HermeS

A constellation of nano-satellites for high energy astrophysics and fundamental physics research

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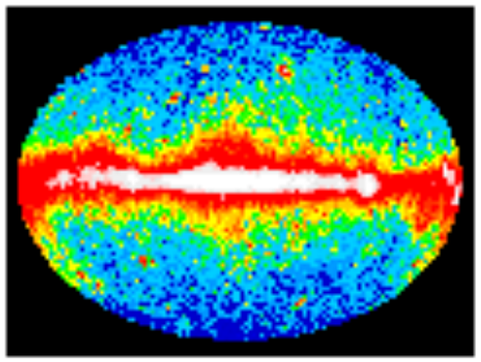
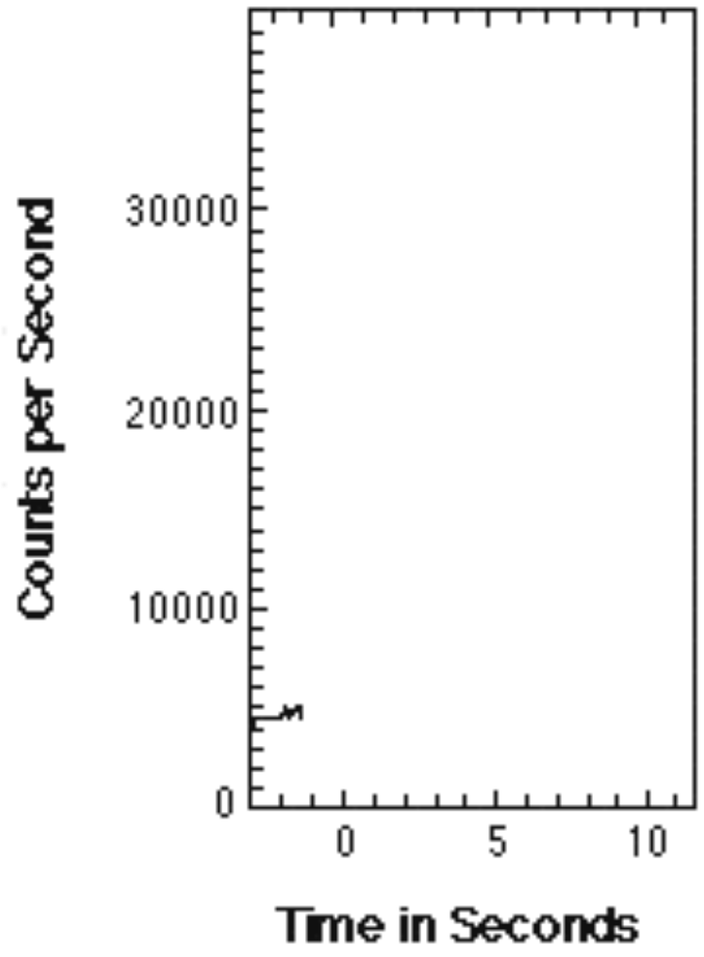
agenzia spaziale italiana

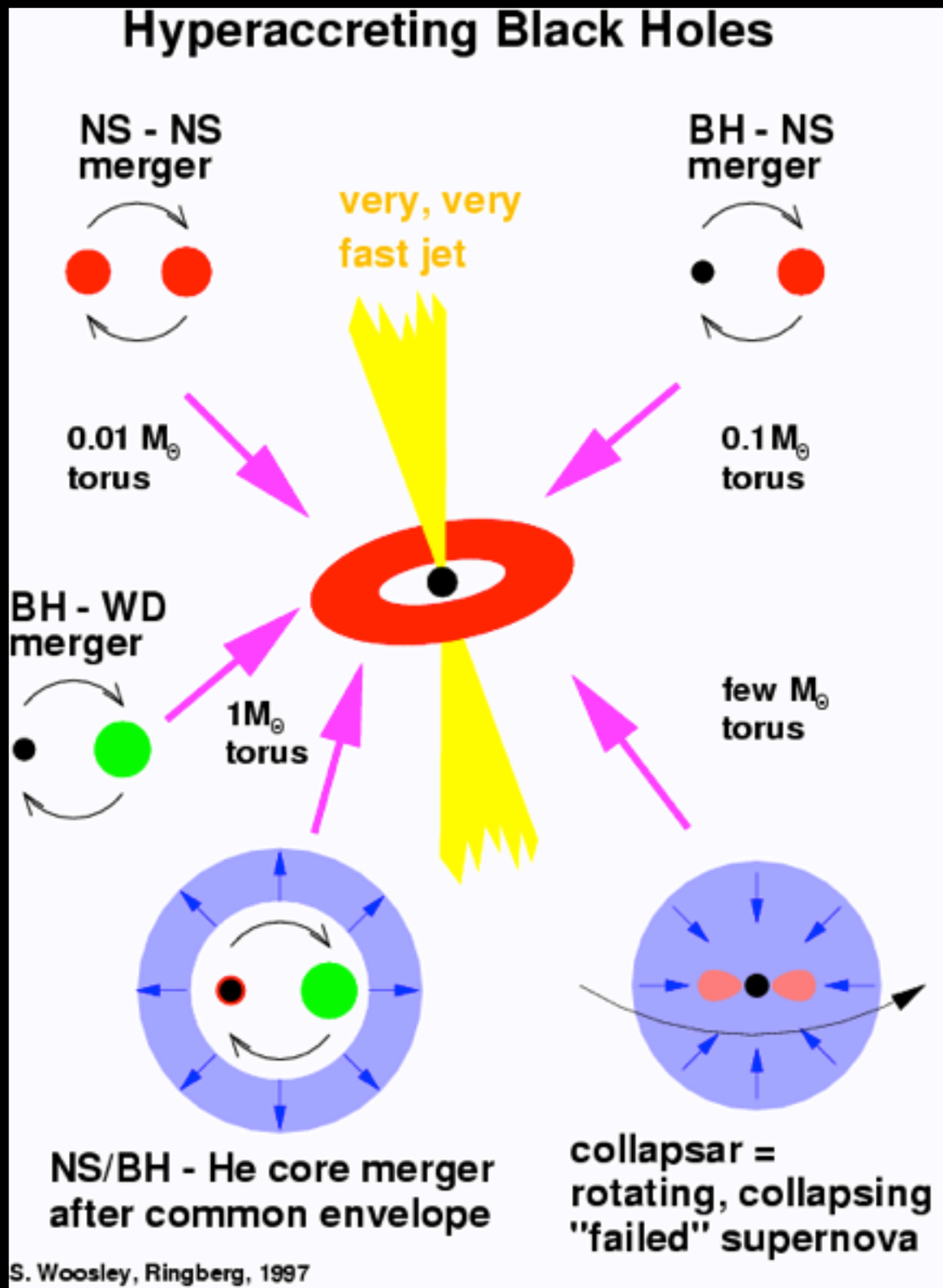
Summary

- Lessons learned
  - 1967: the discovery of Gamma Ray Bursts
  - The Interplanetary Network (IPN)
  - CGRO/BATSE, Fermi/GBM
  - 1997: yes, GRB have cosmological distances (and huge L)
- Today challenges and opportunities: two revolutions:
  - Multimessenger astrophysics
  - Space 4.0
- HERMES: a coming breakthrough

GRBs in a nutshell







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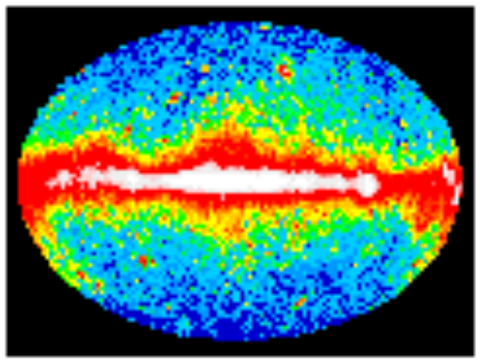

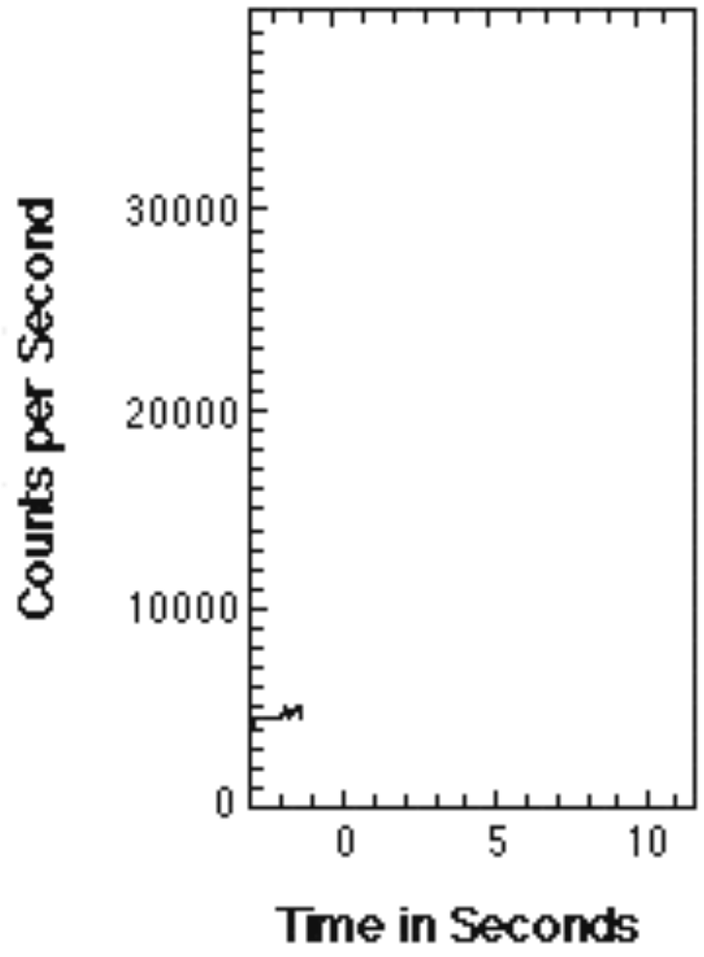

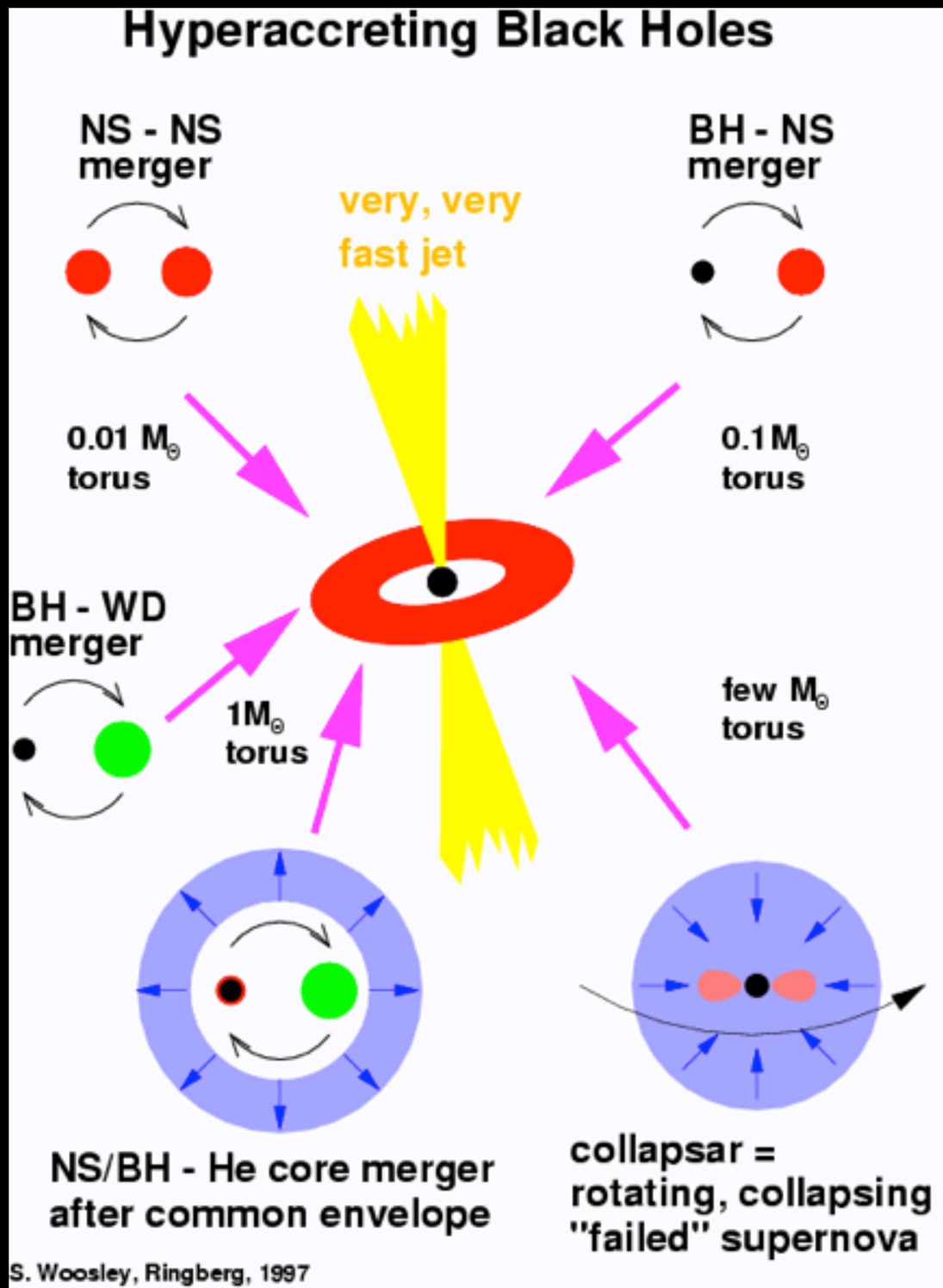

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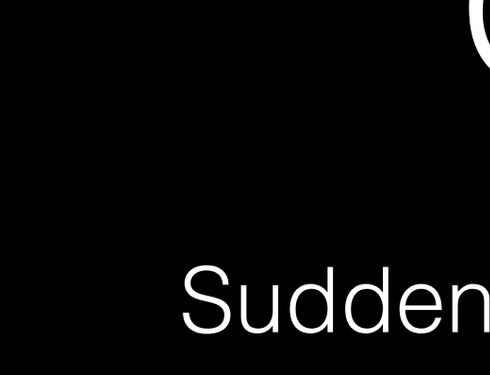
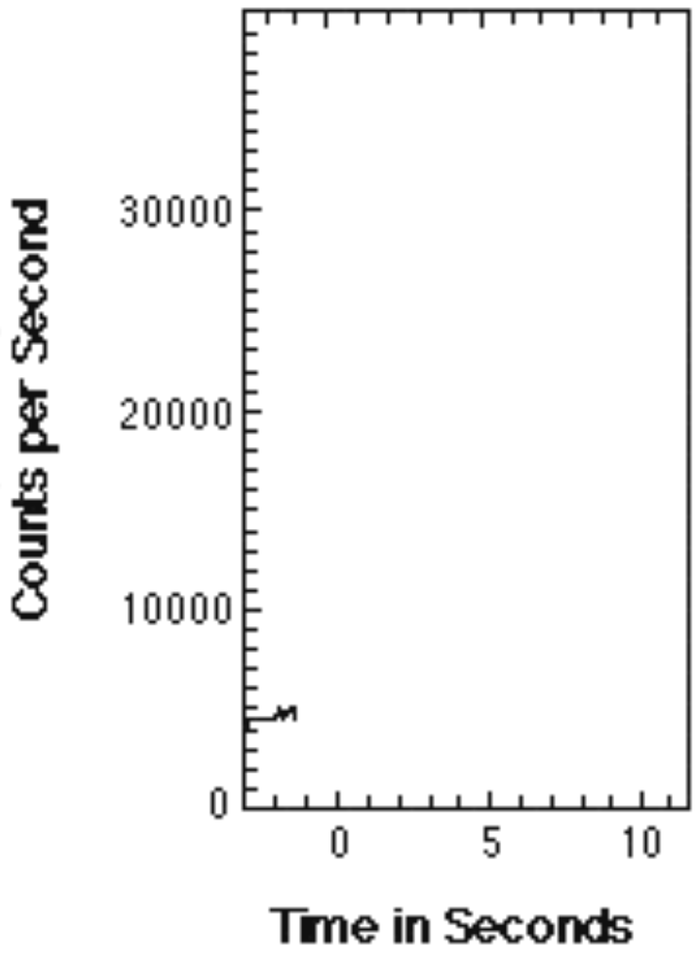
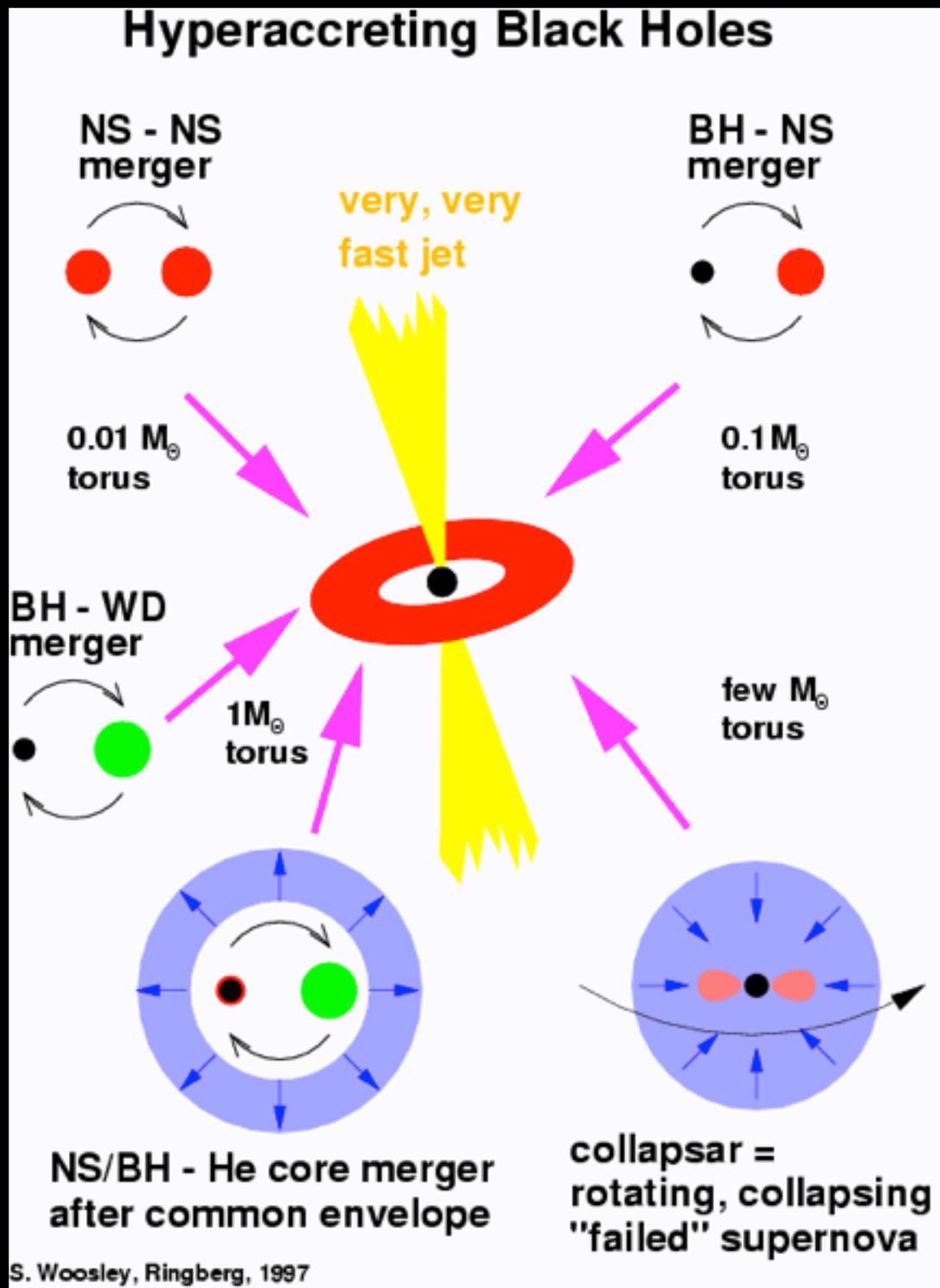
up to 10^{-3} ergs/s/cm^2 (μW/m^2)







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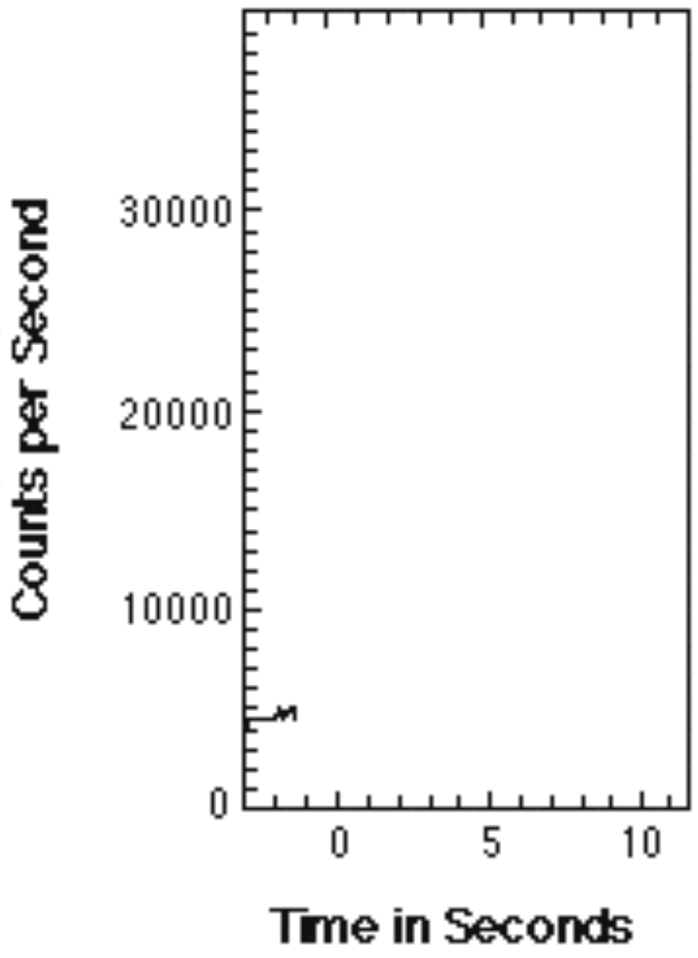

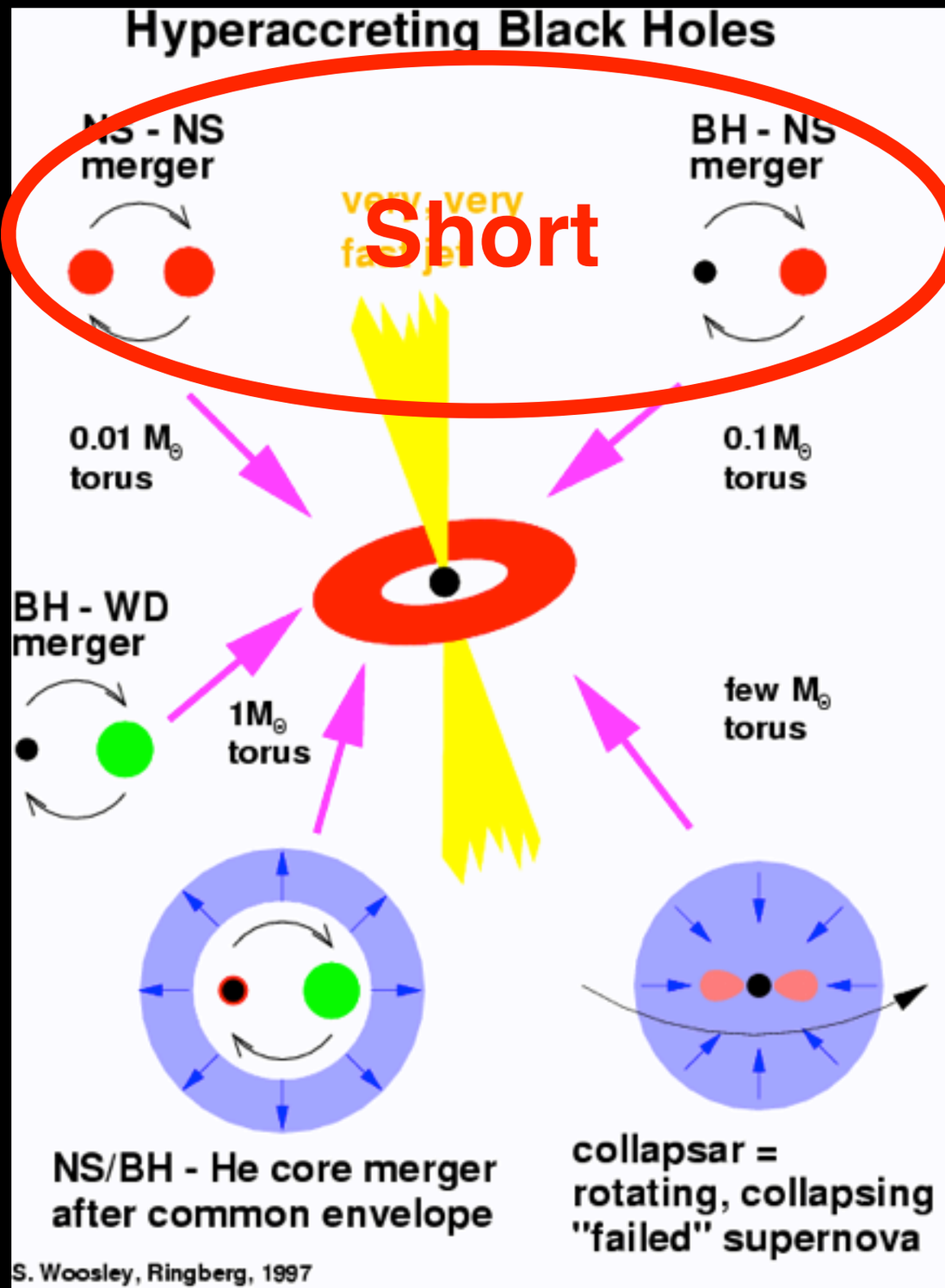

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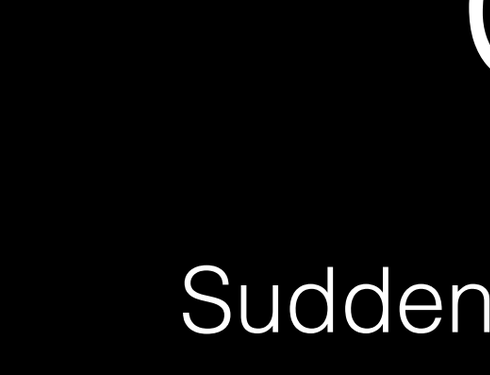

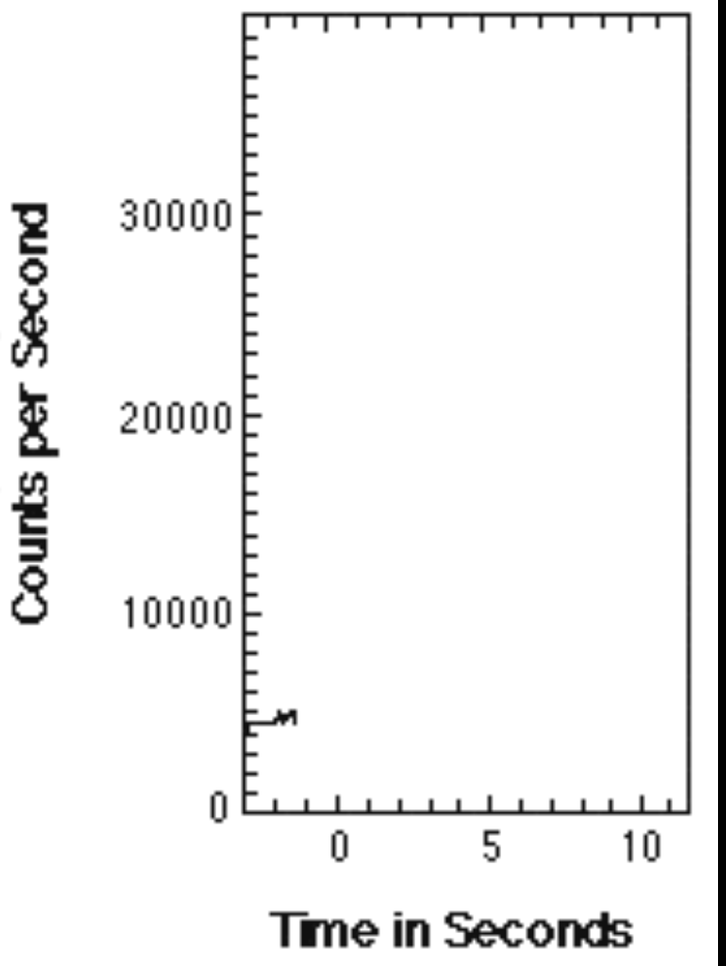

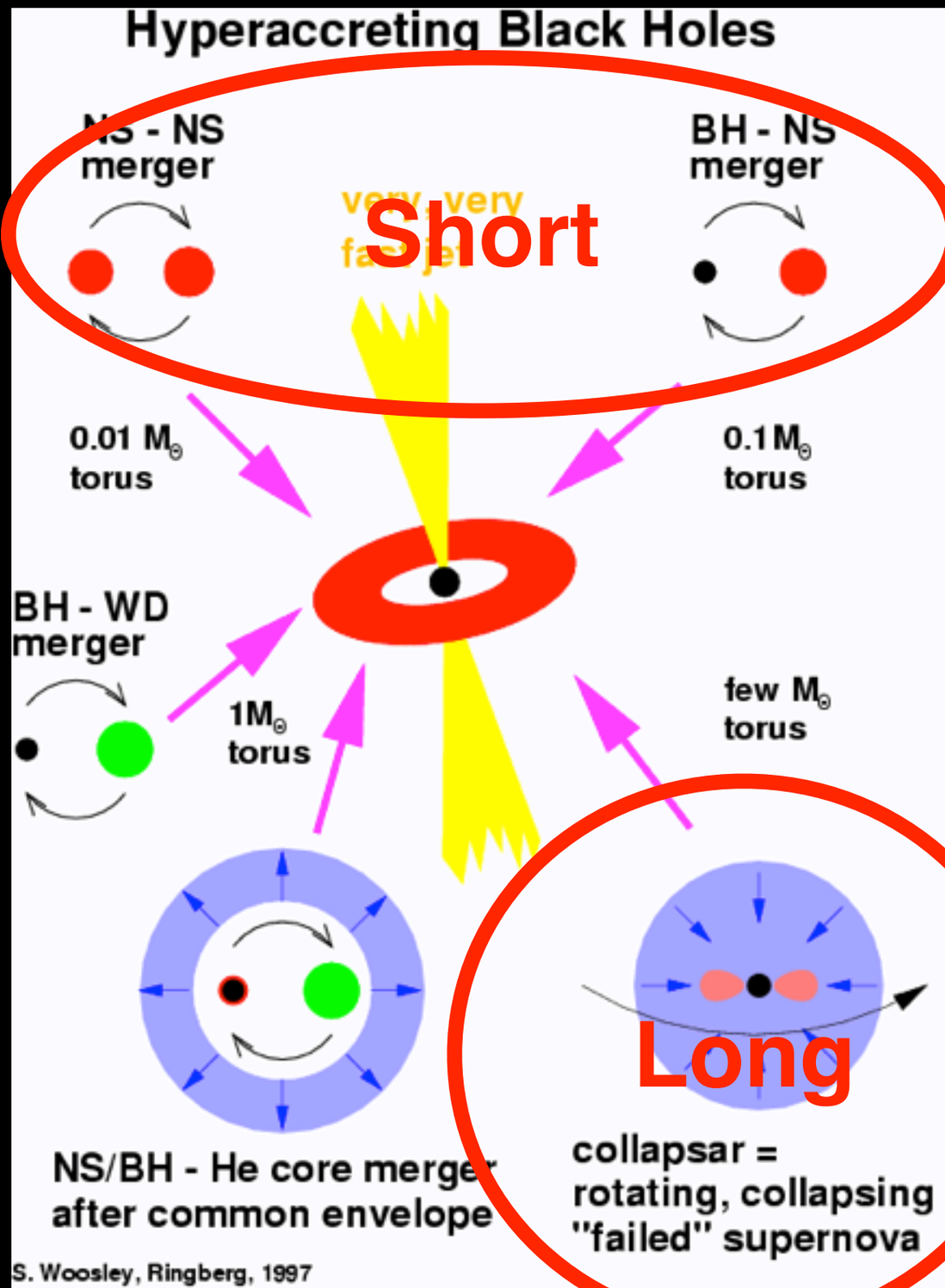

The discovery of GRBs by the Vela satellites

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Constellation of 6+6 satellites carrying simple X-ray scintillators detectors. 10^5 km orbit.

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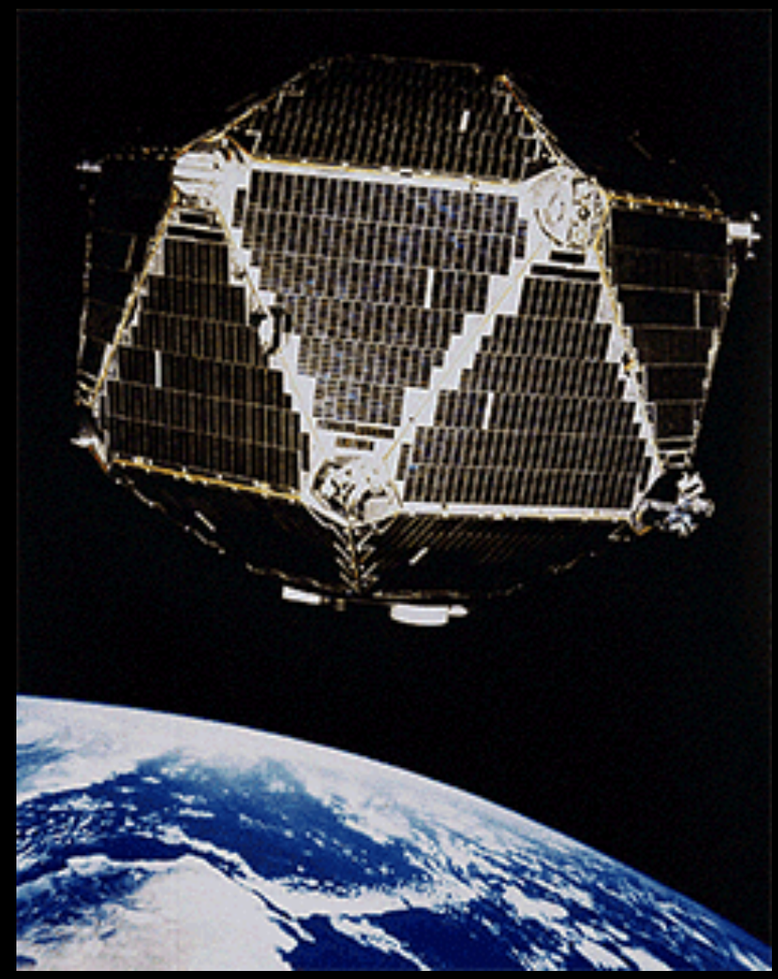

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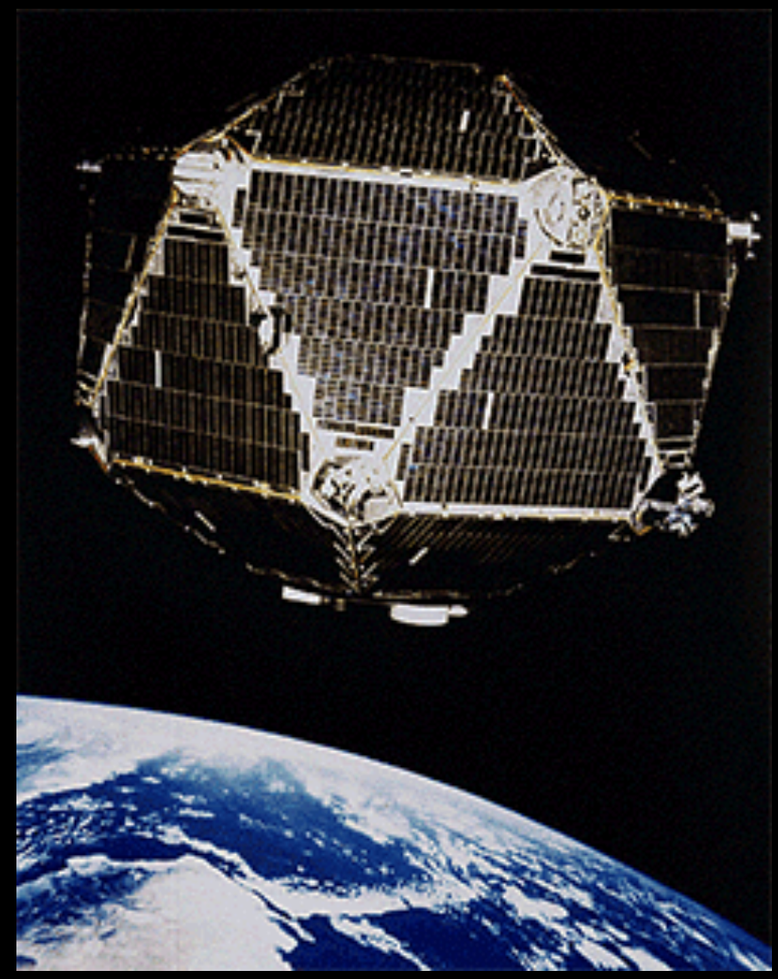
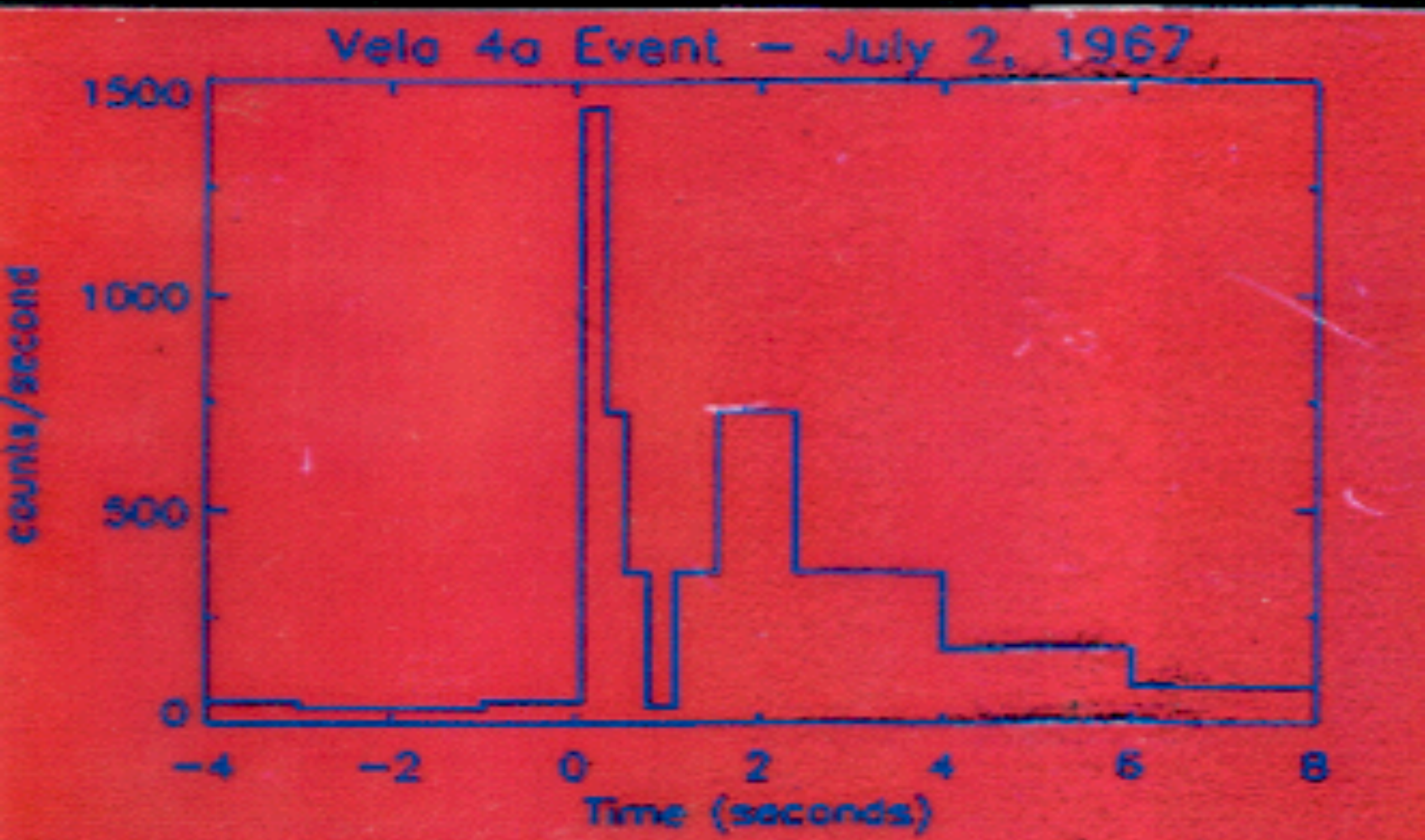


Detect γ-rays from nuclear explosions

First launch 1963
Last Advanced Vela launch 1970
In operation till 1985

The discovery of GRBs by the Vela satellites



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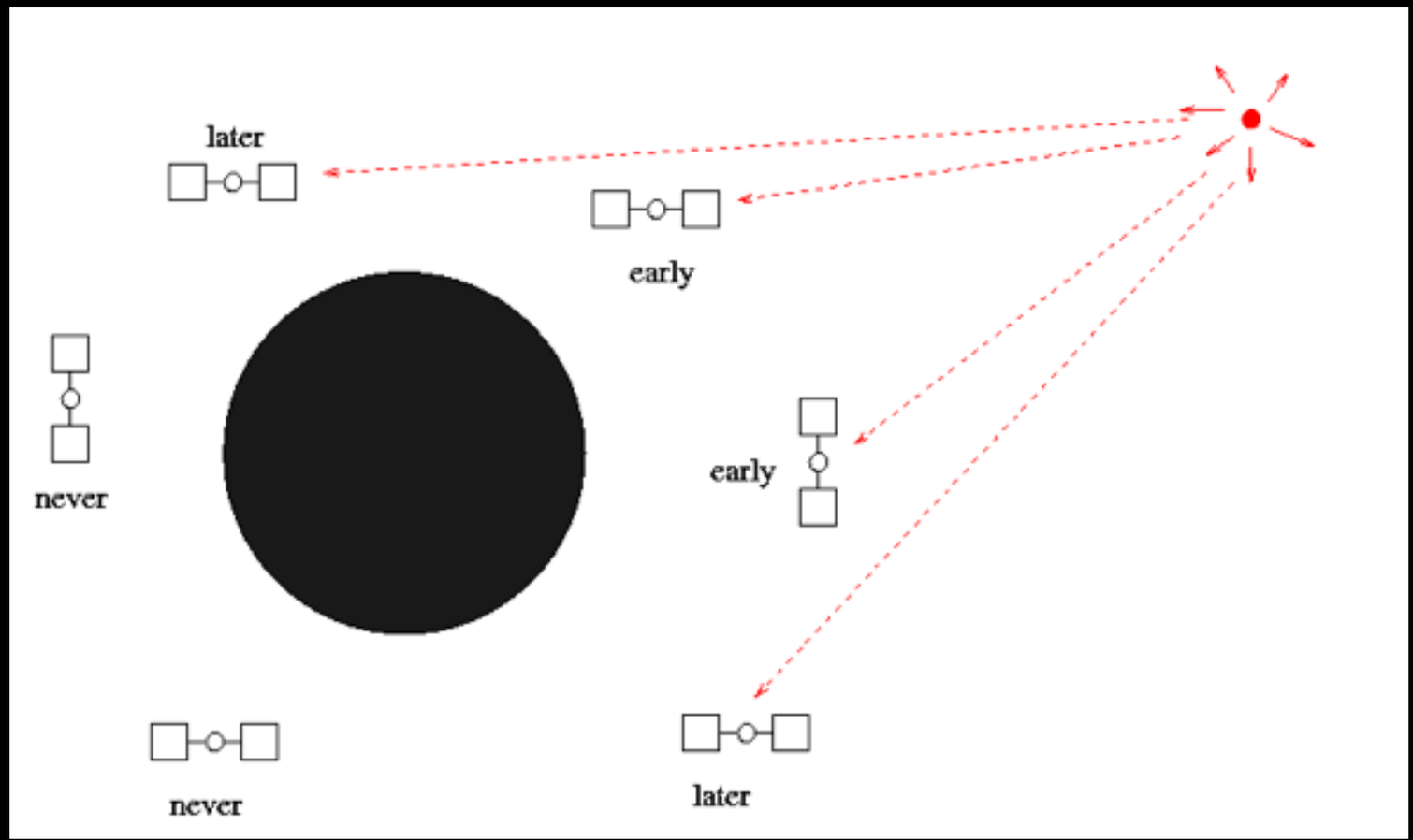
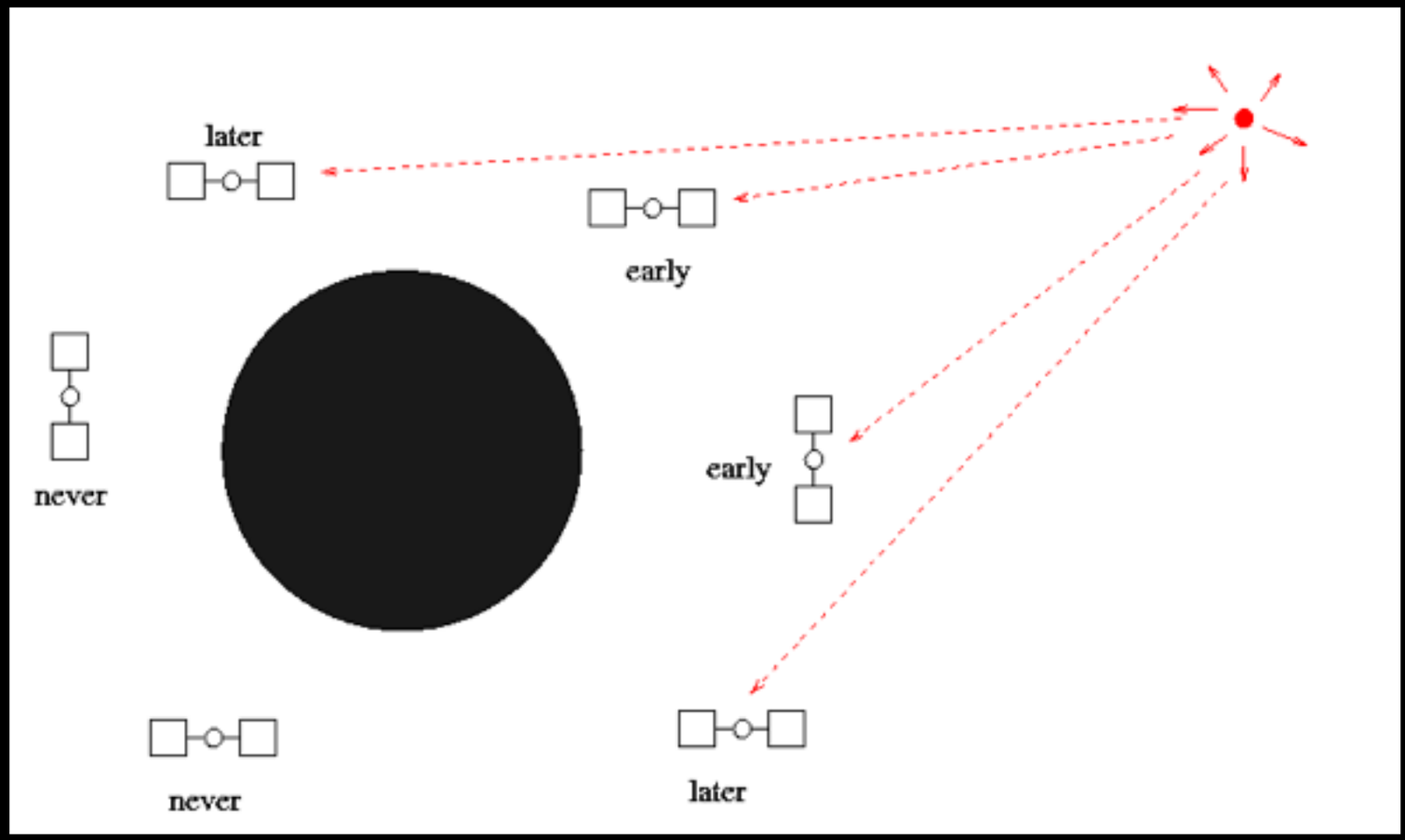


Vela satellites

First 6 Vela equipped with X-ray and γ-ray detectors with limited timing capabilities: rough positions



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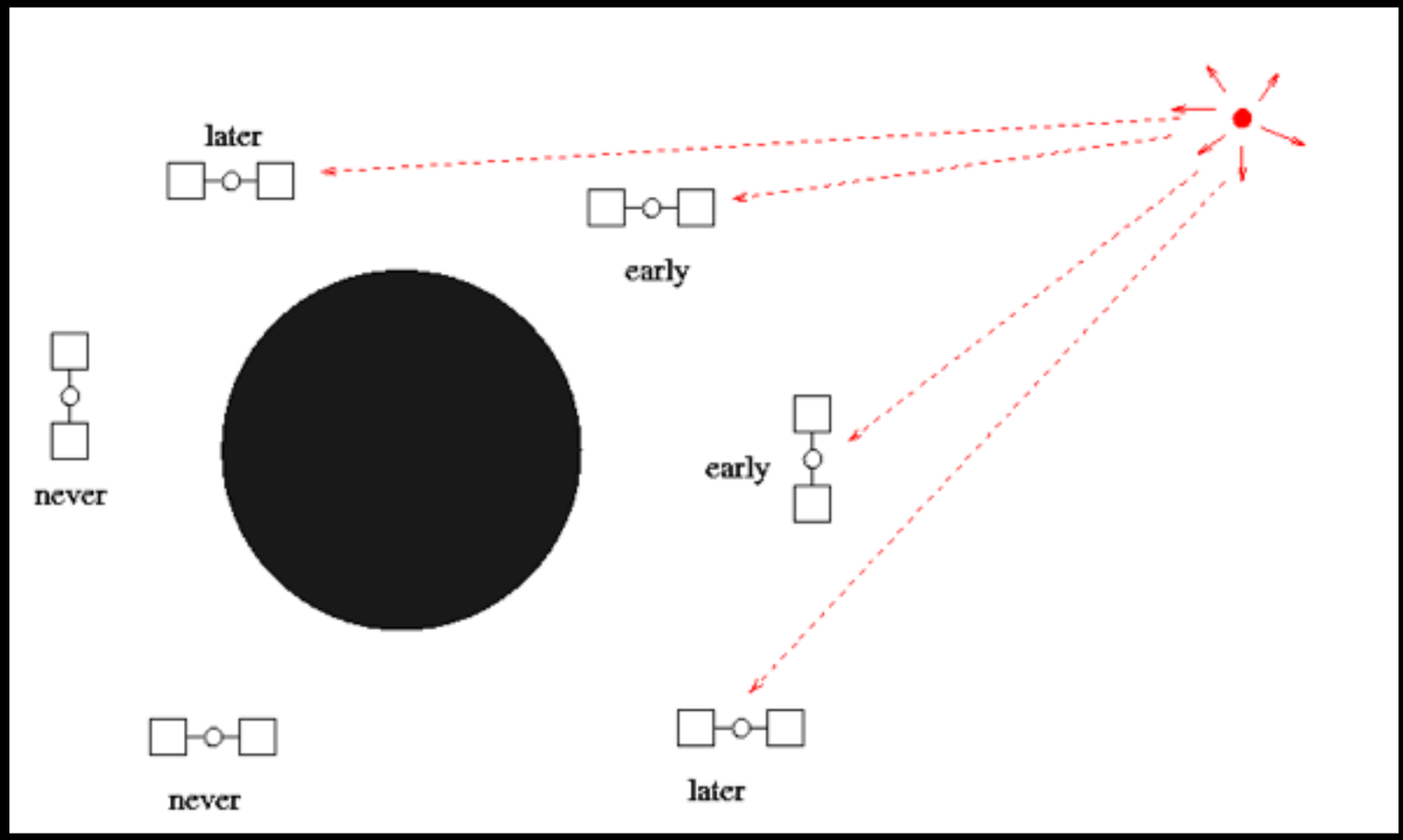

Advanced Vela equipped with silicon photodiode sensors with millisec timing: ~10deg positions

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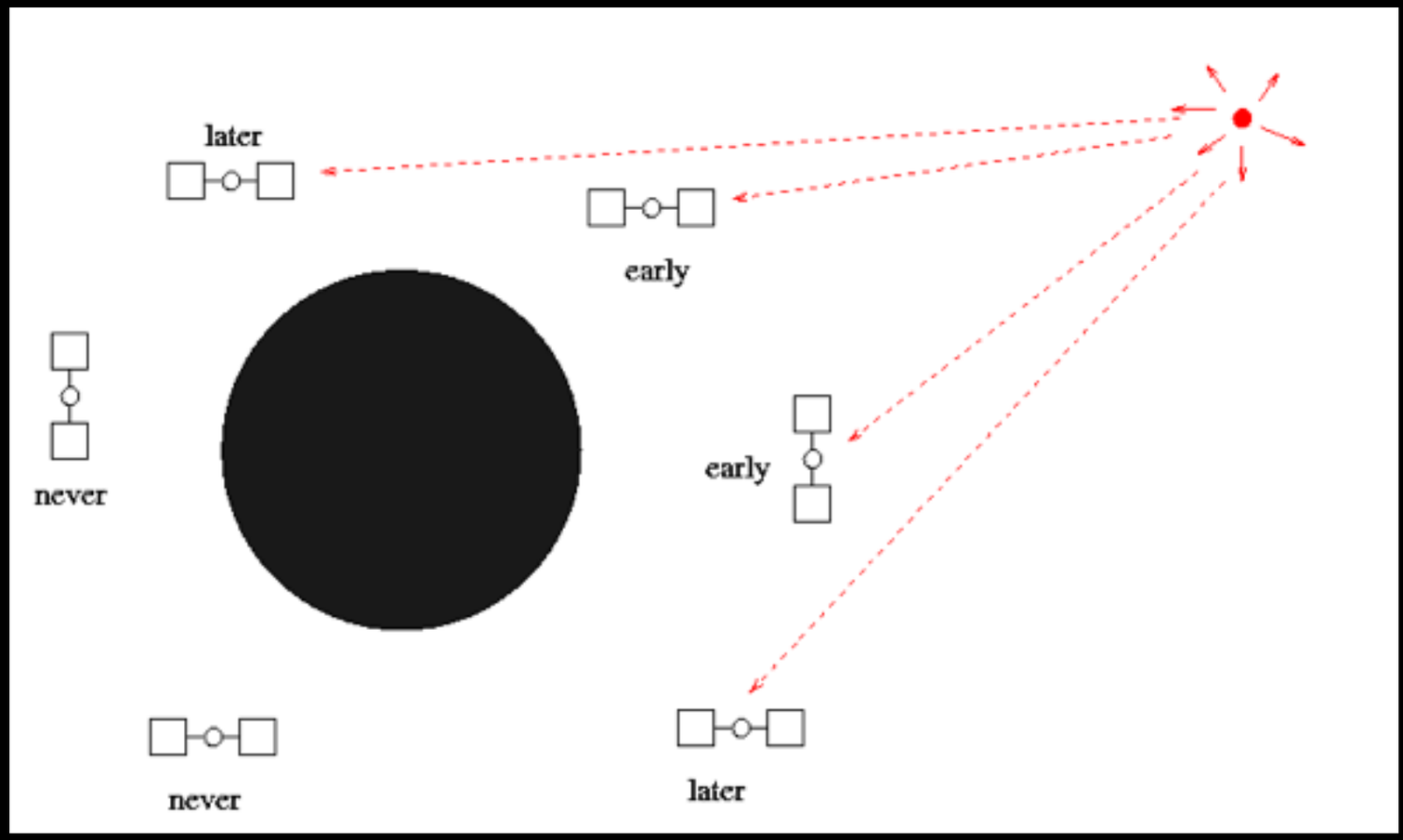


Advanced Vela equipped with silicon photodiode sensors with millisec timing: ~10deg positions

Modularity —> improved performances

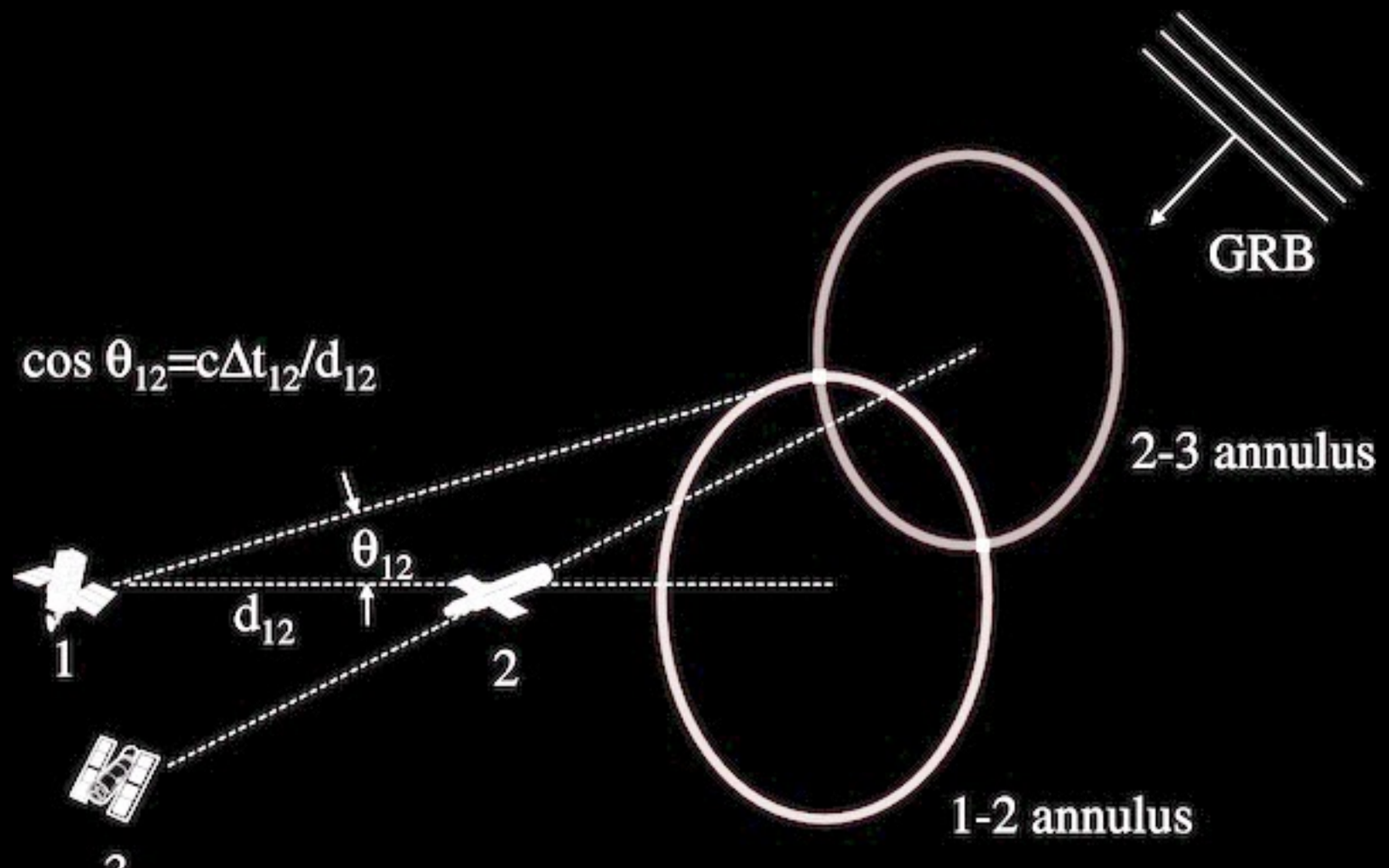
IPN

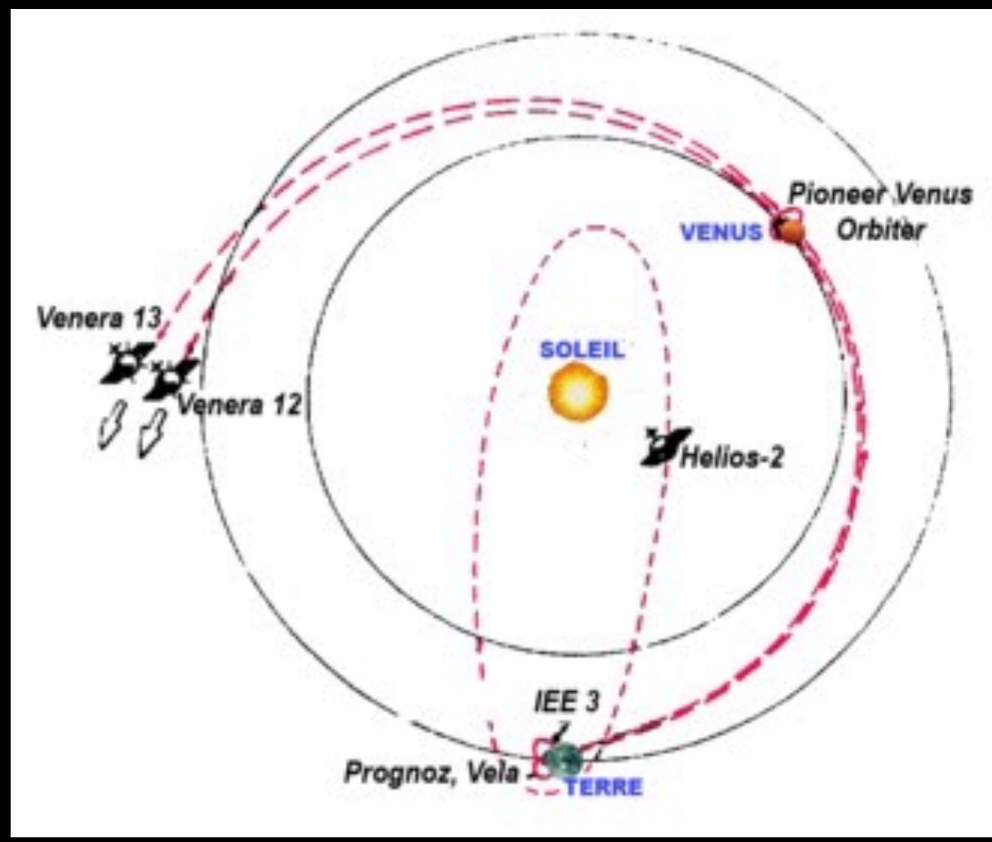
First IPN 1976
4-6 spacecrafts.
Baseline ~ 1 AU

Second IPN ~1990
PVO, Ulysses, CGRO, Wind

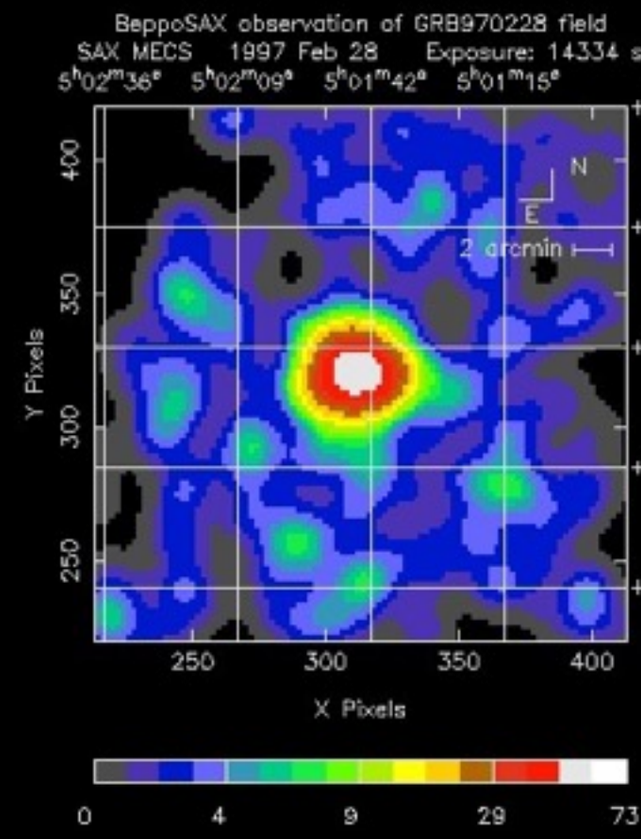
Third IPN 2000
~ 20 spacecrafts

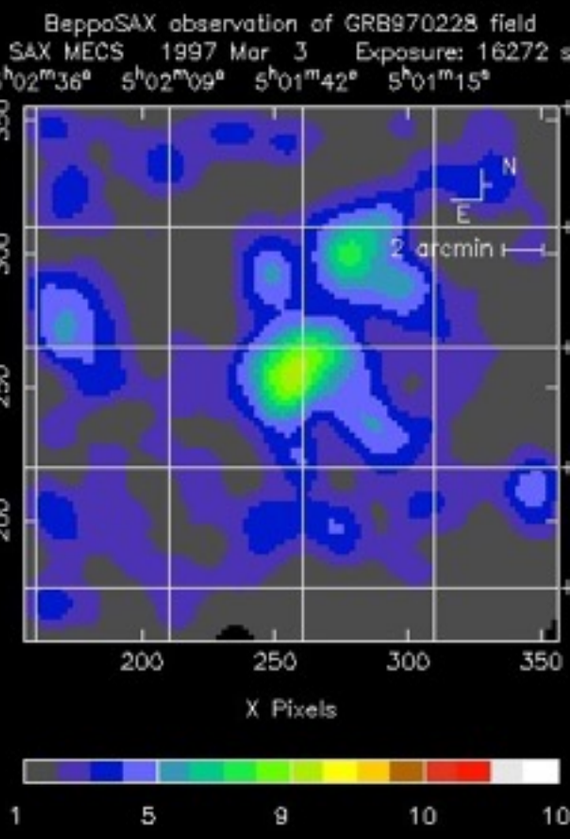
Localisations: arcmin-deg
Main disadvantage: long data acquisition ~days

