APS DPF Town Meeting
UC Riverside

30 August 2004

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The Realm of Elementary Particle Physics Today is Grand and Expansive

- What is the Nature of the Universe and What is It Made Of?
- What Are Matter, Energy, Space And Time?
- How Did We Get Here and Where Are We Going?

– P. Drell et al, *The Quantum Universe*

Greatest Set of Discovery Opportunities in 50 Years or More

- Are There Undiscovered Principles Of Nature, New Symmetries, or New Physical Laws?
- How Can We Solve The Mystery Of Dark Energy?
- Are There Extra Dimensions of Space?
- Do All The Forces Become One?
- Why Are There So Many Kinds of Particles?
- What Is Dark Matter? Can We Make It In The Laboratory?
- What Are Neutrinos Telling Us?
- How Did The Universe Come To Be?
- What Happened to Antimatter?

The Big Questions
from The Quantum Universe,
P. Drell et al

Many – but not all – of the compelling questions can be addressed with accelerators

Some will required "telescopes" – Earth-based, space-based, or underground

Deep Science

- Identify the constituent of dark matter
- Determine the masses of the neutrinos
- Detect and study lowest-energy solar neutrinos
- Measure key nuclear physics for astrophysics
- Biology (extreme microbial biology)
- Geoscience (fluid flow, rock deformation)
- Engineering
- National Security

The MPS-led NSF Process

- Working with GEO, ENG, and BIO Directorates through an Underground Science Working Group
- Working with DOE to develop mechanisms for reviewing and funding experiments
- Actions to date
  - Three unsolicited proposals (Homestake, San Jacinto, and Soudan) returned without prejudice (6 February 2004)
  - Informational Meeting at NSF (29 March 2004)
- Actions to come
  - Series of three solicitations to help the community develop competitive proposal(s) for an underground laboratory

Modularize Science

- Science in modules with common infrastructure needs permits initiating laboratory without doing all the science at once
- Possibility of multiple laboratory sites, including international sites

Unify Community

The Science Modules

- “Deep” (eg, dark matter, solar neutrinos, double beta decay)
- “Large" (eg, proton decay, neutrino oscillation)
- Engineering
- Biology
- Geosciences
- National Security
- Other (eg, nuclear physics)

Timeline

- Community establishes science case (1980-2002)
  - Workshops (…, NESS2002, EarthLab), Reports (Bahcall Cmte 2000, NRC: Neutrinos and Beyond, Quarks to the Cosmos), National Strategy (IWGPOU)

Done

- Planning and Development by Community
  - Solicitation 1: Planning grant(s) to define science and infrastructure requirements for science modules
  - Solicitation 2: ~4 Site development grants

In Process

- Down-select to 1 or 2 sites
  - Solicitation 3: Planning grant to develop full proposal including suite of initial experiments

