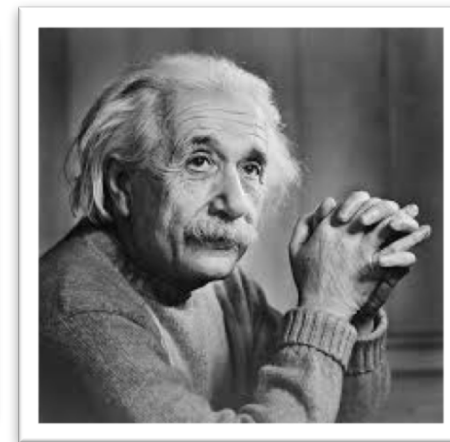
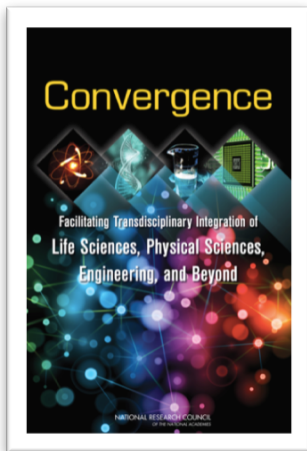


Revolution in Computational and Data-enabled Science and Engineering

Edward Seidel

Vice President for Economic Development and Innovation, University of Illinois System

Founder Professor of Physics, Professor of Astronomy, Computer Science, University of Illinois at Urbana-Champaign

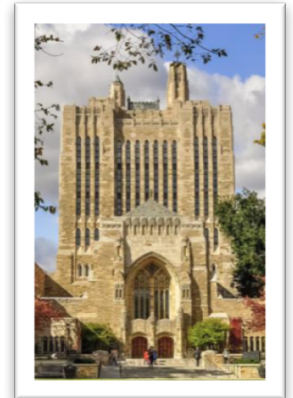
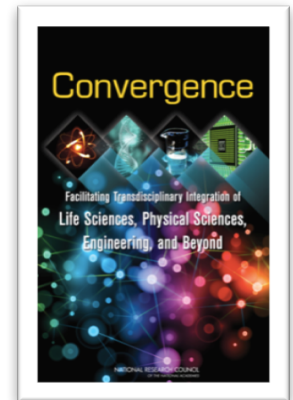
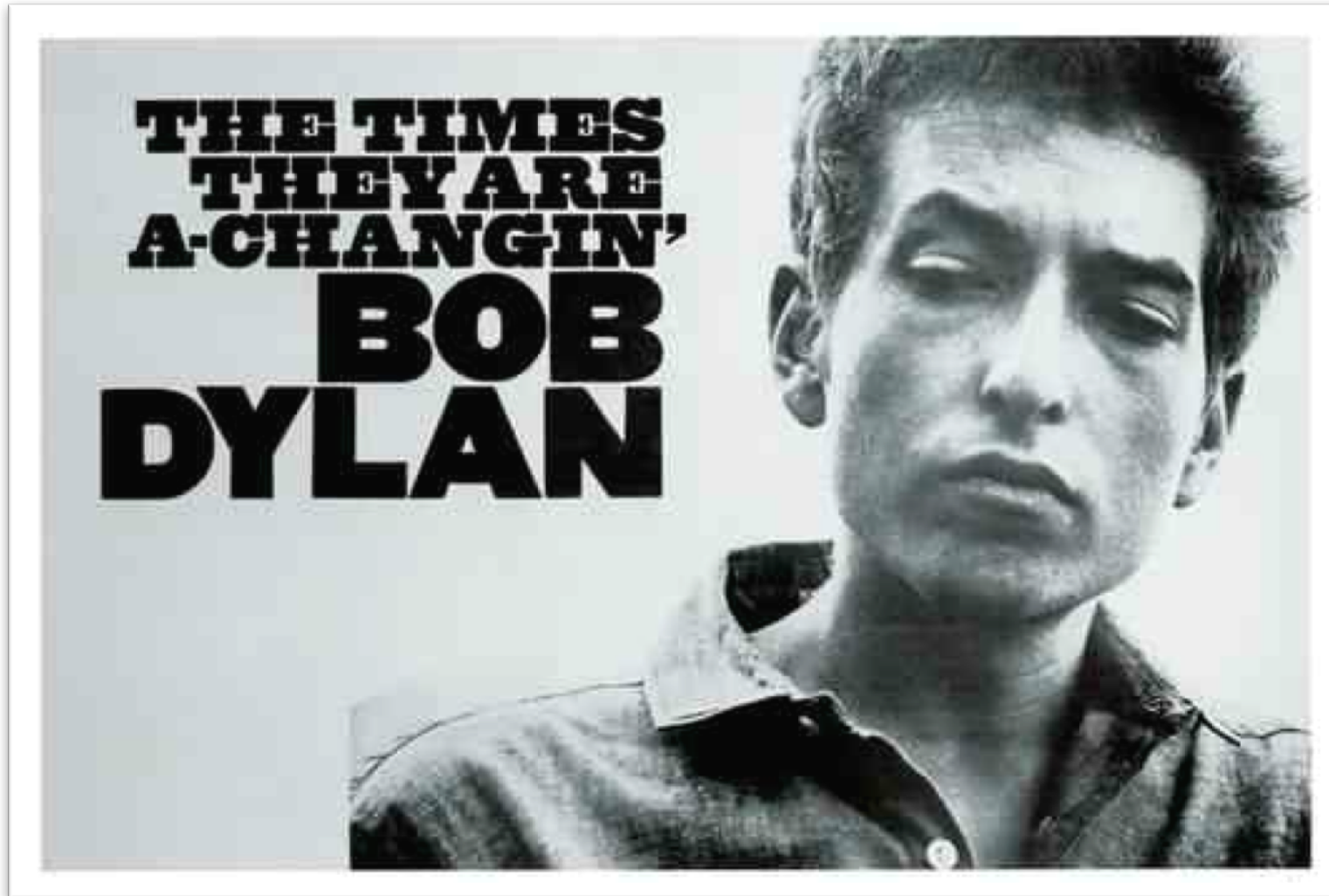


