The Adolph C. and Mary Sprague

MILLER INSTITUTE

Newsletter Spring 2017

Icy Ocean Worlds

Miller Fellow Focus: Doug Hemingway

Understanding our home planet—and whether there may be life elsewhere in the Universe—depends on developing an understanding of planetary bodies in general, their abundance, their differences and similarities, and their potential for habitability. Within the last decade, planetary astronomers have learned that most stars host their own system of planets, some fraction of which are in what is called the "habitable zone", where warming from the host star permits the existence of liquid water on the surface. But is liquid water on the *surface* an absolute requirement for habitability?

Dobotic exploration within our own **N**solar system has revealed an intriguing class of bodies known as icy ocean worlds, some of which contain more liguid water beneath their ice shells than is found in all the Earth's oceans. Several of the moons of Jupiter and Saturn, including Europa, Ganymede, Titan, and Enceladus, appear to belong to this group, and recent evidence has suggested that even Pluto might belong to this group as well. Could life also emerge within these dark subsurface oceans? Might these worlds in our own solar system present our most promising opportunity for discovering life beyond Earth? More basically, how do we know the extent of these internal oceans, or that they are even present at all? Are these oceans a persistent or transient phenomenon? What are the characteristics of the overlying ice shells? Is there hope for gaining access to and studying these subsurface oceans?



Dart of my doctoral work, and part of my ongoing work as a Miller Fellow, where I am hosted by Michael Manga in the Department of Earth & Planetary Science, has involved addressing these and other related questions through a combination of geophysical modelling and spacecraft observations. In particular, measurements of the shapes and gravity fields of these bodies can place constraints on their interior structures, and in turn, provide clues about their formation and evolution. Although we have yet to send dedicated orbiters—the best way to measure the figure and gravity field precisely—to any of the outer solar system's many icy moons, spacecraft like Galileo (orbiting Jupiter) and Cassini (orbiting Saturn) have performed numerous flybys, gradually accumulating enough information to provide basic constraints. Shape determination typically involves combining a series of image-based limb profiles (where the illuminated edge of the body

CONTINUED ON PAGE 6 >

Inside this edition:

Miller Fellow Focus	, 6, /
Call for Applications/Nominations	2-3
Miller Fellowship Awardees	4-5
In the News	7-8
Birth Announcements	8

Call for Nominations

Miller Research Fellowship Nominations Deadline: Sunday, September 10, 2017

Miller Research Professorship Applications Deadline: Thursday, September 14, 2017

Visiting Miller Professorship Departmental Nominations Deadline: Friday, September 15, 2017

For more information on all our programs online: miller.berkeley.edu & on PAGES 2 & 3.

"[My] visit has been a tremendously rich experience, both from a human and a scientific point of view. I learned a lot of new science, and filled my research agenda for the coming years. I have no words to thank enough the support of the Miller Institute and its wonderful staff that made this experience possible and so profitable."

- Jean-Philippe Vert

Visiting Miller Professor 2016, Director of the Centre for Computational Biology at Mines ParisTech, Professor at the Department of Mathematics and their Applications at the École Normale Supérieure.



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The Adolph C. and Mary Sprague Miller Institute for Basic Research in Science

Call for Miller Professor Applications

Online Application Deadline: Thursday, September 14, 2017

Miller Research Professorship AY 2018-2019

The Miller Professorship program is looking with a view to the future in announcing the call for applications for terms in 2018-2019. The goal is to accommodate a greater range of campus faculty to participate in the vibrant Miller community. The objective of the Miller Professorship program is to provide opportunities for faculty to pursue new research directions on the Berkeley campus. For some, this may best be enabled by taking time off from teaching. This continues to be an option. For others, the teaching obligations are critical to maintaining campus academic programs. There is thus a second option for Miller Professors, allowing the continuation of campus service and teaching. Funds will be distributed differently depending upon the choice selected. Details of the terms and the application procedure are posted on the Miller Institute website. The primary purpose of the Miller Professorship program and the evaluation criteria will continue to be research excellence. Applicants are encouraged to describe their interest in participating in the Miller Institute community.

