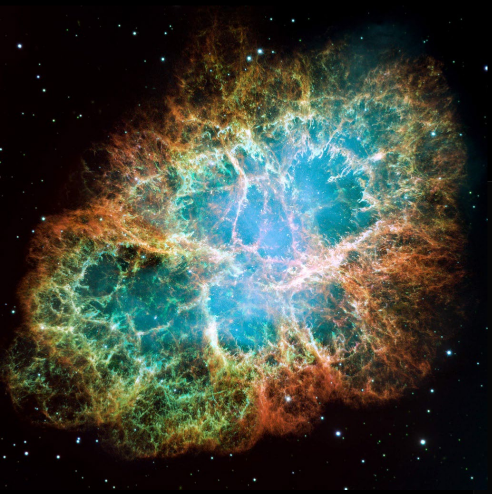
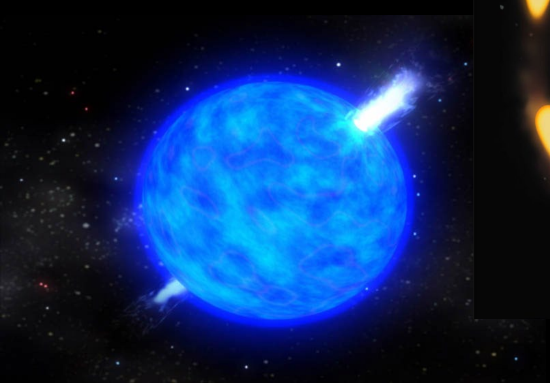
ENERGETIC EXPLOSIONS IN SPACE

