GRB Science, Problems and Prospects

Early Light from Gamma Ray Bursts

Probe of the Dawn of Universe

Epic of Reionization

their Progenitors & Science

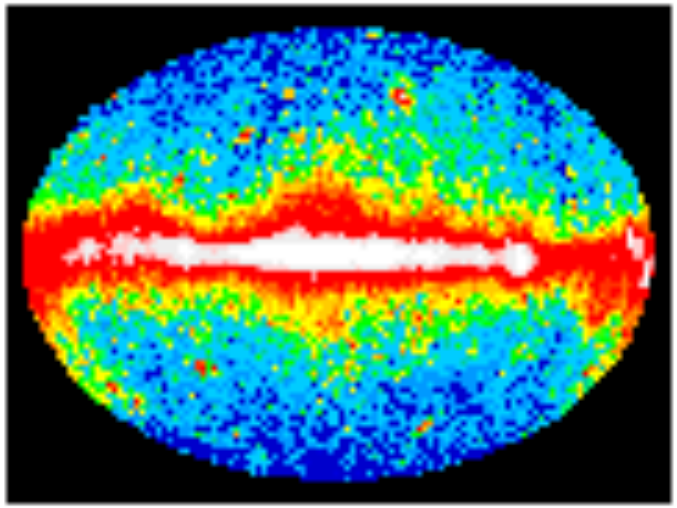
Prof. George F. Smoot

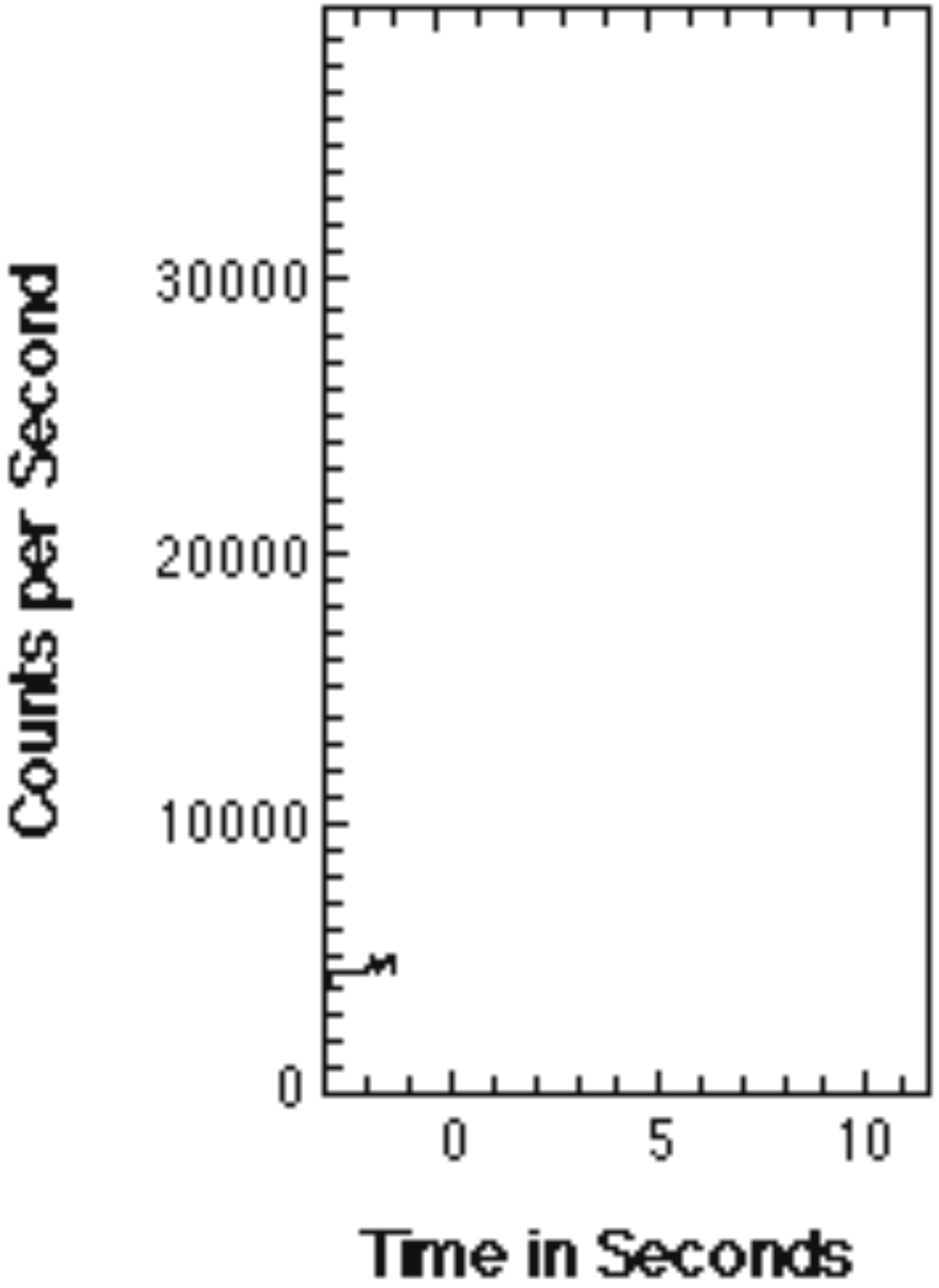
Ewha University, Seoul, Korea
Universite Paris Diderot, France
University of California, Berkeley, USA
Moscow State University, Moscow, Russia
Extreme Universe Laboratory

GRB Workshop 13-18 June 2012 EUL Moscow State U.

Chalonge School July 28

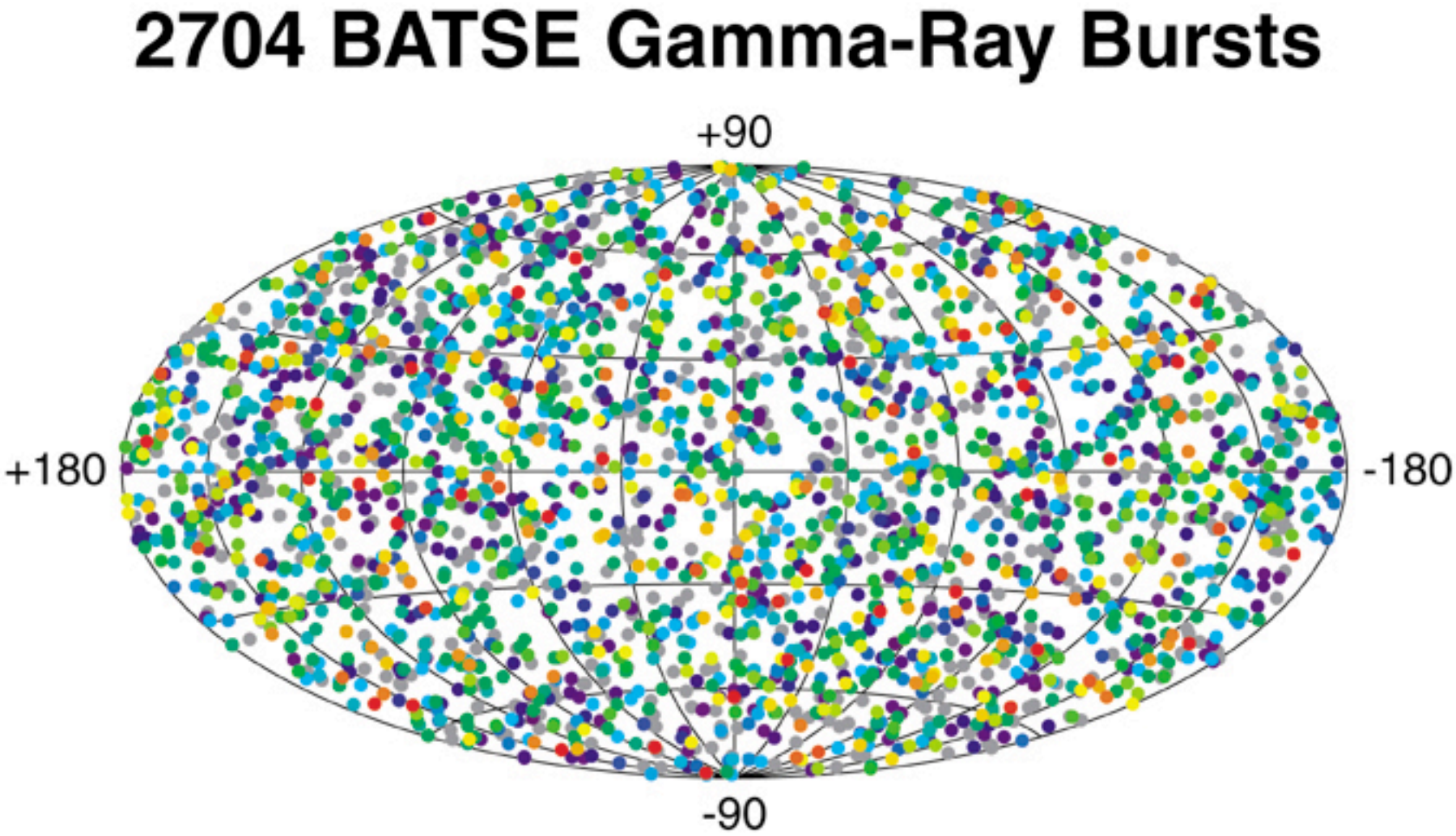
GRB Appears
And vanishes





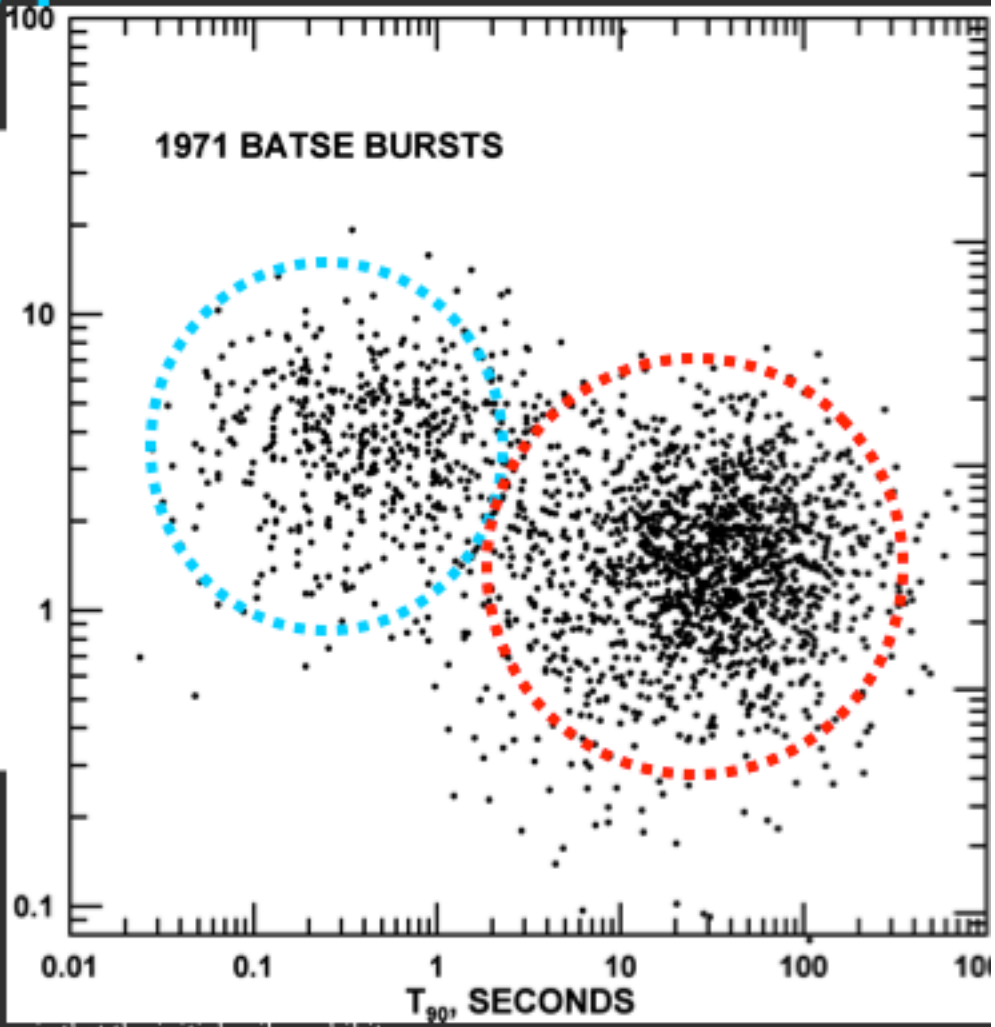
500 GRBs Observed by Swift

GRBs Uniform on Sky => Extragalactic



2 Main Types of GRB

- GRB=Gamma-Ray Burst
- LGRB=Long, softer
  $t_{90\gamma}$ >2 s, Typical ~ 20 s
- SGRB = Short GRB
  $t_{90\gamma}$ < 2 s, Typical ~ 0.4 s
  - "harder" X-γ spectra,
  - much fainter all optical
  - faint X-γ afterglow
- (OTHER classifications exist)



-we show that the fundamental defining characteristic of the short-burst class is that the initial spike exhibits negligible spectral evolution at energies above ~25 keV. "- Norris & Bonnell 2005

$t_{90\gamma}$ = GRB duration = interval of 90% fluence in γ light curve.

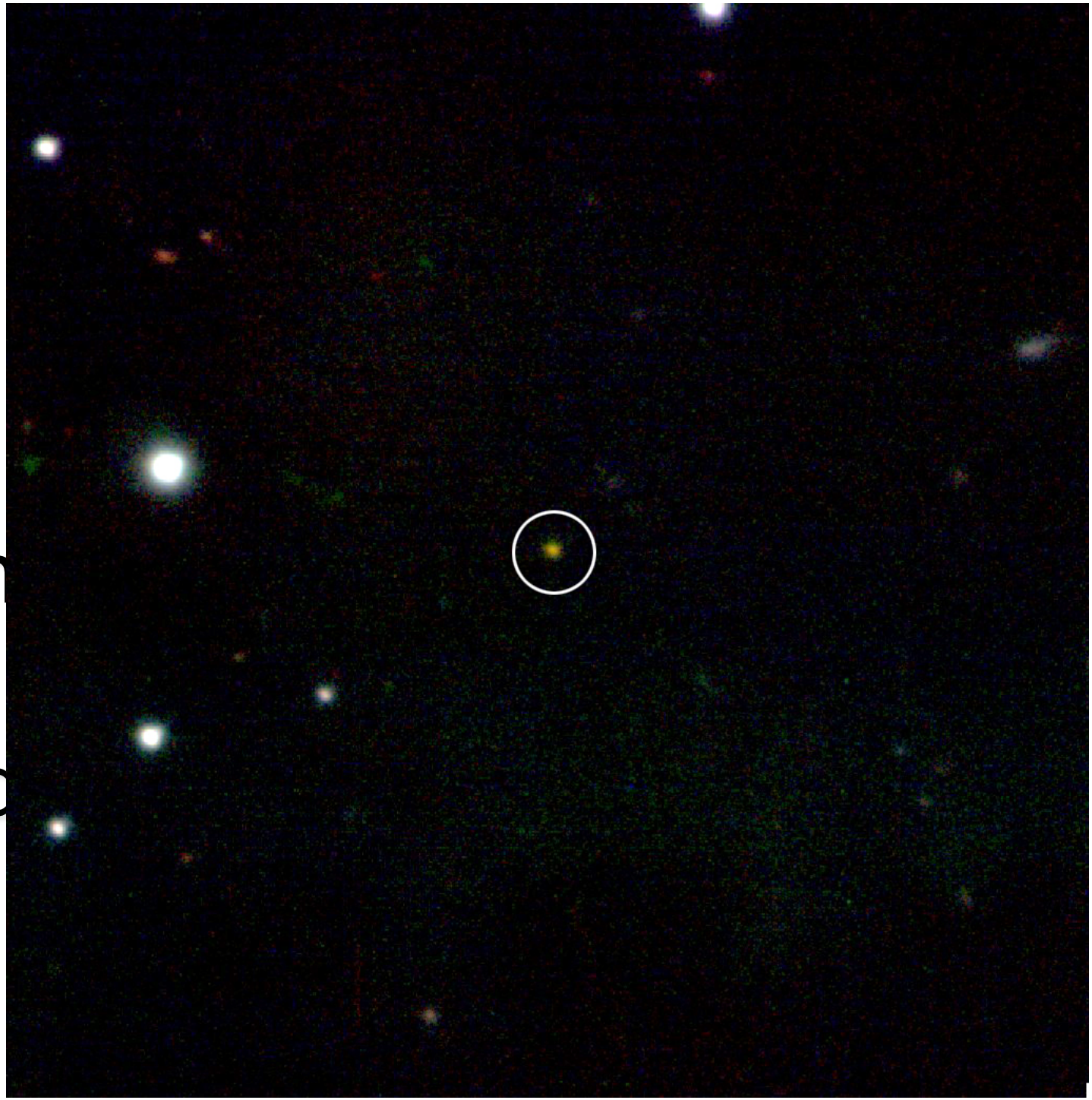
Hard = flatter spectrum = crude ratio of high, low energy channels.