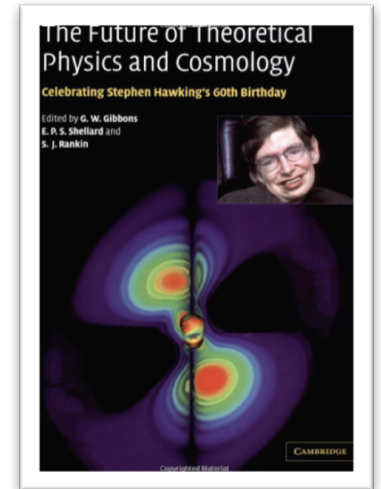
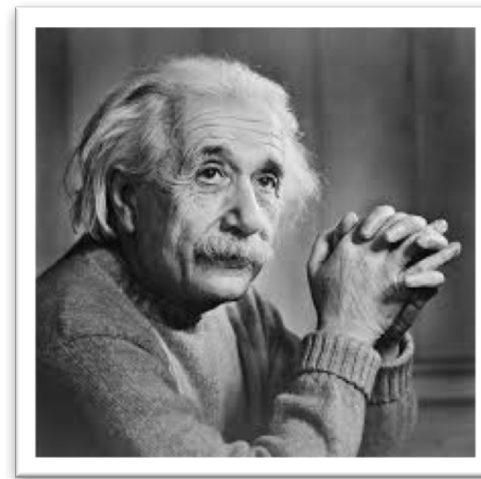
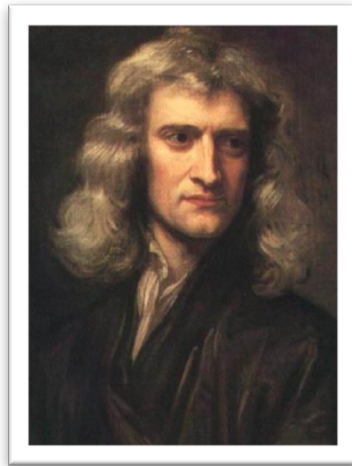
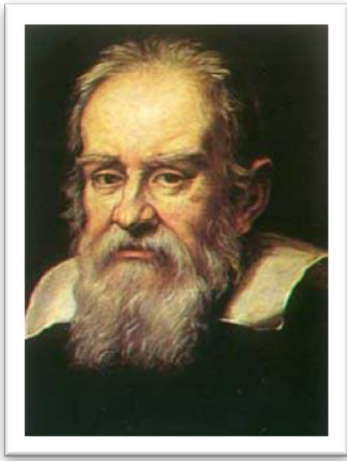
VPEDI

