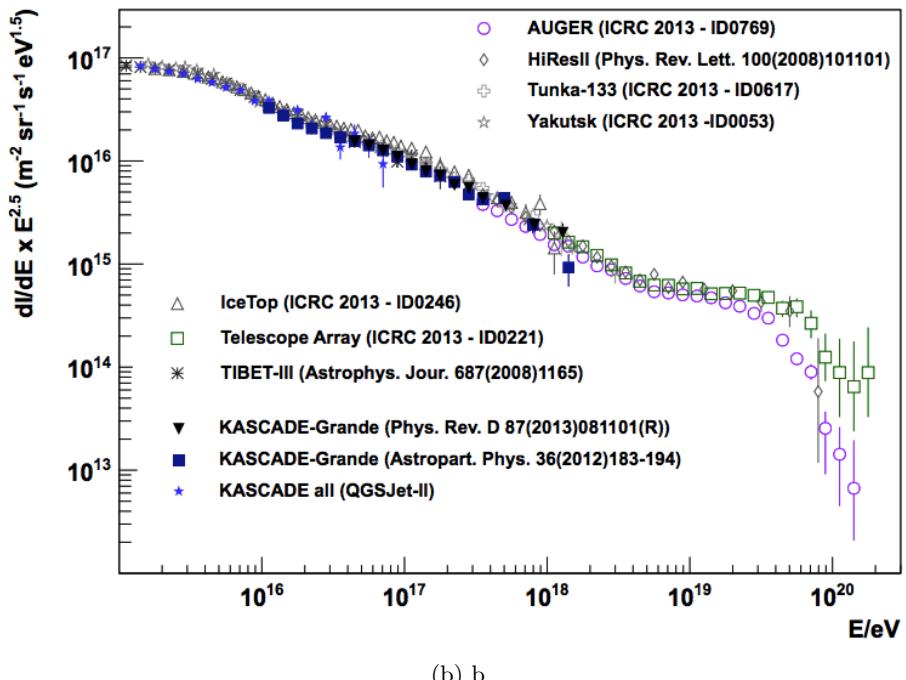
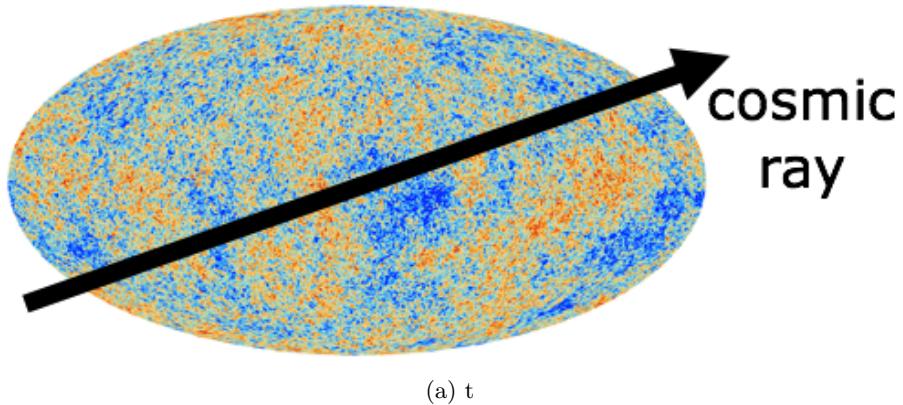


Figure 1.3: Top: Depiction of a cosmic ray interacting with the CMB. Thanks to the Planck telescope for the CMB picture. Bottom: Energy spectra of cosmic rays measured by different experiments. Andreas Haungs showed this plot at the 13th International Conference on Topics in Astroparticle and Underground Physics. UHE cosmic rays can only travel for about 50 Mpc before they interact with CMB photons and lose energy, therefore, we see a sharply falling spectrum at about 10^{20} eV energy.