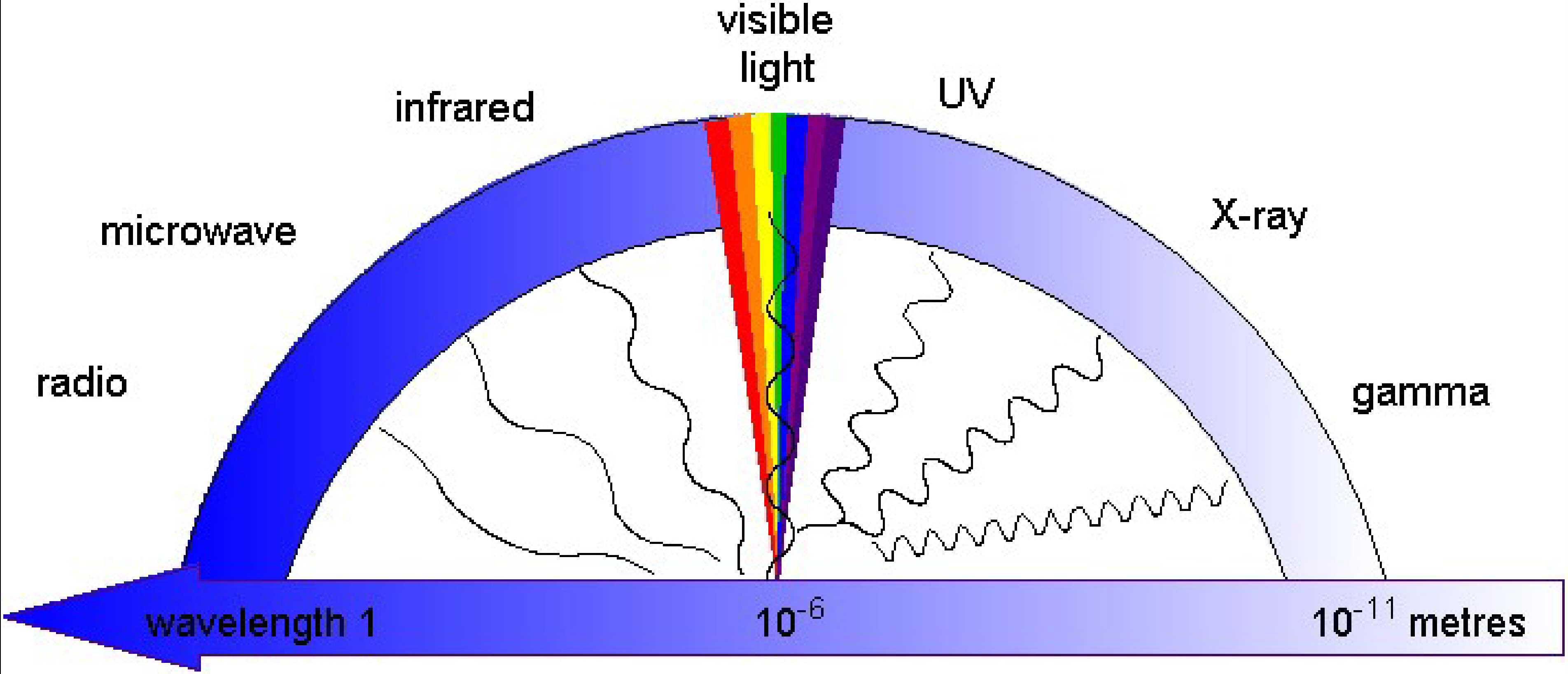


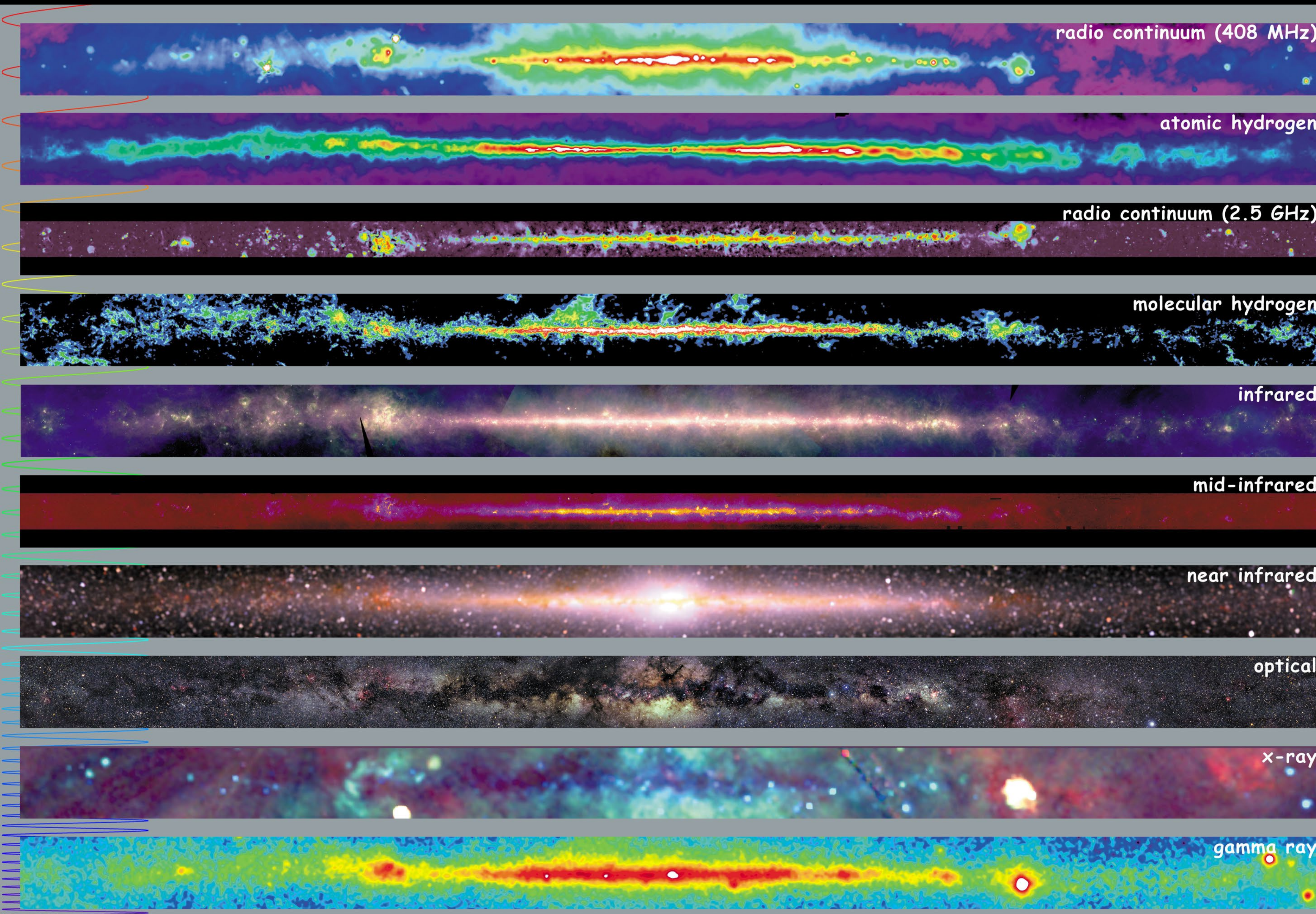


Dr. Frank Schinzel
National Science Foundation

September 16, 2024

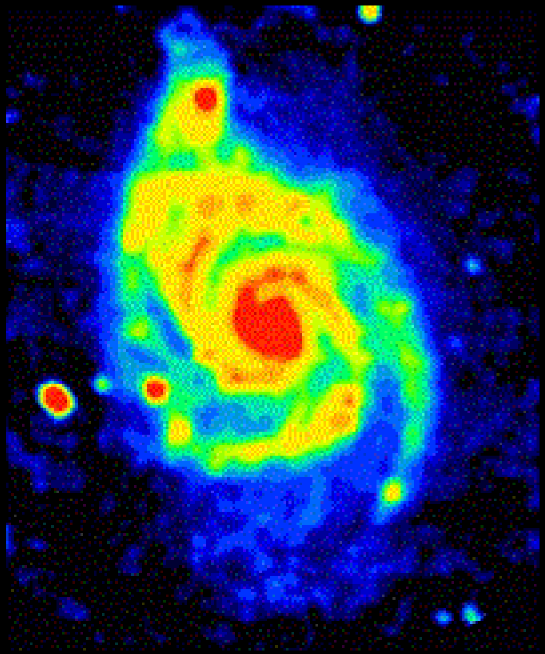
Electromagnetic Spectrum

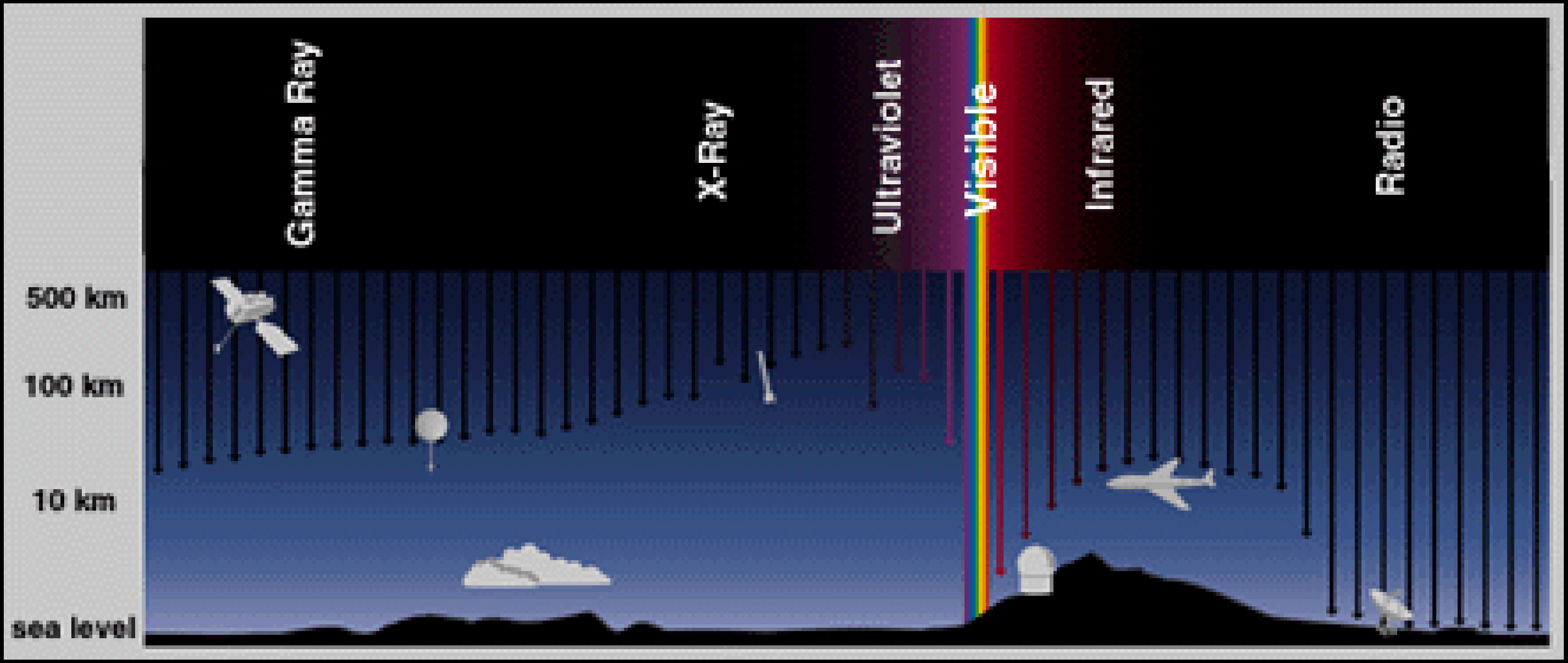