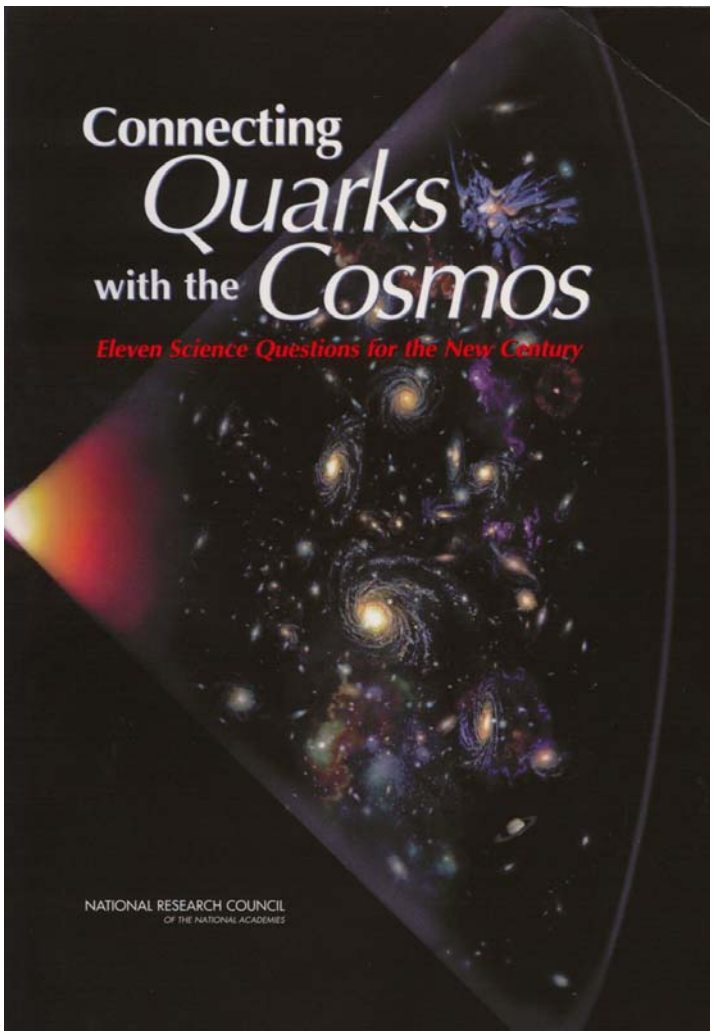
FY05

- Review and decision to proceed through the Major Research Equipment Facility Construction (MREFC) process*

FY06

*Projects that exceed 10% of the Directorate's budget (100M$ for MPS) must proceed via the MREFC process

Scientific case has been established and validated by two National Academy Studies, two long-range plans and several community workshops



Determine the neutrino masses, the constituents of the dark matter and the lifetime of the proton. The Committee recommends that DOE and NSF work together to plan for and to fund a new generation of experiments to achieve these goals. We further recommend that an underground laboratory with sufficient infrastructure and depth be built to house and operate the needed experiments.

A 21st Century Frontier for Discovery

The Physics of the Universe

A Strategic Plan for Federal Research at the Intersection of Physics and Astronomy

A 21st Century Frontier of Discovery: The Physics of the Universe

A Strategic Plan for Federal Research at the Intersection of Physics and Astronomy

A Report of the Interagency Working Group on the Physics of the Universe

National Science and Technology Council
Committee on Science

February 2004

Recommendations

Ready for Immediate Investment

Dark Energy

* NASA and DOE will develop a space-based Joint Dark Energy Mission (JDEM) with a target launch date in the middle of the next decade. Studies of JDEM undertaken in 2004 will identify the best methodology.

* A high-priority independent approach to place constraints on the nature of Dark Energy will be made by studying the weak lensing produced by Dark Matter. This is a scientific goal of the LSST. Significant technology investments to enable the LSST are required, and NSF and DOE will begin technology development of detectors, optical testing, and software algorithms leading to possible construction with first operations in 2012. NASA and DOE will contribute their expertise as appropriate.

* Another priority method to constrain Dark Energy will be to use clusters of galaxies observed by ground-based CMB and space-based X-ray observations. A coordinated NSF and NASA effort using this technique will provide independent verification and increase the precision of the overall measurements.

Dark Matter, Neutrinos, and Proton Decay

* NSF will be the lead agency for concept development for an underground facility. NSF will develop a roadmap for underground science by the end of 2004.

* NSF and DOE will work together to identify a core suite of physics experiments. This will include research and development needs for specific experiments, associated technology needs, physical specifications, and preliminary cost estimates.

Gravity

* NSF, NASA, and DOE will strengthen numerical relativity research in order to more accurately simulate the sources of gravitational waves.

* The timely upgrade of LIGO and execution of the LISA mission are necessary to open this powerful new window on the Universe and create the new field of gravitational wave astronomy.

Next Steps for Future Investments

Origin of Heavy Elements

* DOE and NSF will generate a scientific roadmap for the proposed Rare Isotope Accelerator (RIA) in the context of existing and planned nuclear physics facilities worldwide.