Gamma-Ray Bursts in 1 Slide

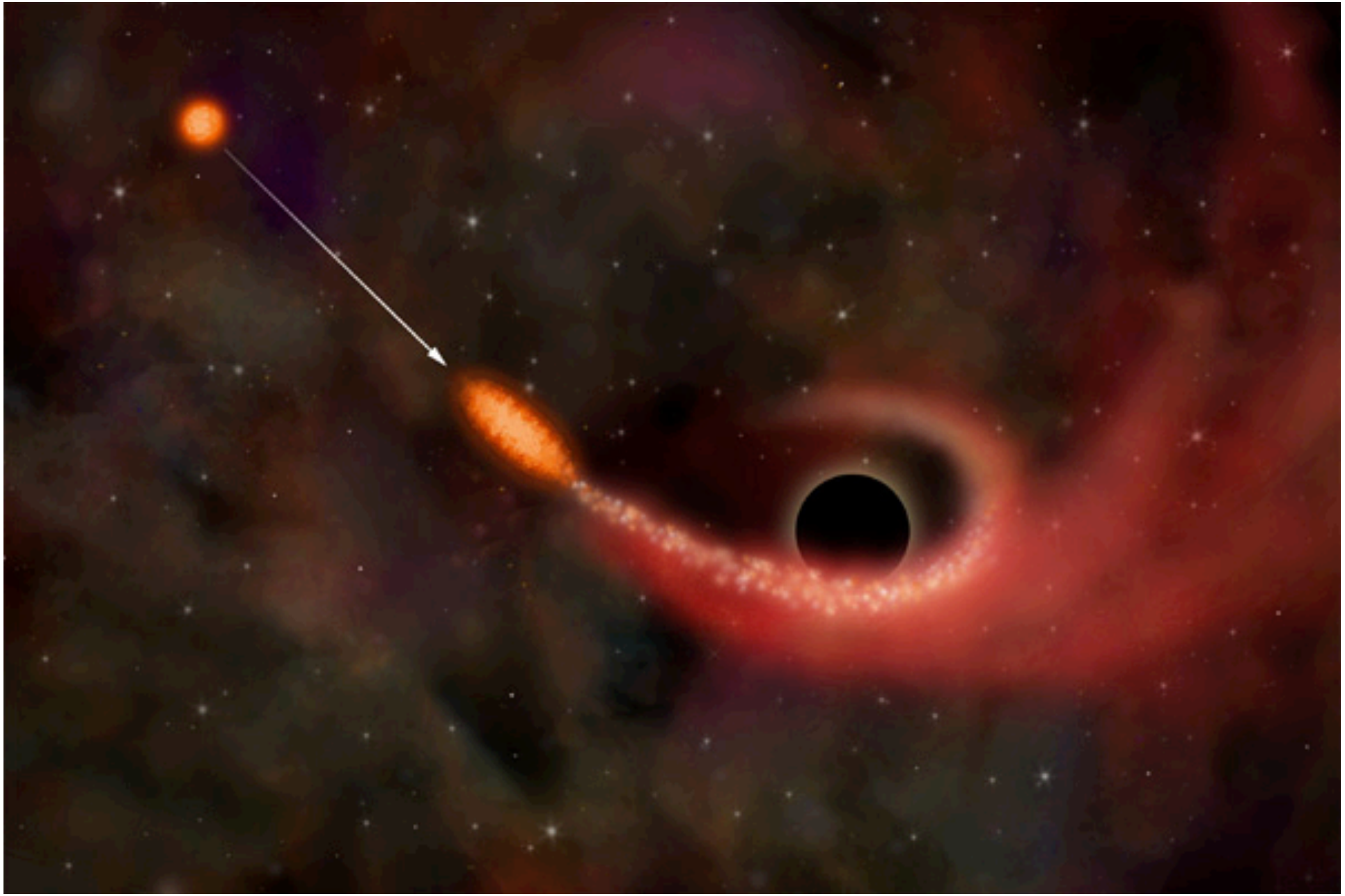
- Most energetic events in the universe
  - Measured to z = 8.2 (GRB090423)
  - Can be seen to z~12 with large detectors

- Gamma-Ray Bursts (GRB) last msec – hr.
- Measured up to GeV (rest energy of a proton)
- Afterglow can be detected weeks after burst, has power law decay light curve in all bands for some long type GRBs
- Long Type GRB associated with massive star collapse SuperNovae

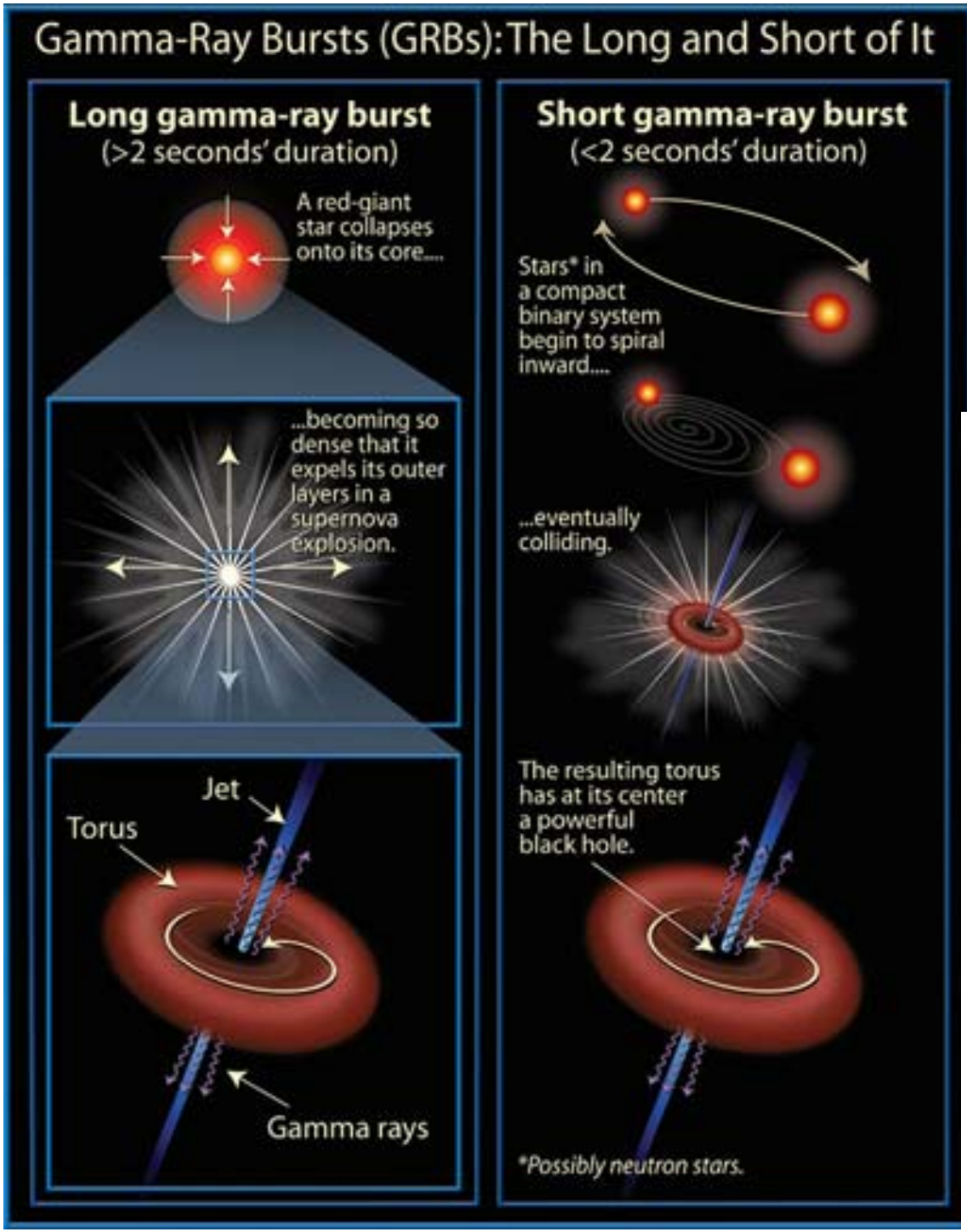
GRB 090423: The Farthest Explosion Yet Measured z = 8.2