VICE PRESIDENT FOR ECONOMIC DEVELOPMENT AND INNOVATION

UNIVERSITY OF ILLINOIS SYSTEM
URBANA-CHAMPAIGN • CHICAGO • SPRINGFIELD

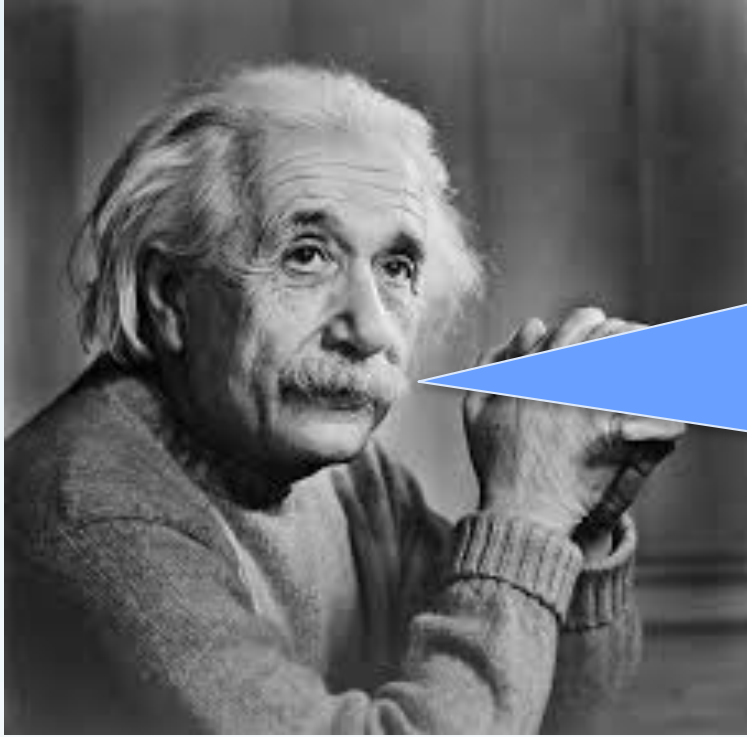
Three Major 21st Century Challenges





Four Centuries of Gravitational Physics

TRANSDISCIPLINARY CONVERGE
AROUND COMPLEX PROBLEMS IN
SCIENCE AND SOCIETY



Three trends made
this possible:

- Instrumentation
- HPC
- Data Science

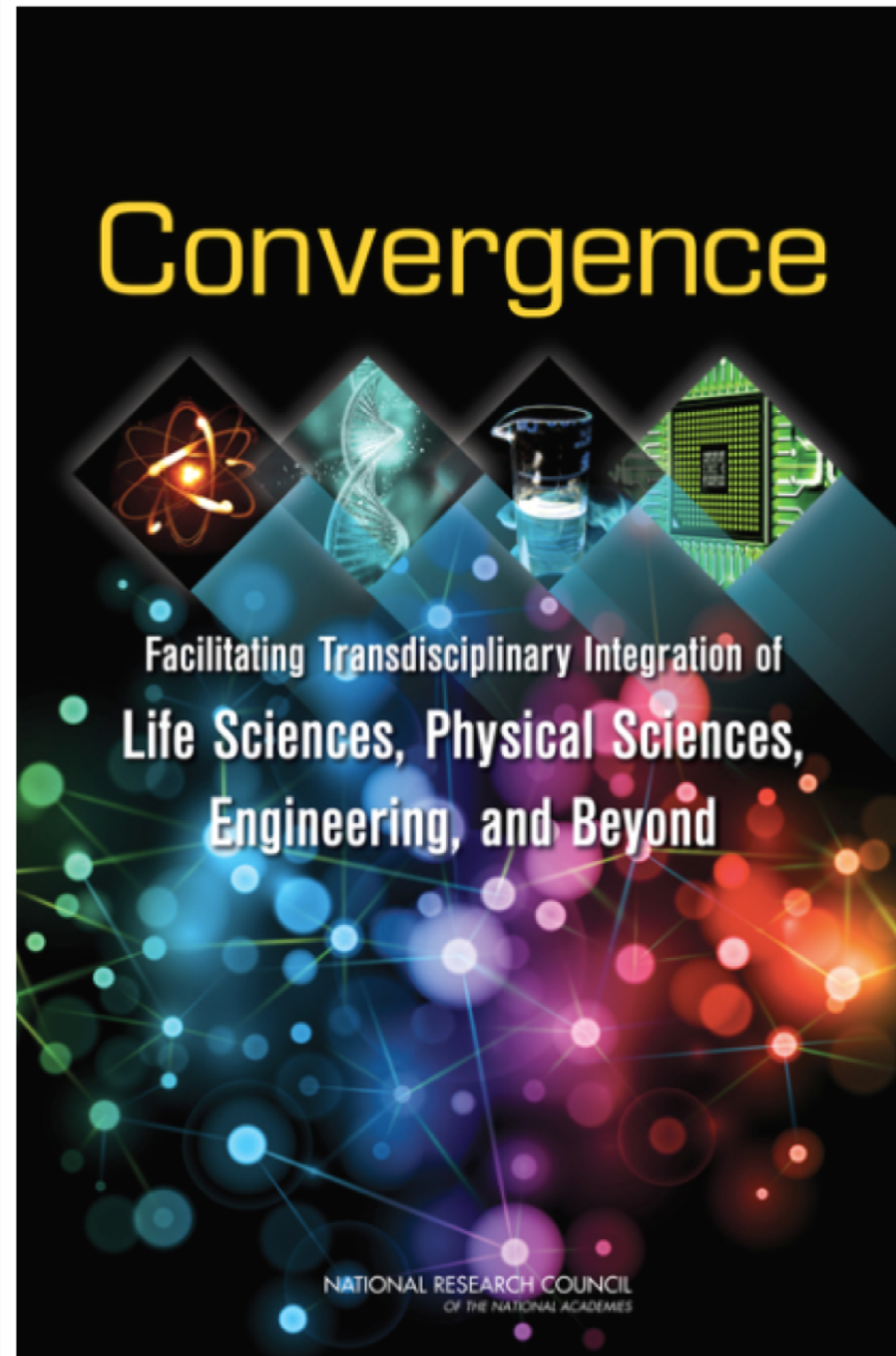
They are intricately
connected!