http://adc.gsfc.nasa.gov/mw

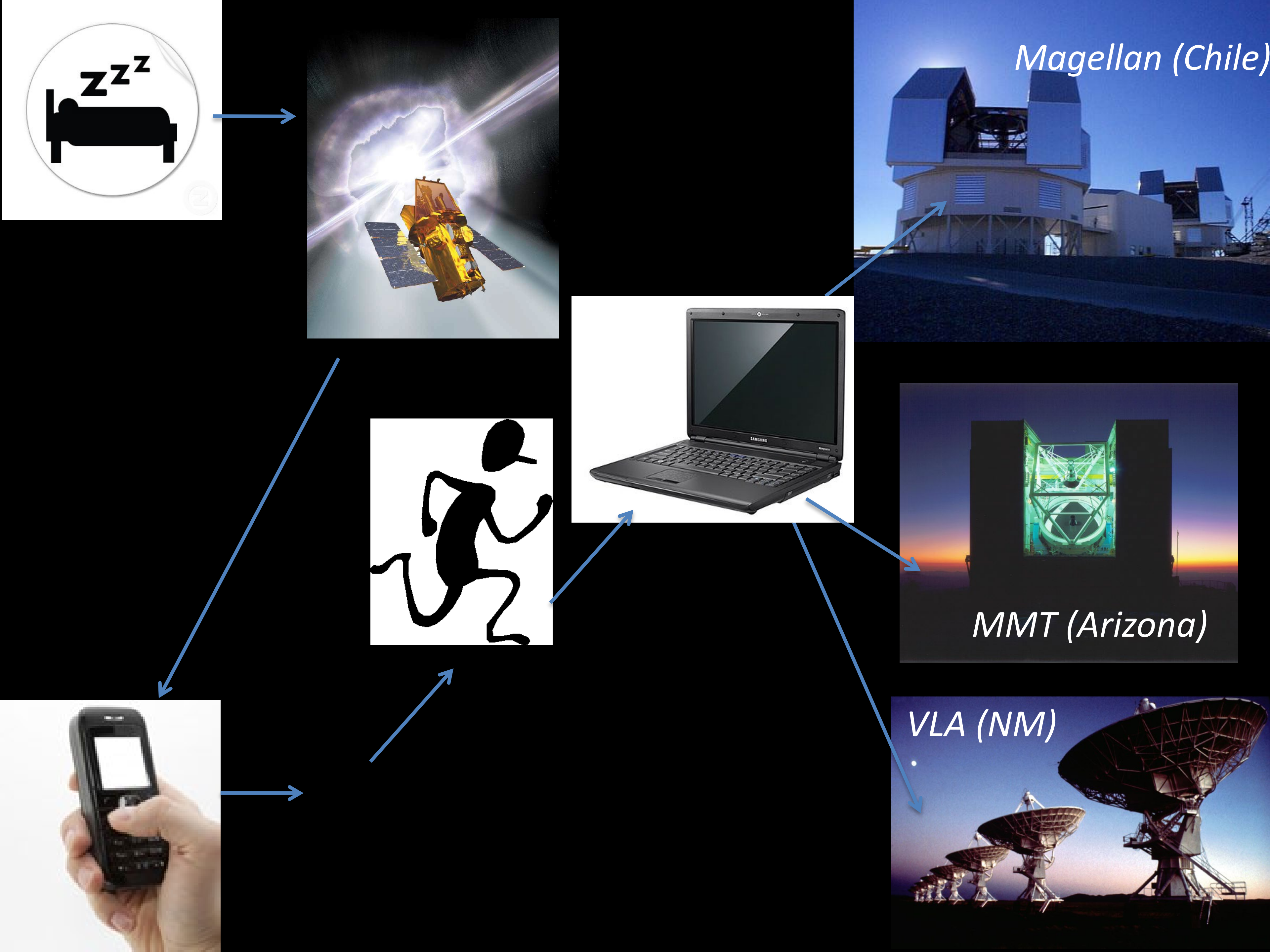
Multiwavelength Milky Way



Gamma Ray
X-Ray
Ultraviolet
Visible
Infrared
Radio
500 km
100 km
10 km
sea level

Boston Skyline at Night from www.globeimages.net

Boston Skyline at Night on July 4th. Photo from www.bostonteapartyship.com


Magellan (Chile)
MMT (Arizona)
VLA (NM)

Overview

- Types of Explosive Events
  - Supernovae
  - Gamma Ray Bursts
  - Tidal disruption of stars by really big black holes
- Methods of Detection
- What is known / open questions

