National Academies, SPACE SCIENCE WEEK 2023

Spring Meeting of the Discipline Committees of the Space Studies Board

Sustainability & ADEI – Research Scientist in Higher Education Academic Setting

Early-Career Panel

CBPSS Open Session 3

March 29, 2023

Yu-Chien (Alice) Chien, Panelist

Mechanical and Aerospace Engineering, University of California, Irvine

Ajay K. Agrawal, Moderator

University of Alabama

Mohammad (Mo) Kassemi, Moderator

Case Western University

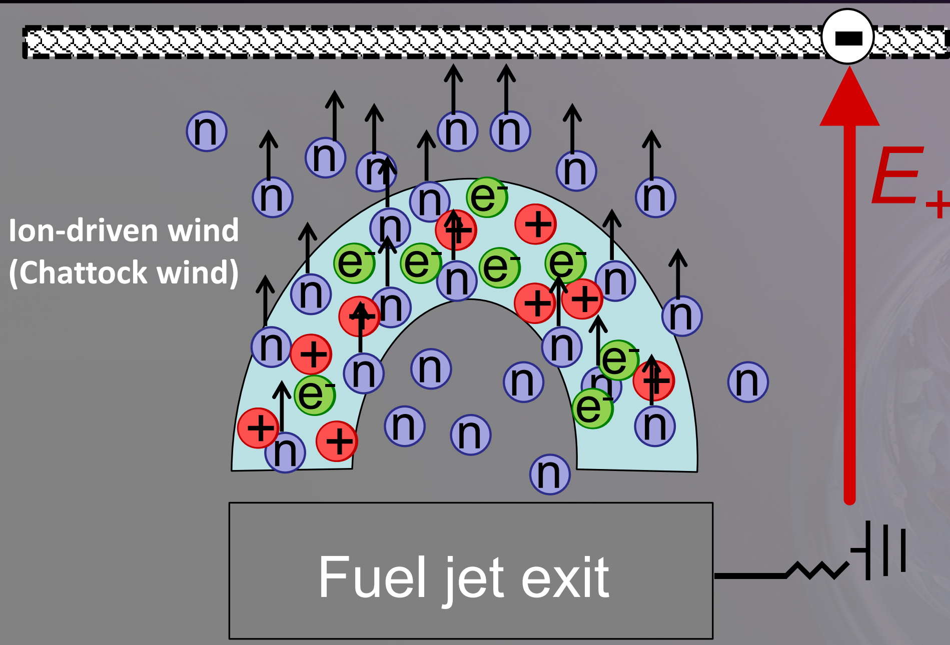
Lasers, Flames & Aerosols Research Group

Table of Content

Technical – Current Microgravity Research

Electric fields, ions and flames

- The dominant ion, H_3O^+, from the hydrocarbon flame zone is found experimentally and numerically.
- $CHO^+ + H_2O \rightarrow$ $\mathbf{H_3O^+}$ $+ CO$
- The ion transport is dominated by the **electrokinetic drift** while the ion convection and diffusion are relatively small.
- Chemi-ion driven wind is the result of the ion drift.

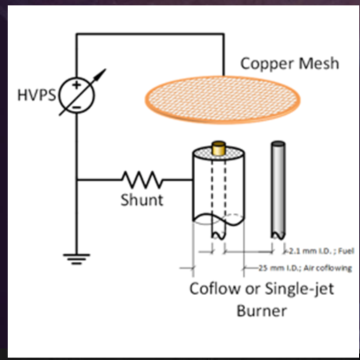


Conceptual animation

- **Ion drift velocity**: the positive ion accelerates between each collision with neutral gas molecules.
- **Induced drift velocity (bulk)**: each collision transfers the newly acquired kinetic energy to the neutral gas.
- $\overrightarrow{F_\pm} = \vec{j}/K_\pm$
  - F: body force
  - J: current density
  - K: mobility
- Electric body force is usually around 1-10 times the buoyant force on earth.