* DOE and NSF will develop a roadmap that lays out the major components of a national nuclear astrophysics program, including major scientific objectives and milestones, required hardware and facility investments, and an optimization of large-scale simulation efforts.

Birth of the Universe Using Cosmic Microwave Background

* The three agencies will work together to develop by 2005 a roadmap for decisive measurements of both types of CMB polarization. The road map will address needed technology development and ground-based, balloon-based, and space-based CMB polarization measurements.

High Density and Temperature Physics

* In order to develop a balanced, comprehensive program, NSF will work with DOE, NIST, and NASA to develop a science driven roadmap that lays out the major components of a national HEDP program, including major scientific objectives and milestones and recommended facility modifications and upgrades.

* NNSA will add a high energy high-intensity laser capability to at least one of its major compression facilities in order to observe and characterize the dynamic behavior of high-energy-density matter.

* DOE and NSF will develop a scientific roadmap for the luminosity upgrade of RHIC in order to maximize the scientific impact of RHIC on HED physics.

High Energy Cosmic Ray Physics

* DOE and NSF will work together to ensure that the Pierre Auger southern array is completed and will jointly review the results from the Auger array after the first full year of operations in order to consider plans for a possible northern array.

Solicitation 1:
Research Definition & Associated Infrastructure Requirements

- Define science and engineering research
  - Clearly articulate the program (initial suite of experiments, future program) and associated underground infrastructure requirements
  - Describe any associated requirements for instrumentation R&D
  - International context (partnering, duplication, …)
- Science and engineering organized into modules with common infrastructure needs
  - Describe the infrastructure needs for each Module, including depth, space, power, cooling, special safety features, etc.

Solicitation 1

Research Definition & Associated Infrastructure Requirements

- Solicitation issued in June (NSF 04-595); proposals due 15 September
- Key proposal elements
  - Comprehensive site-independent approach
  - Involve broad underground science and engineering community
  - Professional expertise of the team
  - View research within international context
- Award planning
  - 1-3 awards up to $500,000 for 6 months

Solicitation 2

Site Development and Conceptual Design

- Provide sufficient information about possible sites to permit down-select in conjunction with information coming from Solicitation 1
  - Existing capabilities
  - Potential capabilities with additional work and time and cost of completing such work
  - Connection to infrastructure requirements of underground science and engineering experiments
- Estimated cost and development schedules

Solicitation 2
Site Development and Conceptual Design

- Solicitation to be issued in days; proposals due early December 2004
- Key proposal elements include
  - Plans for
    - Obtaining and developing needed information on the site to verify existing and potential capabilities
    - Ascertain potential risks and obstacles to development of the site and possible means of mitigation including permitting and safety, environmental concerns
    - Development and operations of the infrastructure, including realizing the potential for broader impacts
  - Site that connects to infrastructure requirements of underground science and engineering as identified by community
- Award planning
  - ~4 awards of up to $500,00 for six months

Solicitation 3 (as currently envisioned)

Detailed Infrastructure Plan for Underground Science and Engineering

- Solicitation will incorporate information gained from awards made under Solicitations 1 and 2 to invite detailed plans for 1 or 2 sites
- Site dependent design of laboratory facilities in the context of the science modules
- Preliminary baseline, including suite of initial experiments and future plans
- Parallels continuing development of experiments within the community

The MREFC Approval Process

- Divisonal/Directorate Review*
- Review by NSF MREFC Committee**
- Review by Director's Review Board
- Approved by Director for consideration by the NSB
- Approved by the NSB for inclusion in "the queue"
- Approved by Director and NSB for inclusion in NSF's budget request to the President
- Approved for inclusion in the President's budget request (currently working on FY06)***
- Congress appropriates Funds
- NSF (Director and NSB) approves award when appropriated funds are available