100 years ago, Einstein predicted gravitational waves. Feb 11, 2016 their historic discovery was announced!

Collaborations Grow as Problems Become More Complex; Systems and Data Sizes, too!

2 Black Hole Collisions, 100 Years of Science

Four centuries...and over 100 years of science!



1600-1972: Galileo, Newton, Einstein, Hawking. 1 person, no computer, 50GB

1998: 15 people, 100GB, 1000 processors, 50GB



VPEDI

VICE PRESIDENT FOR ECONOMIC DEVELOPMENT AND INNOVATION

UNIVERSITY OF ILLINOIS SYSTEM
URBANA-CHAMPAIGN • CHICAGO • SPRINGFIELD

Gravitational Wave Astrophysics

Interplay between Simulation and Experiment

Models & Simulation



$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$

Compact binaries, supernovae collapse, gamma-ray bursts, oscillating NSs, gravitational waves, ...

A collage of three newspaper front pages. The left page is The New York Times, the middle is The Washington Post, and the right is The News-Gazette. The Washington Post headline reads 'Discovery confirms Einstein'.

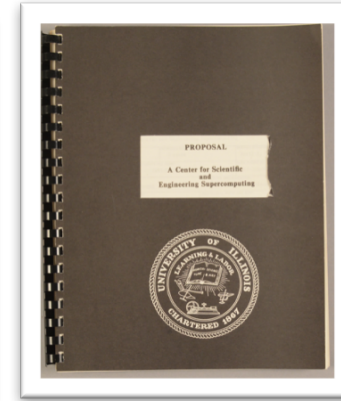
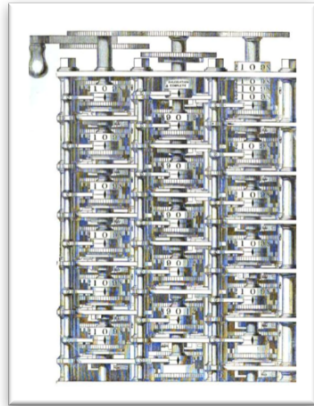
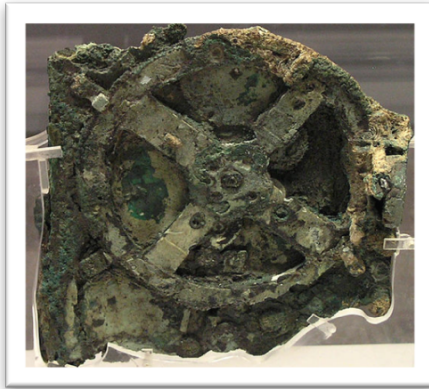
By ADAM NAGOURNEY

C



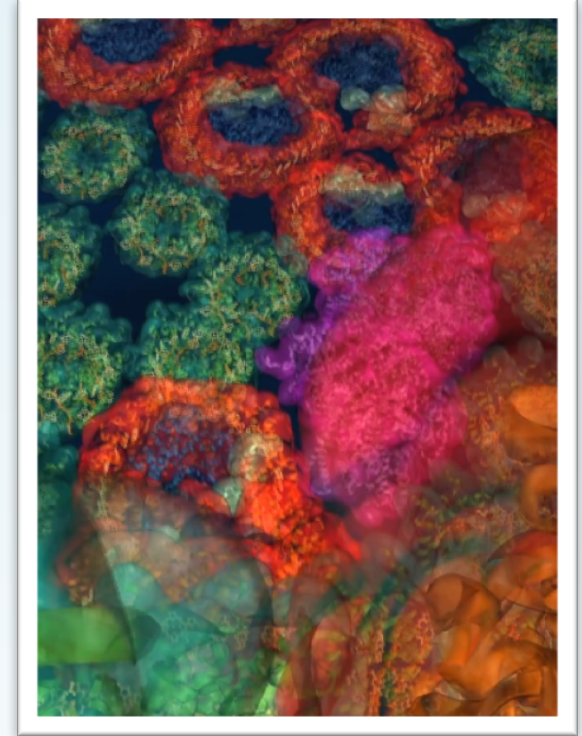
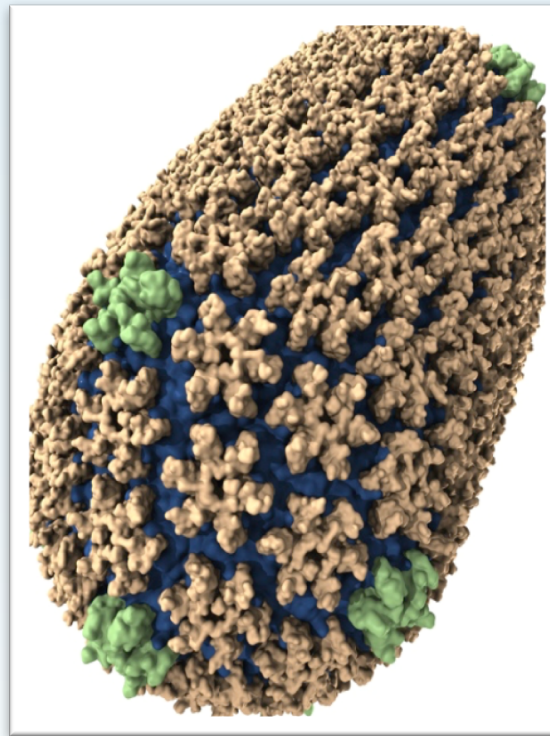
CLASSIFI

