



COBE (Cosmic Background Explorer) Mission and Results

PI Masters Forum 2011

John Mather

COBE Project Scientist & FIRAS PI

JWST Senior Project Scientist

Goddard Space Flight Center



Lemaitre's Law – 1927

Hubble's Law - 1929 data

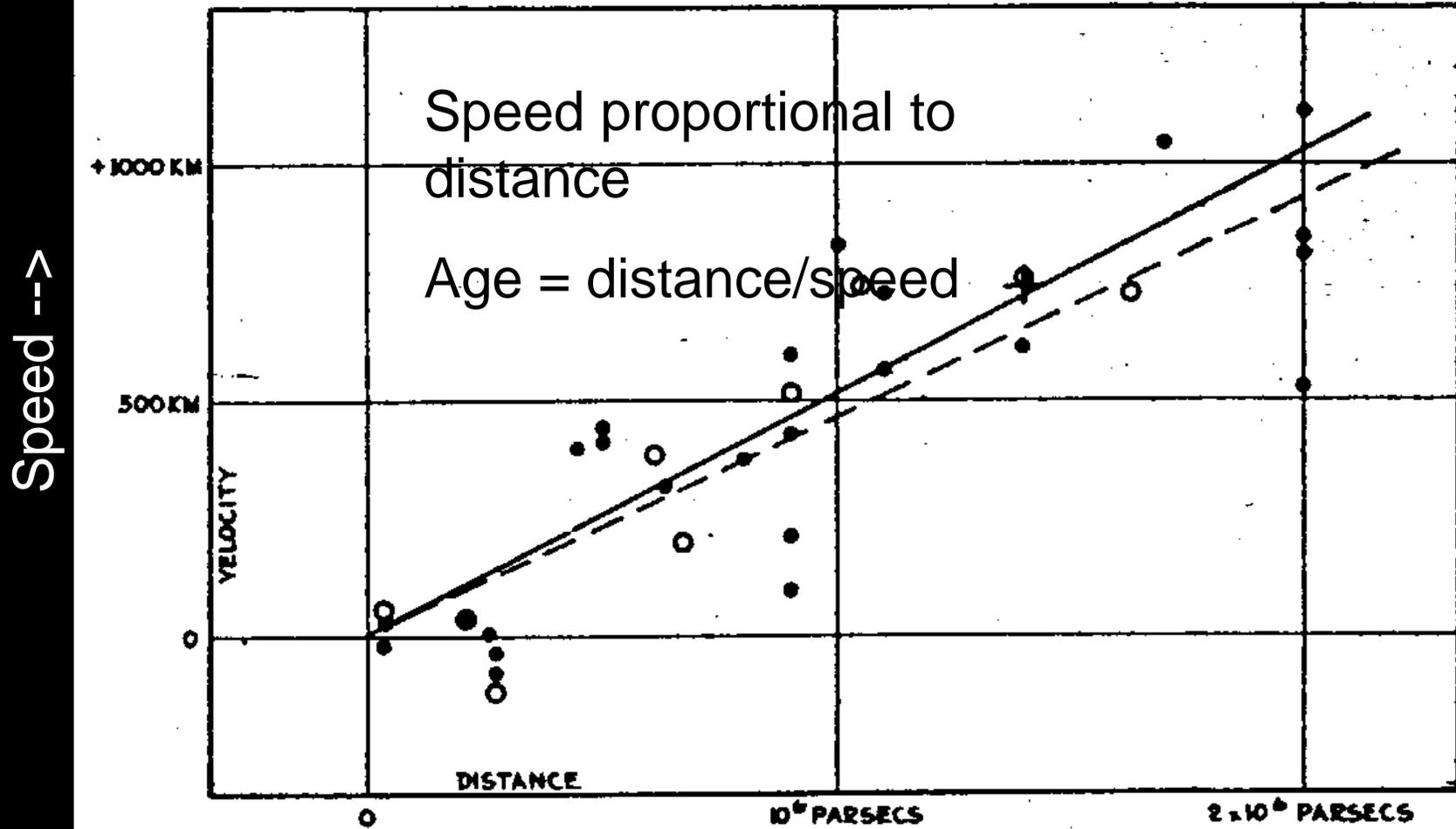


FIGURE 1



Big Bang - Cosmic Explosion 13.7
billion years ago

**IMPOSSIBLE TO
DRAW A PICTURE!**

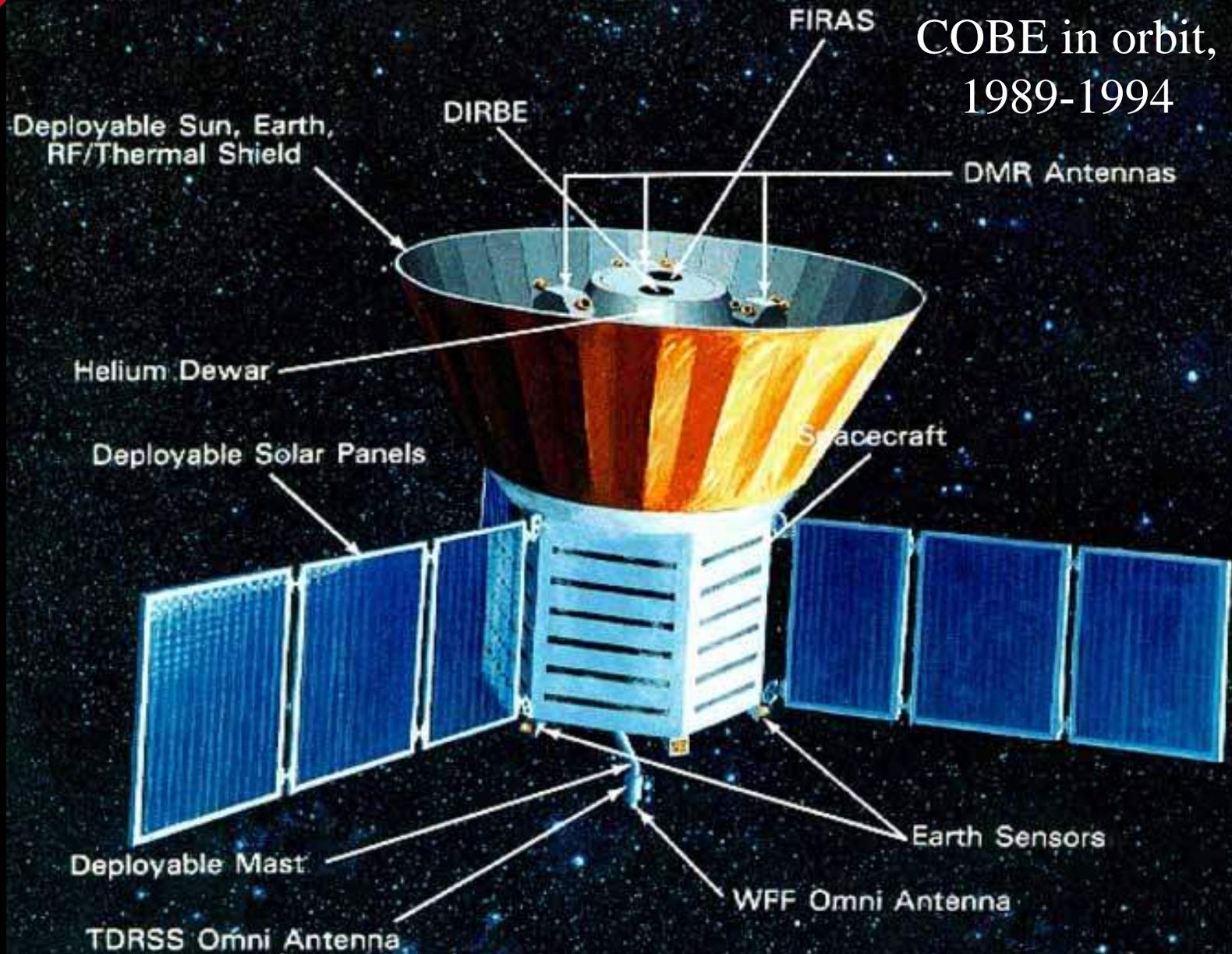


How did a smooth Big Bang make complicated things like us?

