# Cosmology, the embodied human experience, and holistic physics education

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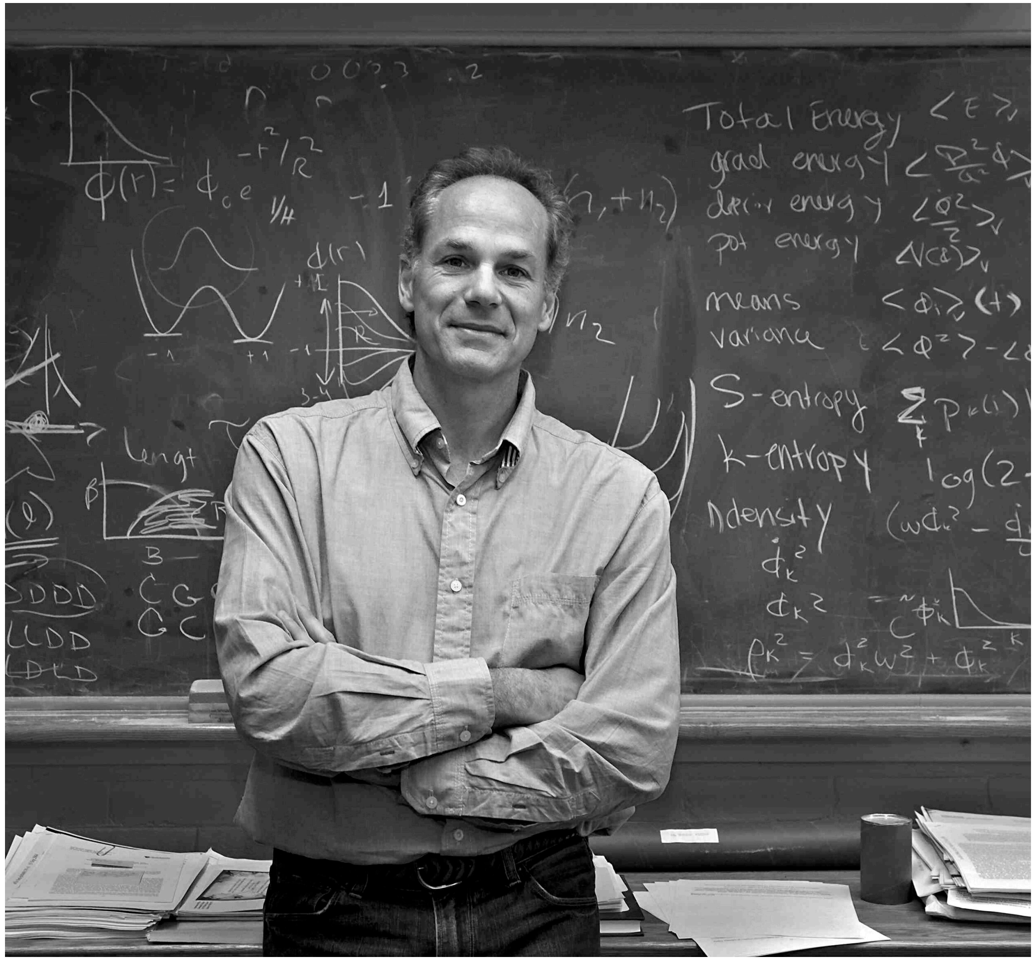
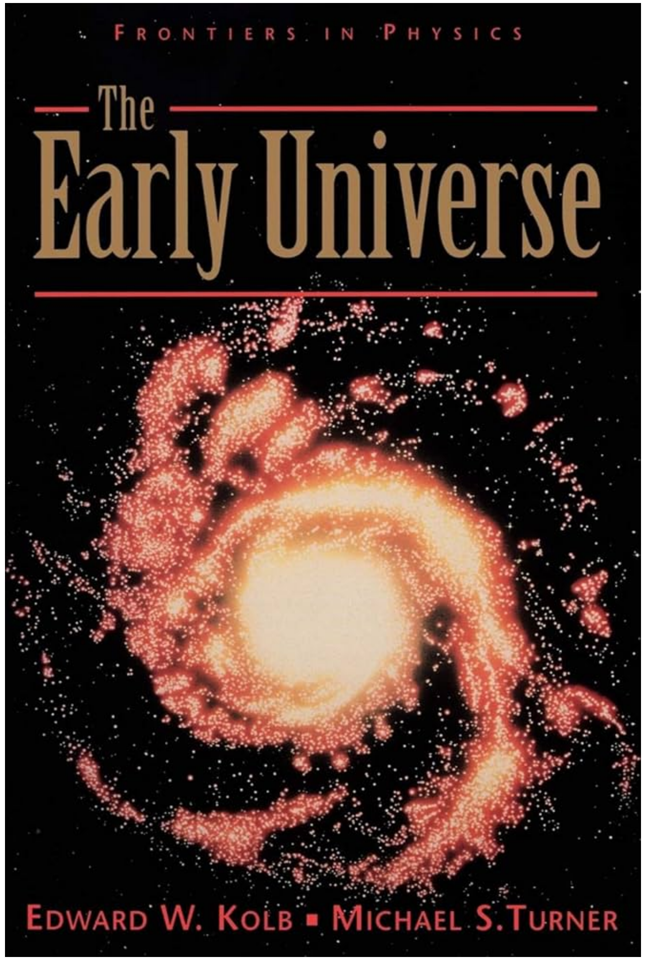
# Some reminiscing…