Beginning May 2017 applications will be accepted from UC Berkeley faculty only for terms in the 2018-19 academic year. The purpose of the Professorship is to allow members of the faculty to pursue new research directions on the Berkeley campus. Appointees are encouraged to follow promising leads that may develop in the course of their research.

Applications are judged competitively and are due by Thursday, September 14, 2017. It is anticipated that between five to eight awards will be made.

Call for Visiting Miller Professor Nominations

Online Nomination Deadline: Friday, September 15, 2017

Visiting Miller Research Professorship AY 2018-2019

The Advisory Board of the Miller Institute for Basic Research in Science invites Berkeley faculty to submit online departmental nominations for Visiting Miller Research Professorships and the Gabor A. and Judith K. Somorjai Visiting Miller Professorship Award for terms in Fall 2018 or Spring 2019. The purpose of these Visiting Miller Professorships is to bring promising or eminent scientists to the Berkeley campus on a short-term basis for collaborative research interactions. It is required that awardees are in residence at Berkeley during their appointment term. Faculty members or research scientists from any place in the world are eligible to be considered for sponsorship. Non-US citizens must be eligible for J-1 Scholar visa status. Faculty members at other UC campuses are eligible to be nominated for this program. The Miller Institute, as the sponsor and administrative department, will extend an invitation after advising the department of its selection.

Any questions regarding this program may be directed to the Institute's office by phone at (510) 642-4088 or by emailing the Miller Institute.

:: Nomination & Application details: miller.berkeley.edu

:: Questions? Kathryn Day: 510-642-4088 | millerinstitute@berkeley.edu





Call for Nominations: Miller Research Fellowship



Nomination Deadline: Sunday, September 10, 2017

The Miller Institute for Basic Research in Science invites department chairs, faculty advisors, professors and research scientists at institutions around the world to submit nominations for Miller Research Fellowships in the basic sciences. The Miller Institute seeks to discover and encourage individuals of outstanding talent, and to provide them with the opportunity to pursue their research on the Berkeley campus. Fellows are selected on the basis of their academic achievement and the promise of their scientific research. Miller Fellows also have a keen curiosity about all science and share an appreciation for an interdisciplinary experience. The Miller Institute is the administrative home department for each Miller Fellow who is hosted by an academic department on the Berkeley campus. All research is performed in the facilities provided by the UC Berkeley academic department. A list of current and former Miller Research Fellows can be found at: <u>http://miller.berkeley.edu/fellowship/members/all-mf-by-name</u>

Miller Research Fellowships are intended for exceptional young scientists of great promise who have recently been awarded, or who are about to be awarded, the doctoral degree. Normally, Miller Fellows are expected to begin their Fellowship shortly after being awarded their Ph.D. A short period as a post-doctoral fellow elsewhere does not exclude eligibility. However, applicants who have already completed five years of post-doctoral experience are not eligible for nomination. A nominee cannot hold a paid or unpaid position on the Berkeley campus at the time of nomination or throughout the competition and award cycle. Nominees who are non-US citizens must show eligibility for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship. Non-US citizens will be required to prove English language proficiency prior to award. The Miller Institute does not support H1B visa status. The Fellowship term must commence between July 1 and September 1, 2018. Eligible nominees will be invited by email by the Institute to apply for the Fellowship after the nomination has been reviwed. Direct applications and self-nominations are not accepted.

*All nominations must be submitted using the Online Nomination System at: http://miller.berkeley.edu

Nominators will need the following required information to complete the online nomination process:

- Nominee's complete <u>full and legal name</u> (do not use nicknames)
- Nominee's current institution
- Nominee's complete, current, and active E-mail address that will be valid through March 2018, current mailing address with postal code and telephone number
- Nominee's Ph.D. Institution and (expected) Date of Ph.D. (month & year required)
- Letter of recommendation and judgment of nominee's promise by the nominator (saved in PDF format). Letter must be specific to the Miller Fellowship, have a current date, and be on institutional letterhead. The Executive Committee finds it helpful in the recommendation letter to have the candidate compared with others at a similar stage in their development.
- Nominator's current active E-mail address, title, and professional mailing address (include zip code/campus mail code)

The Institute provides a stipend of \$65,000 with annual 2% increases and an annual research fund of \$10,000, for total initial compensation of \$75,000. There is provision for travel to Berkeley for Miller Fellows and their immediate families and a maximum allowance of \$3,000 for moving personal belongings. Benefits, including medical, dental, vision and life insurance are provided with a modest contribution from the Miller Fellow. All University of California postdocs are represented by the UAW. Fellowships are awarded for three years, generally beginning August 1, 2018 and ending July 31, 2021. Approximately eight to ten Fellowships are awarded each year. Candidates will be notified of the results of the competition starting in mid-December, and a general announcement of the awards will be made in the spring.