Discovery confirms Einstein



←→ 2000 years ←→ 100 years ←→ 40 years ←→ 30 years, 10^9

COMPUTING AND DATA REVOLUTION



*100M atoms! AIDS Virus, Chromatophore
Schulten, UIUC*

**UNDERSTANDING LIFE &
OTHER MATERIALS!**

Starry Night

Turbulence in Fluids

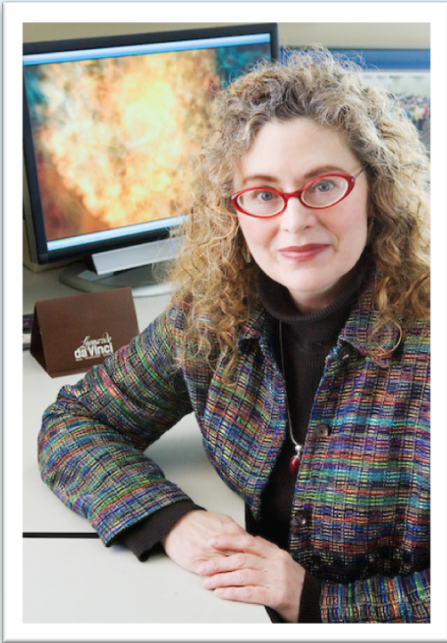


Vincent van Gogh, 1889

“When I die and go to heaven there are two matters on which I hope for enlightenment. One is quantum electrodynamics, and the other is the turbulent motion of fluids. And about the former I am rather optimistic.” Horace Lamb, 1932...

- Turbulent flow via direct numerical simulation (DNS) just possible on modern Petascale systems
 - 100PF+ would allow complete engine simulation with turbulence
 - 40 Exaflop would allow complete airplane simulation!

CONVERGENCE OF ARTS, COMPUTING AND DATA SCIENCES



Lifetime Achievement
Award , IMERSA 2017
Summit, for

“Significant contributions to the world of full dome film. This honor is truly the highest accolade we can give to someone who has had such a profound impact on our profession.”

Donna Cox

Michael Aiken Chair

Professor, School of Art and Design

Director, Illinois Emerging Digital Research and
Education in Arts Media Institute (eDream)

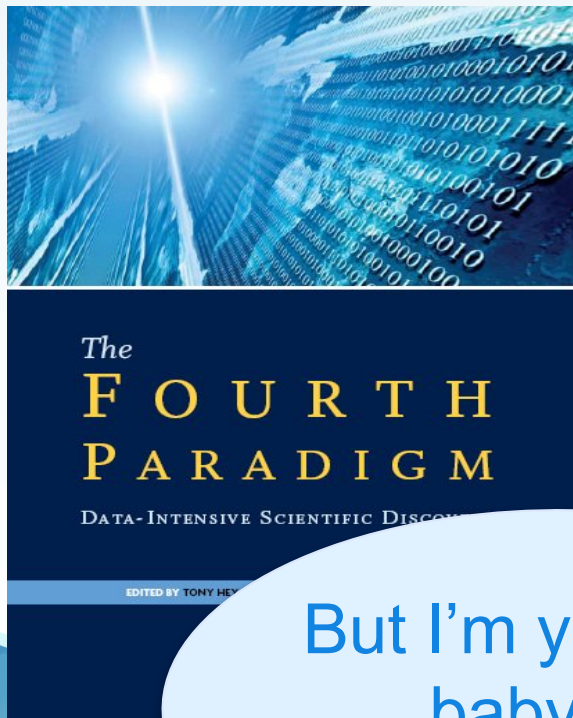
Head, Research and Education Directorate, NCSA



IMAX *Hubble* 3D narrated by Leonardo DiCaprio



The Growth of Data



But I'm your new
baby big
brother...