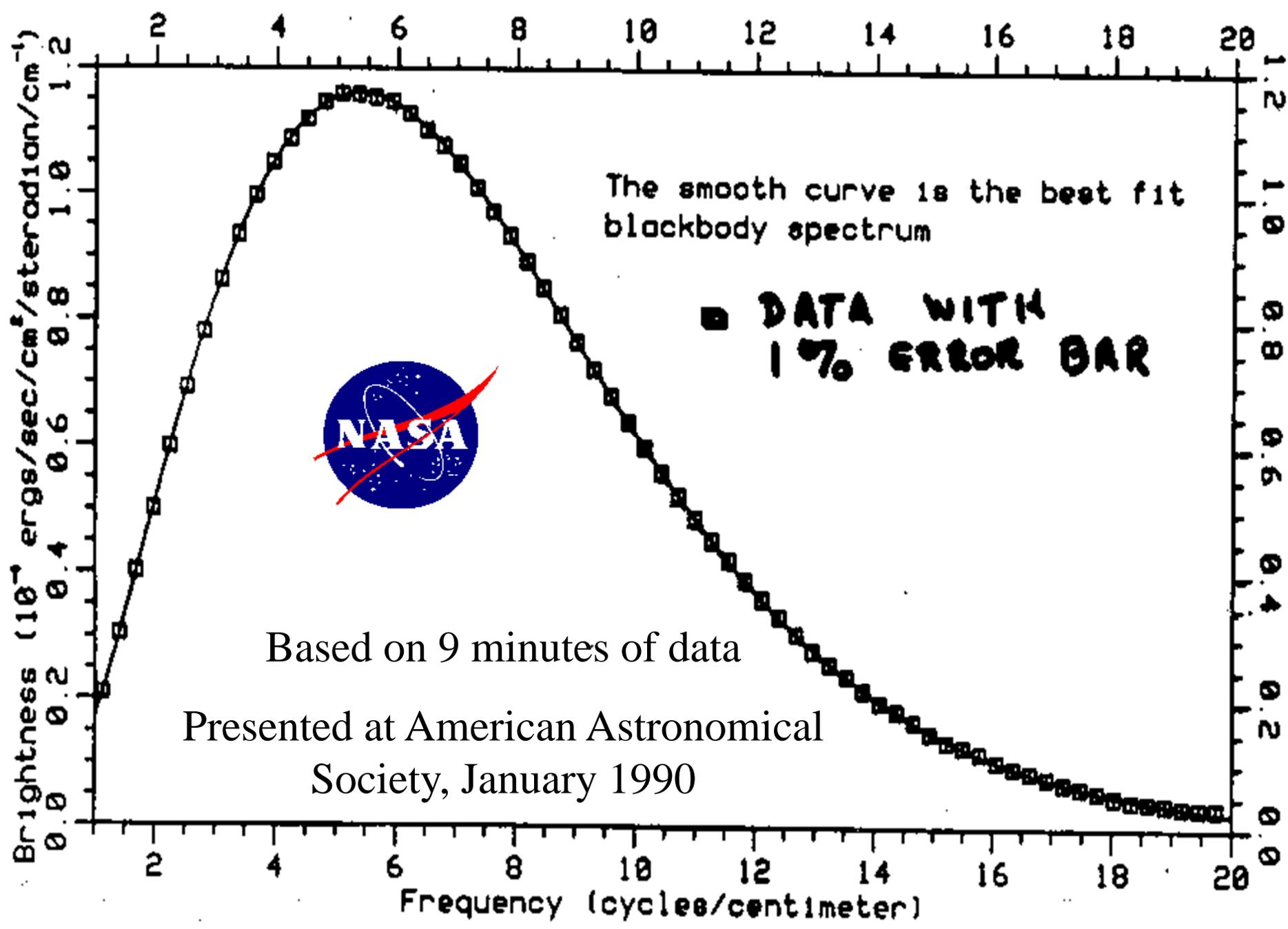
- Gravity is long range attractive force
 - Matter distribution is unstable
 - Remove heat, and system heats up more
 - Makes condensed objects (stars, galaxies, etc.)
 - Gravitational energy flows support complexity
- Stars release heat from nuclear reactions
 - Heat & light received by Earth support complexity, from weather to photosynthesis