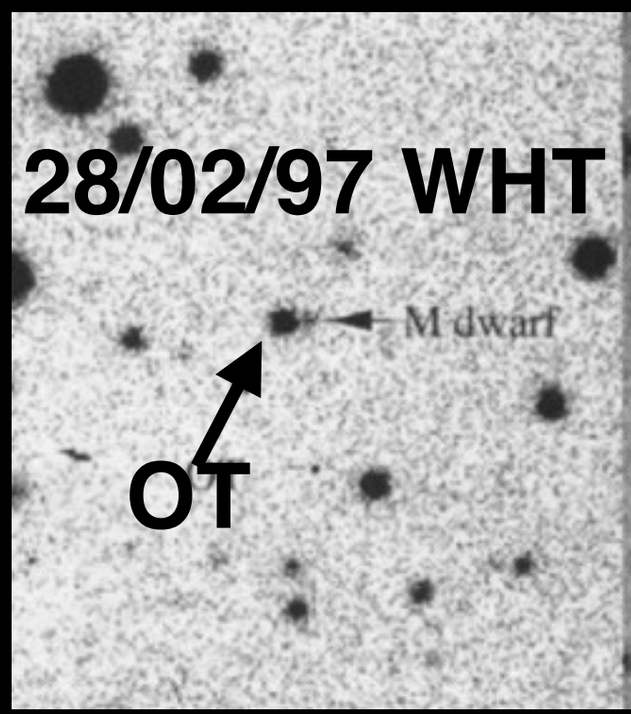


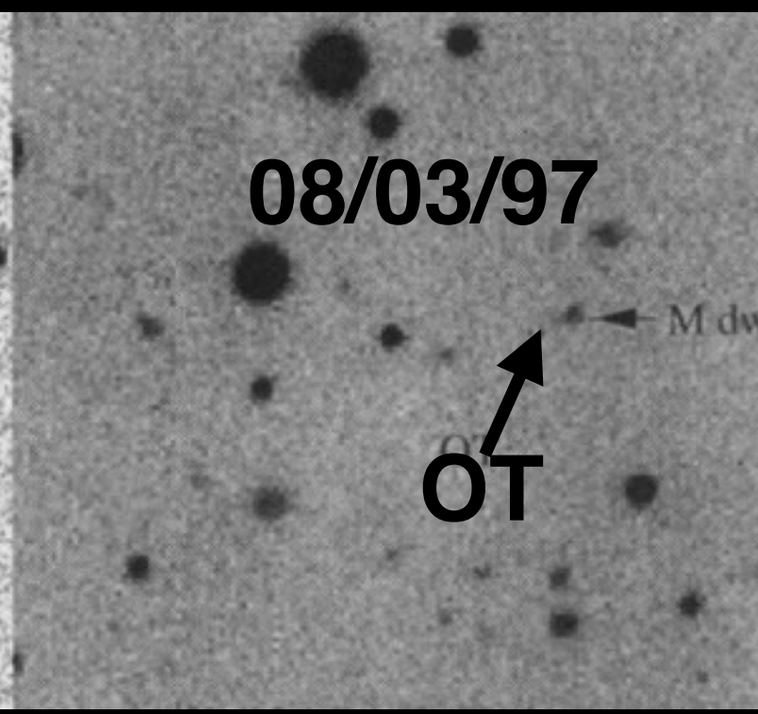


GRB970228


BeppoSAX observation of GRB970228 field
SAX MECS 1997 Feb 28 Exposure: 14334 s
5h02m36s 5h02m09s 5h01m42s 5h01m15s
+12°00'00"
+11°54'00"
+11°48'00"
+11°42'00"
+11°36'00"
N
E
2 arcmin
Y Pixels
X Pixels
250 300 350 400
0 4 9 29 73


BeppoSAX observation of GRB970228 field
SAX MECS 1997 Mar 3 Exposure: 16272 s
5h02m36s 5h02m09s 5h01m42s 5h01m15s
N
E
2 arcmin
Y Pixels
X Pixels
200 250 300 350
1 5 9 10 10


28/02/97 WHT
M dwarf
OT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OT

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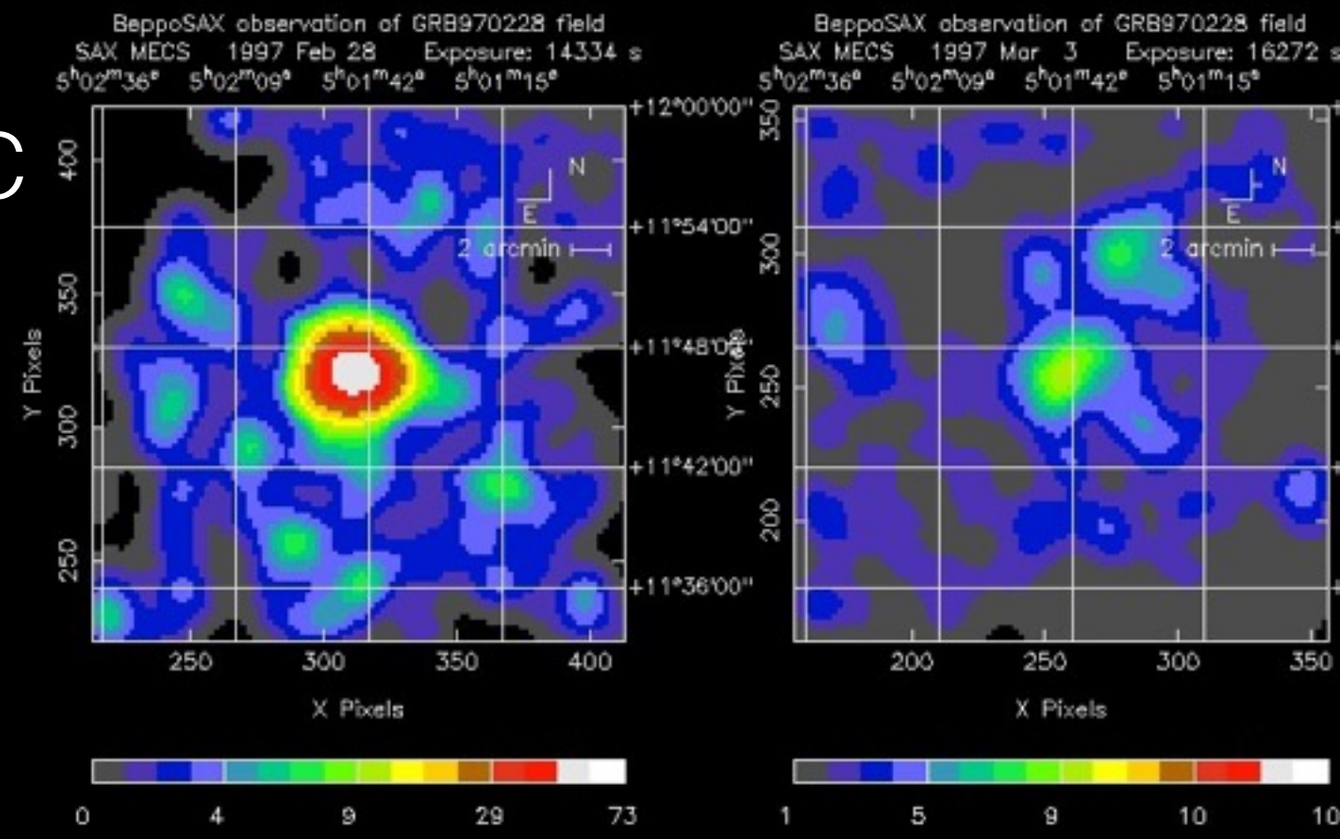
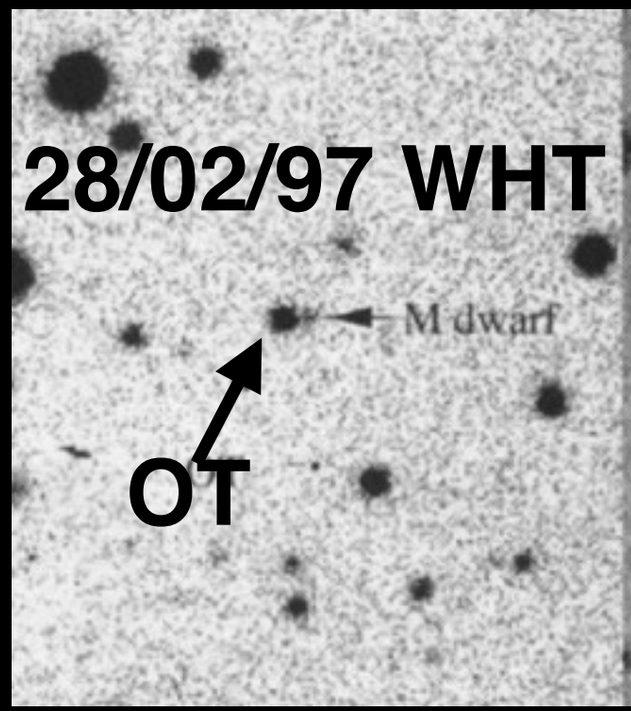
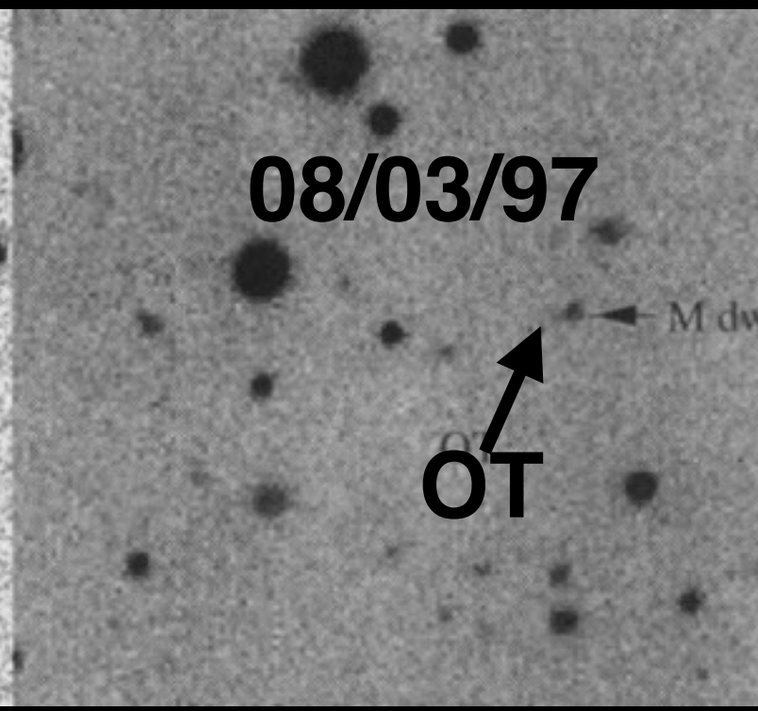
Detected and localised to a several arcmin by BSAX/WFC







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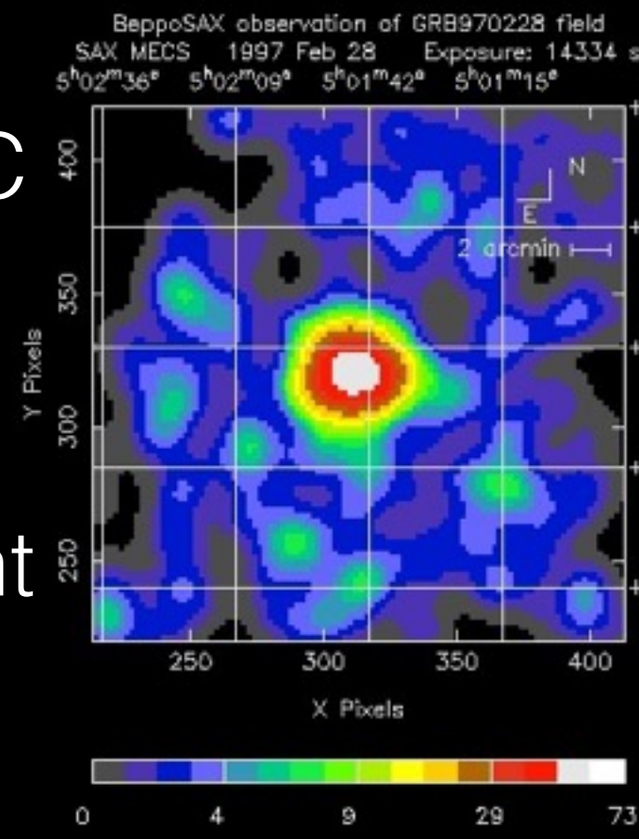
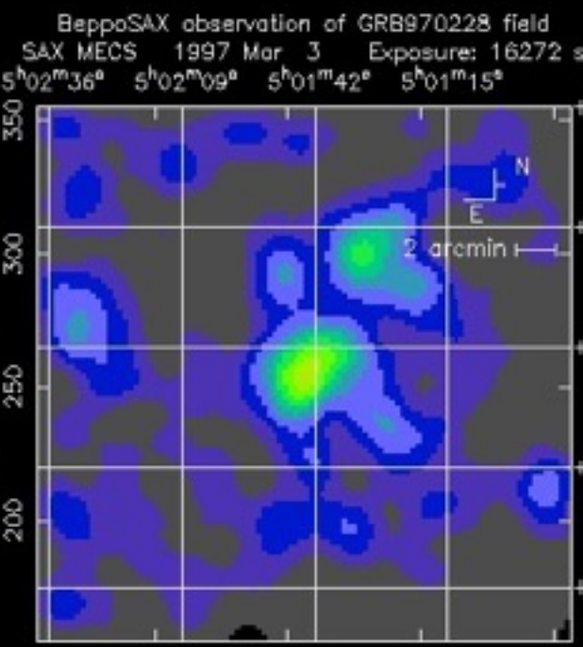
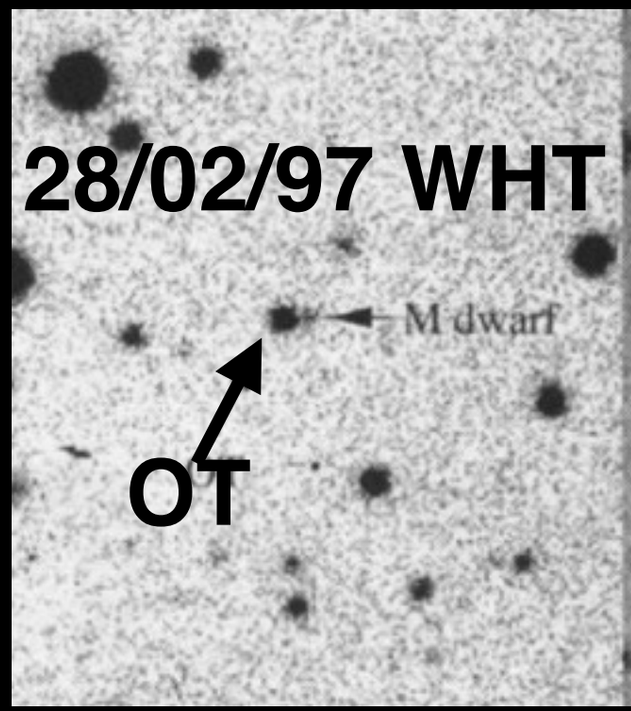
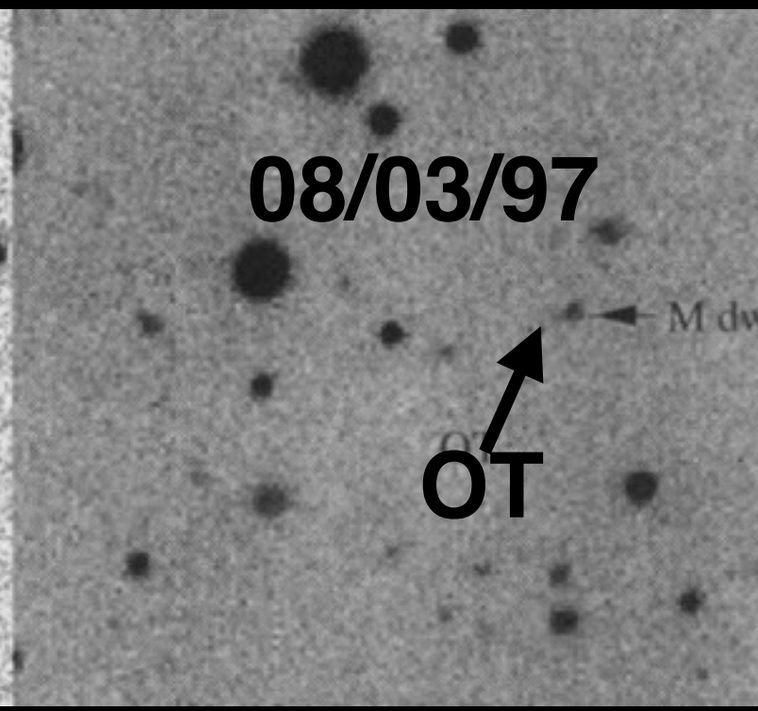
Satellite repointed and field observed with X-ray telescopes 8hr after the event









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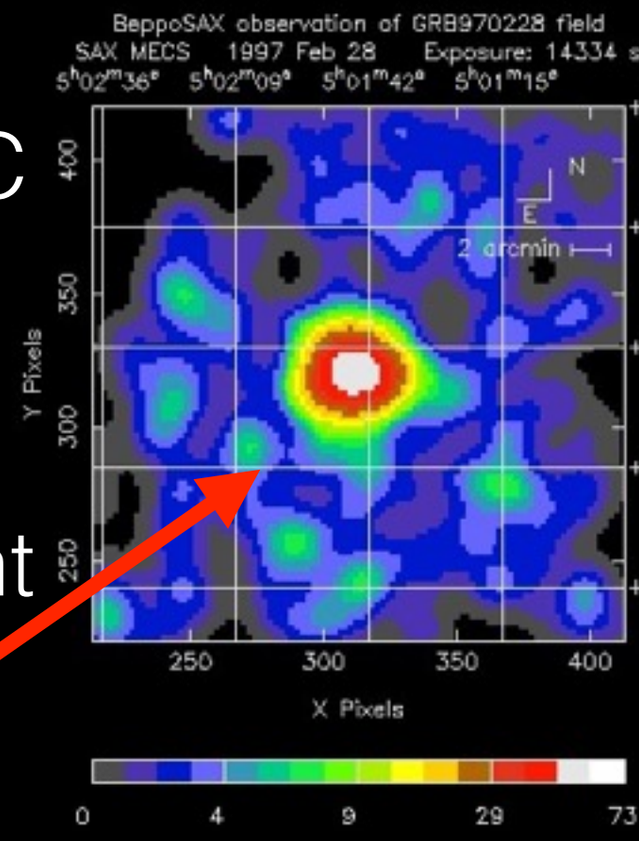
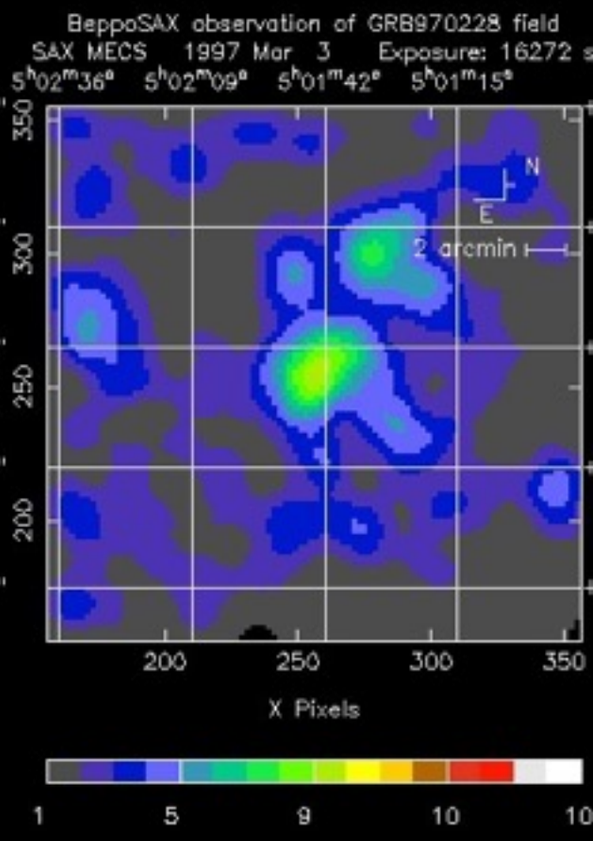
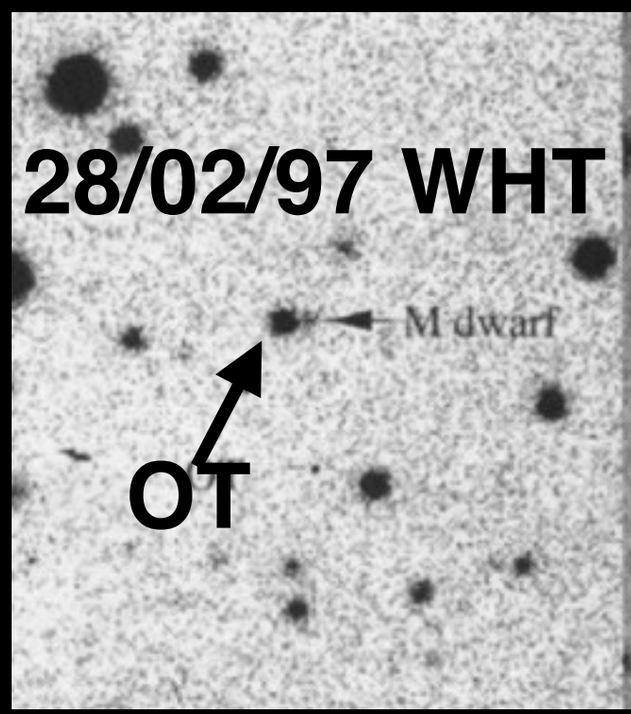
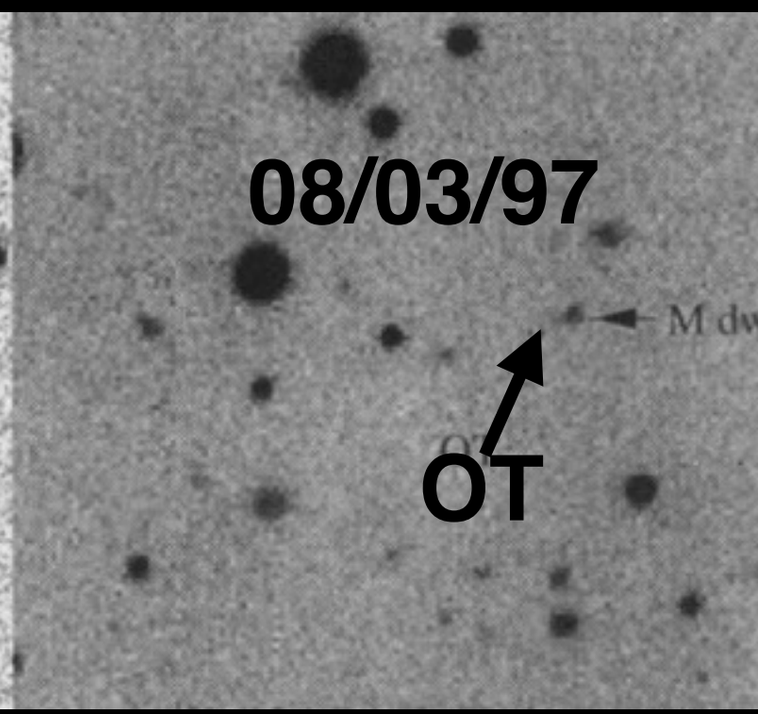
Discovery of first X-ray afterglow. <1arcmin position disseminated









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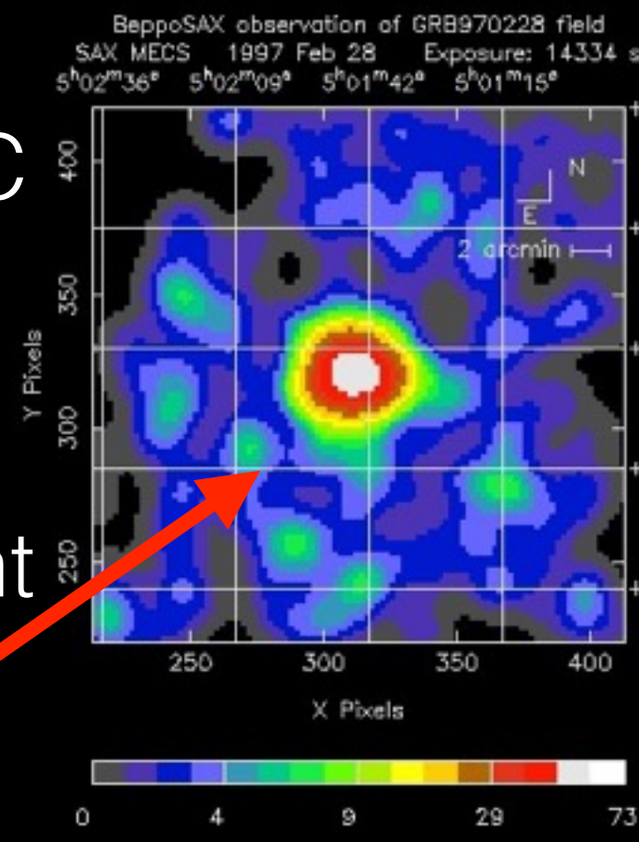
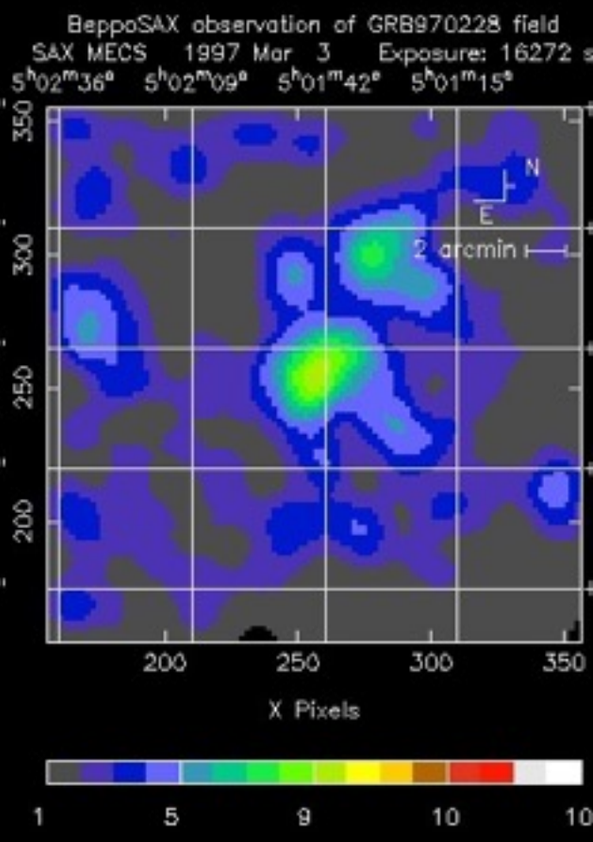
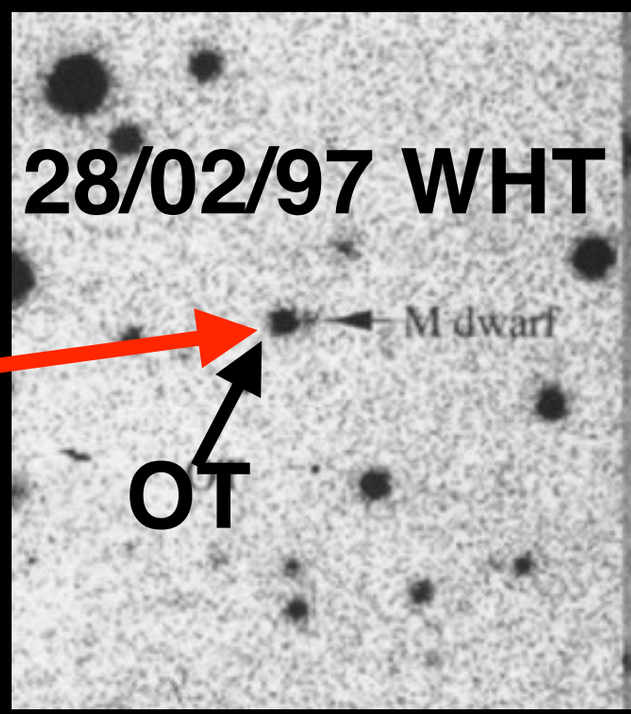
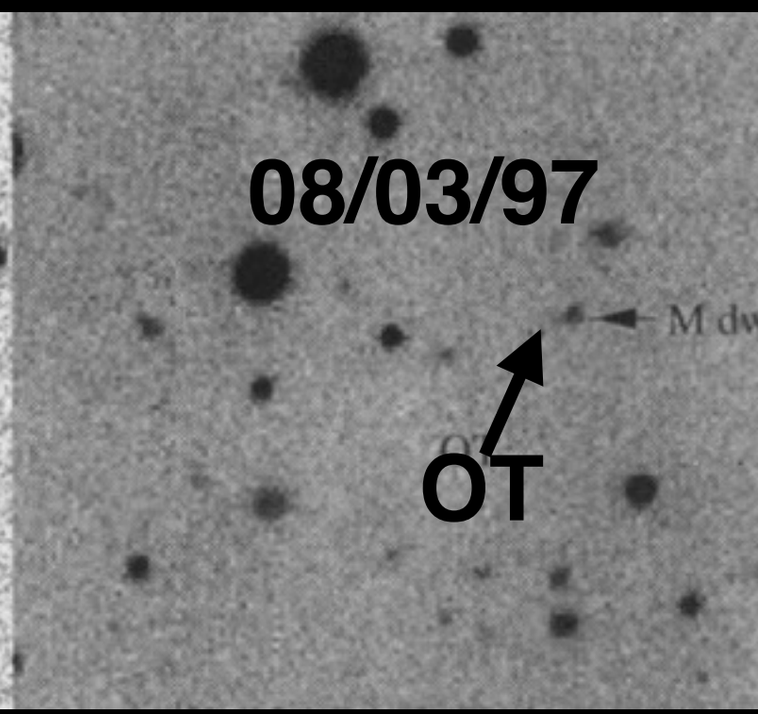
Discovery of first optical afterglow









GRB 970228

IPN

BeppoSAX WFC
error
circle

MECS

error
annulus

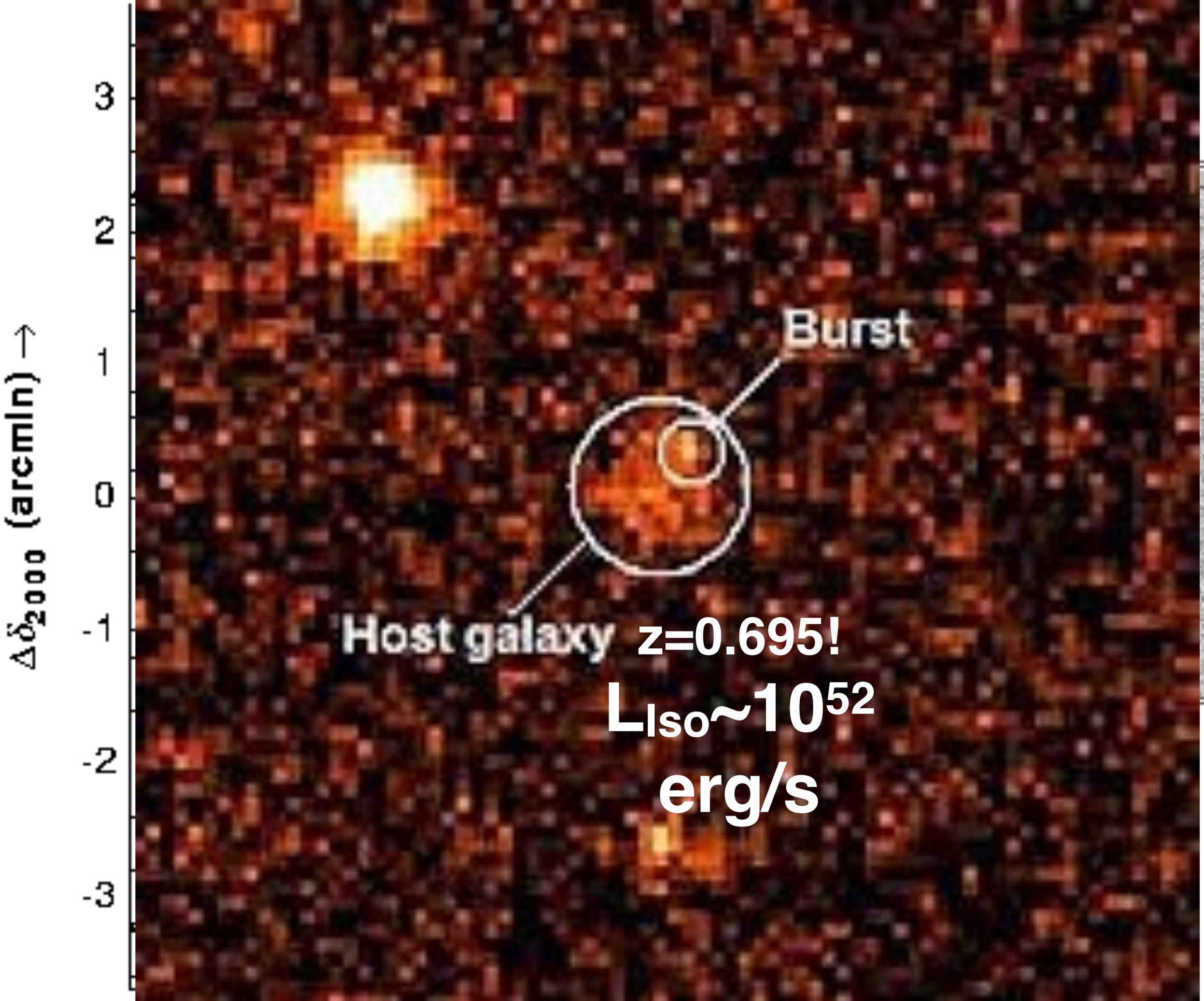
WHT 28/2/97

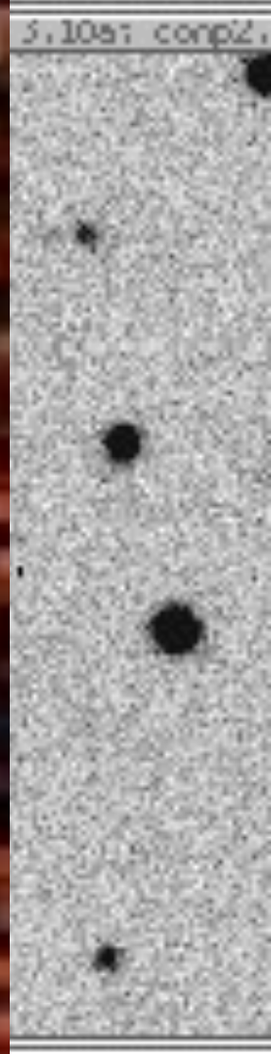
O1

SAX-WFC
SAX-LECS/MECS
SAX/Ulysses
Wind/Ulysses
Optical Transient
VLA Radio Source

$\Delta\delta_{2000}$ (arcmin) →

3
2
1
0
-1
-2
-3


3
2
1
0
-1
-2
-3
Δδ2000 (arcmin) →
Burst
Host galaxy
z=0.695!
Liso~10^52
erg/s


3.10s: comp2.

Lessons learned

Vela satellites, IPN, BeppoSAX, Swift

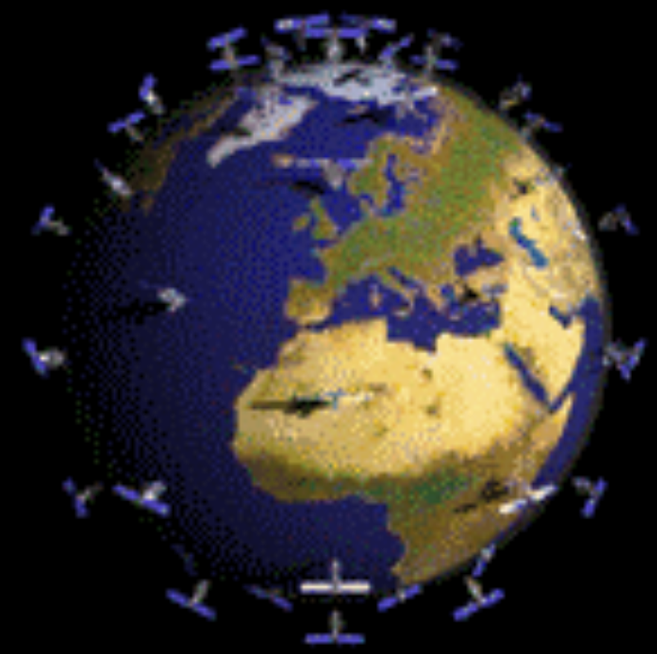
Distributed instrument —> arcmin-deg positions

Modularity —> improved performances

Prompt arcmin-arcsec positions —> game changer

The multi-messenger revolution

Phinney 2009



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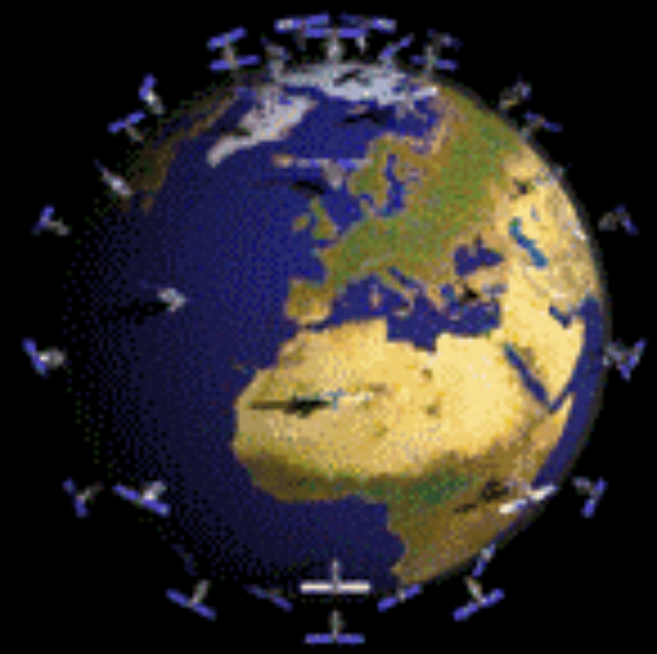
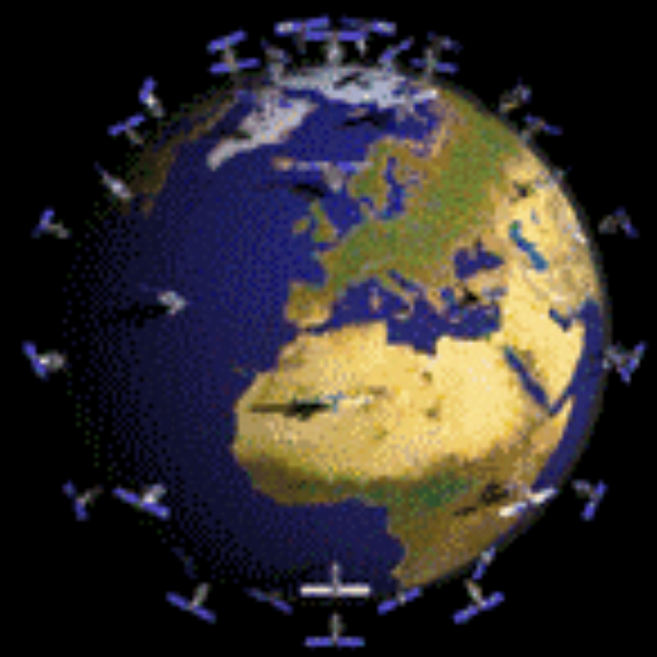


The multi-messenger revolution Phinney 2009

Is NS-NS & BH-NS coalescence the engine of short GRBs? Associations of GWEs and SGRBs will tell.



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Are GRBs powered by BH accretion or magnetars?
GW detections provide mass of final compact object.

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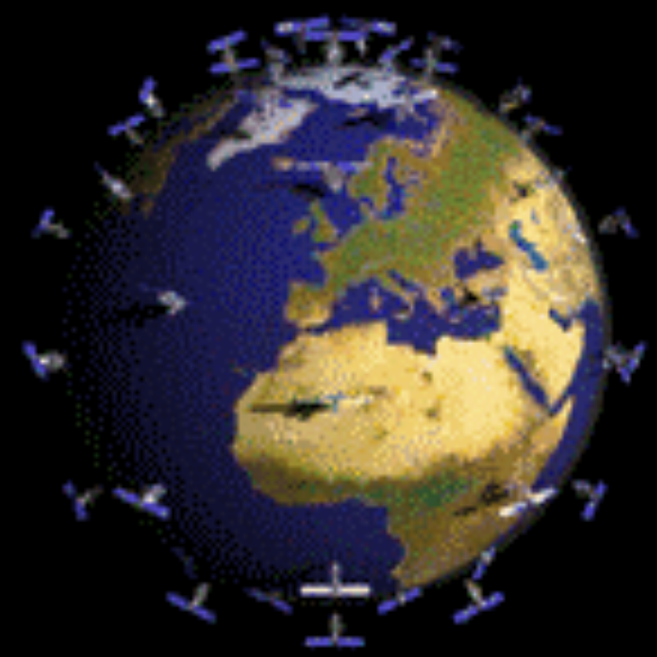
Which are the GRB, outflows and afterglows opening angles?
GW detections provide system inclination.

The multi-messenger revolution Phinney 2009

Which are the galaxy environments where coalescing NS-NS, BH-NS and BH-BH are found?

Identification of the GWE host galaxy will tell



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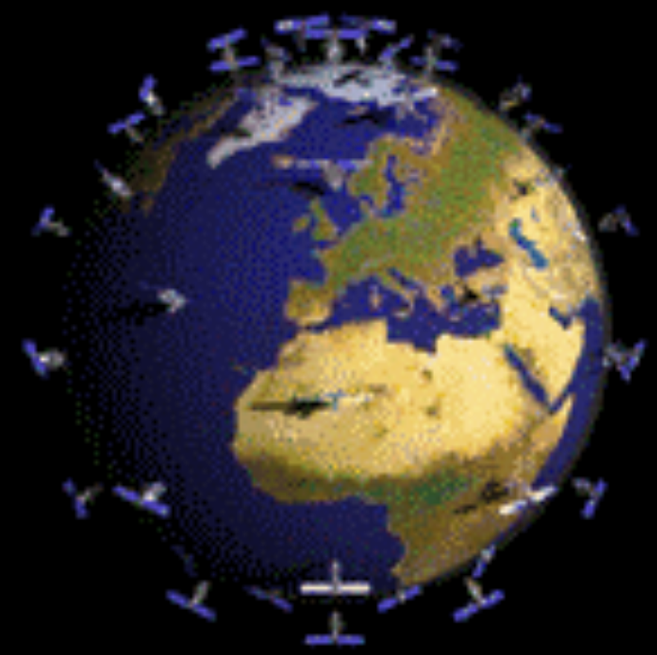
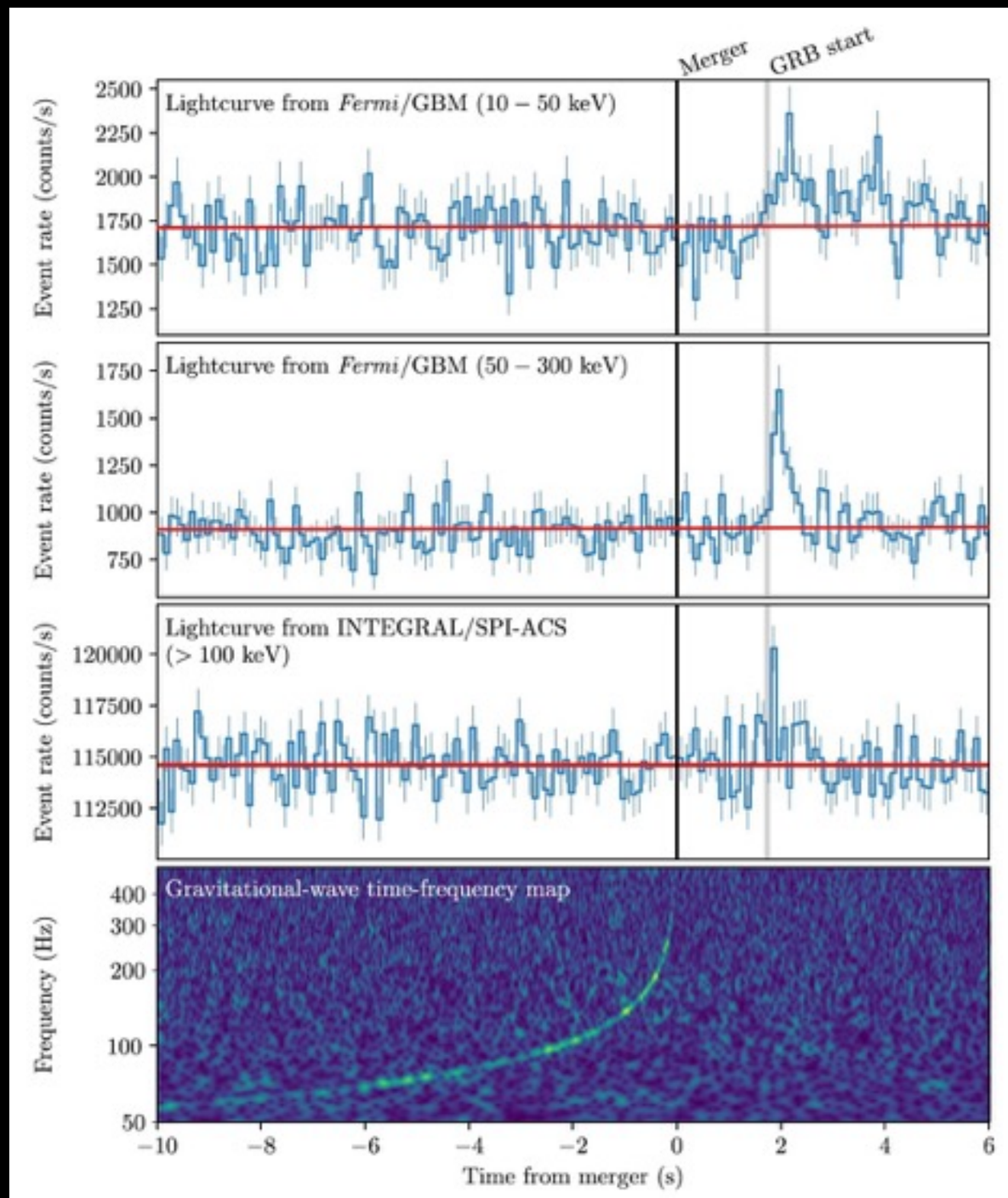


How some stars explode as SNe?
GW will provide core dynamics, EM will provide explosion type, nucleosynthesis, BH vs NS remnant

The multi-messenger revolution is today!: GW170817



The multi-messenger revolution is today!: GW170817

M_1 = 1.36-2.26 M_{Sun}

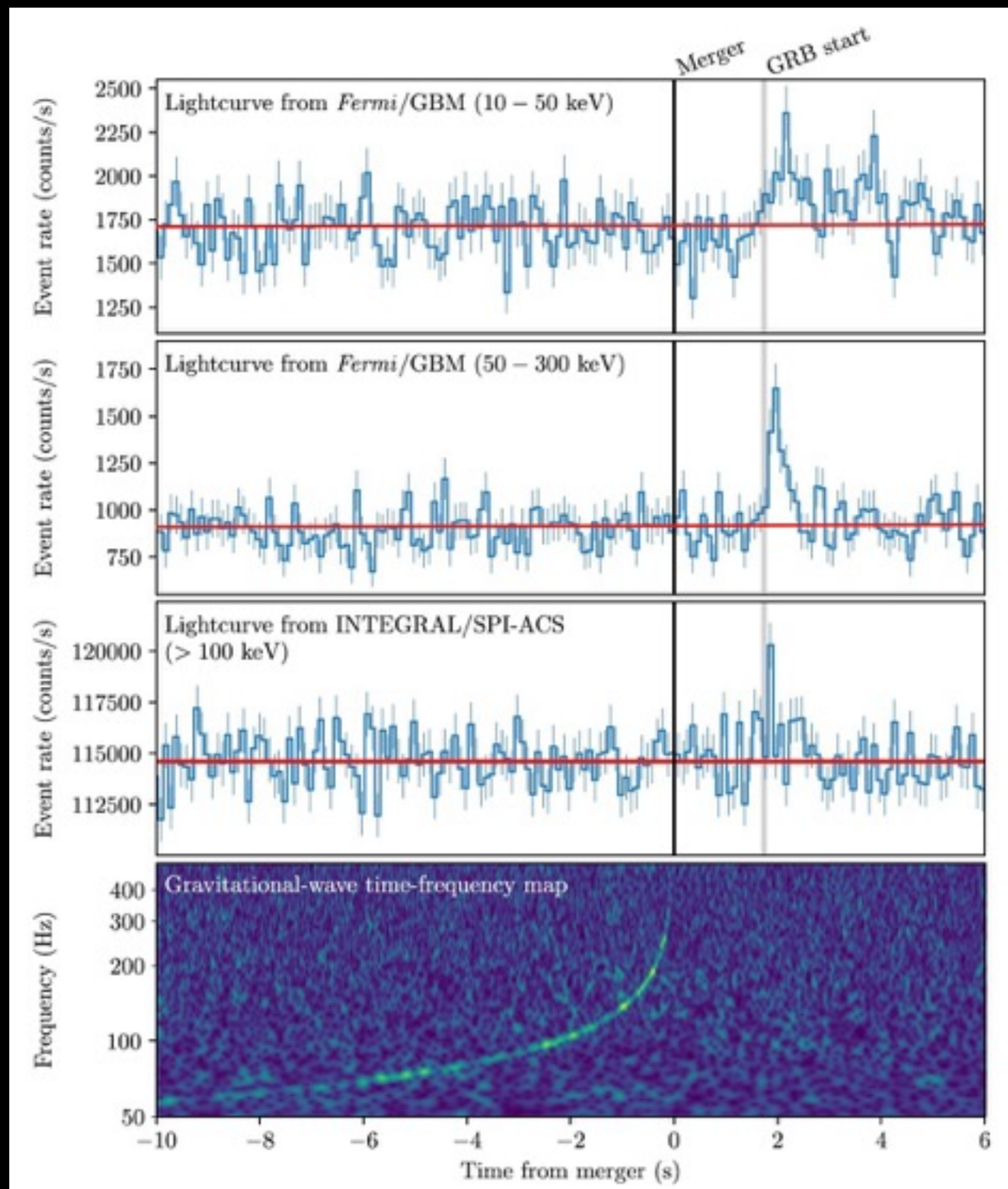
M_2 = 0.86-1.36 M_{Sun}

M_{chirp} = 1.188

$D_L = 40^{+8}_{-14}$ Mpc

E_{rad} = 0.025 M_{Sun} c^2

Error box ~ 30deg^2



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Error box ~ 30deg^2

t_{delay} = 1.7s

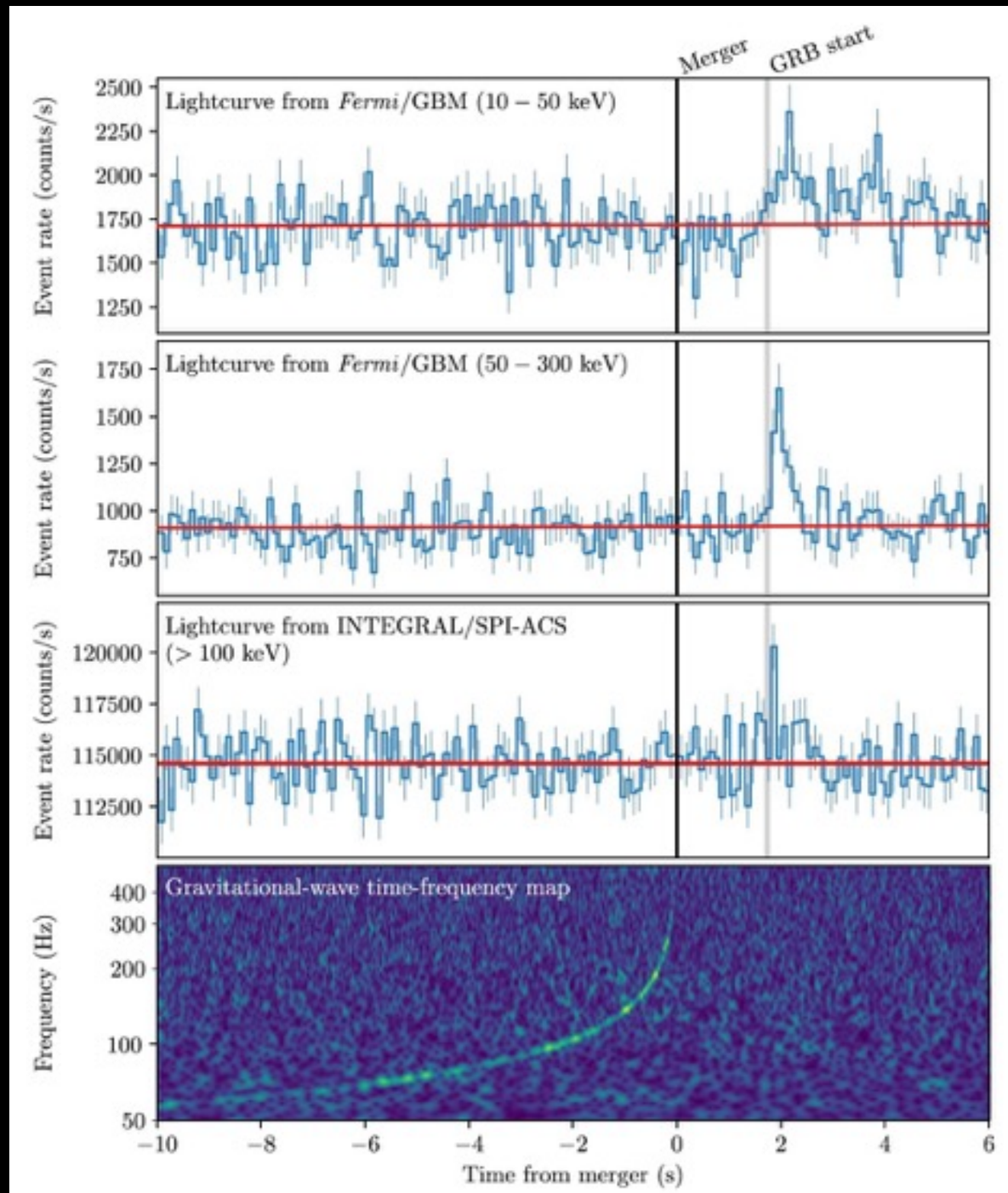
T_{90} = 2s

Fluence = 1.4x10^{-7} erg/cm^2

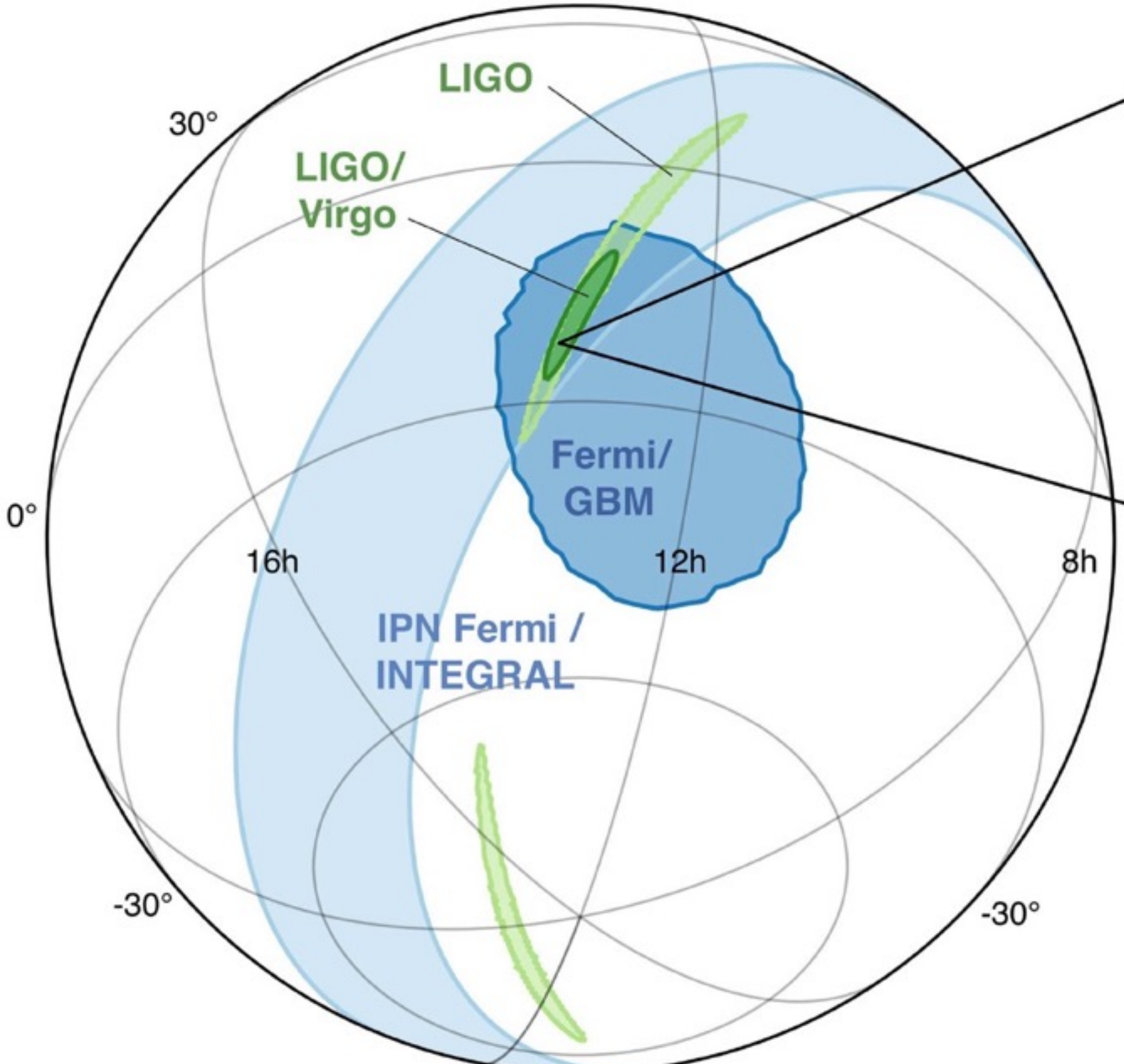
E_{peak} = 250+/-50 keV

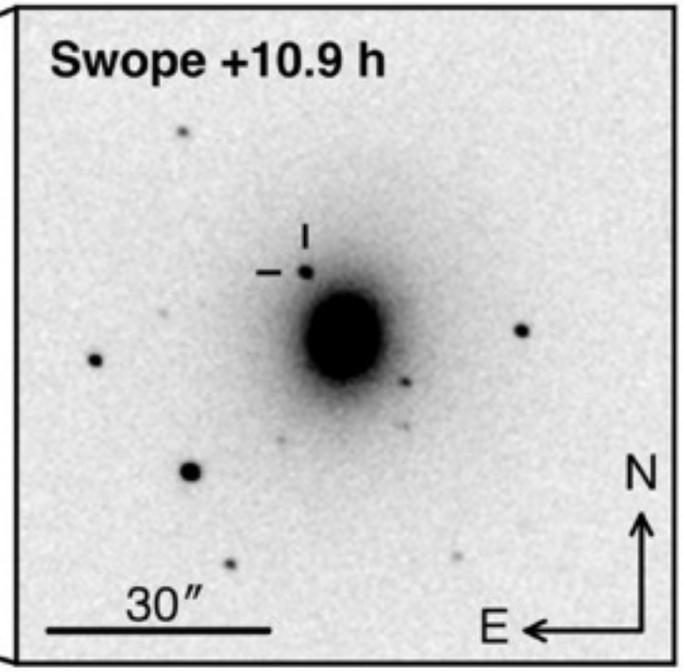
E_{iso} = 3x10^{46} erg

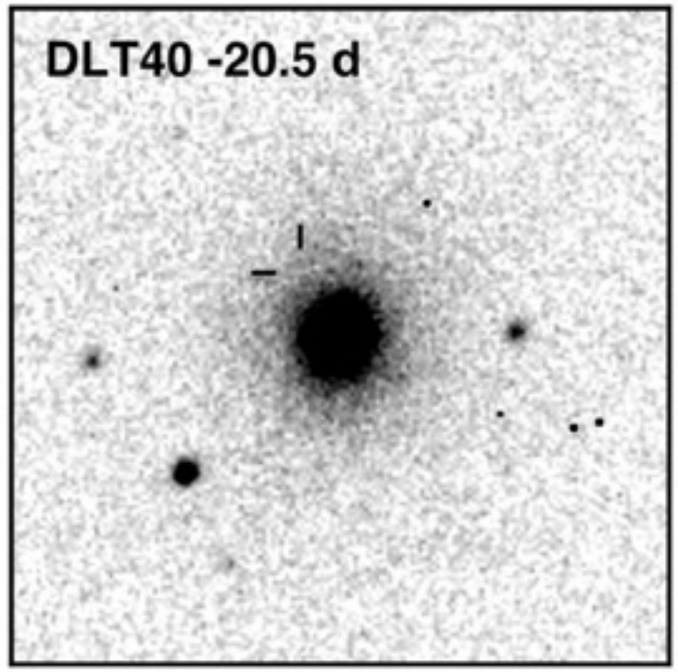
L_{iso} = 1.6x10^{47} erg/s



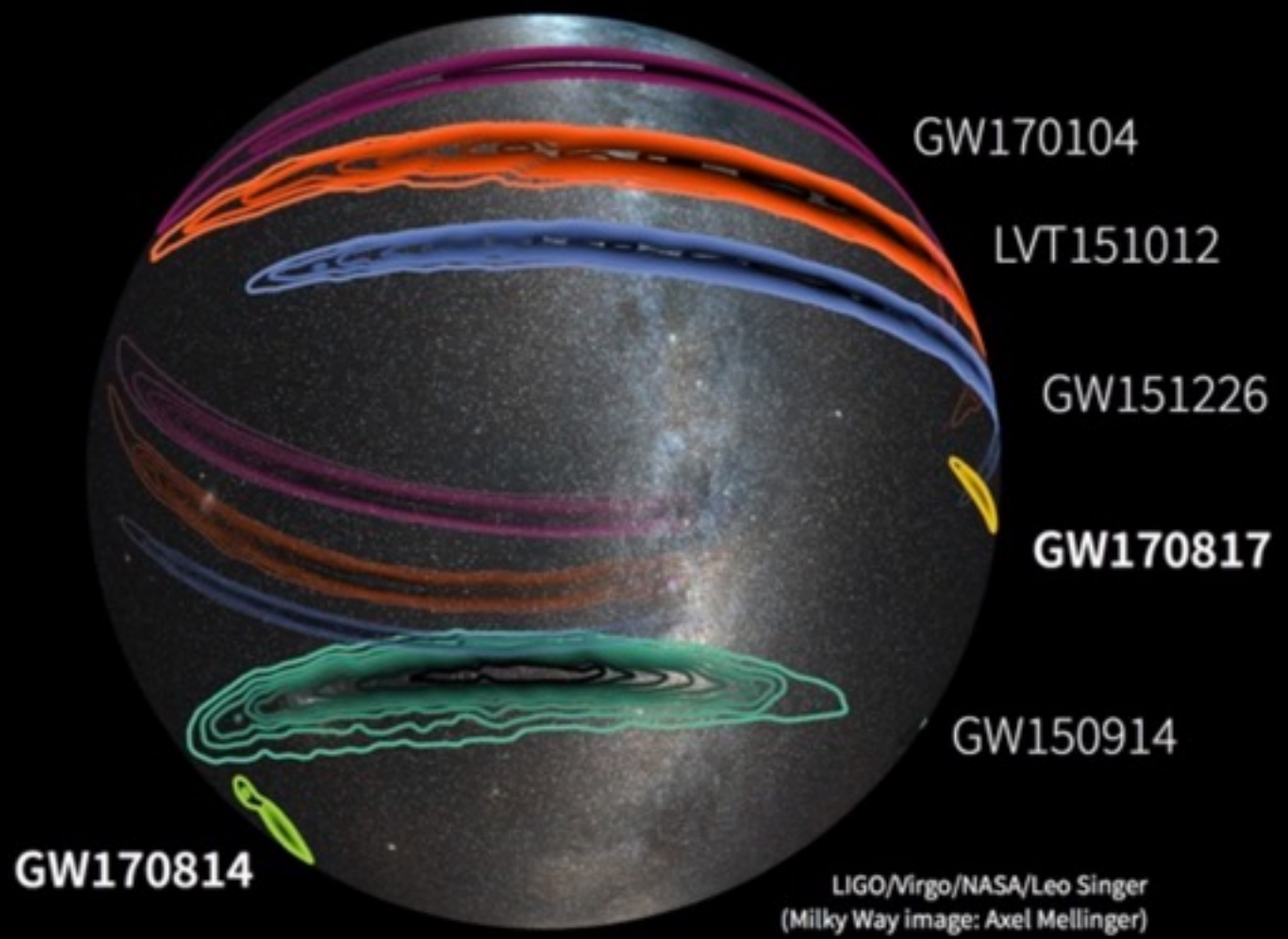
The multi-messenger revolution





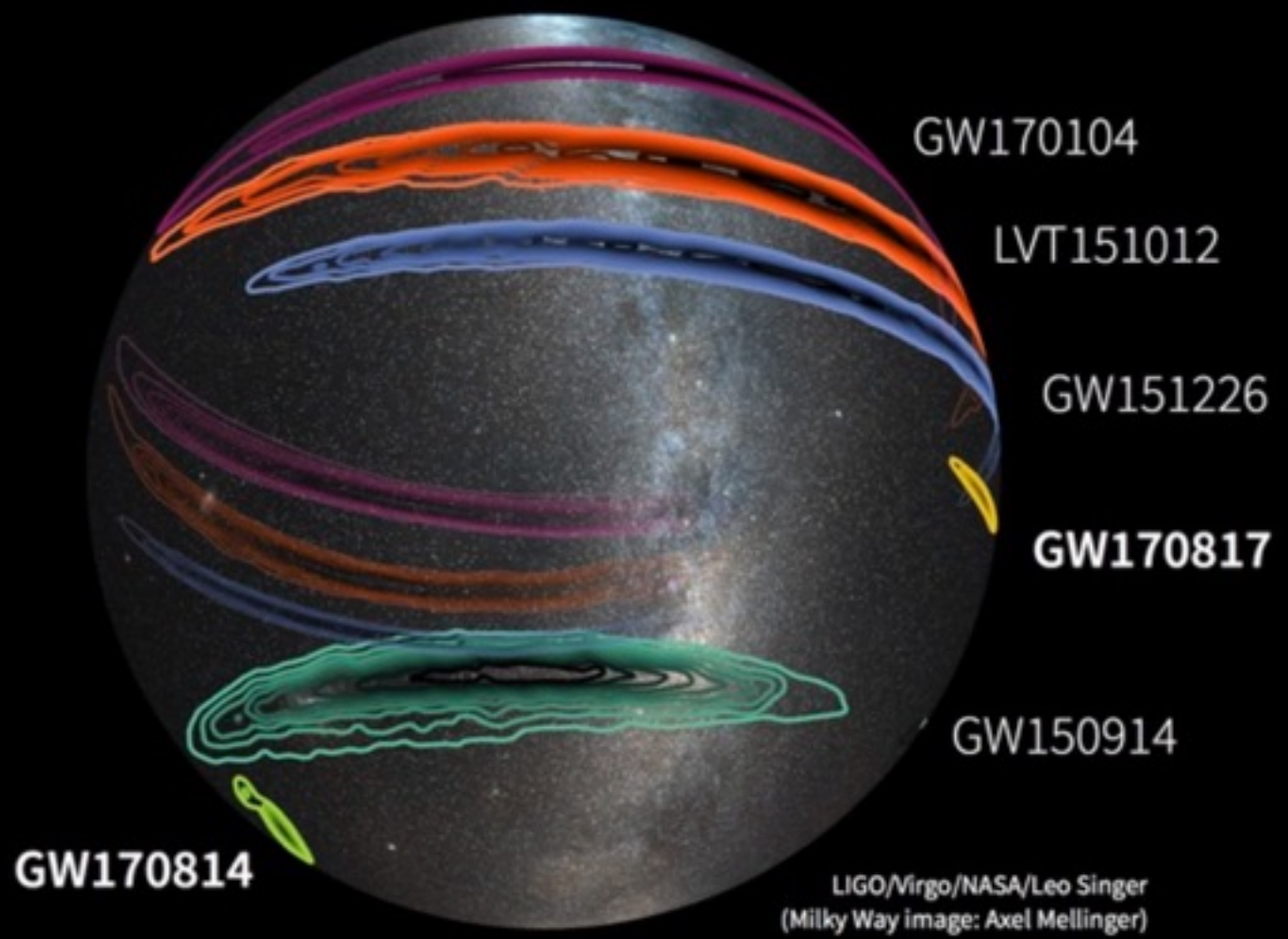


The multimessenger revolution



The multimessenger revolution

Advanced Ligo/Virgo provide position with accuracy ~ tens deg



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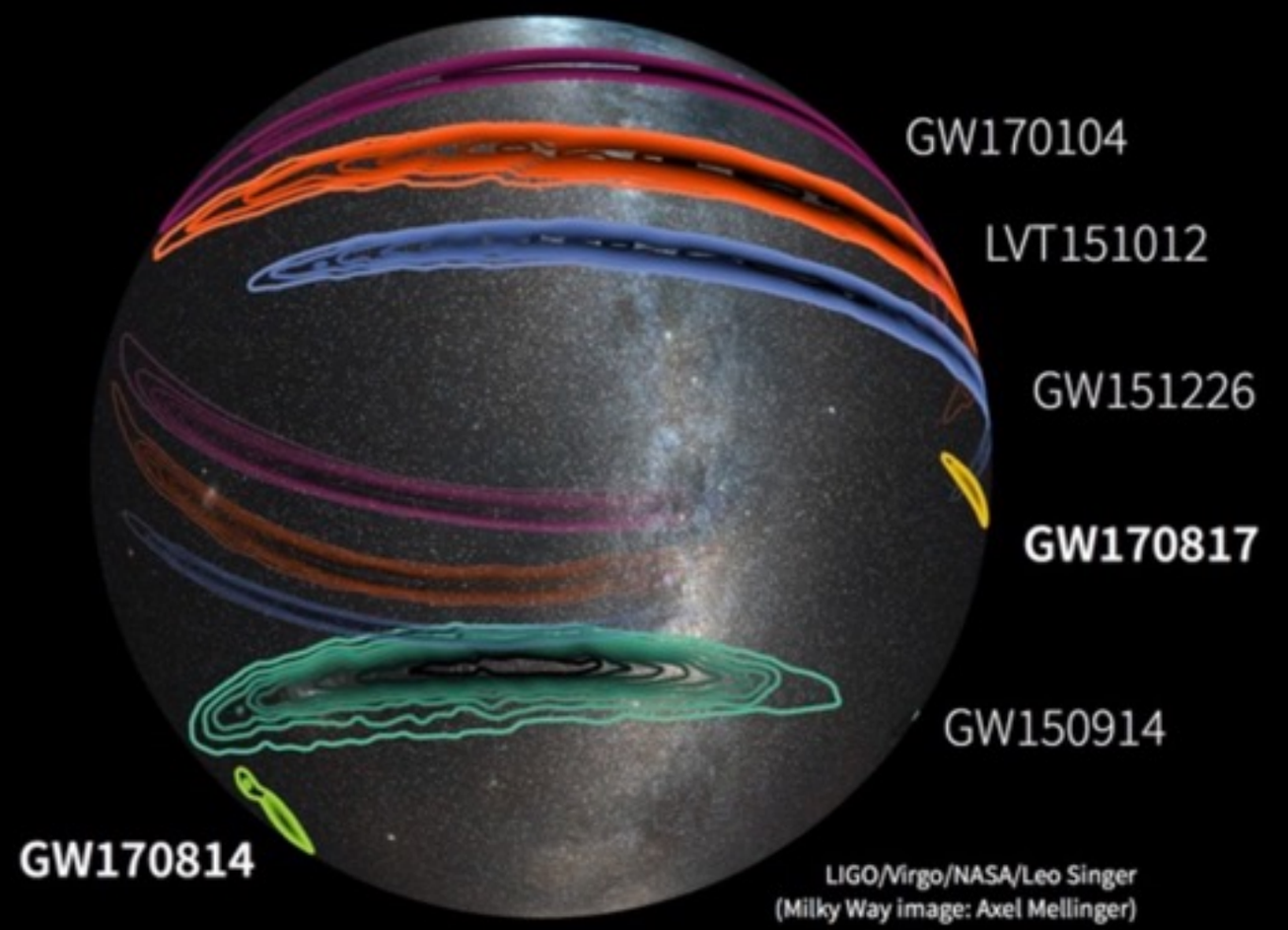
Advanced Ligo/Virgo provide position with accuracy ~ tens deg

NS-NS and BH-NS coalescence: 100-200 Mpc horizon GRB, cocoon, kilonova..