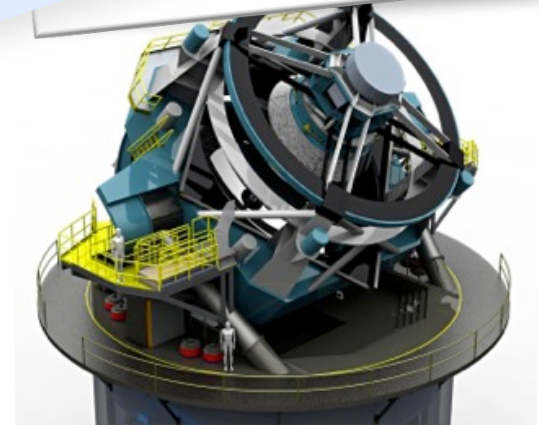
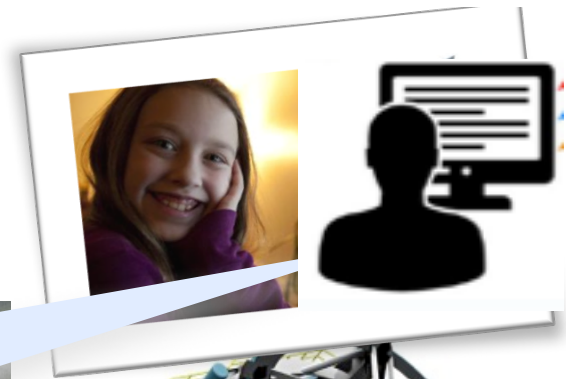


Data Tsunami

"I'm still
here..."

With millions of
processors...

Data-enabled Transformation of Science



Astronomy 1500- 2000:

- Single scientist looks through telescope
- Record KB of data in notebook
- Require reproducibility

Sloan Digital Sky Survey 2000+

- Record data for decade (40TB)
- Serve to entire world
- Thousands of scientists work “together”

DES (now)

- 200GB/night
- PB in decade

LSST (6 years)

- Record data for decade
- SDSS/night!
- 200 PB/decade

Integrating it all: Multi-Messenger Astronomy...

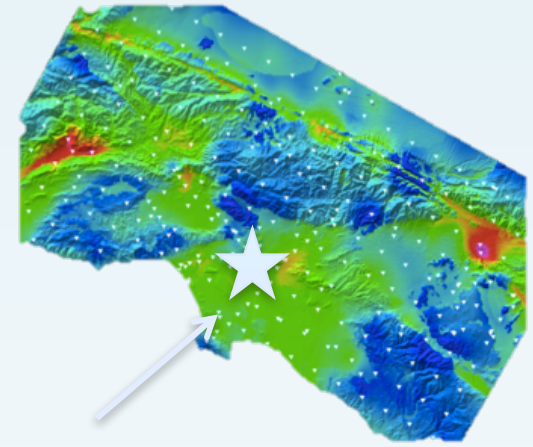
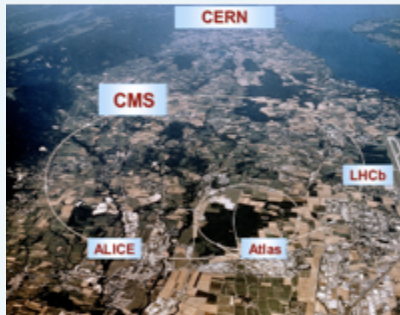
Astronomy c. 2020!

- New era: seeing events as they occur
- Here now
 - ALMA, EVLA
 - Ice Cube neutrinos
- On horizon
 - 20-30m optical?
 - LSST
 - aLIGO, Indigo
- SKA = exabytes
- Simulations integrate physics

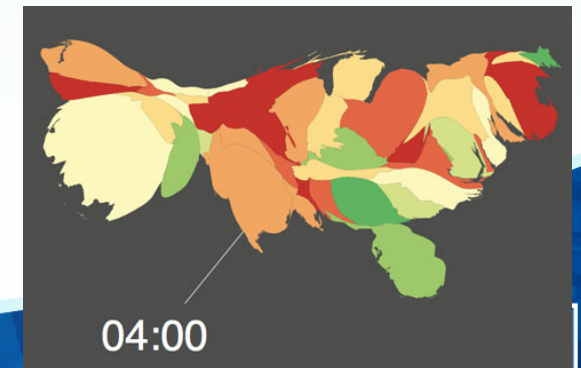
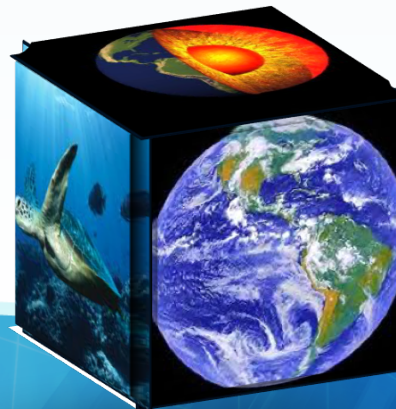
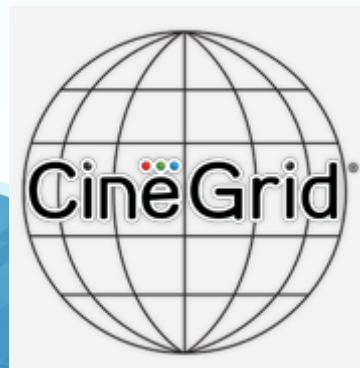
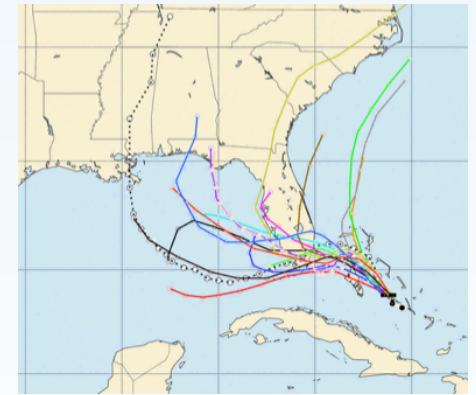
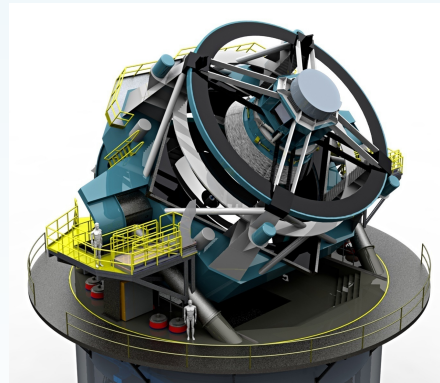