COBE in orbit, 1989-1994



Cosmic Background Spectrum at the North Galactic Pole





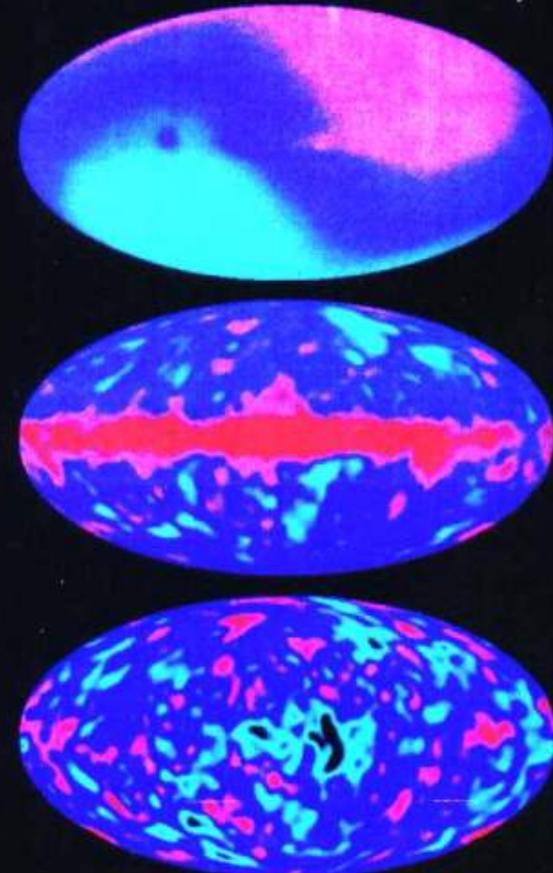
PHYSICS TODAY

JUNE 1992

Sky map from DMR,
2.7 K +/- 0.003 K

Doppler Effect of Sun's motion
removed ($v/c = 0.001$)

Cosmic temperature/density
variations at 389,000 years, +/-
0.00003 K (part in 100,000)