Dartmouth cosmologists @ Rockyfest:
Marcelo Gleiser, Abby Vieregg, ZK, Rob Caldwell


Total Energy
grad energy
pot energy
means
S-entropy
k-entropy
density


FRONTIERS IN PHYSICS
The Early Universe
EDWARD W. KOLB ■ MICHAEL S. TURNER

arXiv > hep-ph > arXiv:0808.3384

High Energy Physics – Phenomenology

[Submitted on 25 Aug 2008 (v1), last revised 3 Nov 2009 (this version, v2)]

# Deducing the nature of dark matter from direct and indirect detection experiments in the absence of collider signatures of new physics

Maria Beltran, Dan Hooper, Edward W. Kolb, Zosia C. Krusberg

Despite compelling arguments that significant discoveries of physics beyond the standard model are likely to be made at the Large Hadron Collider, it remains possible that this machine will make no such discoveries, or will make no discoveries directly relevant to the dark matter problem. In this article, we study the ability of astrophysical experiments to deduce the nature of dark matter in such a scenario. In most dark matter studies, the relic abundance and detection prospects are evaluated within the context of some specific particle physics model or models (e.g. supersymmetry). Here, we attempt to develop a model-independent approach toward the phenomenology of weakly interacting massive particles in the absence of any discoveries at the Large Hadron Collider. In particular, we consider generic fermionic or scalar dark matter particles with a variety of interaction forms, and calculate the corresponding constraints from and sensitivity of direct and indirect detection experiments. The results may provide some guidance in disentangling information from future direct and indirect detection experiments.

arXiv > hep-ph > arXiv:1002.4137

High Energy Physics – Phenomenology

[Submitted on 22 Feb 2010 (v1), last revised 23 Aug 2010 (this version, v2)]

# Maverick dark matter at colliders

Maria Beltran, Dan Hooper, Edward W. Kolb, Zosia A. C. Krusberg, Tim M. P. Tait

Assuming that dark matter is a weakly interacting massive particle (WIMP) species X produced in the early Universe as a cold thermal relic, we study the collider signal of pp or ppbar -> XXbar + jets and its distinguishability from standard-model background processes associated with jets and missing energy. We assume that the WIMP is the sole particle related to dark matter within reach of the LHC--a "maverick" particle--and that it couples to quarks through a higher dimensional contact interaction. We simulate the WIMP final-state signal XXbar + jet and dominant standard-model (SM) background processes and find that the dark-matter production process results in higher energies for the colored final state partons than do the standard-model background processes, resulting in more QCD radiation and a higher jet multiplicity. As a consequence, the detectable signature of maverick dark matter is an excess over standard-model expectations of events consisting of large missing transverse energy, together with large leading jet transverse momentum and scalar sum of the transverse momenta of the jets. Existing Tevatron data and forthcoming LHC data can constrain (or discover!) maverick dark matter.