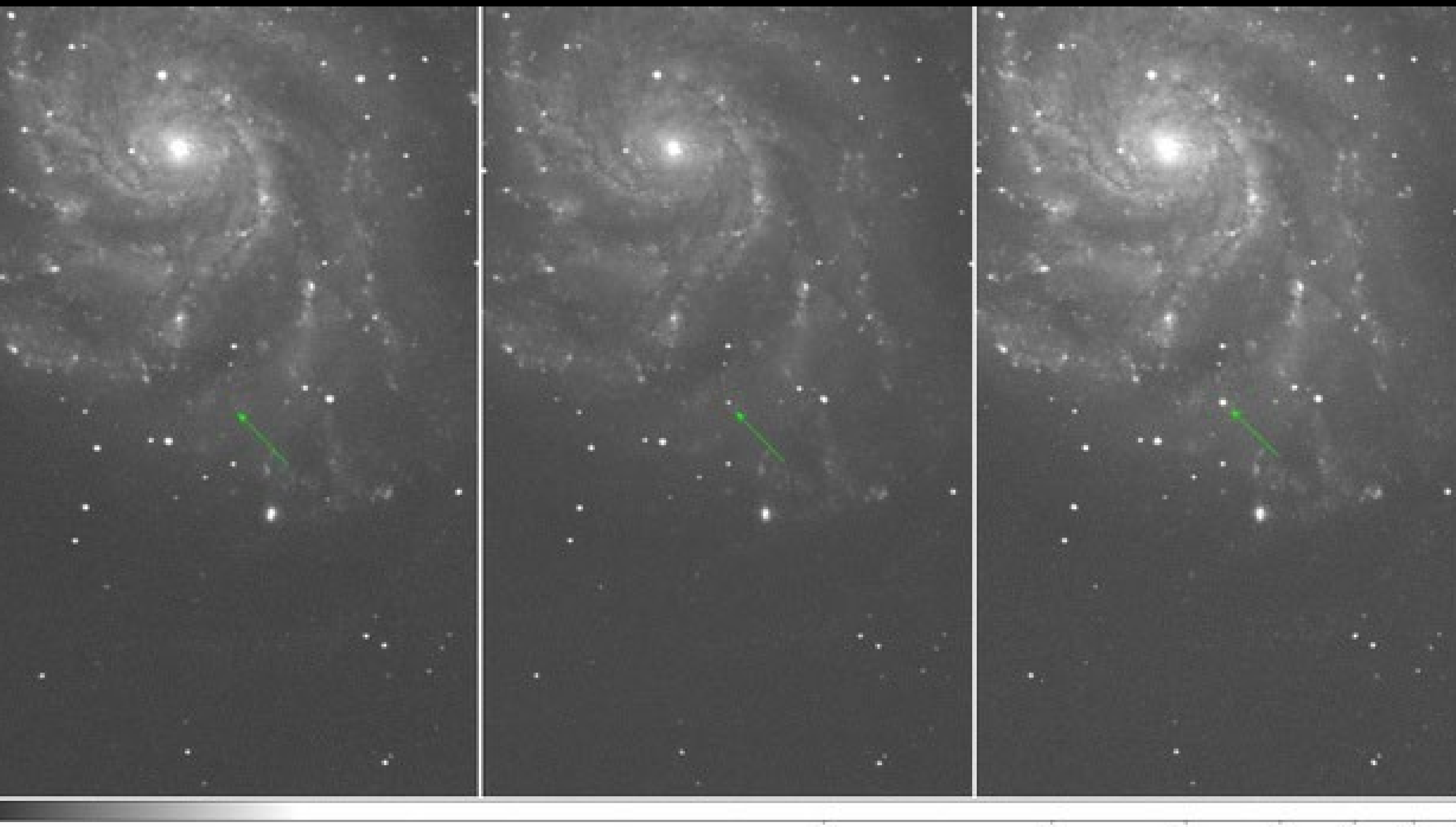
The Dynamic Sky….

Chaco Canyon, NM
SN 1054

Crab nebula, SN 1054

Image courtesy of NASA

PALOMAR TRANSIENT FACTORY




A. Riou

Pan-STARRS

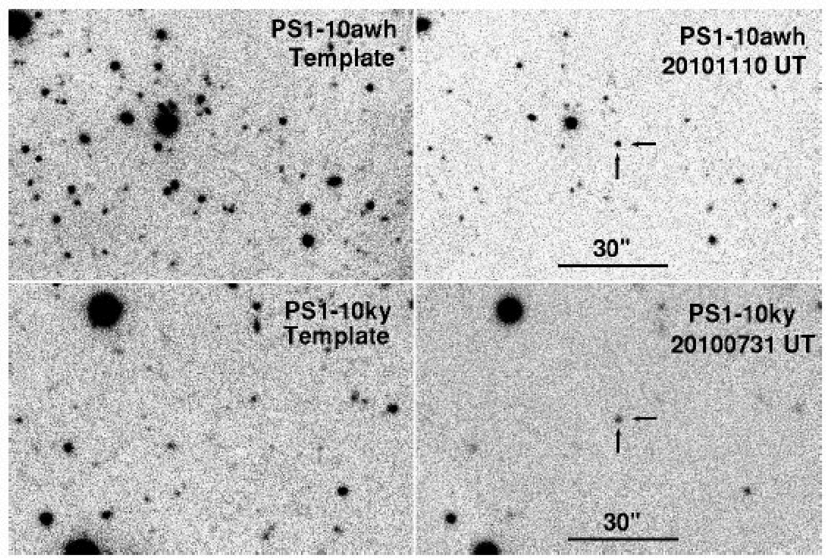


FIG. 1.— Cut-outs of PS1 i_{P1}-band images showing the region around PS1-10awh (top) and PS1-10ky (bottom). The left column shows stacked images using data before explosion; the right column shows images from single nights around maximum light.