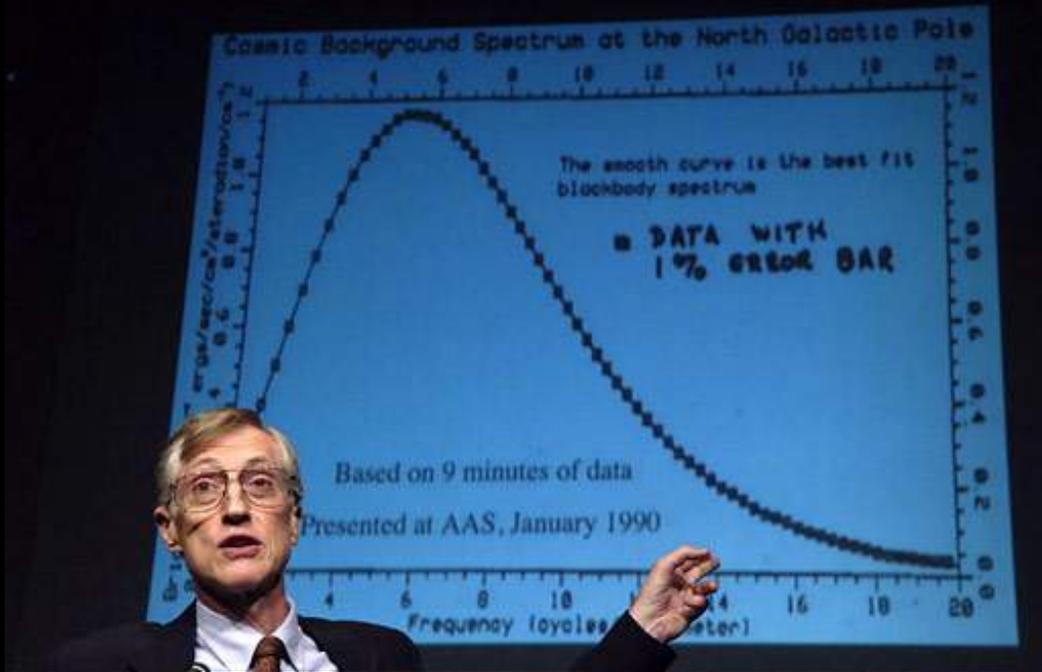


Nobel Prize Press Release

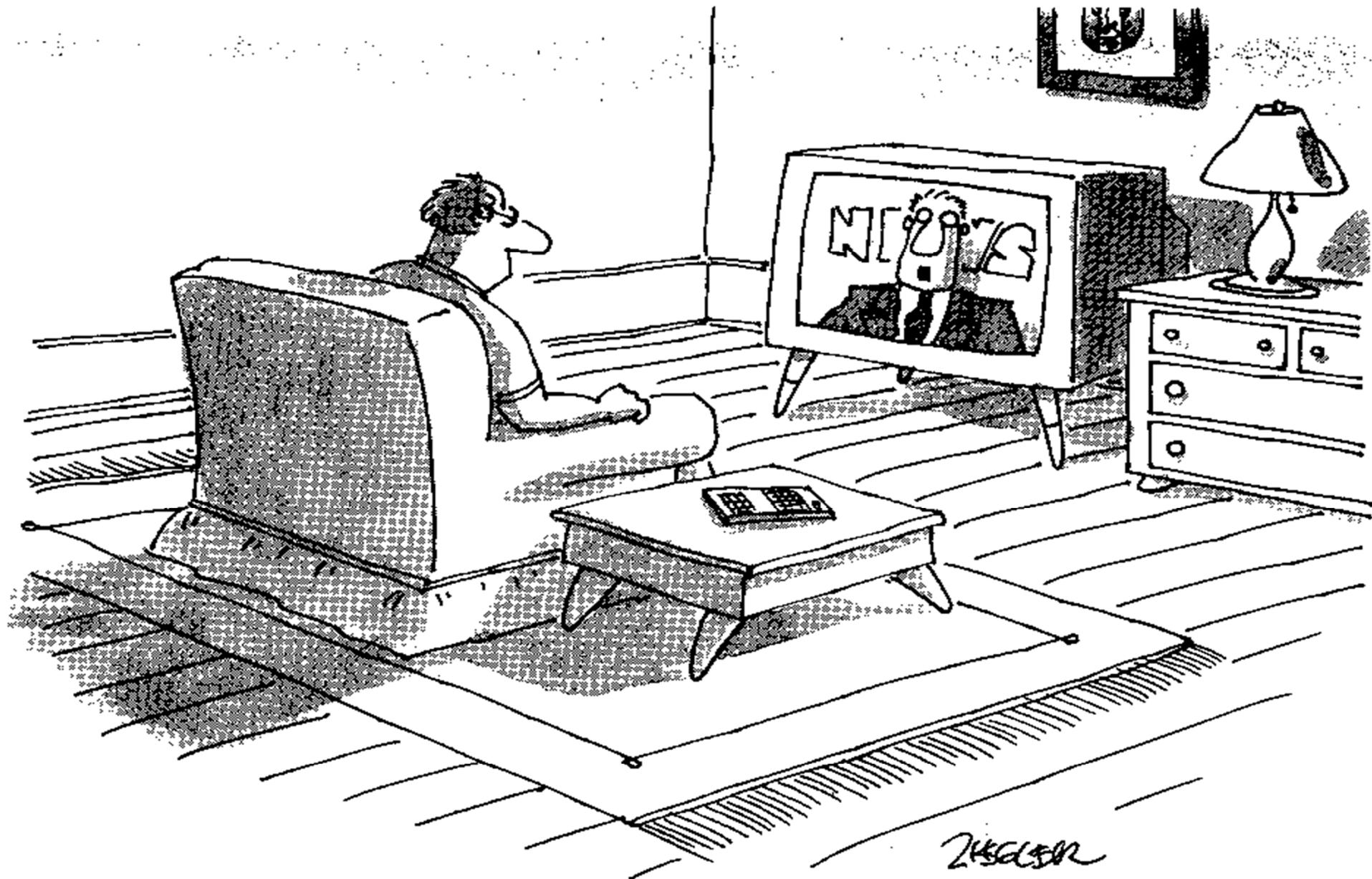
The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2006 jointly to **John C. Mather**, NASA Goddard Space Flight Center, Greenbelt, MD, USA, and **George F. Smoot**, University of California, Berkeley, CA, USA *"for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"*.