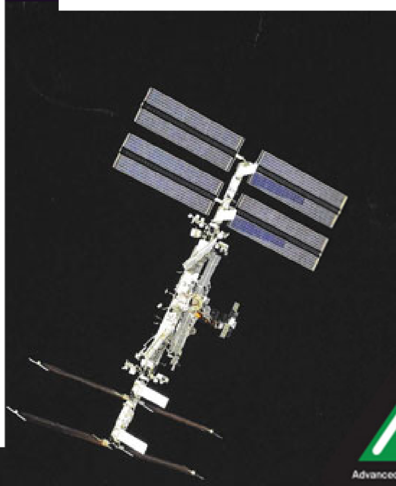
Introduction, Background and Motivation

Introduction
Advanced Combustion via Microgravity Experiment (ACME) –
E-FIELD Flames (Electric-Field Effects on Laminar Diffusion Flames)



E-FIELD Flames log of test points and flames ignited							
First round of tests, with the coflow burner, in March to May 2018 (Increment 55)							
Test period	Experiment Conditions	Fuel	Bottle	Flow Conditions	Burner	E-Field test types	E-Field Flame Tests
10 wks over 3 months	42+ conditions	CH4, C2H4	4 kinds of bottles	4+ fuel/air flow combinations	Coflow burner 1 tube diameter	5+ procedures conducted with 1 script and 2 polarities	131 pts 120 pts ignited
Second round of tests, with the gas-jet burner, in Sept.-Nov. 2018 (Increments 56-57)							
08 wks over 3 months	32+ conditions	CH4, C2H4	4 kinds of bottles	2+ fuel flow combinations	Gas-jet burner 1 tube diameter	5+ procedures conducted with 1 script and 2 polarities	120 pts 99 pts ignited
*Flames ignited is the number ignited on that day (neglecting the day change on ISS). Pre-flight and post-flight activities are generally not addressed in this report.						**Overall E-Field Flames**	**251 pts 219 pts ignited**

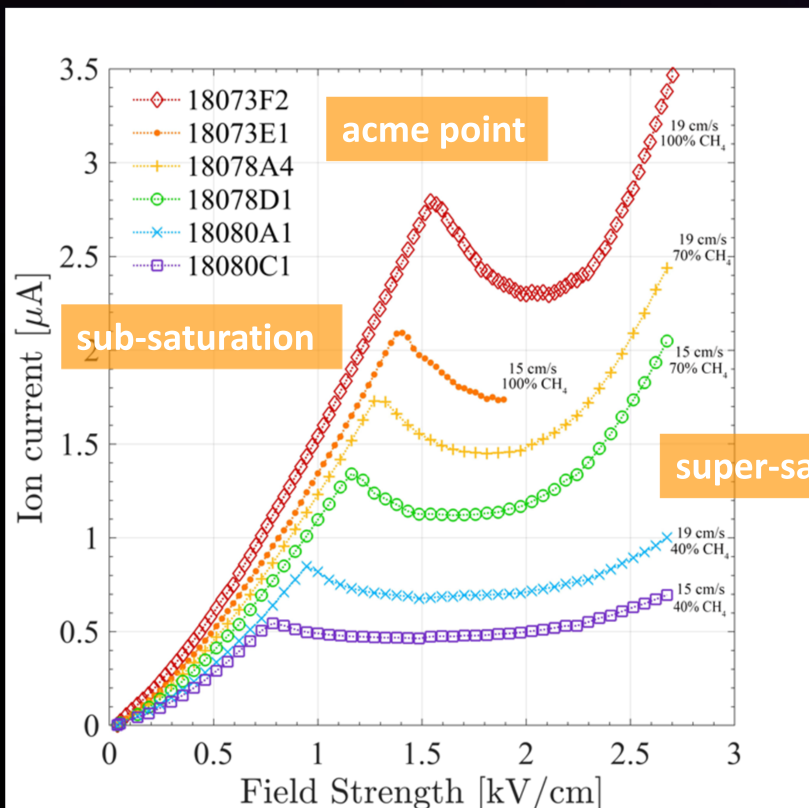
The numbers reported here only give an integrated overview of the E-FIELD Flames experiment. The actual scientific insights depend on the set of data and experiment conditions on each test day.