We are grateful for your thoughtful participation in this process and hope that you regard the time you may devote to this effort justified by the contribution you will be making to the careers of distinguished young scientists.

MILLER INSTITUTE FOR BASIC RESEARCH IN SCIENCE

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Miller Research Fellowship Awardees 2017-2020

The Miller Institute is pleased to introduce the 2017-2020 Miller Research Fellows. Each year, the Miller Institute seeks to discover individuals of outstanding talent and to bring to Berkeley young scholars of great promise. Candidates are nominated for these awards and are selected on the basis of their academic achievement and the potential of their scientific research. The Fellows will be working with Berkeley faculty hosts for a three-year term beginning in the 2017 academic year. A full list of all past and present Miller Fellows is available on our website.

Nikhil Bhatla

Ph.D. - MIT Berkeley Dept. - HWNI / MCB Faculty Host: Hillel Adesnik



For millennia, humans have contemplated how it is that we are conscious, that is, how we have

subjective experience or qualia. Blindsight is a neurological condition in which patients lose the conscious experience of seeing but can still accurately locate visual stimuli and guess their properties. Blindsight is caused by damage to primary visual cortex in the human brain, and by manipulating visual cortex function in the mouse brain, I am working on establishing a mouse model of blindsight. Such a model will enable identification of neural circuits that contribute specifically to the conscious component of vision, and ultimately to development of a general theory of why some neural circuits support experience and others do not.

Cara Brook

Ph.D. - Princeton Berkeley Dept. - Integrative Biology / PMB Faculty Host: Mike Boots & Britt Glaunsinger

Bats are the purported reservoir hosts for several of the world's most virulent emerg-

ing human diseases, including Hendra and Nipah henipaviruses, Ebola and Marburg filoviruses, and SARS and MERS coronaviruses. Bats appear to host these viruses without experiencing extensive morbidity or mortality, leading researchers to ask whether bats might be uniquely adapted for their roles as pathogen hosts. I bridge field ecology, cellular immunology, and quantitative epidemiology to investigate this question, at both within-host and population levels, with a particular focus on viral infections in Madagascar fruit bats.

 Private donations are becoming an increasingly significant resource for the Miller Institute. Your personal investment in support of the future of the Miller Institute will be greatly appreciated. Visit our: "Make a Gift" page at: miller.berkeley.edu/gift

Thibault de Poyferre de Cere

Ph.D. - École Normale Supérieure Berkeley Dept. - Mathematics Faculty Host: Daniel Tataru



I study partial differential equations arising from fluid dynamics and oceanography. I focus on finding and studying models for water waves near a shore.

Amy Goldberg

Ph.D. - Stanford Berkeley Dept. - Integrative Biology / Statistics Faculty Host: Rasmus Nielsen



Past population migrations and expansions

greatly impact modern human genetic and physical variation, as well as disease risk. My research develops and applies quantitative methods to understand the dynamic relationship between humans, their cultures, and their environments during the last tens of thousands of years. Towards this goal, I leverage modern and ancient genetic data, interpreted in the context of paleoenviornmental and archeological records.

Rebecca Jensen-Clem Ph.D.-CalTech Berkeley Dept. - Astronomy Faculty Host: James Graham

The last twenty years of astronomy have seen a revolution in planetary science, with more

than 3000 extra-solar planets discovered orbiting nearby stars. I'm interested in developing new technologies for directly imaging and characterizing the atmospheres of these other worlds.



Berkeley

Louis Kang

Ph.D. - University of Pennsylvania Berkeley Dept. - Physics / HWNI Faculty Host: Michael DeWeese

Human cognition ultimately emerges from sophisticated computations performed by networks of neurons. I use and

develop tools from theoretical physics and applied mathematics to investigate how our brains make sense of and respond to our dynamic environments. Theoretical neuroscience forms one part of my overall mission to better understand human biology and pathology through quantitative analysis.