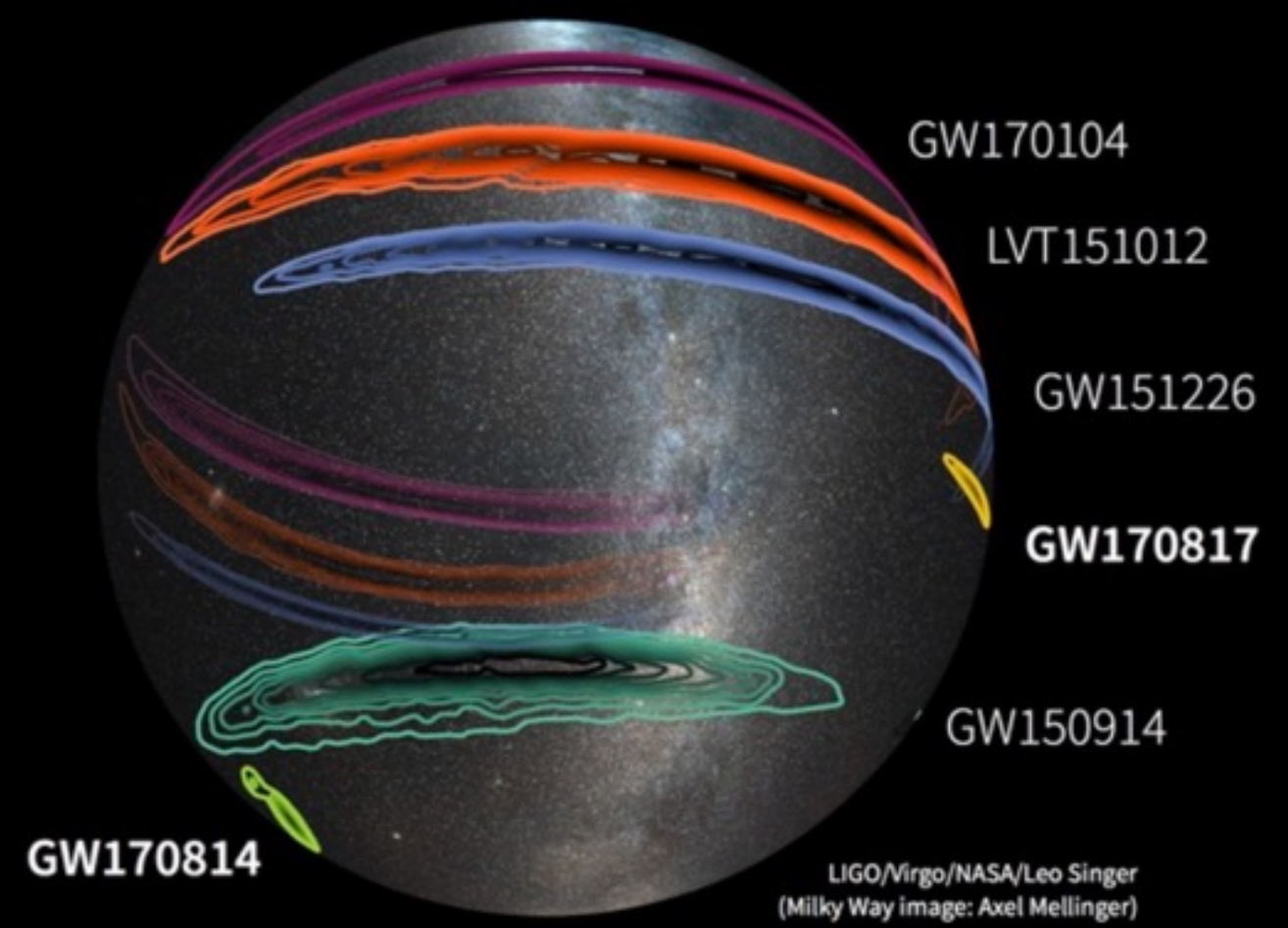


The multimessenger revolution

Advanced Ligo/Virgo provide position with accuracy ~ tens deg

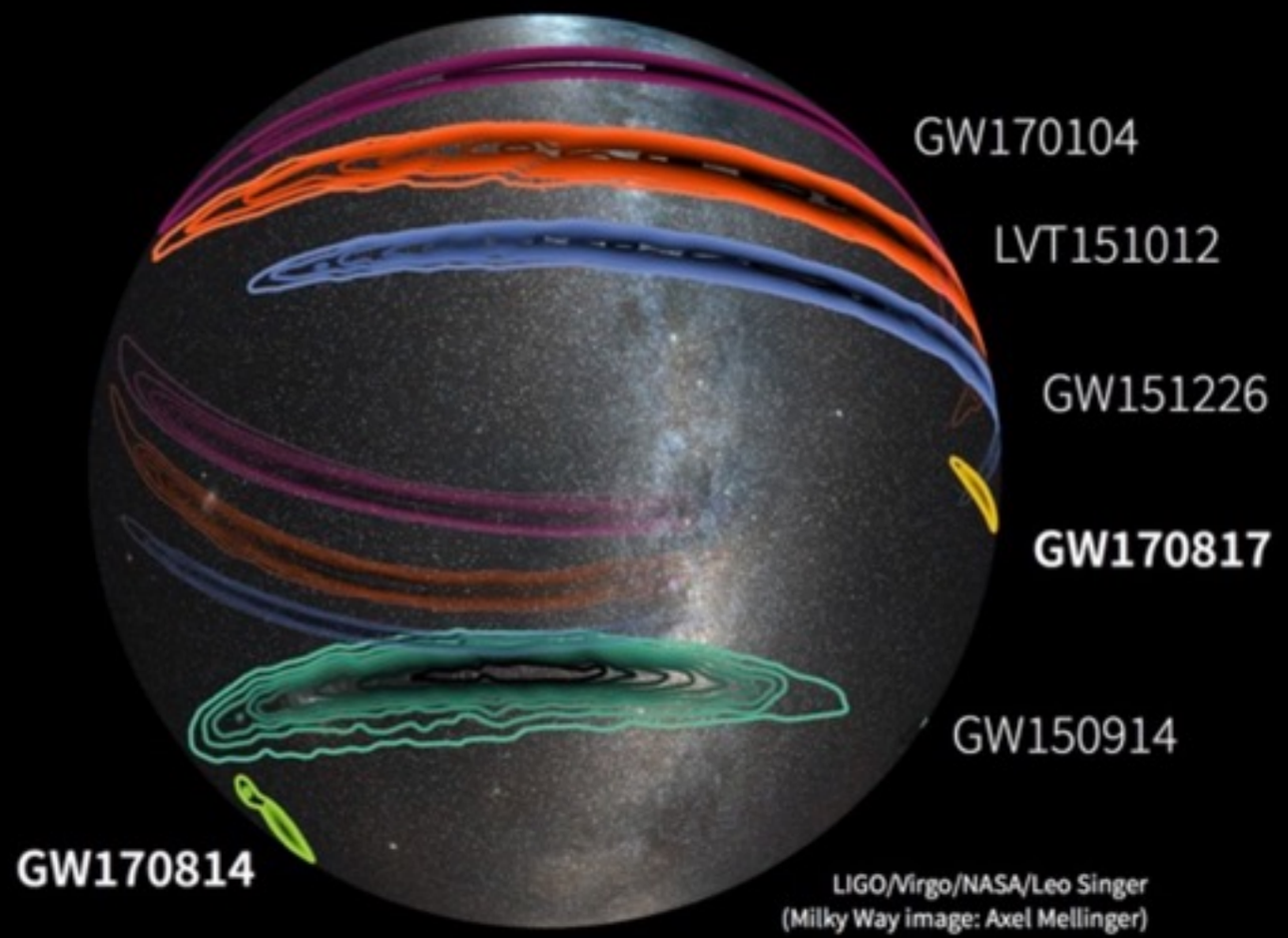
NS-NS and BH-NS coalescence:
100-200 Mpc horizon
GRB, cocoon, kilonova..

BH-BH coalescence:
>Gpc horizon
no expected EM counterpart
(even more exciting if one is found…)



The multimessenger revolution

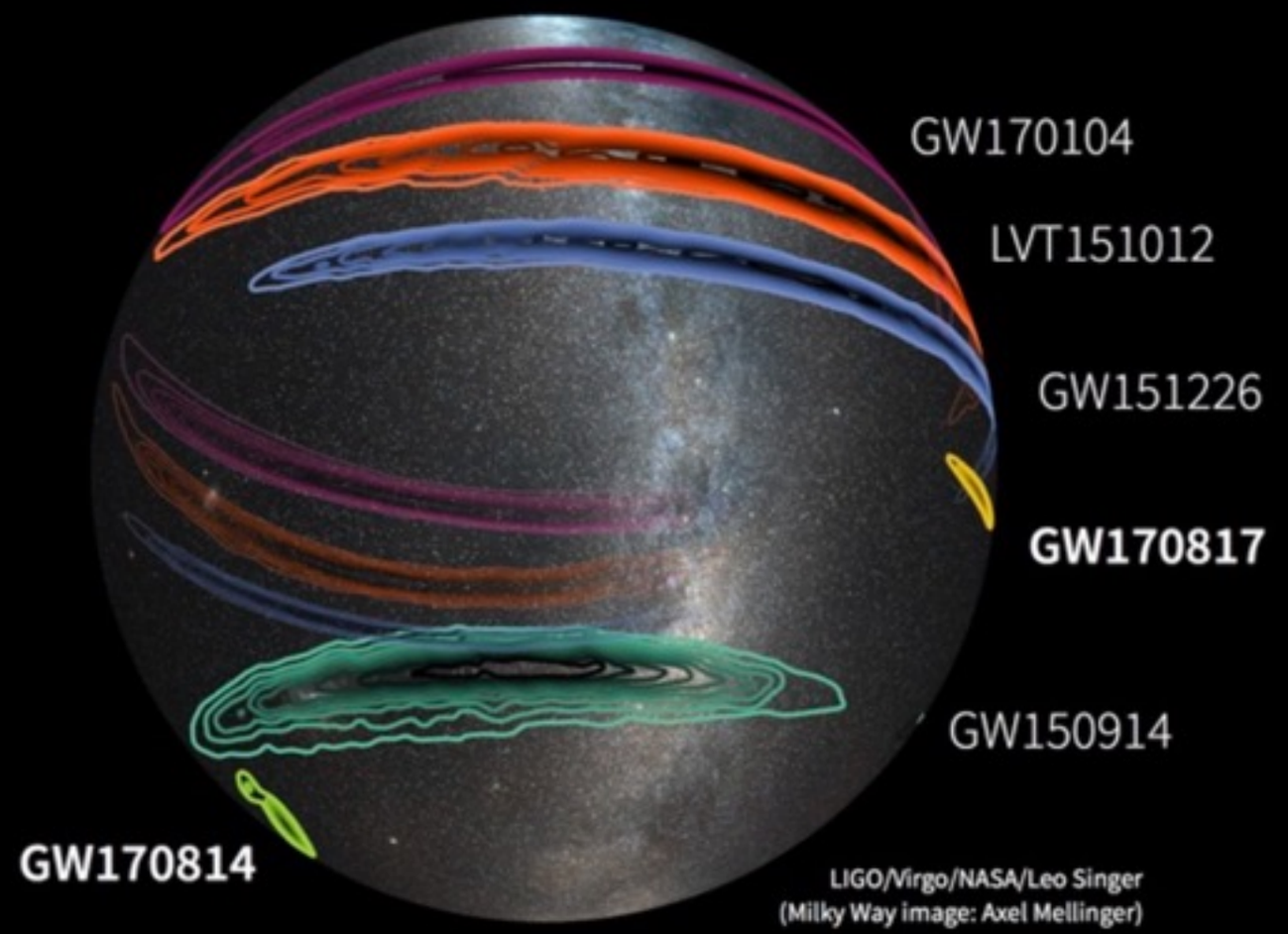
Large volumes difficult to survey at optical λ.



The multimessenger revolution

Large volumes difficult to survey at optical λ.

Tens/hundreds/thousands optical transients.

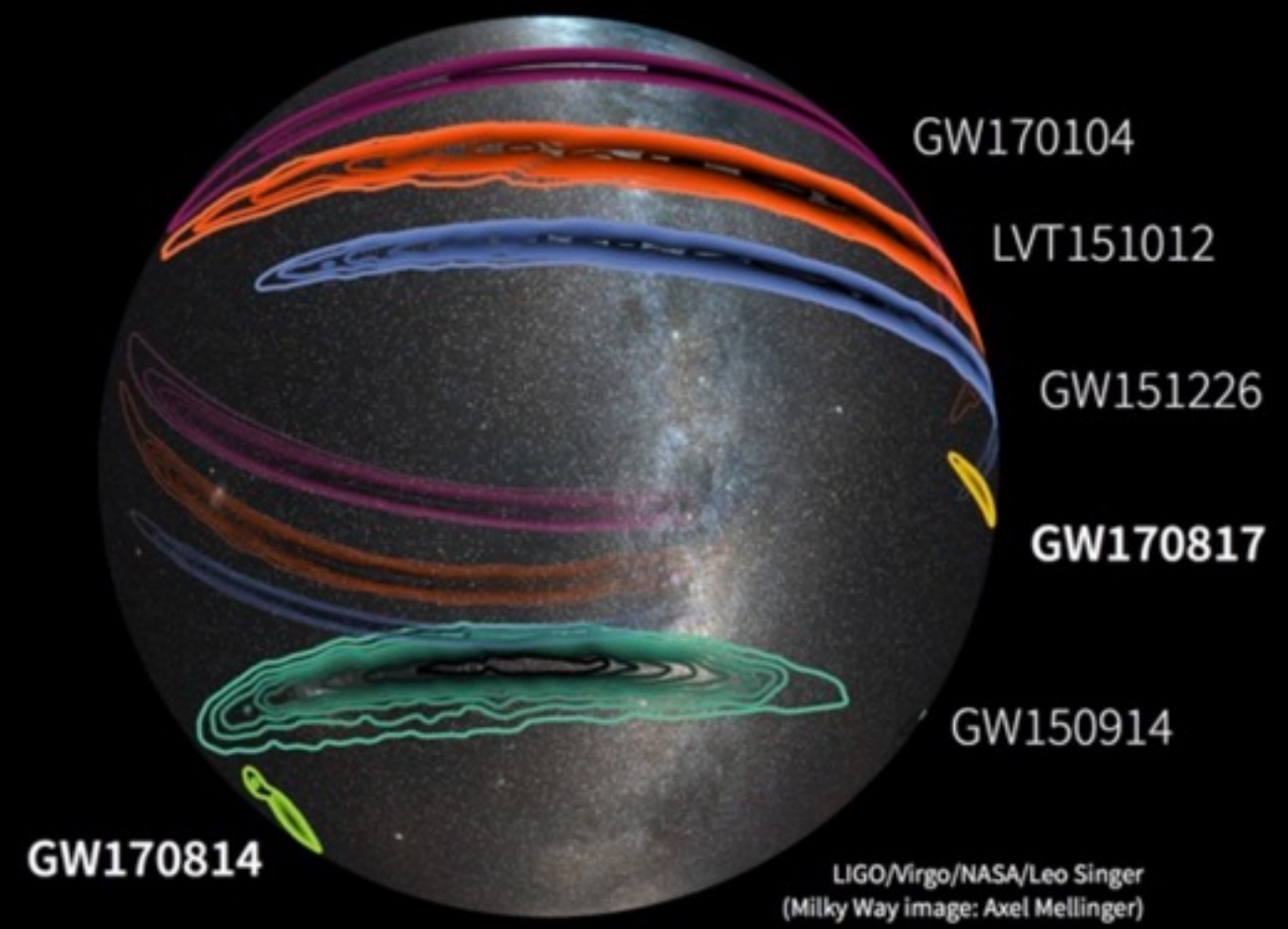


The multimessenger revolution

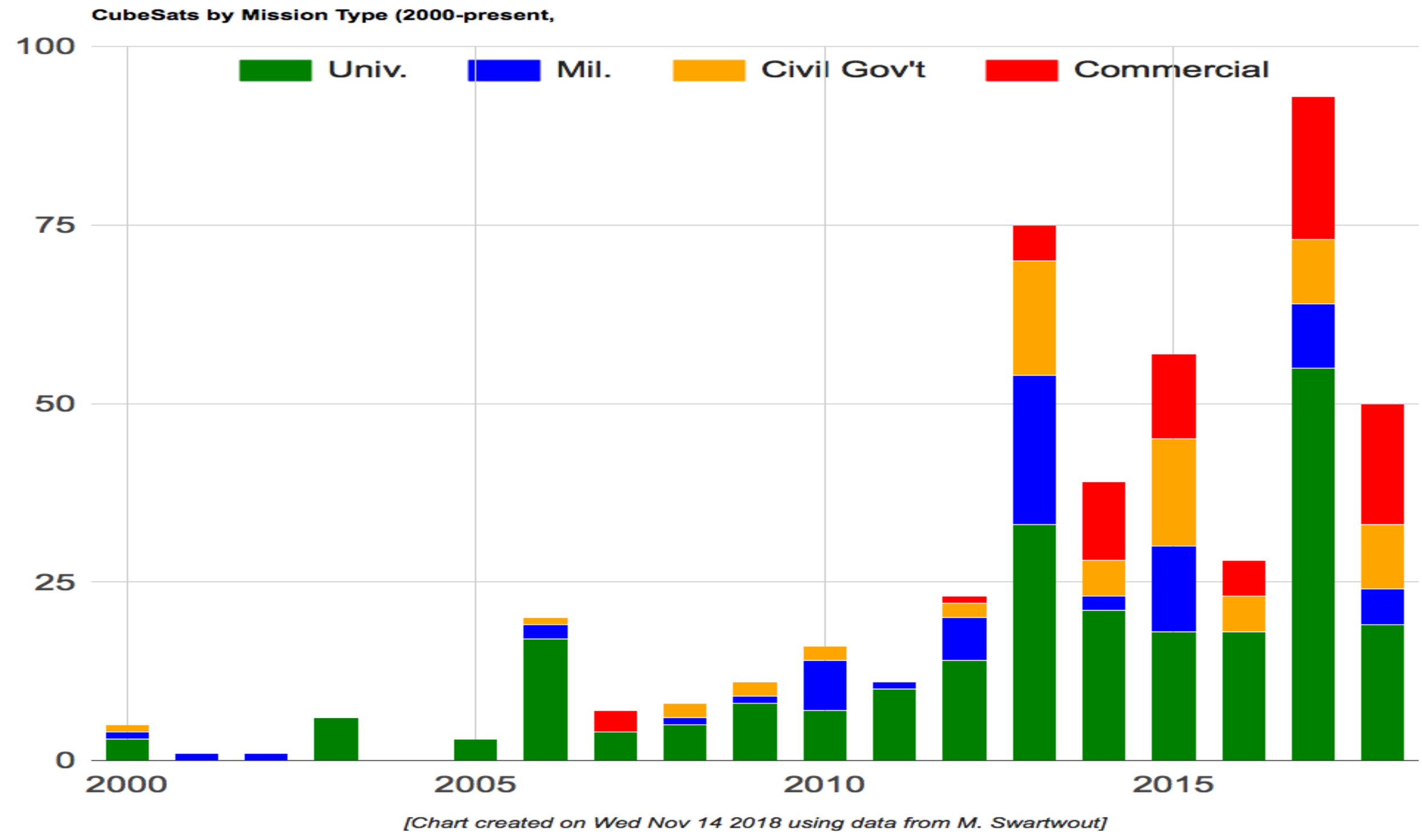
Large volumes difficult to survey at optical λ.

Tens/hundreds/thousands optical transients.

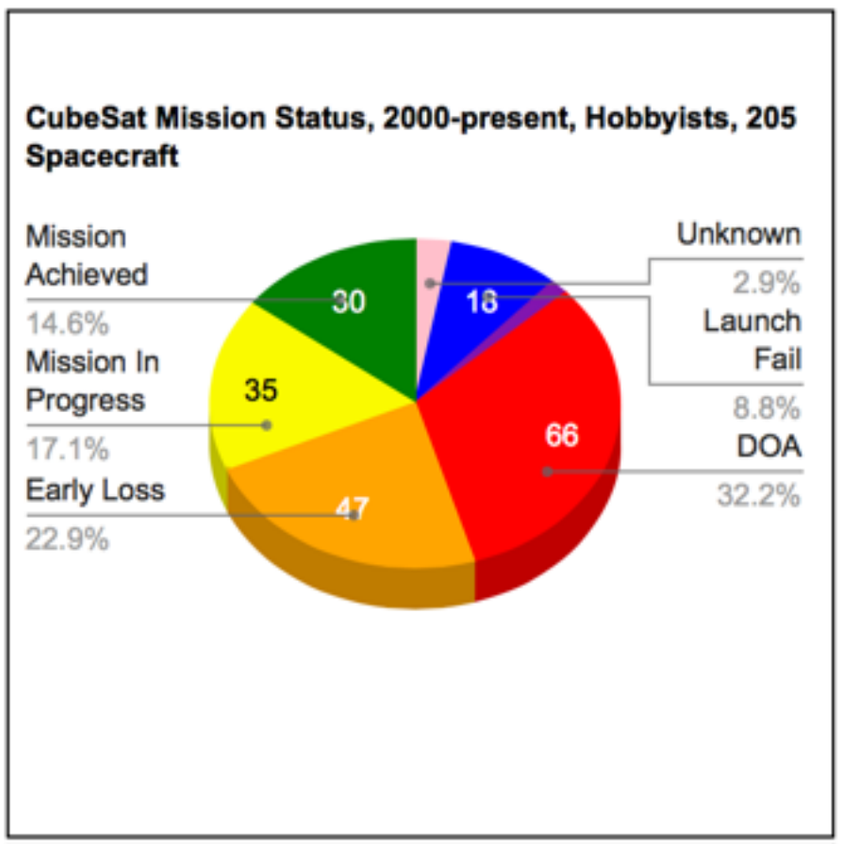
Best strategy:
~ all sky prompt search for transients at high energies.
Negligible probability to find an uncorrelated HEA transient at the time of GWE

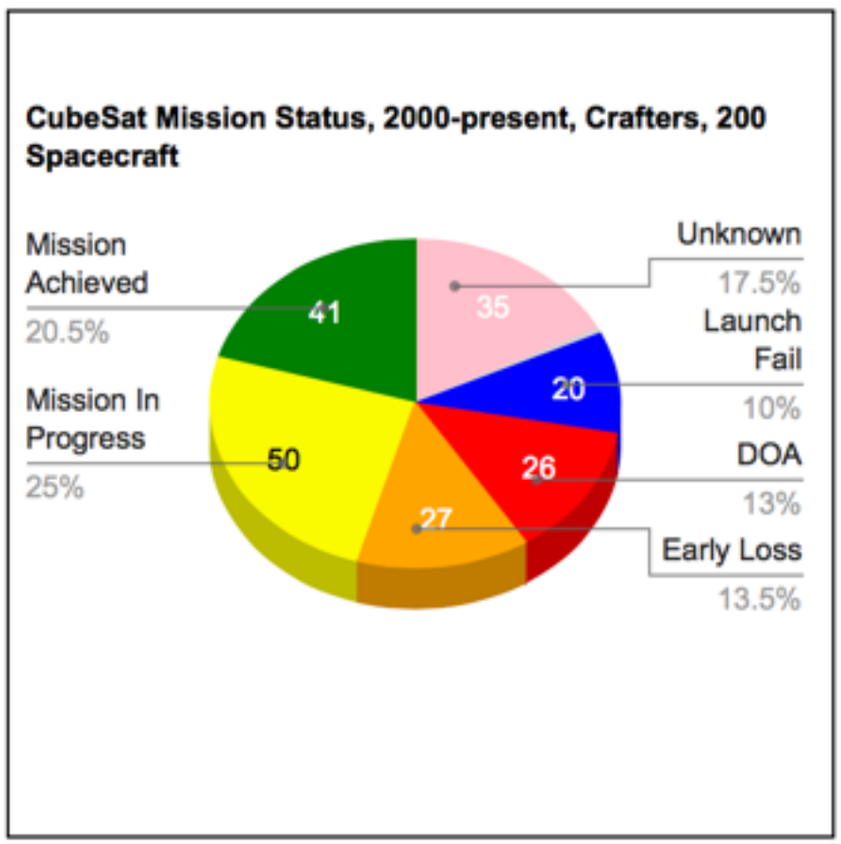


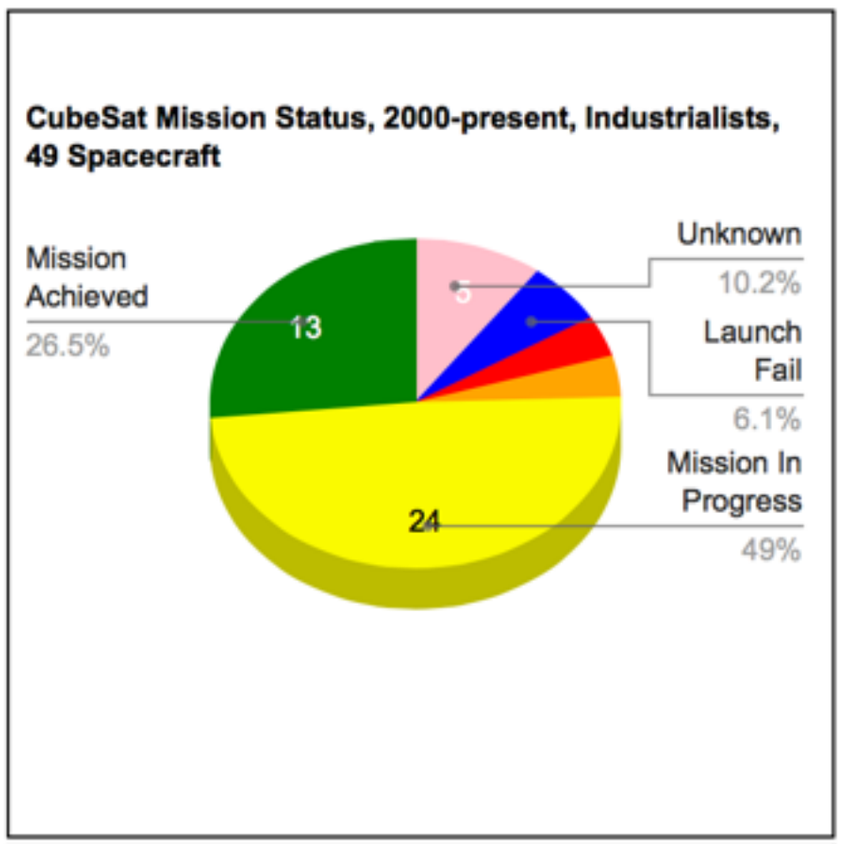
Space 4.0


CubeSats by Mission Type (2000-present,
Univ.
Mil.
Civil Gov't
Commercial
100
75
50
25
0
2000
2005
2010
2015
[Chart created on Wed Nov 14 2018 using data from M. Swartwout]

Space 4.0







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Mission concept

Disruptive technologies: cheap, underperforming, but producing high impact. Distributed instrument, tens/hundreds of simple units

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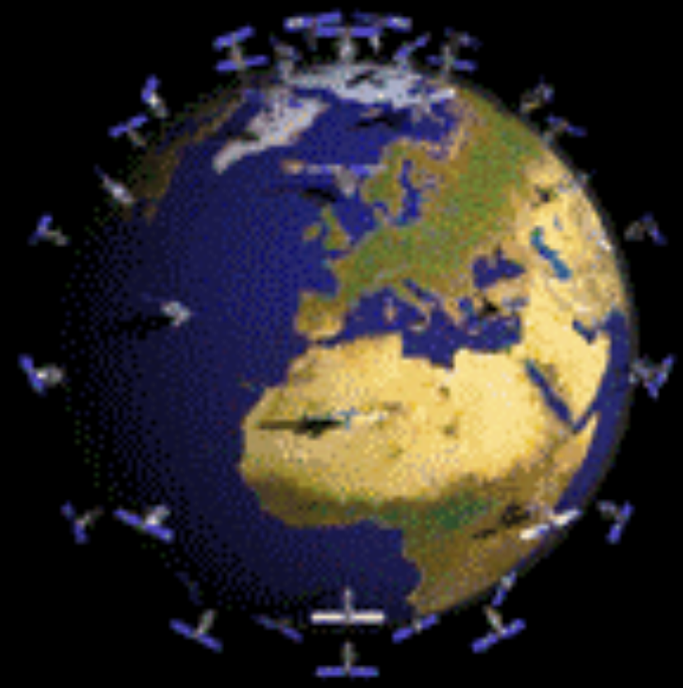
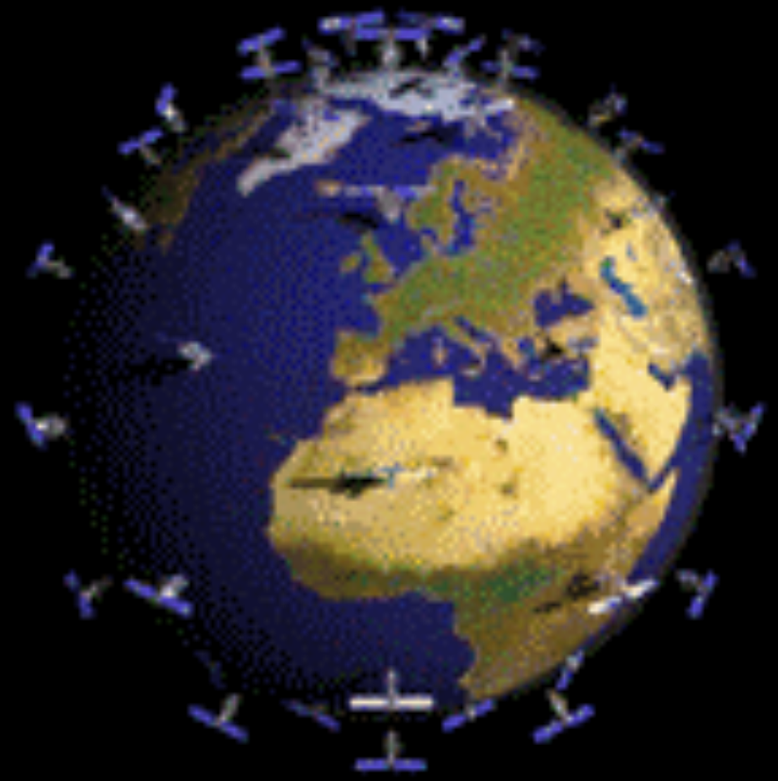
HERMES constellation of cubesat

2016: ASI funds for detector R&D
2018: MIUR funds for pathfinder (Progetti premiali 2015)
2018 H2020 Space-SCI-20 project

2018 ASI internal proposal



Why HERMES now



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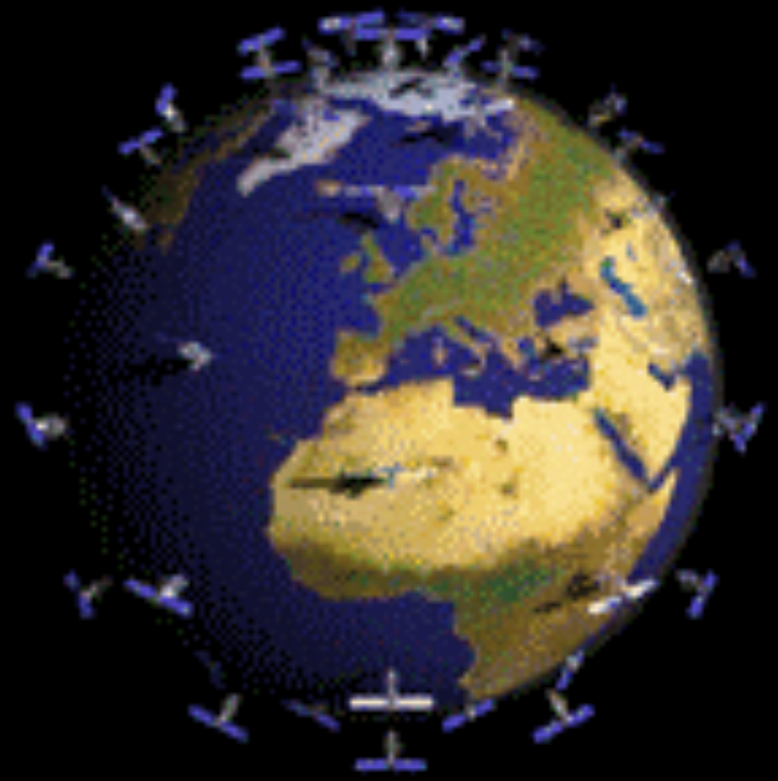

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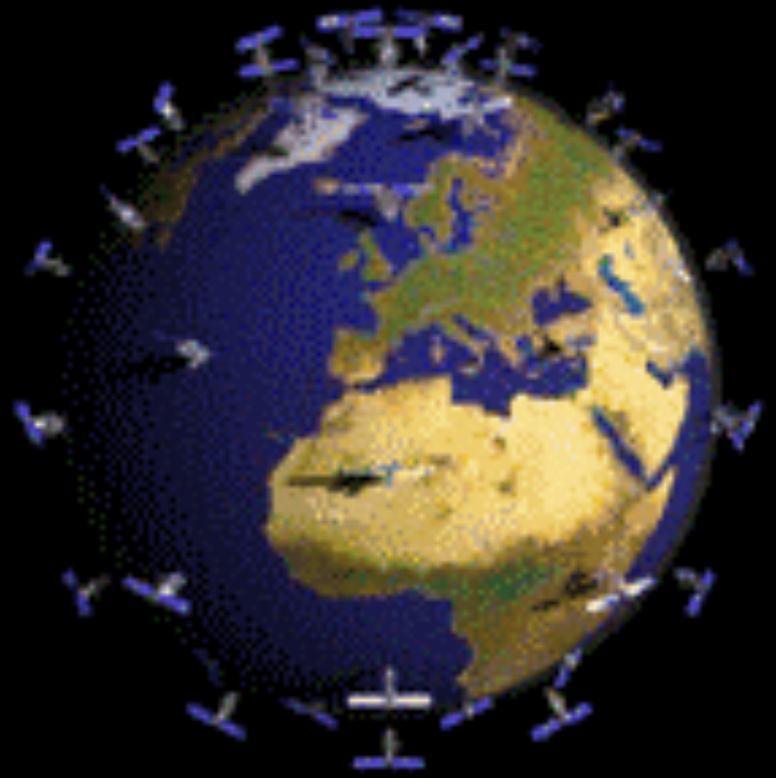
Breakthrough scientific case:

- EM of GWE



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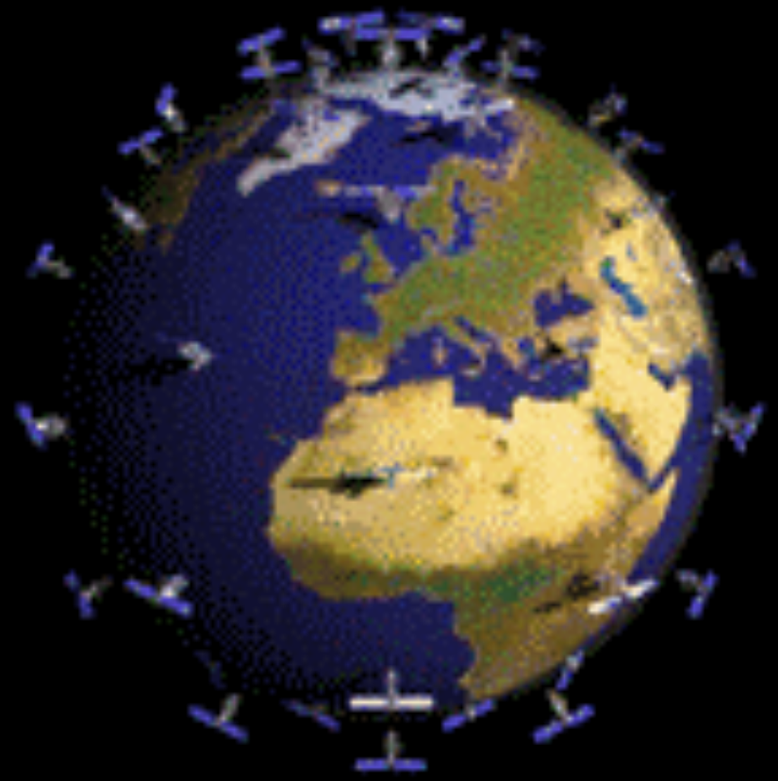
Modularity:

- Avoid single point failures, improve hardware
- Pathfinder



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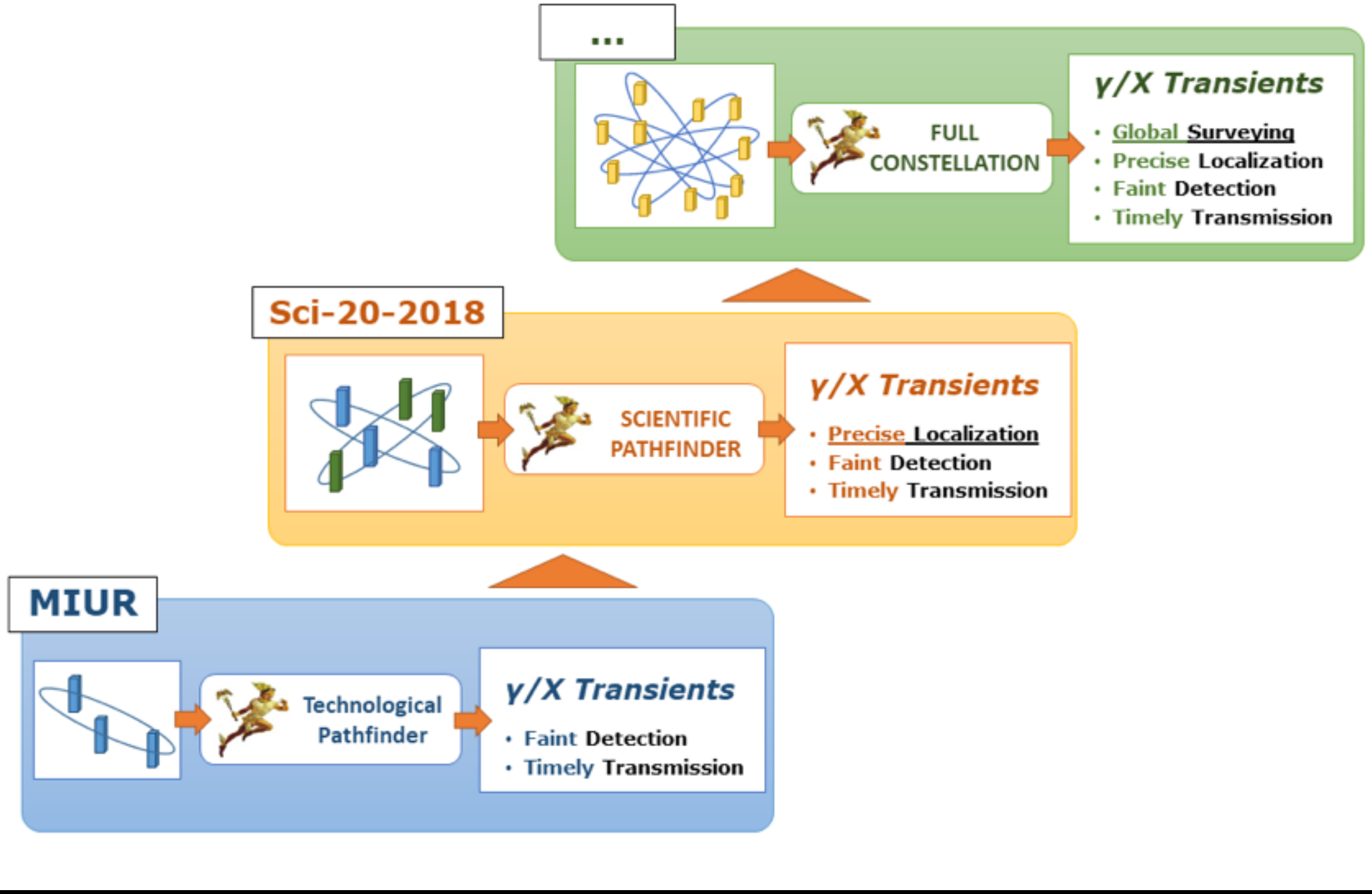

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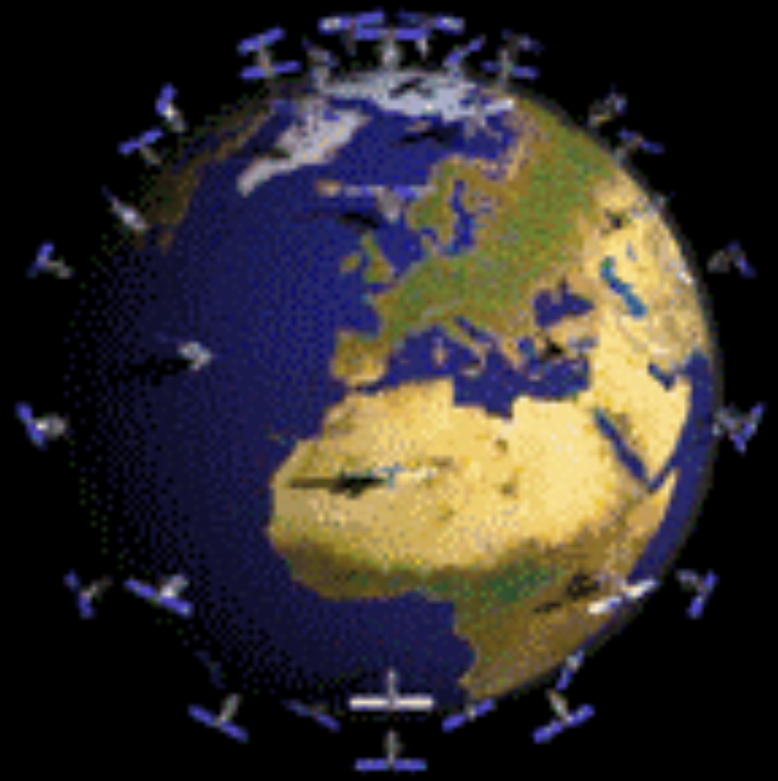

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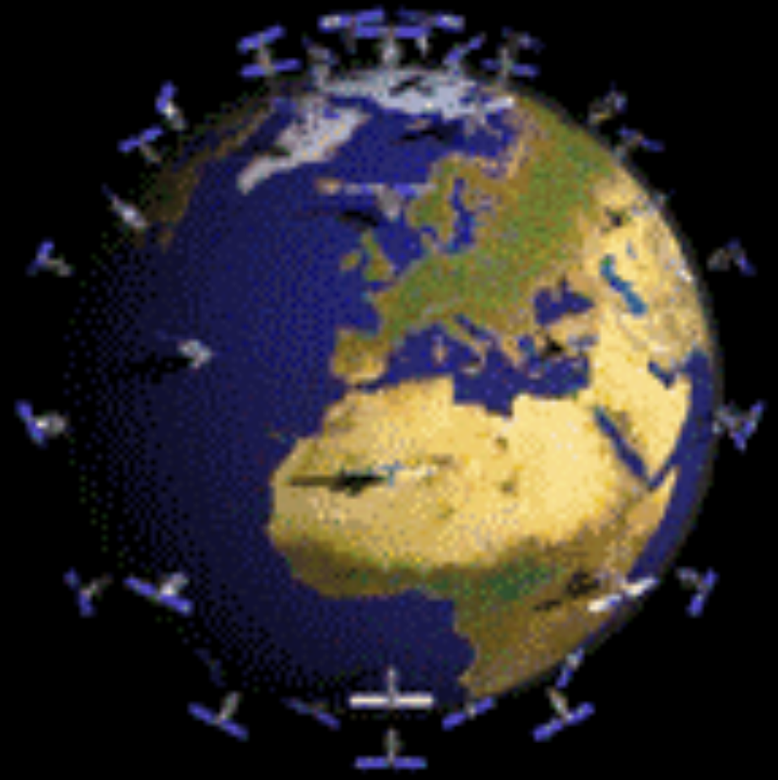
Open μsec - msec window:

- Accurate positions
- QG tests



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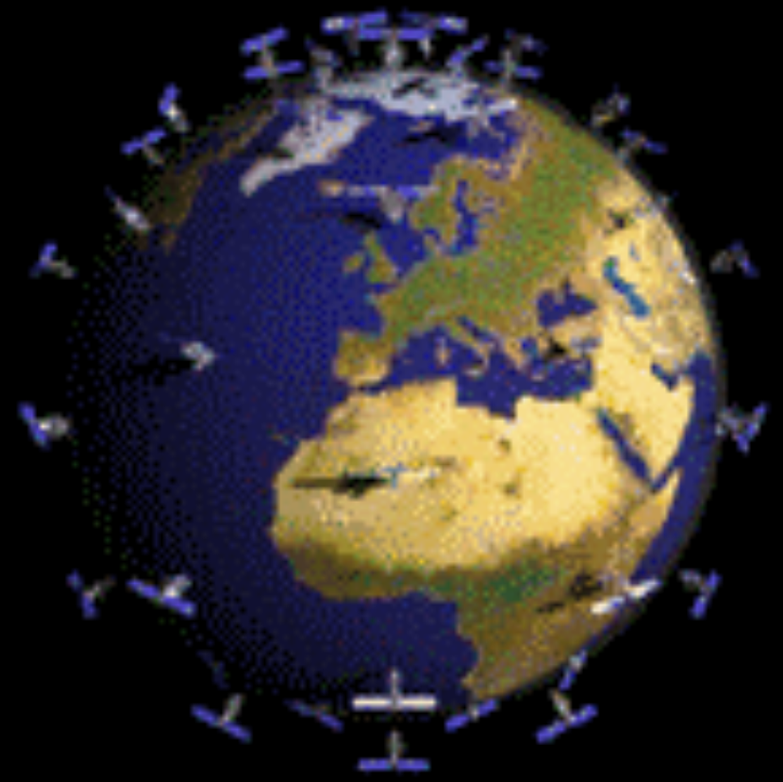

Limited cost and quick development

- COTS + in-house components
- Trend in cost reduction of manufacturing and launching QS

HERMES-SP goals

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1. ***join the multimessenger revolution*** by providing a first mini-constellation for GRB localizations

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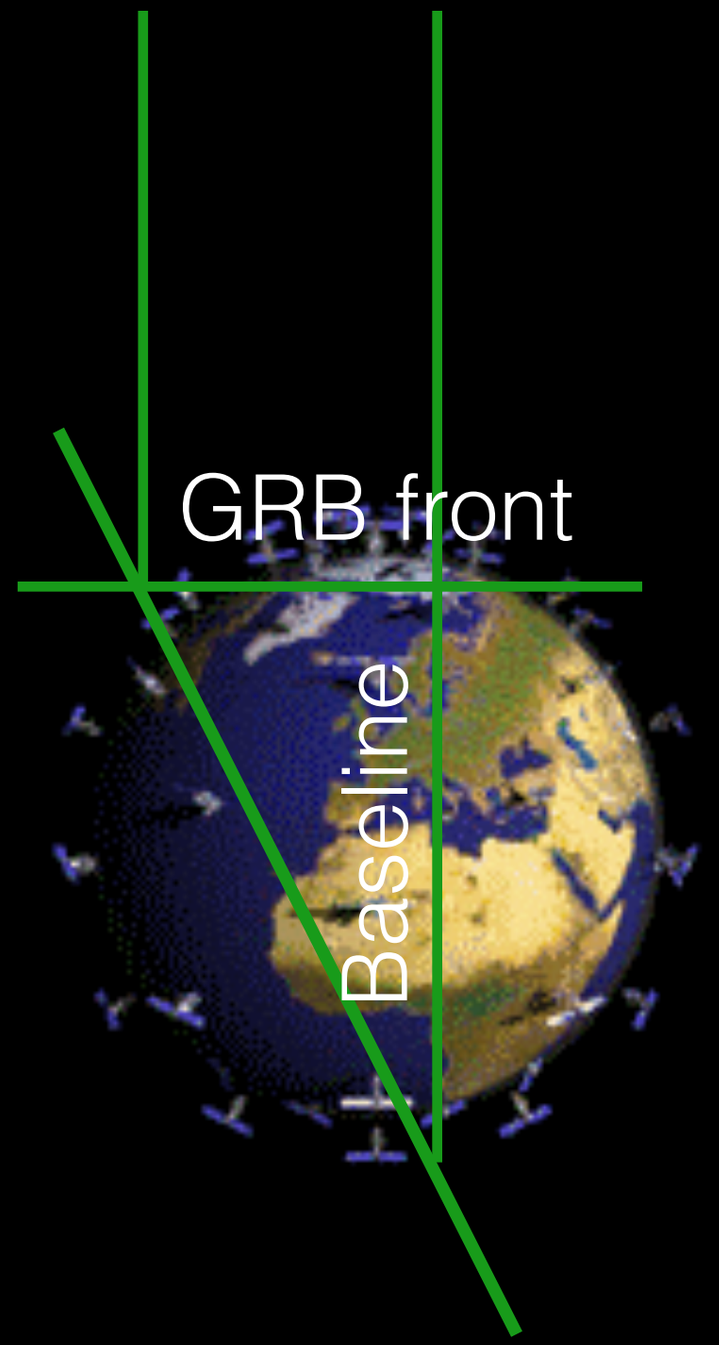
HERMES-SP goals

1. ***join the multimessenger revolution*** by providing a first mini-constellation for GRB localizations
2. develop ***miniaturized payload technology*** for breakthrough science
3. demonstrate COTS applicability to challenging missions, ***contribute to Space 4.0 goals***
4. push and prepare for a high reliability, large constellations

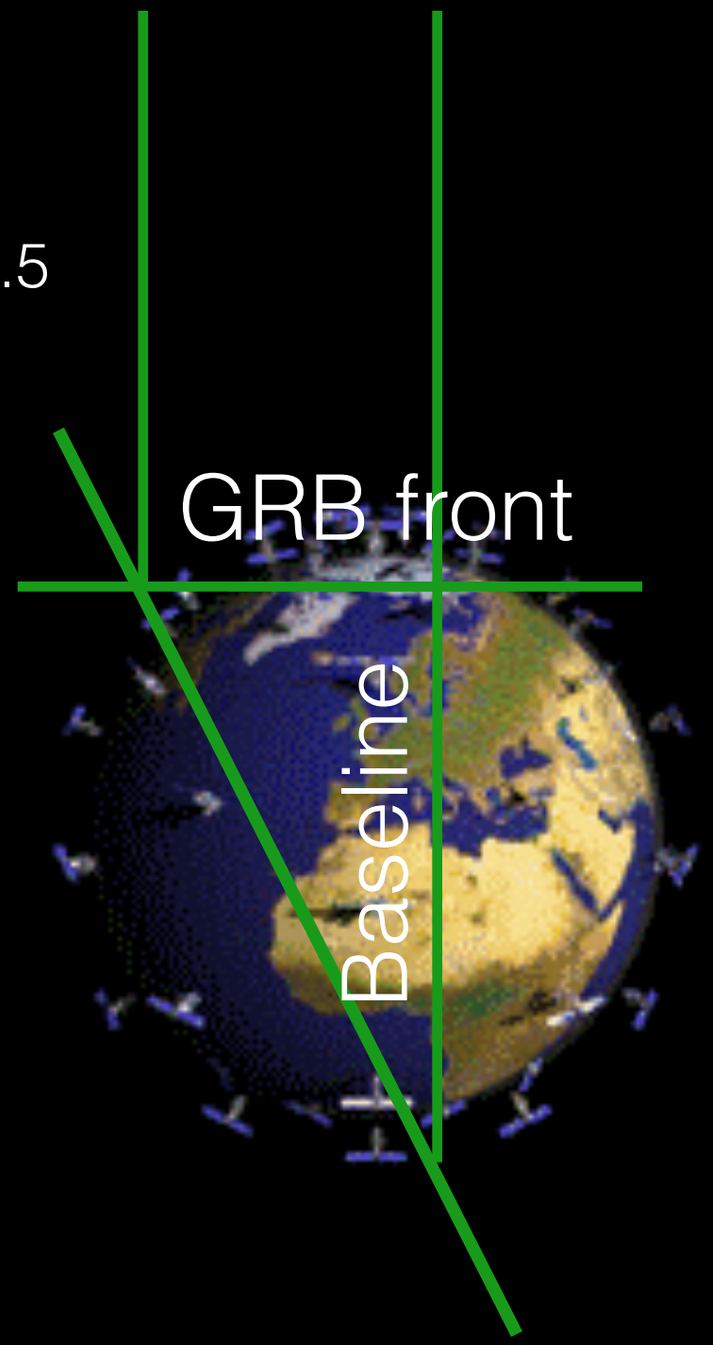
Experiment concept



Experiment concept

1. Measure GRB positions through delays between photons arrival times:

$$\sigma_{Pos} = (\sigma^2_{CCF+}\sigma_{sys}^2)^{0.5} \times c / \langle B \rangle / (N - 1 - 2)^{0.5}$$



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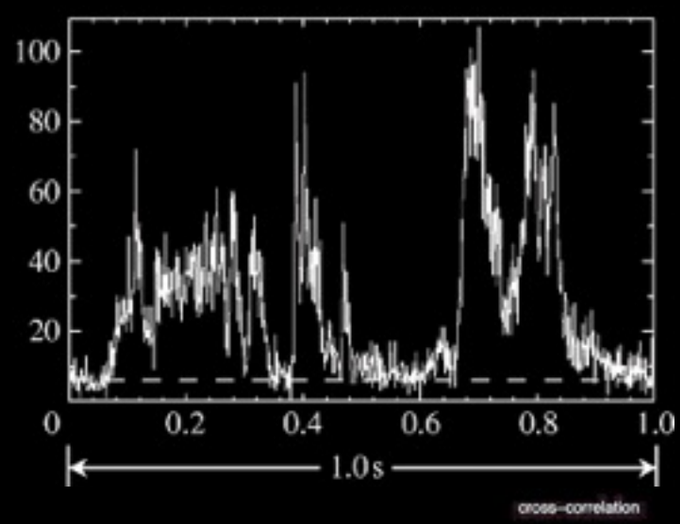

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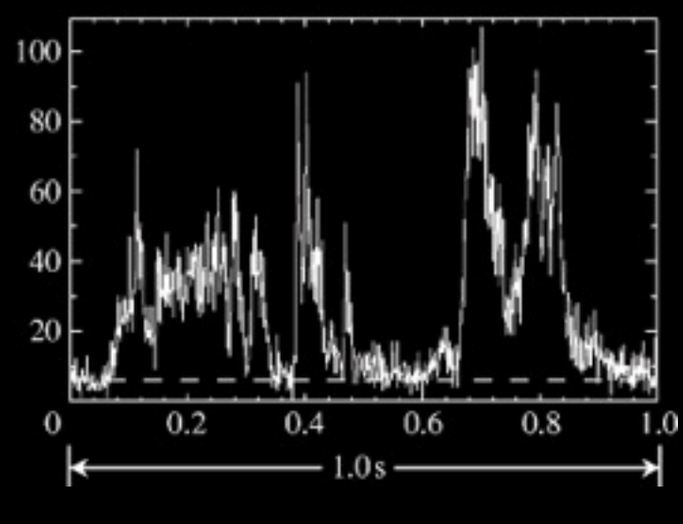