From Press Conference to Stockholm



© Nobel Foundation
Photo by Hans Mehlin

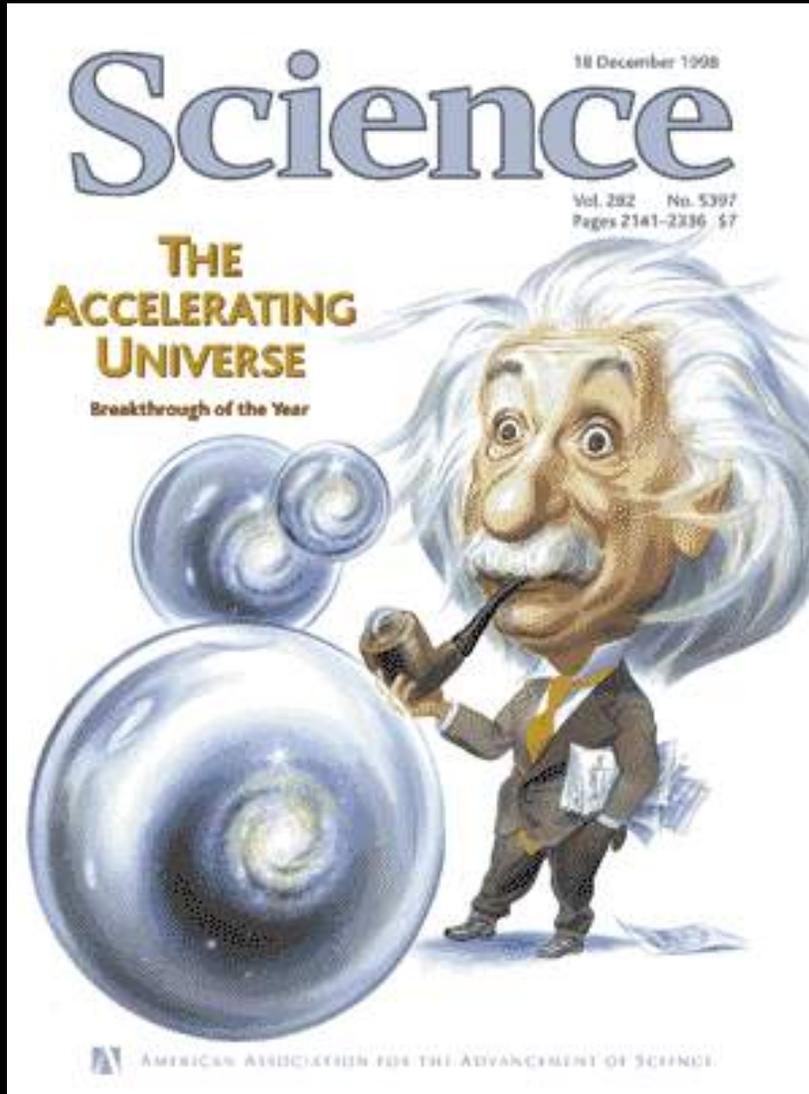


"Scientists confirmed today that everything we know about the structure of the universe is wrongdy-wrong-wrong."



Dark Energy!