Farnaz Niroui Ph.D. - MIT Berkeley Dept. - MSE / Chemistry Faculty Host: Paul Alivisatos



Unique properties and phenomena emerge at the nanoscale that can lead to unexplored

scientific and technological paradigms. Exploring these opportunities at the few-nanometer regime requires unprecedented precision, resolution and control, not readily feasible through conventional techniques. Working at the interface of device physics, nanofabrication, and materials science, my research aims to study, manipulate and engineer nanoscale devices and systems with unique functionalities.

Grant Remmen

Ph.D. - CalTech Berkeley Dept. - Physics Faculty Host: Yasunori Nomura

The quests to understand the properties of black holes, the fundamental nature of

spacetime, and the high-energy behavior of gravity have been drivers of immense progress in theoretical physics. My research interests lie at the nexus of quantum field theory, quantum gravity, general relativity, cosmology, and particle physics. Important open problems on which I work include using effective field theory techniques to address fieldtheoretic questions in quantum gravity, such as characterizing the possible laws of low-energy physics permitted by quantum gravity, including quantum corrections to the Einstein equations. My work also includes investigating the relationship that connects spacetime geometry and gravity with quantum entanglement and information, as well as research in theoretical cosmology.

Sho Takatori Ph.D. - CalTech Berkeley Dept. - Bioengineering Faculty Host: Dan Fletcher



A core feature of many living systems is their ability to move, to self-propel, to

be active. From bird flocks to bacteria swarms, to even cytoskeletal networks, "active matter" systems exhibit collective and emergent dynamics owing to their constituents' ability to convert chemical fuel into mechanical activity. I combine experimental and computational methods to demonstrate how activity imparts new behaviors to soft living materials that explain a variety of nonequilibrium phenomena, including intracellular protein transport and the complete loss of shear viscosity in fluid suspensions.

Alexander Turner

Ph.D. - Harvard Berkeley Dept. - Chemistry / EPS Faculty Host: Ron Cohen & Inez Fung



My primary research objective is to improve our understanding of the carbon

cycle through inverse modeling. Specifically, I'm interested in quantifying greenhouse gas fluxes and understanding the physical processes driving them. To reach this end, I use atmospheric observations from satellites, aircraft, and surface networks and interpret them in the context of atmospheric models (e.g., chemical transport models and particle dispersion models.)

Peter Walters

Ph.D. - University of Illinois Berkeley Dept. - Chemistry Faculty Host: Eric Neuscamman

Both experimentation and simulation are crucial aspects of science. As the nature of



experimentation is constantly evolving and changing, so too must the nature of simulation evolve and change. With recent developments in ultrafast experimental techniques it is now possible to probe the motions of the molecule's electrons. With this in mind, my research focuses on developing computational techniques for accurately simulating the motions of a molecule's electrons.



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contrasts with the black of deep space behind it) into a sparse, but global, elevation map. Gravity determination, meanwhile, involves precise Earth-based radio Doppler tracking of the spacecraft during close gravitational encounters with the body of interest.

Babout their interiors? Due to their rotation, planetary bodies experience centrifugal flattening (like a squashed basketball), and moons that are tidally locked (always keeping the same side facing their parent planet) experience permanent tidal elongation (into a football-like shape) along the axis connecting the two bodies. The combined effect of rotational flattening and tidal elongation produces a characteristic (squashed football-like) figure (**Figure** 1), and the redistribution of mass associated with this deviation from spherical symmetry leads to corresponding asymmetries in the gravitational field.



Figure 1. Synchronous (tidally-locked) moons experience both centrifugal flattening and tidal elongation, leading to a characteristic triaxial ellipsoidal figure (like a squashed football), and corresponding asymmetries in the gravitational field. The tidal/rotational deformation is greatest for bodies with uniform density and subtler for strongly differentiated bodies (bodies with their denser materials more concentrated toward their centers).