*Must compete against other proposals, now including: LSST, ATST, GSMT, ERL

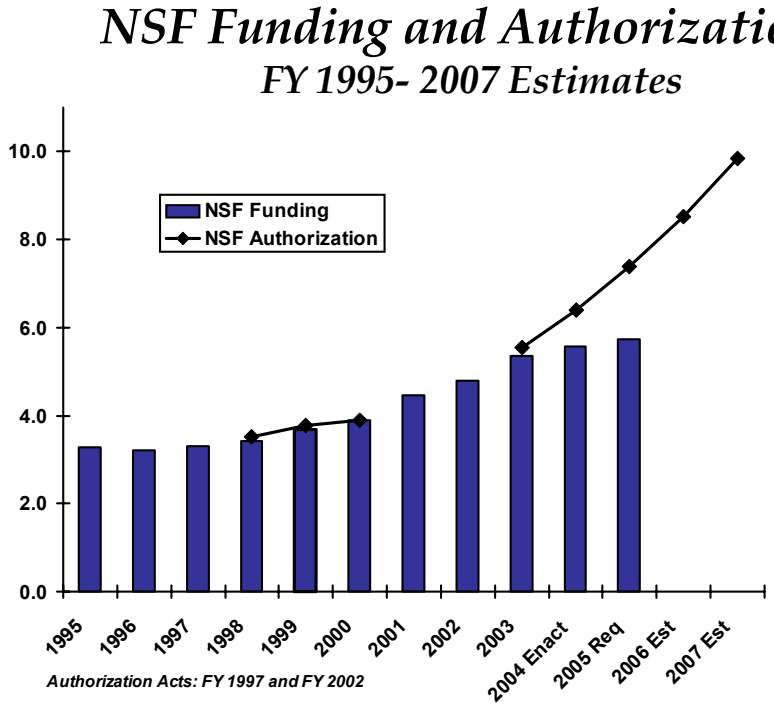
**Must compete against projects proposed by other Directorates

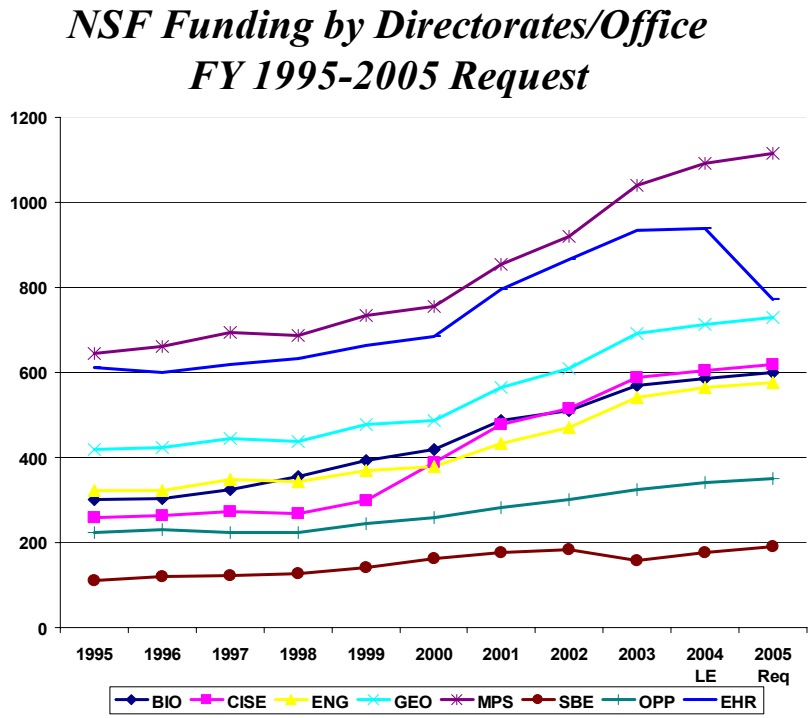
***If Division/Directorate review begins in FY06, could compete for slot in FY08