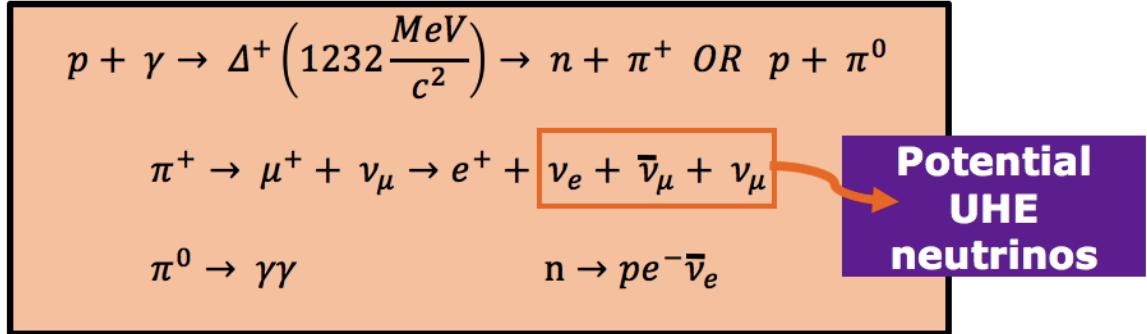


Figure 1.4: A process for production of UHE neutrinos.

1.4 Optical Cherenkov neutrino detectors

IceCube and ANTARES are both optimized for the detection of muons from charged current interactions of high energy astrophysical neutrinos. IceCube uses the Antarctic ice as a target medium for high energy neutrinos to interact in. ANTARES uses sea-water instead. They both look for optical Cherenkov signatures of high energy neutrino interactions. ANTARES is sensitive to neutrinos of energy 10 GeV - 100 TeV. IceCube was built to detect neutrinos of energy of order MeV.

1.5 Radio Cherenkov neutrino detectors

Radio Cherenkov neutrino experiments look for **ultra-high-energy (UHE)** neutrinos in the energy regime of $> 10^{16}$ eV. The main challenge for detection by these experiments and a potential solution for detection are presented below. We also introduce two complementary radio Cherenkov experiments, and in this section. Where they are on the energy scale as compared to other particle physics experiments is shown in Figure

1.5.1 Askaryan Effect

If light in the medium. The particle shower would mainly consist of photons, electrons and positrons. As it travels through the dielectric, the particle shower develops about a 20% negative charge. This happens primarily due to Compton scattering of electrons in the

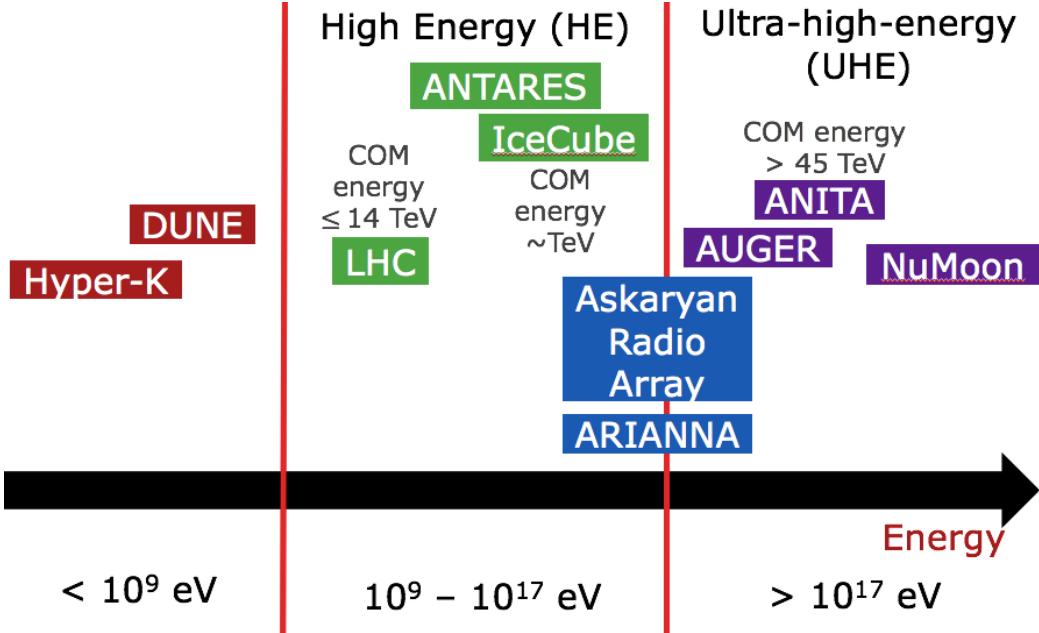


Figure 1.5: The ANITA experiment looks for particles, specifically, neutrinos of energies that are to close to the extreme right of the energy scale.