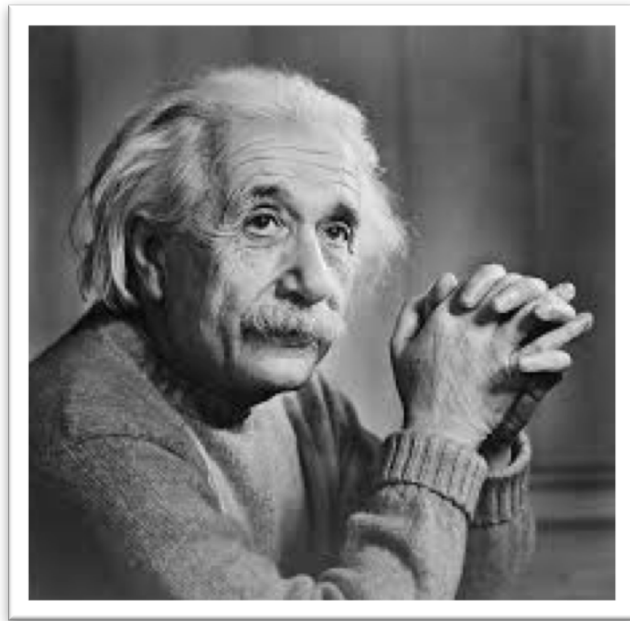
Communities
communicate by
sharing data,
software...
knowledge...

Scenarios like this in all fields...



Los Angeles





$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$



A. EINSTEIN ET AL
REFRIGERATION
Filed Dec. 16, 1927

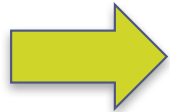
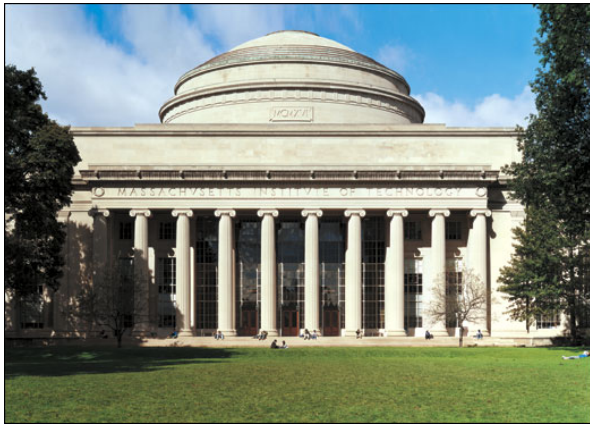
1,781,541

New Approaches from Baton Rouge to Jeddah
to Oxford to Moscow...to Champaign-Urbana!

INNOVATION AND THE KNOWLEDGE ECONOMY

Skoltech: New University Needed for 21st Century

Addressing all three challenges...



MIT Skoltech Initiative

Building the Future of the Skolkovo Institute of Science and Technology

VPEDI

VICE PRESIDENT FOR ECONOMIC DEVELOPMENT AND INNOVATION

UNIVERSITY OF ILLINOIS SYSTEM
URBANA-CHAMPAIGN • CHICAGO • SPRINGFIELD

Manufacturing

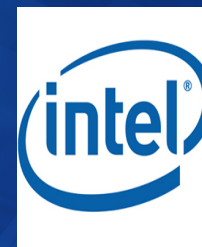


Rolls-Royce



Manufacturing

Technology



Technology



Energy



Life Sciences

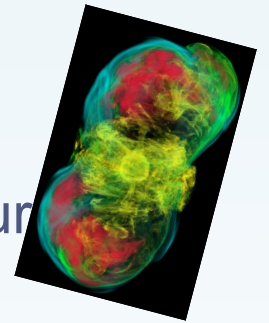


Institutes

Center for Supercomputing
University of Illinois at Urbana-Champaign

Summary & Exhortations!