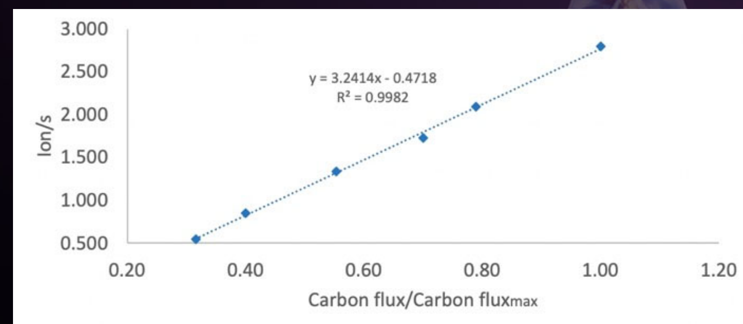
Photos taken by the Expedition 56 crew October 2018

Positive Field Data

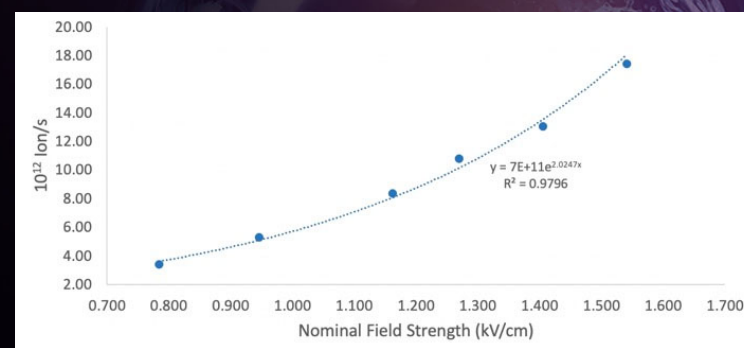
Voltage-current characteristic curve (VCC)



Conditions	100% CH_4 19 cm/s	100% CH_4 15 cm/s	70% CH_4 19 cm/s	70% CH_4 15 cm/s	40% CH_4 19 cm/s	40% CH_4 15 cm/s
Acme nominal field (kV/cm)	1.541	1.405	1.270	1.162	0.946	0.784
Acme current (μA)	2.793	2.093	1.730	1.341	0.848	0.545