The Astrophysical Journal, 752:78 (10pp), 2012 June 20 doi:10.1088/0004-637X/752/2/78

PANCHROMATIC OBSERVATIONS OF SN 2011dh POINT TO A COMPACT PROGENITOR STAR

A. M. Soderberg[1], R. Margutti[1], B. A. Zauderer[1], M. Krauss[2], B. Katz[3,22], L. Chomiuk[1,2], J. A. Dittmann[1], E. Nakar[4], T. Sakamoto[5,6], N. Kawai[7], K. Hurley[8], S. Barthelmy[9], T. Toizumi[7], M. Morii[7], R. A. Chevalier[10], M. Gurwell[1], G. Petitpas[1], M. Rupen[2], K. D. Alexander[1], E. M. Levesque[11], C. Fransson[12], A. Brunthaler[13], M. F. Bietenholz[14,15], N. Chugai[16], J. Grindlay[1], A. Copete[1], V. Connaughton[17], M. Briggs[17], C. Meegan[18], A. von Kienlin[19], X. Zhang[19], A. Rau[19], S. Golenetskii[20], E. Mazets[20], and T. Cline[21]

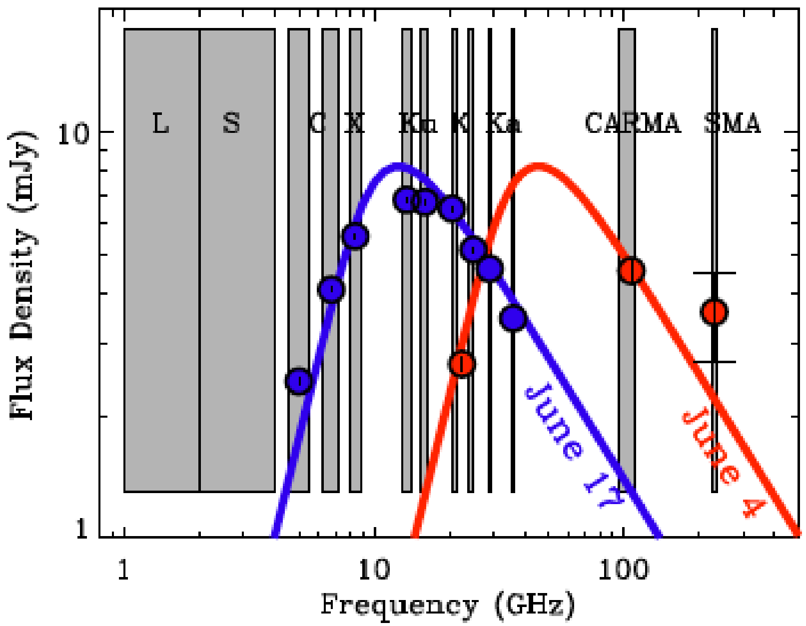
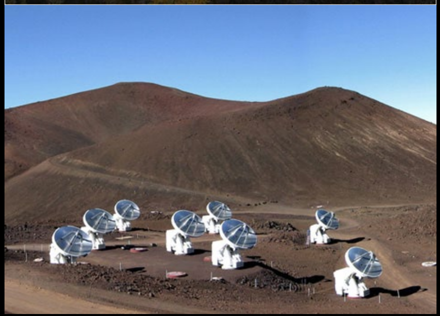
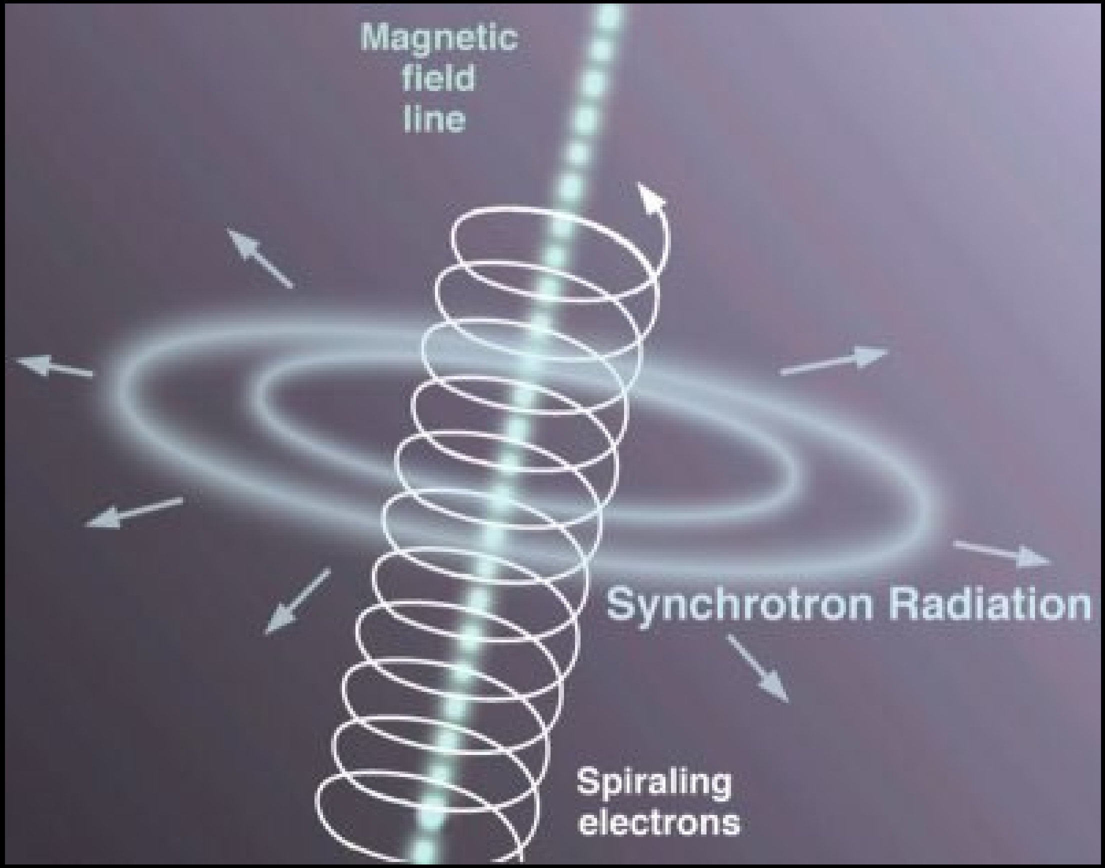
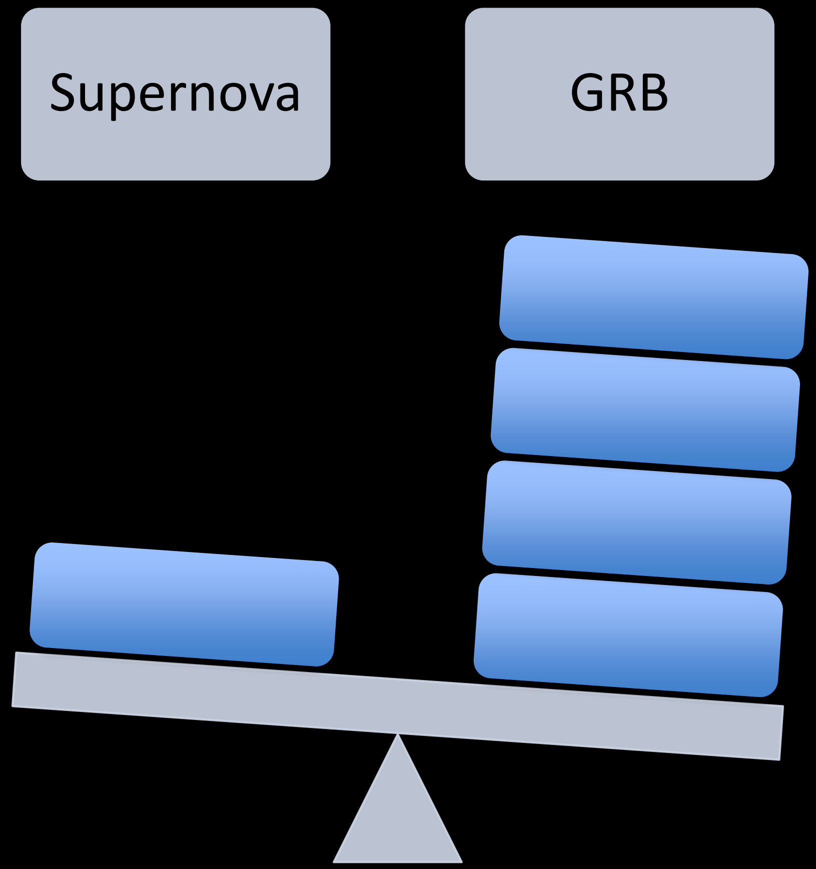
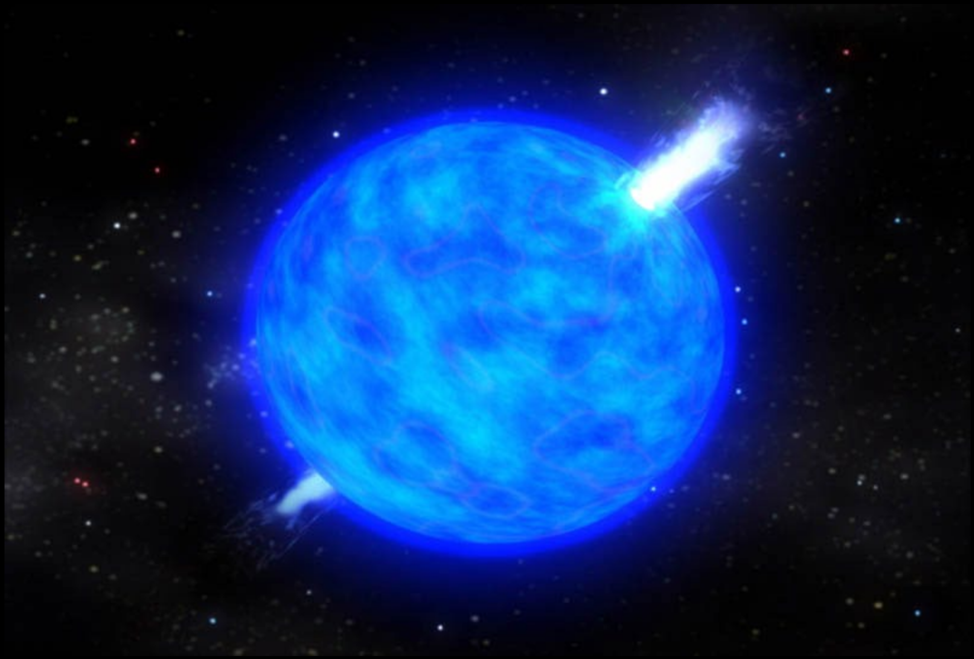