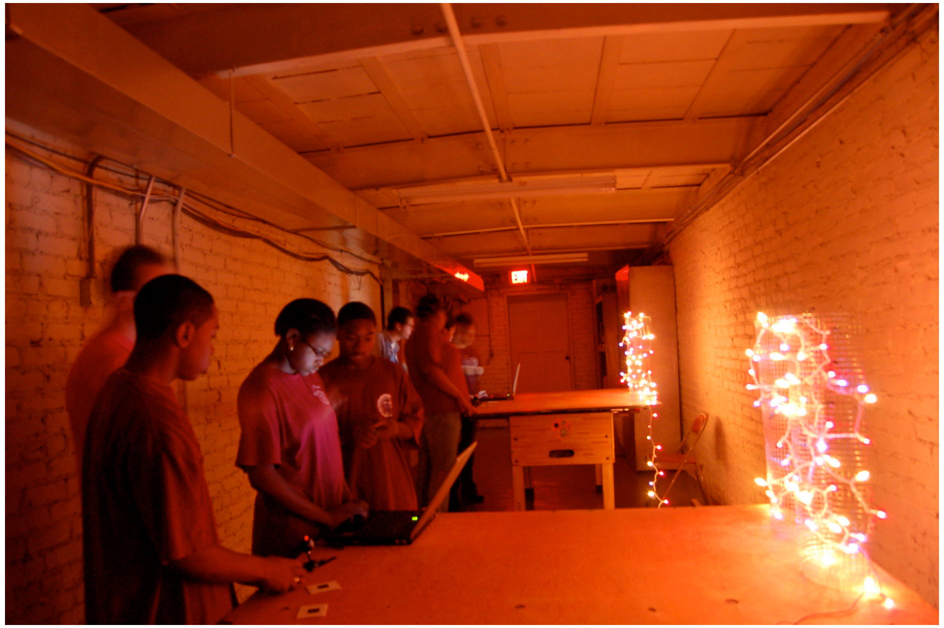
KICP Holiday Party 2007
(my apologies to everybody pictured)

Denis Erkal, Callum Quigley, Hannes Schimmelpfennig (">99% C.L."), Matthew Szydagis, Cora Dvorkin, ZK, Brian Odom


ELKINS·WIDENER·MEMORIAL·LIBRARY·A·D·MCMXIV


Some teaching venues

KICP Space Explorers 2007 – 2008



Yerkes Summer Institutes 2007 & 2008


Dr. Ashley Hartwell
BS Stanford, PhD MIT
Mechanical Engineer at NIST


Freddie Collier
BA UIUC
Professional Photographer in Chicago

# Motivation

A couple of observations

- Discrepancy between physics education and our understanding of teaching and learning from research in cognitive science and neuroscience
- Discrepancy between the rich cognitive and affective (subjective) experience of doing physics and a learning environment that generally only acknowledges the objective

# Motivation

Led to a commitment to developing a pedagogy that is

- Engaging, meaning students are actively involved in the learning process both inside and outside the classroom,
- Inclusive to students of all backgrounds, motivations for studying physics, and learning styles,
- Inclusive to the whole student and the richness of their subjective experience,

all in service of the fundamental objectives of physics education.