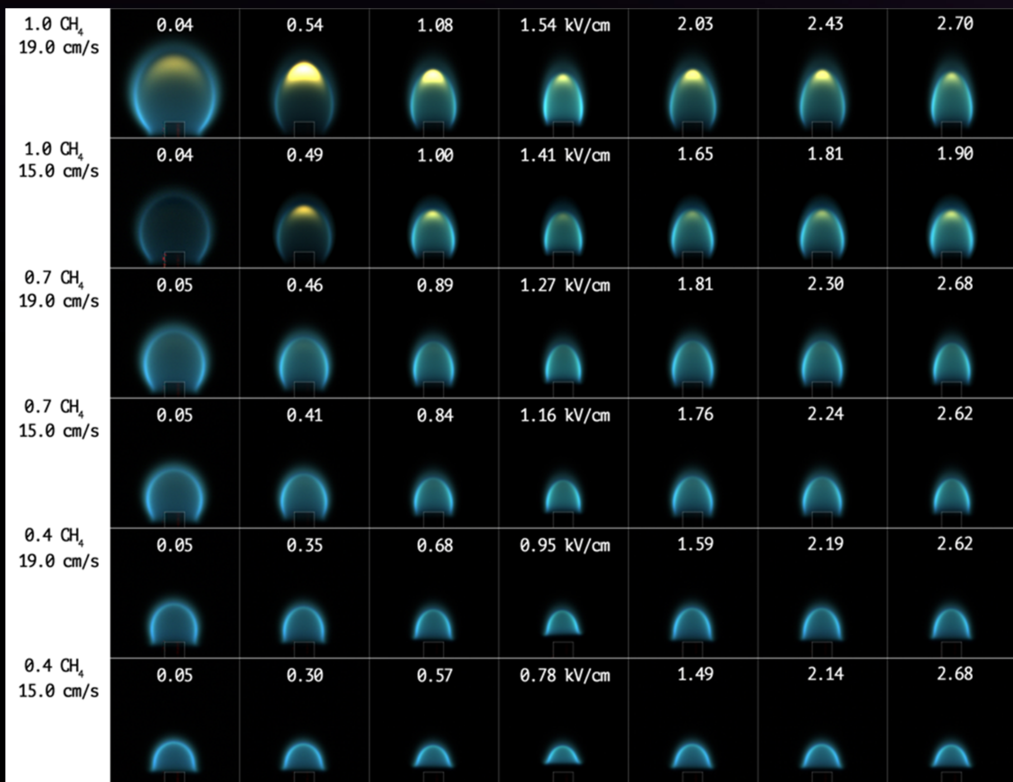
Values at acme point



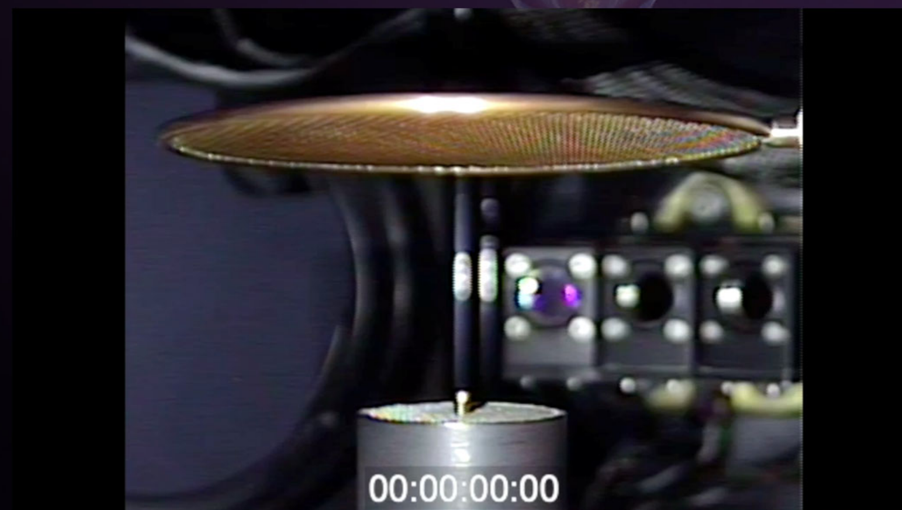
Y.-C. Chien, D. Stocker, U. Hegde and D. Dunn-Rankin,
Electric-Field Effects on Methane Coflow Flames Aboard the International Space Station (ISS): ACME E-FIELD Flames
Vol 246, Nov. 2022, Combustion and Flame (gold open access)

Positive Field Data

Overall results



sub-saturation | ***acme point*** | super-saturation



- The most compact flame always occurs at the acme point
- The video
  - 3 min 9 seconds in 35 seconds
  - Shows from 0.2 kV – 10 kV (0.04 – 2.7 kV/cm)
  - The video speed has been adjusted at different speeds

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Transient flame response – PeleLM E-FIELD Flames

This loop relies on an unsteady, fully coupled electrodynamic, fluid dynamic, and chemical kinetic system simulation.

Predicted H_3O^+ concentration is physically unreliable

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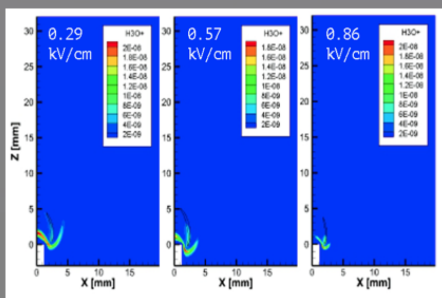