Key Points

- Modular Concept (space and time)
- Estimated cost of Lab and initial suite of experiments ~300M$ (does not include DOE and Foreign contributions)
- Up to 3 down selects
  - Site planning grants (~4 to be funded)
  - UG Lab planning grants (up to 2 to be funded)
  - Selection of a single proposal to go through MREFC process
- Earliest Funding of Lab FY 2008
- Fiscal Realities – good news and bad news

NSF Funding





+68% since 1998, but leveling (out years from FY05 budget)

2005	2006	2007	2008	2009
5.77B$	5.666B$	5.674B$	5.723B$	5.749B$
(5.48B$ House Mark)				
vs FY05:	-1.8%	-1.6%	-0.8%	-0.4%

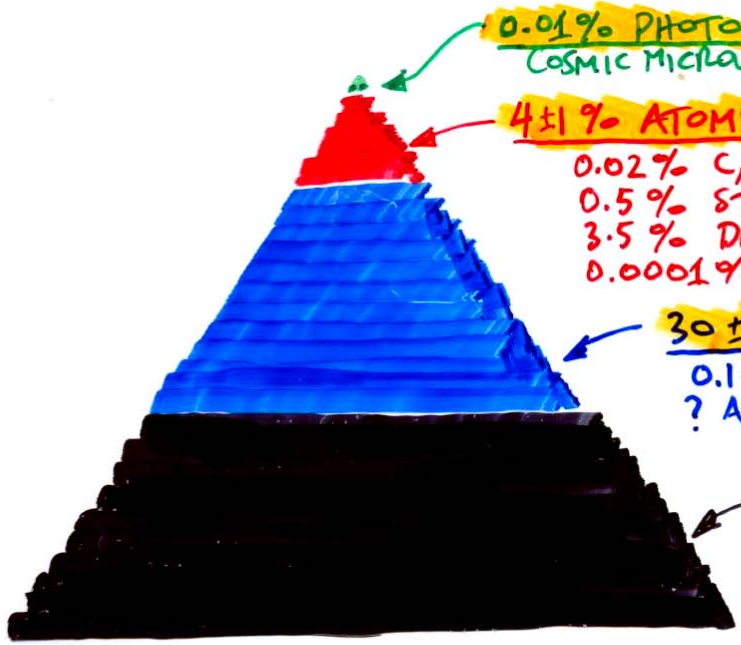
MREFC Account
(from President's 2005 Budget, in millions of dollars)