At a month-long meditation retreat in Crestone, CO

# Contemplative practice in physics education

# Some collaborators

Meredith Ward
Psychology,
Vassar '18
Clinical Therapist

Calais Larson
Cognitive Science,
Vassar '17
Data Analyst

Andrew Feldman
Cognitive Science,
Northwestern '21
High School Teacher

Noa Perlmutter
Cognitive Science,
UChicago '25

Akash Harjivan
Neuroscience,
UChicago '24

Elam Coalson
UChicago Medicine

# The objectives of physics education

- Physics (fundamental concepts; mathematical, computational, and experimental skills; problem-solving strategies)
- Physics in context (STEM fields; human society; personal experience)
- Knowledge of oneself (metacognition; meta-affect)

National Research Council (2013)

# The objectives of physics education

| | |
|---|---|
| *metacognition* | awareness of one's cognitive states and processes |
| *affect* | emotion, motivation, and mood |
| *meta-affect* | awareness of one's affective states and processes |

# The objectives of physics education

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National Research Council (2013)

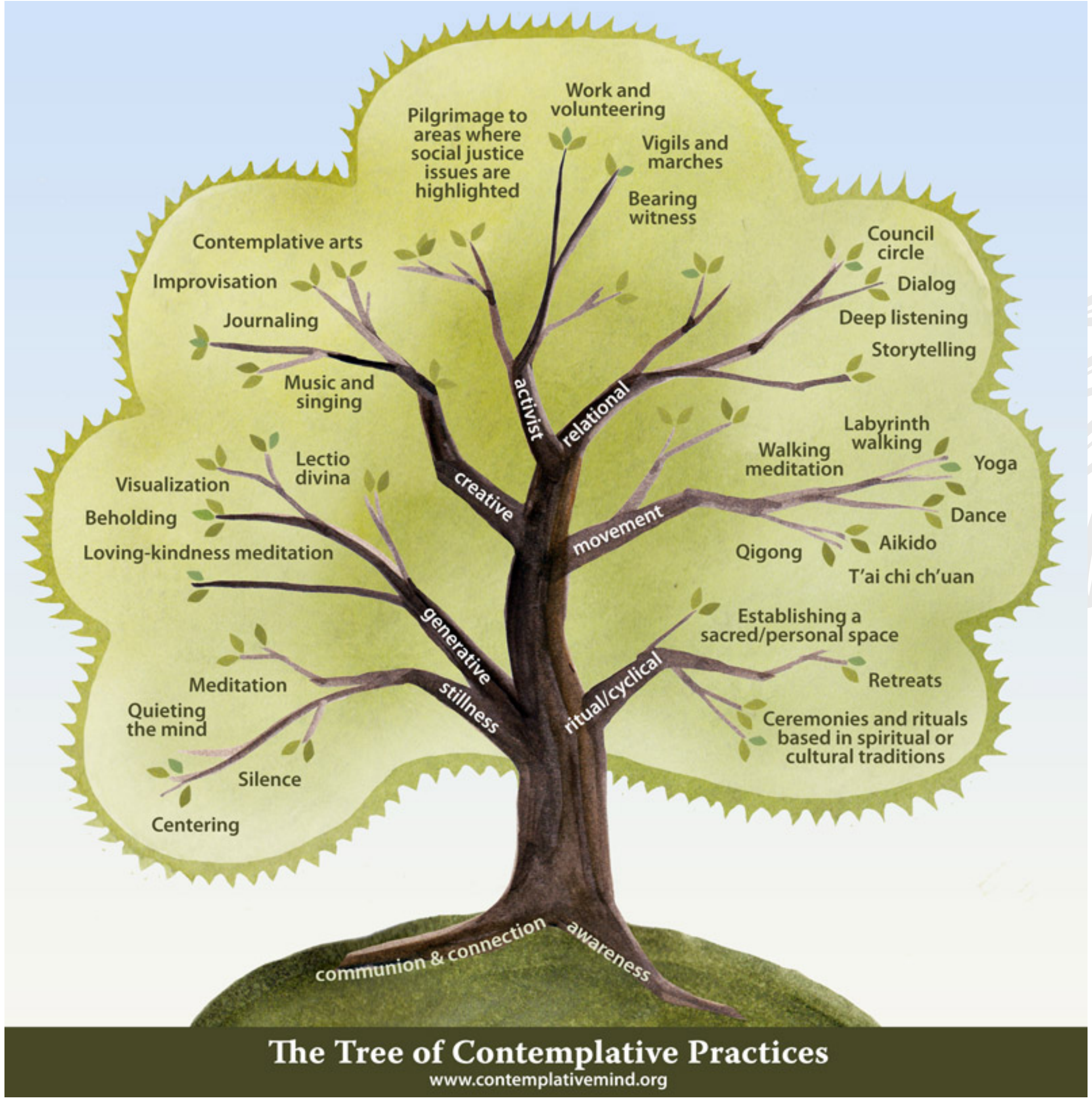
# The objectives of physics education

| Maryland Physics Expectations Survey (MPEX) Item | Favorable pre | Favorable post |
|---|---|---|
| Physical laws have little relation to what I experience in the real world. | 84% | 87% |
| To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed. | 59% | 54% |
| Learning physics helps me understand situations in my everyday life. | 72% | 51% |

Madsen, McKagan, & Sayre (2015)

# Contemplative practices

*contemplative practices* — practices with an internal, introspective, and reflective first-person focus that foster an awareness of the present experience


Pilgrimage to areas where social justice issues are highlighted
Work and volunteering
Vigils and marches
Bearing witness
Contemplative arts
Improvisation
Journaling
Music and singing
Council circle
Dialog
Deep listening
Storytelling
activist
relational
creative
Lectio divina
Visualization
Beholding
Loving-kindness meditation
Labyrinth walking
Walking meditation
Yoga
Dance
Aikido
Qigong
T'ai chi ch'uan
movement
generative
Meditation
Quieting the mind
Silence
Centering
stillness
Establishing a sacred/personal space
Retreats