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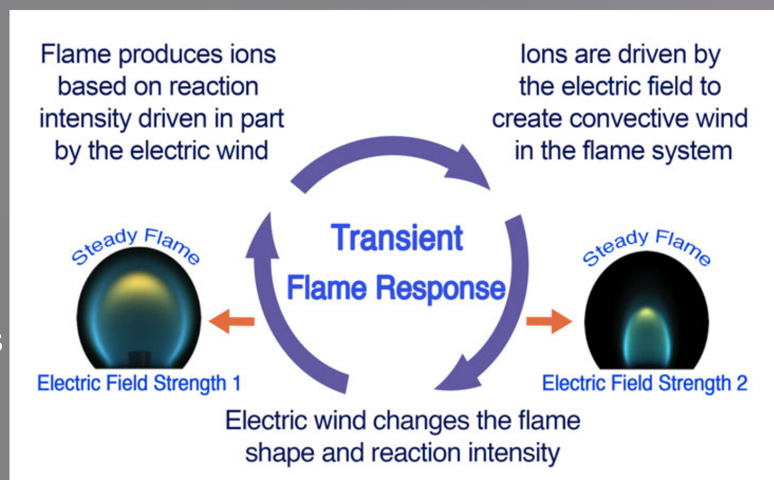
https://www.proquest.com/docview/2558090910?pq-origsite=gscholar&fromopenview=true p111, Lopez-Carama

Challenges in predicting charges species



Key features:
- solve the multi-species Navier-Stokes equations in the low-Mach number limit
- detailed chemistry and transport based on standard CHEMKIN format
- spectral deferred correction (SDC) to couple slow and fast physico-chemical processes while enforcing the low Mach velocity divergence constrain
- Embedded boundary method to include complex geometry
- AMR supported by the open-source AMReX library
- Ported to the next generation of GPU-accelerated supercomputers

Marc Day, Manager and Principal Scientist of the HPACF group, NREL
Lucas Esclapez, Computational Scientist in the HPACF group, NREL

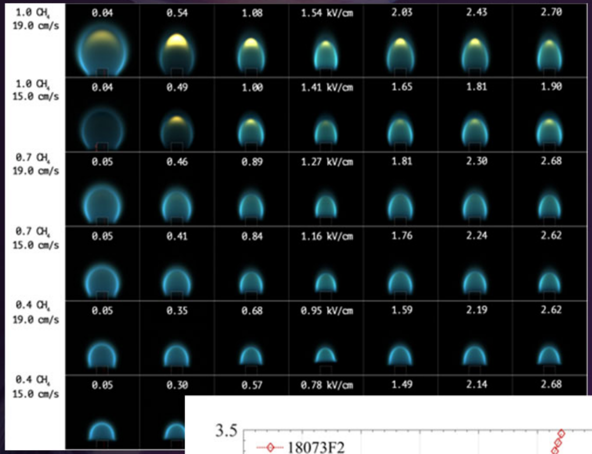
Adaptive Mesh Refinement (AMR)

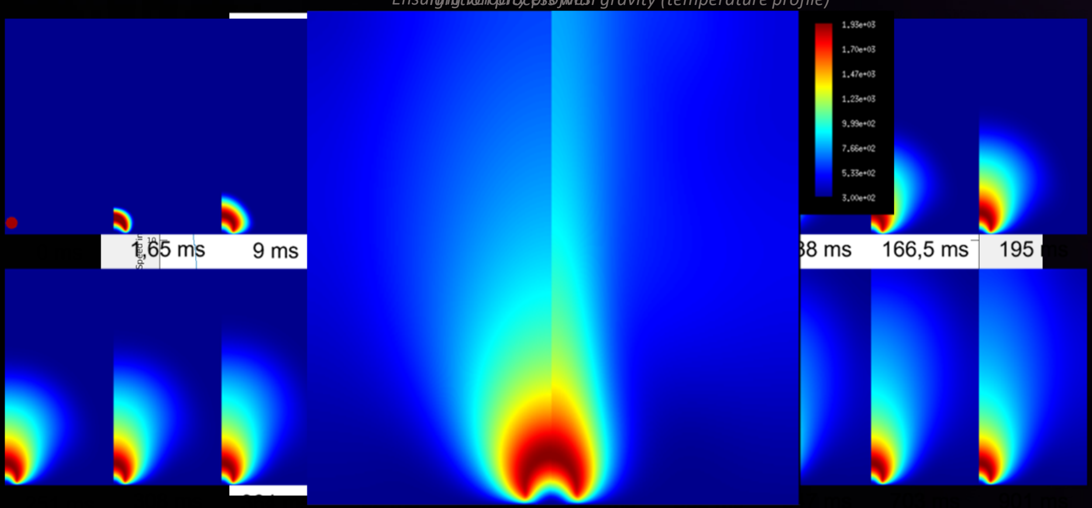
Link the changes in the flow field driven by the ions to the changes in the flame behavior, and then connect the changes in the ion production that results from the changes to the flame.