MacArthur Fellow
2008 - Adam
Riess





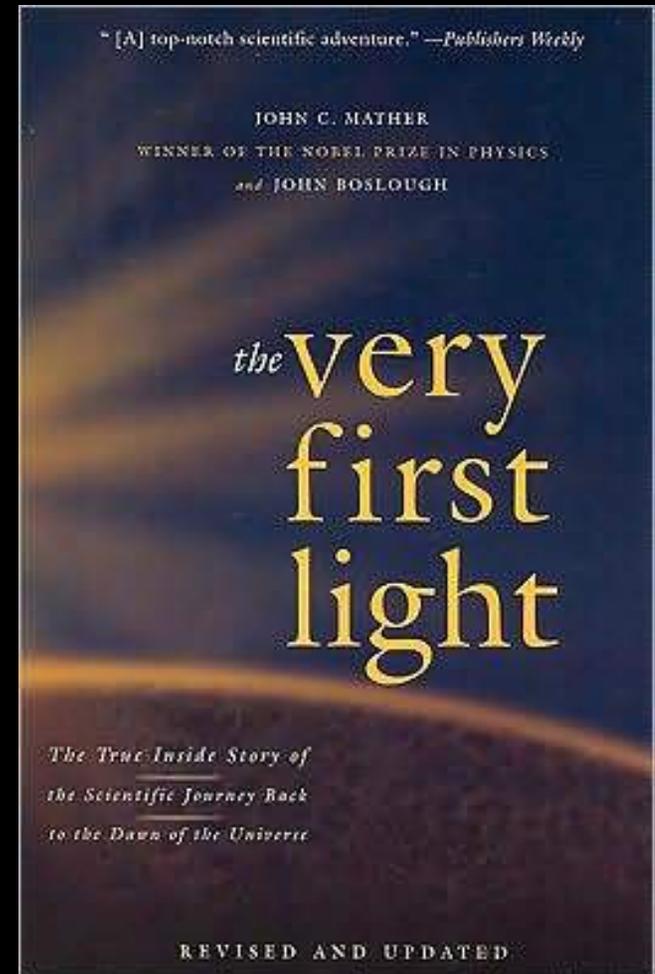
Galaxy Evolution Simulation





More Info:

- <http://www.jwst.nasa.gov>
- <http://lambda.gsfc.nasa.gov/>
- <http://nobelprize.org>
- Book, 2nd Edition:





Some Science PI Lessons

- Bad idea to have Project Scientist be a PI: not enough time in a day
- Deputies essential: too much for a PI to do, and “the bottleneck is at the top”; hiring freezes (especially under Jimmy Carter) were serious issue
- PI role for in-house projects does not include financial management - but he who has the gold, rules: must be on good terms with Project Management!
- Government lab can't delegate financial or personnel responsibility to outside PI - delicate situation for DMR PI



Major COBE Risks were social

- Concept: what if we forgot to think about a new effect due to cryogenics, noise, superfluid helium, spinning spacecraft, etc.?
 - Cold cables wouldn't flex
 - Aluminum distorted on cooling
 - Systematic errors hidden in noise, averaged for years
 - Magnetic susceptibility of RF switches
 - Electrical interference between computer clock, picked up by the ultrasensitive detectors
 - Light coming up from Antarctica stressed power system
 - Conclusion: **PI or team inexperience is a major risk**
- Test: what if we can't afford to test something?
 - Nature doesn't care if we can afford it or not
 - What if something breaks in test? We won't have resources to fix it, so why test?
 - After Challenger, Columbia, etc. we can confirm: **management (including PI and customer) attitude is a major risk**



Lessons from COBE

- Aim high - the world will change in 20 yrs.
- Do only what can't be done any other way
- If there's no law of nature against it, maybe it can be done: don't be intimidated
- If it's not forbidden, it's required: physics & astronomy
- Mather's Principle of Management: If it's not required, it's forbidden (but what *IS* required?)
- If it's not tested, it won't work: confidence \neq success
- If it's tested, it won't work the first time either - plan to rehearse, test, rework, retest
- Elementary things fail: simple \neq successful
- It's worth all this work: no substitute for major space missions



The end and the beginning...