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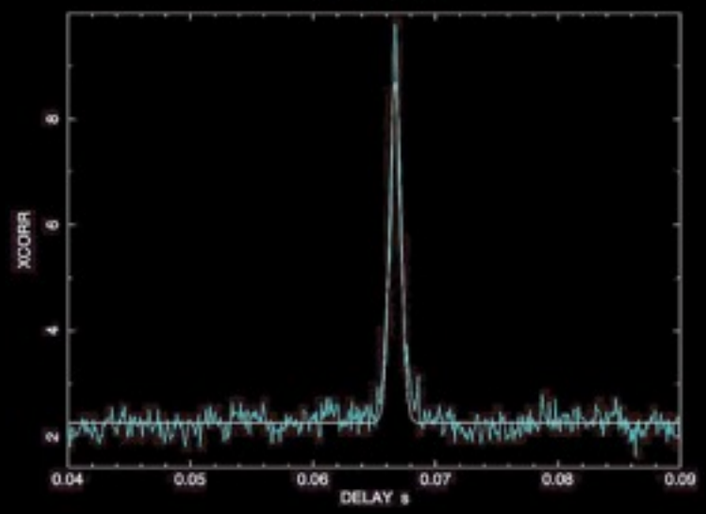
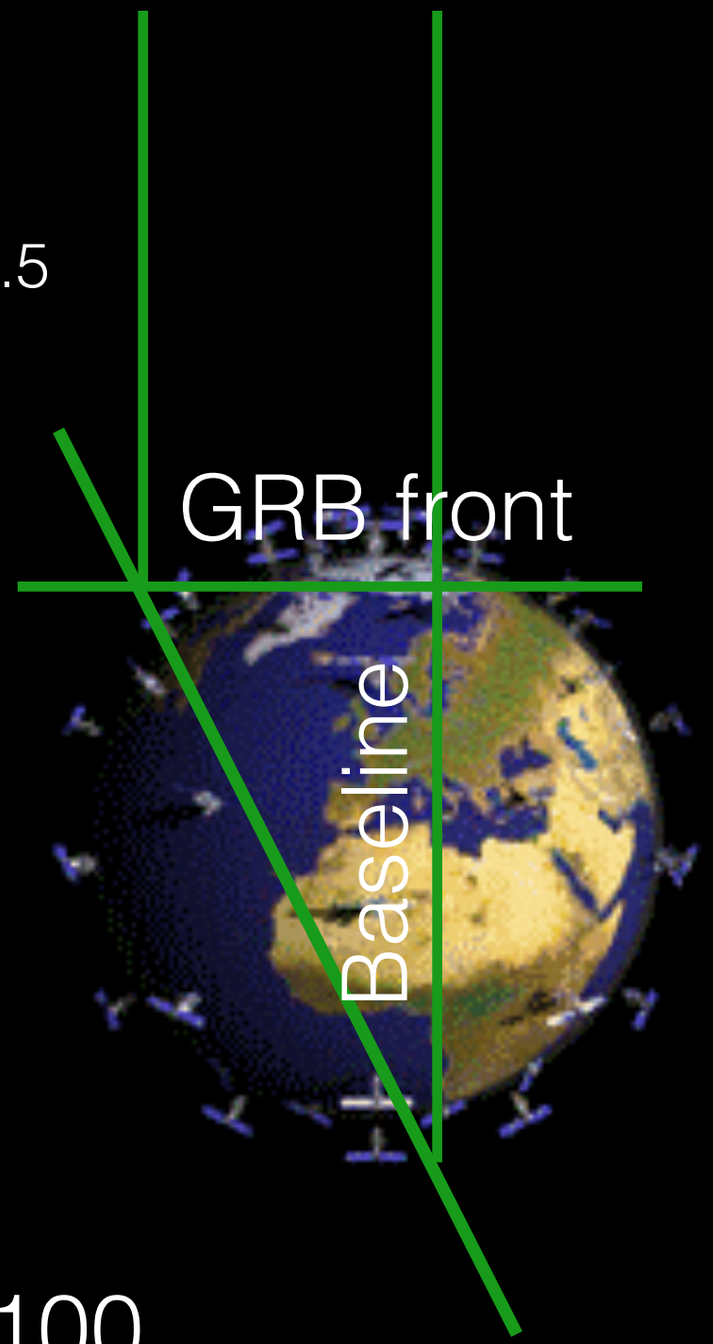


$\sigma_{CCF} \sim 10\mu s$

$\sigma_{Pos} \sim 10arcsec$

if $\langle B \rangle \sim 7000km$, $N \sim 100$



>2020 GRB all sky monitor

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GRB targets for CTA

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Fast repositioning (tens of secons)
FOV ~ 4.5° at tens of GeV
~1000 deg^2 in divergent pointing mode

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Jet Lorenz factor

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Synchrotron vs. Inverse Compton radiation

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Synchrotron vs. Inverse Compton radiation

B field strength and configuration

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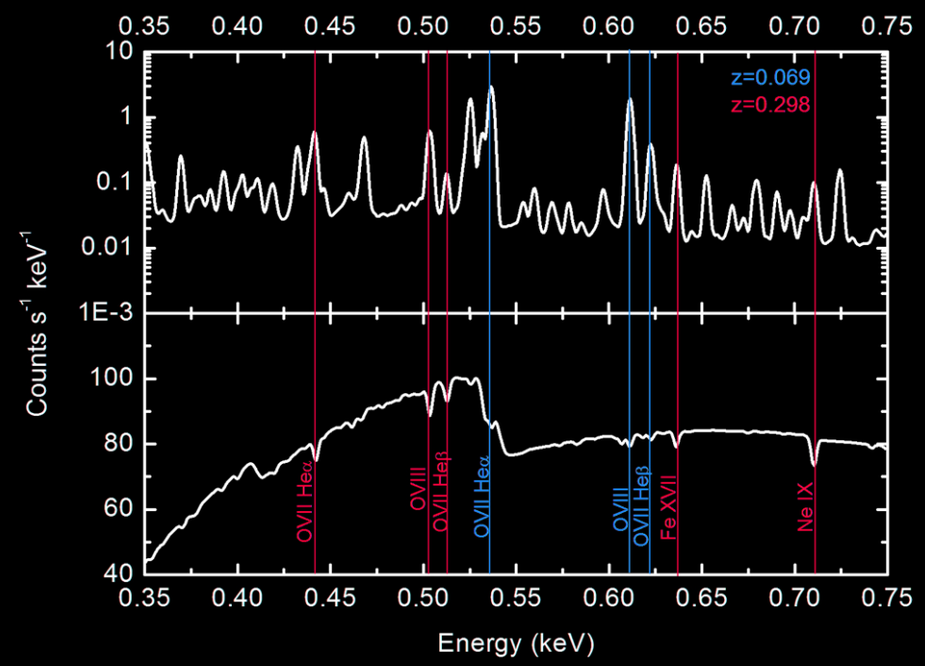
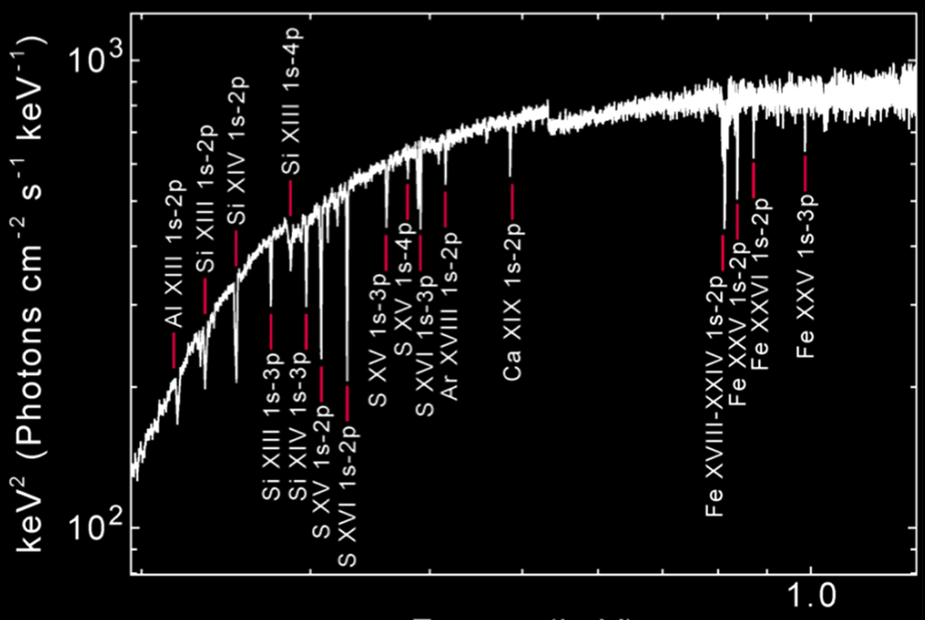
Synchrotron vs. Inverse Compton radiation

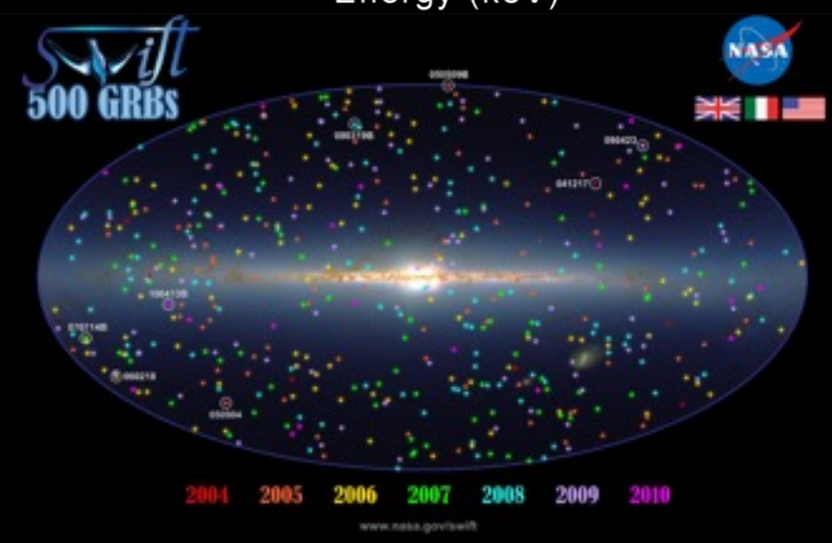
B field strength and configuration

UHECR

>2030 GRB all sky monitor

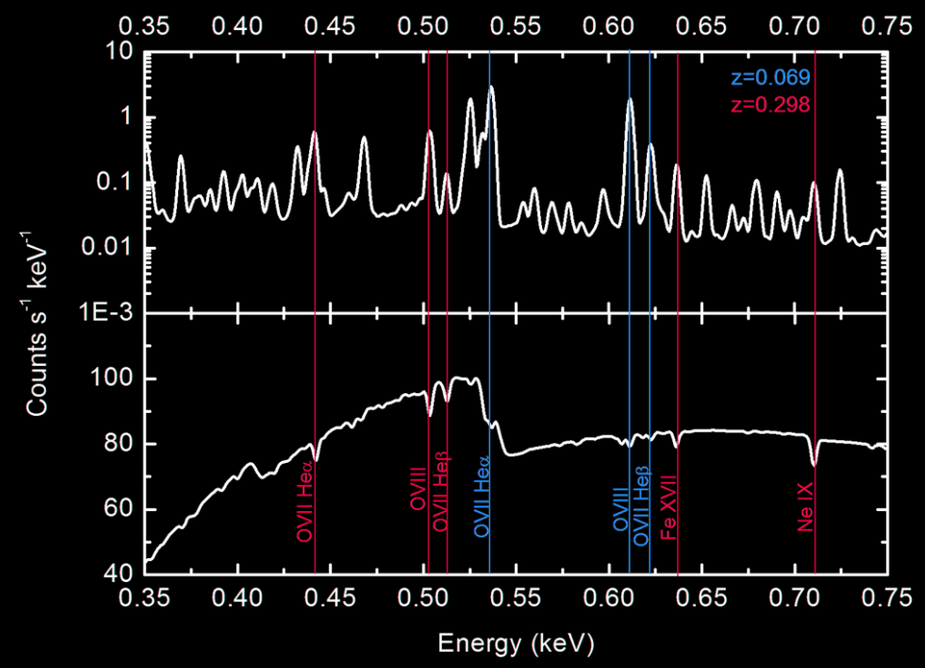


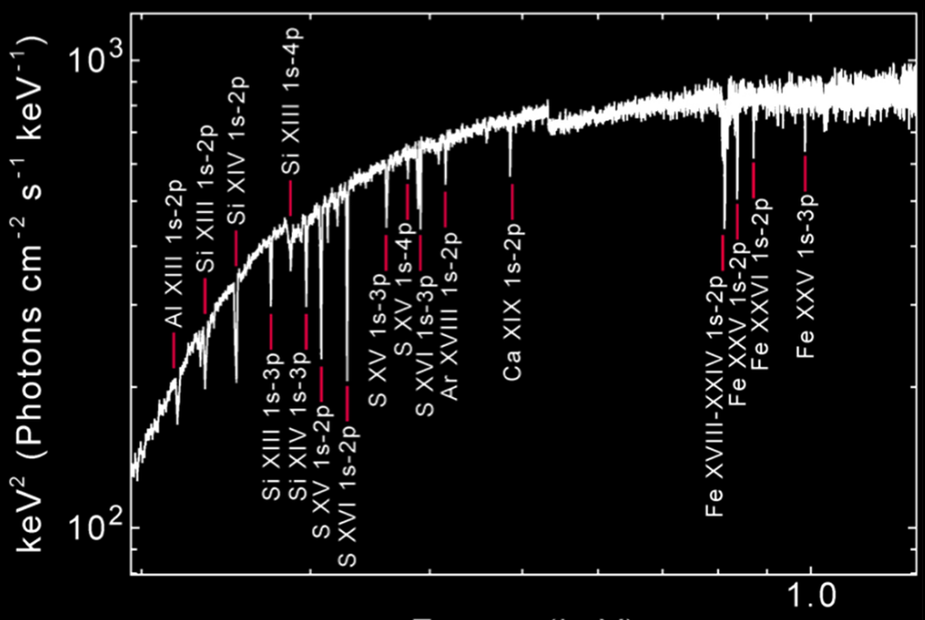


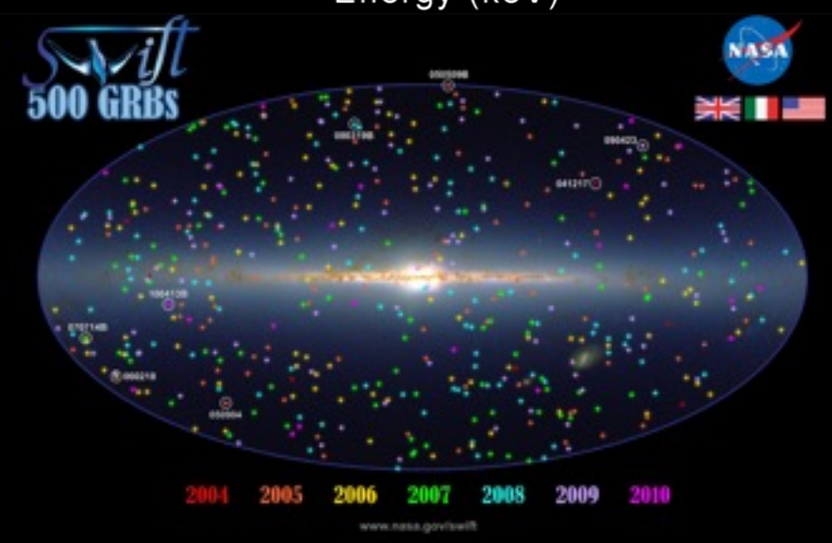


>2030 GRB all sky monitor

GRB targets for Athena







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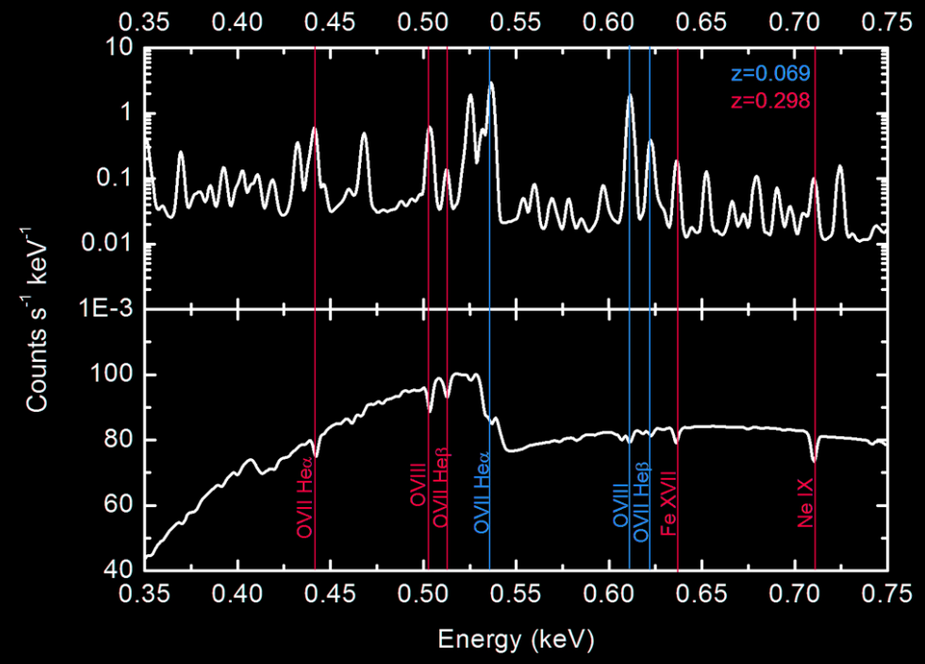
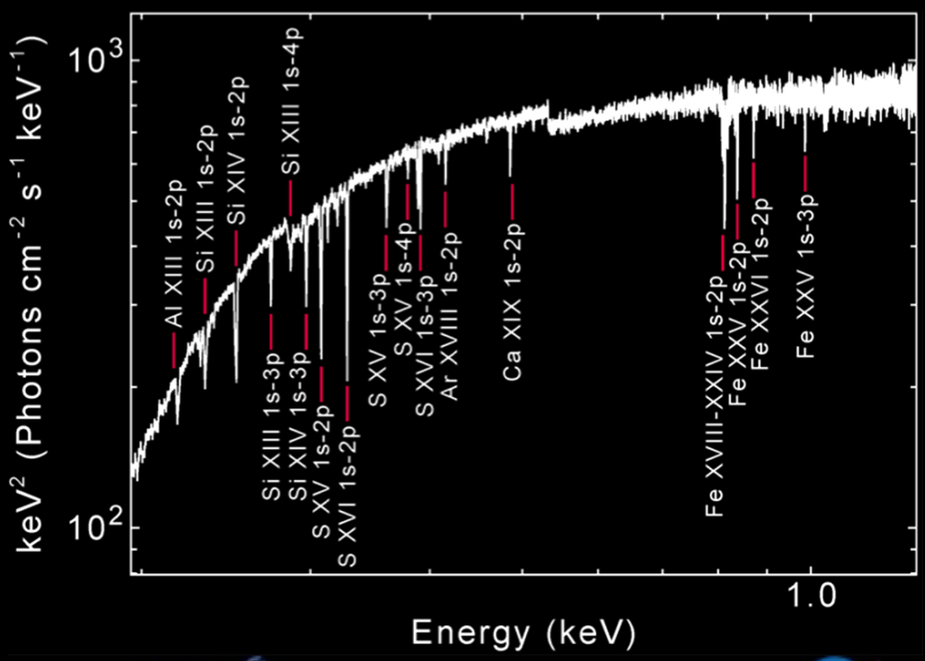
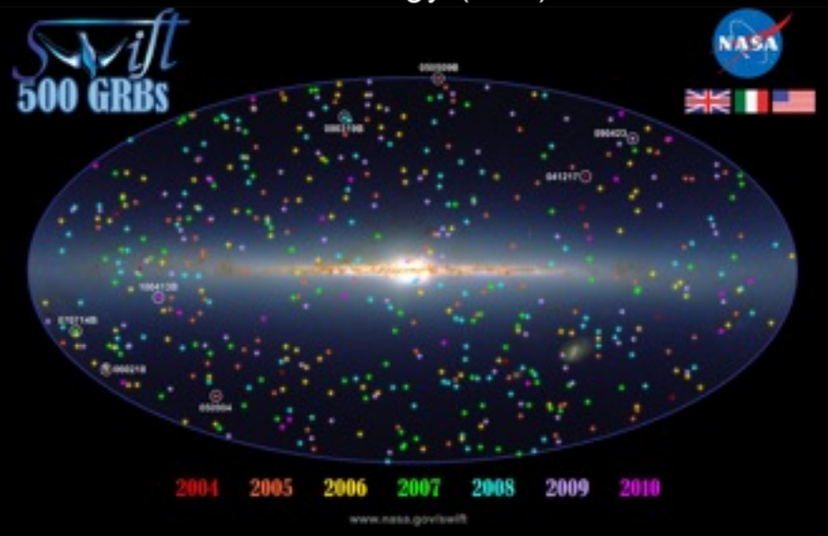
GRB targets for Athena

Where are the missing baryons in the local Universe? Warm IGM? Bright GRB to X-raying IGM







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GRB targets for Athena

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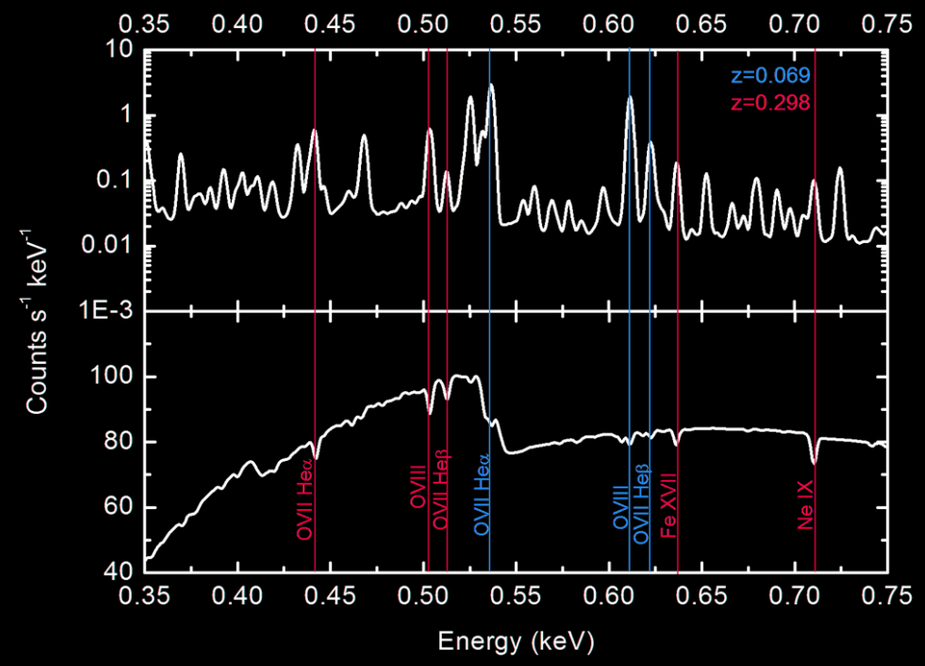
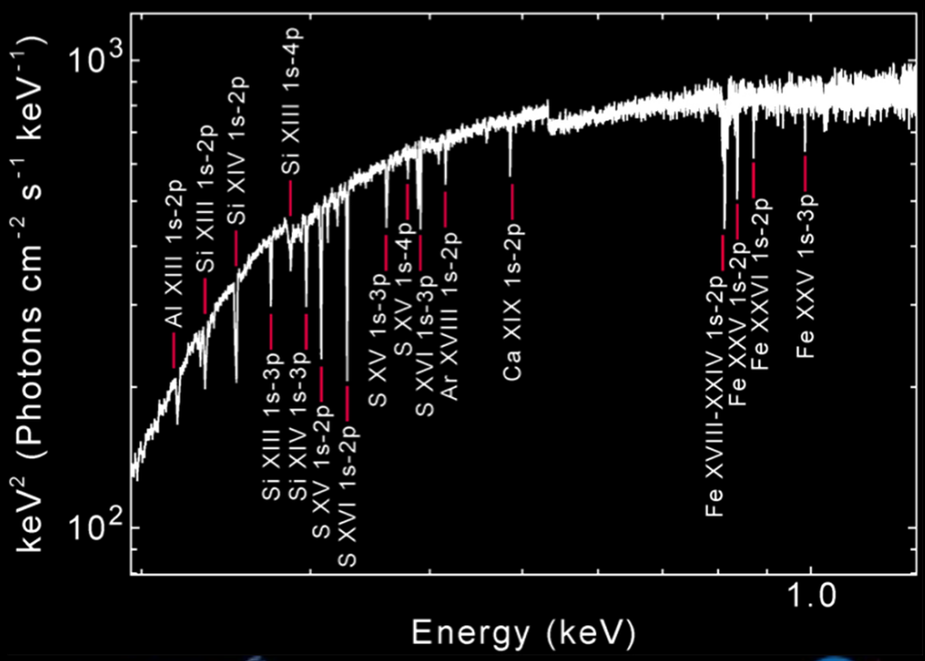
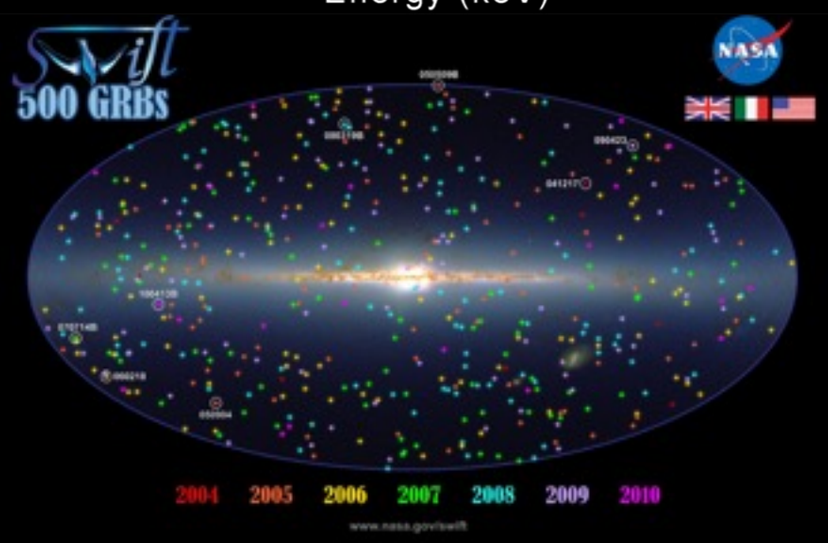
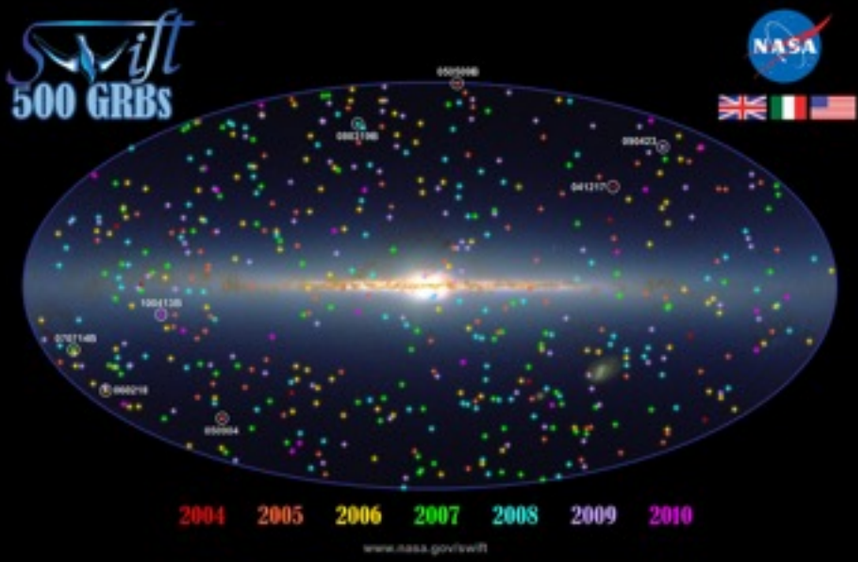
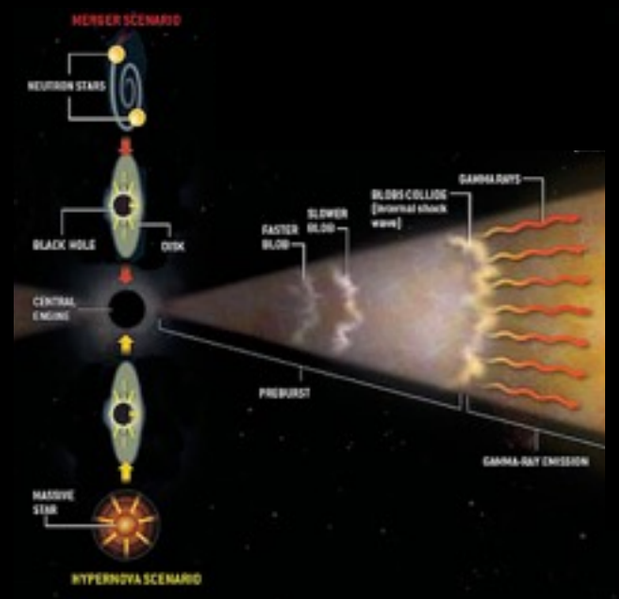
Can we probe the rirst PopIII stars?
High-z GRBs are the best tracer

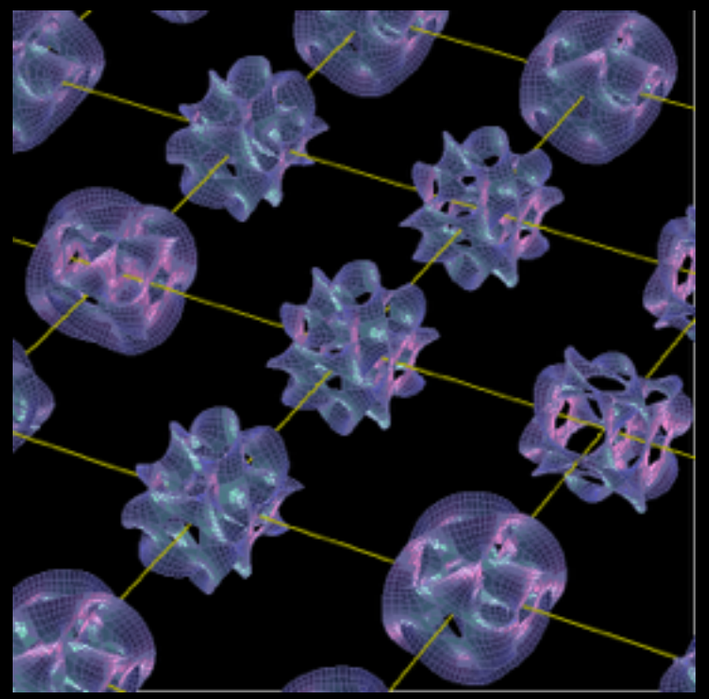


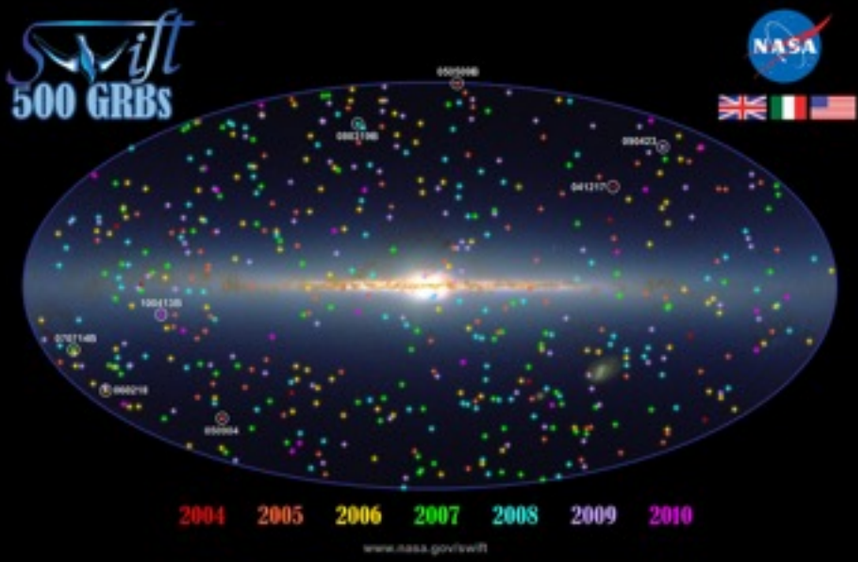


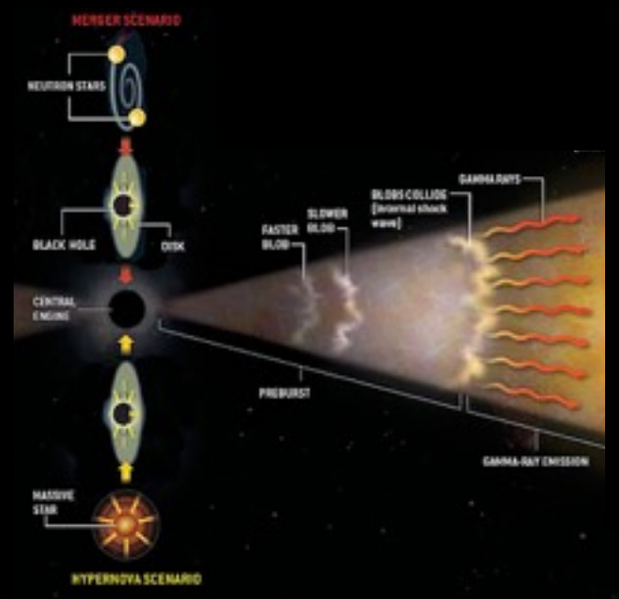


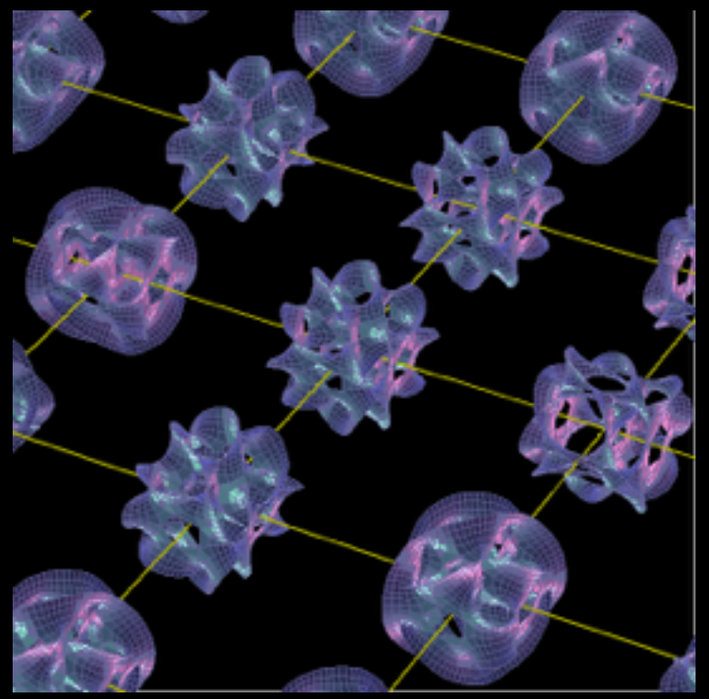

Swift
500 GRBs
2004
2005
2006
2007
2008
2009
2010
www.nasa.gov/swift


MERGER SCENARIO
NEUTRON STARS
BLACK HOLE
DISK
CENTRAL ENGINE
MASSIVE STAR
HYPERNOVA SCENARIO
FASTER BLOB
SLOWER BLOB
BLOBS COLLIDE (internal shock wave)
GAMMA RAYS
PREBURST
GAMMA-RAY EMISSION

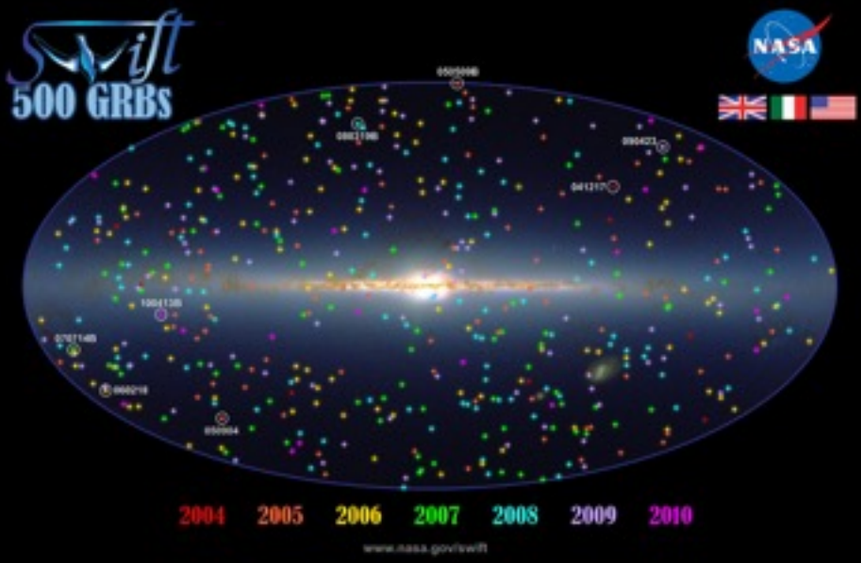


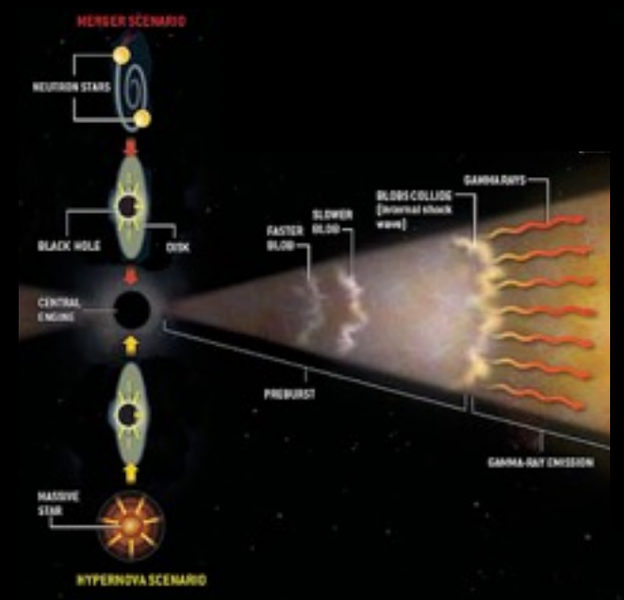

Swift
500 GRBs
2004
2005
2006
2007
2008
2009
2010
www.nasa.gov/swift

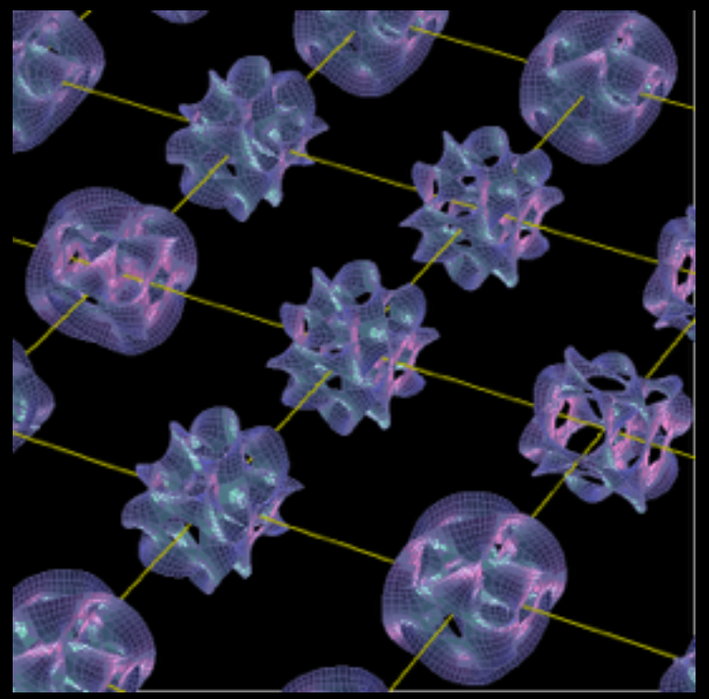

MERGER SCENARIO
NEUTRON STARS
BLACK HOLE
DISK
CENTRAL ENGINE
MASSIVE STAR
HYPERNOVA SCENARIO
FASTER BLOB
SLOWER BLOB
BLOBS COLLIDE (internal shock wave)
GAMMA RAYS
PREBURST
GAMMA-RAY EMISSION



How to *promptly* localise a GRB *prompt* event?

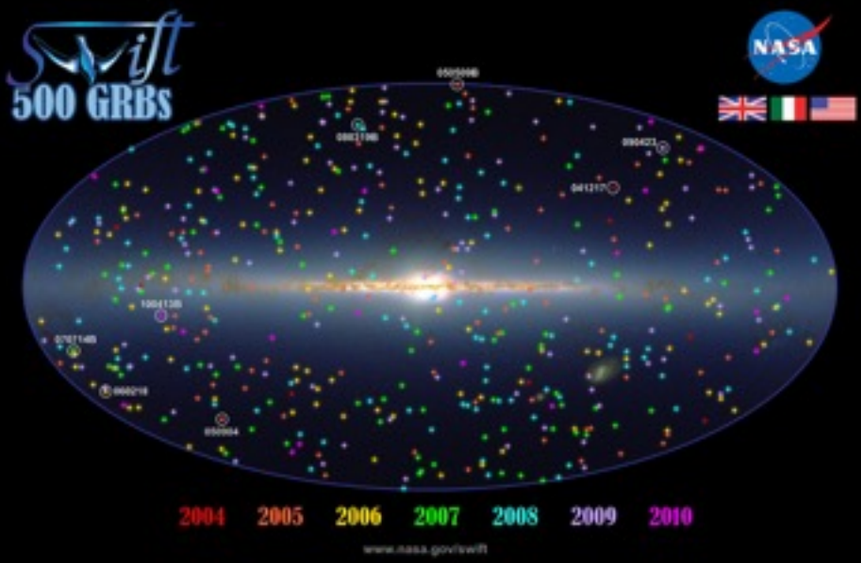


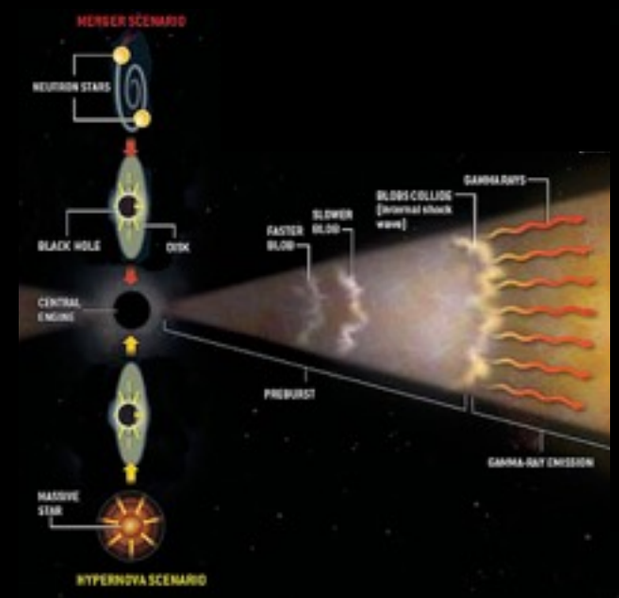


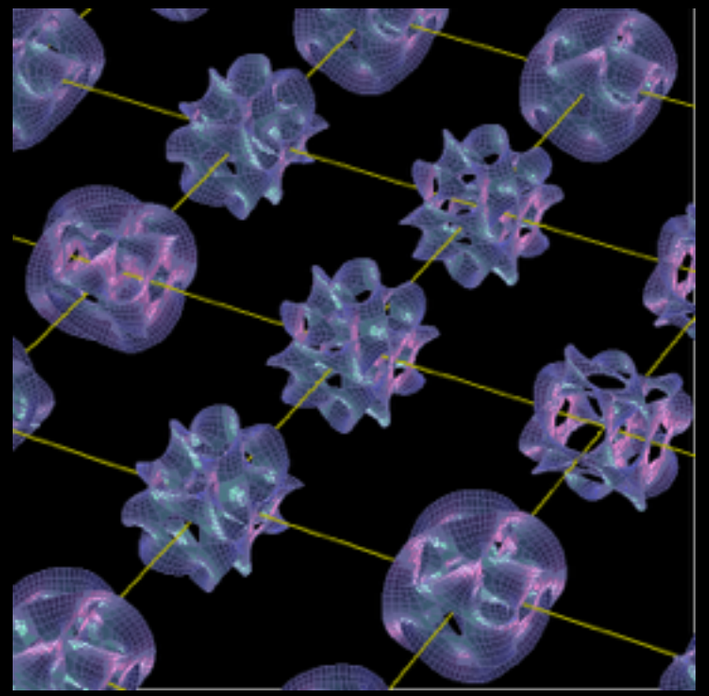


How to *promptly* localise a GRB *prompt* event?

How to construct a GRB engine?



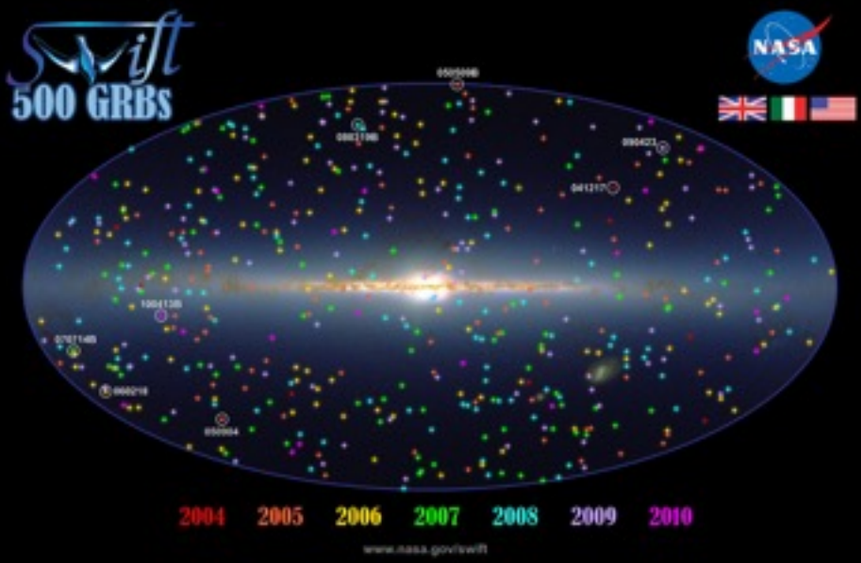


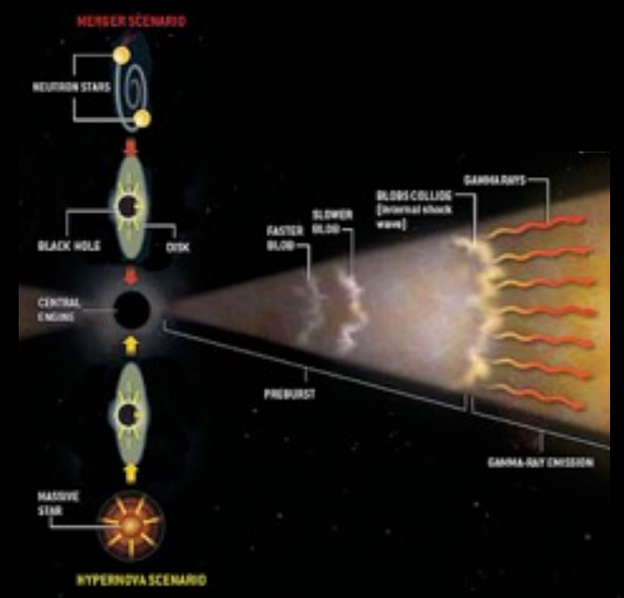


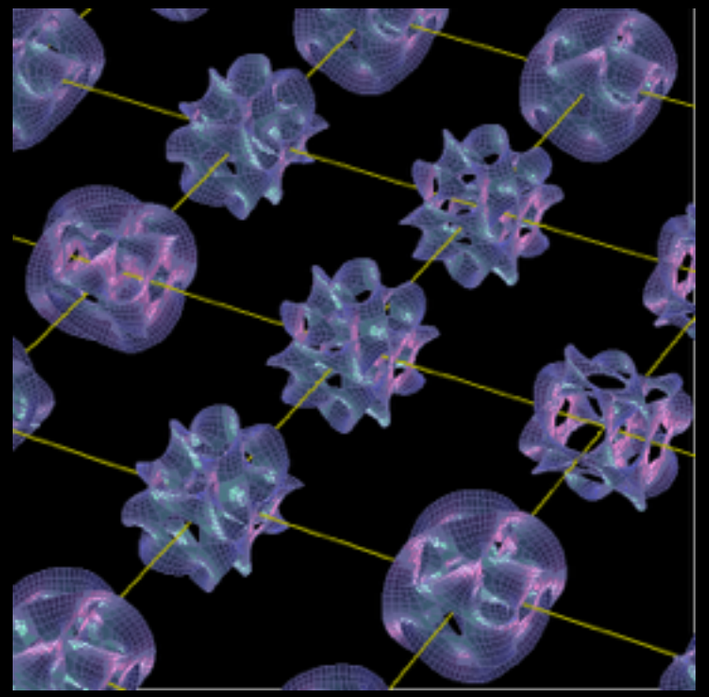
How to *promptly* localise a GRB *prompt* event?

How to construct a GRB engine?

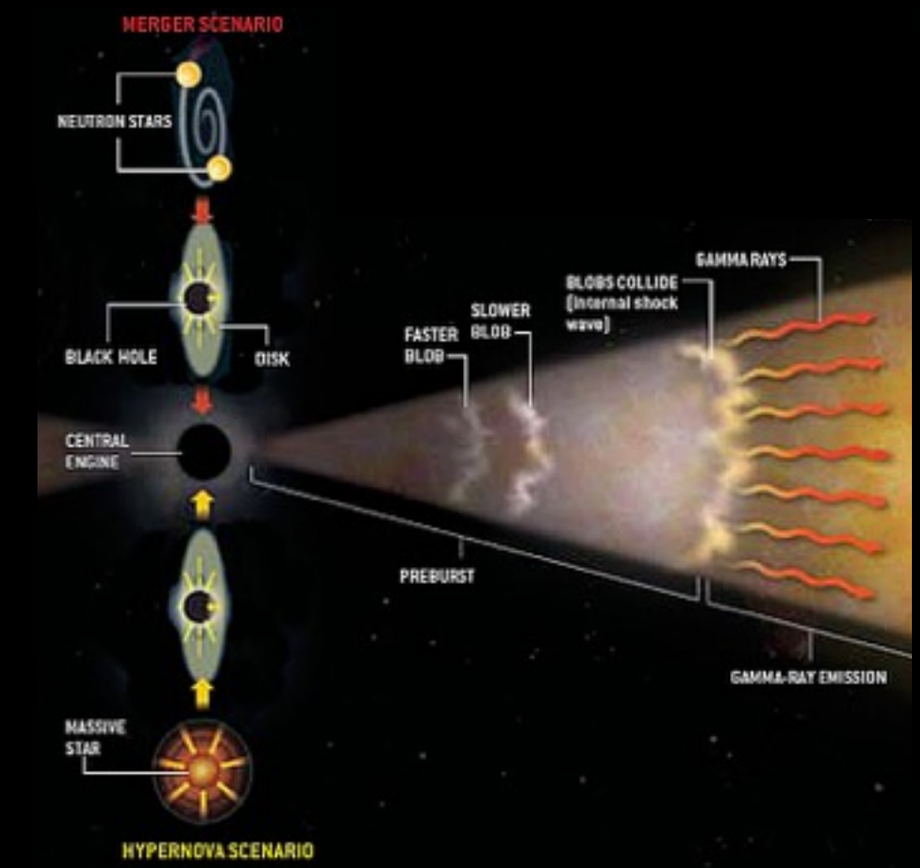
Which is the ultimate granular structure of space-time?

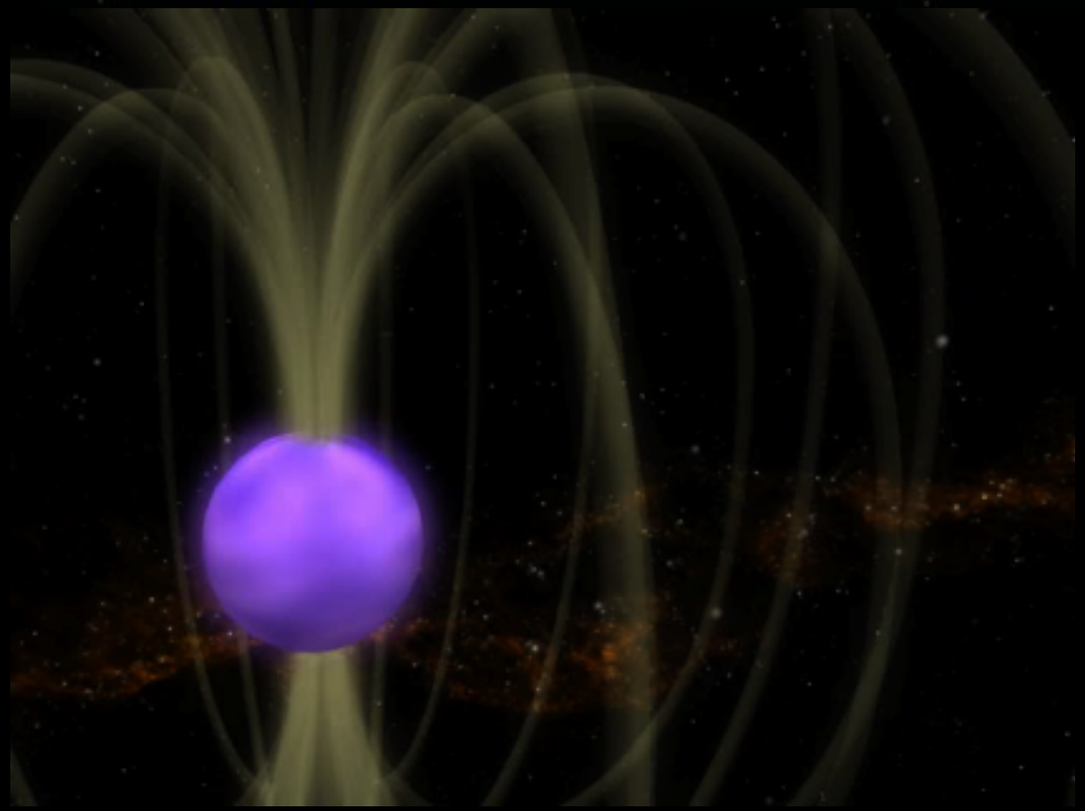






GRB inner engine





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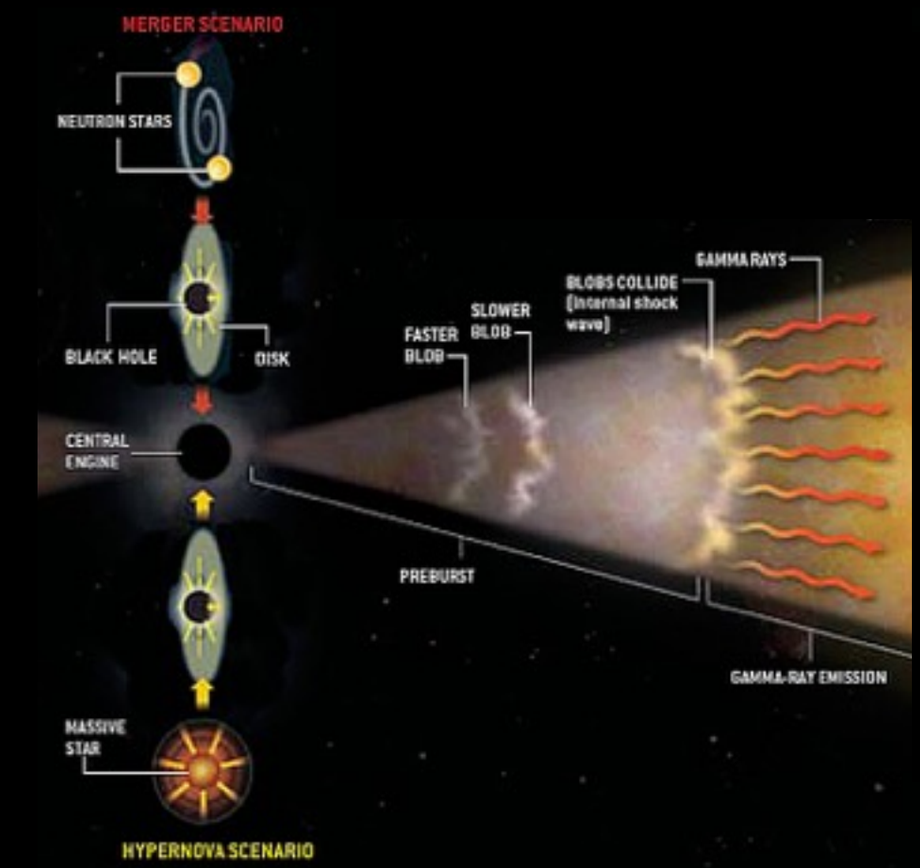
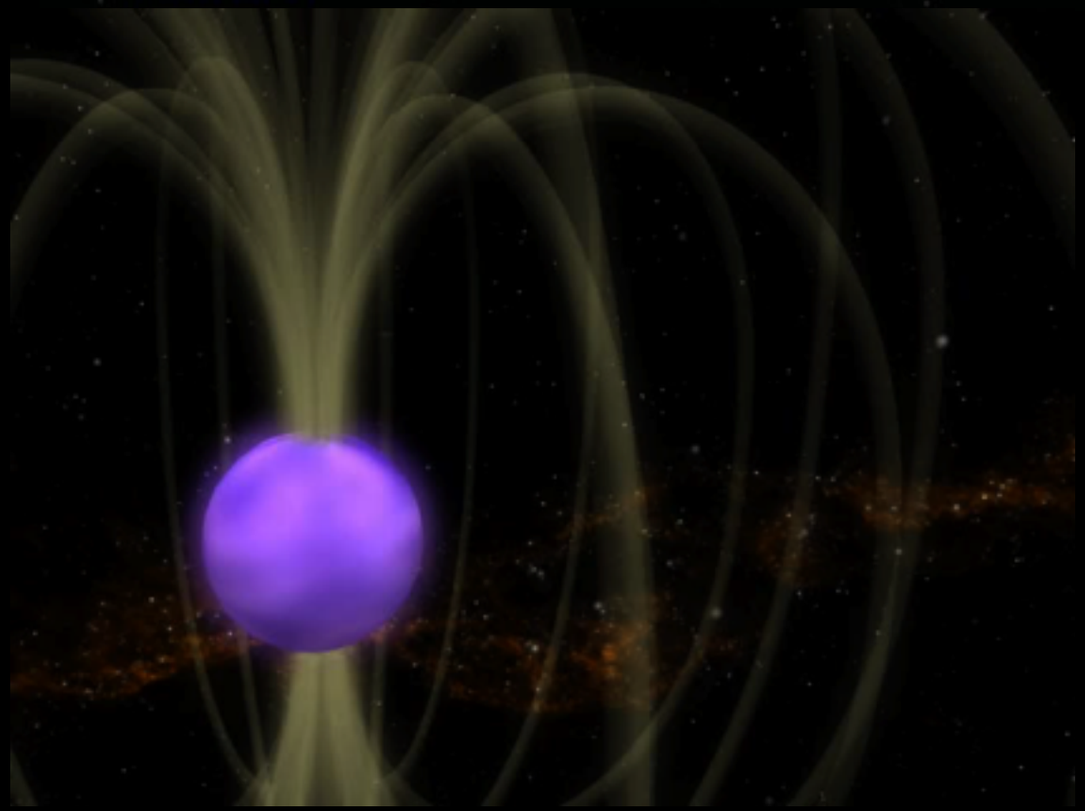
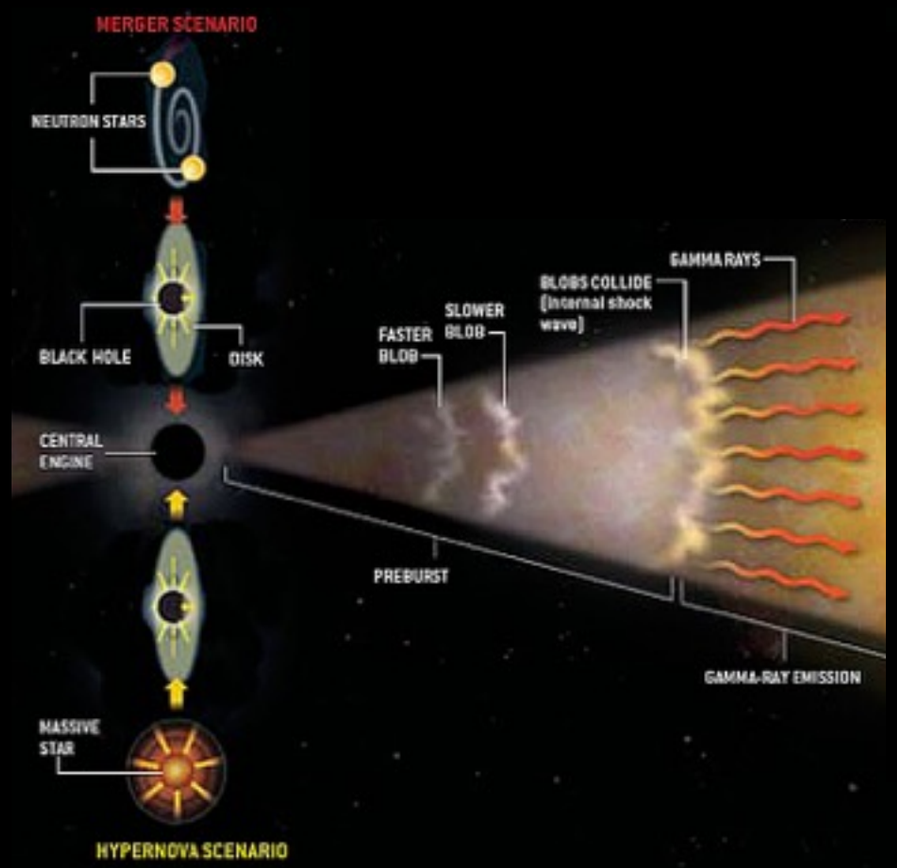
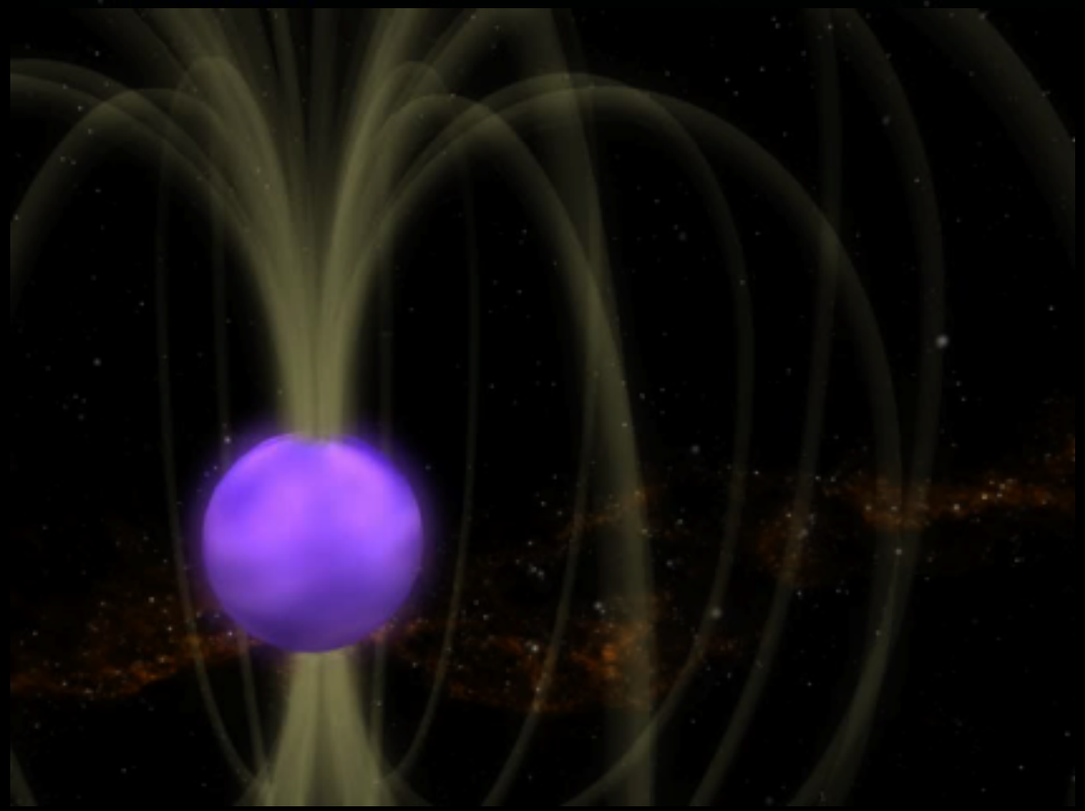