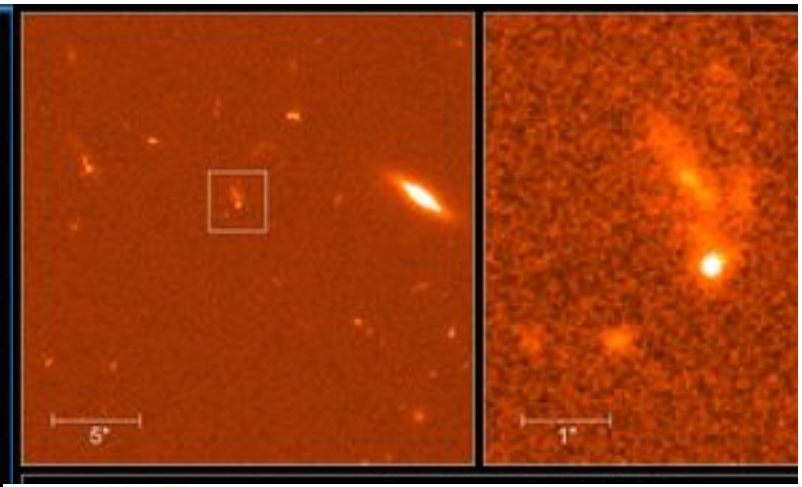


Black Hole disrupts and swallows star

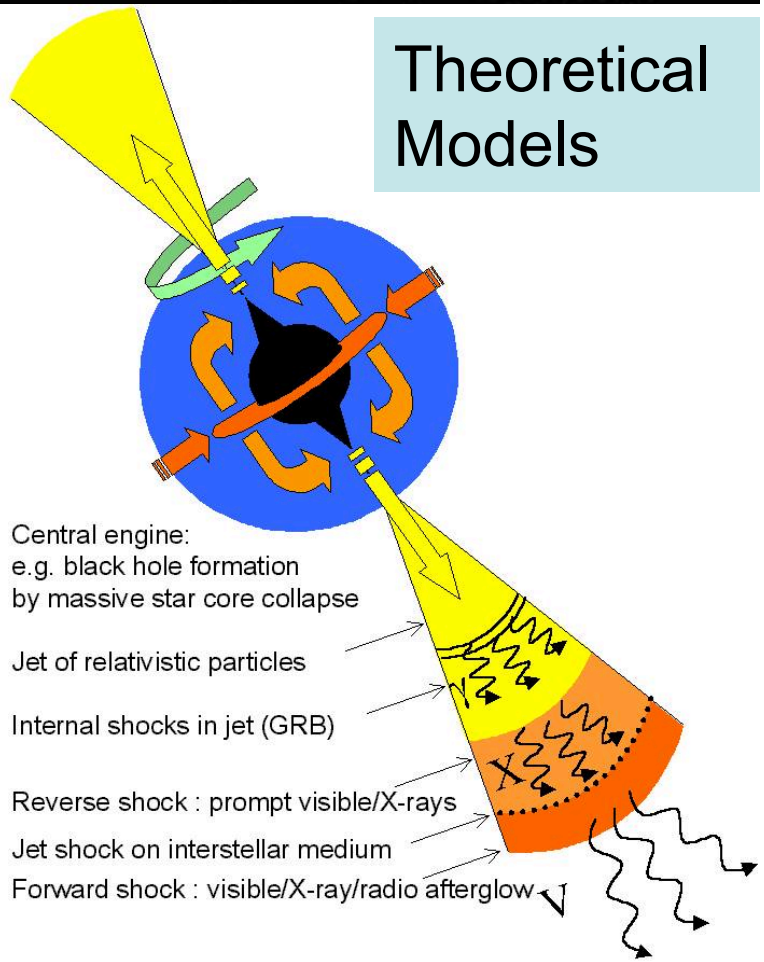


Voracious Black hole

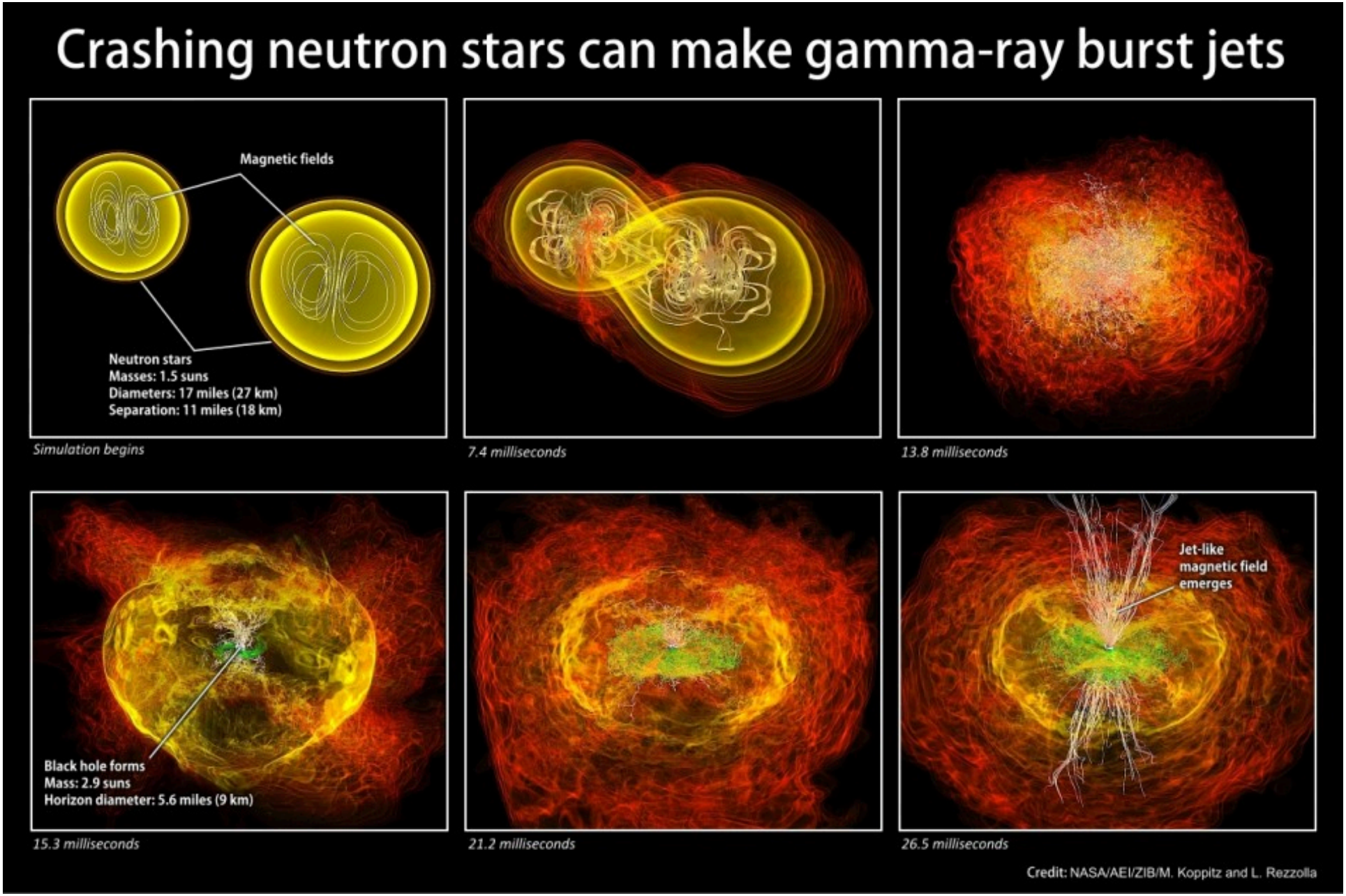




Theoretical Models

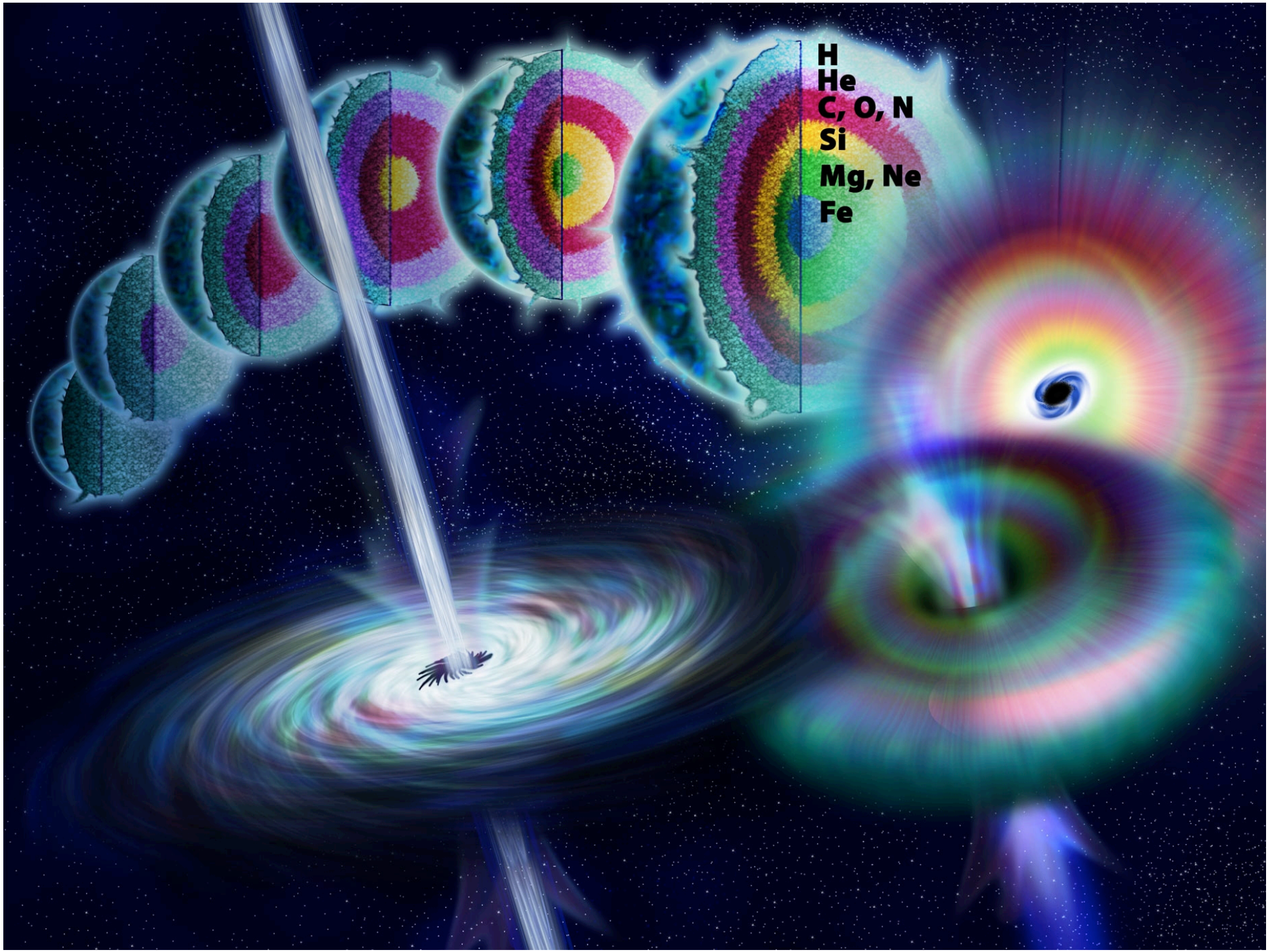


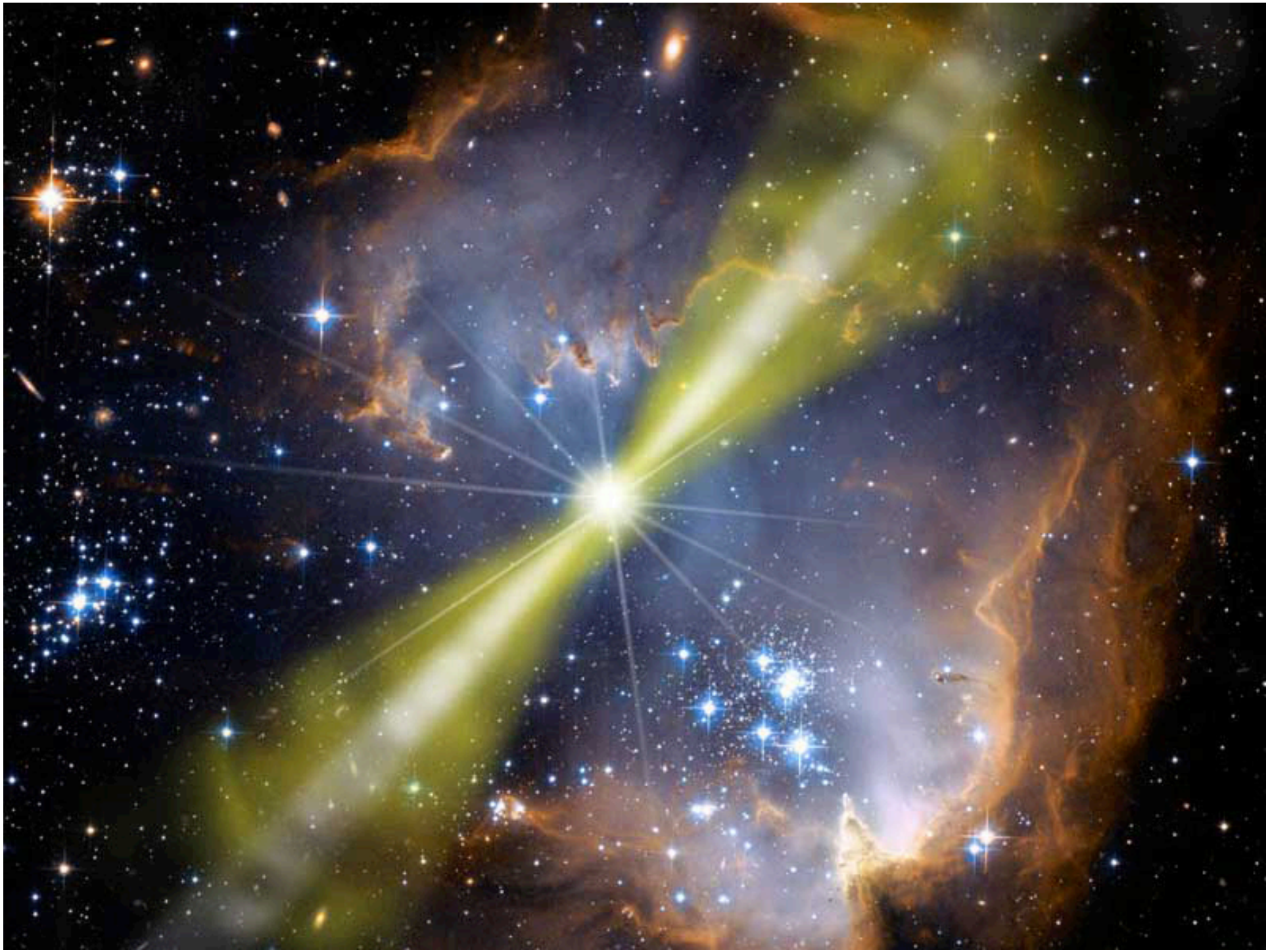
Inspiraling & Merging Neutron Star Model

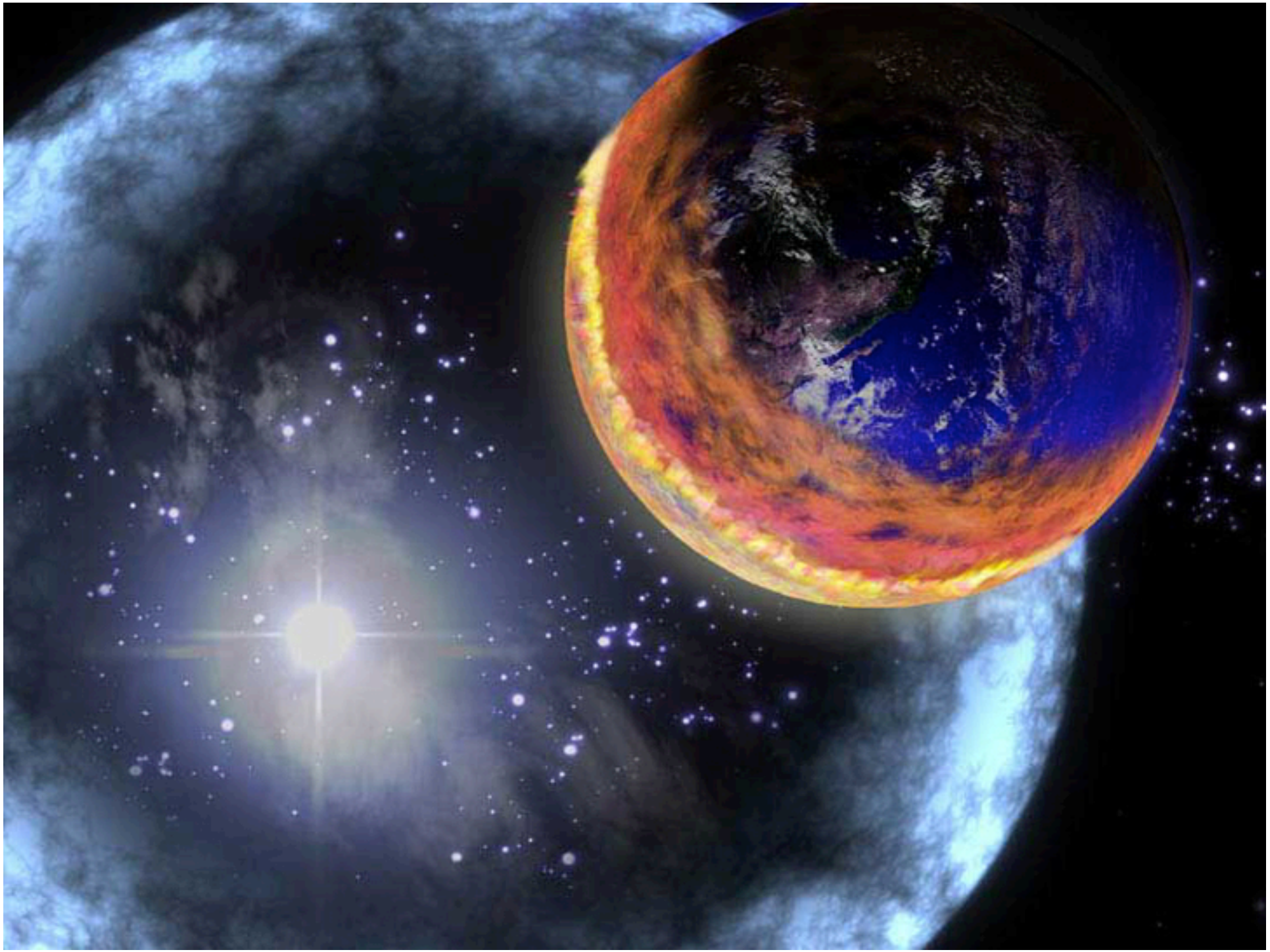


Neutron Star Inspiral Model Video

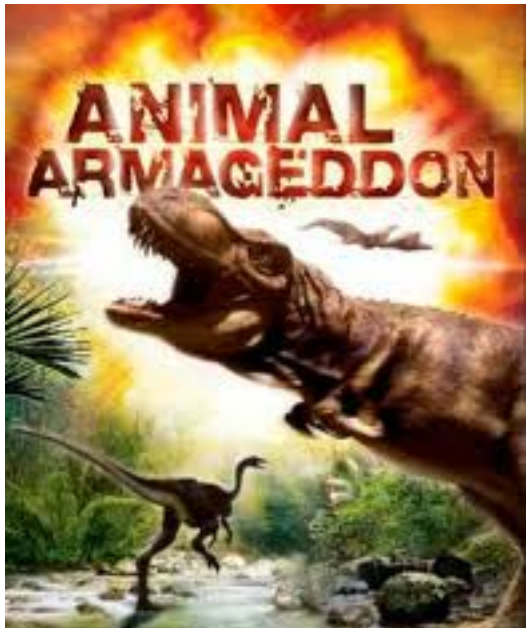
Stellar Death Cry


H
He
C, O, N
Si
Mg, Ne
Fe





Extinctions or Sterilization of Earth



- Using cutting edge research, the latest scientific theories and incredible CGI to bring prehistoric animals back to life,
- Animal Armageddon an eight-part mini-series
  - transports viewers
    disasters ever to ro
  - From a cosmic gam
    atmosphere, trigger
  - to an asteroid the s
    the Yucatan, killing
    natural events caus

    Throughout the 600
    stence, some 99.
    ever lived is no

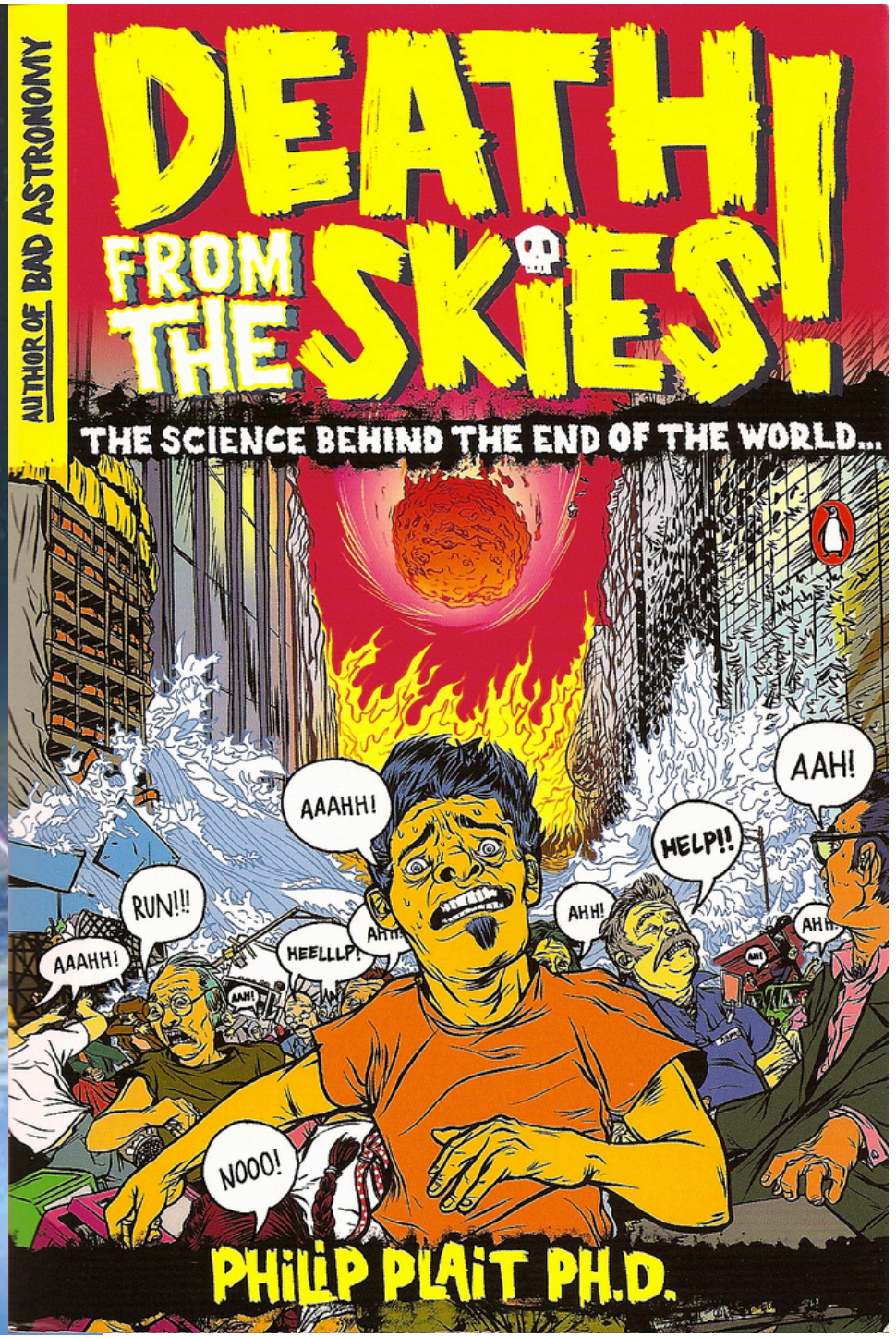
    mal Armageddon
    inction of these a
    datory sea mons
    itiloid, to vicious
    giant mammals li

    mal Armageddon
    ith had on these
    owed.