Risks of Being Good

- If you're the PI, people may think you are always right: so be careful! You are a single-point failure walking on Earth.
- Make sure your calculations are double-checked by somebody who doesn't know the right answer



Some things are sure

- People make errors
 - All 7 deadly sins, and many more
 - Biggest one: I thought I knew what I was doing (and other excuses), so I didn't tell anybody or complain or ask for help
- People find errors
 - Pure thought & document review
 - Peer review panels
 - Technology development (~ people development)
 - Test programs
 - Simulations
- People don't always find errors
 - Not enough time, money, imagination, all possible excuses
 - Your project is wrecking my other plans, so no you can't have any more time and money
 - Nature doesn't care about our excuses



Personal Risk Management

- I know 8 people who fell off a ladder or a roof
- I knew (of) several who died of too much exercise, including a quality assurance expert
- One was murdered
- One died young for no known cause
- Conclusion: **can-do people are not programmed to appreciate $L * C = \text{Likelihood} * \text{Consequences}$**
- Develop and use formal risk management process!!!



Summary & Implications

- Greatest risk is lack of imagination
 - See possibilities
 - Estimate likelihood
 - Appreciate consequence
- We're easily blinded by thinking about the resources we have
- Nature doesn't care what we think



COBE Science & Engineering Team Selection

- 3 proposals submitted on CMB, 1974, out of ~150 total Explorer proposals
- Study done on spectrum experiment on board IRAS
- HQ decision to form Mission Definition Study Team: 6 members (4, 1,1) from proposals; downselect to ~12 Explorers
- Assigned GSFC to provide engineering & management - IUE team, about to launch



Science Team Organization

- Study Scientist drafted a Science Working Group team charter, outlining roles and responsibilities (but no process for resolving disputes or violations of policy)
- All SWG members co-I's on all instruments
- All SWG members have authorship rights on most papers for duration of mission, including coordination of press releases
- PI's have responsibility for instruments and science from them
- Chairman elected
- PI's nominated to HQ by SWG and accepted by HQ



Growth of SWG to 19

- SWG members nominated additional members, and all were accepted by HQ
- Specific roles expected, not always fulfilled
- Key additions: Deputy PI's (Bennett, Kelsall, Shafer), Data Team Leader (Ned Wright)
- Only one theorist, others all instrument experts
- Note: Project Scientist is a NASA position, not a HQ-selected position, so Deputy Project Scientist is not automatically a SWG member
- Experience matters: 2 became PI's of new NASA missions (Bennett - WMAP, Wright - WISE)



COBE Context

- Proposed 1974, before computer revolution
 - No CAD/CAM, no realistic performance modeling, can't visualize hardware before construction
 - No email, and managers couldn't type
- New Start 1982, Challenger 1986, launch 1989
- Instruments far beyond state-of-the-art
 - Detectors not available
 - Accuracy requirements unprecedented
 - Almost no cryogenic experience in space
- In-house project, largest GSFC ever did
- 2 PI's in house, 1 external (Berkeley) with in-house deputy



COBE Requirements

- Engineers wanted detailed requirements documents flowed down to them
- Scientists couldn't do systems engineering all by themselves
- Systems engineers couldn't do it without many iterations with team
 - But teams didn't like iterations and trade studies
- Nevertheless, close interaction of scientists and engineers allowed relaxation and re-interpretation of requirements when needed
 - Pushed state of the art 1000x



Matrix Management

- Prefer full time assignments - undivided loyalty, undivided mental concentration
- Possible with good matrix management, disrupted by bad management
- Beware assignments to organizations - prefer individuals, not “branches” or “departments”
- Scientists are “matrixed” too, typically from University environment
 - 10% time is just enough to go to meetings, not enough to do much useful
 - Better to ask for sabbaticals and release from other duties for a short period to enable concentration



Need Diversity of Personality

- Visionary - forward looking
- Decision making - taking risks for progress
- Fact checking - detail oriented
- Grouch - test everything enough
- Planning - make things happen
- Organization - proper assignments