Ceremonies and rituals based in spiritual or cultural traditions
ritual/cyclical
communion & connection
awareness
The Tree of Contemplative Practices
www.contemplativemind.org

# Contemplative practices in higher education

Contemplative practices have been shown to

- Improve the emotional, cognitive, and social health of both students and instructors
- Support learning, creativity, and the discovery of personal meaning in course material
- Cultivate an awareness of connections between the abstract and the experiential

Contemplative practices have been implemented in courses in the humanities, the social sciences, and the natural sciences, including biology, chemistry, earth science, environmental science, mathematics, and physics.

Barbazat and Bush (2014) and Owen-Smith (2018)

# Purpose

The purpose of this work is

- To introduce contemplative practices to the physics community
- To create a collection of contemplative practices for physics education
- To determine the impact of contemplative practices on students' awareness of the connection between fundamental physics principles and personal experience
- To determine the impact of contemplative practices on the subjective experience of problem solving
- To explore other benefits of contemplative practices on students' learning experience and wellbeing

# The contemplative practices: a sample

- Silence
- Sensory contemplations
    - classical mechanics
    - electrodynamics
- Contemplative videography
- Journaling and reflective writing
    - metacognition
    - meta-affect
    - meaning-making
- Nature-based meditation practices

# The contemplative practices: a sample

Sensory contemplation

- Students are guided through a brief somatic meditation in which they direct their attention into and through their bodies, gradually expanding their awareness into the surrounding space. They are then invited to use their senses to experience and explore the physical phenomena taking place around them. A written reflection follows.

Contemplative videography

- Students are asked to select one concept in classical physics on which to focus their attention. They are then instructed to capture video of their chosen concept manifesting in their surroundings and edit this footage into short, focused films. A written reflection follows.