AUTHOR OF BAD ASTRONOMY

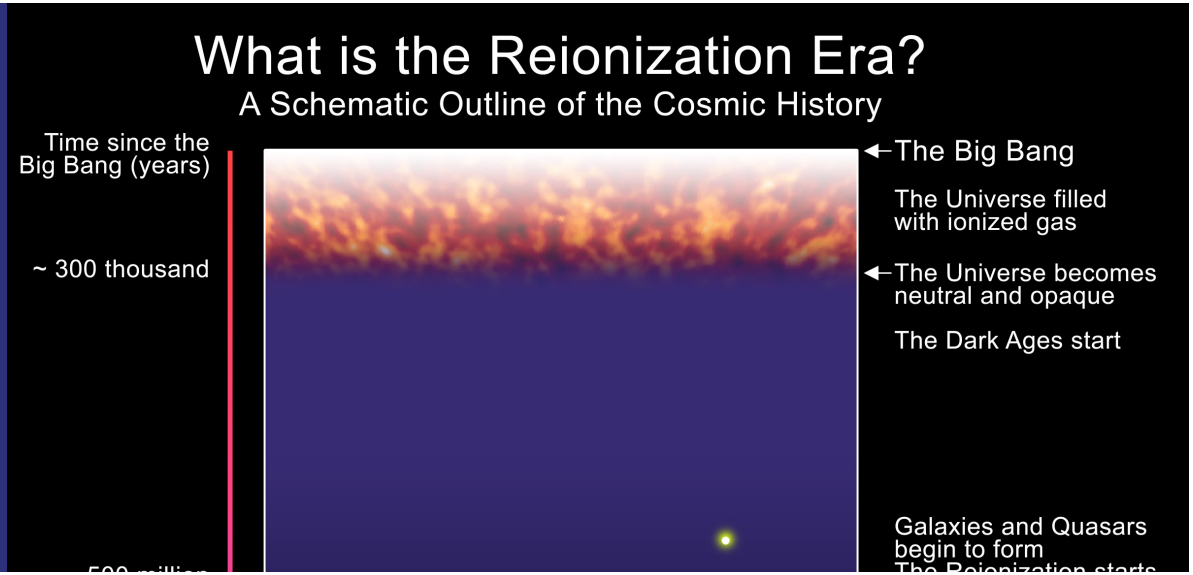
DEATH FROM THE SKIES!

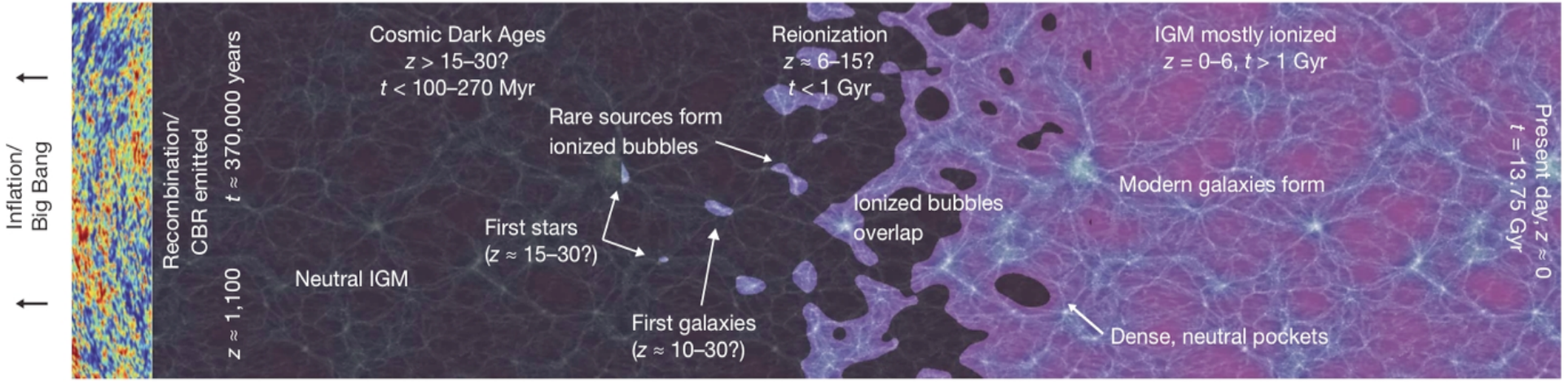
THE SCIENCE BEHIND THE END OF THE WORLD...

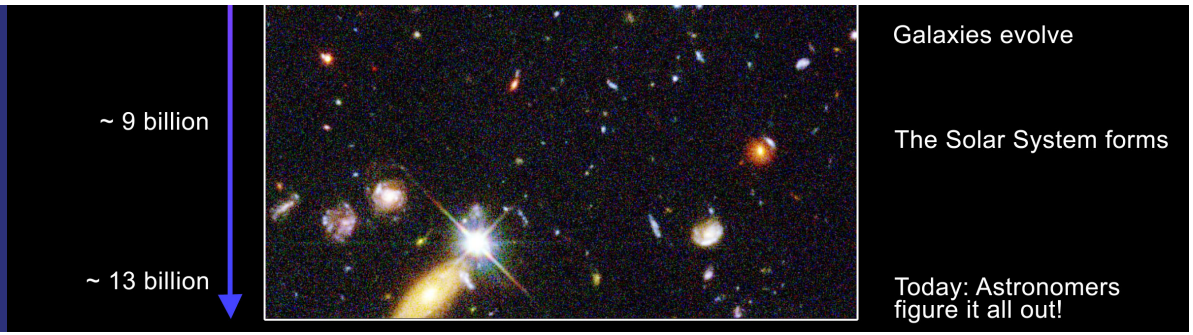


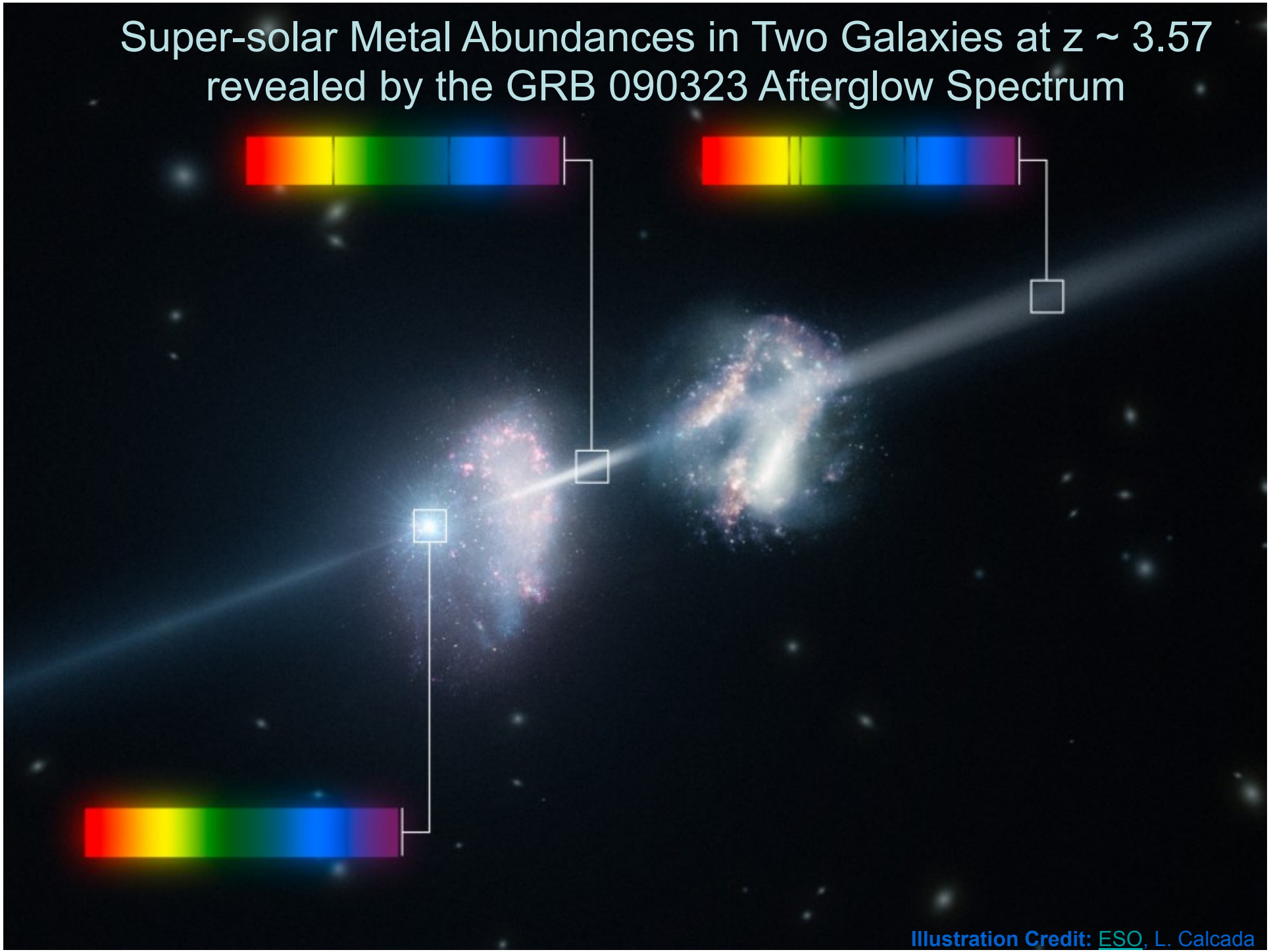
PHILIP PLAIT PH.D.

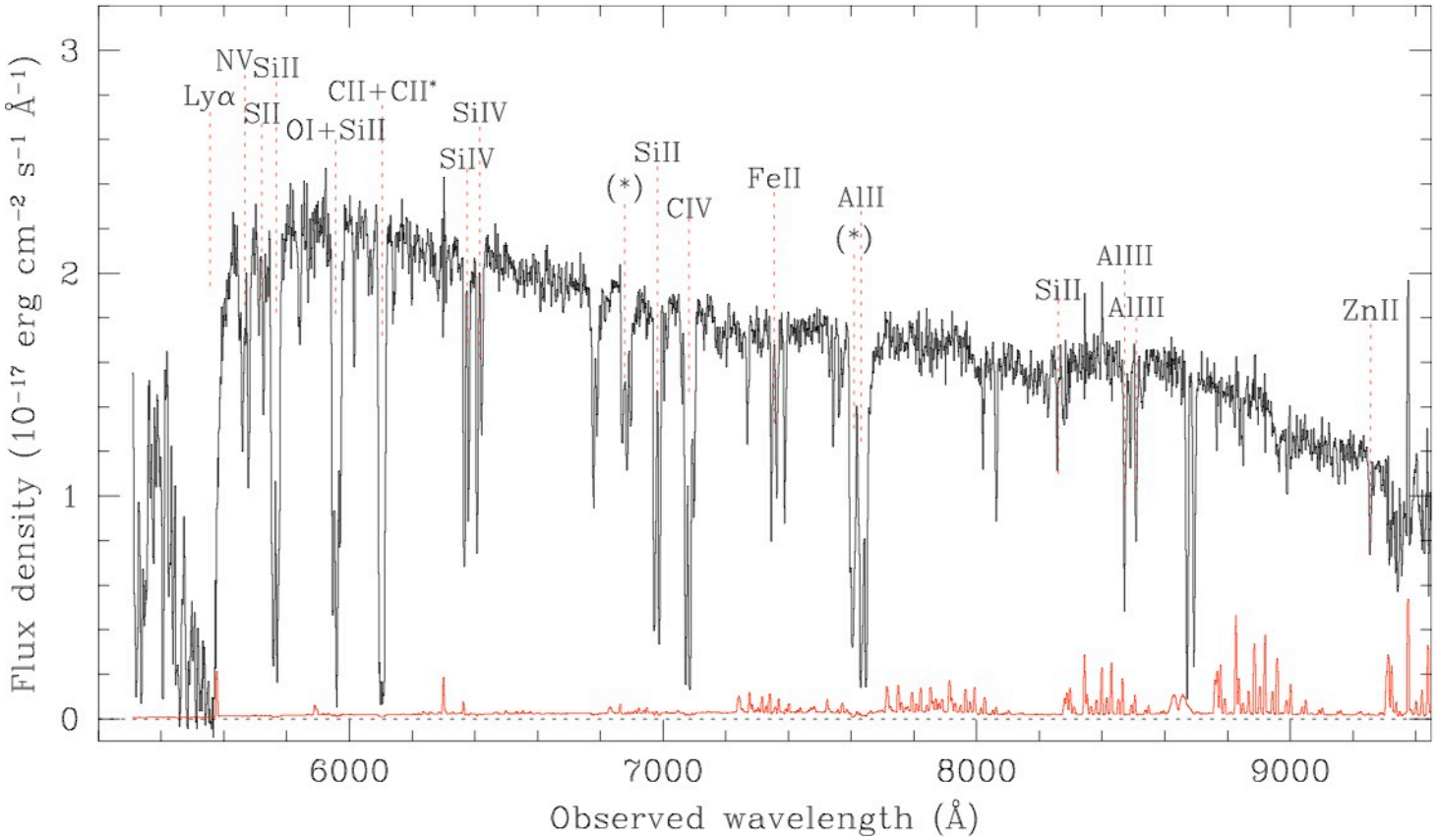
Cosmic Dawn


What is the Reionization Era?
A Schematic Outline of the Cosmic History
Time since the Big Bang (years)
~ 300 thousand
The Big Bang
The Universe filled with ionized gas
The Universe becomes neutral and opaque
The Dark Ages start
Galaxies and Quasars begin to form


Inflation/ Big Bang
Recombination/ CBR emitted
$t \approx 370{,}000$ years
$z \approx 1{,}100$
Cosmic Dark Ages
$z > 15$–30?
$t < 100$–270 Myr
Reionization
$z \approx 6$–15?
$t < 1$ Gyr
IGM mostly ionized
$z = 0$–6, $t > 1$ Gyr
Present day, $z \approx 0$
$t = 13.75$ Gyr
Rare sources form ionized bubbles
First stars ($z \approx 15$–30?)
Neutral IGM
First galaxies ($z \approx 10$–30?)
Ionized bubbles overlap
Modern galaxies form
Dense, neutral pockets


~ 9 billion
~ 13 billion
Galaxies evolve
The Solar System forms
Today: Astronomers figure it all out!

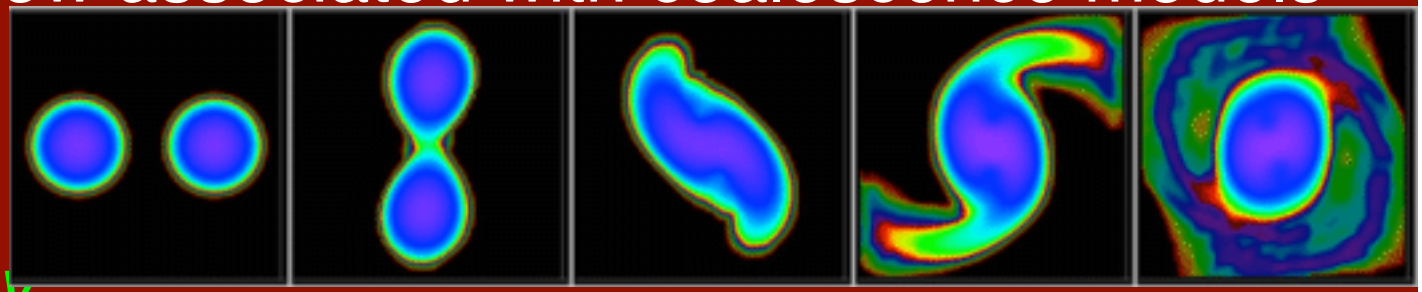

Super-solar Metal Abundances in Two Galaxies at z ~ 3.57
revealed by the GRB 090323 Afterglow Spectrum
Illustration Credit: ESO, L. Calcada



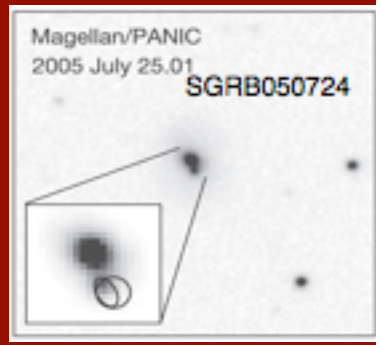
The optical VLT/FORS2 spectrum of the afterglow of GRB 090323. Indicated are the main absorption lines associated with the two systems G0 and G1 at z ~ 3.57. Many other lines, associated with intervening systems are present, but not marked. ZnII absorption is identified in G1. The red line at the bottom is the spectrum of the Earth atmosphere. The two stars indicate the telluric absorption.