GRB inner engine

BH accretion, internal shocks





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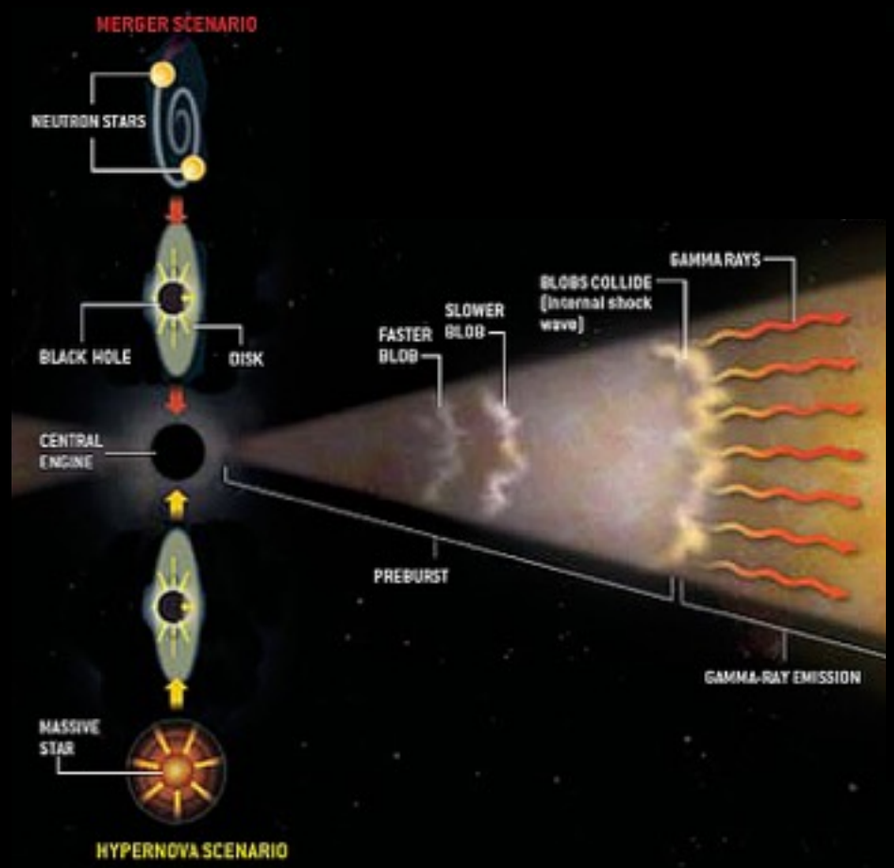
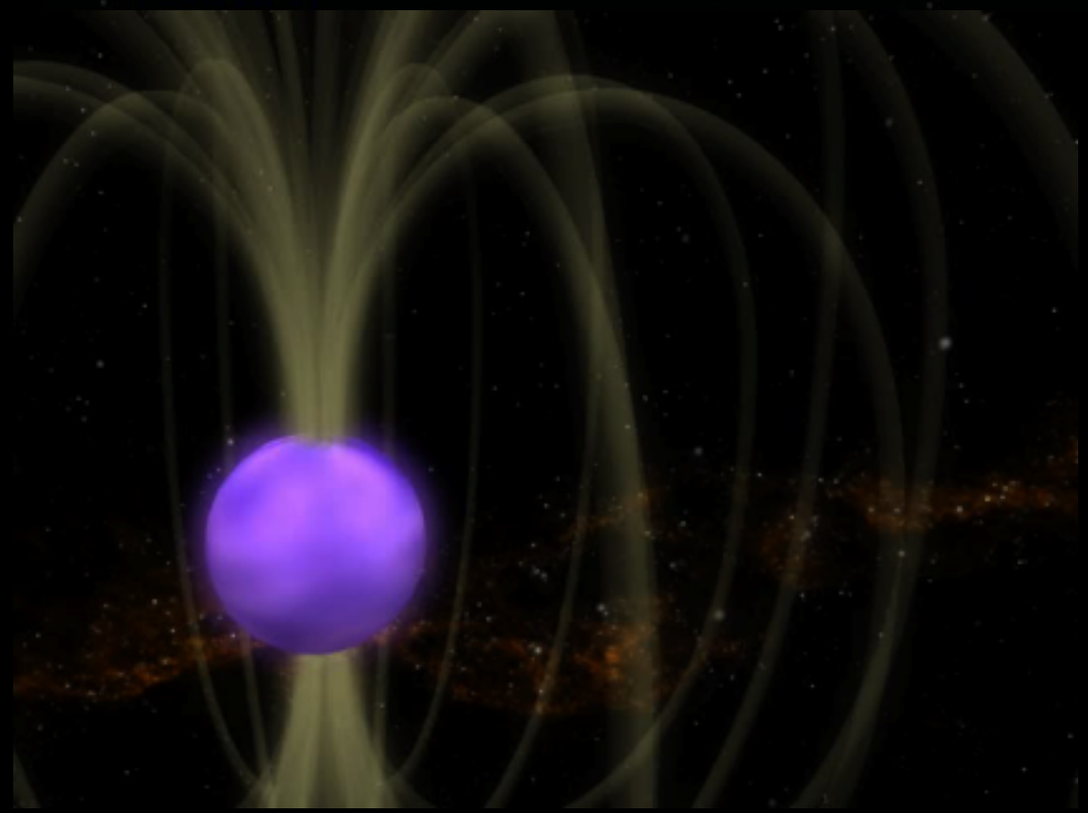


Magnetars



Experiment concept

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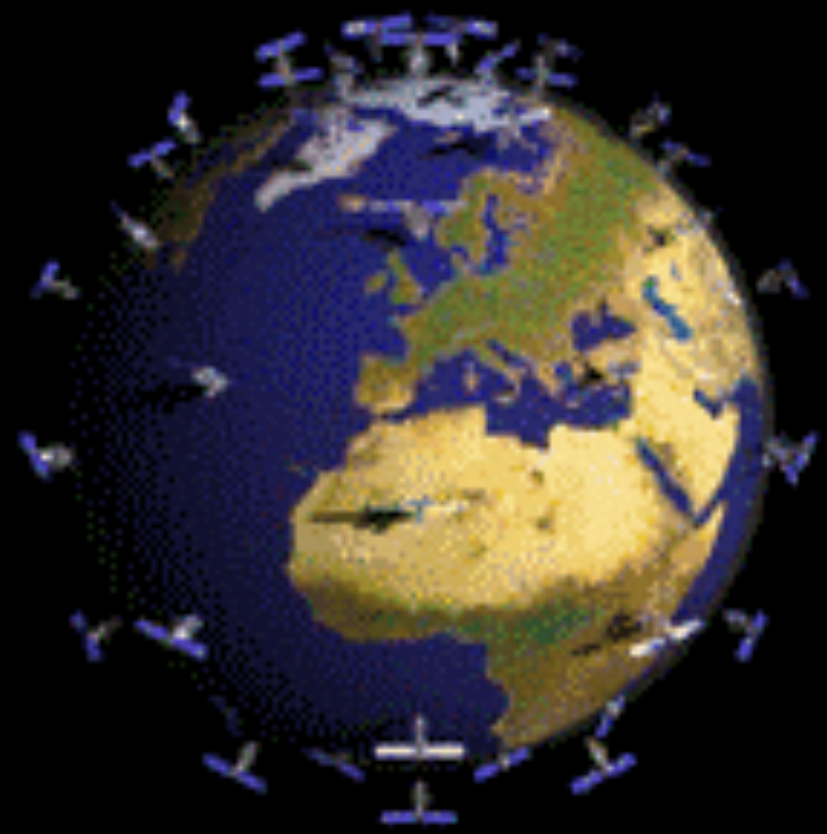
2. Add the signal from different units

Total collecting area 50-100-cm^2 x 100-200 = 0.5-2 m^2



Experiment concept

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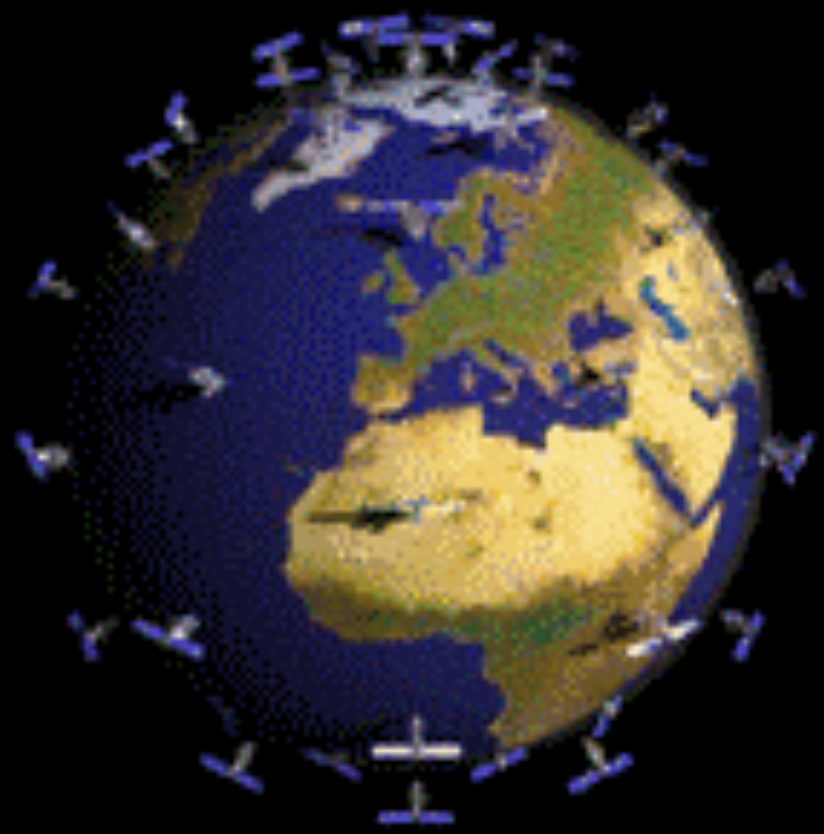
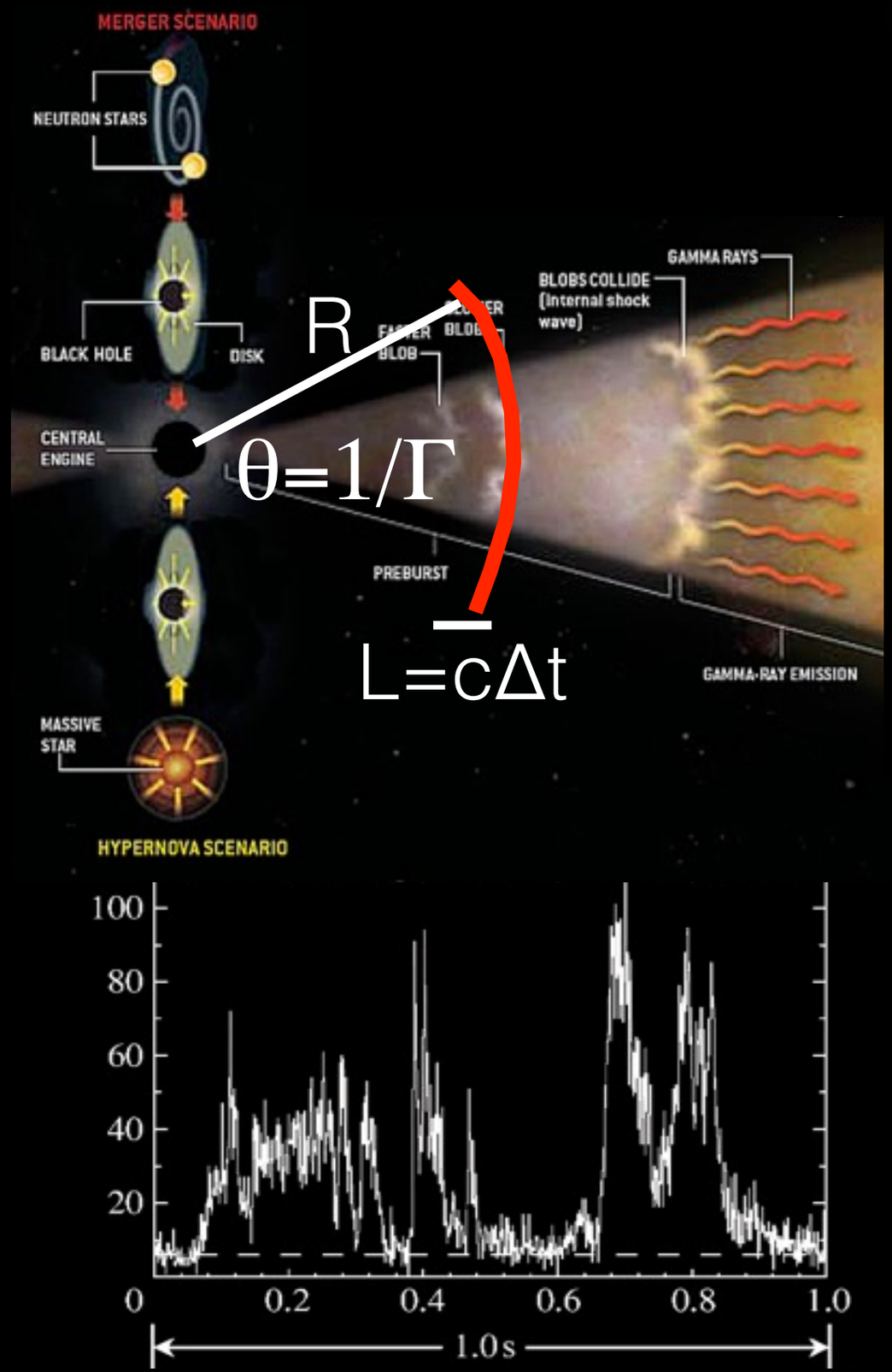
Transient fine (subμs-ms) temporal structure

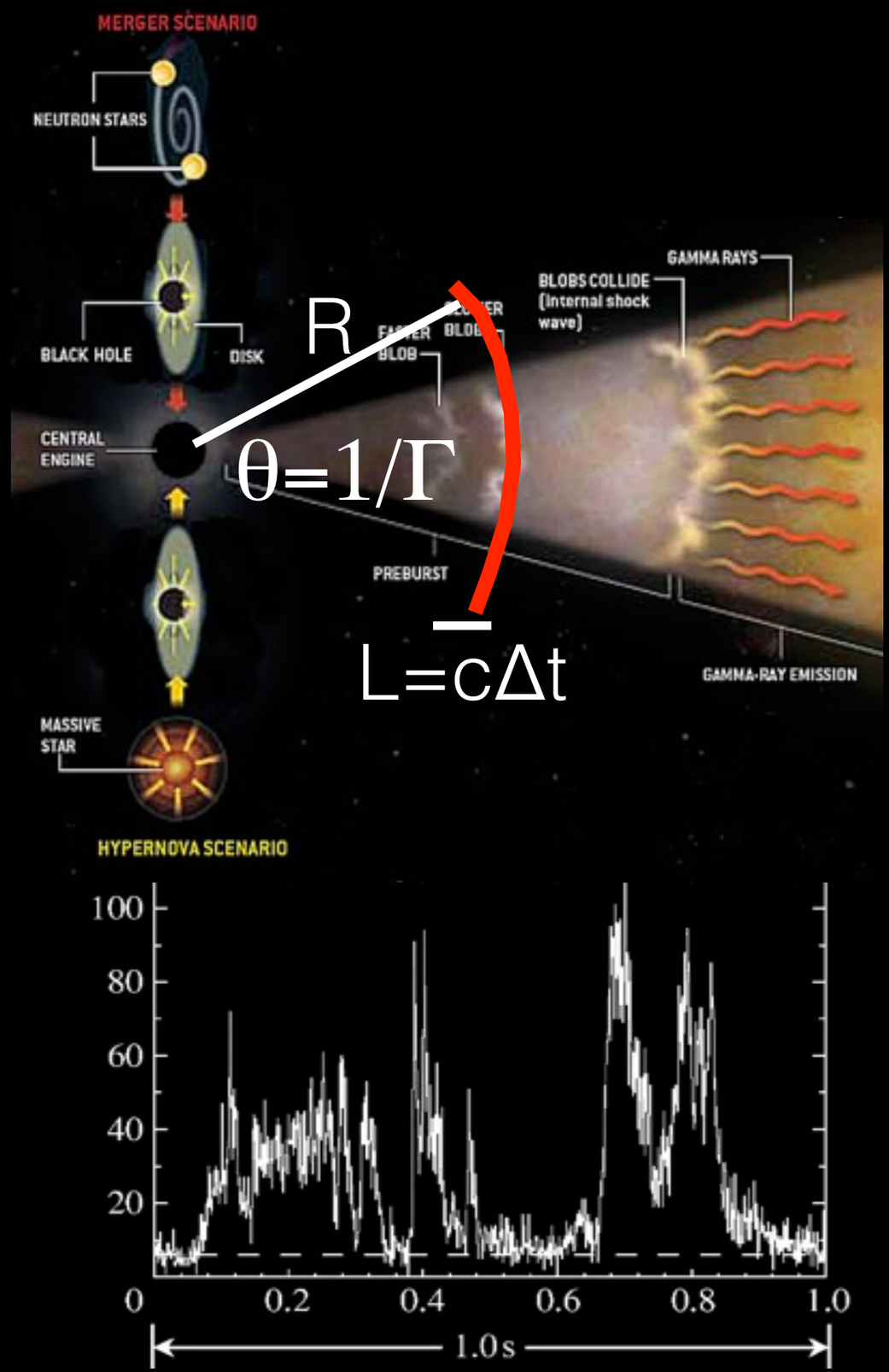


GRB inner engine



GRB inner engine

2 shells ejected at t_1, t_2 , speed Γ_1, $\Gamma_2=a\Gamma_1$ will collide at $R\sim 2\Gamma^2 L$



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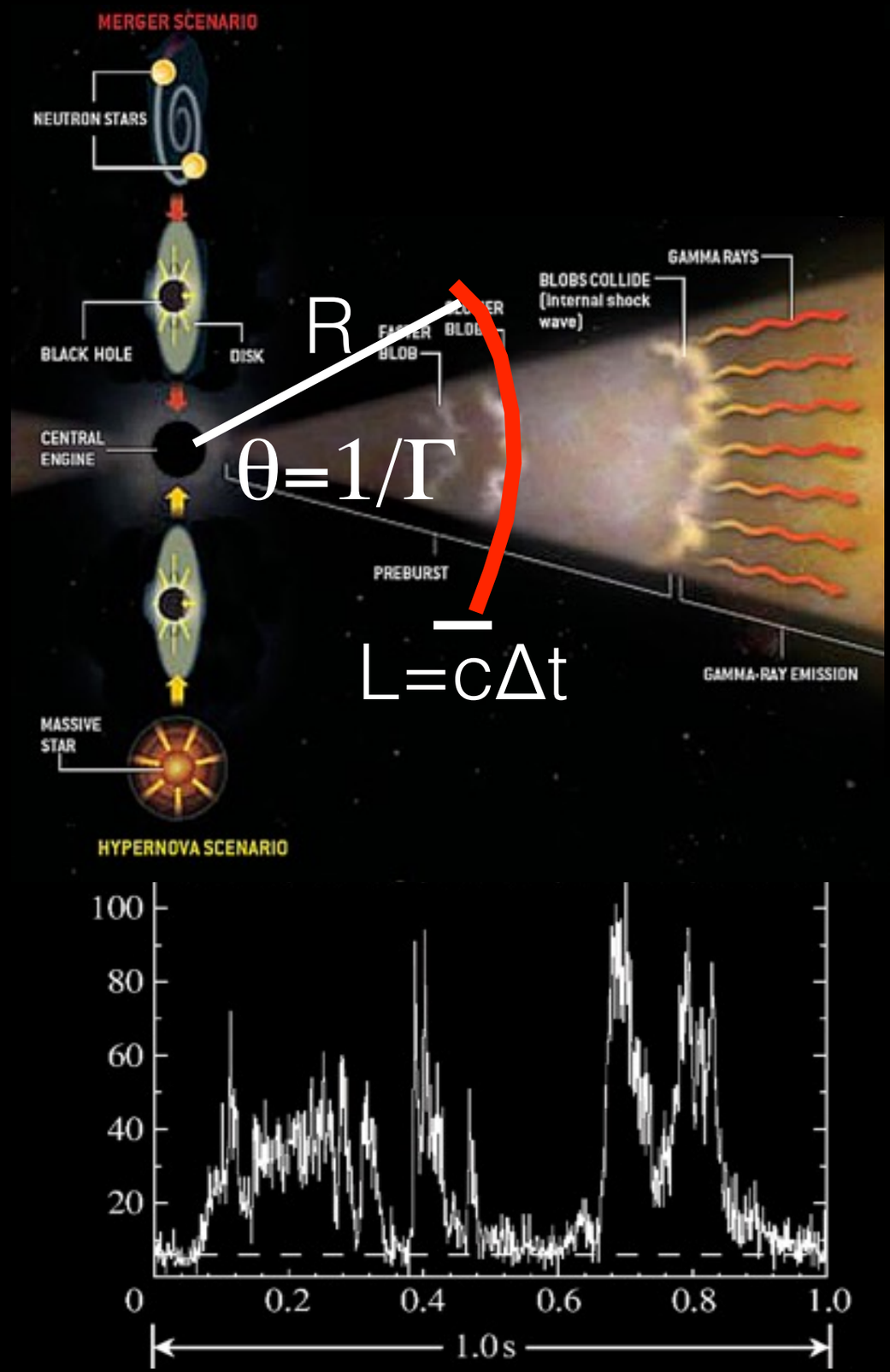
$R\sim(\Gamma/100)\ (\Delta t/1ms)\ 6\times10^{11}cm$



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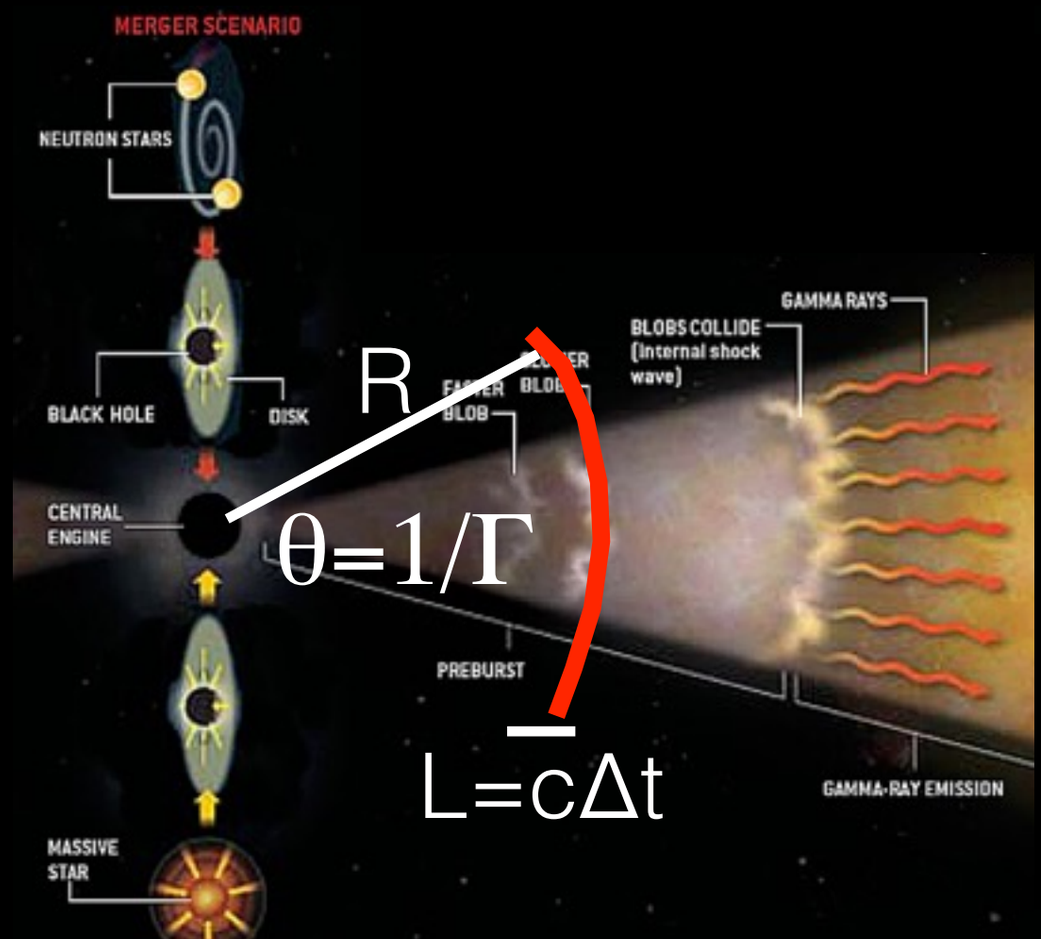
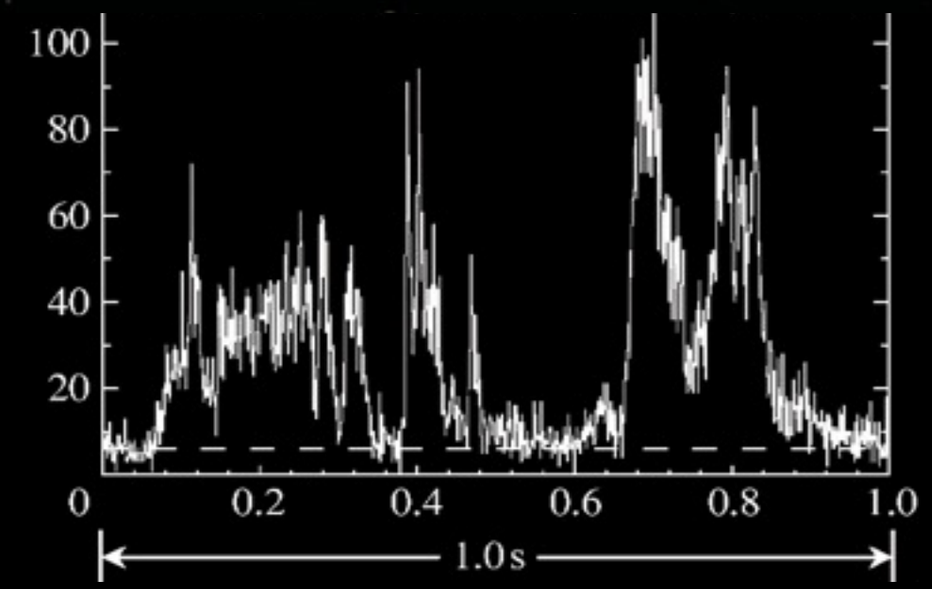
γ-rays from collision reach observer at the same time of hypothetical γ-rays emitted at t_2





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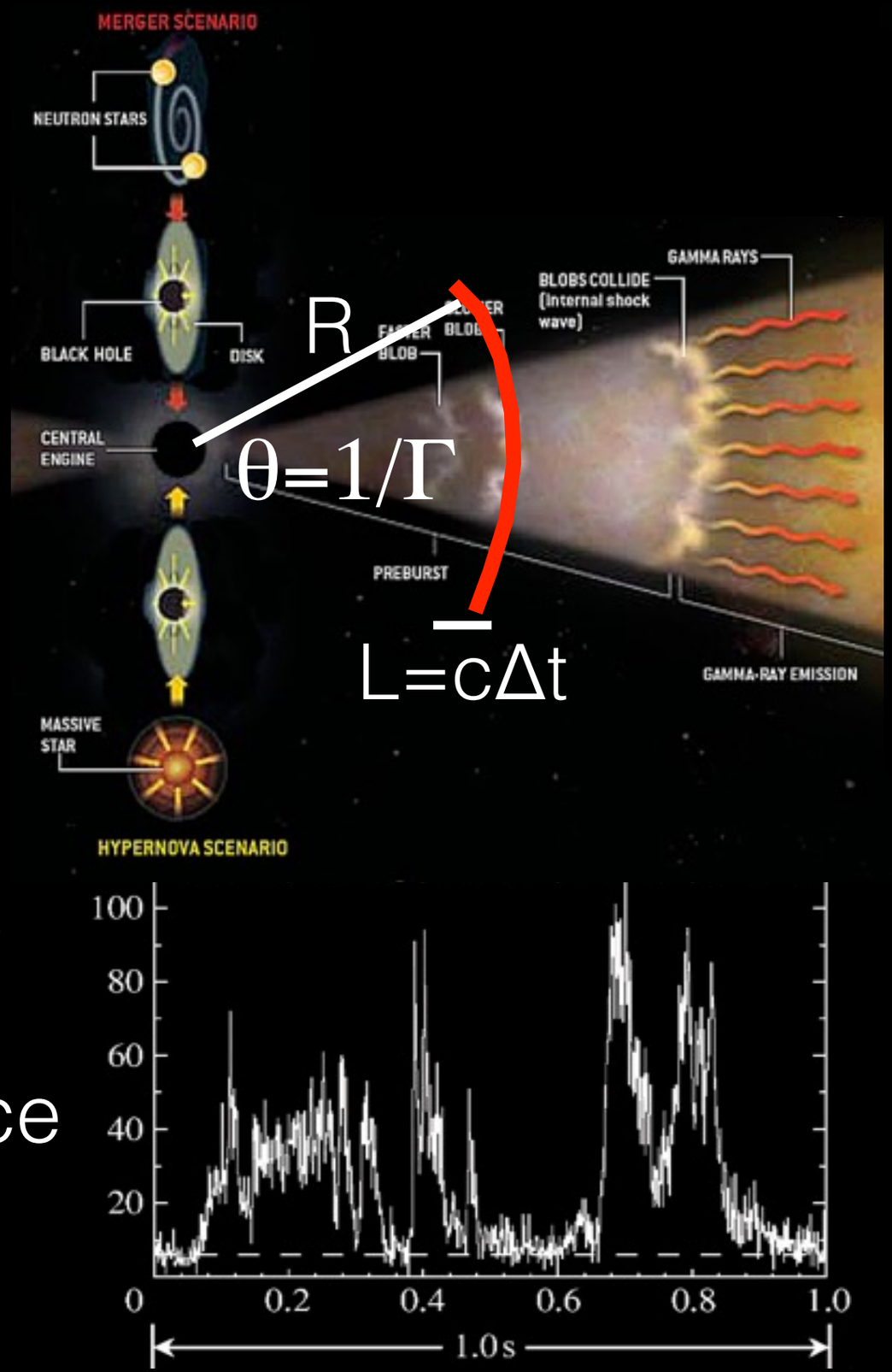
Observed light curves reproduce activity of inner engine
(Nakar-Piran 2002)



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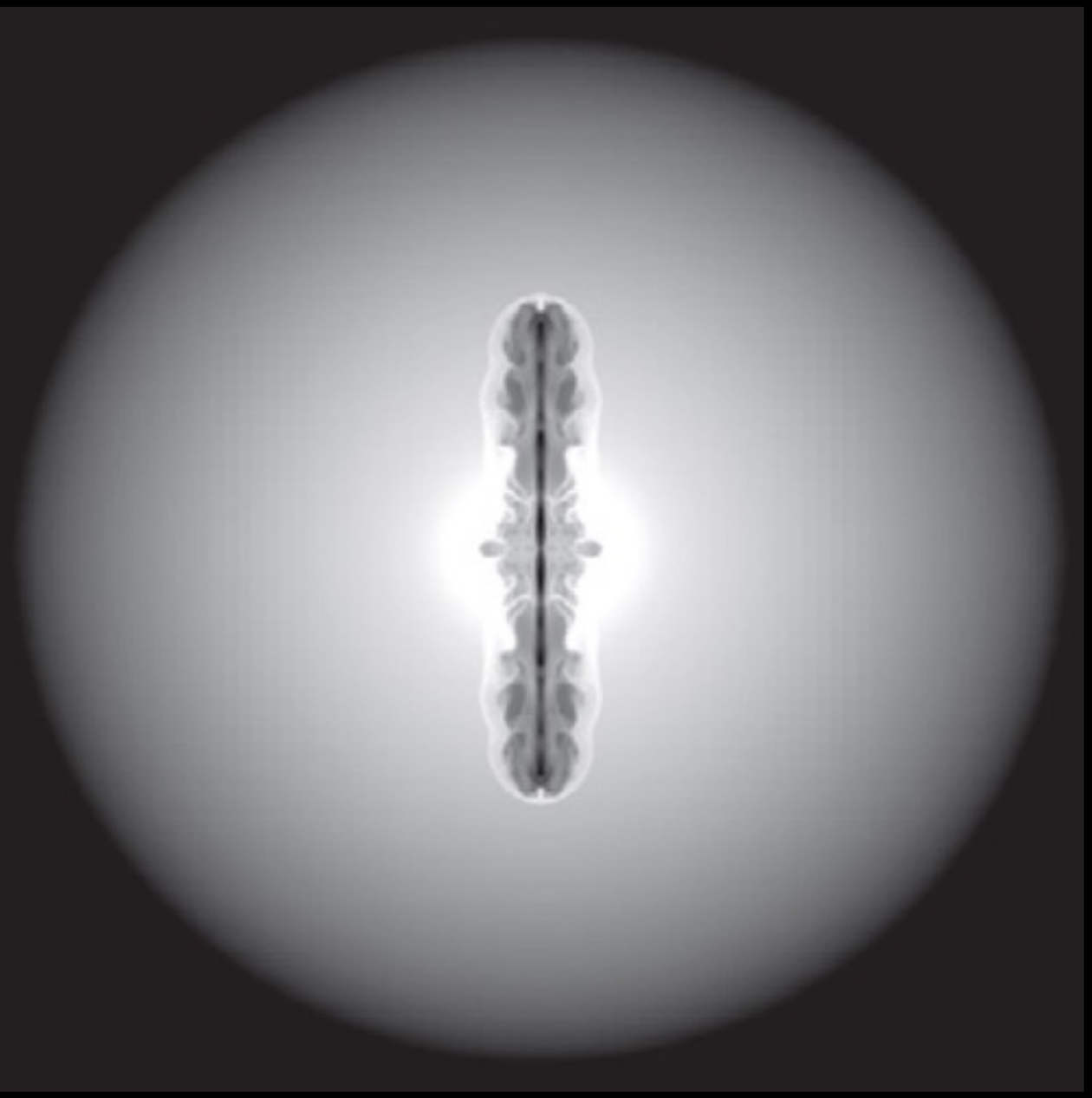
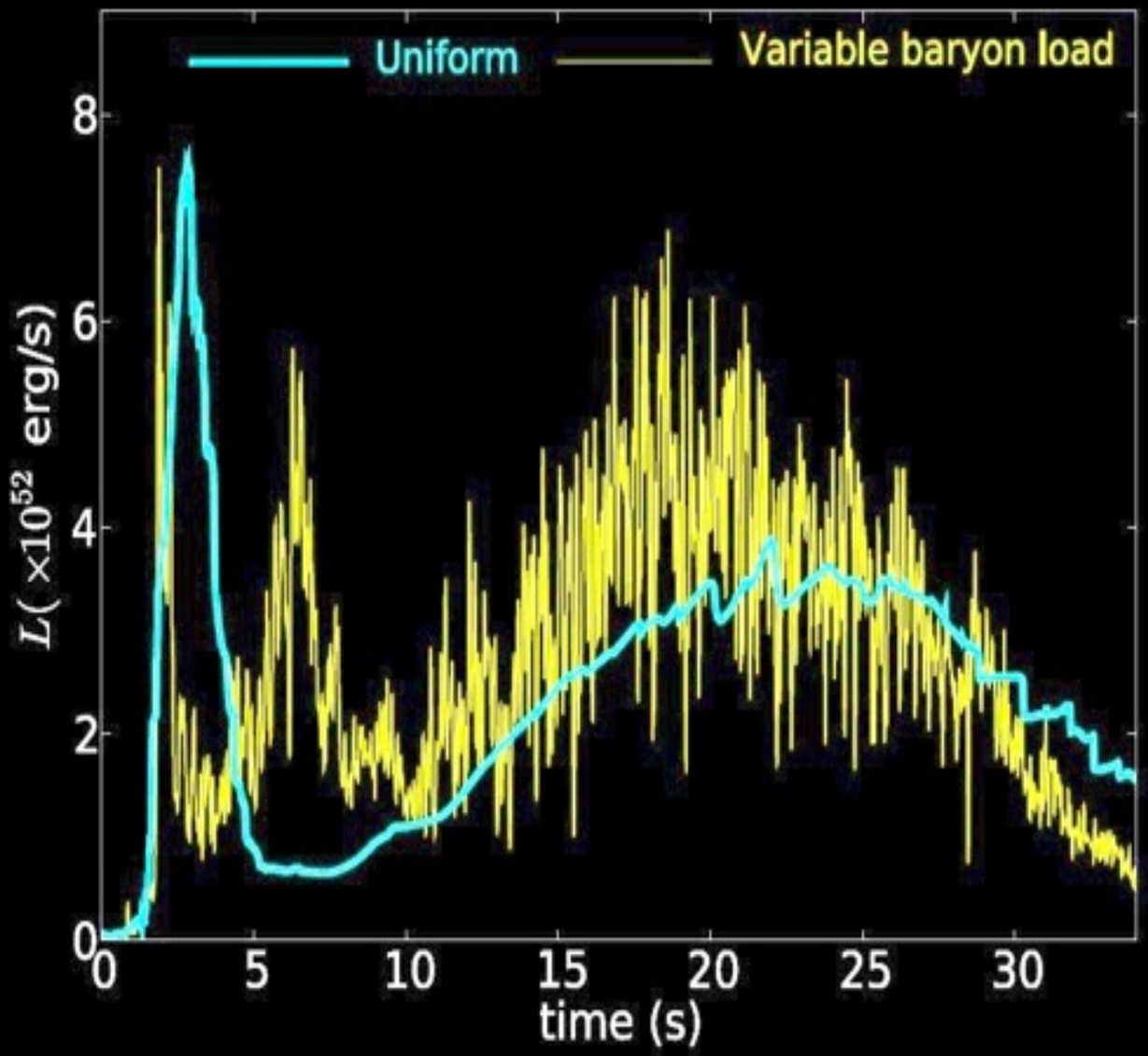
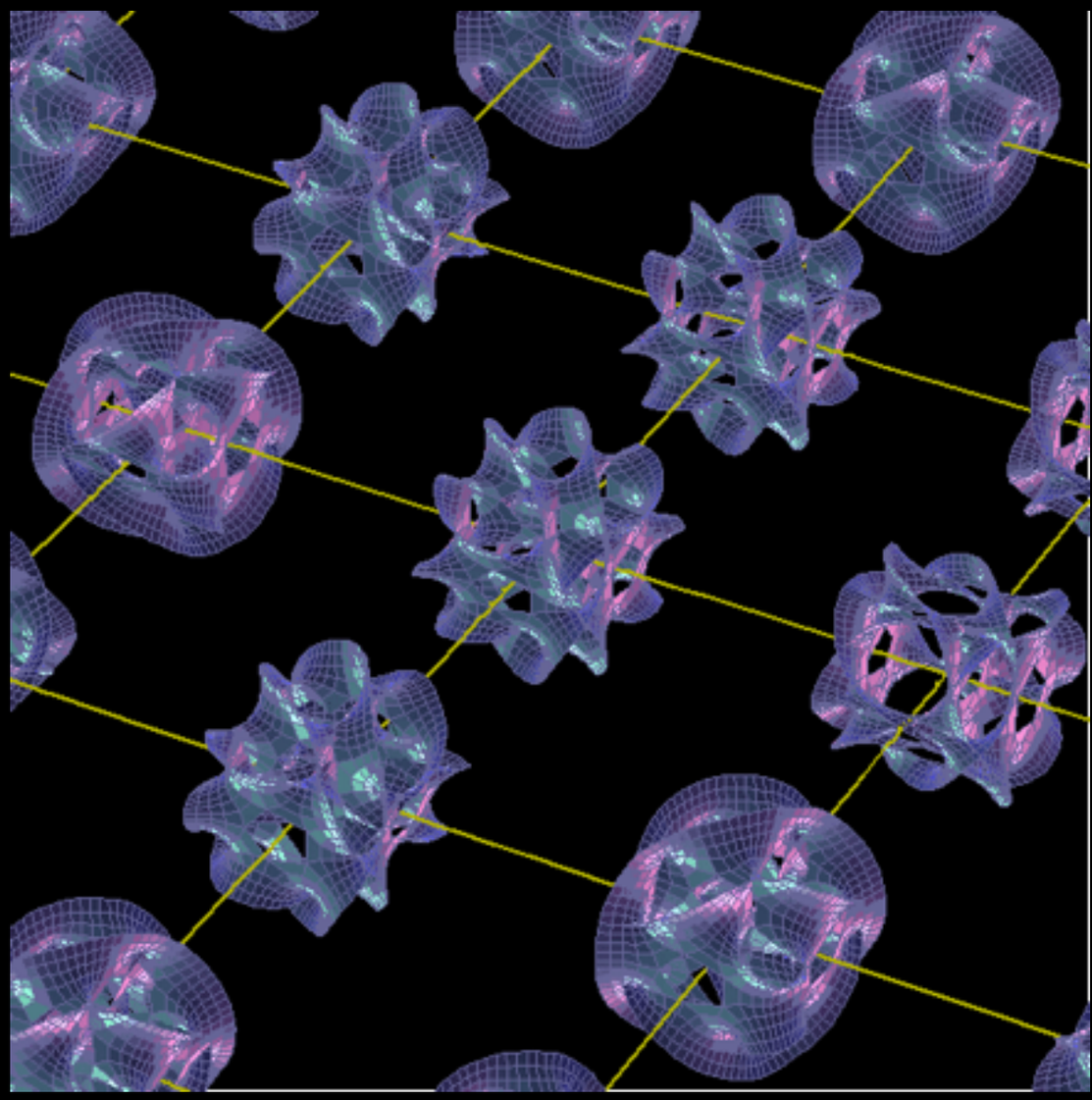




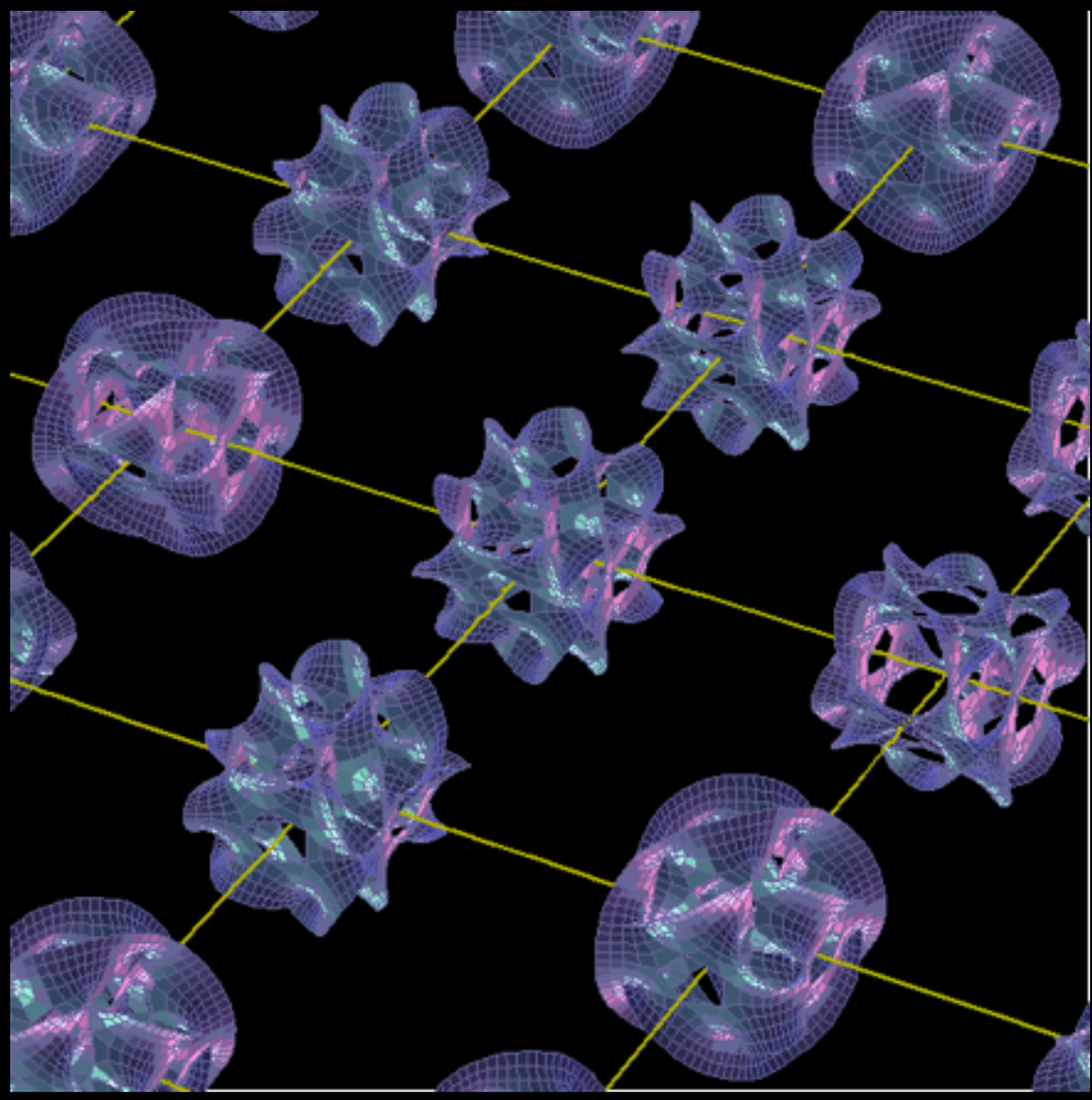
Morsony, Lazzati, Begelman 2010

Space-time structure



Amelino-Camelia + 1998

Space-time structure



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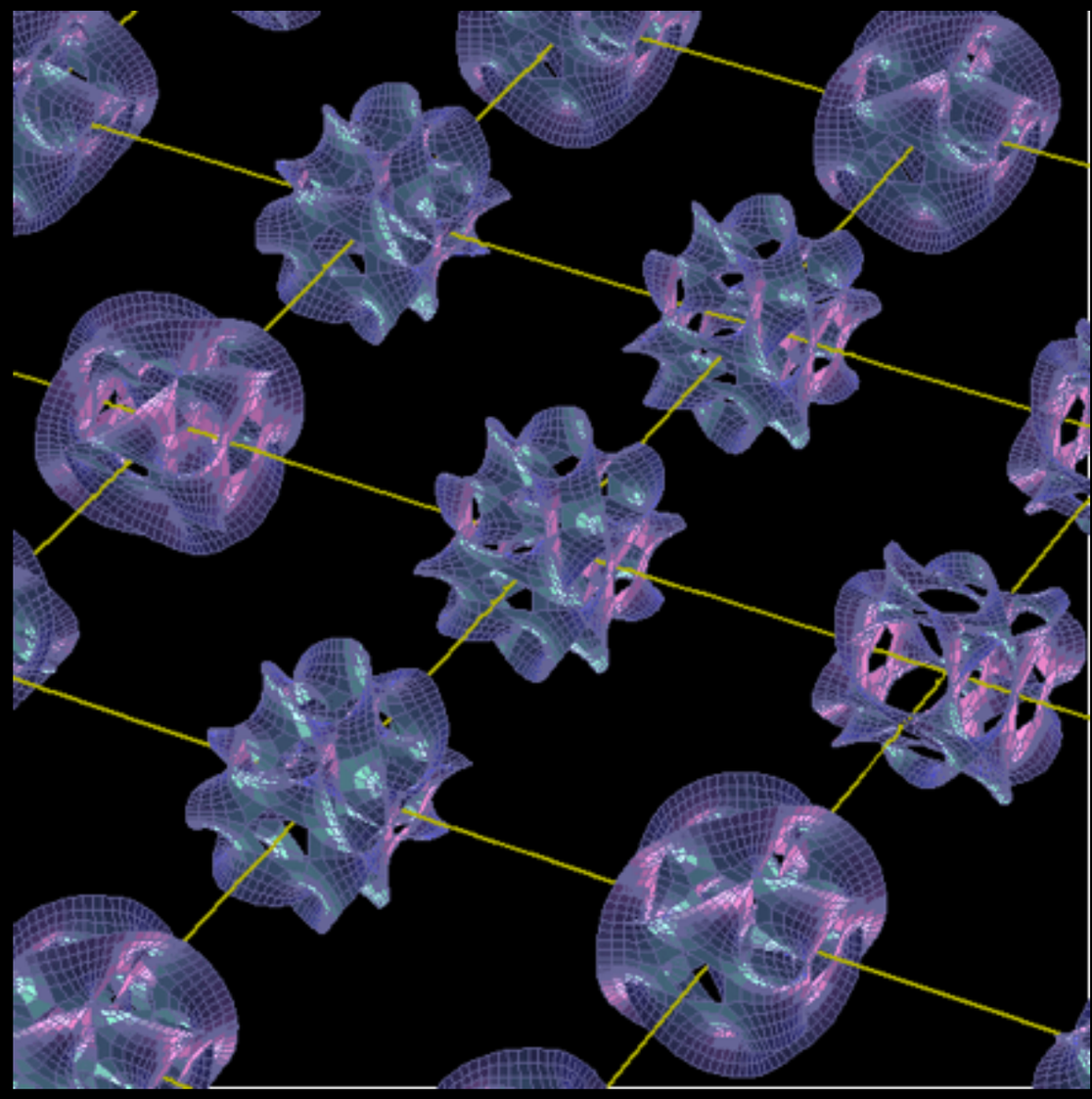
Space-time structure

Granular ST determines a dispersion relation:
$c^2p^2=E^2[1\pm(E/E_{QG})^{\alpha}]$
$E_{QG}=\eta 10^{19}$ GeV



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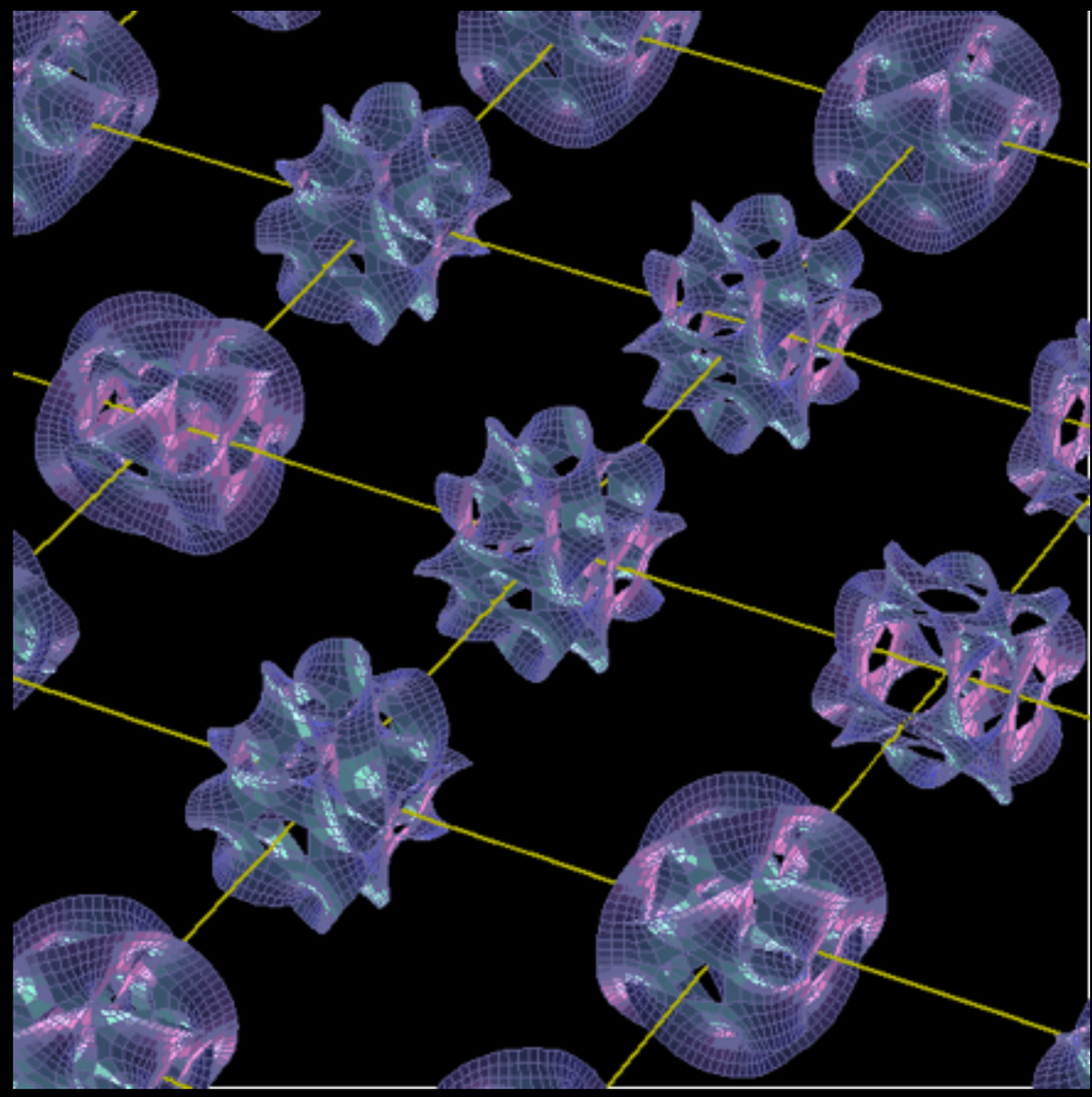

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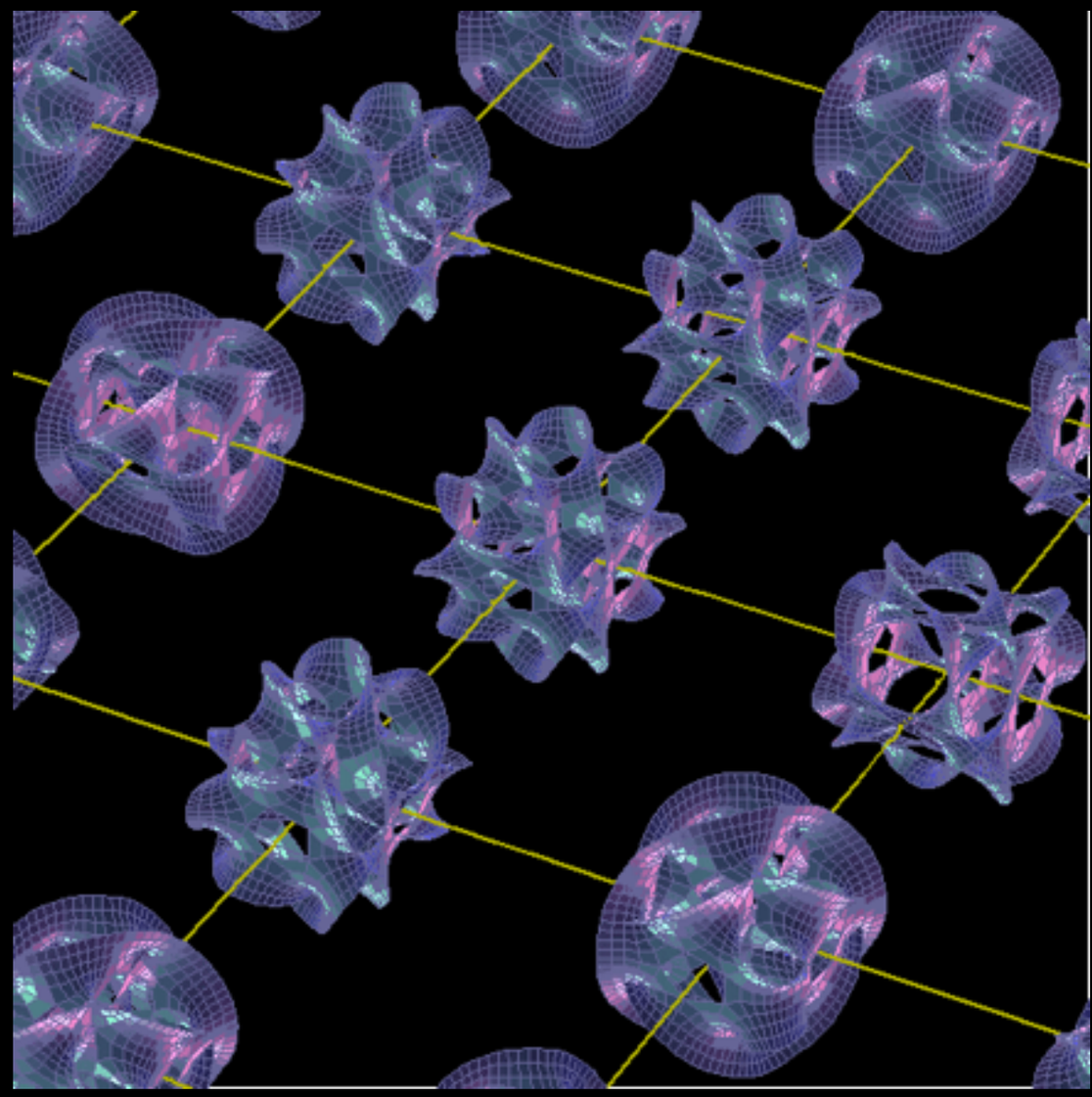

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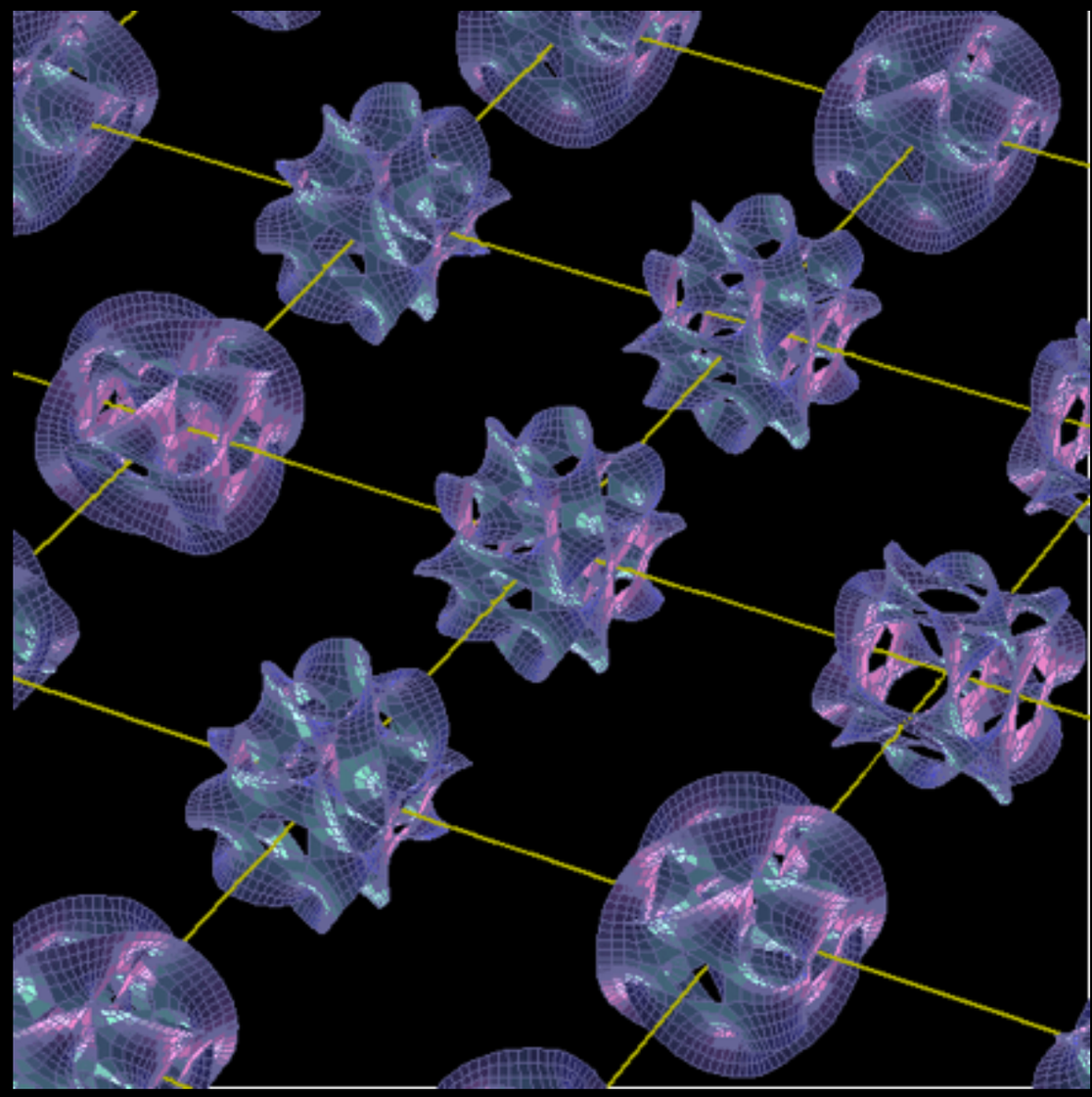
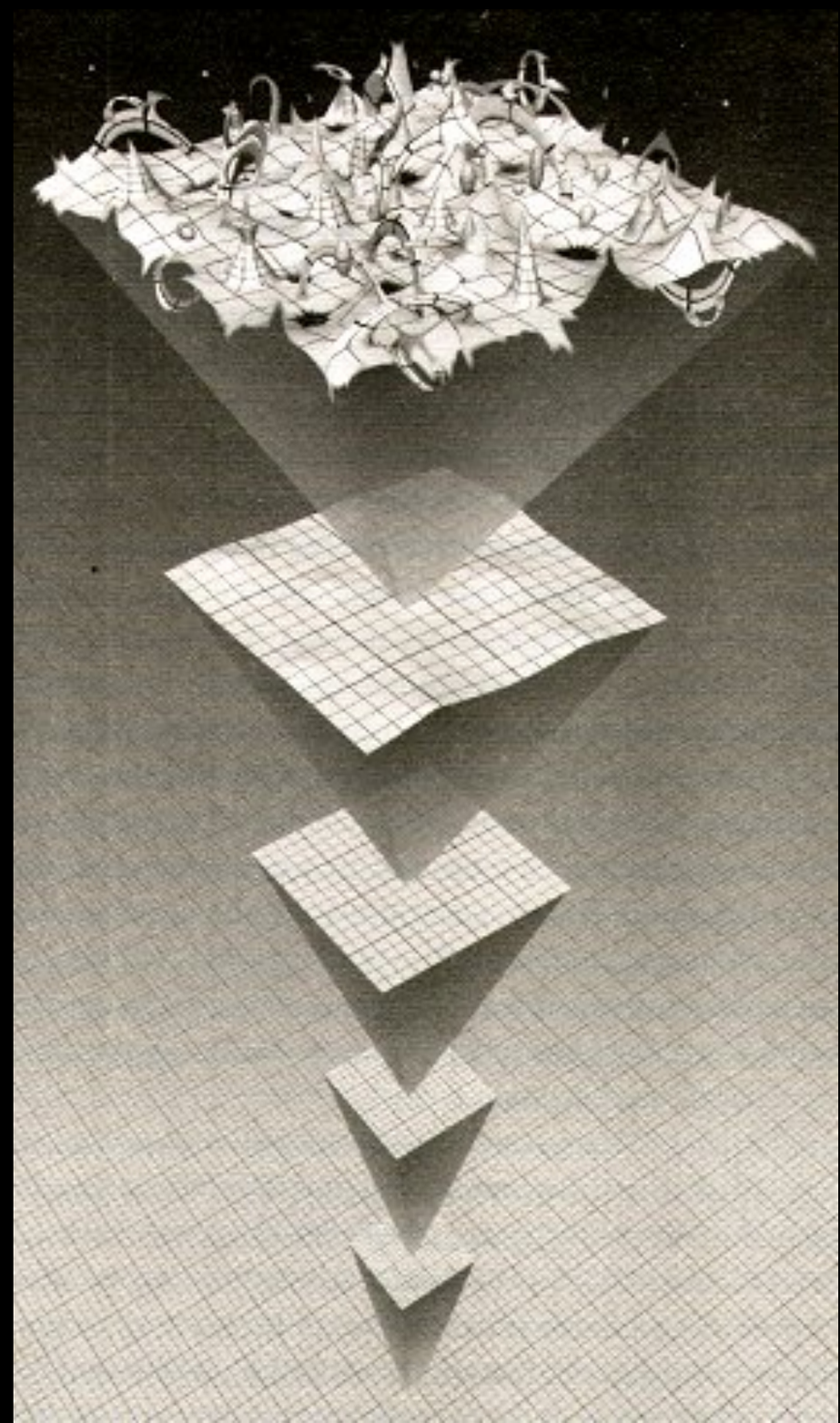
Transverse effect = blur GRB images



Amelino-Camelia + 1998

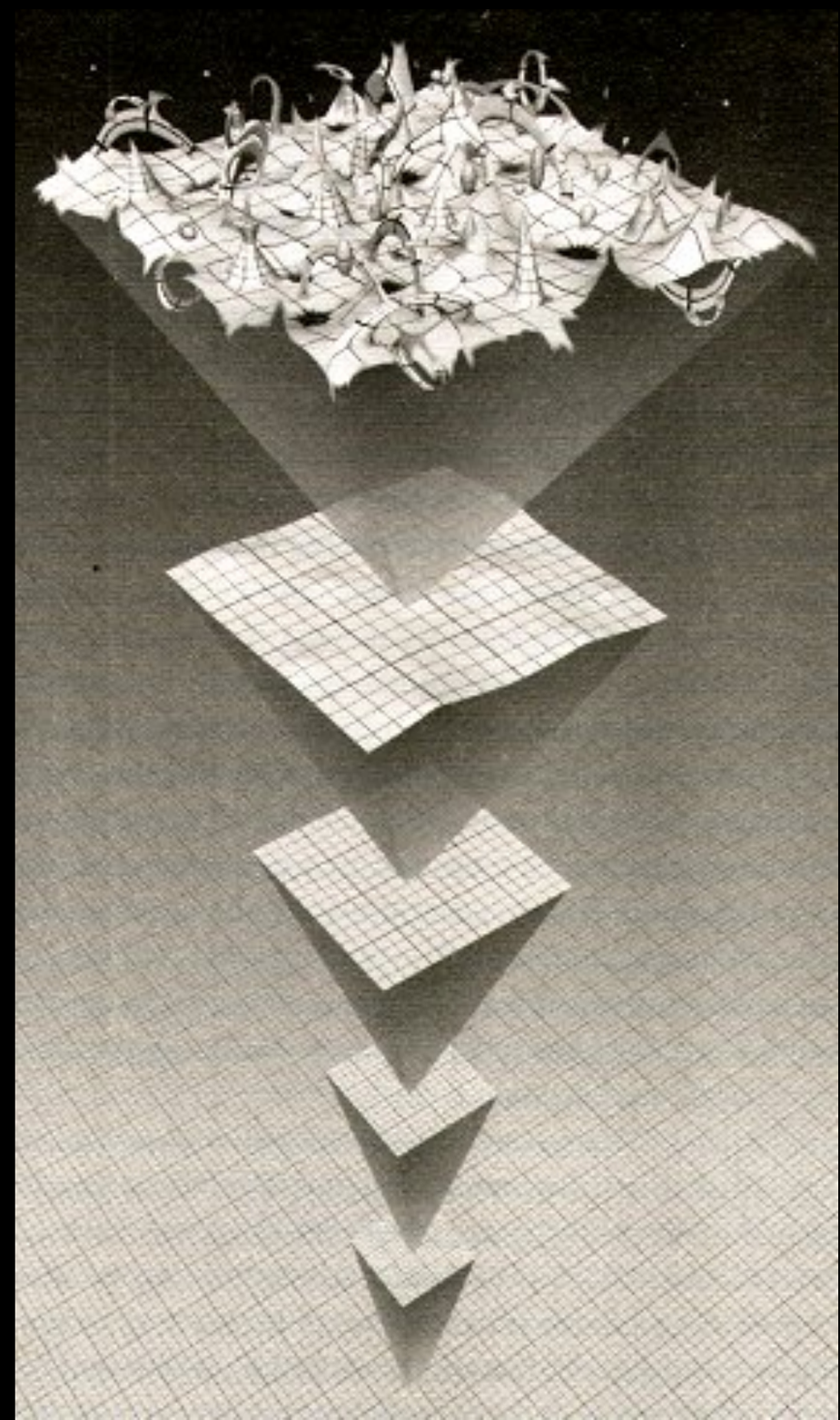
Fermi LAT GRBs



Abdo+2009

Fermi LAT GRBs

- Tests with Fermi:
  single photons
  rare events (1, or a few):
  GRB090510 z=0.9