"PeleLM CFD of Ion-Driven Winds from Diffusion Flames" for E-FIELD Flames ISS data mining and analysis, NASA PSI Project, Jan 2022

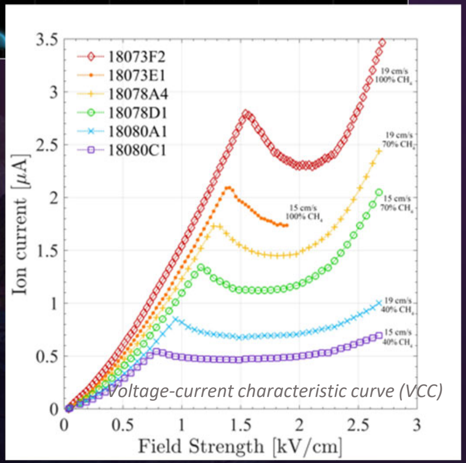
PeleLM E-FIELD Flames – NASA PSI Project

- Hvwdeolvklqj#ShohOPh[rq#wkh#XFL#fdpsxv#Kljk#Shuirupdqfh#Frppxqlw|#Frpsxwlqj# Foxvwhu#+KSF6,#dw#wkh#Uhvhdufk#F|ehuqiudvwuxfwxuh#Fhqwhu#+UFLF,#lq#wkh#foxvwhu1#
- Xvlqj#d#ioxvk#friorz exuqhu#jhrphwu|/#vhw#xs#wkh#lqlwldo#frqglwlrqv#dqg#erxqgdu|# frqglwlrqv#iru#h{wuxghg#ixho#wxeh#erxqgdu|#zlwk#iodph#ljqlwlrq#whvw#+5#vwhsv,1
- Wkh#qhzo|#frqyhuwhg#frgh#zlwk#wzr#glphqvlrqdo#f|olqgulfdo#frruglqdwhv/#dqg#d#ghwdlohg# yhulilfdwlrq#lqfoxghv#wkh#vlgh#erxqgdu|#whvw#zlwk#Glulfkohw#dqg#Qhxpdqq#frqglwlrqv/# exuqhu#zdoo#wklfnqhvv#dqg#erxqgdu|#hiihfw#zhuh#yhulilhg1
- Qhzo|#lpsohphqwhg#hohfwulf#ilhog#frgh#zdv#lqwurgxfhg1#Fdvh#yhulilfdwlrq#zlwk# judylwdwlrqdo#irufh#dqg#plfurjudylw|#whvwlqj#sduwlfxodu|#irfxvlqj#rq#wkh#ljqlwlrq# surfhvv/#dqg#krz#zhoo#lw#frqyhujhv#wr#vwhdg|#vwdwh1#





M. Donzeau, L. Esclapez, M. Day and Y.-C. Chien, ***Recent Progress on numerical simulation for microgravity electric field flames,*** *1D04, US National Combustion Meeting, Texas 3/20/2023*