medium (so electrons leaving the medium and joining the shower) and secondarily due to annihilation of positrons in the shower with electrons in the medium (so positrons leaving the shower). As this charged particle shower travels through the medium at a speed greater than the speed of light in the medium, Cherenkov radiation is produced. If this Cherenkov radiation is observed at wavelengths larger than the shower's transverse dimension of about 10 cm, then it would be seen as coherent waves in radio frequencies.

1.5.2 ANITA

fect utilizing the Antarctic ice as the necessary dielectric target medium for neutrino interaction. Where [ANtarctic Impulsive Transient Antenna \(ANITA\)](#)'s sensitivity lies in the energy scale as compared to other experiments in particle physics and particle astrophysics is presented in Figure=.

A cartoon of an]oats up to an altitude of about 40 km and utilizes the polar vortex to fly in roughly circular orbits over the continent of Antarctica. At its float altitude, the balloon, upon gradual inflation, is bigger than the Ohio Stadium. There have been four flights of [ANITA](#) so far. These are summarized in Figure

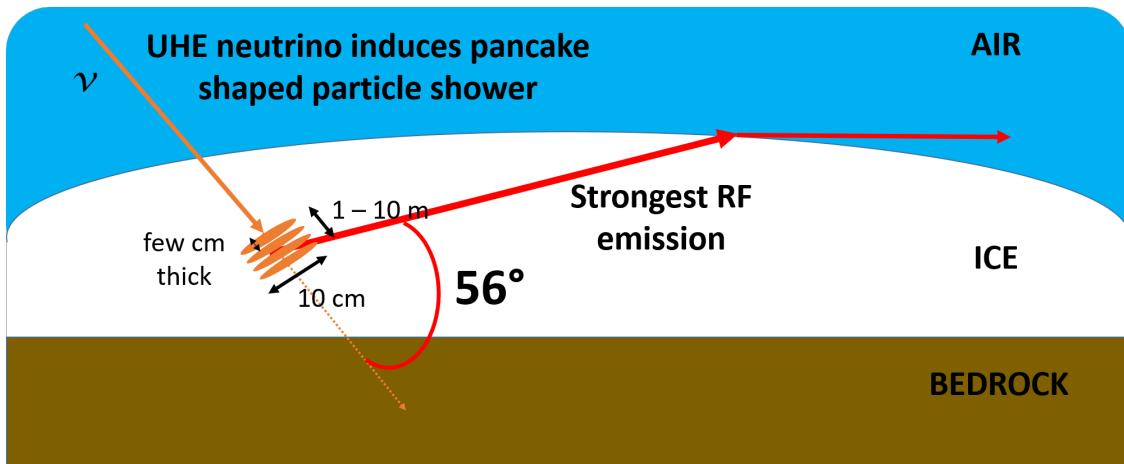


Figure 1.6: A UHE neutrino could start a pancake-shaped particle shower in the ice. Cherenkov radiation due to this particle shower would be coherent at wavelengths greater than the shower size of ~ 10 cm, which correspond to radio waves.

Year	Flight	Length of flight	Status
2006 - 2007	ANITA-1	35 days	Data analysis published
2008 - 2009	ANITA-2	30 days	Data analysis published
2014 - 2015	ANITA-3	22 days	Results public now
2016	ANITA-4	27 days	Data analysis ongoing
2020?	ANITA-5	--	Improving digitizers and trigger

Figure 1.7: Summary of ANITA flights.