The useful thing about these asymmetries is that their magnitudes depend on the interior structure—the more the body's mass is concentrated toward its center, the subtler the deformation and the smaller the asymmetries. Measurements of either shape or gravity, then, can in general be used to constrain interior structure. All of this, however, assumes that these bodies are weak so that they behave essentially like fluids on geologic timescales—if their cold exteriors are sufficiently strong, their shapes (and gravity fields) may deviate from the expectation for a relaxed fluid body, complicating interpretation of the observations.

Consider Enceladus, as a case in point. Enceladus is just a tiny (~250 km radius) moon of Saturn, and yet it is one of the most geologically active bodies in the solar system, with a series of ongoing eruptions sending salt- and organic-rich water ice out into space, with the particles extending hundreds of kilometers above the moon's south pole, and some even going into orbit around Saturn. The activity is powered mainly by tidal heating: time-varying gravitational interactions with Saturn and another moon, Dione, causing the interior to flex and deform back and forth with each orbital cycle, dissipating considerable heat within. The eruptions make Enceladus one of the most compelling exploration targets in the solar system because they suggest the presence of a (possibly habitable) subsurface liquid water reservoir and because they naturally bring some of that material to the surface and out into space, making sample collection a much more realistic goal.

Broadly speaking, its shape and gravity indicate that much of Enceladus' mass is concentrated toward its center (i.e., it likely has a rocky core surrounded by an envelope of H₂O), but more detailed interpretation has been challenging. Ironically, this is in part because of the high quality of the measurements-they are sufficiently precise that we were forced to abandon the usual simplifying assumption of a fully relaxed fluid interior. Furthermore, the shape and gravity field do not immediately appear to be consistent with one another. Large topographic depressions, for example, should correspond with major local reductions in gravity (due to the missing mass), and yet this is not observed. Instead, the gravity appears nearly as it would if there were no such topographic depressions—something in the interior must be offsetting the effect of the irregular topography. The most straightforward way of systematically offsetting the effect the topography has on the gravity is if the ice shell is essentially floating (like an iceberg) on a higher density, lower viscosity fluid—that is, a subsurface ocean (Figure 2). Our conclusion that Enceladus hosts an internal liquid water ocean was subsequently confirmed by an independent analysis of the moon's rotational state: Enceladus wobbles back and forth more than it possibly could if there were no internal ocean to decouple the deep rocky core from the outer icy shell.



Figure 2. (A) For a self-supporting crust, topographic highs and lows should give rise to strong variations in local gravity (because of the excess or deficit in mass). (B) If the crust is instead floating on a higher density, lower viscosity fluid at depth, the relief at the base of the crust will be inverted from the surface topography, nearly cancelling out the effect on the gravity signal.



A lthough we are now confident that an internal global liquid water ocean must be present (**Figure 3**), many important questions remain. Has the ocean been present for billions of years, or do we happen to be seeing Enceladus at a special time? Given the rapid cooling rate, how can the ocean keep from freezing solid? How do the eruptions persist given the tendency for the conduits to close due to freezing and relaxation under the weight of the surrounding ice? Why is all the eruptive activity concentrated at the south pole? Part of my ongoing work as a Miller Fellow involves addressing some of these questions by modeling the structure of the ice shell (the thinner the shell, the more quickly it sheds heat), how much of the observed structure can be explained by tidal heating, and whether or not the current configuration could be in equilibrium.



Figure 3: Approximate interior structure of Saturn's small (~500 km diameter) moon Enceladus (to scale). Its low density rocky core is surrounded by an envelope of H_2O consisting of a subsurface liquid water ocean and an ice shell of variable thickness (thinnest at the south pole—the site of the ongoing eruptions).

Much work remains to be done to understand the inner workings and history of Enceladus, and what we learn will help us prepare for future exploration of other icy ocean worlds like Europa (the target of NASA's next major mission to the outer solar system). With a sufficiently clear understanding of these fascinating little worlds, we can plan for the missions (possibly including sample return) that may one day deliver the first direct evidence of extraterrestrial life.

Doug Hemingway grew up in London, Ontario, Canada, and received his Bachelor of Applied Science in Systems Design Engineering from the University of Waterloo. After working for seven years as a space robotics engineer, helping to build the International Space Station and developing technology for in-orbit robotic satellite serving, he returned to academia, completing an M.Sc. at the International Space University in Strasbourg, France, and then finally a Ph.D. in Planetary Geophysics from the University of California Santa Cruz, under the joint supervision of Francis Nimmo and Ian Garrick-Bethell. Doug's main research interests include planetary interiors in general, planetary magnetism, and space weathering. Doug enjoys exploring the world, hiking, Ultimate Frisbee, and chocolate.