FY03	**FY04**	**FY05**	**FY06**	**FY07**	**FY08**	**FY09**
179	155	213	326	270	188	144

Developing wedge in 2007/8

COSMIC STUFF

0.5% STARS + 33% DARK MATTER + 66% DARK ENERGY



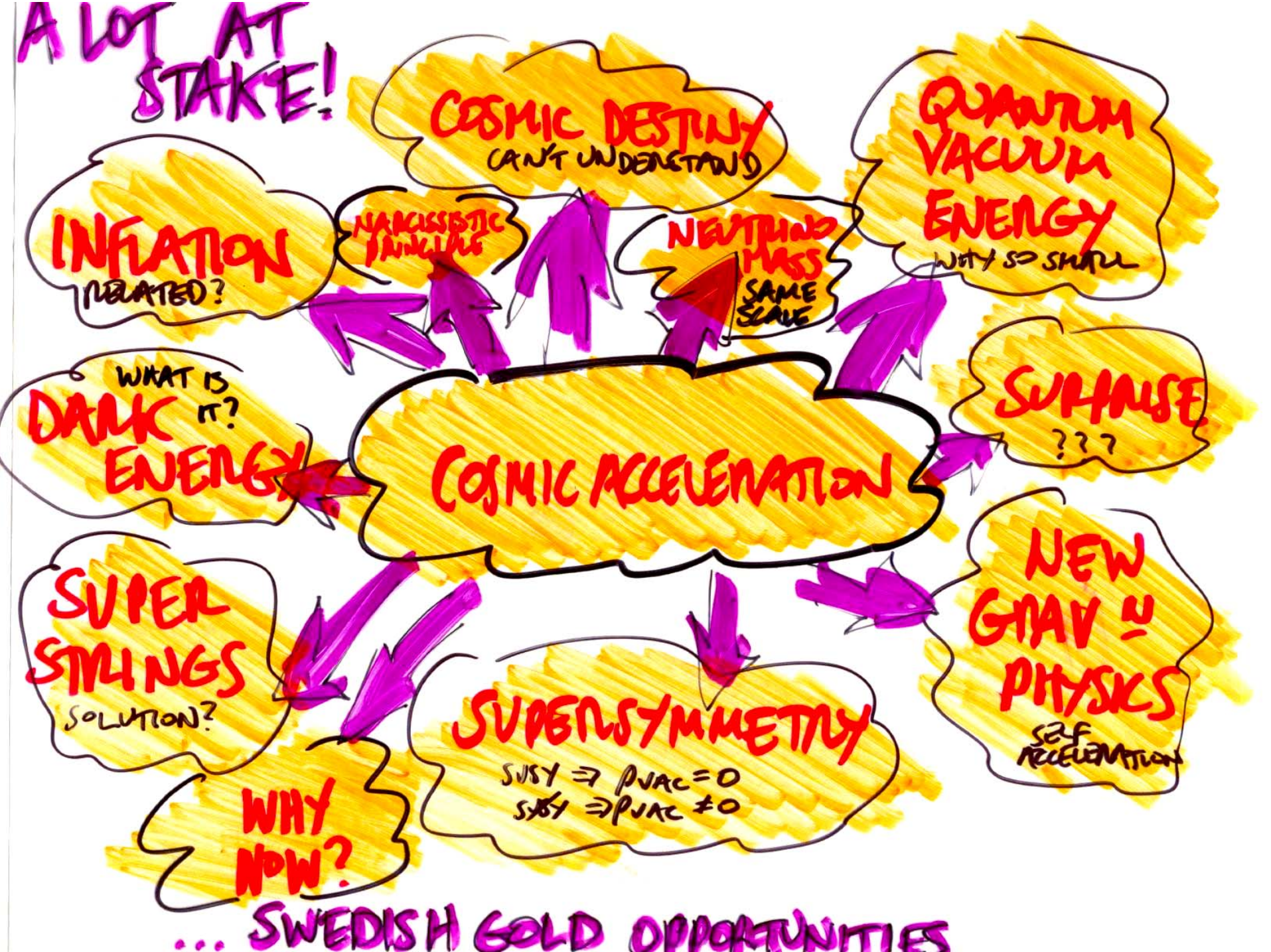
0.01% PHOTONS
COSMIC MICROWAVE BACKGROUND

4±1% ATOMS
0.02% C, N, O, ... Fe, ... U
0.5% STARS
3.5% DIFFUSE GAS
0.0001% BHs

30±4% EXOTIC DARK MATTER
0.1-5% NEUTRINOS
? AXIONS ? NEUTRALINOS

66±4% DARK ENERGY
? VACUUM ENERGY
? QUINTESSENCE
? ? ?

→ 96% IN NEW FORMS OF MATTER & ENERGY


A LOT AT STAKE!
COSMIC DESTINY
CAN'T UNDERSTAND
QUANTUM VACUUM ENERGY
WHY SO SMALL
INFLATION
RELATED?
NARCISSISTIC FANCIFUL
NEUTRINO MASS
SAME SCALE
WHAT IS IT?
DARK ENERGY
COSMIC ACCELERATION
SURPRISE
???
SUPER STRINGS
SOLUTION?
NEW GRAV ≠ PHYSICS
SELF ACCELERATION
SUPERSYMMETRY
SUSY ⇒ ρVAC = 0
SUSY ⇒ ρVAC ≠ 0
WHY NOW?
... SWEDISH GOLD OPPORTUNITIES