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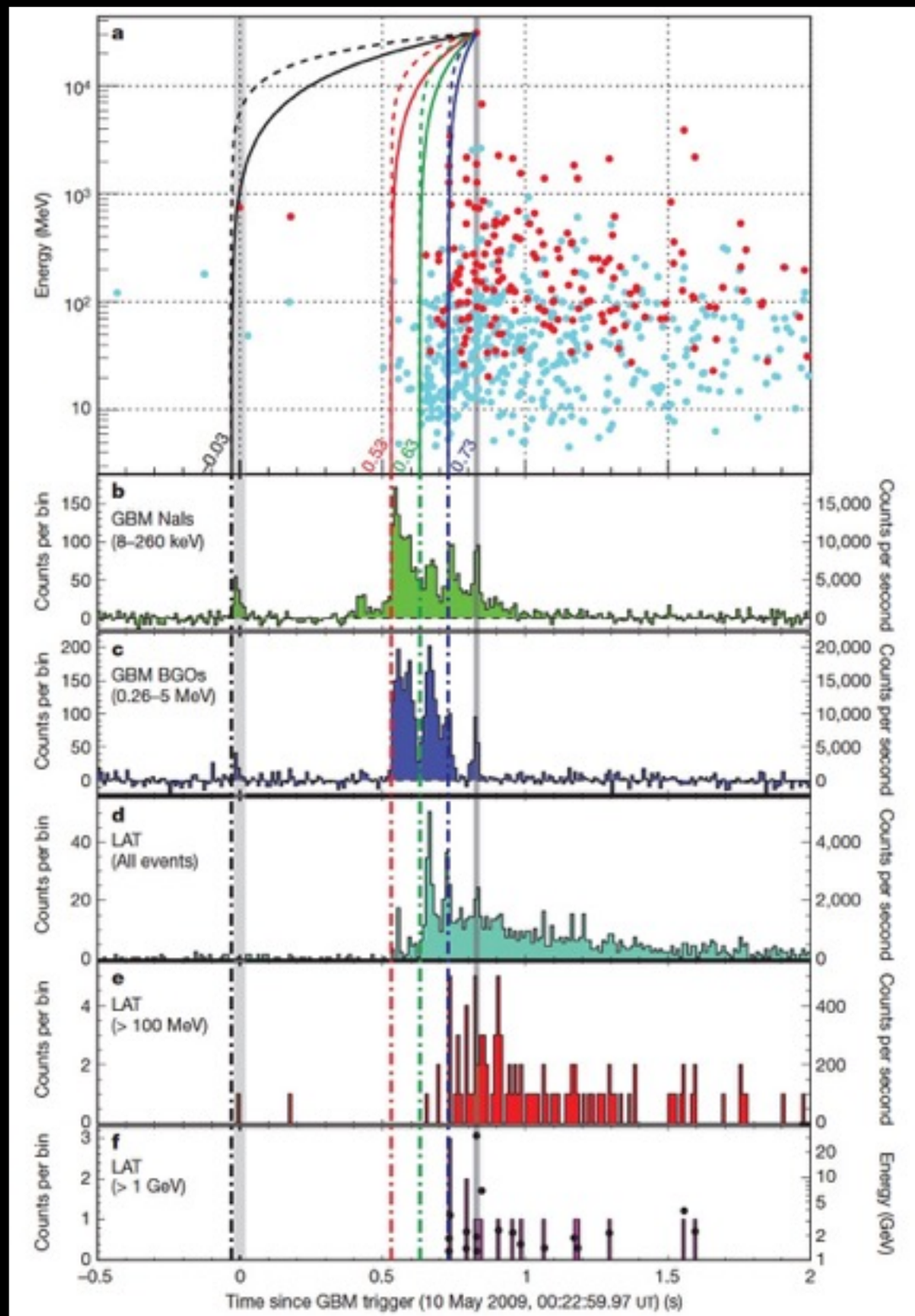

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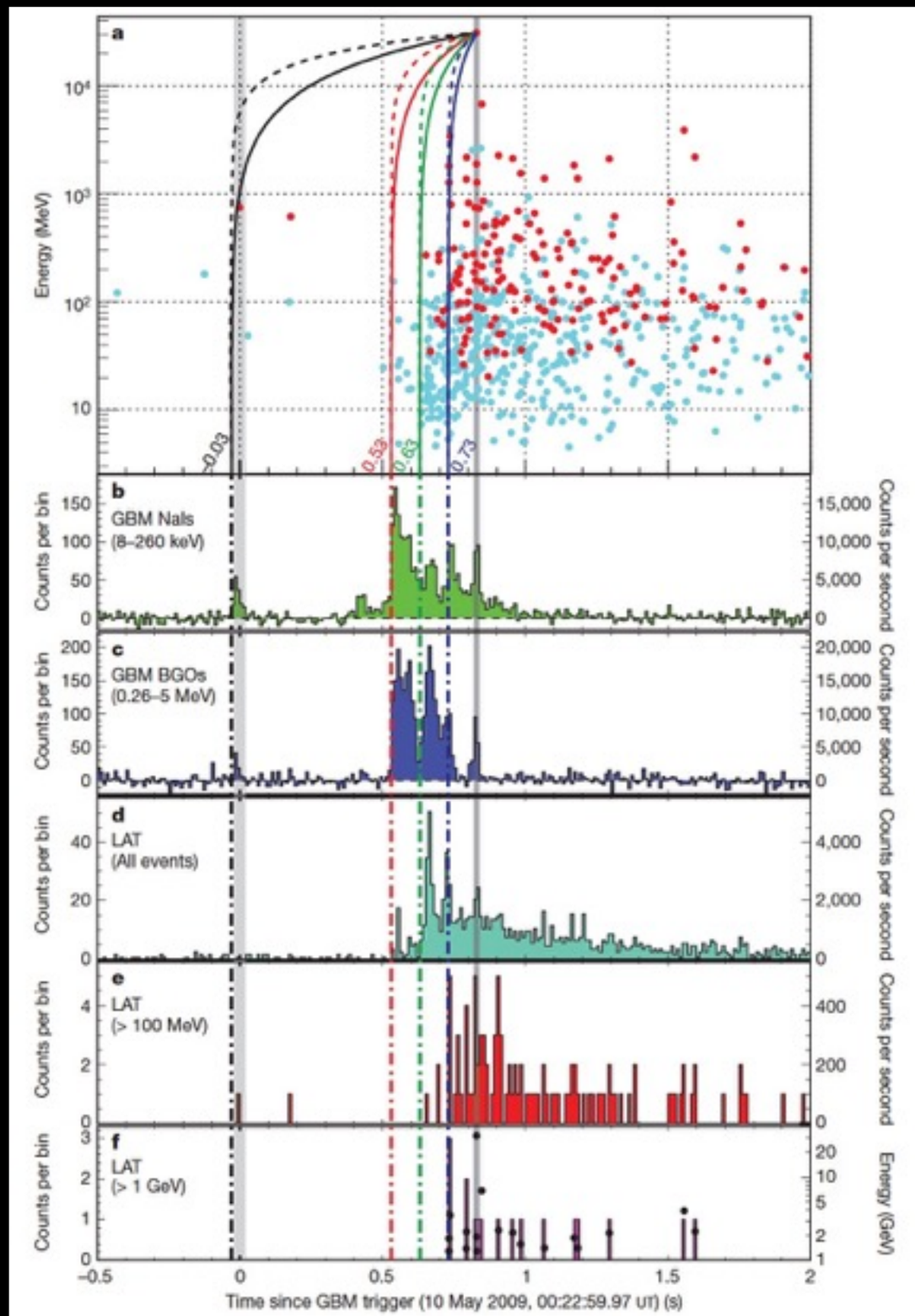

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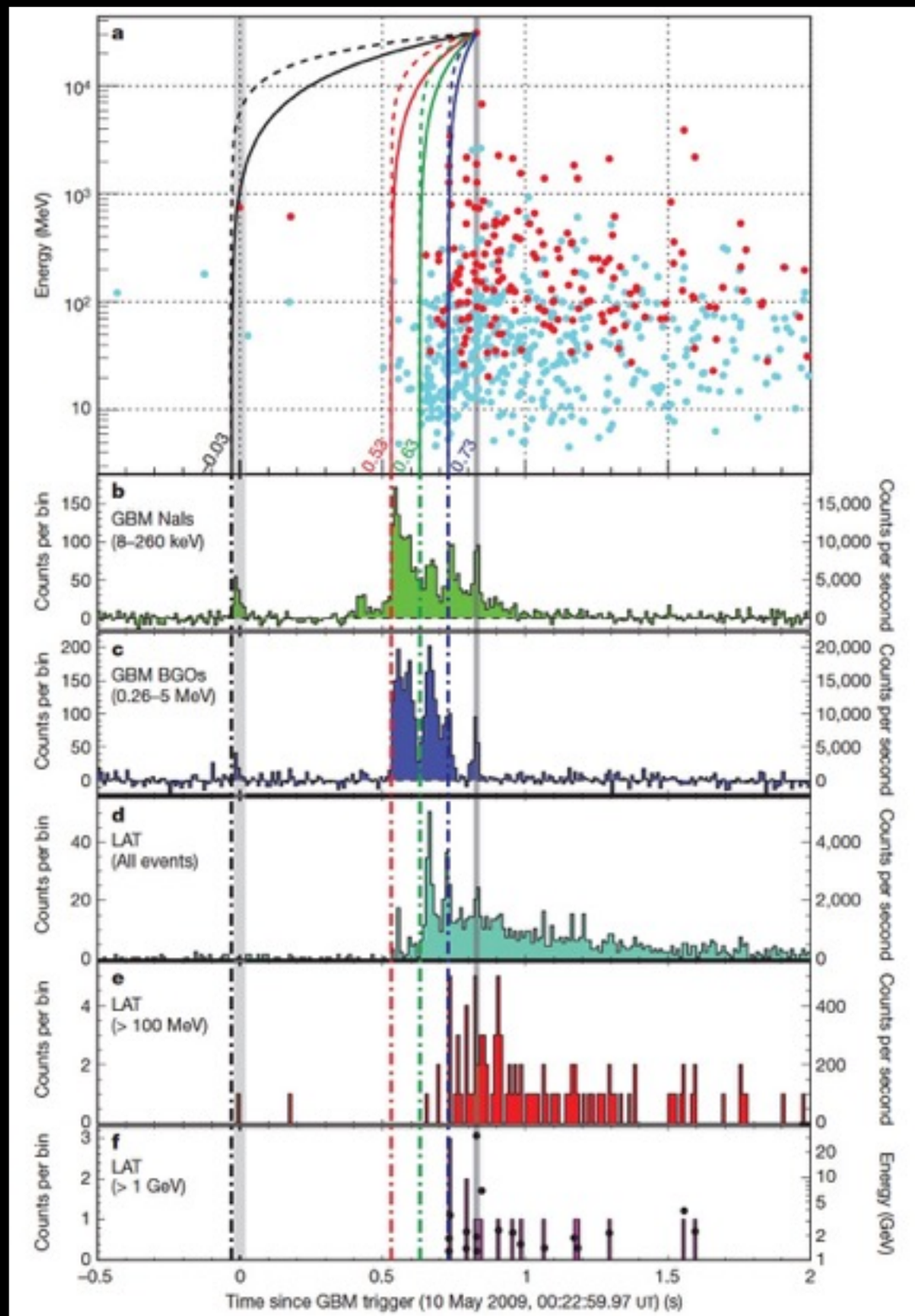
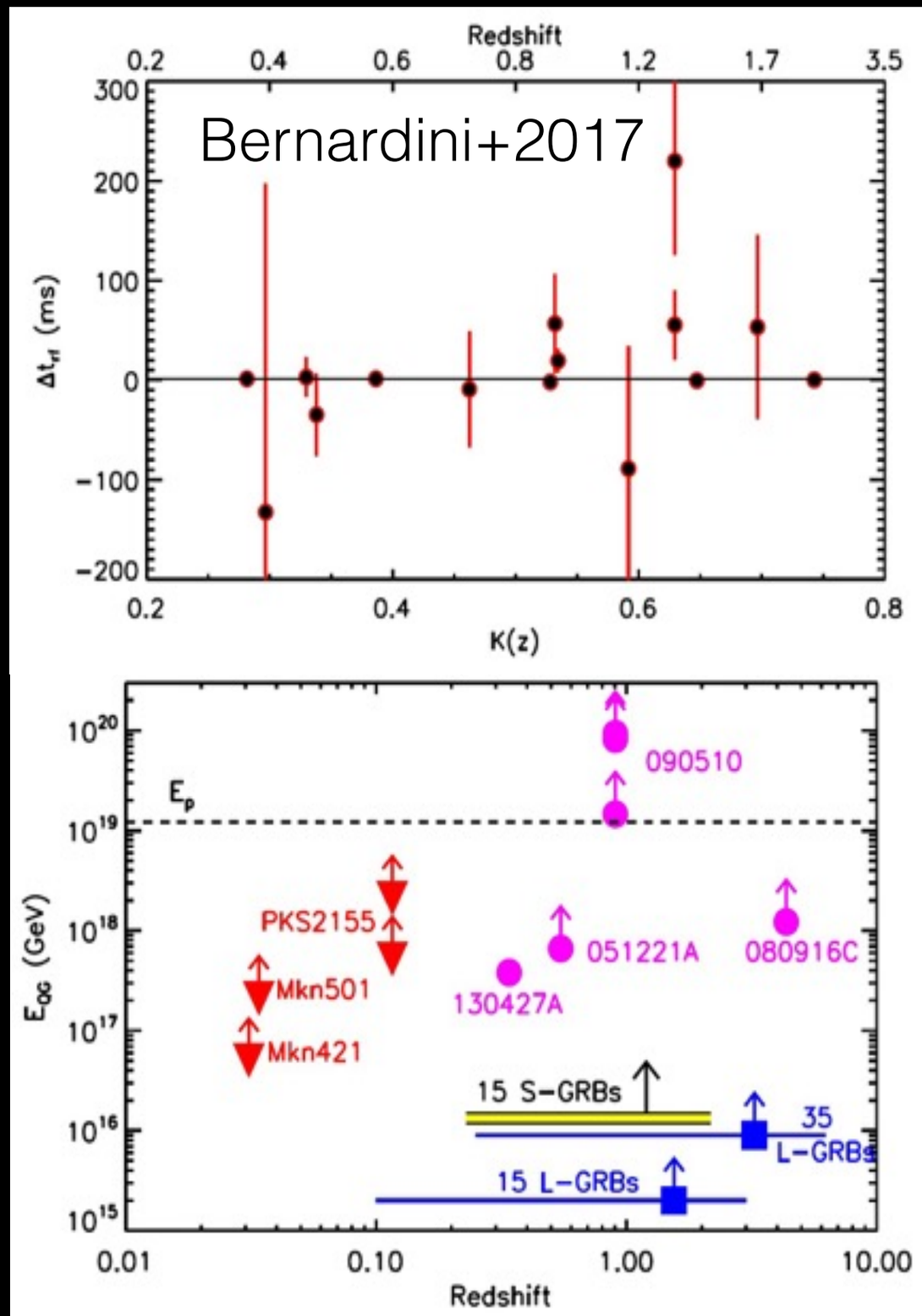
Abdo+2009



Hard X-rays GRBs



Hard X-rays GRBs

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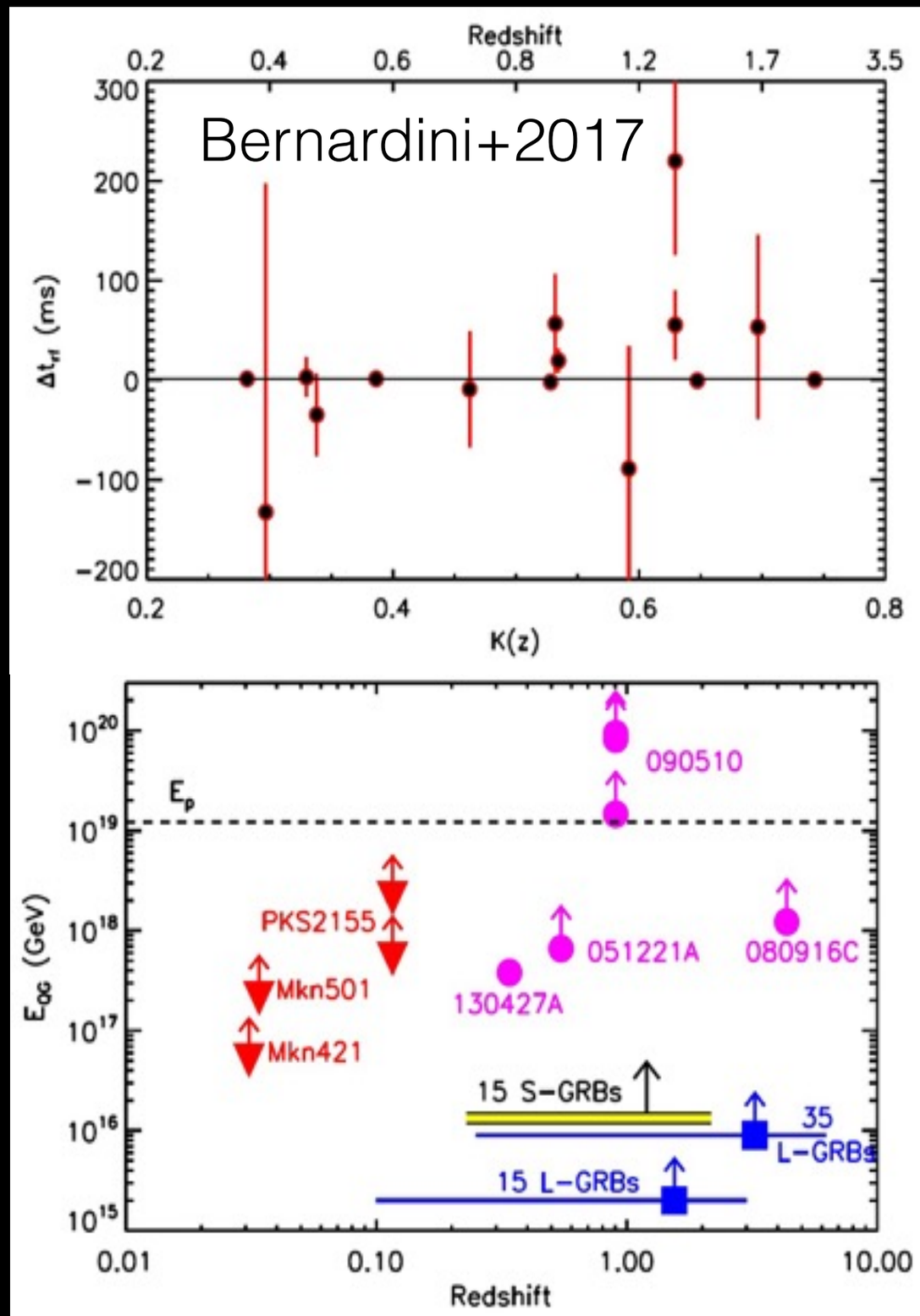

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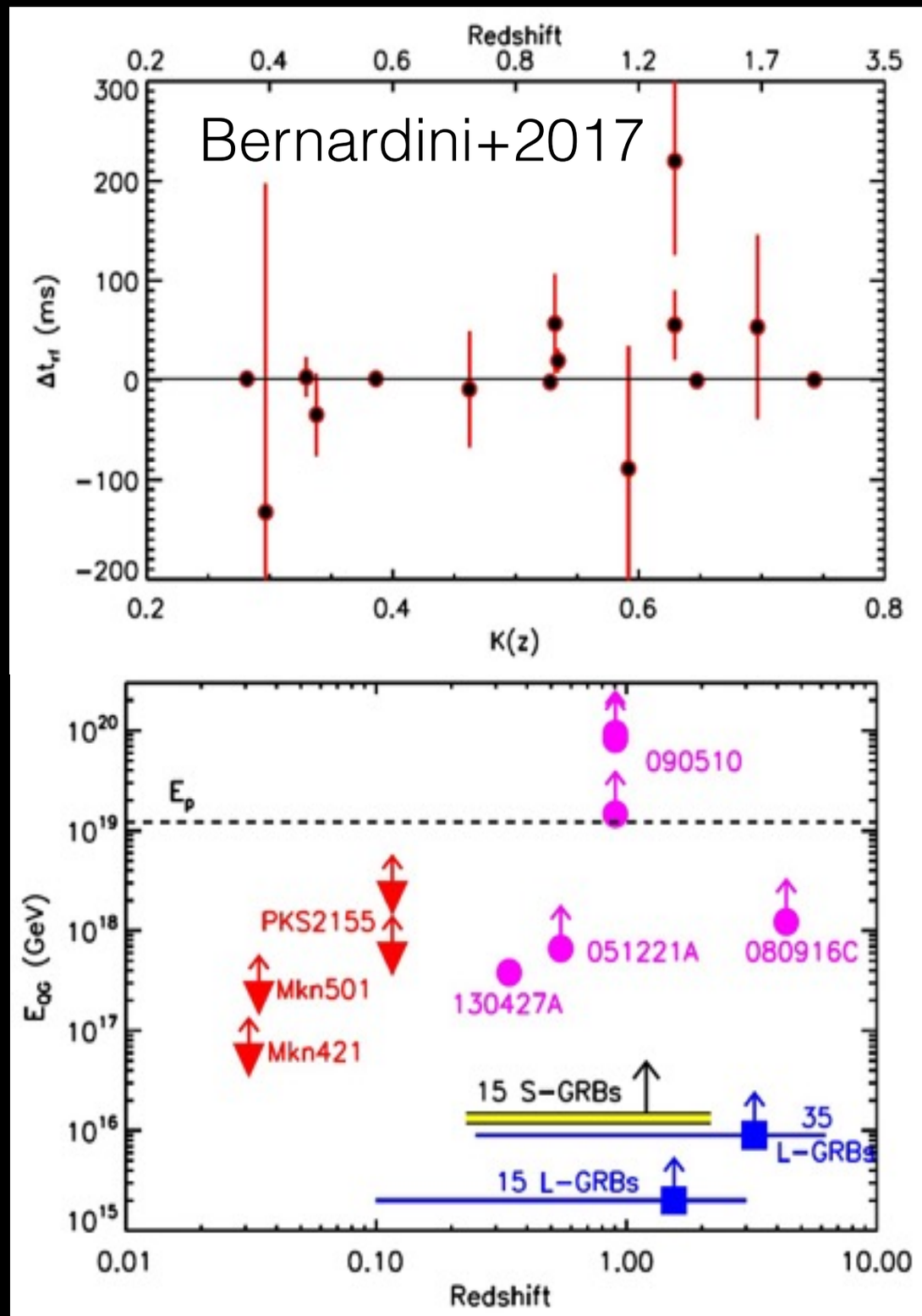

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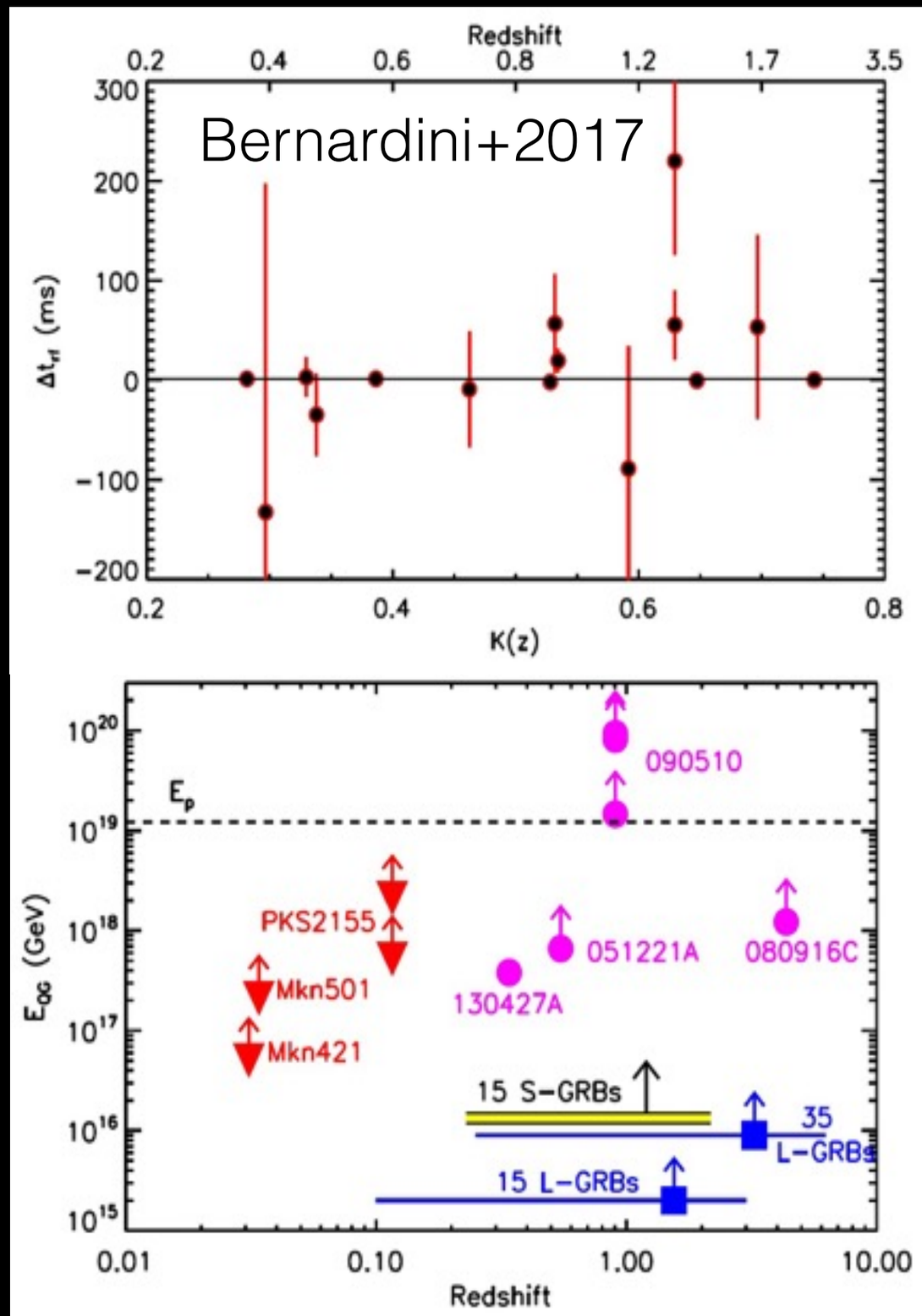

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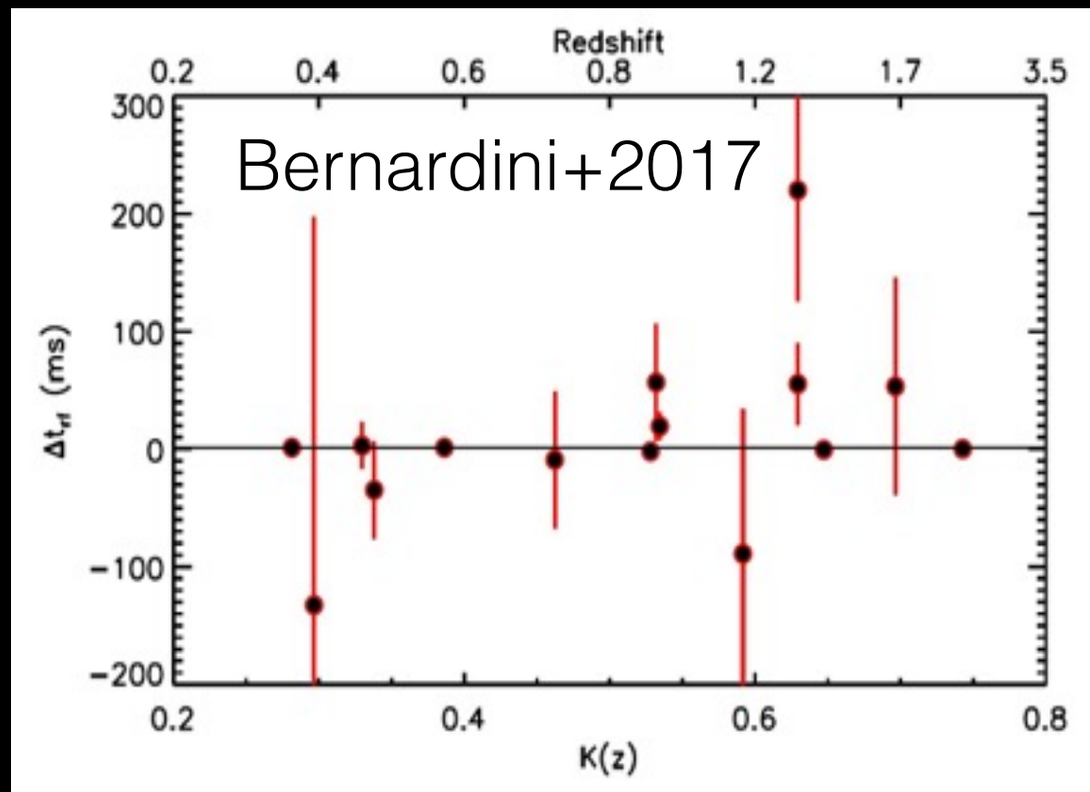
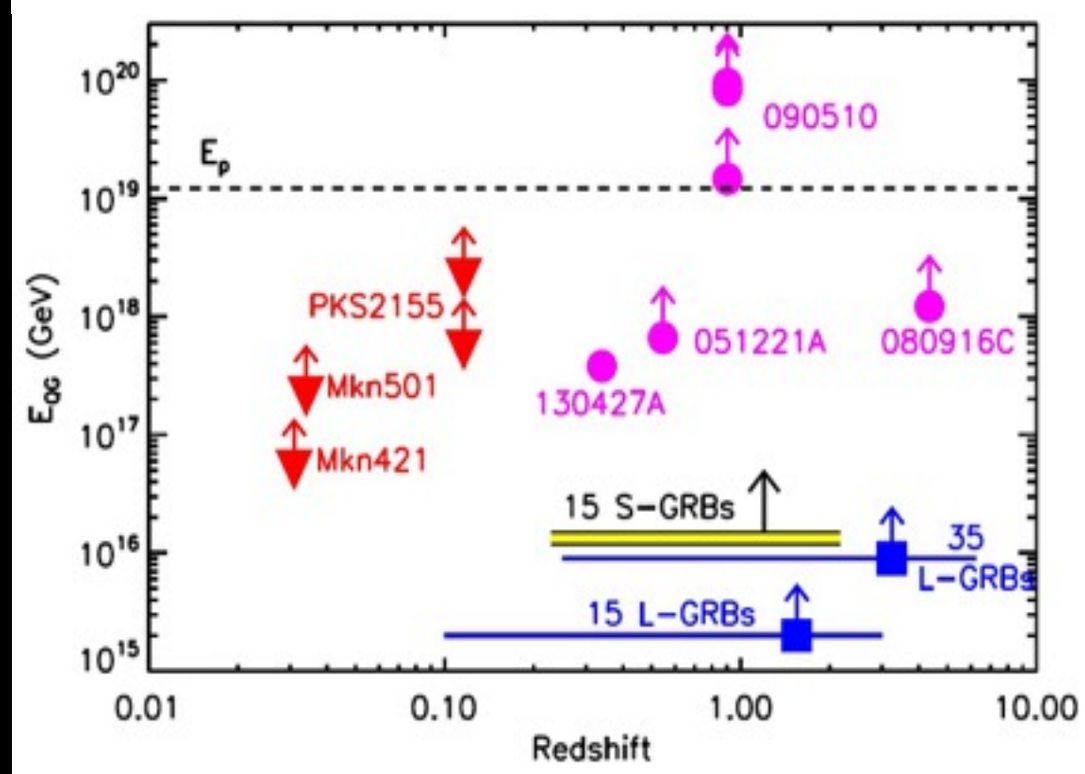
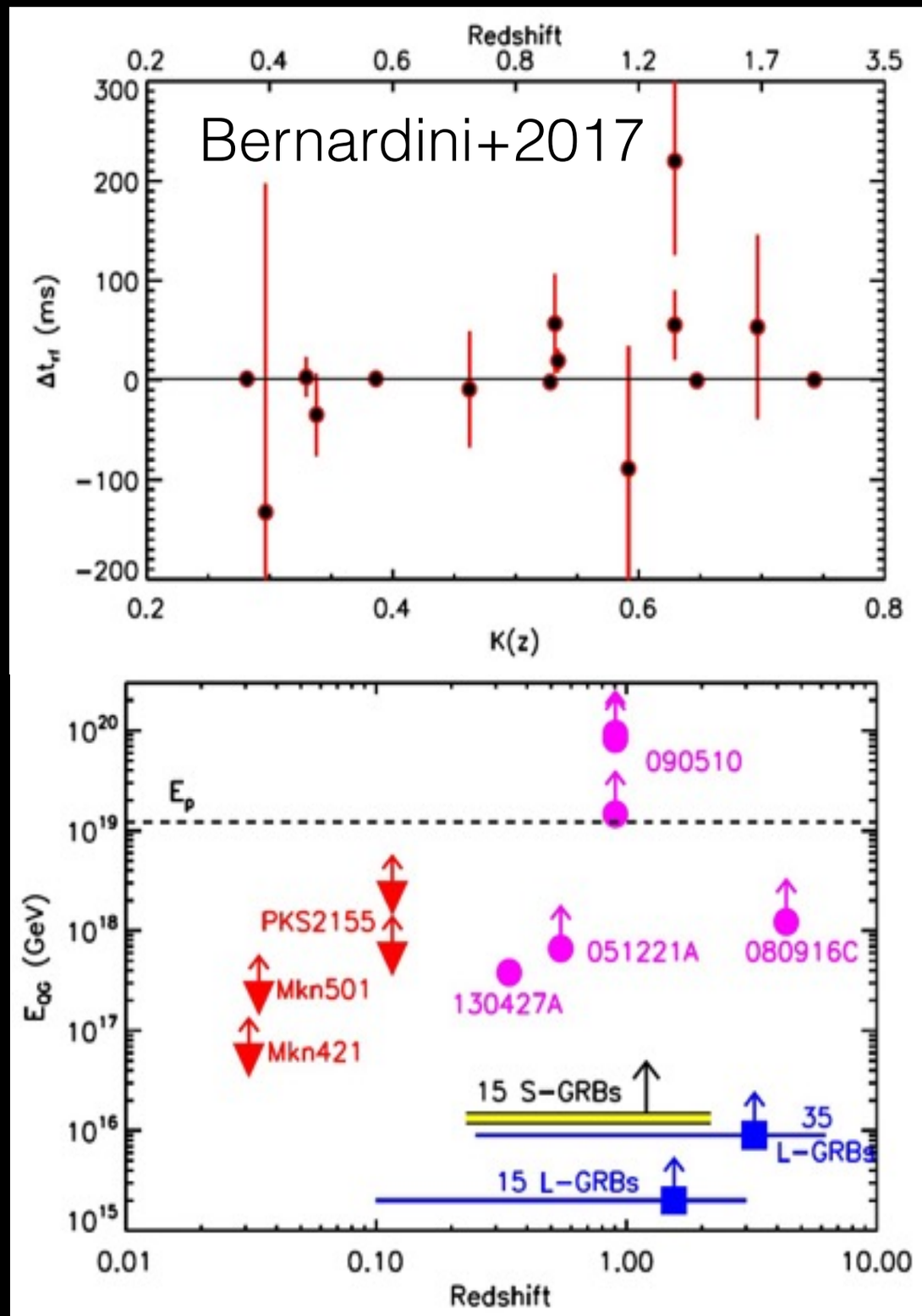
- ~1ph/10μs, GRB with subms variability, detectors with um capability
- $\Delta t/\Delta E$ must scale with D(z) for a given E_{QG}





Hard X-rays GRBs

- Robust test:
  use full GRB information (CCF)
  thousands photons
- $\Delta t/\Delta E \sim 30ms/GeV \sim 3\mu s/100keV$
  $E_{QG} \sim E_{Planck}$, $\alpha=1$, $z \sim 1$
- ~1ph/10μs, GRB with subms variability, detectors with um capability
- $\Delta t/\Delta E$ must scale with D(z) for a given E_{QG}
- Tens/hundreds GRBs: ~10ph/cm^2/s —> Collecting area ~1m^2



Requirements

Requirements

Scientific:

Requirements

Scientific:

Arcmin-arcsec positions of ~a few dozen GRB/yr

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Prompt(minute) localisation

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Prompt(minute) localisation

sub-μs timing

Requirements

Scientific:

Arcmin-arcsec positions of ~a few dozen GRB/yr

Prompt(minute) localisation

sub-μs timing

$\Delta t/\Delta E$~3μs/100keV 30μs/1MeV—> $M_{QG} \sim M_{Planck}$

Requirements

Requirements

System:

Requirements

System:

≈hundreds detectors

Requirements

System:

≈hundreds detectors

single collecting area ≥50cm^2

Requirements

System:

≈hundreds detectors

single collecting area ≥50cm^2

total collecting area ≥1m^2

Requirements

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single collecting area ≥50cm^2

total collecting area ≥1m^2

Energy range 3-10 — 300-1000 keV

Requirements

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≈hundreds detectors

single collecting area ≥50cm^2

total collecting area ≥1m^2

Energy range 3-10 — 300-1000 keV

Temporal resolution a few hundred ns

Requirements

System:

≈hundreds detectors

single collecting area ≥50cm^2

total collecting area ≥1m^2

Energy range 3-10 — 300-1000 keV

Temporal resolution a few hundred ns

Position reconstruction of each satellite < 100m

Requirements

System:

≈hundreds detectors

single collecting area ≥50cm^2

total collecting area ≥1m^2

Energy range 3-10 — 300-1000 keV

Temporal resolution a few hundred ns

Position reconstruction of each satellite < 100m

Absolute time reconstruction <100 ns

Requirements

System:

≈hundreds detectors

single collecting area ≥50cm^2

total collecting area ≥1m^2

Energy range 3-10 — 300-1000 keV

Temporal resolution a few hundred ns

Position reconstruction of each satellite < 100m

Absolute time reconstruction <100 ns

Download full burst info in minutes

Spacecraft

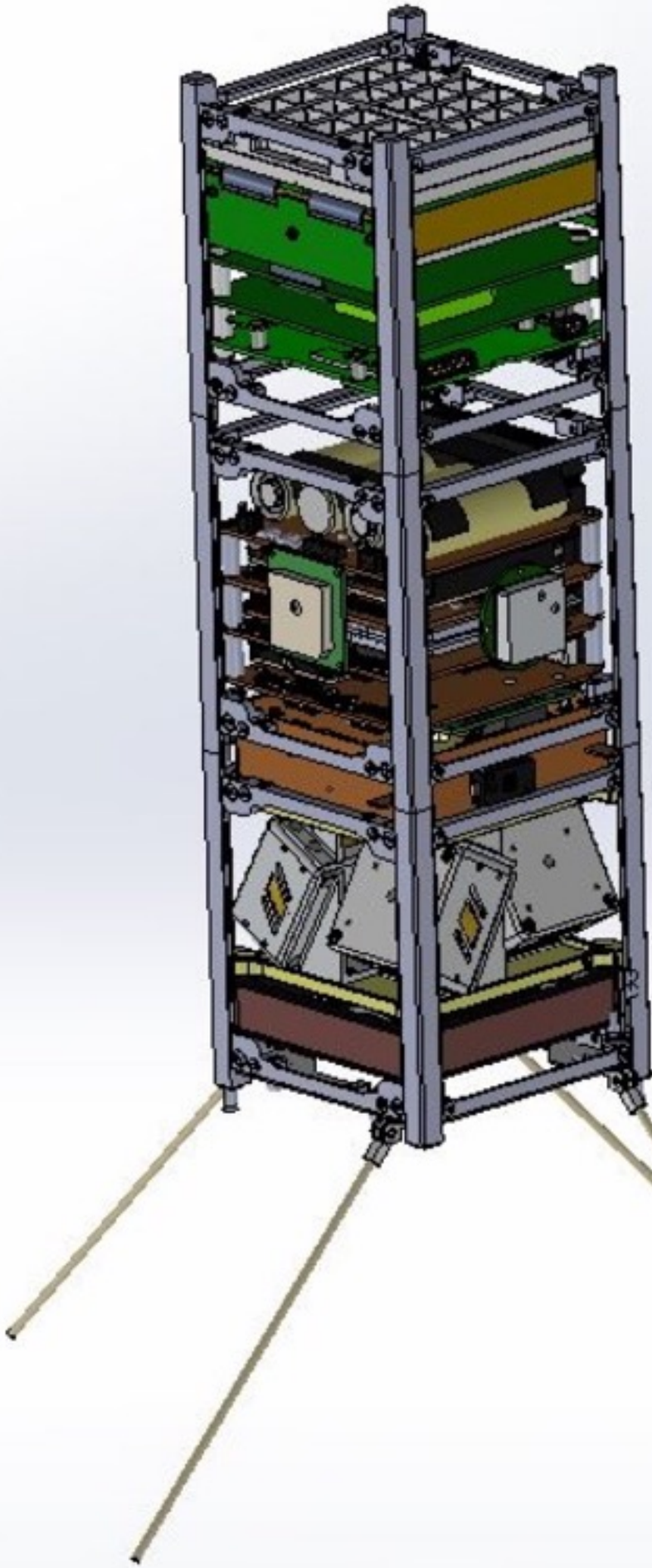
Spacecraft

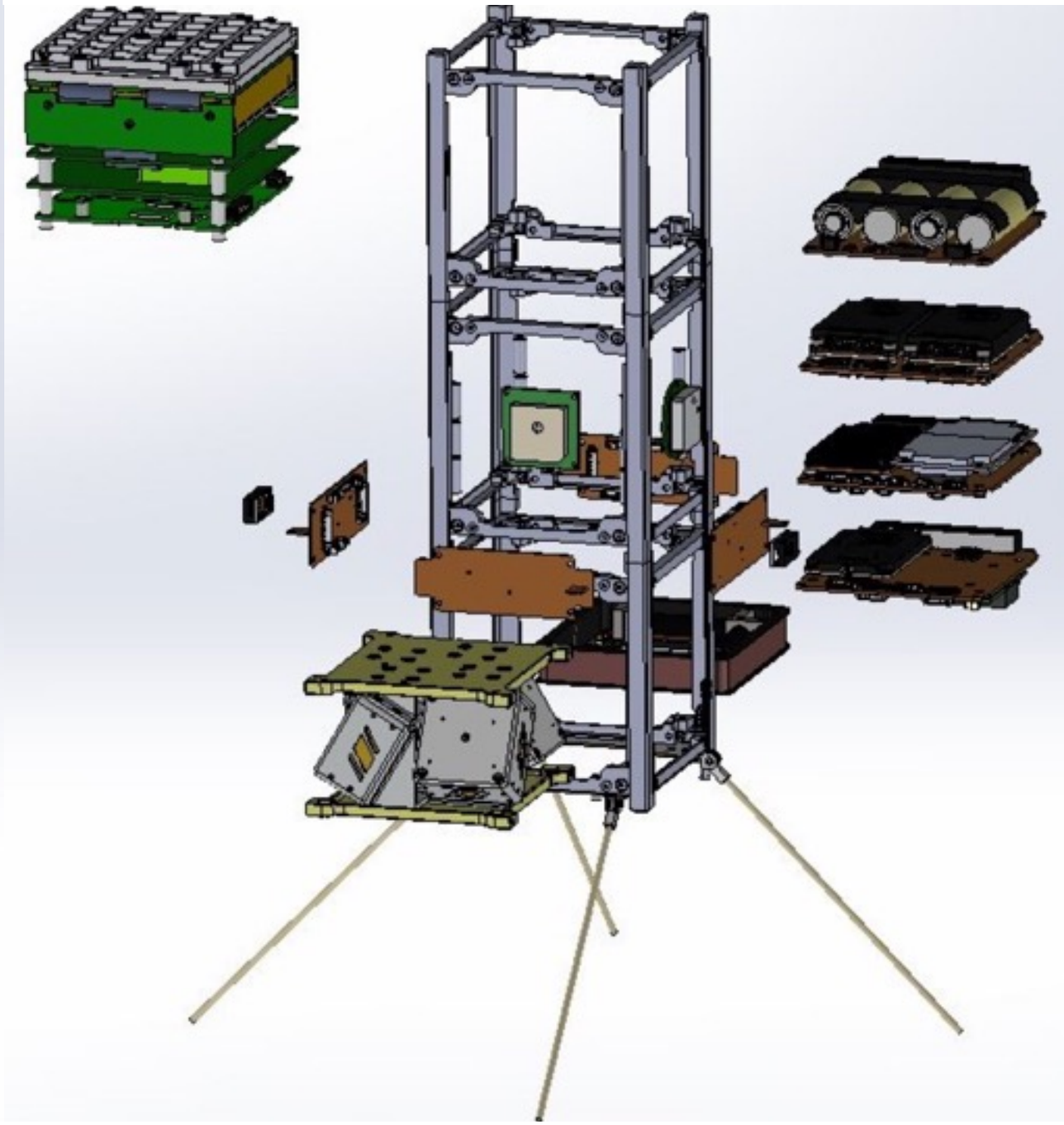
3U minimum, simplest basic configuration
≤100cm^2 detector

Spacecraft

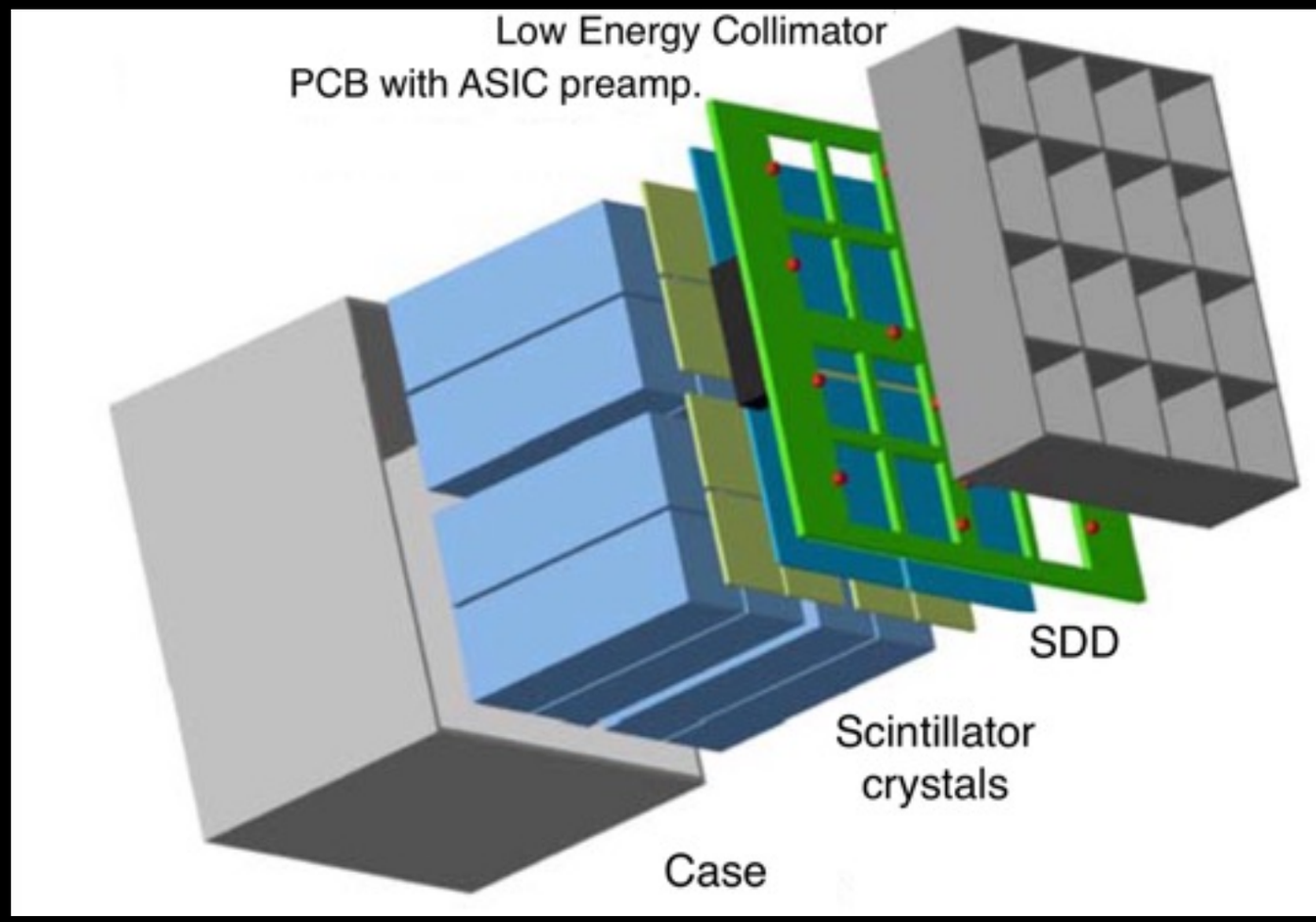
3U minimum, simplest basic configuration
≤100cm^2 detector

6U more performing configuration
≤200cm^2 detector, more accurate GPS, more accurate AOCS





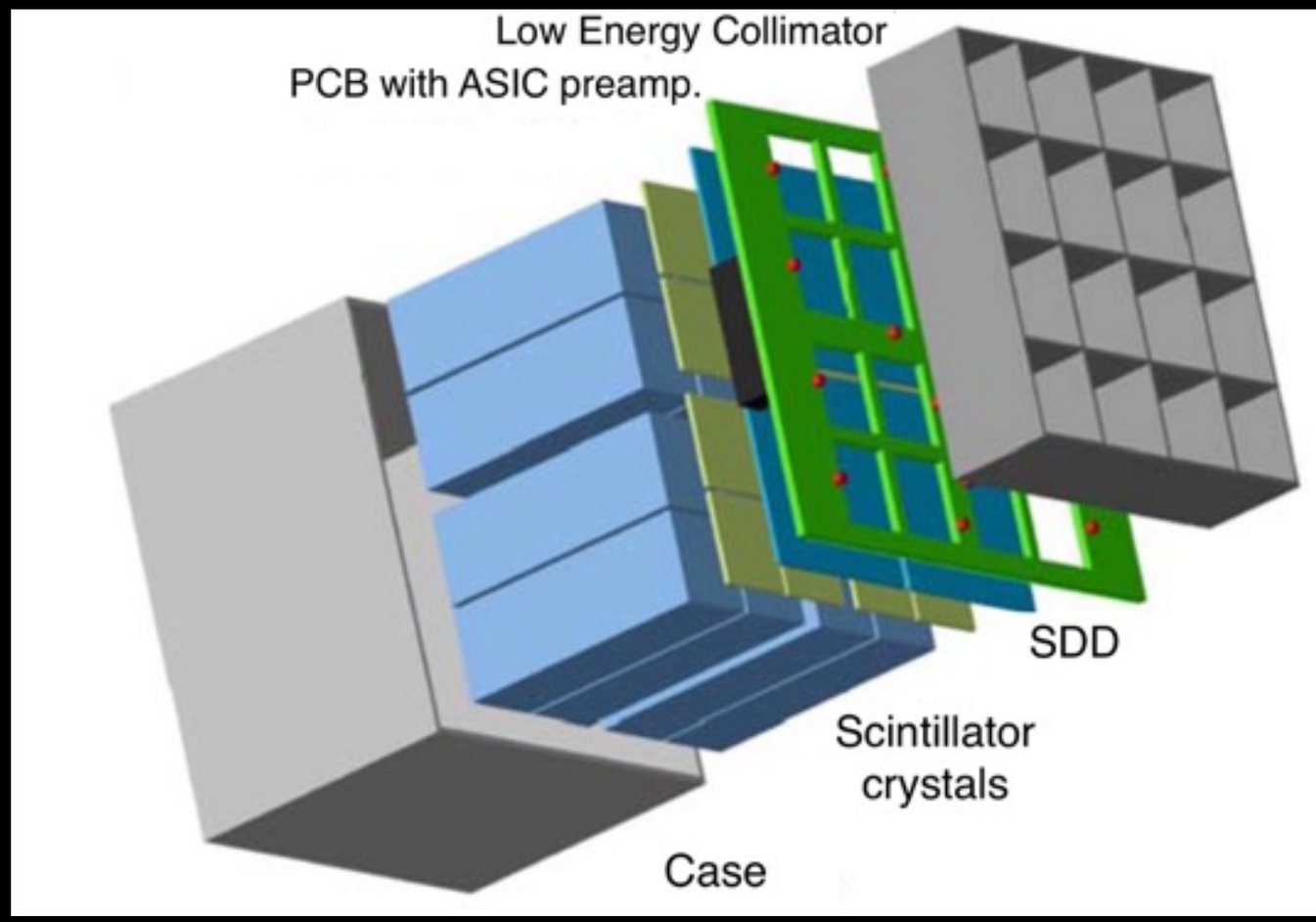
Payload



Fuschino+2018
Evangelista+2018
Campana+2018

Payload

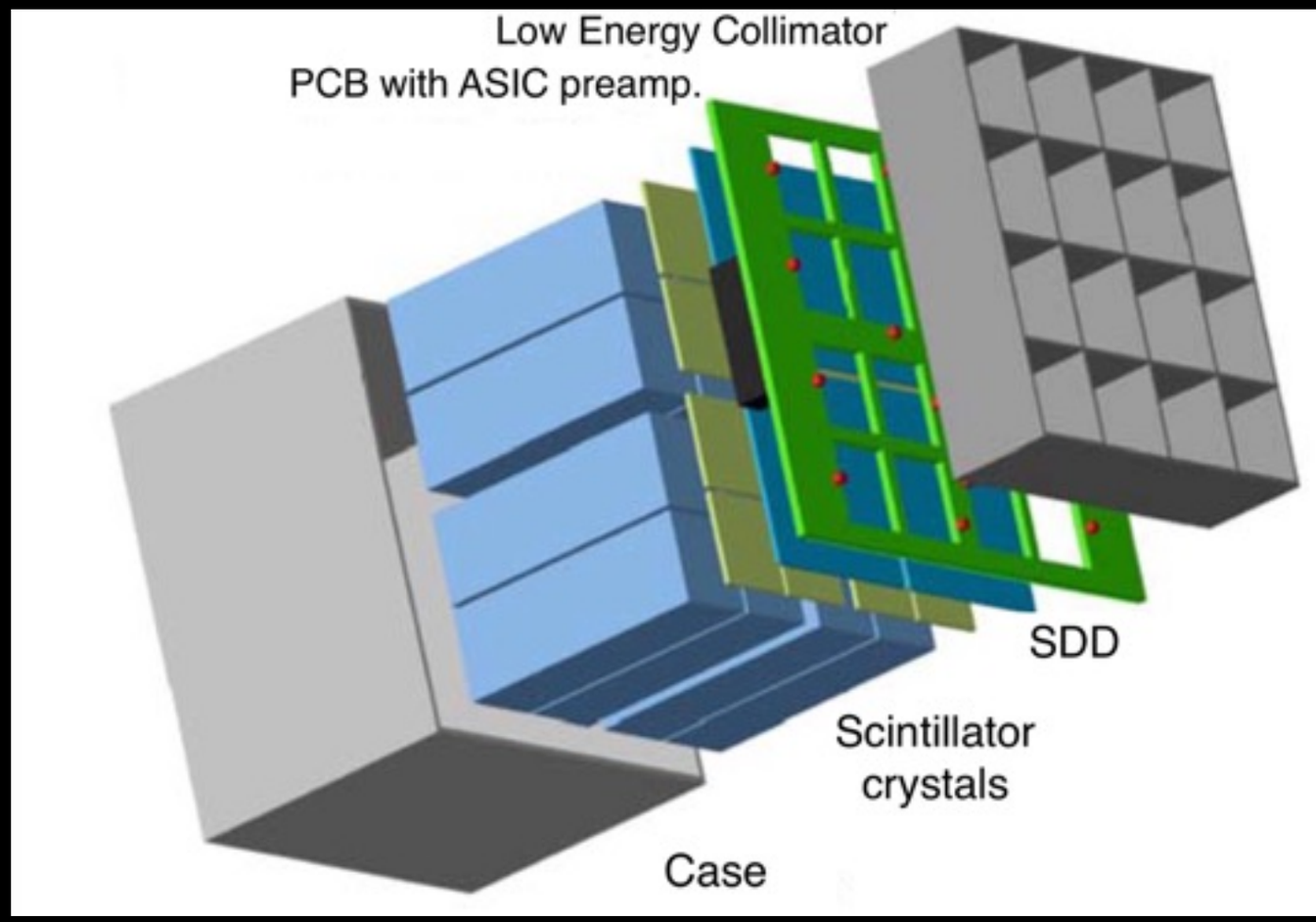
- Scintillator cristal GAGG
  Photo detector, SDD



Fuschino+2018
Evangelista+2018
Campana+2018

Payload

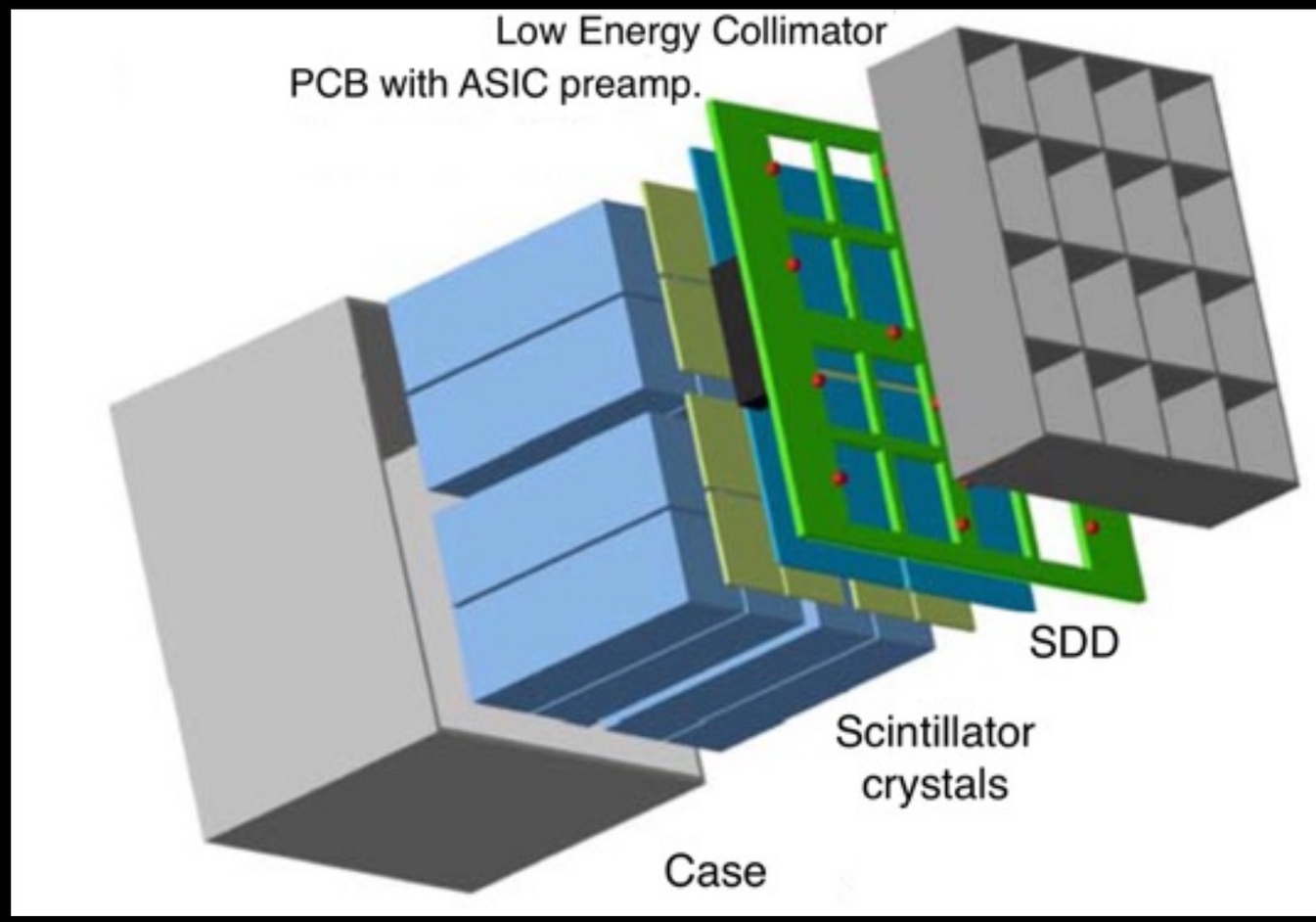
- Scintillator cristal GAGG
  Photo detector, SDD
- 5-300 keV (3-1000 keV)



Fuschino+2018
Evangelista+2018
Campana+2018

Payload

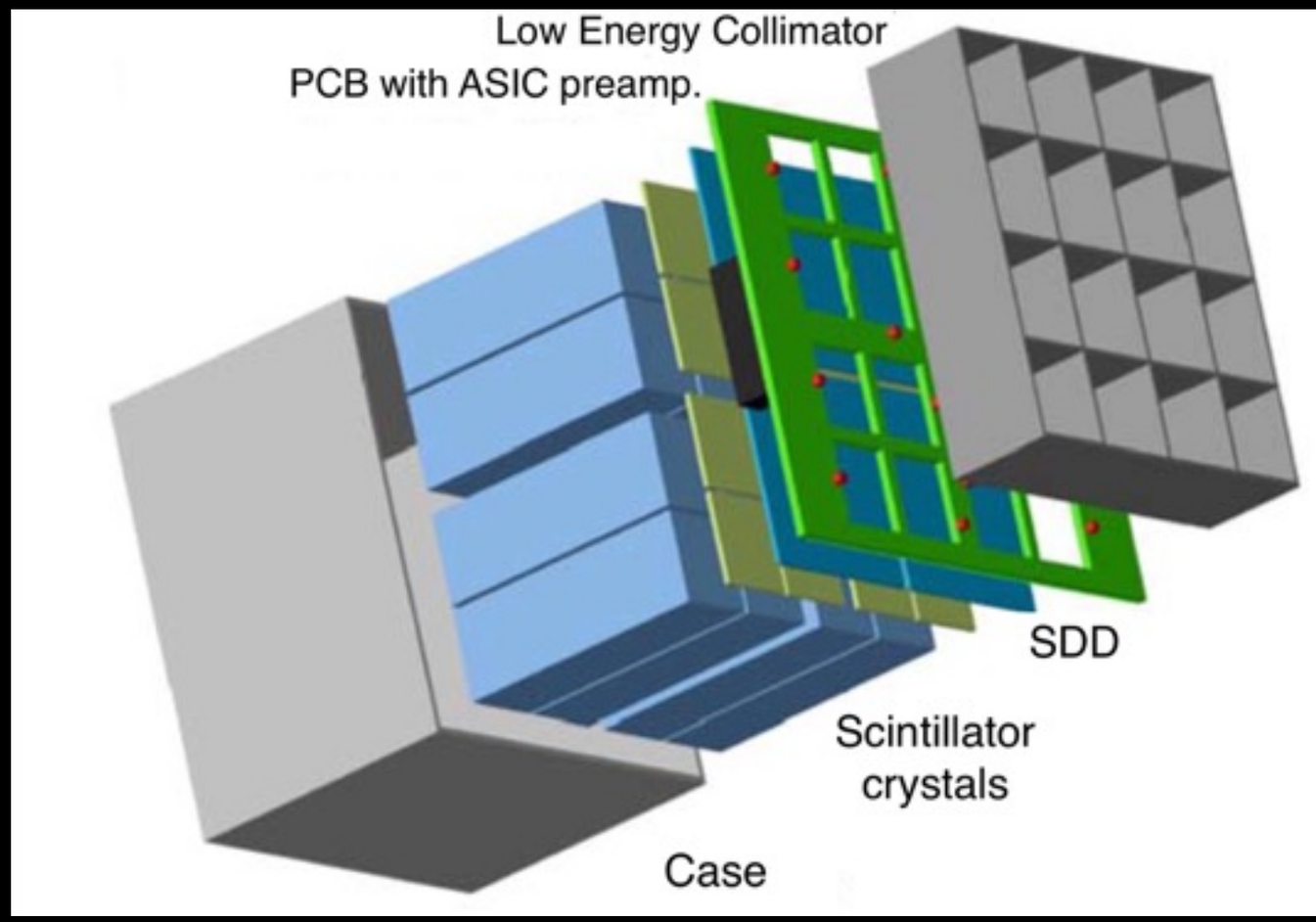
- Scintillator cristal GAGG
  Photo detector, SDD
- 5-300 keV (3-1000 keV)
- ≥50 cm^2 coll. area