Contact: djheming@berkeley.edu

Call for Nominations

Miller Research Fellowship 2018-2021

Online Nomination Deadline: Sunday, Sept. 10, 2017

In the News

Michael Manga (Miller Fellow 1994 - 1996, Miller Professor 2008 - 2009) is among five UC Berkeley faculty selected as recipients of the **2017 Distinguished Teaching Award**, the campus's most prestigious honor for teaching. The Academic Senate's Committee members called out for praise Manga's blend of teaching, research and service.

Christopher Lemon (Miller Fellow 2016 - 2019) is one of the five winners of the 2017 IUPAC-Solvay International Award for Young Chemists, presented for the best Ph.D. theses in the chemical sciences, as described in 1000-word essays.

Jeffrey Townsend (Miller Fellow 2002 - 2005) received the Yale Cancer Center Translational Research Prize for his paper, "Early and multiple origins of metastatic lineages within primary tumors", published in the Proceedings of the National Academy of Sciences.

Mike Ryan (Miller Fellow 1982 - 1984) has been chosen to receive the **2017** Distinguished Animal Behaviorist Award from the Animal Behavior Society. Considered the Society 's most prestigious award, it "recognizes an outstanding career in animal behavior."

Alex Filippenko (Miller Fellow 1984 - 1986, Miller Professor 1996, 2005, Miller Senior Fellow 2017) is recognized by **Caltech's Distinguished Alumni** Award for his contributions to astronomy and his work to enhance the public's interest in science. The award is the highest honor the Institute bestows upon its graduates.

Ken Ribet (Mliller Professor 1990) has been awarded the prestigious Brouwer Medal 2017 for his contributions to number theory, in particular for the groundbreaking work in which he applies methods of algebraic geometry to number theoretical problems. This work later became of decisive importance for the proof of Fermat's Last Theorem.

Paul Alivisatos (Miller Professor 2001 - 2002) a chemist and nanotechnology pioneer was named **Fellow of National Academy of Inventors** for outstanding contributions to innovation in areas such innovative discovery and technology, significant impact on society and support and enhancement of innovation.

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> CONTINUED FROM PAGE 7 [In the News]

In the News

(see more past & current Miller Institute News: miller.berkeley.edu/ news)

Congratulations to 2017 Sloan Research Fellows:

- **Steven Sam** (Miller Fellow 2012 2015) for his promising scientific research in Mathematics.
- Xie Chen (Miller Fellow 2012 2014) for a promising scientific research in Theoretical Physics.

Two Miller Members are among the 47 new investigators chosen by the **Chan Zuckerberg Biohub** to receive up to \$1.5 million each over the next five years to conduct cutting-edge biomedical research:

- Yun Song (Miller Professor Spring 2014) to derive novel mathematical formulas and new analytical techniques for inferring demographic history from population genetic data and for increasing the power of genome-wide natural selection scans.
- Jill Banfield (Miller Professor 2006 2007) to explore the medical, industrial and ecological significance of newly found microorganisms.

Jennifer Doudna (Miller Senior Fellow 2017) has been awarded Japan Prize for invention of CRISPR gene editing.

Norman Yao (Miller Fellow 2014 - 2017) unveils new form of matter: time crystals.

Birth Announcements

Dan Rabosky (Miller Fellow 2008-2012) and his wife, Alison Davis announced the birth of their daughter, Annika Marin Rabosky, born 2/24/17.

Cassandra Hunt (Miller Fellow 2015-2018) and her husband Stefan Pabst welcomed their son, Alexander Friedrich Pabst born 3/3/17.

Online Newsletter

The Miller Institute invites you to enjoy our previous e-newsletters by visiting: http://miller.berkeley.edu/news/newsletters

The Miller Institute is "dedicated to the encouragement of creative thought and the conduct of research and investigation in the field of pure science and investigation in the field of applied science in so far as such research and investigation are deemed by the Advisory Board to offer a promising approach to fundamental problems."

For More Information:

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