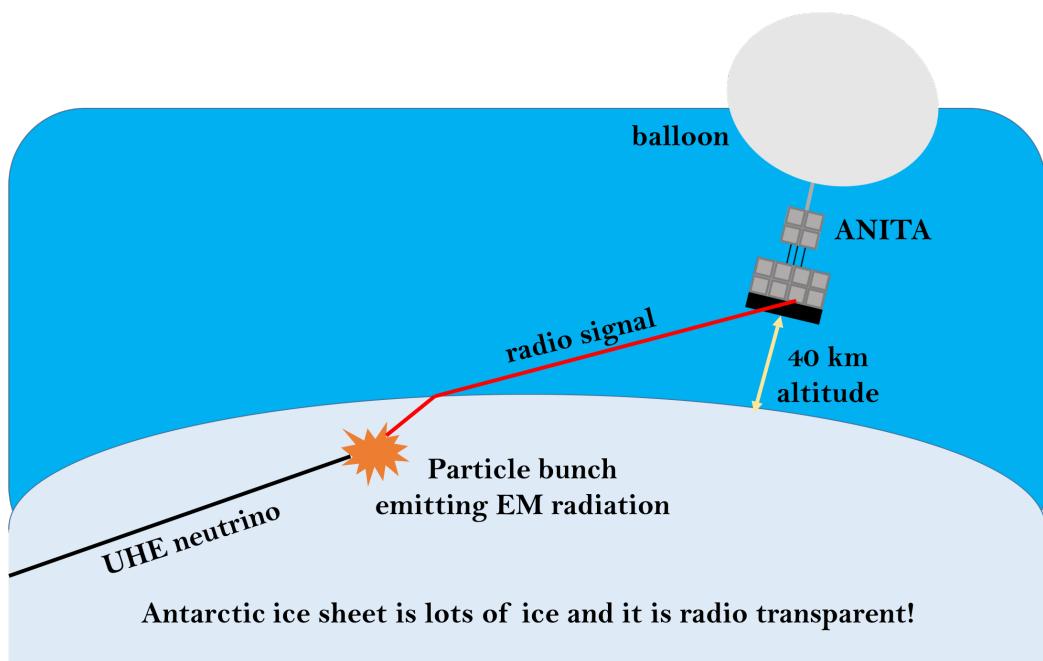


Figure 1.8: Concept of detection of UHE neutrinos with ANITA.

Chapter 2

TWO-SOURCE HIGH HARMONIC GENERATION

2.1 Introduction

A common difficulty in working with extreme ultraviolet (XUV) light is the lack of efficient and broadband optics, especially beam splitters. Here, we introduce a method for generating two sources of XUV light by high harmonic generation using a phase grating. This phase grating allows for precise and stable control of the phase delay between the two generate XUV beams. This can be thought of as an inline interferometer, and it can have applications for XUV Fourier transform spectroscopy, as well as transient absorption spectroscopy.

2.2 Theory

In order to generate two ostensibly identical XUV pulses, we take advantage of a diffractive optical element known as a beam splitting grating. The idea is to introduce a periodic phase step in the beam, which will cause the beam to diffract into different orders. The phase step is designed such that the +1 and -1 orders are most efficiently populated, with an efficiency of up to 81%. These will be used to generate spatially separated harmonics.

A key advantage to this method is that it allows for control of the relative phase between the two sources generating harmonics. By translating the grating relative to the beam, the relative phase difference between the +1 and -1 orders goes from -2π to 2π . This can be seen in the phase of the electric field at the focus:

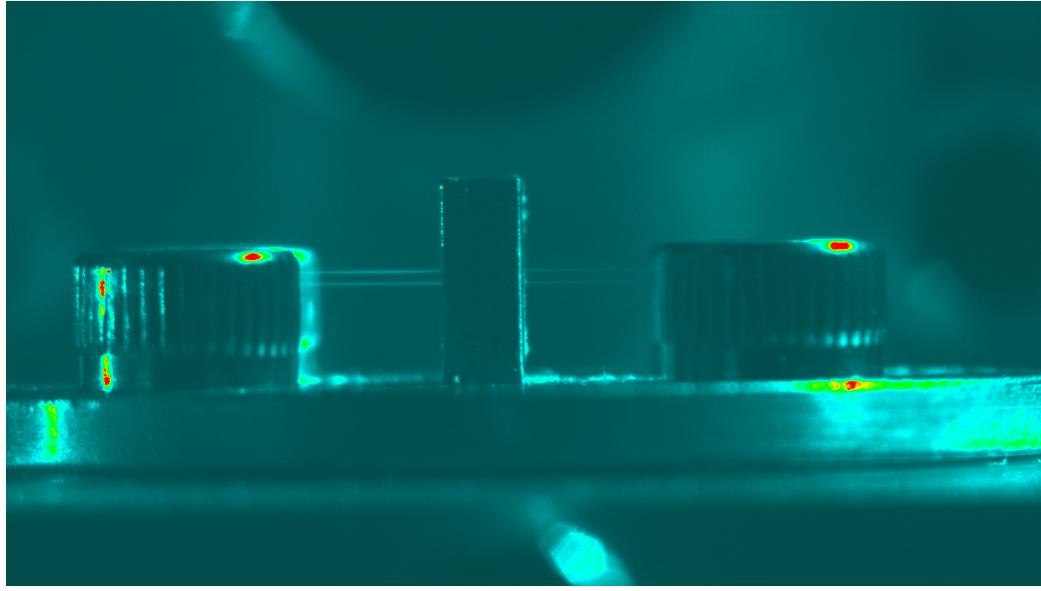


Figure 2.1: Camera image of two sources generating a filament in a gas cell. Image was taken while chamber was vented and at ambient pressure.

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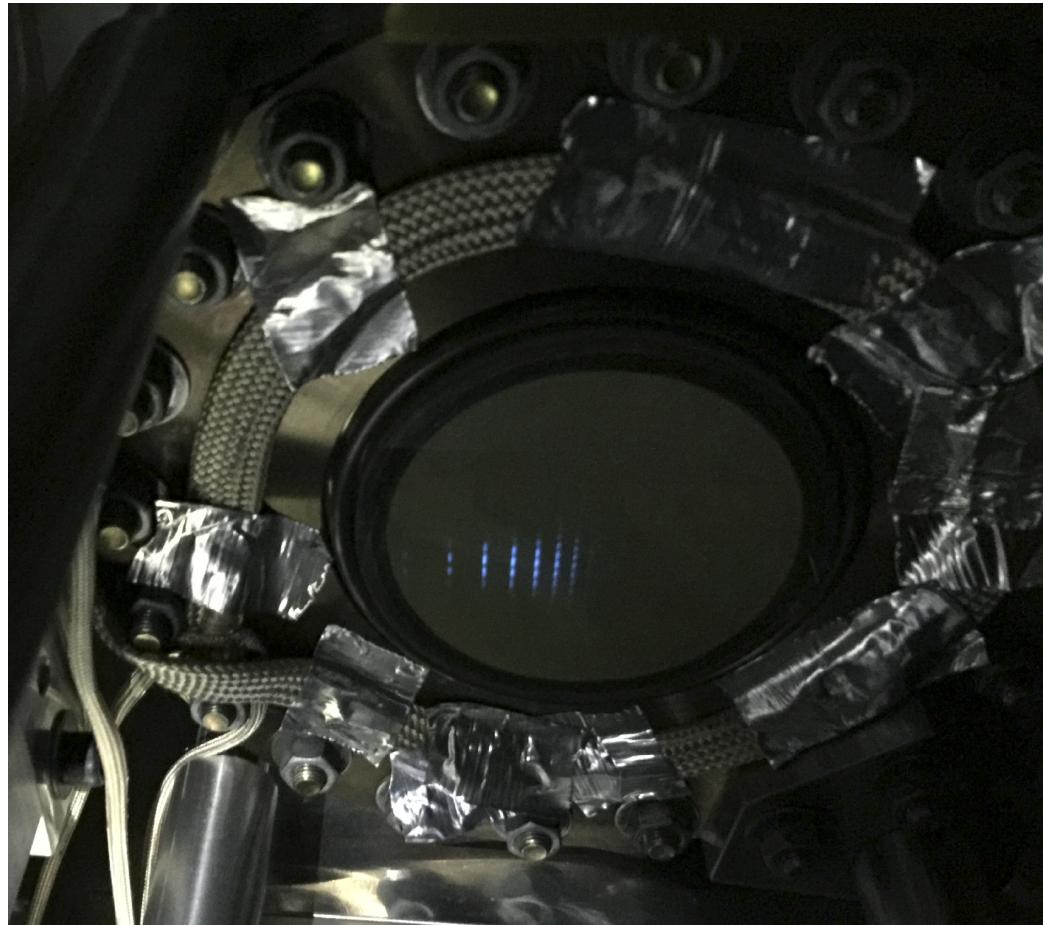


Figure 2.2: Camera image of the output of the phosphor screen. Harmonics are visible by eye.