Fuschino+2018
Evangelista+2018
Campana+2018

Payload

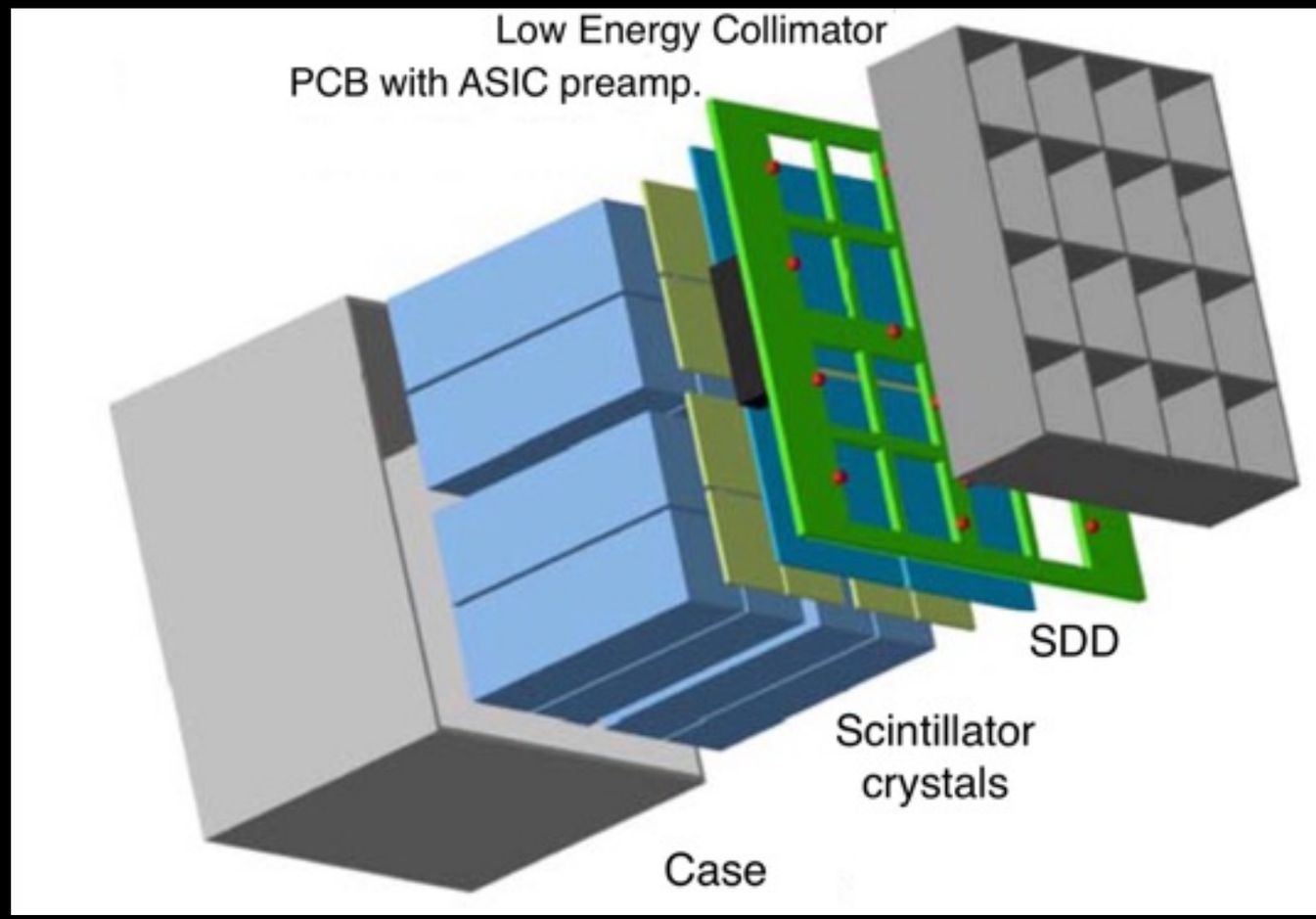
- Scintillator cristal GAGG
  Photo detector, SDD
- 5-300 keV (3-1000 keV)
- ≥50 cm^2 coll. area
- a few st FOV



Fuschino+2018
Evangelista+2018
Campana+2018

Payload

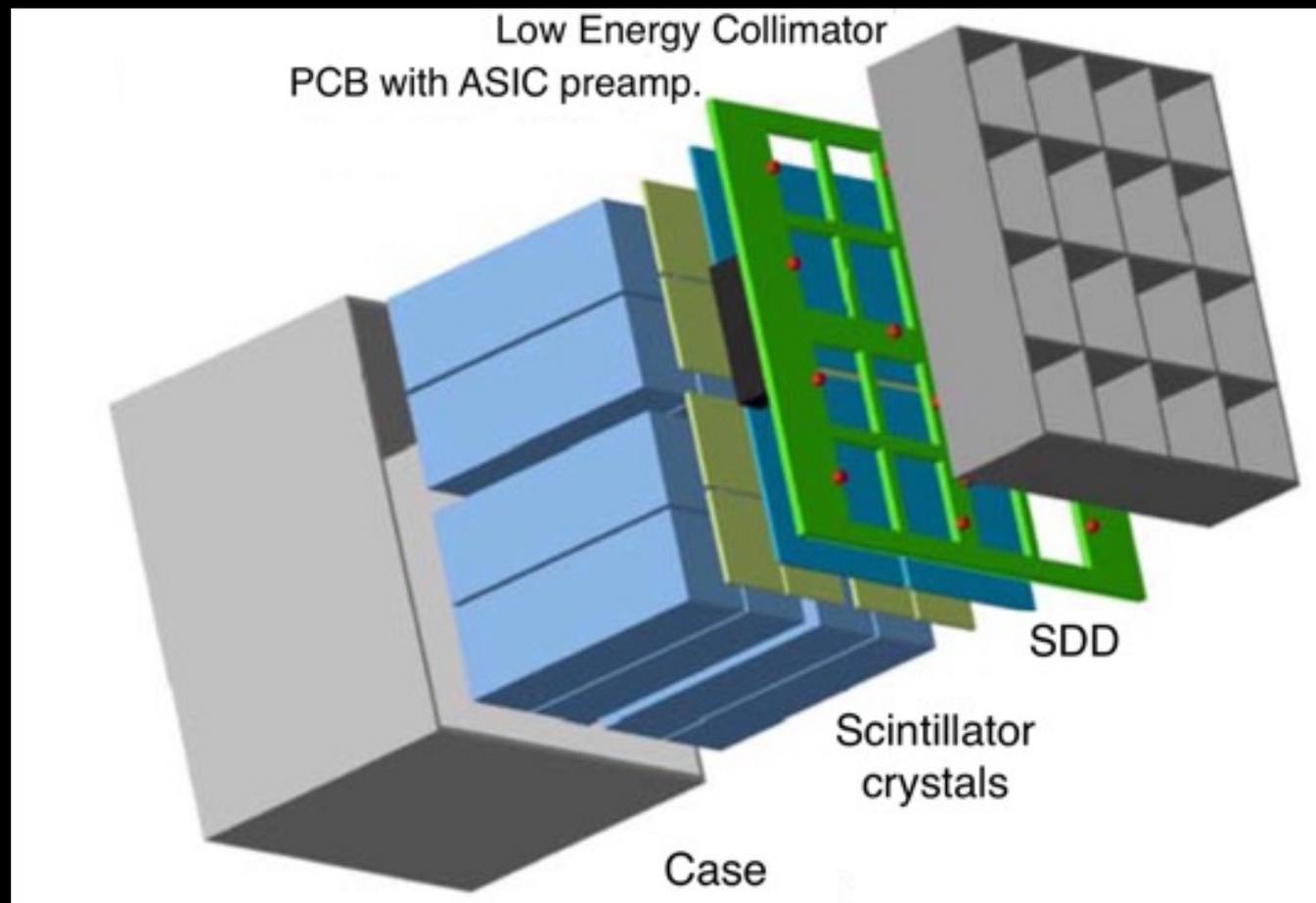
- Scintillator cristal GAGG
  Photo detector, SDD
- 5-300 keV (3-1000 keV)
- ≥50 cm^2 coll. area
- a few st FOV
- Temporal res. ≤300 nsec



Fuschino+2018
Evangelista+2018
Campana+2018

Payload

- Scintillator cristal GAGG
  Photo detector, SDD
- 5-300 keV (3-1000 keV)
- ≥50 cm^2 coll. area
- a few st FOV
- Temporal res. ≤300 nsec
- ~1.8kg



Fuschino+2018
Evangelista+2018
Campana+2018

From ppt to CAD to real stuff…

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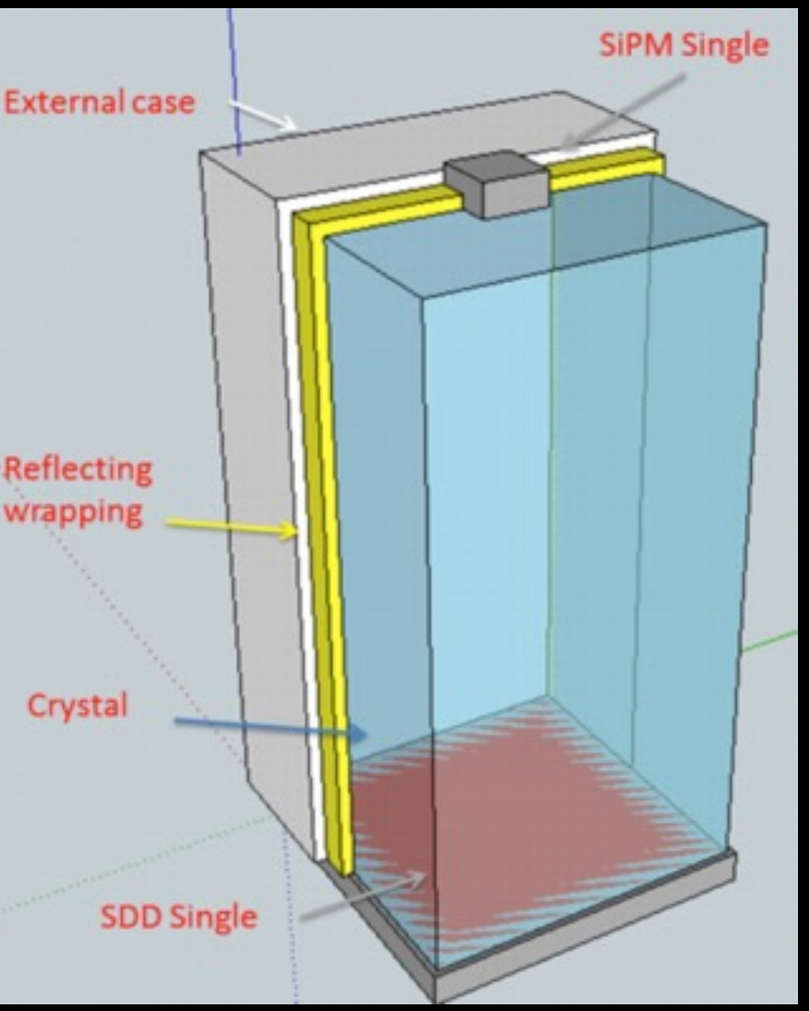

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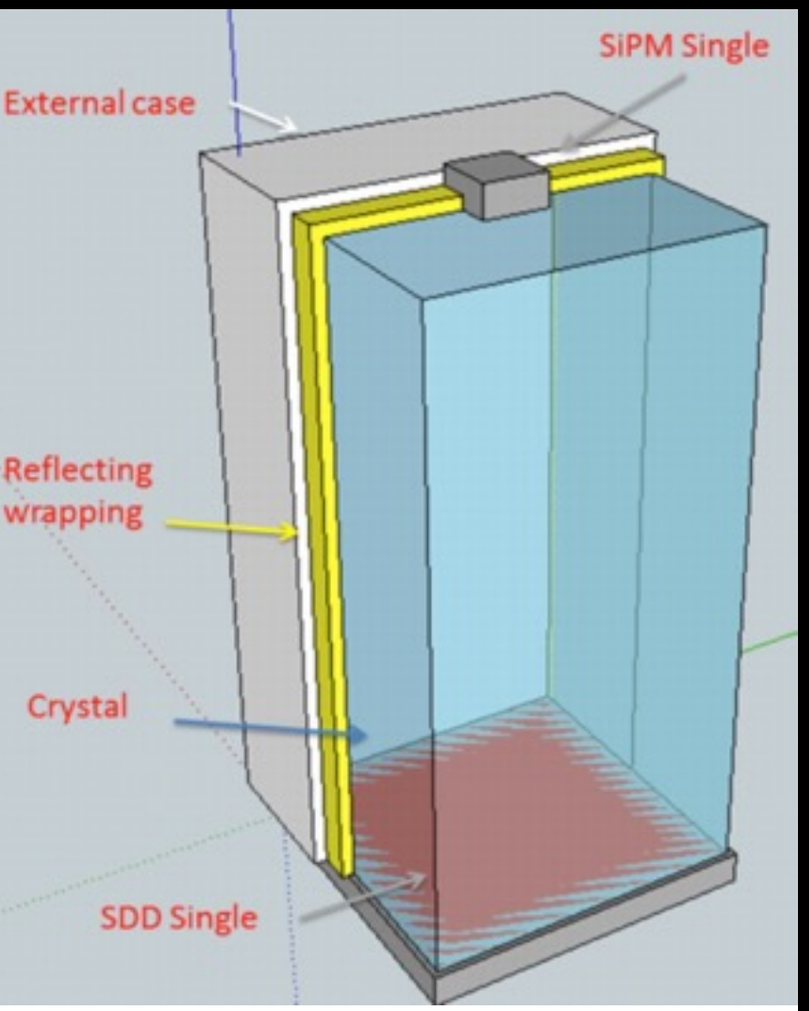

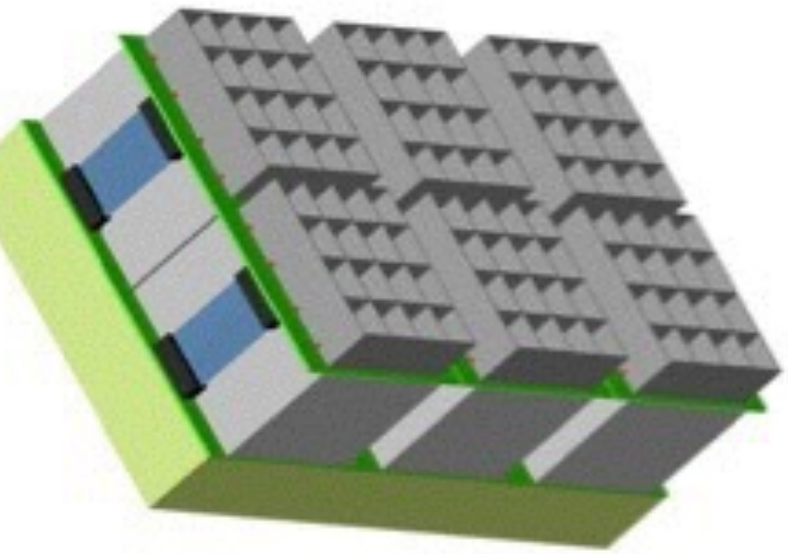

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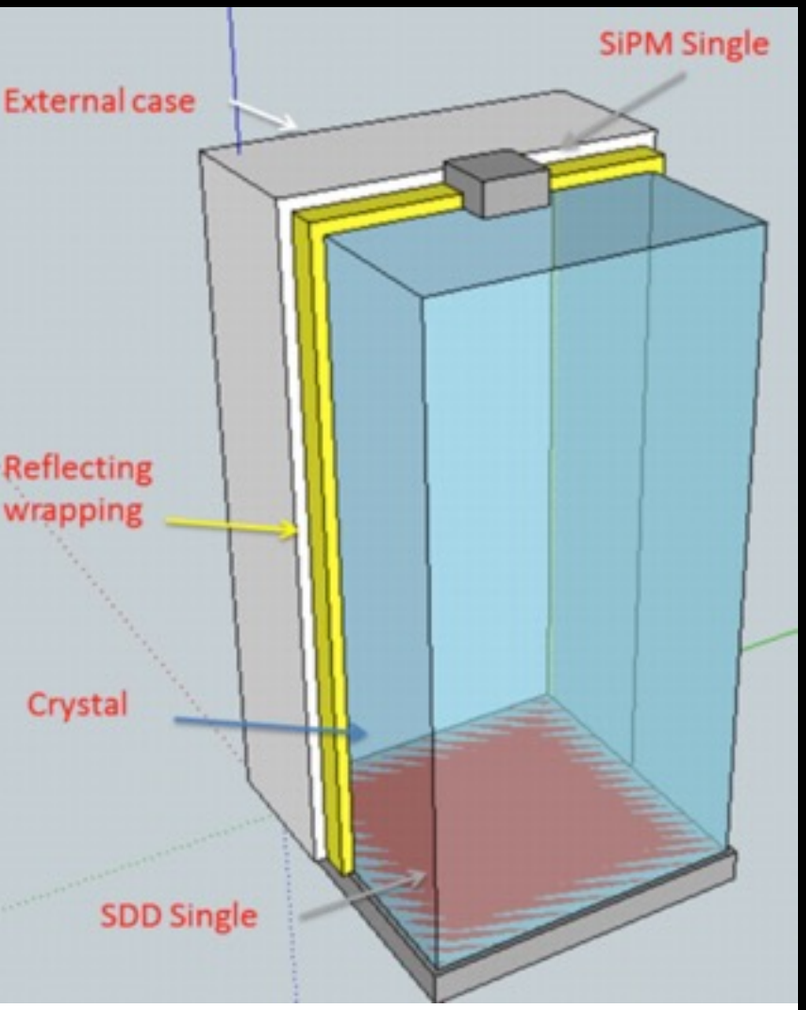

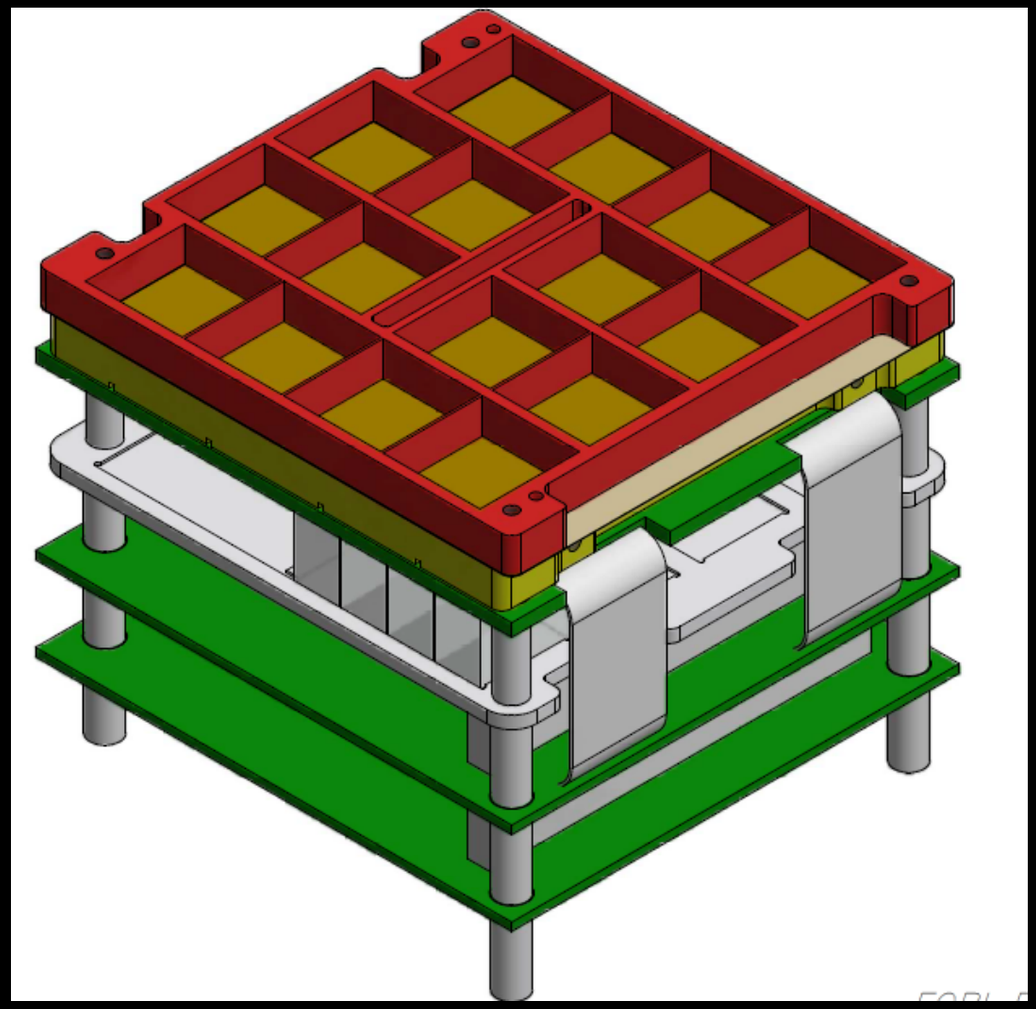

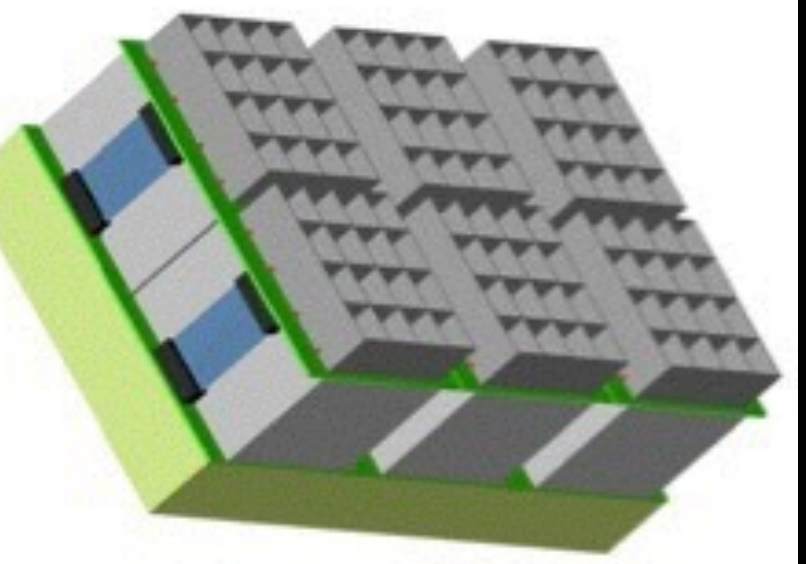

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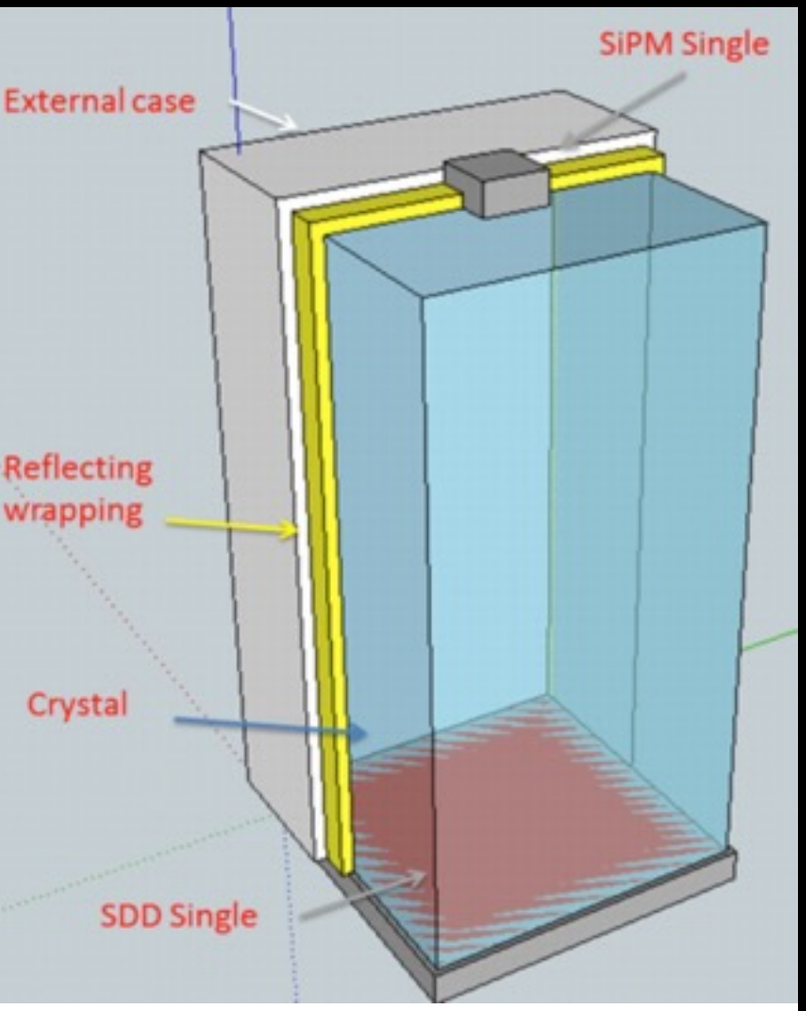

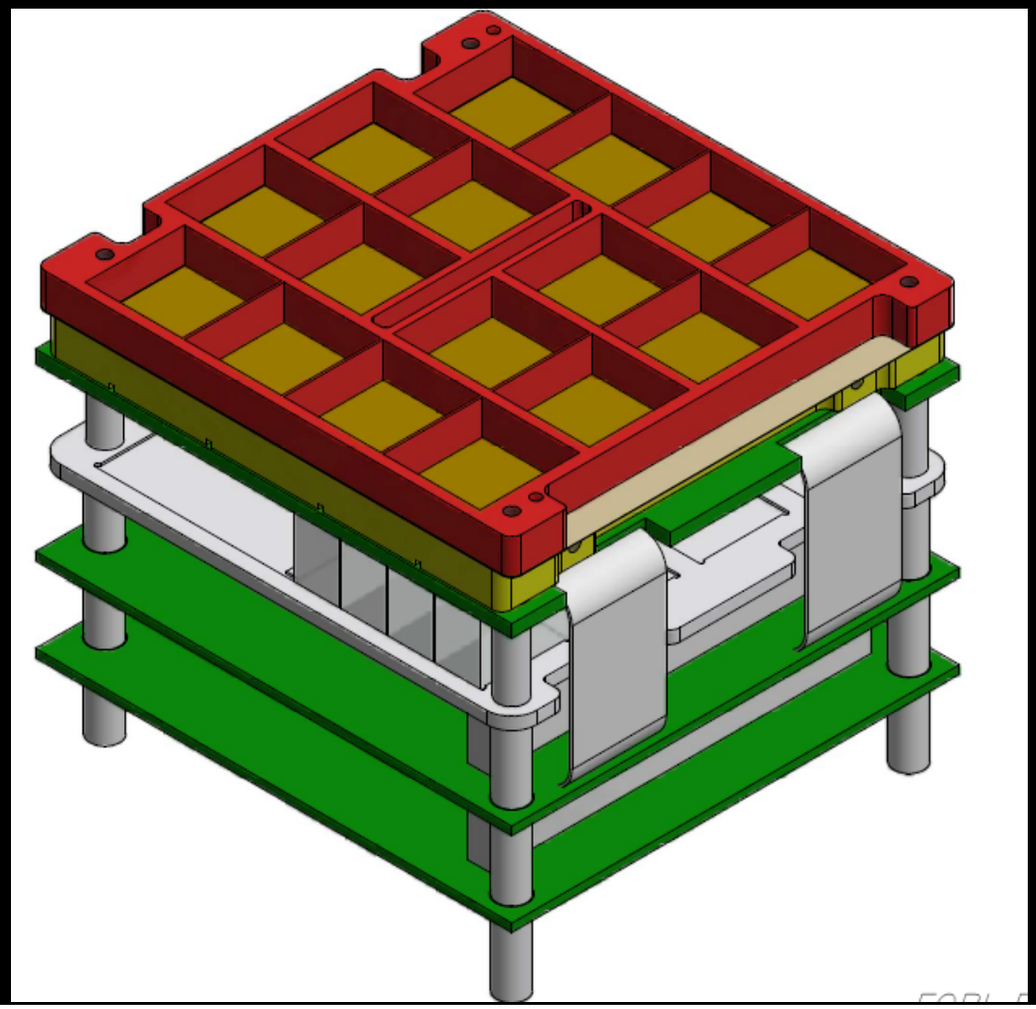

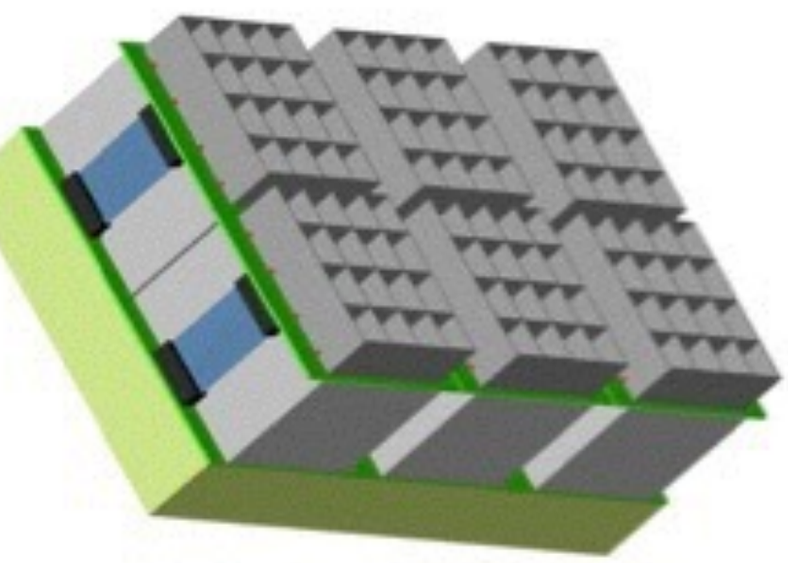

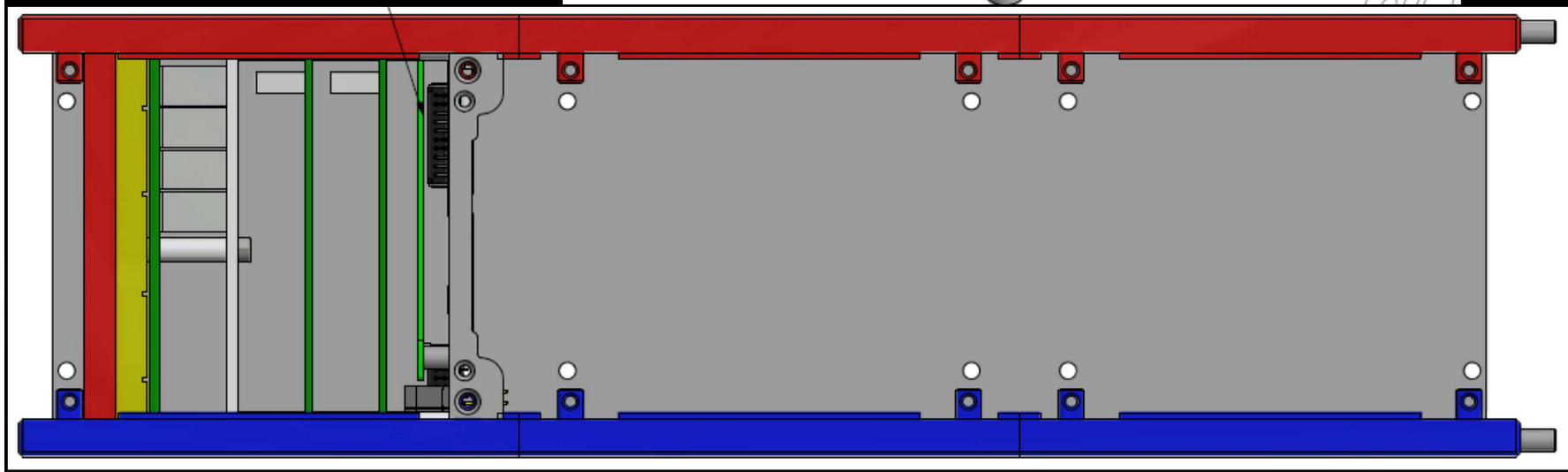

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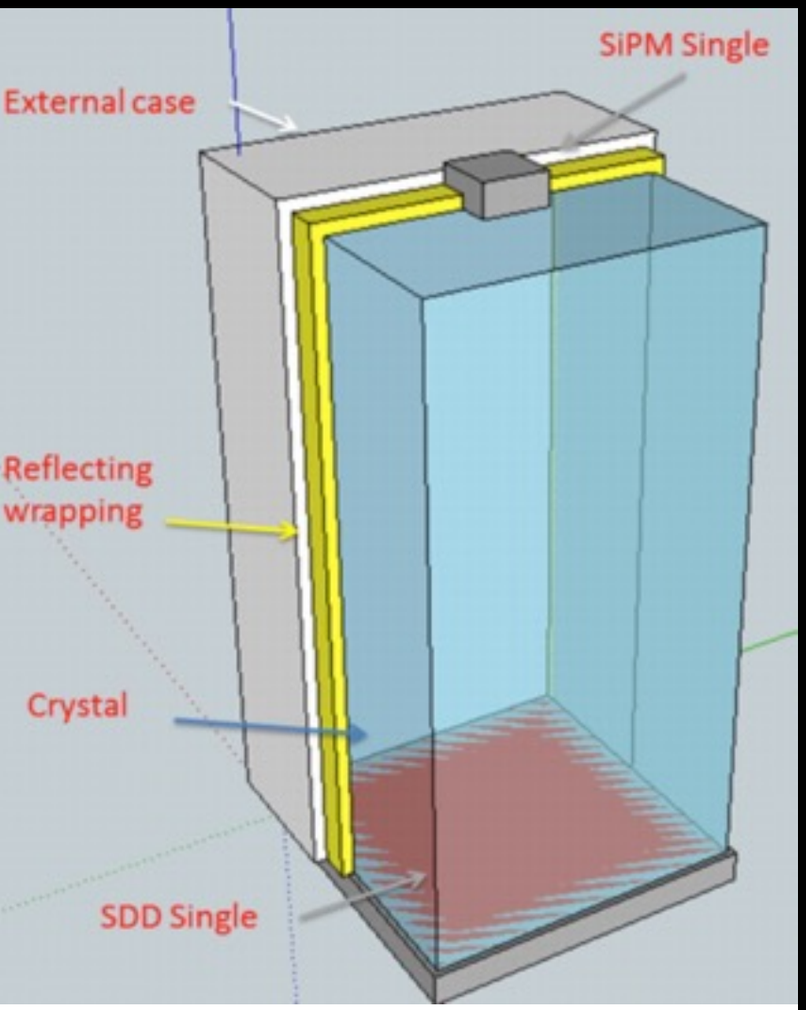

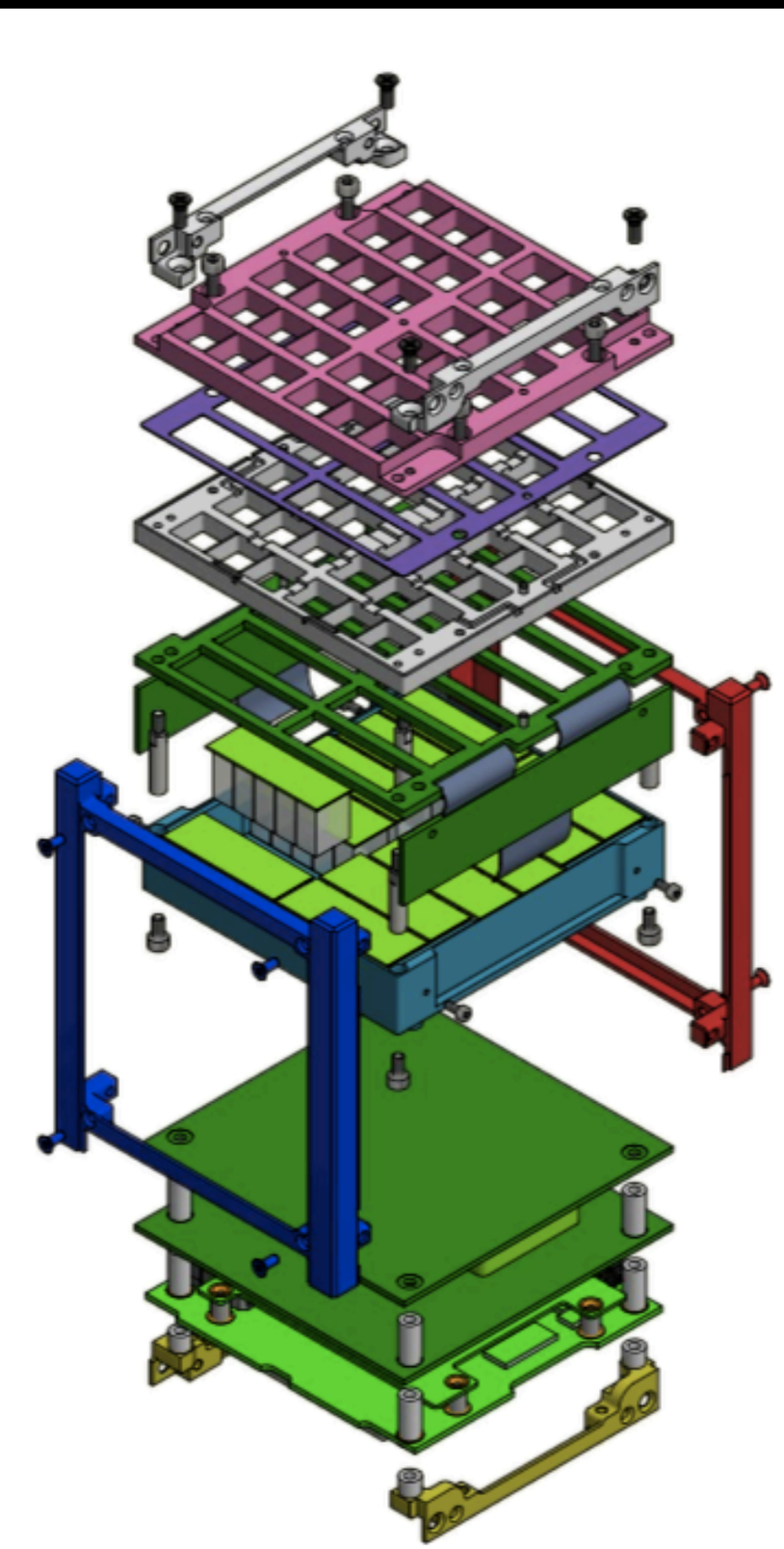

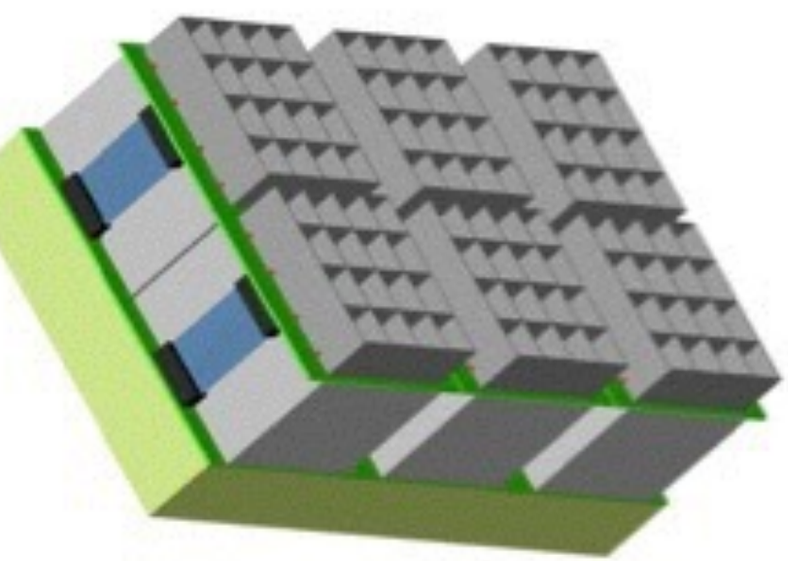

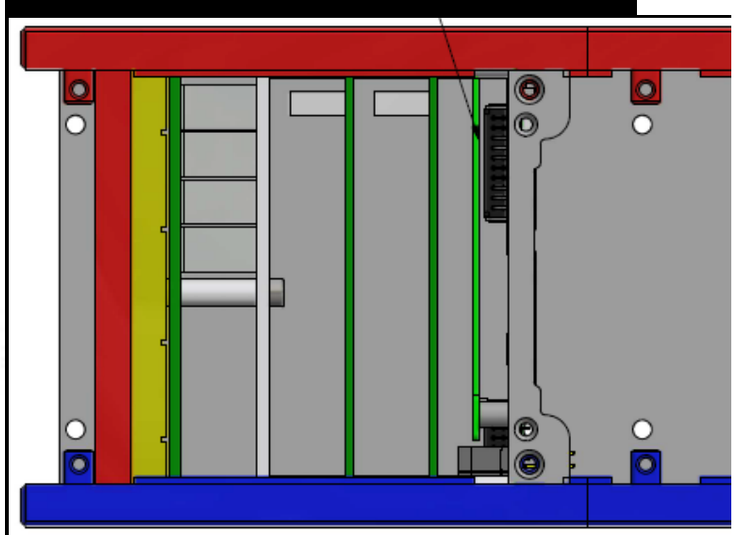

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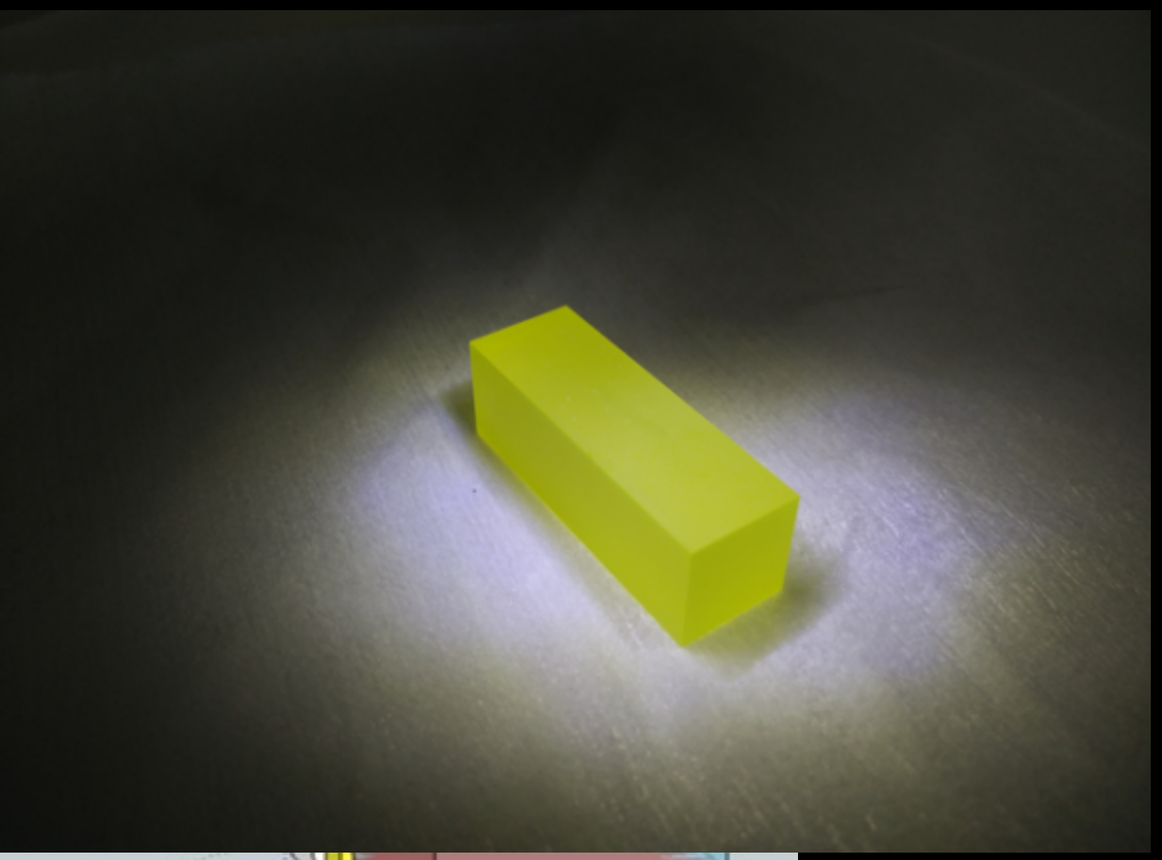

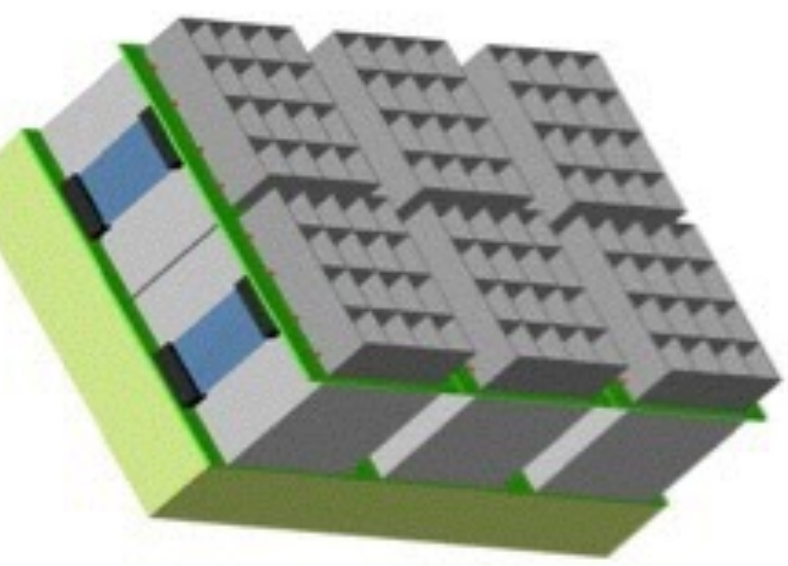

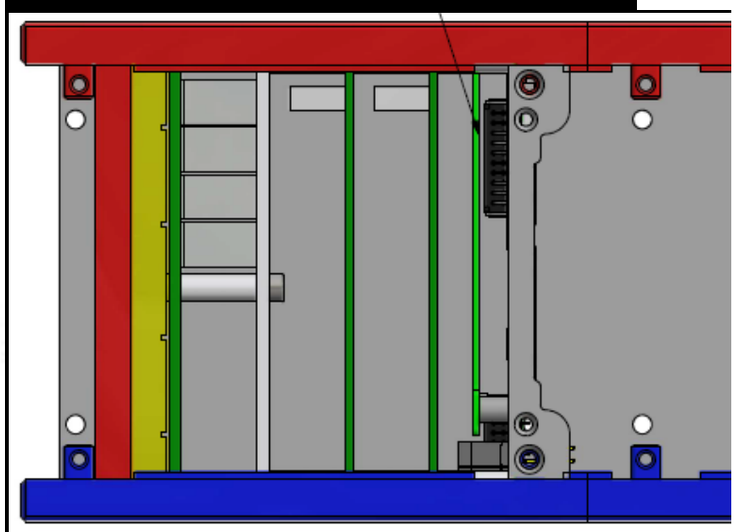

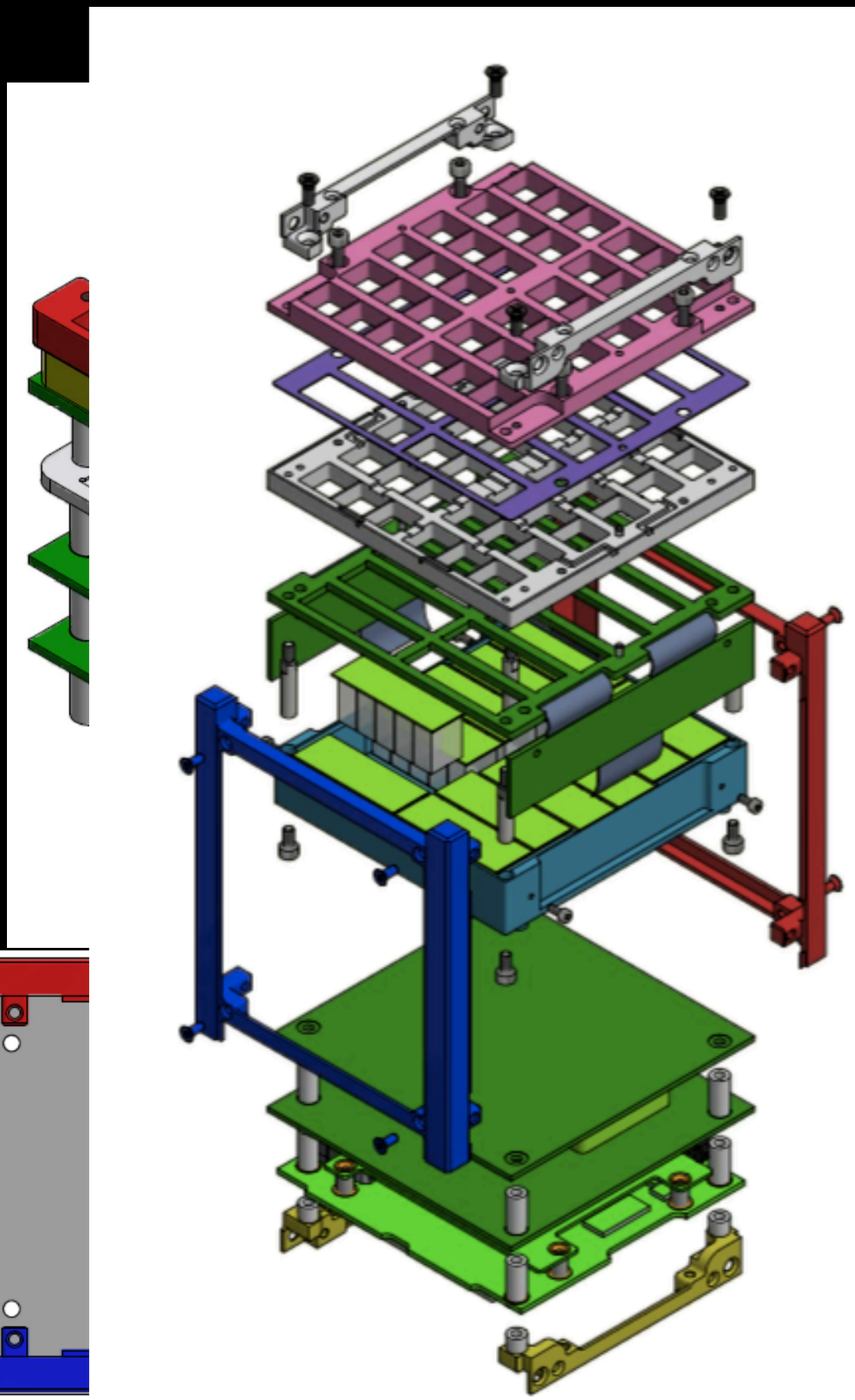

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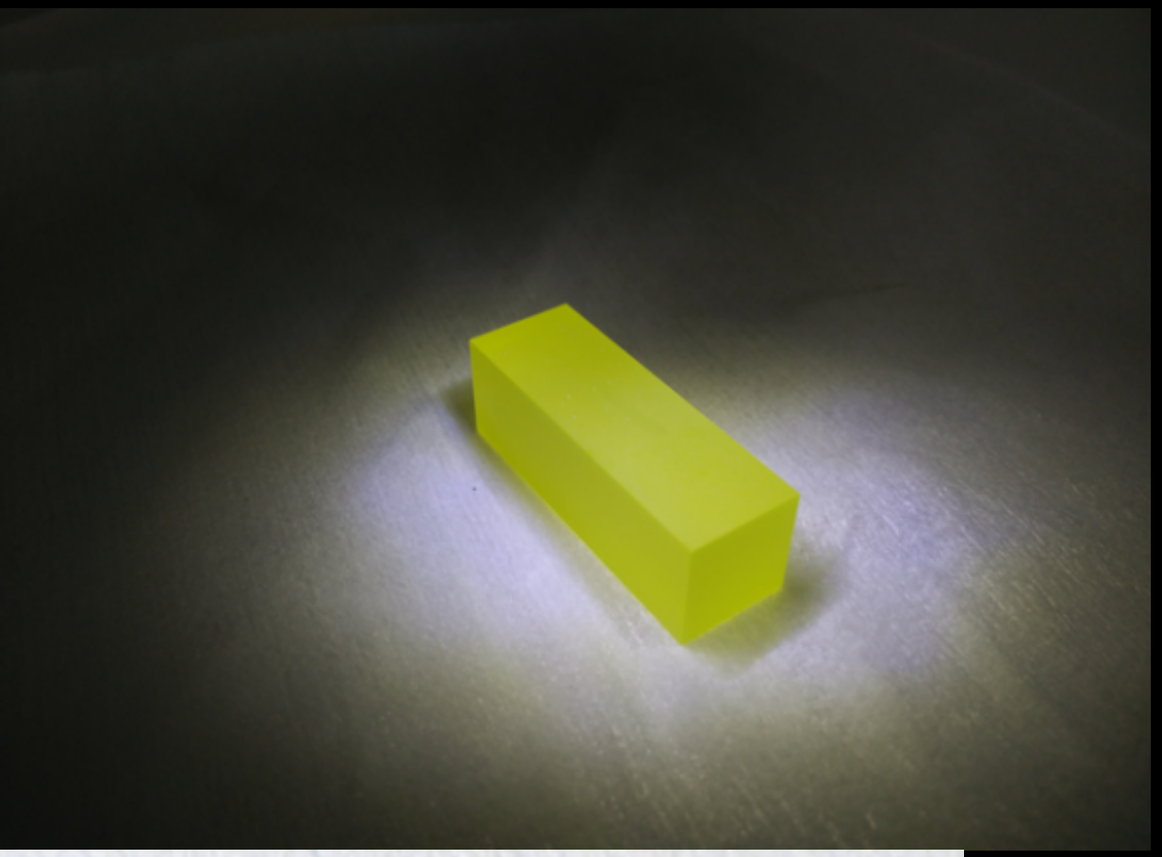

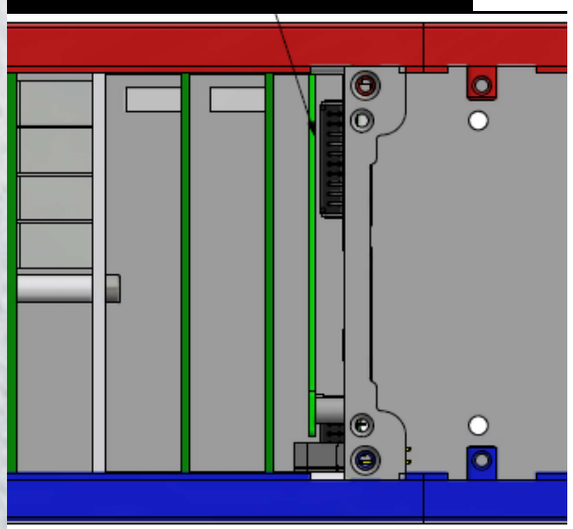

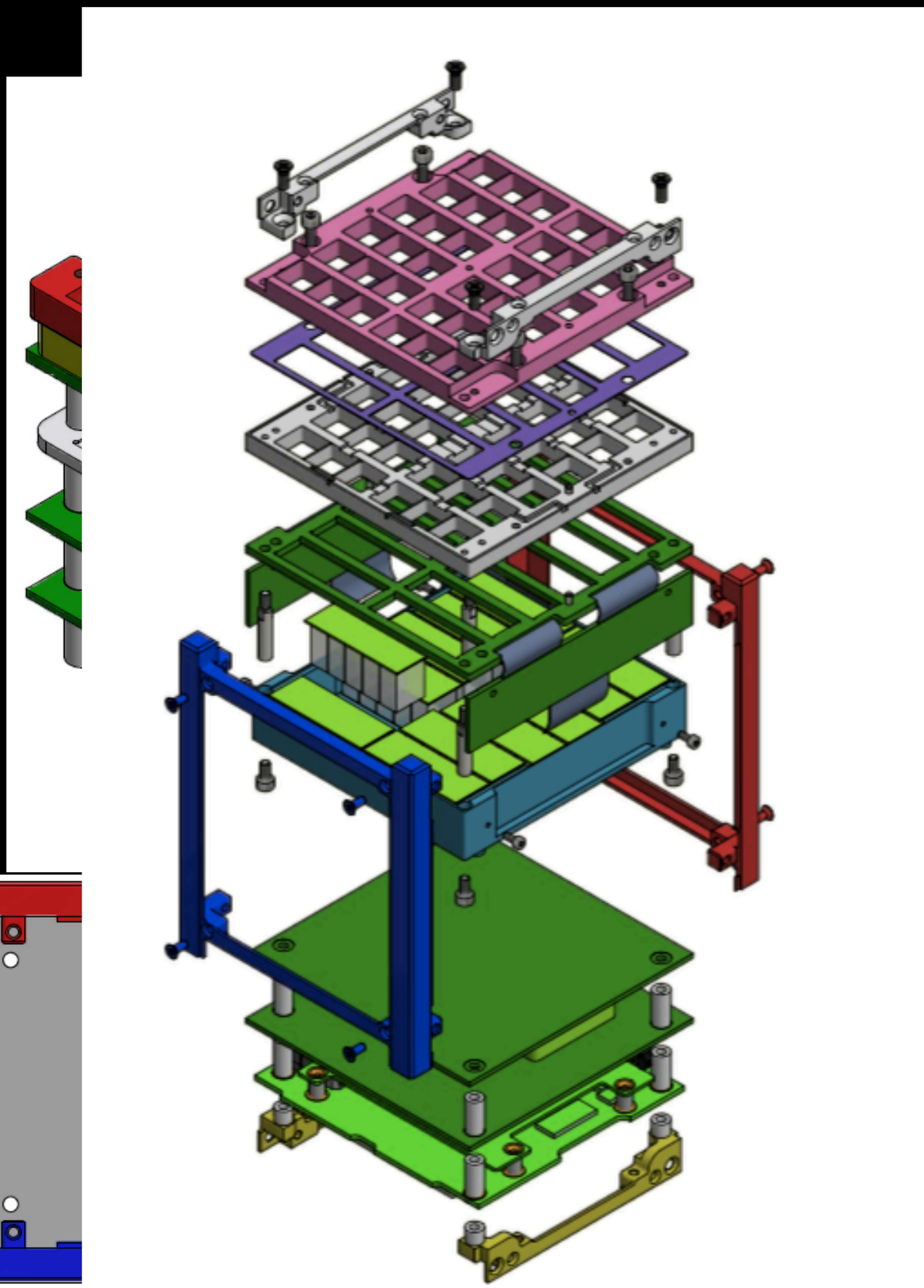

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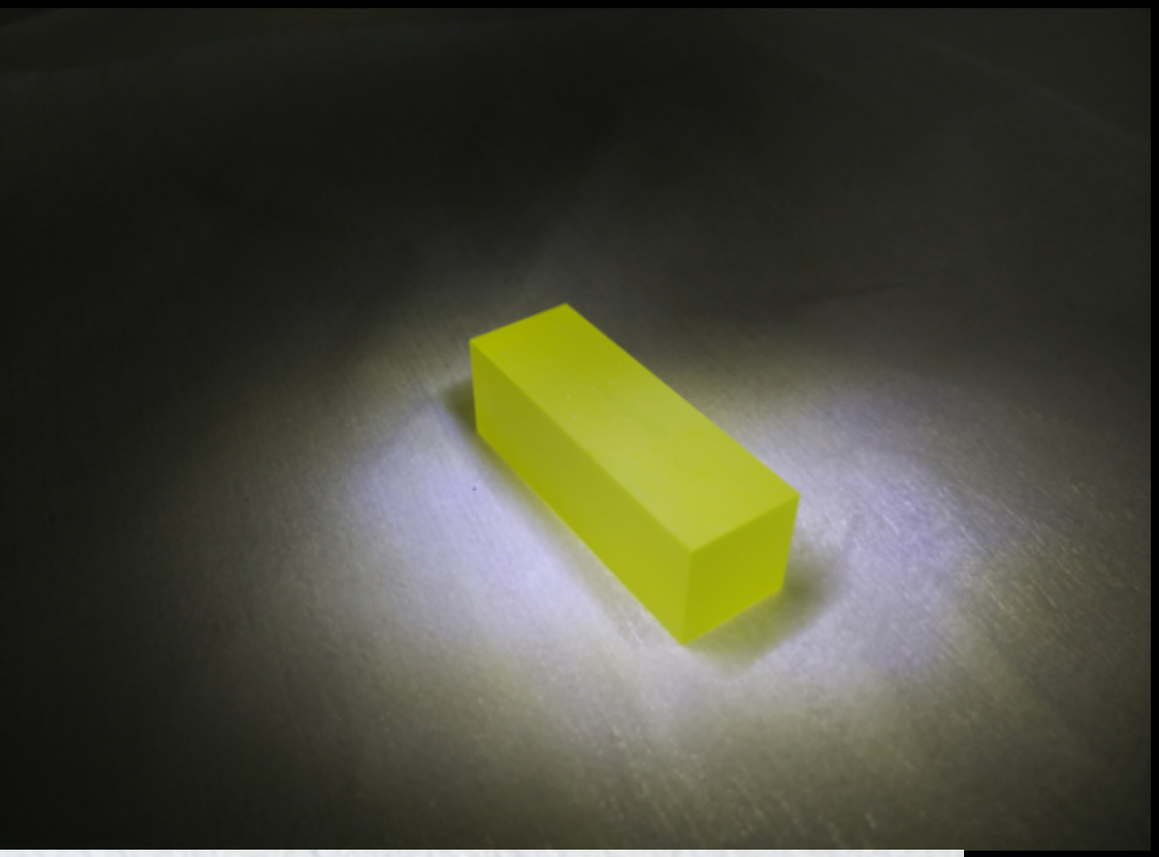