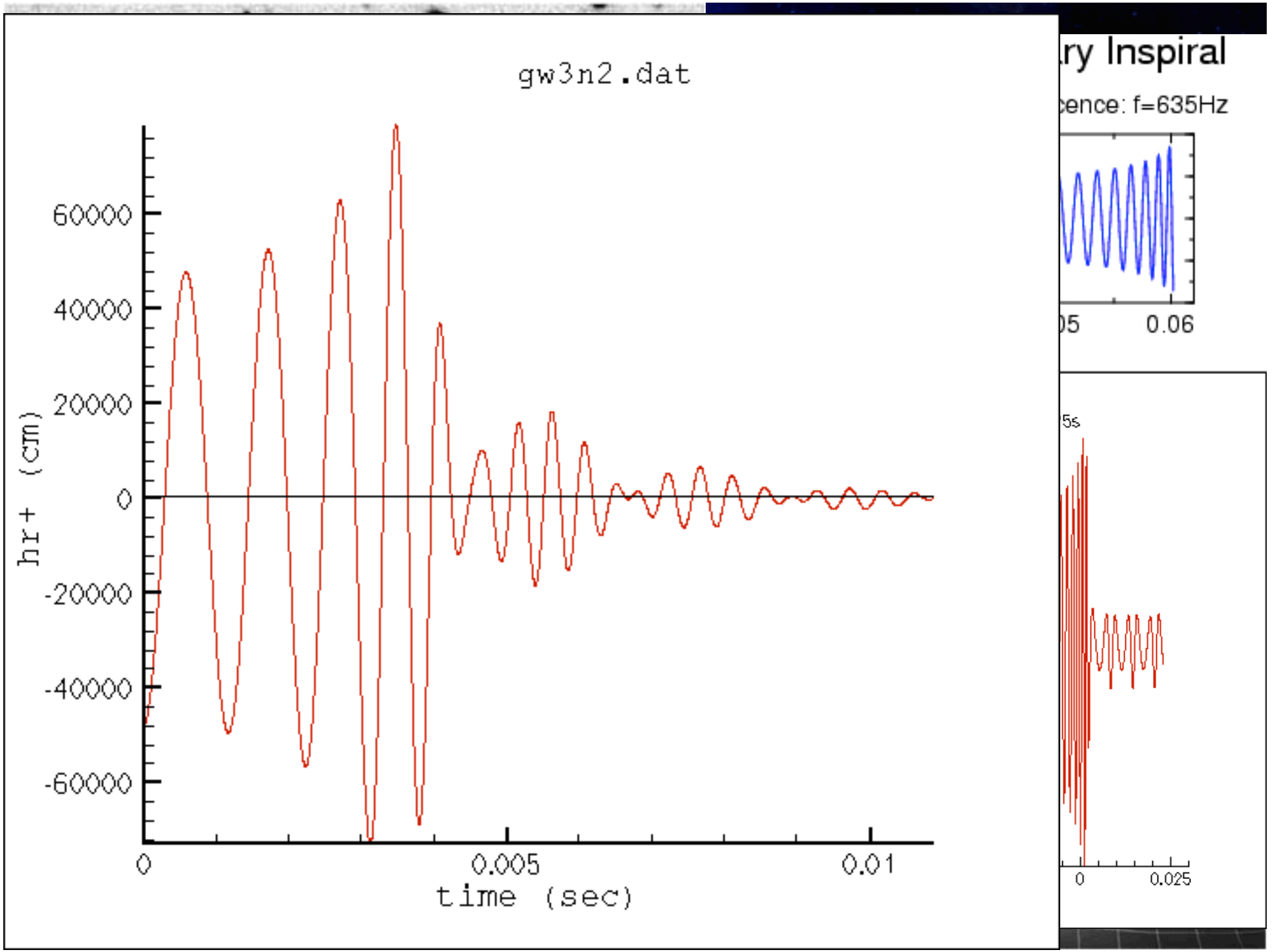
SHGRB Origin Unknown

SHGRB now associated with coalescence models

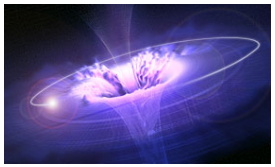


- *Consistency*
  - *SHGRB faint compared to LGRB, lower energy.*
  - *Usually not in star forming regions, far from galaxy, so could be evolved system - like dead neutron stars (NS) or black holes (BHs)*
  - *No actual proof;*
- *Outstanding Mystery*
- Compact object coalescence would mean Gravitational Waves (GW), likely detectable by next-generation GW detectors, if close enough.




gw3n2.dat
60000
40000
20000
0
-20000
-40000
-60000
hr+ (cm)
0
0.005
0.01
time (sec)
ry Inspiral
cence: f=635Hz
05
0.06
5s
0
0.025

Very Short GRBs ?
Black Hole Evaporation Bombs?



- **"Does Very Short Gamma Ray Bursts originate from Primordial Black Holes?"** by D.B. Cline & S. Otwinoski arXiv:1105.5363
- Primordial Black Holes with mass of about 5 x 10^{14} gm evaporate now in a final state explosion. (Power goes as 1/ m^4 and lifetime as $1/m^3$ and see plot to right)

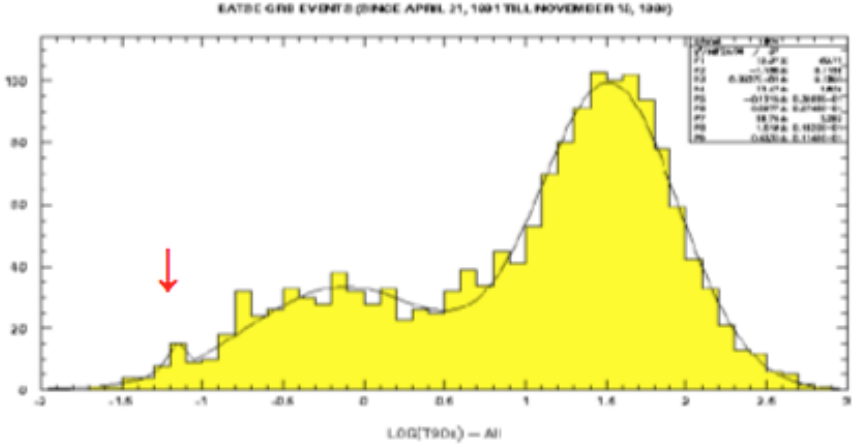


Fig.1. The time distribution T_{90} for all GRB from BATSE detector [1].

7. Time profile of rising part of BATSE VSGRBs is in agreement with evaporation PBH.

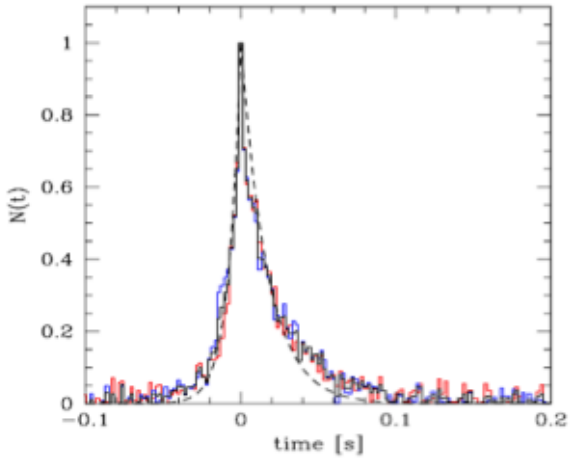


Fig.10. Composite burst profiles for all VSGRB (black line), for bursts from Galactic Anticenter region (red line) and for bursts from outside that region (blue line). The analytical fit (dashed line) is given by Eq.1. Better fit for the decay part is provided by Ryde & Svensson function (Eq. 2) [10].

Hawking 1973, Zel' dovich 1971

To learn more about the GRBs and the Universe

Need more GRBs observed earlier, localized, and follow up

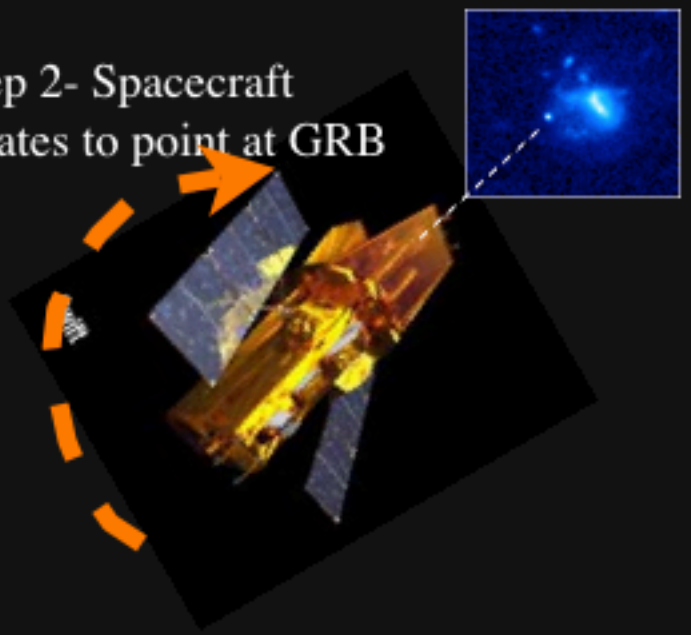
- Trigger on GRB quickly
- Catch them early
- Observe direction more precisely so that large telescopes can follow up
  - Spectra
  - Time response

Faster-Steer the Beam

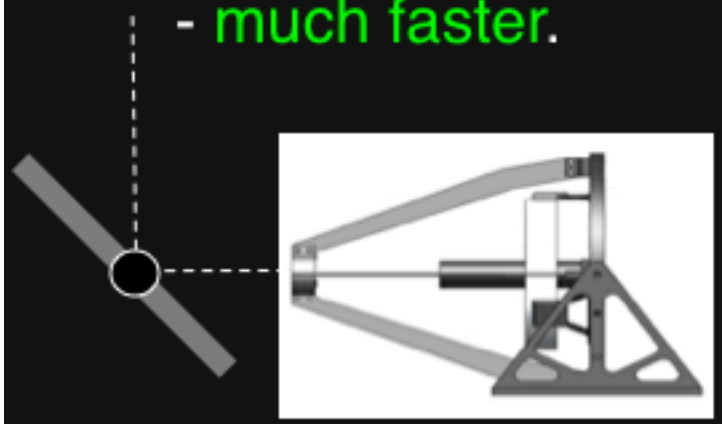
- SWIFT rotates entire spacecraft to point opt instrument

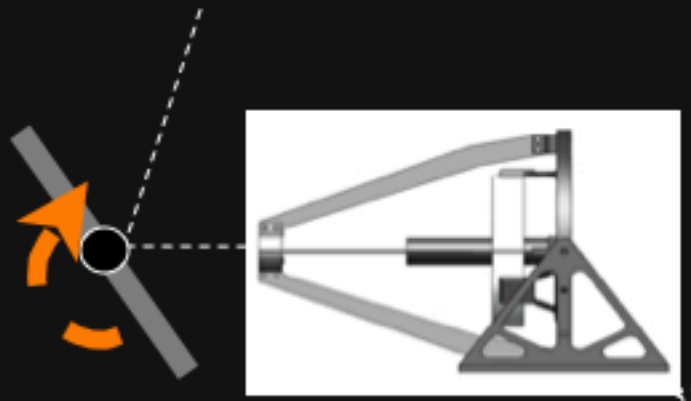
Step 1- Wide FOV X/γ-camera locates GRB

Step 2- Spacecraft rotates to point at GRB



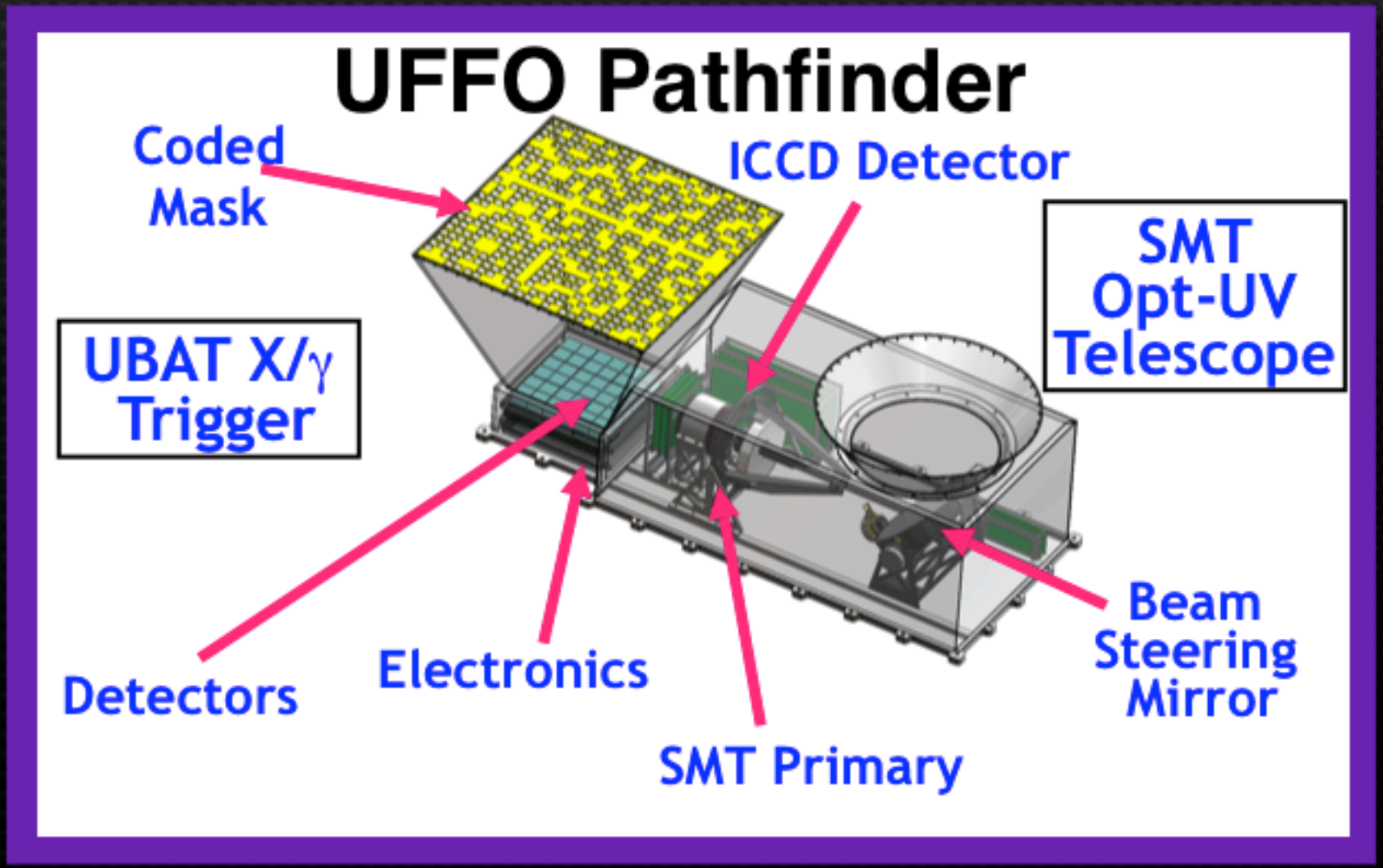
- We use mirrors to steer the *beam*, not the spacecraft - much faster.