# Results: an overview

As a result of engagement with contemplative practices, students reported

- Increased awareness of applicability of formal physics principles to personal experience
- Increased awareness of cognitive and affective processes
- A feeling of curiosity about the physical universe
- A feeling of intrinsic motivation to understand fundamental physics principles
- A sense of physical embodiment and sensory awareness
- A sense of somatic relaxation and mental stillness

Krusberg & Ward (2018); Krusberg, Coalson & Feldman (2023)

# Results: applicability of formal theory to experience

“Looking again at the crashing of the waves into the rocks reminded me of the animations of waves interacting with soft boundaries; since nothing physically pins down the edge of the wave, the wave is able to run up the side of the rock upon contact, and the rock acts as a soft boundary to allow temporary constructive interference within that wave, before sending the wave back the opposite direction. It was an insane realization for me: the waves before me literally mirrored the animation from class!”

Krusberg & Ward (2018); Krusberg, Coalson & Feldman (2023)

# Results: curiosity

“As a child, [I used to] be fascinated with [my] surroundings, but nowadays I have found that fascination to have disappeared. I have ceased wondering why something is the way it is and I find that disappointing. How have I lost that drive? How have I stopped taking the time to take in my surroundings and question why things are the way they are? I’m striving to become a scientist and yet this is the first time I can recall questioning [physical] phenomena in a long time.”

“A contemplative practice would never have occurred to me as part of a physics course … After experiencing this practice in meditation and contemplation however, I now wonder why such exercises are not more commonly encouraged in science courses. By meditating and contemplating my personal connection with electromagnetic phenomena, I found both relaxation and focus, which then allowed me to find a curiosity and interest in physics which I had not previously felt.”

Krusberg & Ward (2018); Krusberg, Coalson & Feldman (2023)

# Results: somatic relaxation and mental stillness

"It is weird seeing everything so still […] Compared to my usual day's commotion, it is a nice change of pace. I feel like I can really think and sort through my thoughts. I also notice that my body is almost as still as my surroundings. Especially for me, this is highly out of the ordinary—I am usually always running around or doing something—I think my body is thankful for the peace and calm."

"[This practice] was an extraordinarily cathartic experience for me. Beginning with the relaxation of my arms, legs, fingers, and toes, I immediately lost all prior stress and completely cleared my mind […] Throughout this stage of relaxation, I enjoyed maintaining a good posture because it helped me breathe better and feel more balanced."

Krusberg & Ward (2018); Krusberg, Coalson & Feldman (2023)

# Results: skepticism

"I was really skeptical going into this assignment. Jaded by past practices of mindful meditation in high school assemblies and office visits to a gastroenterologist with "alternative methods," I approached this assignment as just something I had to trudge through and check off my to-do list. Coming out of this experience, I was surprised to find that I actually enjoyed this assignment. Not only did this assignment force me to take a much-needed, albeit previously unknown to me that it was necessary, break, but it also revealed many ways that I interact with physics in my everyday life."

"I honestly thought that these contemplative practices would be less interesting, but I am very happy to say that they have been a wonderful experience. They reminded me of the reasons why I love science, and that I should not stop asking questions about my surroundings. And of course, they helped me see the many applications of the physics concepts that we learn in the classroom in a more personal way. The fact that all I needed to do was to relax and truly observe and appreciate nature made the experience very enjoyable. "

Krusberg & Ward (2018); Krusberg, Coalson & Feldman (2023)

# Further reading


Barbezat and Bush (2013), *Contemplative Practices in Higher Education: Powerful Methods to Transform Teaching and Learning*

Gaard and Ergüner-Tekinalp (2022), *Contemplative Practices and Anti-Oppressive Pedagogies for Higher Education: Bridging the Disciplines*

Krusberg, Coalson, and Feldman (2023), "Contemplating electromagnetic phenomena in lived experience through somatic meditation"

Krusberg and Ward (2018), "Classical physics and human embodiment: The role of contemplative practice in integrating formal theory and personal experience in the undergraduate physics curriculum"

Owen-Smith (2017), *The Contemplative Mind in the Scholarship of Teaching and Learning*