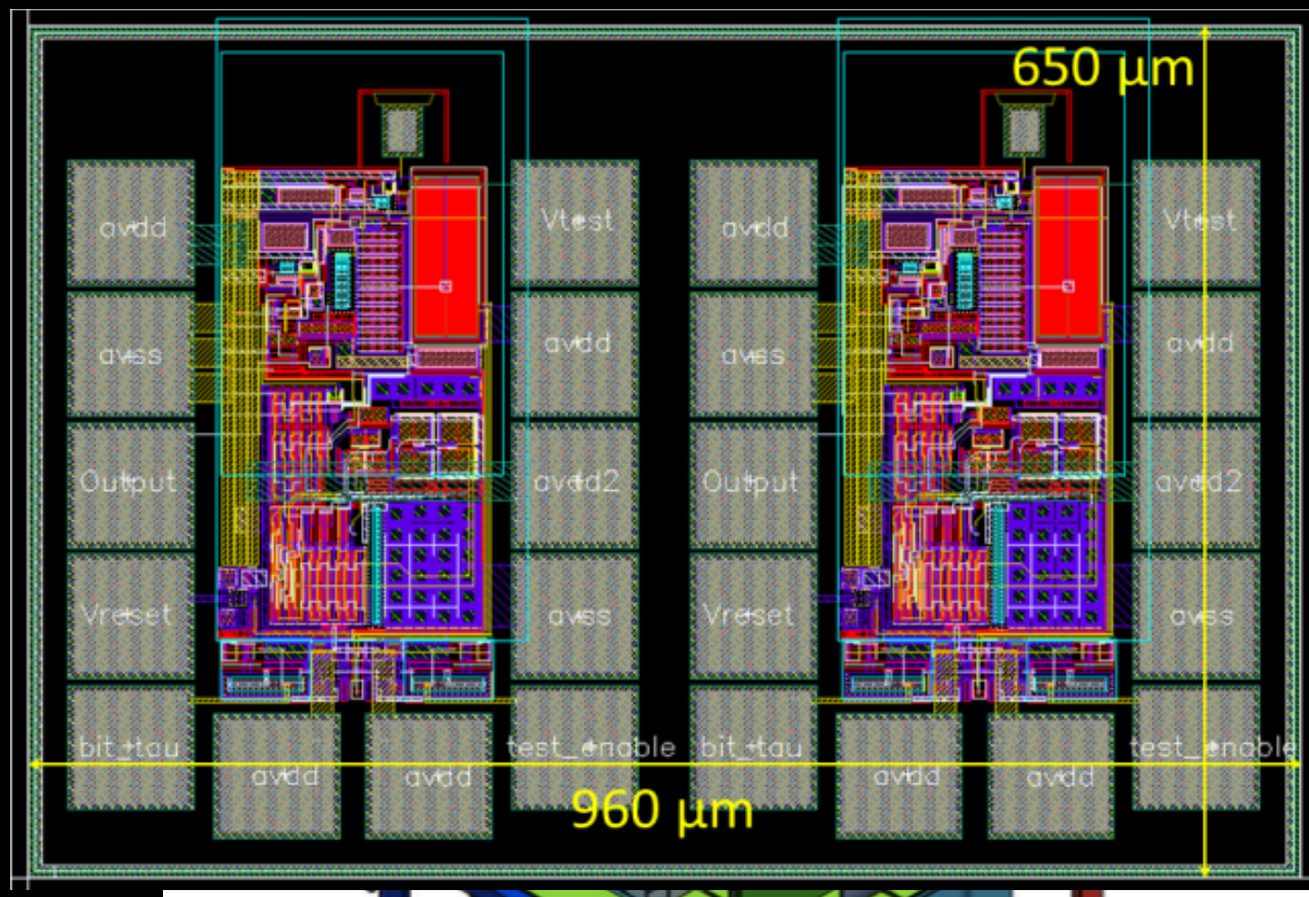

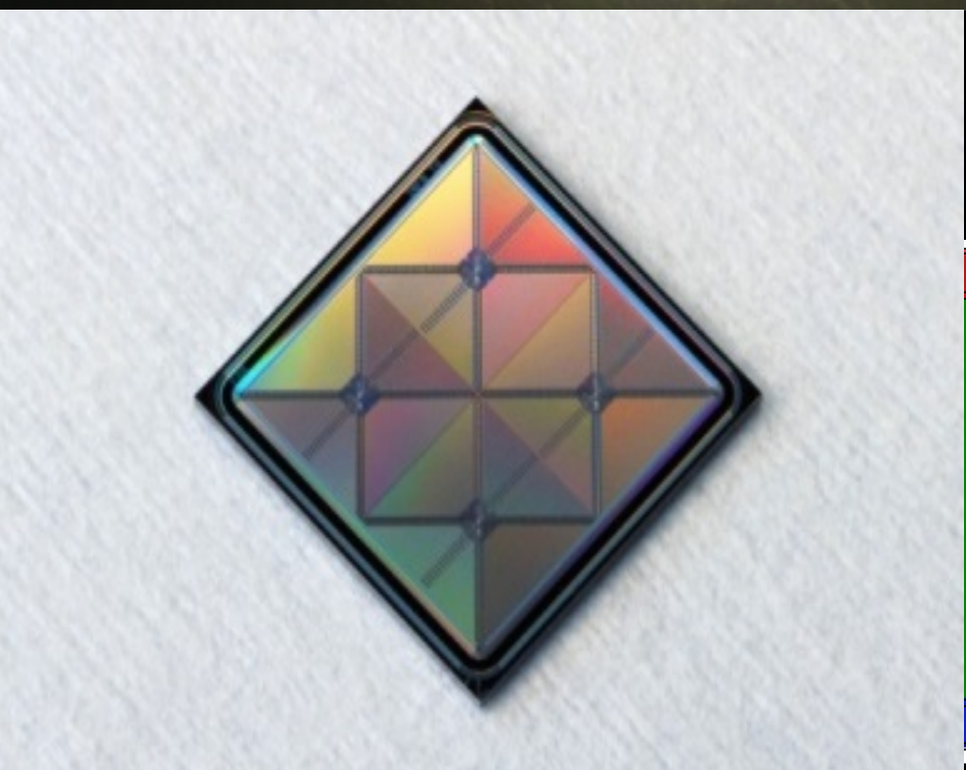

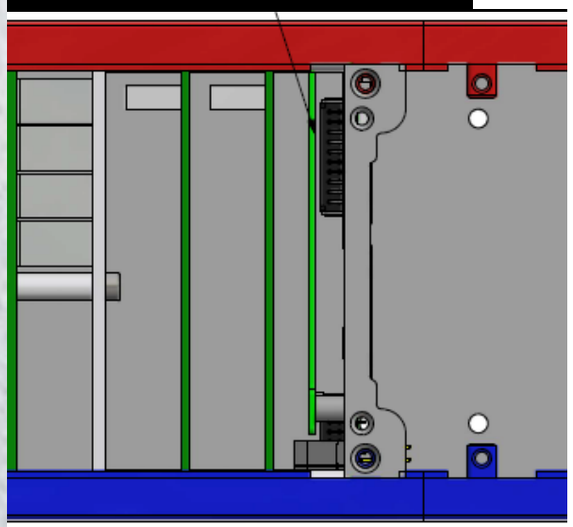

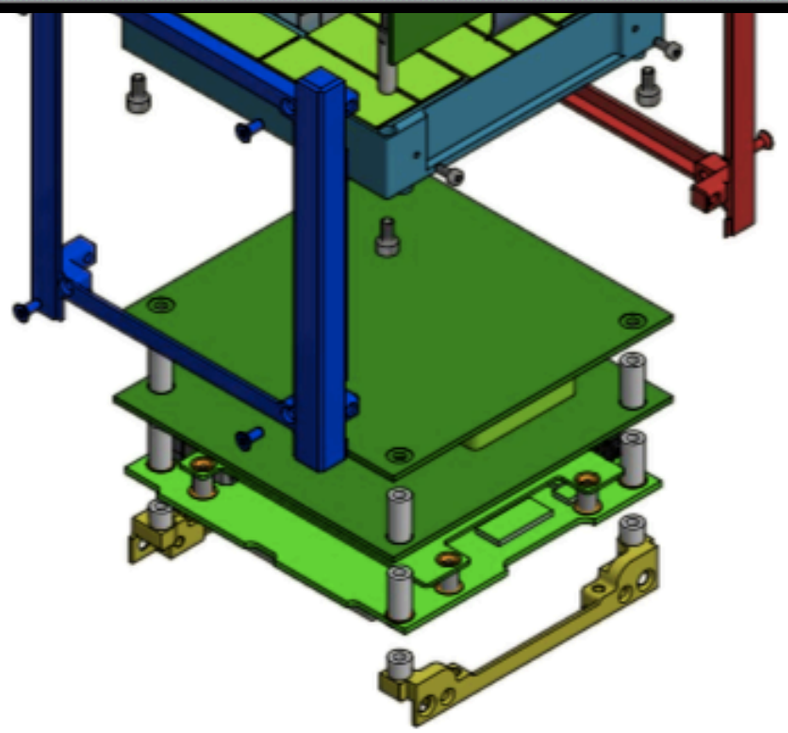

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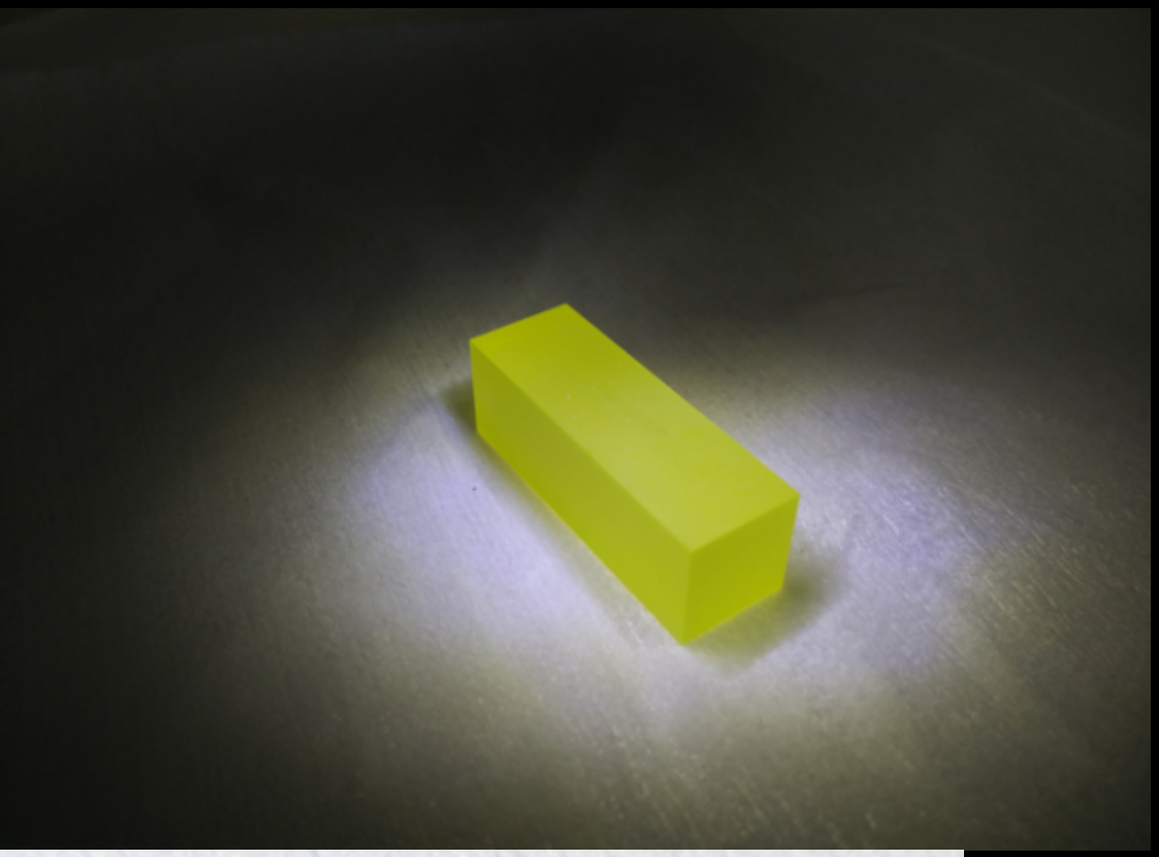
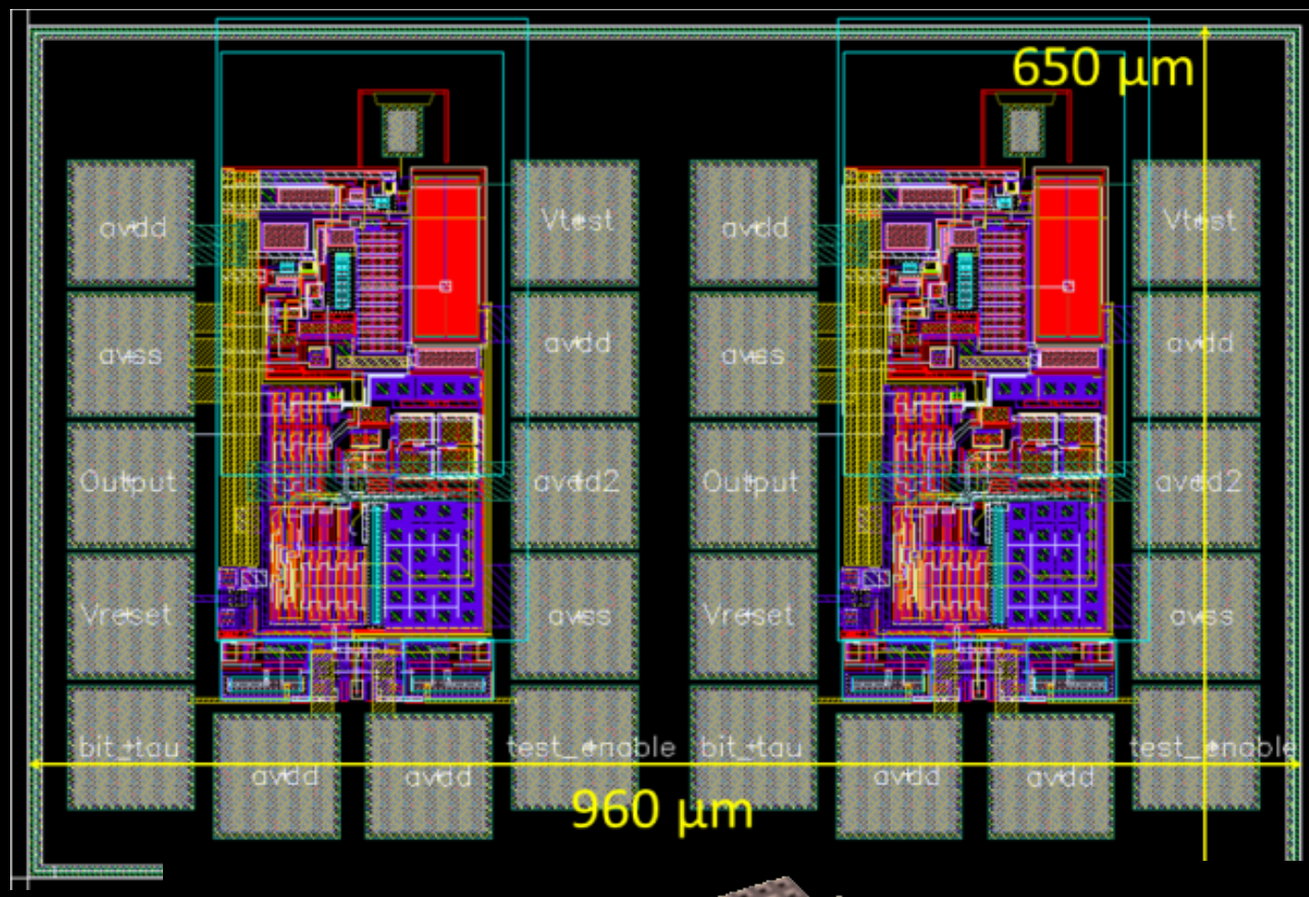
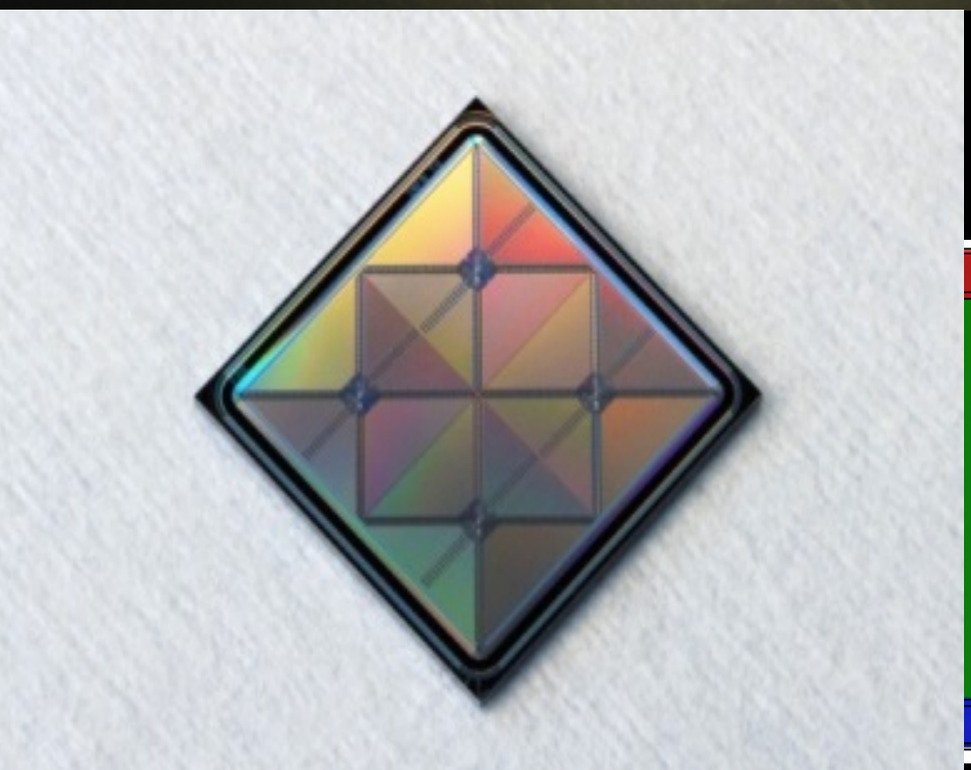
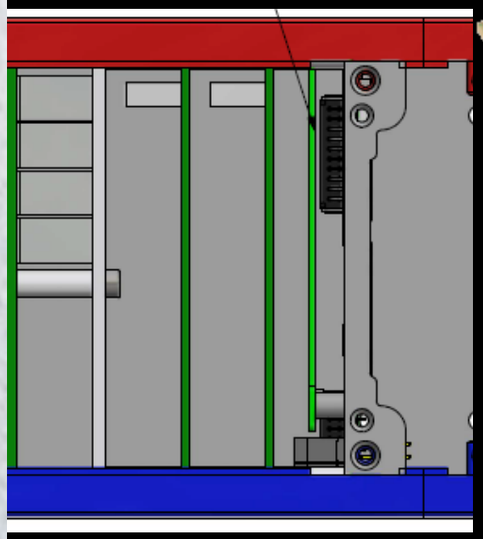
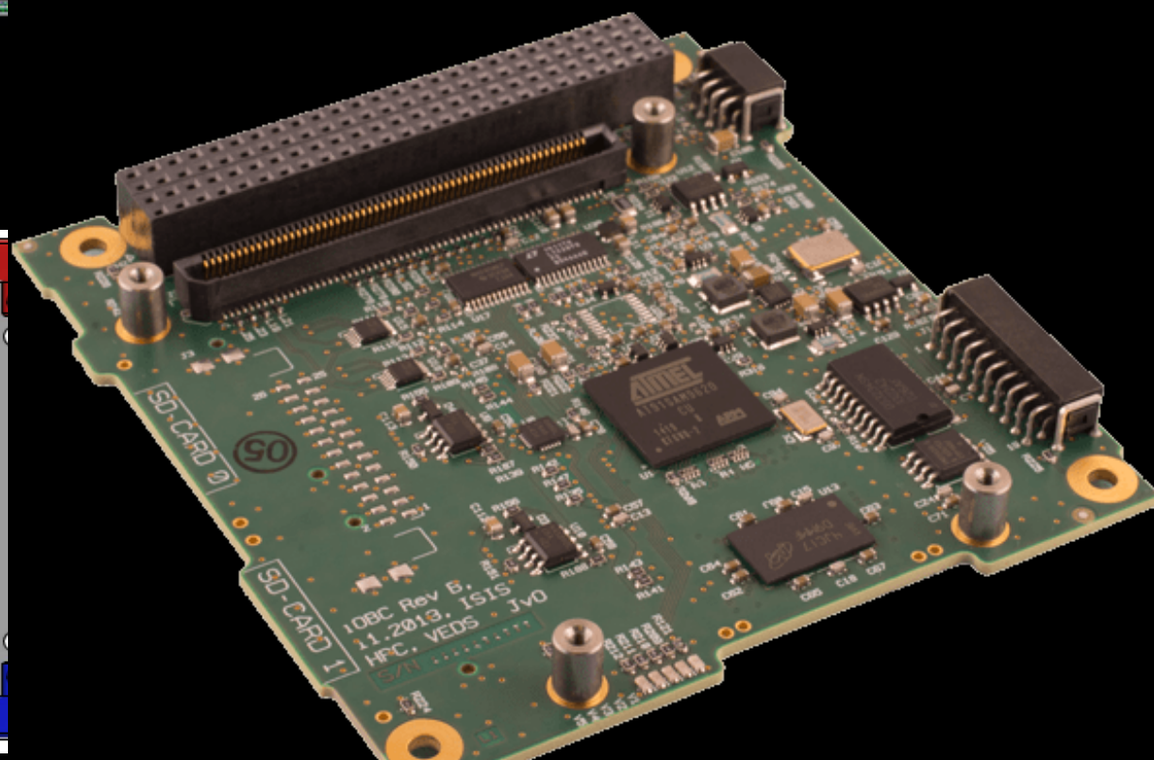










HERMES performances

Assumptions:

Instrument ~ 1 GBM module

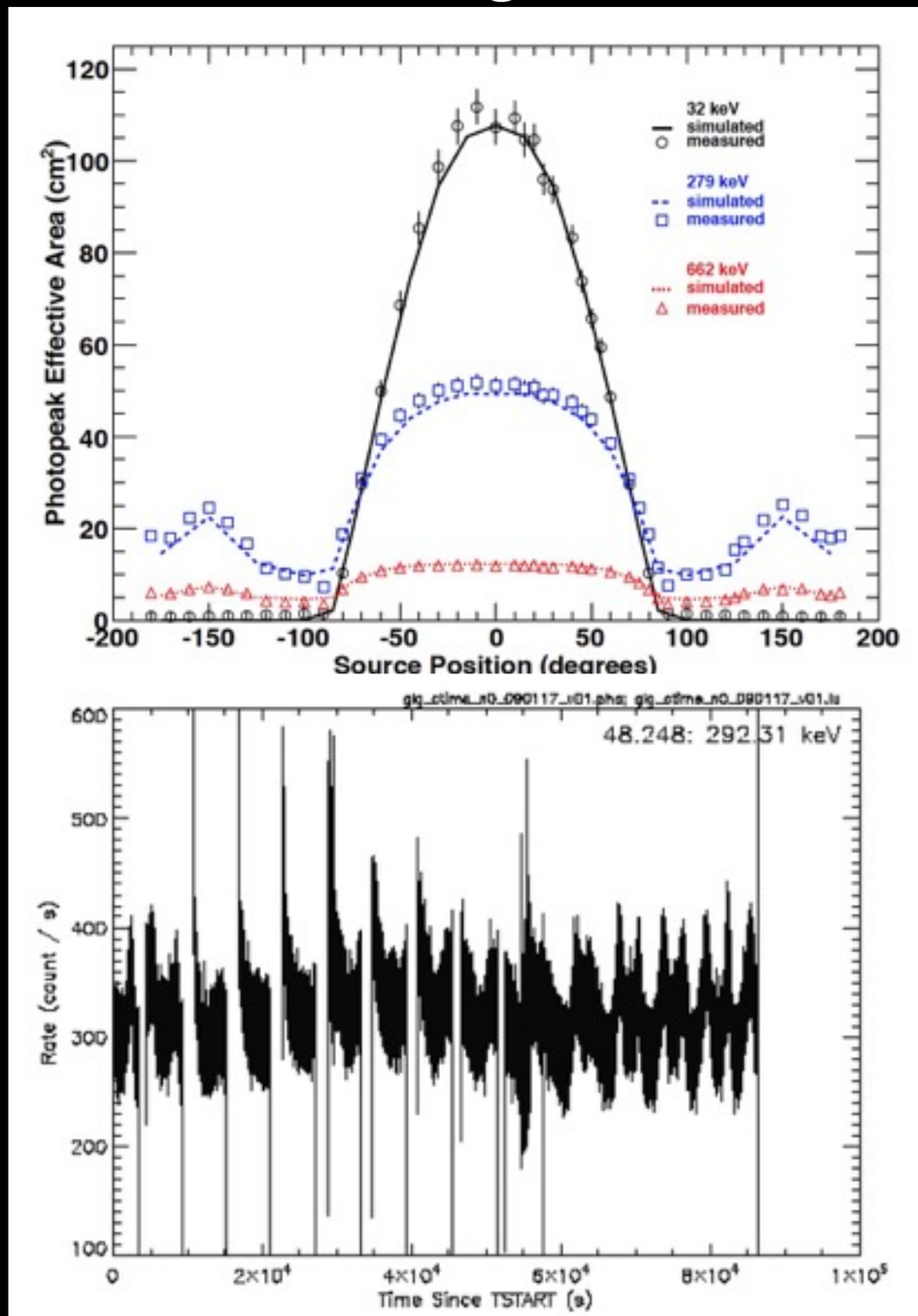
~100cm^2 collecting area

Offaxis response ~ a few sterad

Background ~ 300-500 cts/s

50-300 keV

GBM: Meegan+2009



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Minimum detectable count rate
~ 1 ph/cm^2/s

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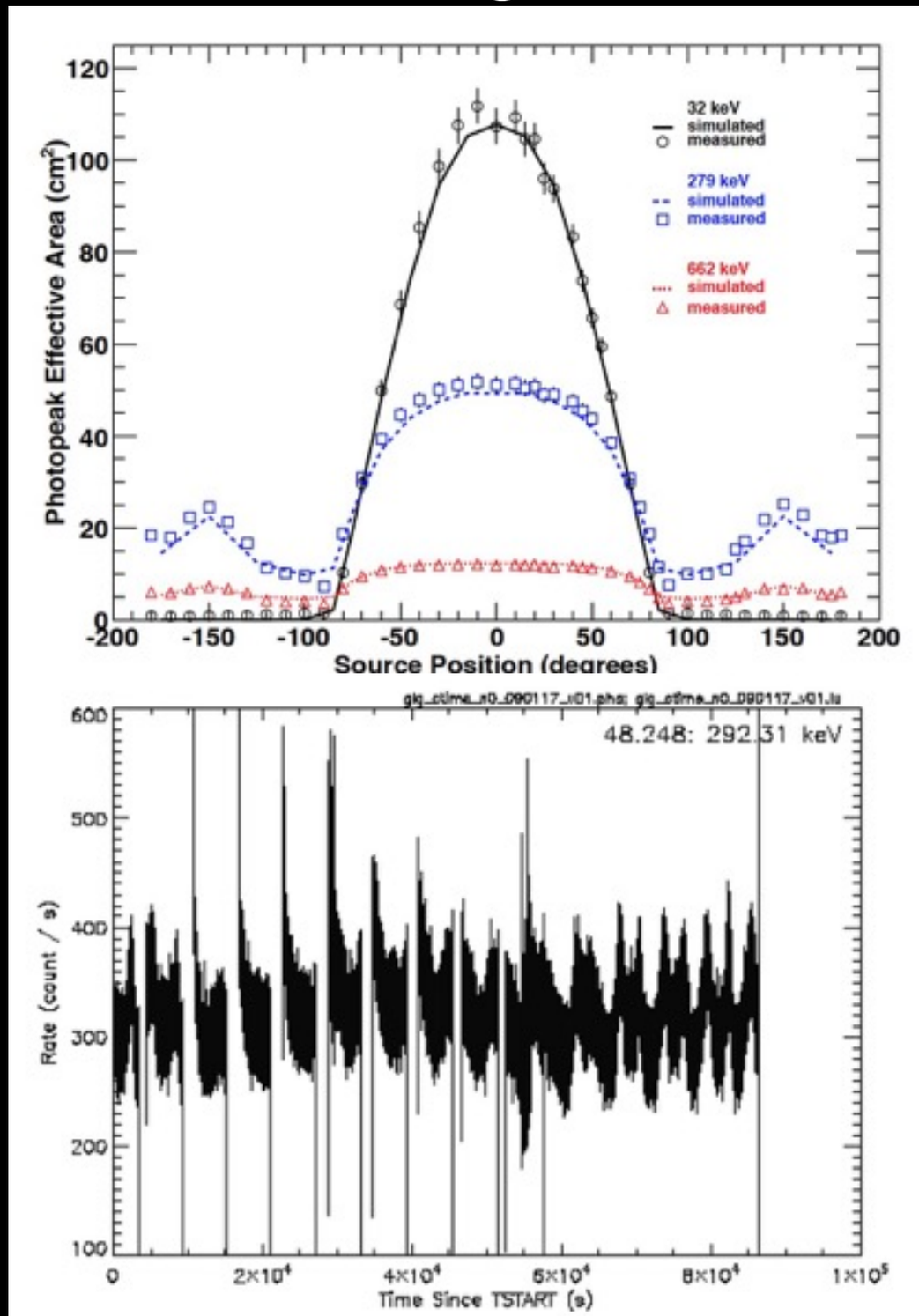

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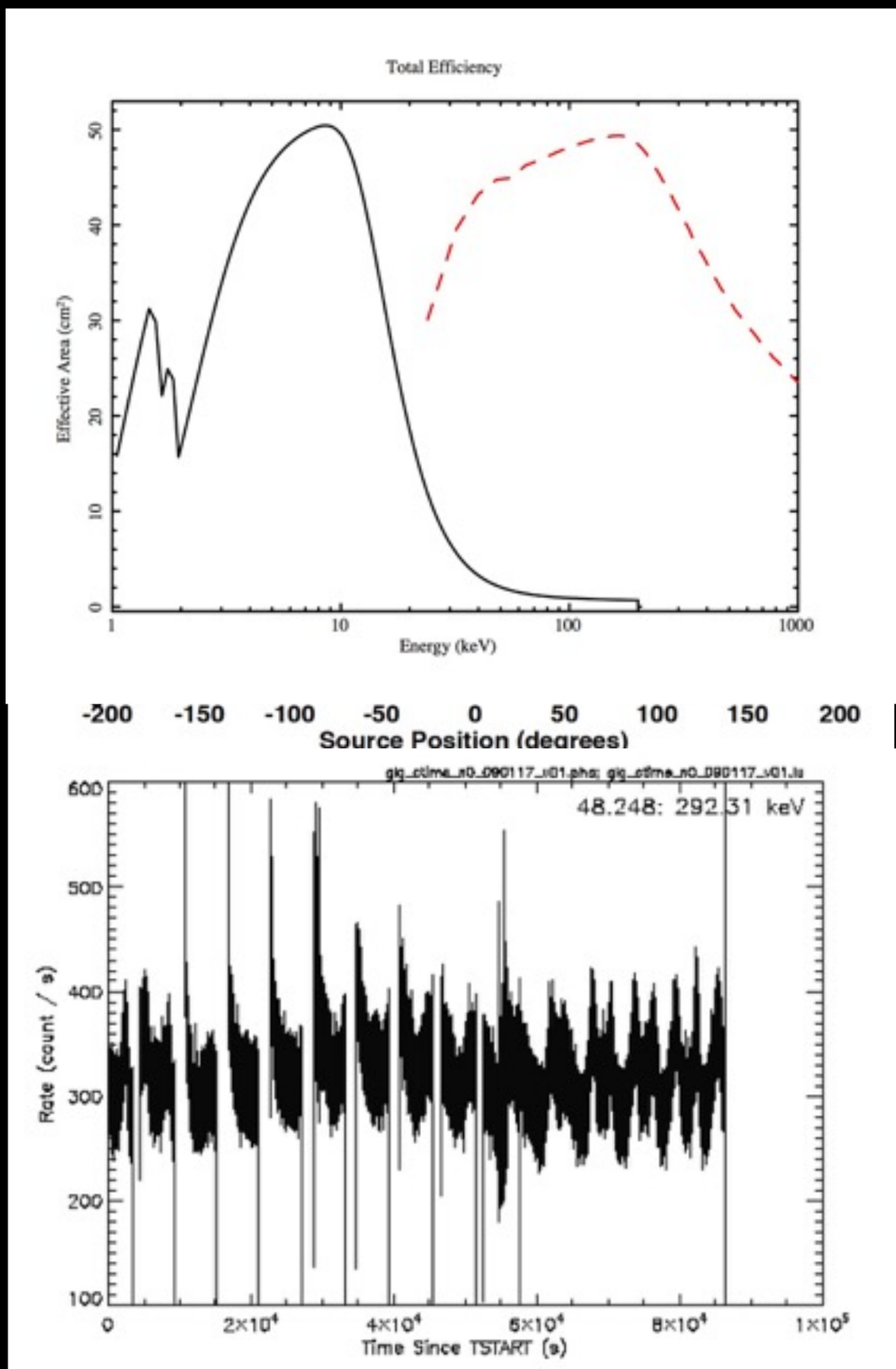
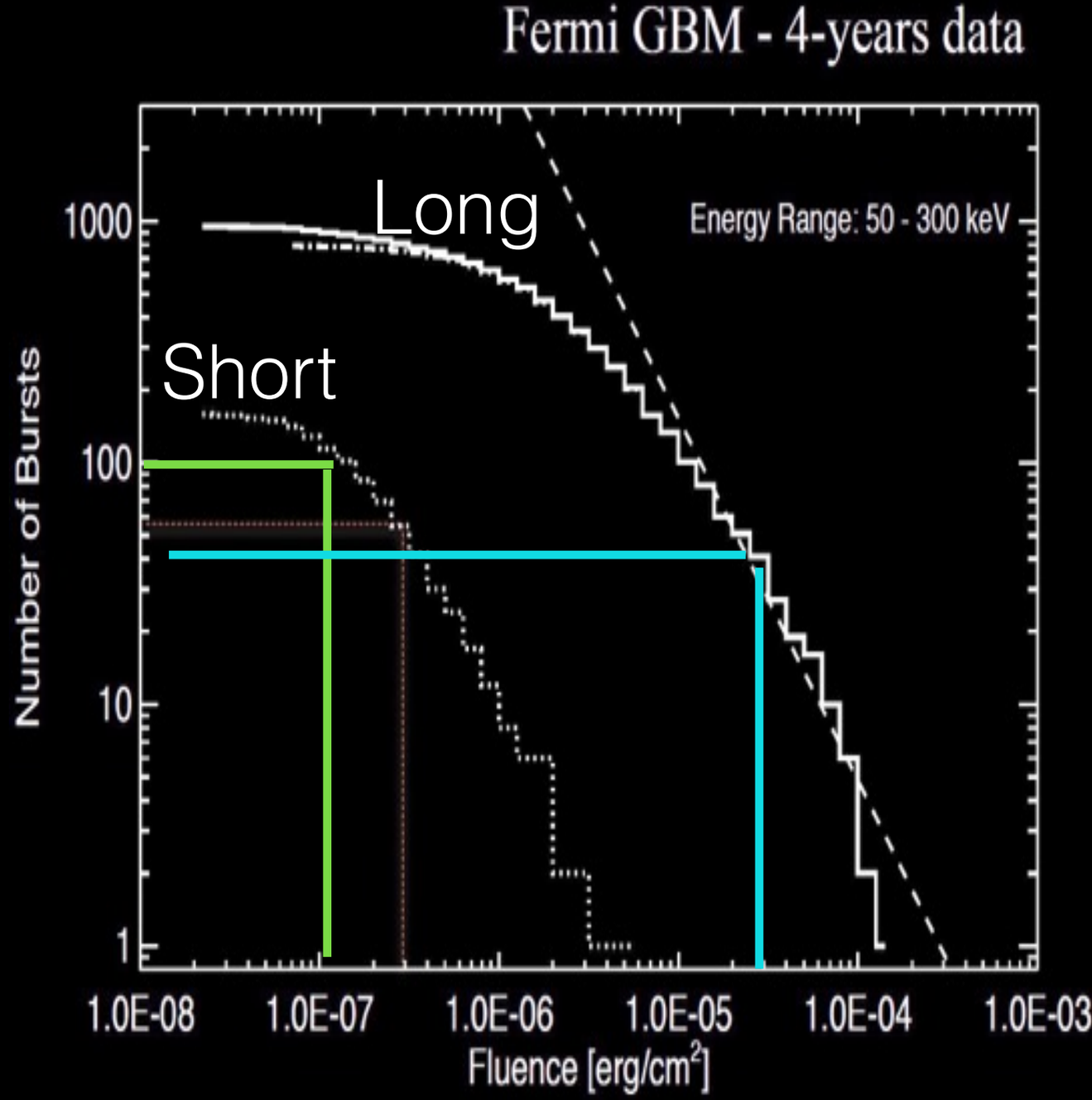
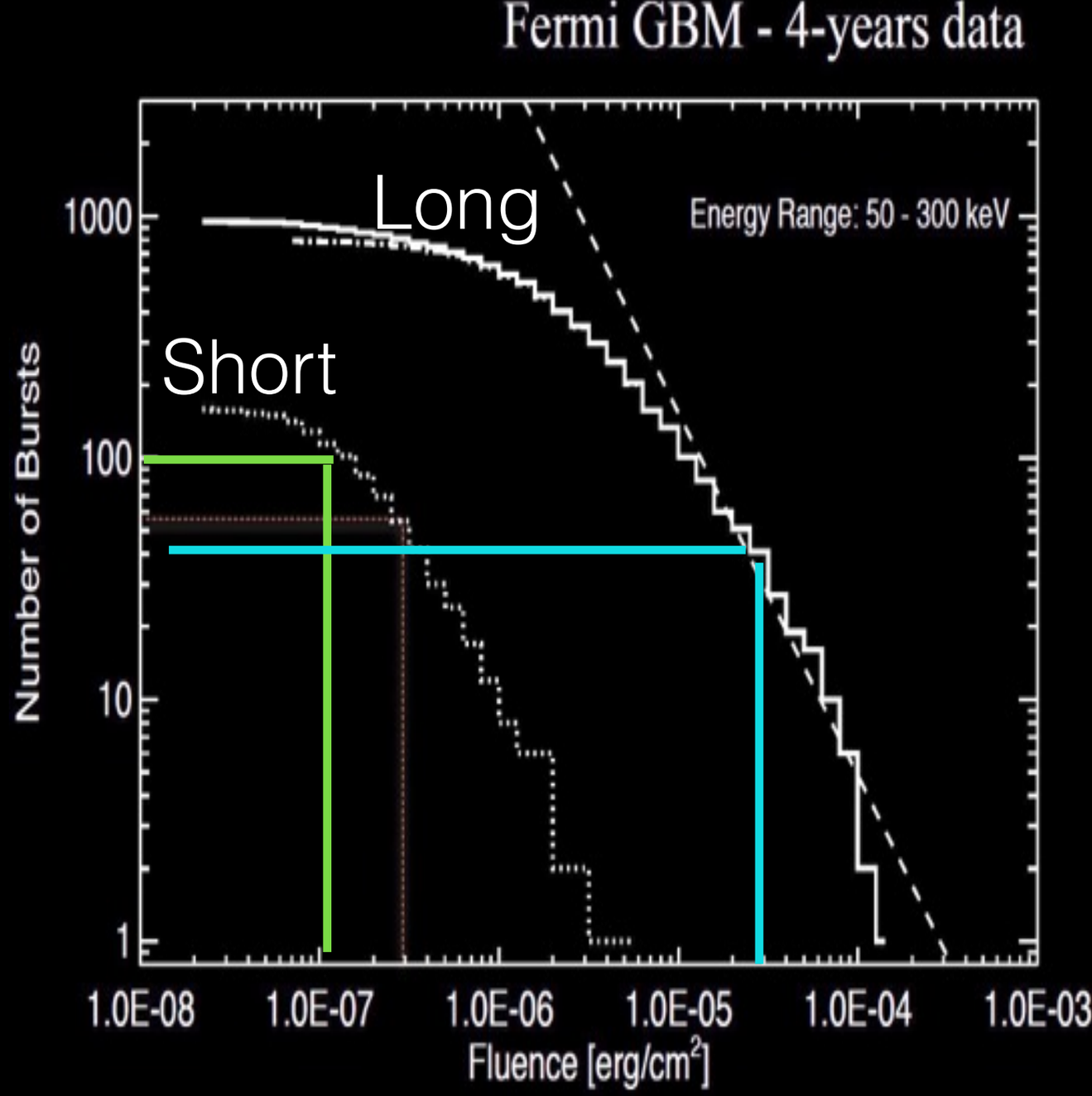


How many GRBs?



How many GRBs?

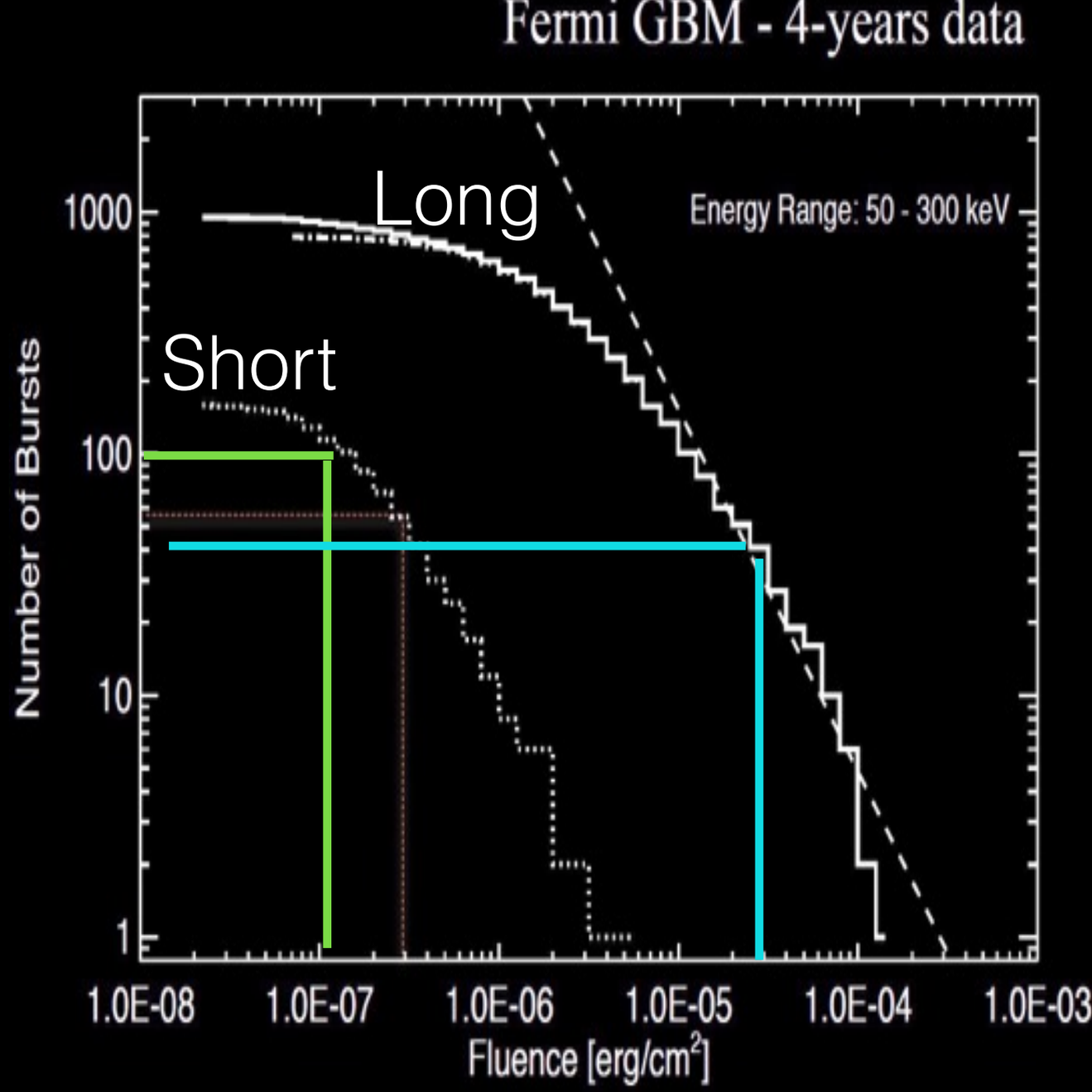
- **Long**: Fl≥10^{-5} erg/cm^2
  ≥8 ph/s/cm^2
  10/yr



How many GRBs?

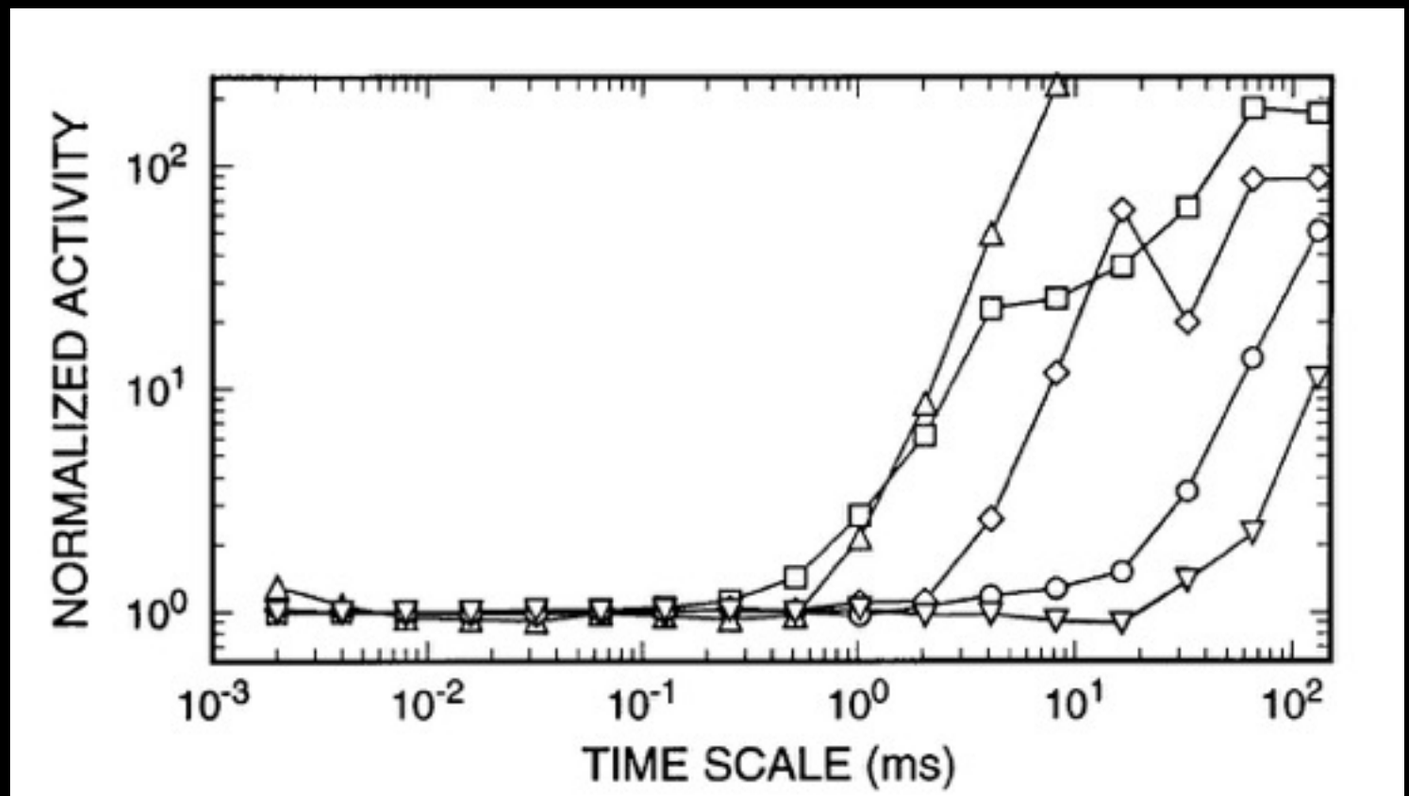
- **Long**: Fl≥10^{-5} erg/cm^2
  ≥8 ph/s/cm^2
  10/yr

- **Short**: Fl≥10^{-7} erg/cm^2
  ≥1-2 ph/s/cm^2
  20/yr



GRB fast variability

Walker+2000



GRB fast variability

20 strong BATSE GRB
TTE, 2us resolution

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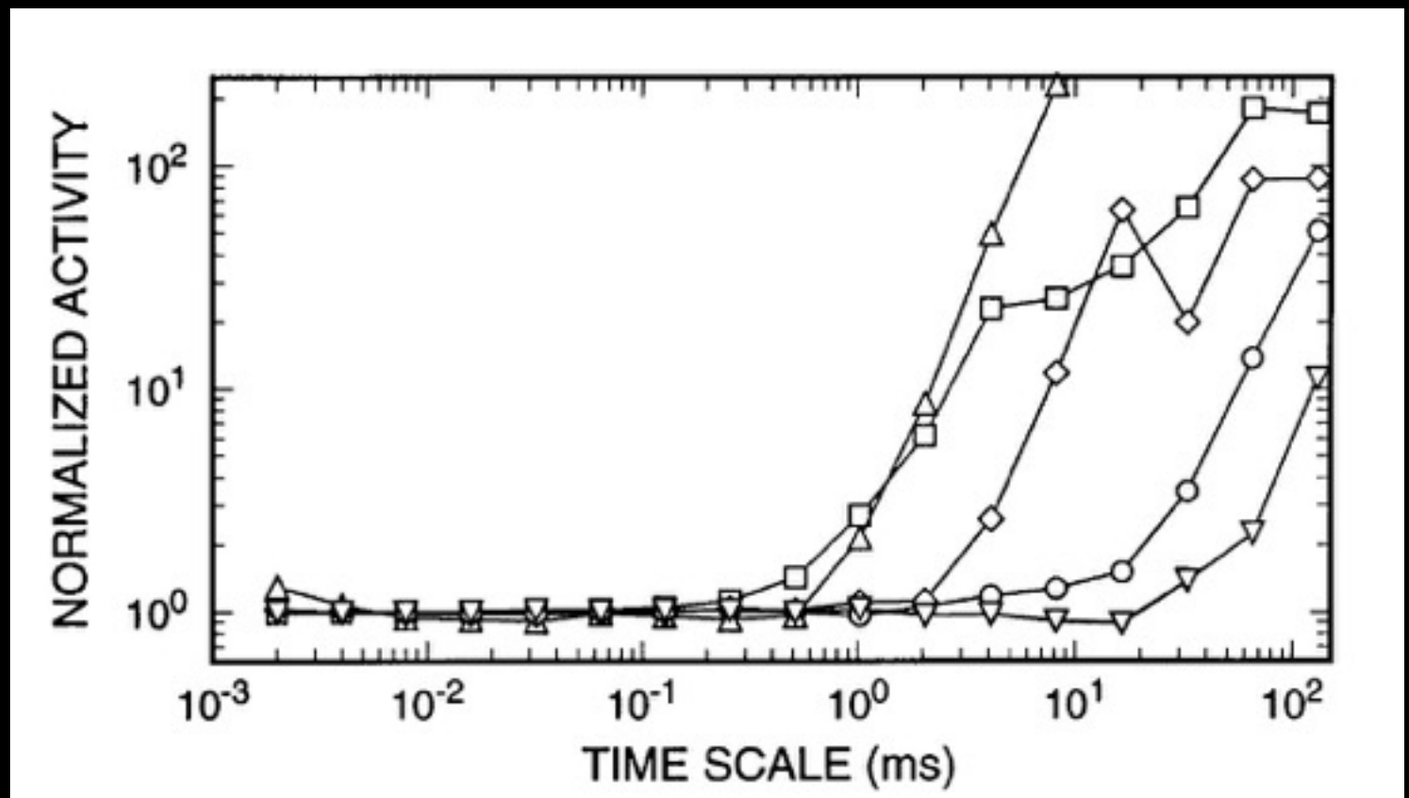

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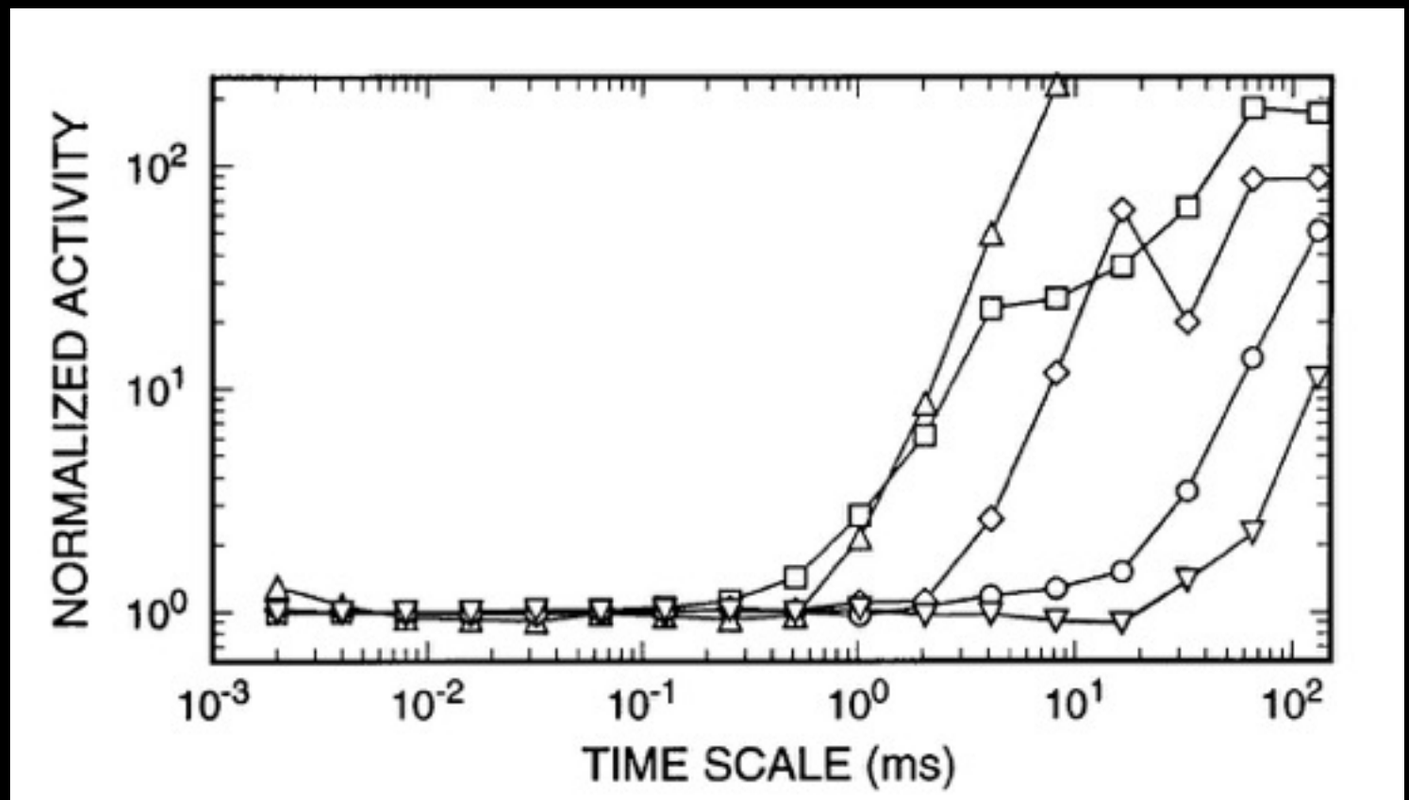

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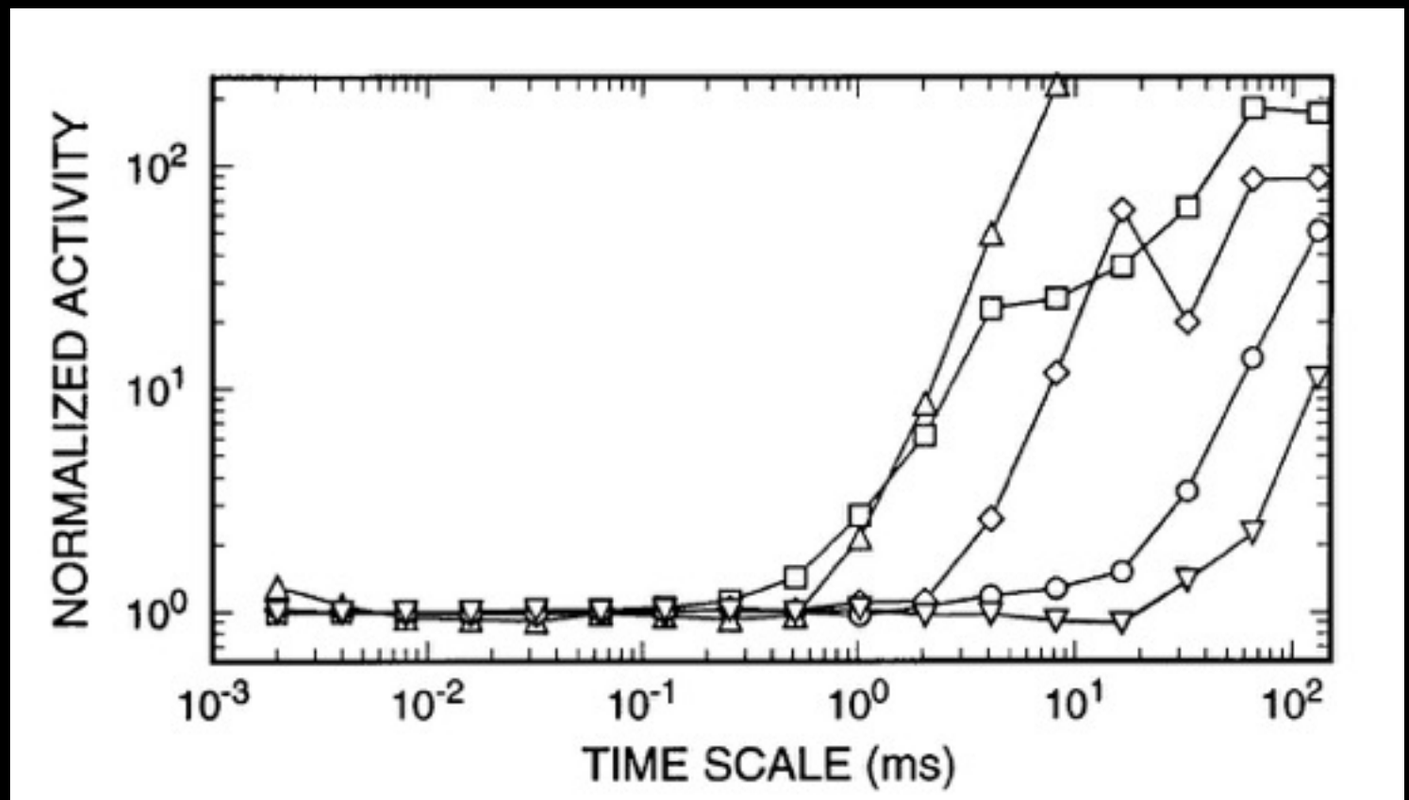

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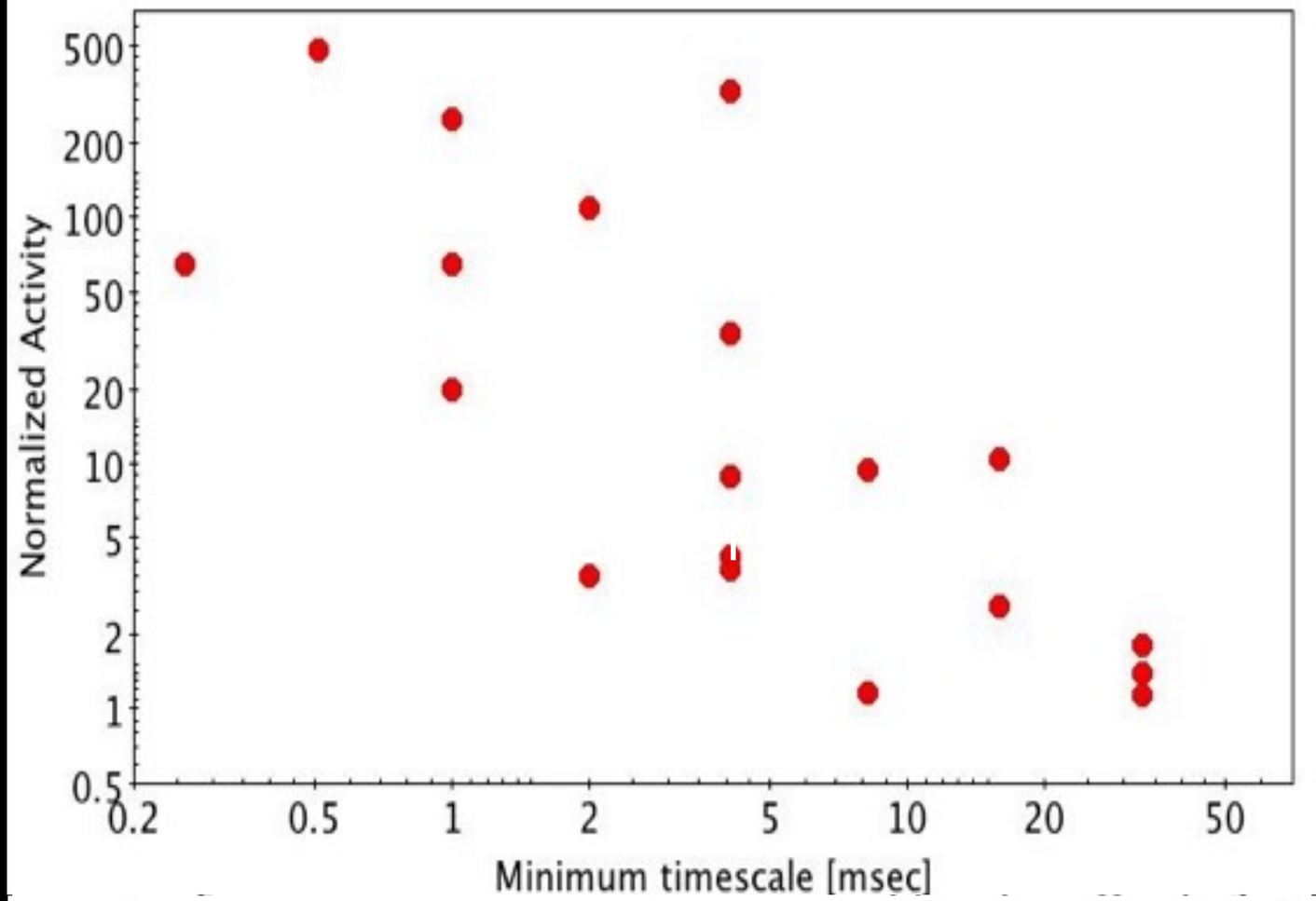

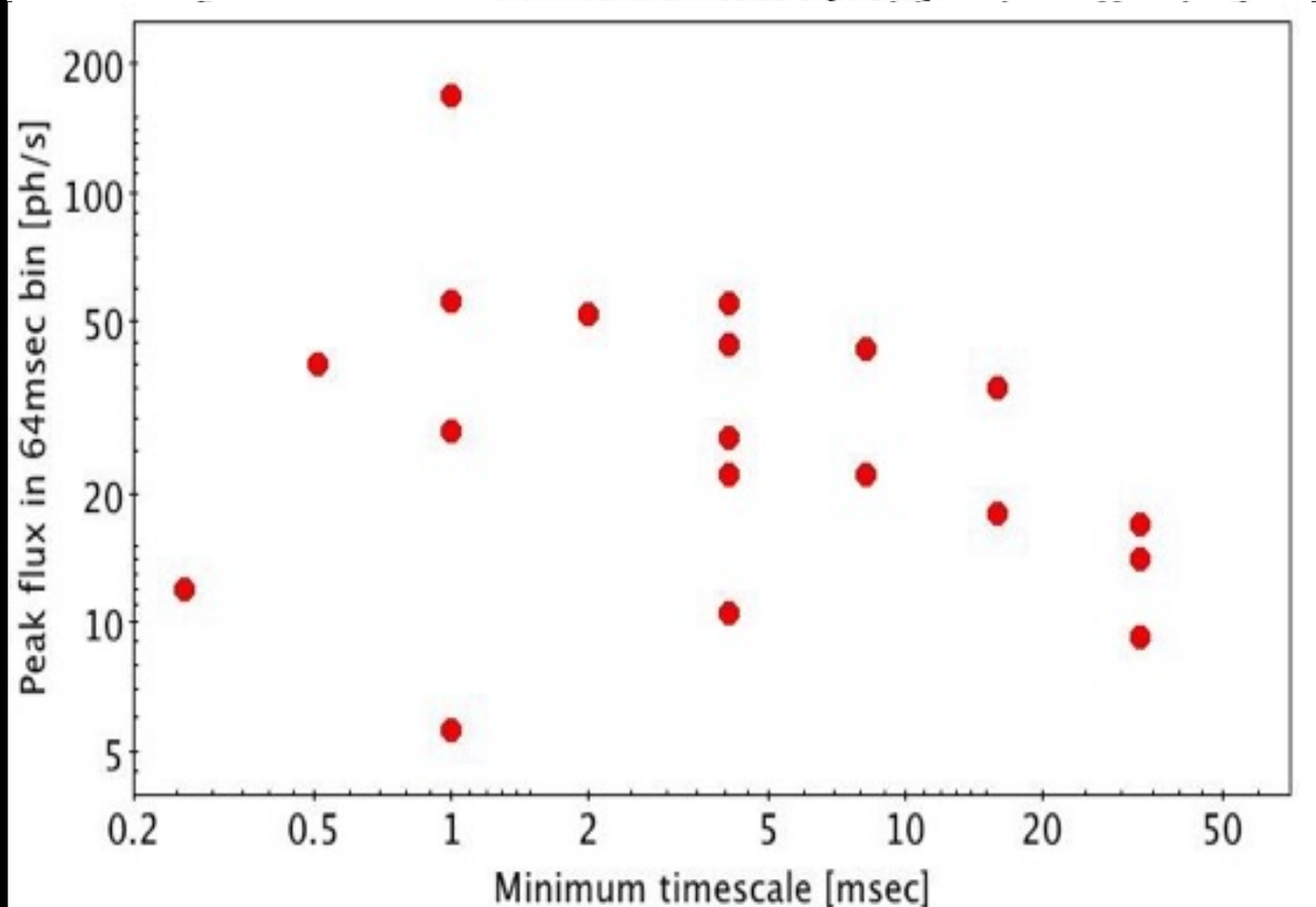

HERMES performances

$$\sigma_{Pos} = 2.4°[(\sigma_{CCF}^2 + \sigma_{sys}^2)/(N-3)]^{0.5}$$

<B>~7000km

N(pathfinder)~6-8, active simultaneously 4-6

N(final constellation) ~100, active 50

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$\sigma_{Pos(pathfinder)}$ ~ 1 arcmin if σ_{CCF}, σ_{sys}~10usec

$\sigma_{Pos(FC)}$ <1arcsec if σ_{CCF}, σ_{sys}~10usec

Bright GRBs with msec structure

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Bright GRBs with msec structure

$\sigma_{Pos(pathfinder)}$ ~ 2.4 deg if σ_{CCF},σ_{sys}~0.001s

$\sigma_{Pos(FC)}$ ~ 3 arcmin if σ_{CCF},σ_{sys}~0.001s

Short GRBs without substructure, risetime fraction of second.

HERMES Institutes

- INAF, ASI, PoliMi, UniCagliari, UniPalermo, UniUdine, UniTrieste, UniPavia, UniFedericoII, UniFerrara, FBK, FPM
- University of Tubingen (Germany)
- University of Eotvos Budapest, C3S (Hungary)
- University of Nova Gorica, Skylabs, AALTA (Slovenia)
- Deimos (Spain)

HERMES Institutes

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HERMES is open to ideas and collaboration
Want to be involved? Send an e-mail
fabrizio.fiore@inaf.it
burderi@dsf.unica.it

It will never fly

It will never fly

If it flies it will never work

It will never fly

If it flies it will never work

If it works it will not see anything!

Programmatics 1

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Progetto Premiale 2015: **HERMES-Techonogic Pathfinder**

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Main objectives:

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- AR T0+24 —> PFM2+PFM3

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(VegaC maiden flight or Vega, or other opportunities)

Programmatics 2

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H2020 SPACE-SCI-20: **HERMES-Scientific Pathfinder**

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- KO November 2018

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- KO November 2018
- CDR+QR T0+15 QM—> PFM1
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- Launch 2021 (ASI provided)

Programmatics 3

Programmatics 3

ASI 2019: **HERMES - Advanced Scientific Pathfinder**

Programmatics 3

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- Main objectives:

Programmatics 3

ASI 2019: **HERMES - Advanced Scientific Pathfinder**

- Main objectives:

  1. Nearly all sky coverage

Programmatics 3

ASI 2019: **HERMES - Advanced Scientific Pathfinder**

- Main objectives:

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  2. First accurate GRB localization experiment with ≥6 CubeSat

Programmatics 3

ASI 2019: **HERMES - Advanced Scientific Pathfinder**

- Main objectives:

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  2. First accurate GRB localization experiment with ≥6 CubeSat

- Submitted to ASI September 2018

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  2. First accurate GRB localization experiment with ≥6 CubeSat

- Submitted to ASI September 2018

- Launch 2022? (ASI provided)