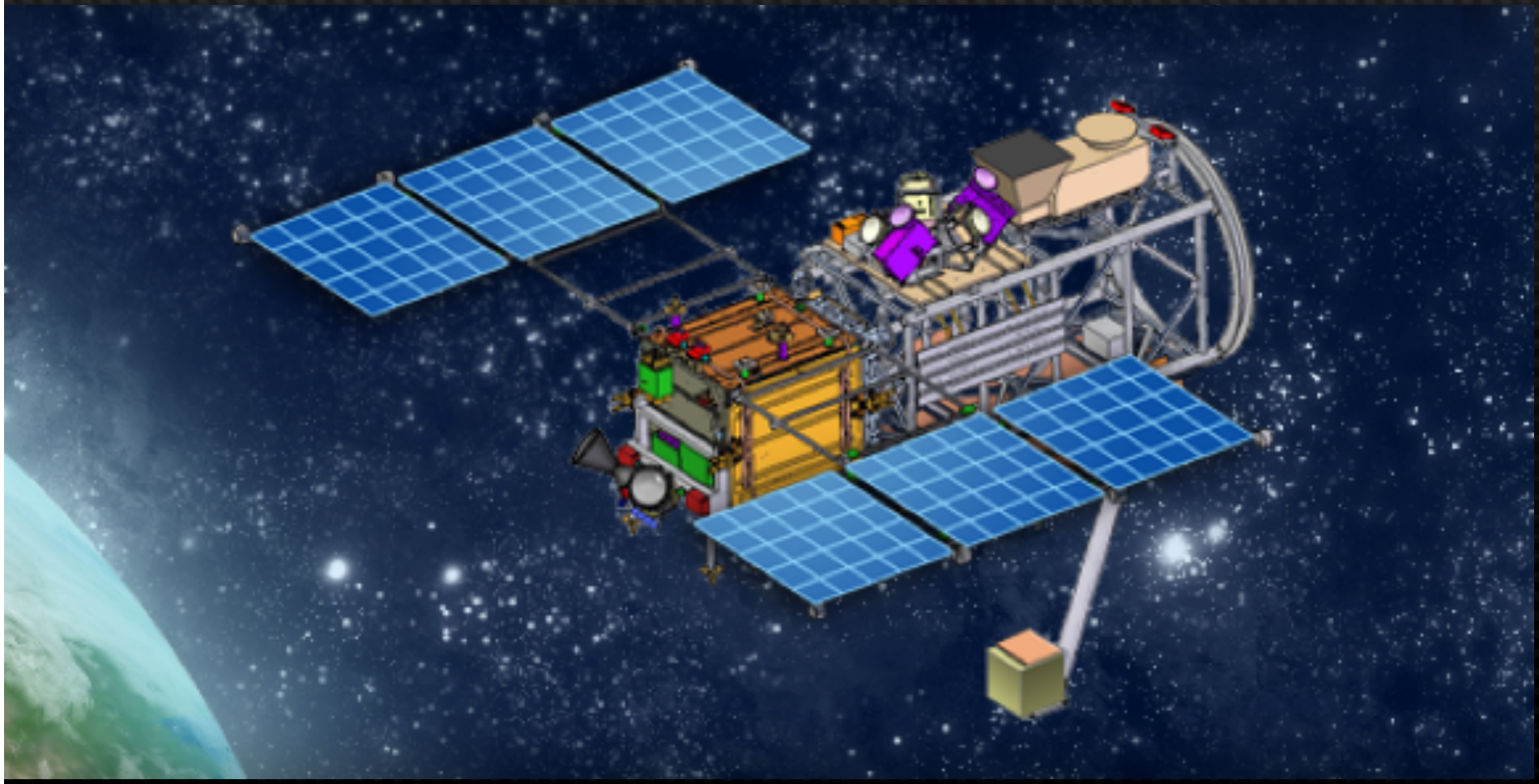
UFFO pathfinder design

- MODEST! - 20 kg, 10 W



UFFO -pathfinder mission

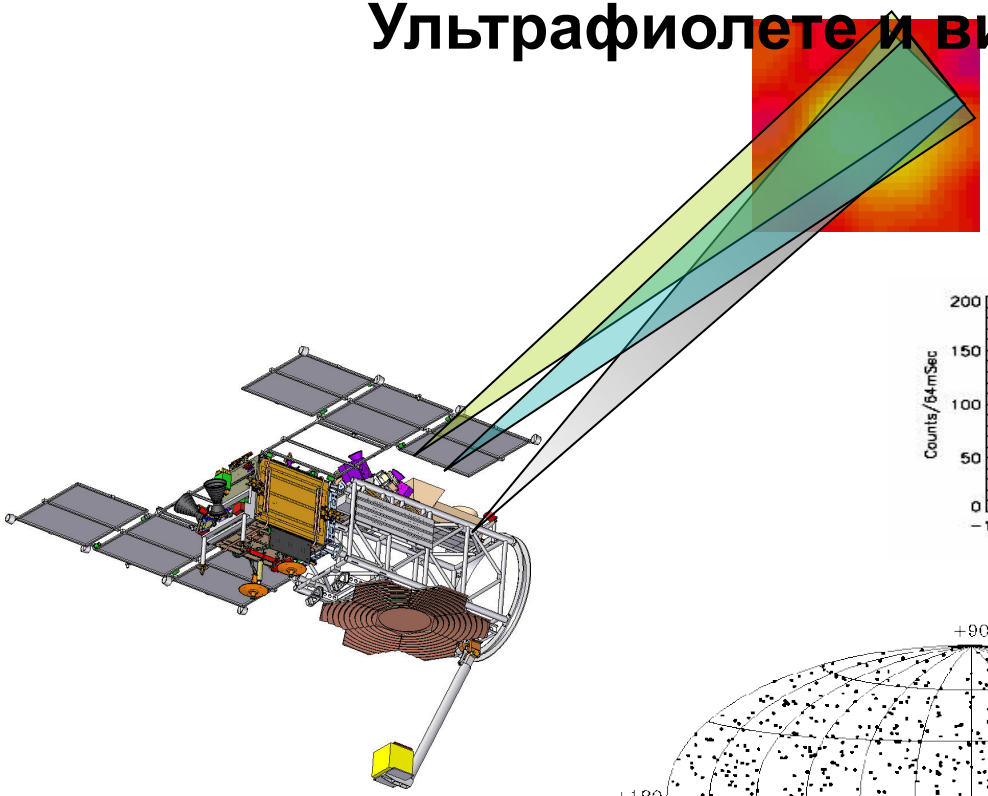
- We were *given* 20 kg on the Russian Lomonosov spacecraft in UNIVERSITAT program-Launch in Nov. June ?

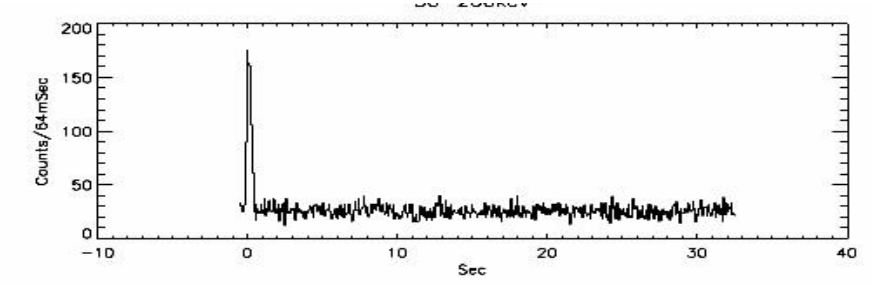


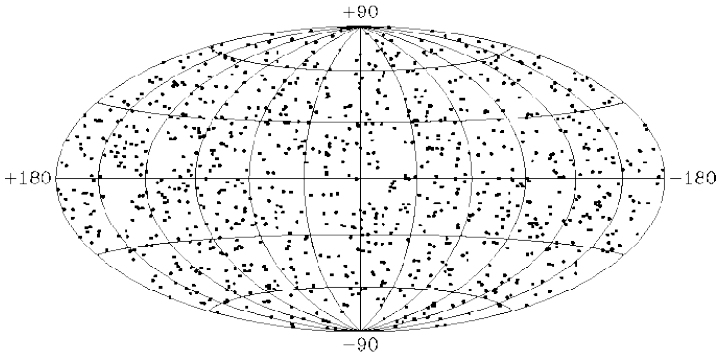
Il Park is P.I. UFFO-Pathfinder

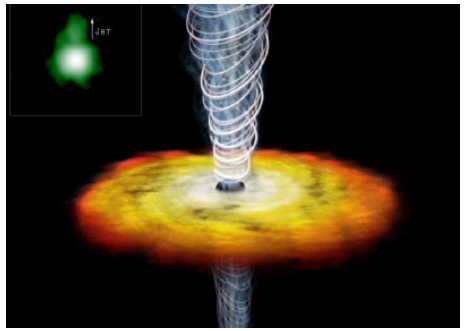
Гамма -всплески

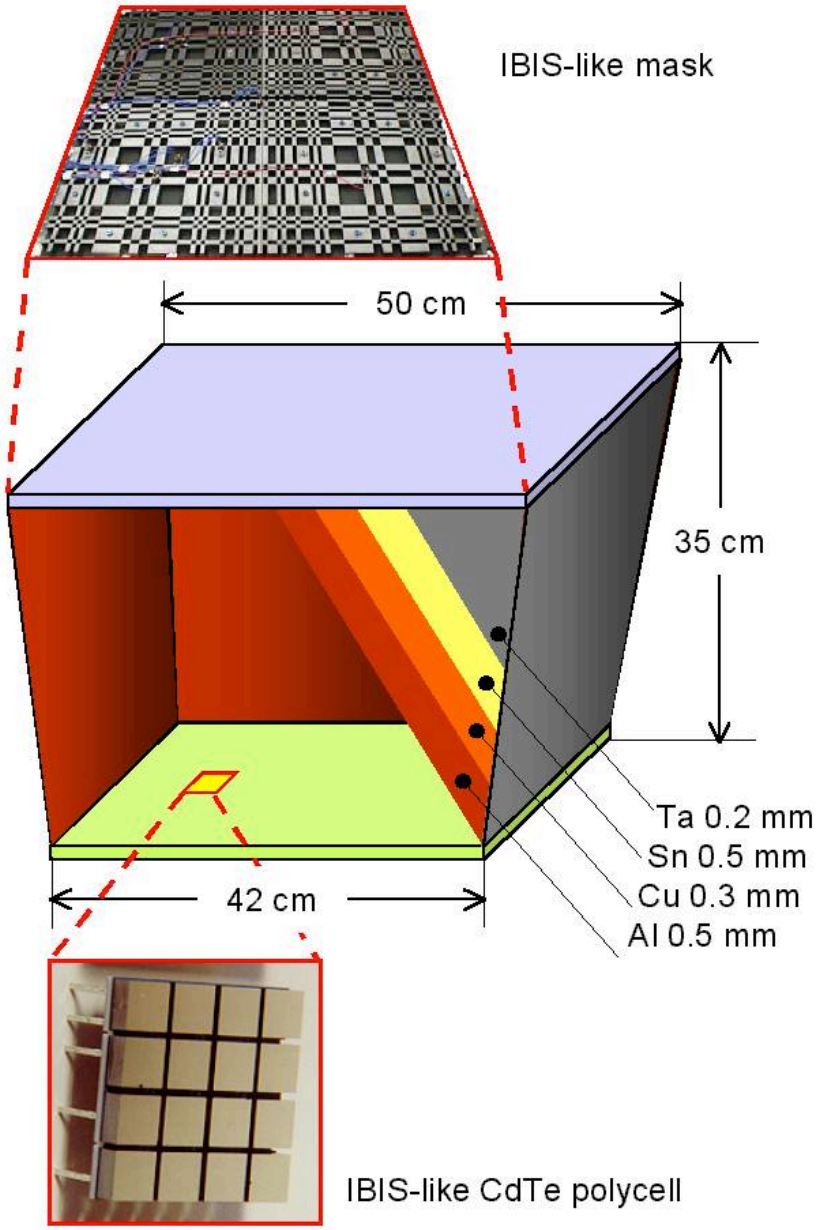
Эксперименты на «Ломоносове» обеспечат наблюдения гамма-всплесков в гамма, рентгене, Ультрафиолете и видимом свете