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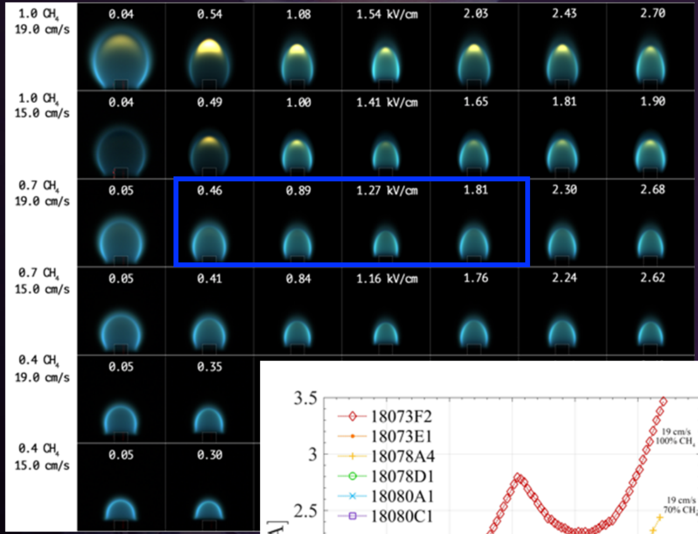
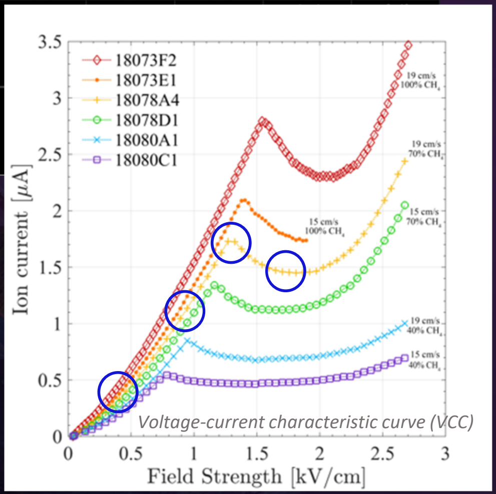
PeleLM E-FIELD Flames – NASA PSI Project

- Vlp xodwlqj#rq#fxuhqw#xvlqj#P 1#Jhq}r#dqg#E1#Fxhqrwuhgxfhg#p hfkdqlvp /#D# uhgxfhg#fkhp lfdo#p hfkdqlvp #iru#wkh#vlp xodwlrq#ri#hohfwulilhg#p hwkdqh2dlu#iodp hv/#¶#59# vshflhv#dqg#467#uhdfwlrqv#lqfoxglqj#wz r#srvlwlyh#lrqv#+KFR .#dqg#K6R .,#rqh# qhjdwlyh#lrq#+R − 5#,/#dqg#wkh#hohfwurqv1 grl#431434921frp exvwiodp h15355144557 9,1#
- G hwdlohg#vhwwlqjv#lqfoxglqj#fkdujhv/#lrqv/#hohfwurqv#dw#hdfk#srodulw|#dqg#krz #wkh|# hvfdsh#lq#frxsolqj#z lwk#hohfwulf#ilhog#olqhv#uhtxluhv#d#ghwdlohg#xqghuvwdqglqj1#
- Wkh#fxuuhqw#z run#jrhv#wr#vhfrqg#ohyho#hiihfw#hqw#rudqjh#olqh,#z kloh#wkh#frduvh#uxq# +eoxh#olqh,#ghp rqvwudwhv#vlp lodu#wuhqgv#dv#p hdvxuhg#rq#hduwk1#Wkh#lrq#fxuhqw#uhvxow# duh#z lwklq#wkh#vdp h#udqjh#dw#wkh#p lfurdp sv#vfdoh1#
- G hwdlohg#hohfwulf#irufh#hvshfldoo|#z lwk#fkdujhg#vshflhv#dqg#krz #wkh|#lqwhudfw#lq#wkh# iorz #ilhog#z khq#vroylqj#dorqj#z lwk#wkh#Q dylhu0Vwrnhv#p rp hqwxp #qhhgv#p ruh#z run#lq# xqghuvwdqglqj1#