- Major paradigm and culture shifts: is changing dramatically
 - Complex problems require collaborations at new scales
 - Way too complex for single groups
 - Establishing networks of people will be critical to your future
 - Computing and data capabilities growing at unprecedented rate
- Take time to look at the bigger picture...
 - Talk to your colleagues about what is going on
- Problems in academia, industry, society converging
 - Amazing similarity



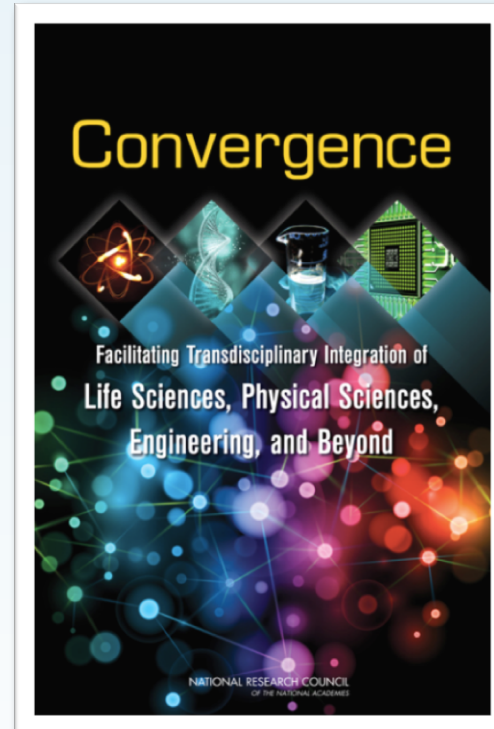
National Academy Reports...

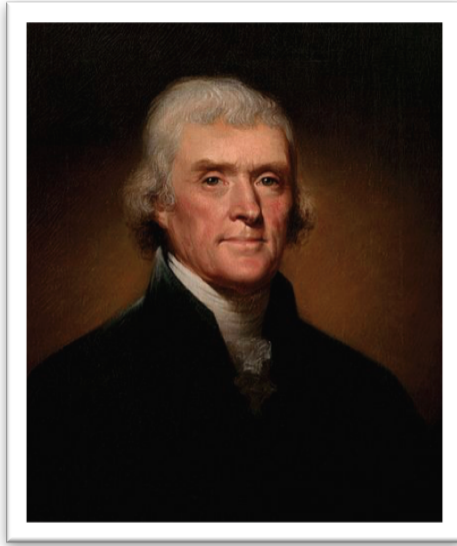
“*Convergence* [is] a culture shift for academic organizations that are traditionally organized around discipline-based departments....”

“...most difficult problems do not respect disciplinary boundaries...convergent science, [integrates] insights and approaches from many fields...barriers to convergent science...

Data is a key enabler of collaborations to support convergence...

- Enabled 1000+ scientists to discover gravitational waves or 10K scientists to discover the Higgs particle



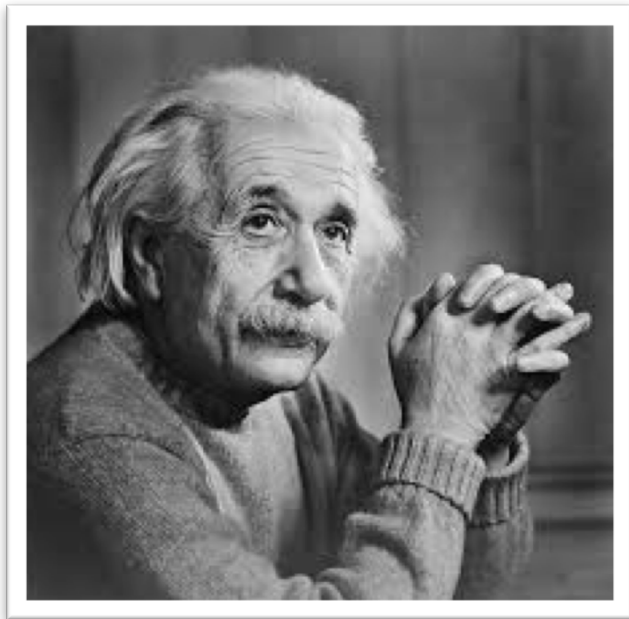


“Knowledge-products show *infinite expansibility*. They do not get used up, physically”

New Approaches from Baton Rouge to Jeddah
to Oxford to Moscow...to Champaign-Urbana!

INNOVATION AND THE KNOWLEDGE ECONOMY

Basic Research and Economic Development



A. EINSTEIN ET AL
REFRIGERATION

Filed Dec. 16, 1927

$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$



1,781,541