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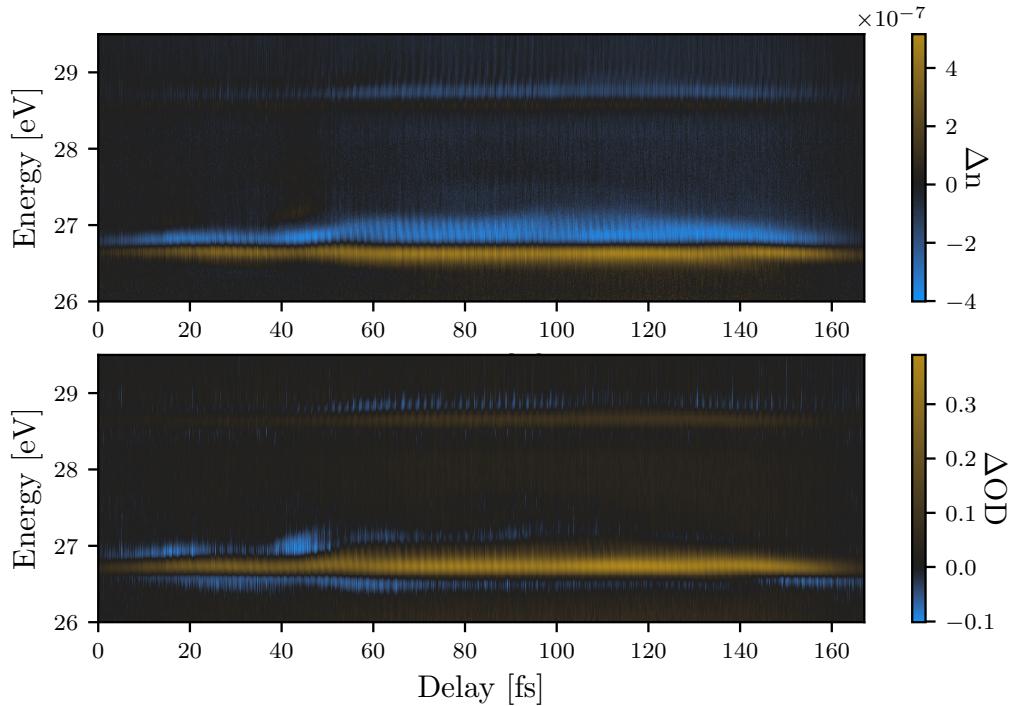


Figure 2.3: Camera image of two sources generating a filament in a gas cell. Image was taken while chamber was vented and at ambient pressure.

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Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellen-

tesque, augue quis sagittis posuere, turpis lacinia congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacinia commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacinia. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacinia vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacinia.

Appendix A

ANITA DATA STRUCTURE

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi.

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetur eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetur tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris port-

titor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

Etiam ac leo a risus tristique nonummy. Donec dignissim tincidunt nulla. Vestibulum rhoncus molestie odio. Sed lobortis, justo et pretium lobortis, mauris turpis condimentum augue, nec ultricies nibh arcu pretium enim. Nunc purus neque, placerat id, imperdiet sed, pellentesque nec, nisl. Vestibulum imperdiet neque non sem accumsan laoreet. In hac habitasse platea dictumst. Etiam condimentum facilisis libero. Suspendisse in elit quis nisl aliquam dapibus. Pellentesque auctor sapien. Sed egestas sapien nec lectus. Pellentesque vel dui vel neque bibendum viverra. Aliquam porttitor nisl nec pede. Proin mattis libero vel turpis. Donec rutrum mauris et libero. Proin euismod porta felis. Nam lobortis, metus quis elementum commodo, nunc lectus elementum mauris, eget vulputate ligula tellus eu neque. Vivamus eu dolor.

Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo. Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est. Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec id mauris. Morbi molestie justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi. In hac habitasse platea dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

Curabitur tellus magna, porttitor a, commodo a, commodo in, tortor. Donec interdum. Praesent scelerisque. Maecenas posuere sodales odio. Vivamus metus lacus, varius quis, imperdiet quis, rhoncus a, turpis. Etiam ligula arcu, elementum a, venenatis quis, sollicitudin sed, metus. Donec nunc pede, tincidunt in, venenatis vitae, faucibus vel, nibh. Pellentesque wisi. Nullam malesuada. Morbi ut tellus ut pede tincidunt porta. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam congue neque id dolor.

Donec et nisl at wisi luctus bibendum. Nam interdum tellus ac libero. Sed sem justo, laoreet vitae, fringilla at, adipiscing ut, nibh. Maecenas non sem quis tortor eleifend fermentum. Etiam id tortor ac mauris porta vulputate. Integer porta neque vitae massa. Maecenas tempus libero a libero posuere dictum. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Aenean quis mauris sed elit commodo placerat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Vivamus rhoncus tincidunt libero. Etiam elementum pretium justo. Vivamus est. Morbi a tellus eget pede tristique commodo. Nulla nisl. Vestibulum sed nisl eu sapien cursus rutrum.

Nulla non mauris vitae wisi posuere convallis. Sed eu nulla nec eros scelerisque pharetra. Nullam varius. Etiam dignissim elementum metus. Vestibulum faucibus, metus sit amet mattis rhoncus, sapien dui laoreet odio, nec ultricies nibh augue a enim. Fusce in ligula. Quisque at magna et nulla commodo consequat. Proin accumsan imperdiet sem. Nunc porta. Donec feugiat mi at justo. Phasellus facilisis ipsum quis ante. In ac elit eget ipsum pharetra faucibus. Maecenas viverra nulla in massa.

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Etiam pede massa, dapibus vitae, rhoncus in, placerat posuere, odio. Vestibulum luc-

tus commodo lacus. Morbi lacus dui, tempor sed, euismod eget, condimentum at, tortor. Phasellus aliquet odio ac lacus tempor faucibus. Praesent sed sem. Praesent iaculis. Cras rhoncus tellus sed justo ullamcorper sagittis. Donec quis orci. Sed ut tortor quis tellus euismod tincidunt. Suspendisse congue nisl eu elit. Aliquam tortor diam, tempus id, tristique eget, sodales vel, nulla. Praesent tellus mi, condimentum sed, viverra at, consectetur quis, lectus. In auctor vehicula orci. Sed pede sapien, euismod in, suscipit in, pharetra placerat, metus. Vivamus commodo dui non odio. Donec et felis.

Etiam suscipit aliquam arcu. Aliquam sit amet est ac purus bibendum congue. Sed in eros. Morbi non orci. Pellentesque mattis lacinia elit. Fusce molestie velit in ligula. Nullam et orci vitae nibh vulputate auctor. Aliquam eget purus. Nulla auctor wisi sed ipsum. Morbi porttitor tellus ac enim. Fusce ornare. Proin ipsum enim, tincidunt in, ornare venenatis, molestie a, augue. Donec vel pede in lacus sagittis porta. Sed hendrerit ipsum quis nisl. Suspendisse quis massa ac nibh pretium cursus. Sed sodales. Nam eu neque quis pede dignissim ornare. Maecenas eu purus ac urna tincidunt congue.

Donec et nisl id sapien blandit mattis. Aenean dictum odio sit amet risus. Morbi purus. Nulla a est sit amet purus venenatis iaculis. Vivamus viverra purus vel magna. Donec in justo sed odio malesuada dapibus. Nunc ultrices aliquam nunc. Vivamus facilisis pellentesque velit. Nulla nunc velit, vulputate dapibus, vulputate id, mattis ac, justo. Nam mattis elit dapibus purus. Quisque enim risus, congue non, elementum ut, mattis quis, sem. Quisque elit.