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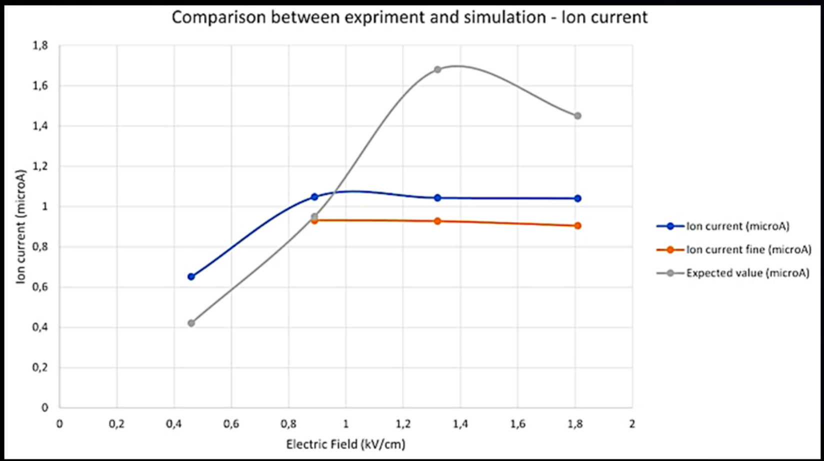

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Personal Development – Early Career in BPS

About me

- 2001 – 2005: Aerospace Engineering, B.E., TKU, Taipei, Taiwan
- 2005 – 2007: Aeronautics and Astronautics, M.S., NCKU, Tainan, Taiwan
- 2009 – 2014: Mechanical and Aerospace Engineering, Ph.D., UCI, Irvine, California, U.S.A.
- 2015 – Present:
  - Associate Project Scientist, Mechanical and Aerospace Engineering, UC Irvine
  - Director of Lasers, Flames & Aerosols | W.M. Keck Foundation Deep Ocean Power Science Lab
  - Principal Investigator, NASA PSI
  - Faculty partner, UCI California Alliance for Minority Participation (CAMP)
  - SWE-UCI Advisor/Collegiate Counselor, UCI Society of Women Engineers (SWE)
  - Coeditor, Combustion Science and Technology (CST), International Colloquium on the Dynamics of Explosions and Reactive Systems (ICDERS) Special Issue
  - Contingent participant, Science Technology Education Workgroup (STEW) between stake holders, School of Engineering & School of Education, UC Irvine

Recent new roles:

- Western States Section/The Combustion Institute (WSSCI) board member at large
- SWE-OC (Orange County) Professional Development Officer FY23
- Chair of the UCI Combustion Institute Summer School 2023

PSI MICROGRAVITY PHYSICAL SCIENCES DATA

Ground-based in-lab experimental flame study (gravity)

CAMP

Serving Students in STEM Since 1991

Realtime remote operations PS from earth

California Alliance for Minority Participation

American Society for Gravitational and Space Research

Society of Women Engineers

W. M. KECK FOUNDATION

What programs, institutions, and professional societies helped you along your research career?

How you got involved with microgravity combustion research?

Where you see yourself in the future in this program?

ex:

RESEARCH AND EDUCATION INTEGRATION

- Sustainability
  - Ground-Based (Incubator) Programs (ex: combustion; high pressure transcritical combustion; plasma combustion/electric field combustion)
  - Open-Source Science
- Access, Diversity, Equity, & Inclusion (ADEI)

How you currently and in the future work with students and mentor them to be also successful and continue this line of research?

RESEARCH AND EDUCATION

1. Create-your-own canal as a non-faculty at R1 university
   - Teaming up with National Renewable Energy Laboratory (NREL)
   - Teaming up with ENSMA
2. Seeking for NASA supported graduate student (ex: Pathway participants; Minority University Research and Education Project……etc.)

Acknowledgment

- Thanks to the National Academies Committee on Biological and Physical Sciences in Space.
- Thanks to NASA Physical Science Informatics (PSI) System under cooperative agreement 80NSSC22K0364, with Dennis Stocker's management.
- Thanks to UCI RCIC for the high-performance and high-throughput computing.

Thank you!