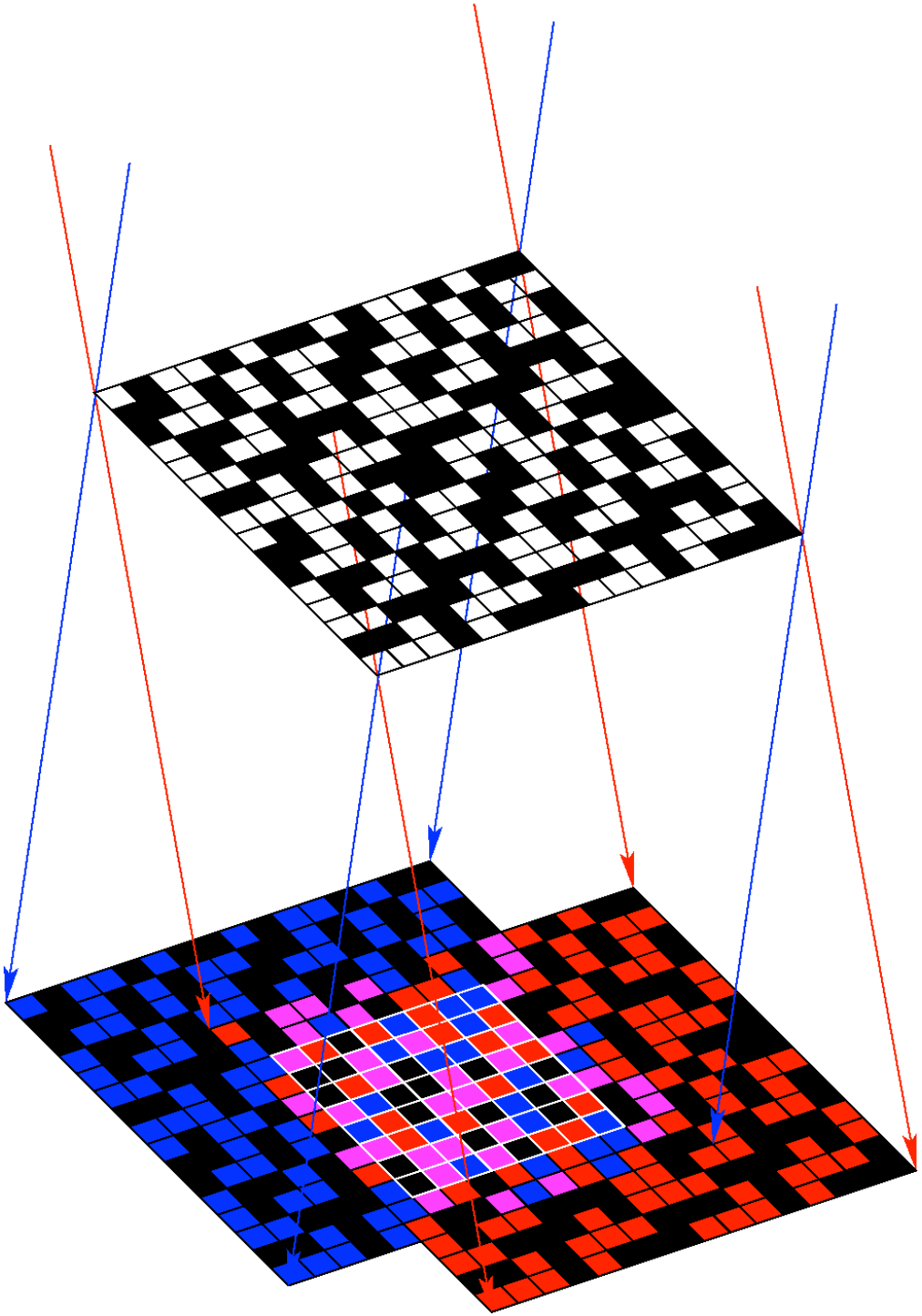




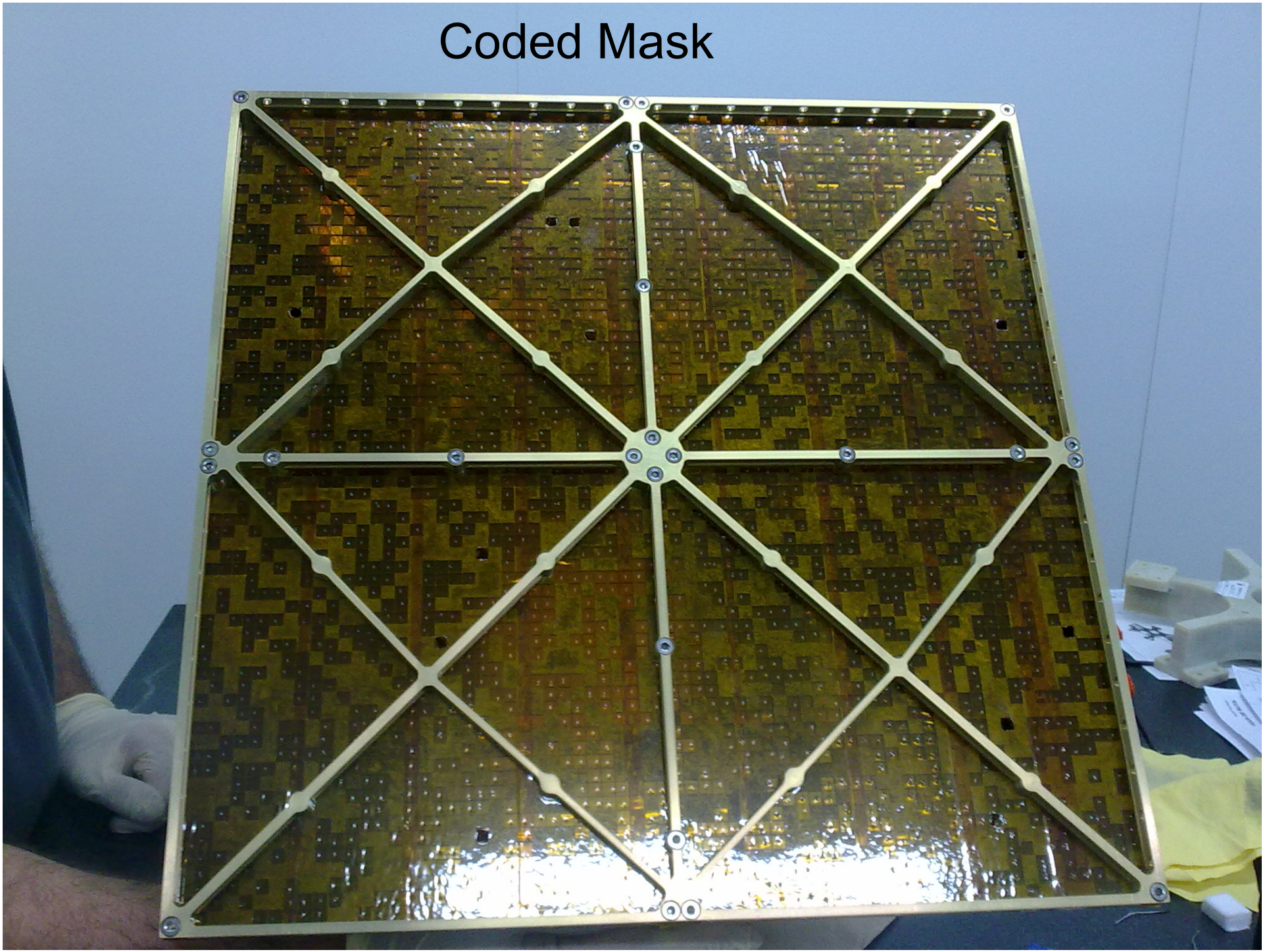




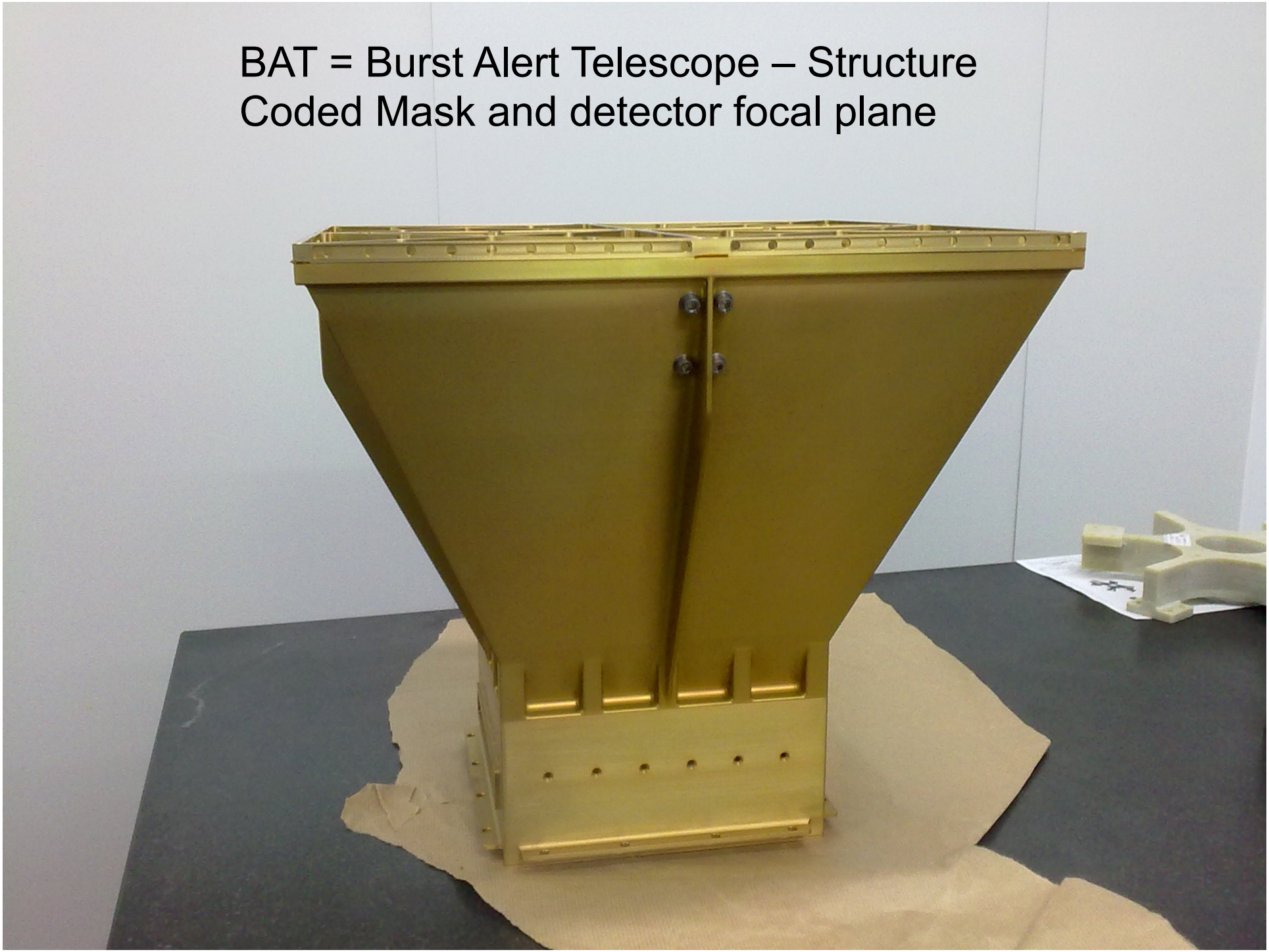

IBIS-like mask
50 cm
35 cm
Ta 0.2 mm
Sn 0.5 mm
Cu 0.3 mm
Al 0.5 mm
42 cm
IBIS-like CdTe polycell

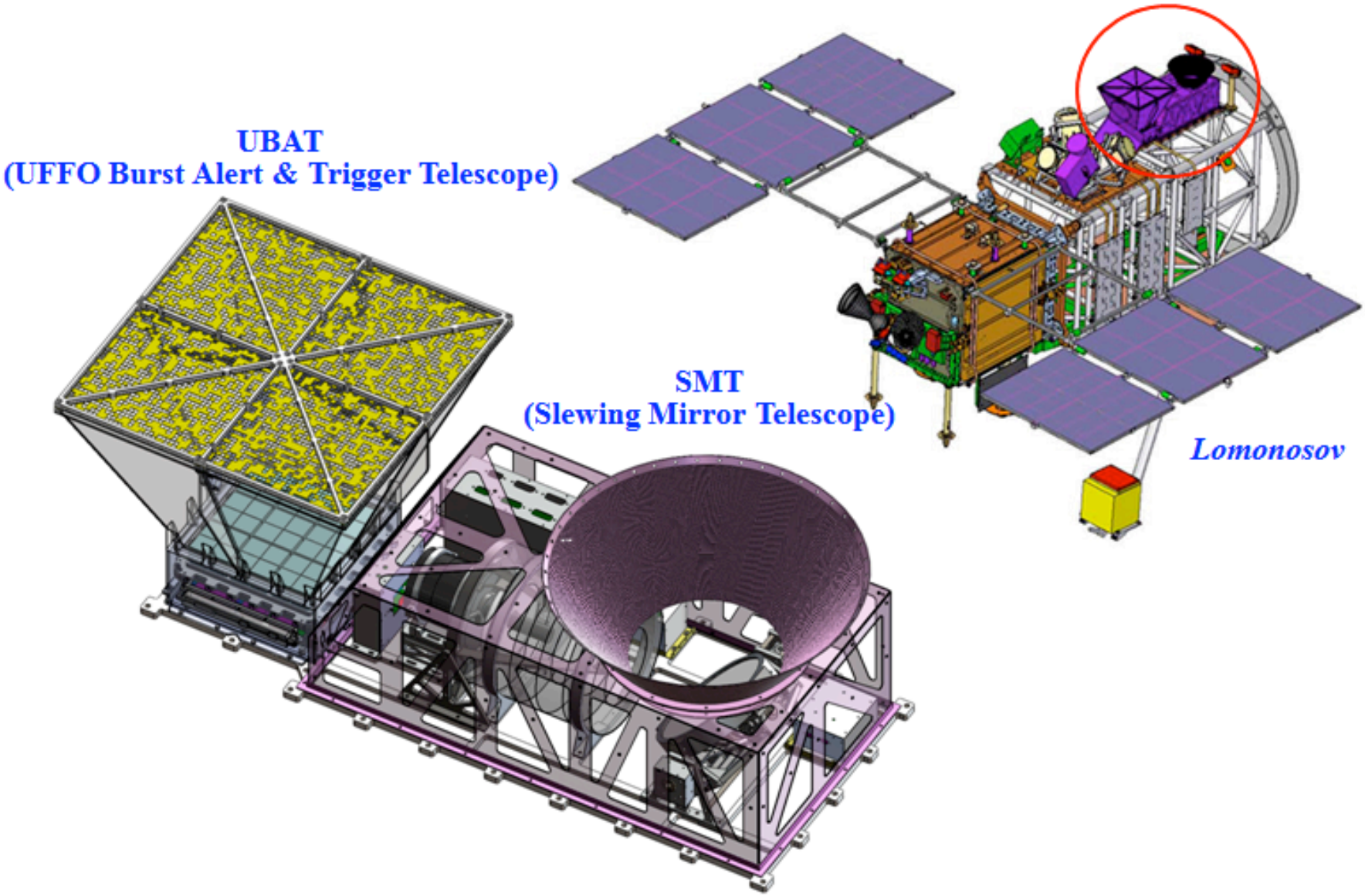


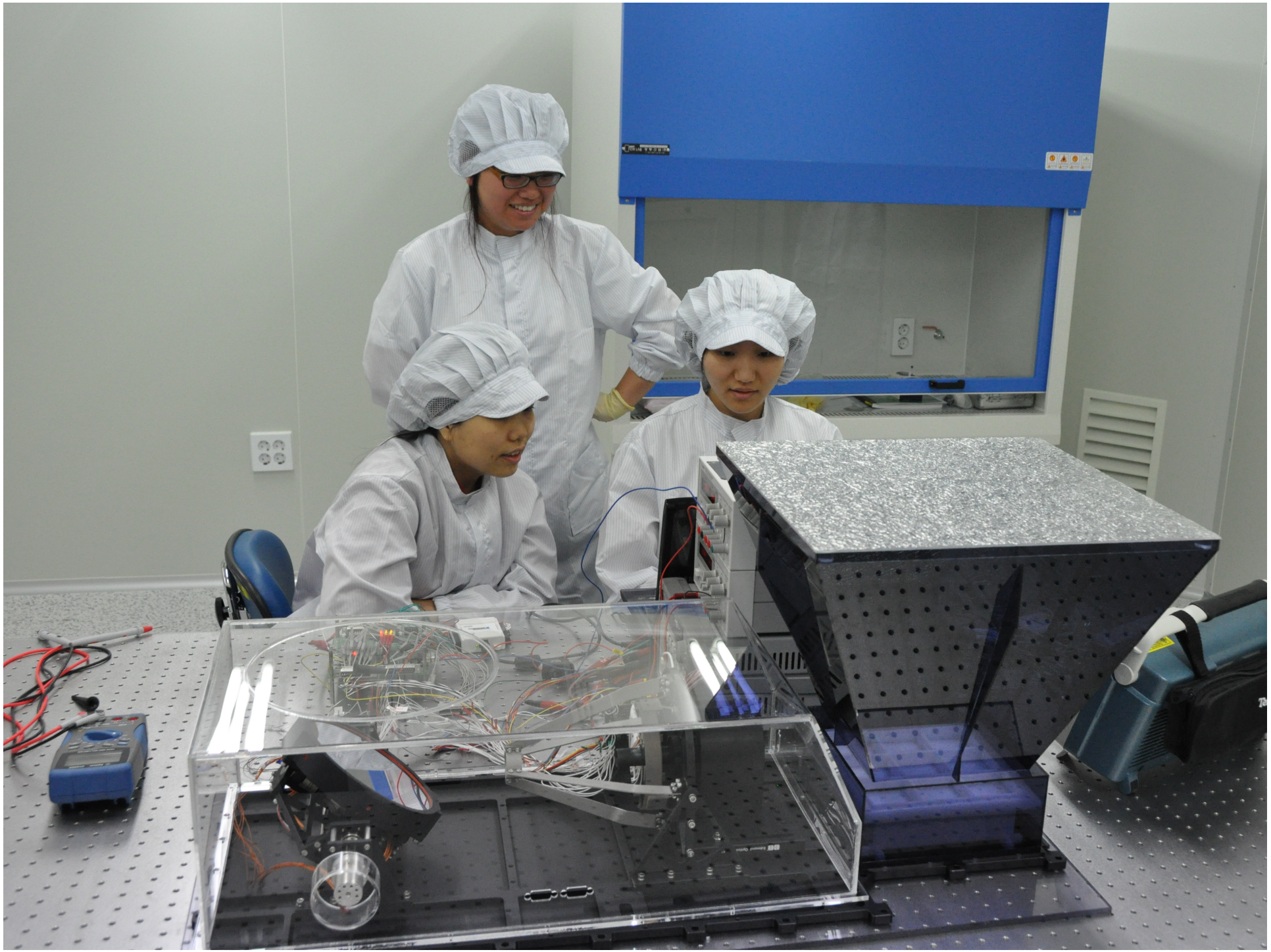
Coded Mask



BAT = Burst Alert Telescope – Structure
Coded Mask and detector focal plane




UBAT
(UFFO Burst Alert & Trigger Telescope)
SMT
(Slewing Mirror Telescope)
Lomonosov




Ultra Fast Flash Observatory
UFFO
Observation of early photons from Gamma-Ray Bursts
(한국주도 국제공동연구 프로젝트)
RCMST
ABCDEF
GHJKLM
NOPQRS
TUVXYZ
WOW!