Maecenas non massa. Vestibulum pharetra nulla at lorem. Duis quis quam id lacus dapibus interdum. Nulla lorem. Donec ut ante quis dolor bibendum condimentum. Etiam egestas tortor vitae lacus. Praesent cursus. Mauris bibendum pede at elit. Morbi et felis a lectus interdum facilisis. Sed suscipit gravida turpis. Nulla at lectus. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Praesent nonummy luctus nibh. Proin turpis nunc, congue eu, egestas ut, fringilla at, tellus. In hac habitasse platea dictumst.

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ipsum. Suspendisse condimentum, tortor at egestas posuere, neque metus tempor orci, et tincidunt urna nunc a purus. Sed facilisis blandit tellus. Nunc risus sem, suscipit nec, eleifend quis, cursus quis, libero. Curabitur et dolor. Sed vitae sem. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Maecenas ante. Duis ullamcorper enim. Donec tristique enim eu leo. Nullam molestie elit eu dolor. Nullam bibendum, turpis vitae tristique gravida, quam sapien tempor lectus, quis pretium tellus purus ac quam. Nulla facilisi.

Duis aliquet dui in est. Donec eget est. Nunc lectus odio, varius at, fermentum in, accumsan non, enim. Aliquam erat volutpat. Proin sit amet nulla ut eros consectetur cursus. Phasellus dapibus aliquam justo. Nunc laoreet. Donec consequat placerat magna. Duis pretium tincidunt justo. Sed sollicitudin vestibulum quam. Nam quis ligula. Vivamus at metus. Etiam imperdiet imperdiet pede. Aenean turpis. Fusce augue velit, scelerisque sollicitudin, dictum vitae, tempor et, pede. Donec wisi sapien, feugiat in, fermentum ut, sollicitudin adipiscing, metus.

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Donec molestie, magna ut luctus ultrices, tellus arcu nonummy velit, sit amet pulvinar elit justo et mauris. In pede. Maecenas euismod elit eu erat. Aliquam augue wisi, facilisis congue, suscipit in, adipiscing et, ante. In justo. Cras lobortis neque ac ipsum. Nunc fermentum massa at ante. Donec orci tortor, egestas sit amet, ultrices eget, venenatis eget, mi. Maecenas vehicula leo semper est. Mauris vel metus. Aliquam erat volutpat. In rhoncus sapien ac tellus. Pellentesque ligula.

Cras dapibus, augue quis scelerisque ultricies, felis dolor placerat sem, id porta velit odio eu elit. Aenean interdum nibh sed wisi. Praesent sollicitudin vulputate dui. Praesent iaculis viverra augue. Quisque in libero. Aenean gravida lorem vitae sem ullamcorper

cursus. Nunc adipiscing rutrum ante. Nunc ipsum massa, faucibus sit amet, viverra vel, elementum semper, orci. Cras eros sem, vulputate et, tincidunt id, ultrices eget, magna. Nulla varius ornare odio. Donec accumsan mauris sit amet augue. Sed ligula lacus, laoreet non, aliquam sit amet, iaculis tempor, lorem. Suspendisse eros. Nam porta, leo sed congue tempor, felis est ultrices eros, id mattis velit felis non metus. Curabitur vitae elit non mauris varius pretium. Aenean lacus sem, tincidunt ut, consequat quis, porta vitae, turpis. Nullam laoreet fermentum urna. Proin iaculis lectus.

Sed mattis, erat sit amet gravida malesuada, elit augue egestas diam, tempus scelerisque nunc nisl vitae libero. Sed consequat feugiat massa. Nunc porta, eros in eleifend varius, erat leo rutrum dui, non convallis lectus orci ut nibh. Sed lorem massa, nonummy quis, egestas id, condimentum at, nisl. Maecenas at nibh. Aliquam et augue at nunc pellentesque ullamcorper. Duis nisl nibh, laoreet suscipit, convallis ut, rutrum id, enim. Phasellus odio. Nulla nulla elit, molestie non, scelerisque at, vestibulum eu, nulla. Ut odio nisl, facilisis id, mollis et, scelerisque nec, enim. Aenean sem leo, pellentesque sit amet, scelerisque sit amet, vehicula pellentesque, sapien.

BIBLIOGRAPHY