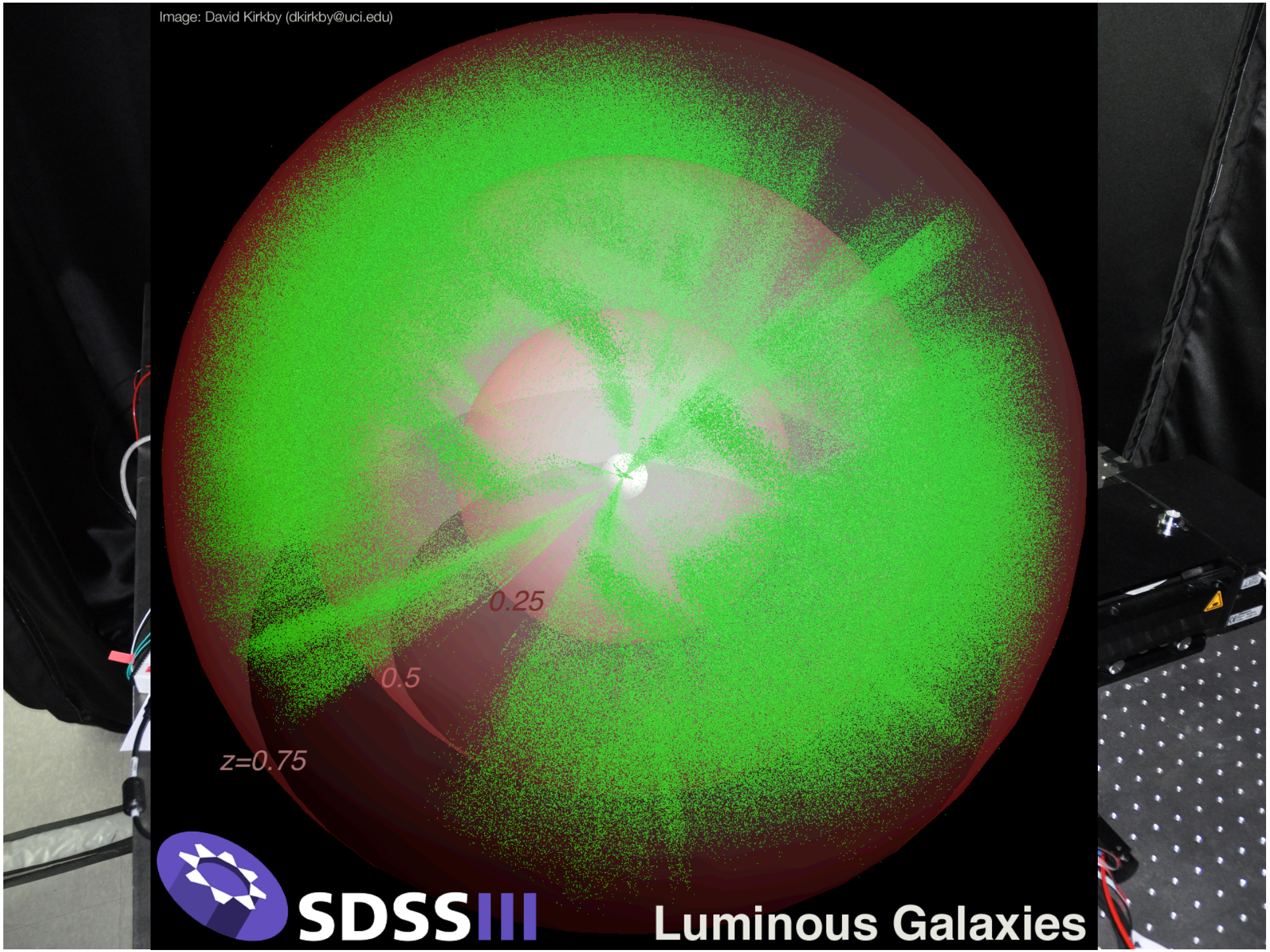
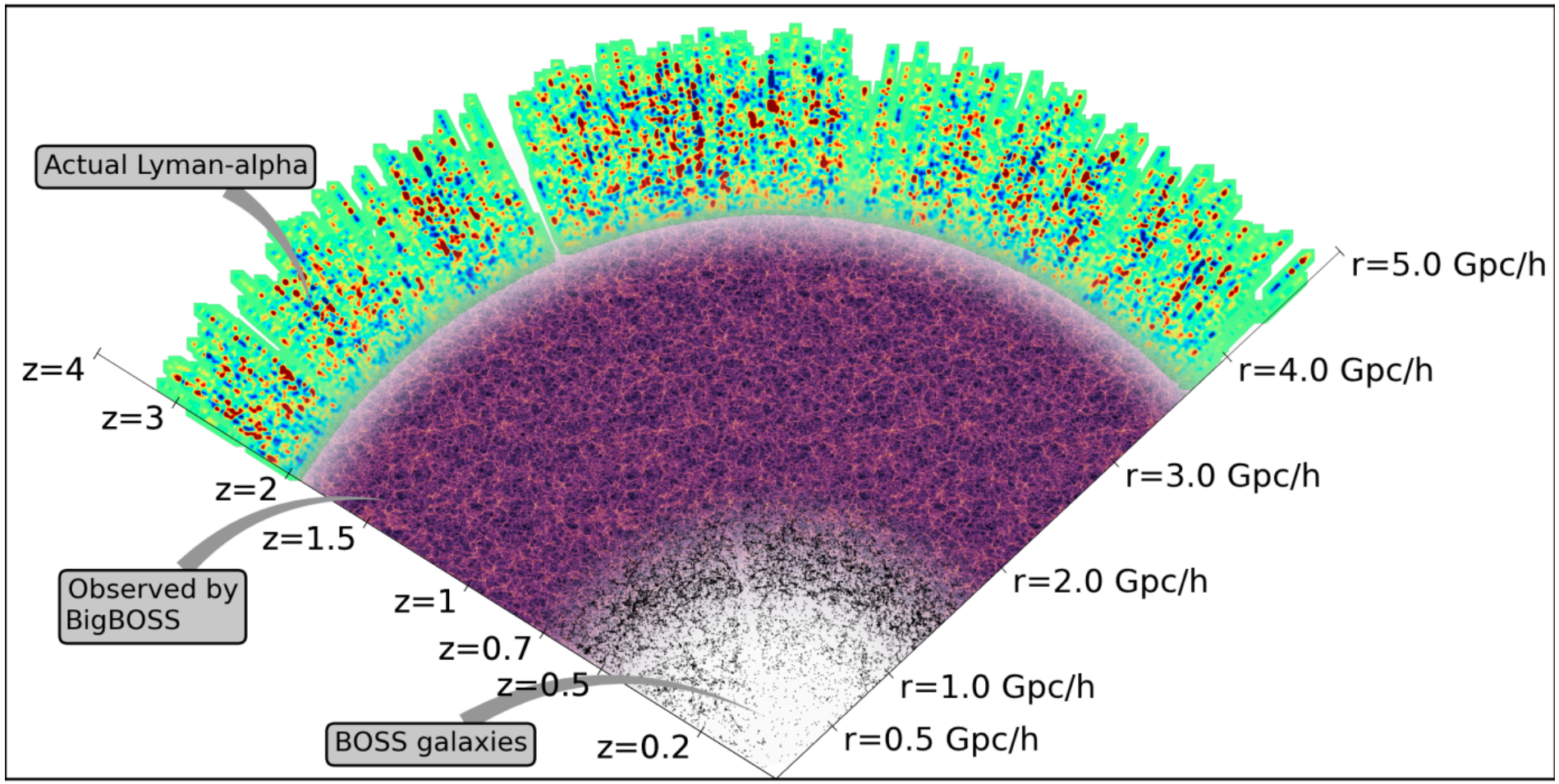


Image: David Kirkby (dkirkby@uci.edu)
0.25
0.5
z=0.75
SDSSIII
Luminous Galaxies

BigBOSS Survey



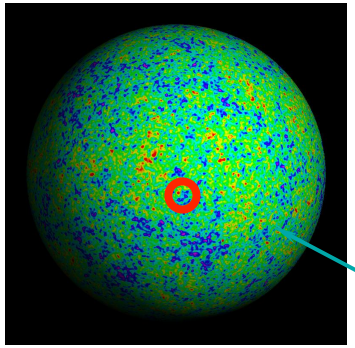
3D map of 50 (Gpc/h)^3 volume with 4M Luminous Red Galaxies, 14 M Emission Line Galaxies, 2M Quasars

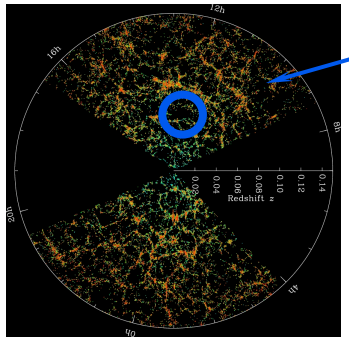
Tomographic surveys of density/velocity field.

Baryon Acoustic Oscillations

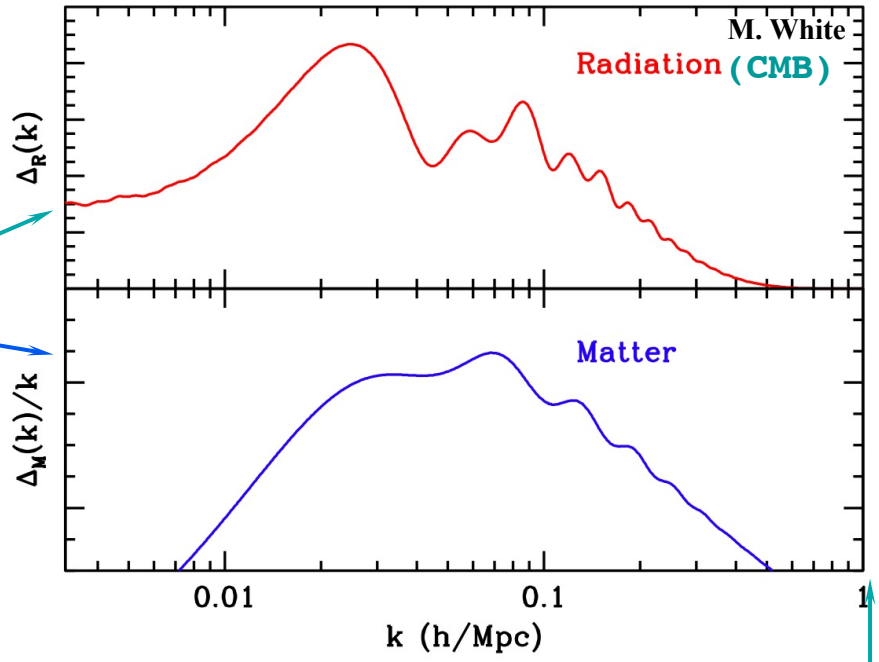
In the beginning... (well, 10-350,000 years after)

It was hot. Normal matter was p^+,e^- – charged – interacting fervently with photons.
This tightly coupled them, photon mfp << ct, and so they acted like a fluid.
Density perturbations in one would cause perturbations in the other, but gravity was offset by pressure, so they could not grow - merely oscillated. Then swift decoupling so on the largest scales, set by the sound horizon, the perturbations were preserved.





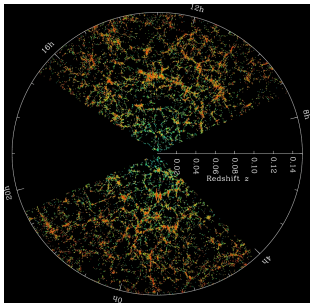
The same primordial imprints in the *photon* field show up in *matter* density fluctuations.



Baryon acoustic oscillations **= patterned distribution of galaxies on very large scales (~150 Mpc).**

Cosmic Structure

Galaxy 3D distribution or power spectrum contains information on:



- **Growth - evolving amplitude**
- **Matter/radiation density, H - peak turnover**
- **Distances - baryon acoustic oscillations**
- **Growth rate - redshift space distortions**
- **Neutrino mass, non-Gaussianity, gravity, etc.**

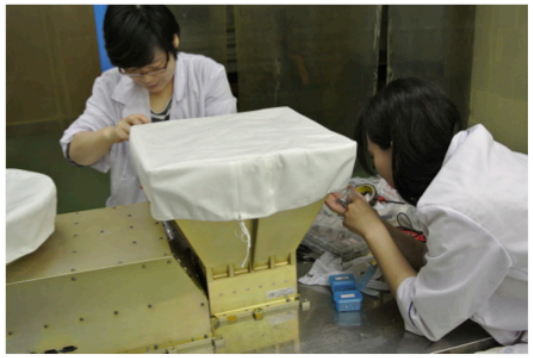
Baryon Acoustic Oscillations

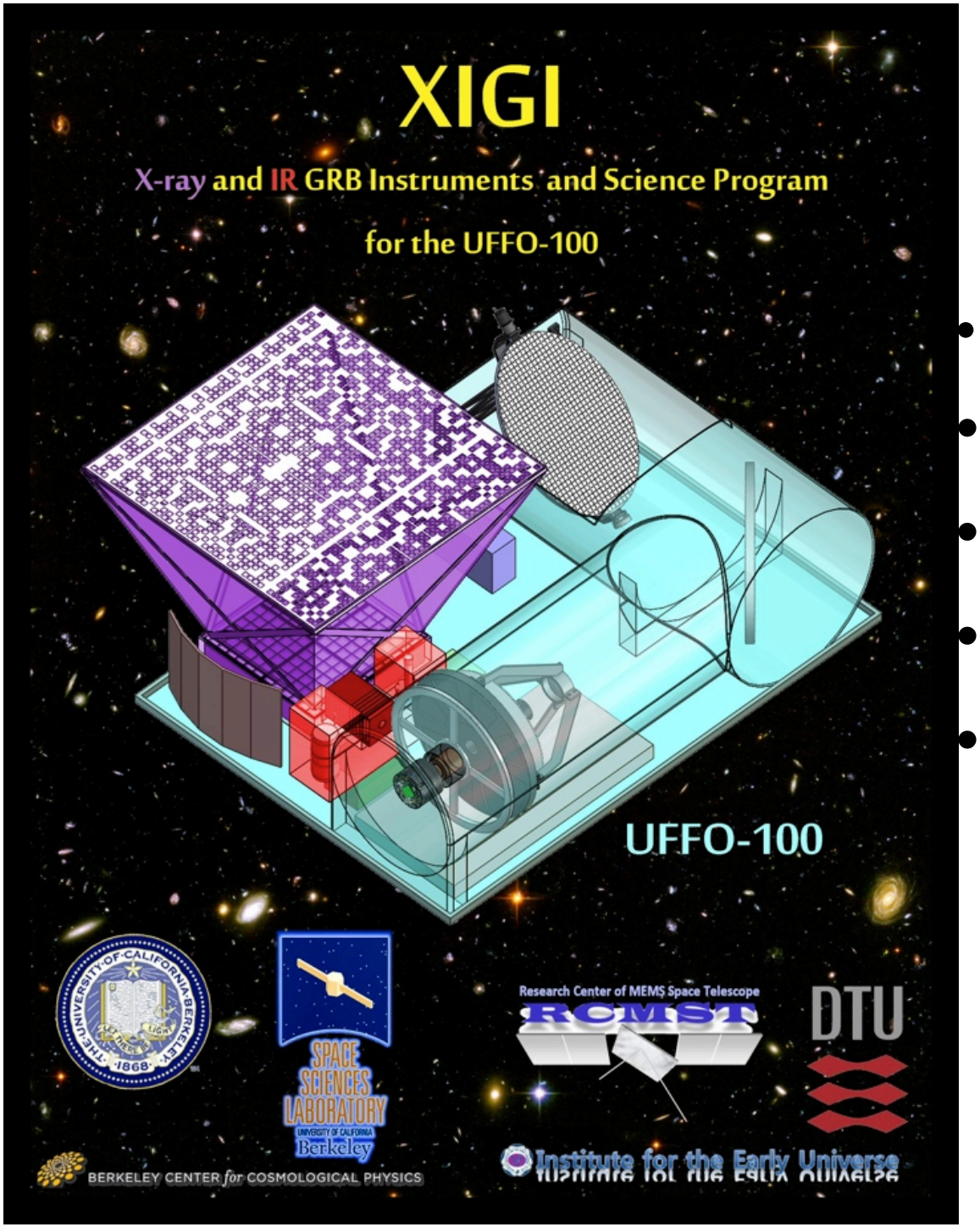
	Photons	Baryons
Name	CMB acoustic peaks	Baryon acoustic oscillations
Scale	1°	100 h^{-1} Mpc comoving
Base amplitude	5 x 10^{-5}	10^{-1}
Osc. amplitude	O(1)	5%
Detection	10^{15}/hand/sec	indirect: light from <10^{10} gal

Scale of oscillations informs re cosmic distances.
Angular separation → angular distance d(z)
Radial distance in z → expansion rate H(z)

Cosmic volume surveys can measure d to <1%, H to <1.5%

Big-MIK at ISTRA





XIGI -> UFFO-100 Next Generation

- Dr. Bruce Grossan PI
- 120 kg design
- X-Ray Coded Mask
- 30-cm optical telesc
- Science Goals
  - Lorentz factor
  - Calibration
  - Internal vs External shocks
  - Multimessenger

XTiGResat

- Next Generation
- XT – X-ray timing and large area imaging
- GR – hard X-ray and Gamma Ray detectors combined with UV, Opt, Infrared observations

Conclusion

- There is still much potential science to come from GRB observations
- c. f. GRB workshop at MSU in June