Fig. 3.— The radio spectrum of SN 2011dh across multiple epochs – $\Delta t \approx 4$ (red) and 17 (blue) days – is well described by a synchrotron self-absorbed spectral model with $F \propto \nu^{5/2}$ ($F_\nu \propto \nu^{-(p-1)/2}$) below (above) the spectral peak, ν_p. The observations indicate an electron energy index of $p \approx 3$. Error bars are 1σ. The gray bands mark the EVLA, CARMA, and SMA bands used in our long-term study of SN 2011dh as the spectral peak cascades to lower frequencies with time (see Krauss et al. 2012 for a detailed discussion).




Magnetic
field
line
Synchrotron Radiation
Spiraling
electrons


Supernova
GRB



Limited Nuclear Test Ban Treaty (1963)

Signed in Moscow by the Soviet Union, the United States and the United Kingdom:

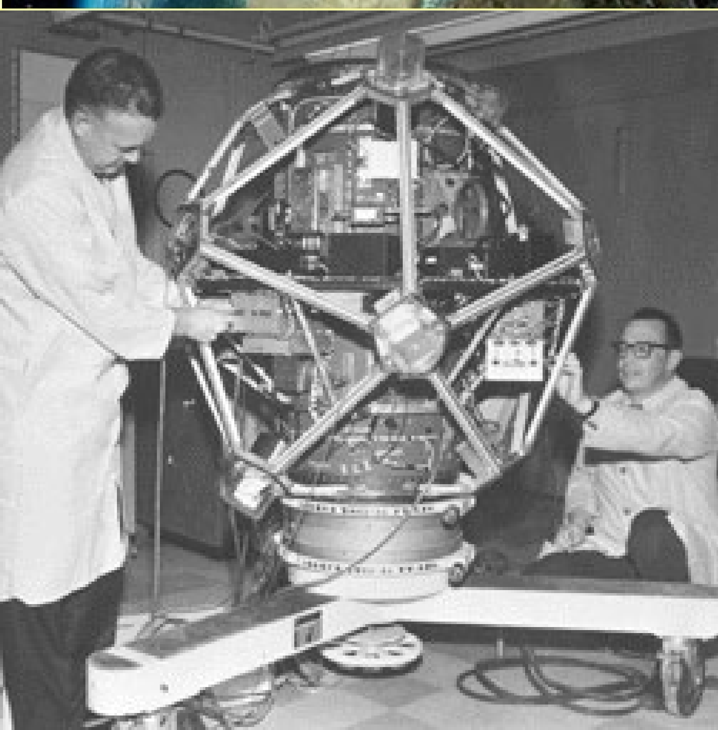
… to prohibit, prevent, and not to carry out any nuclear weapon test:

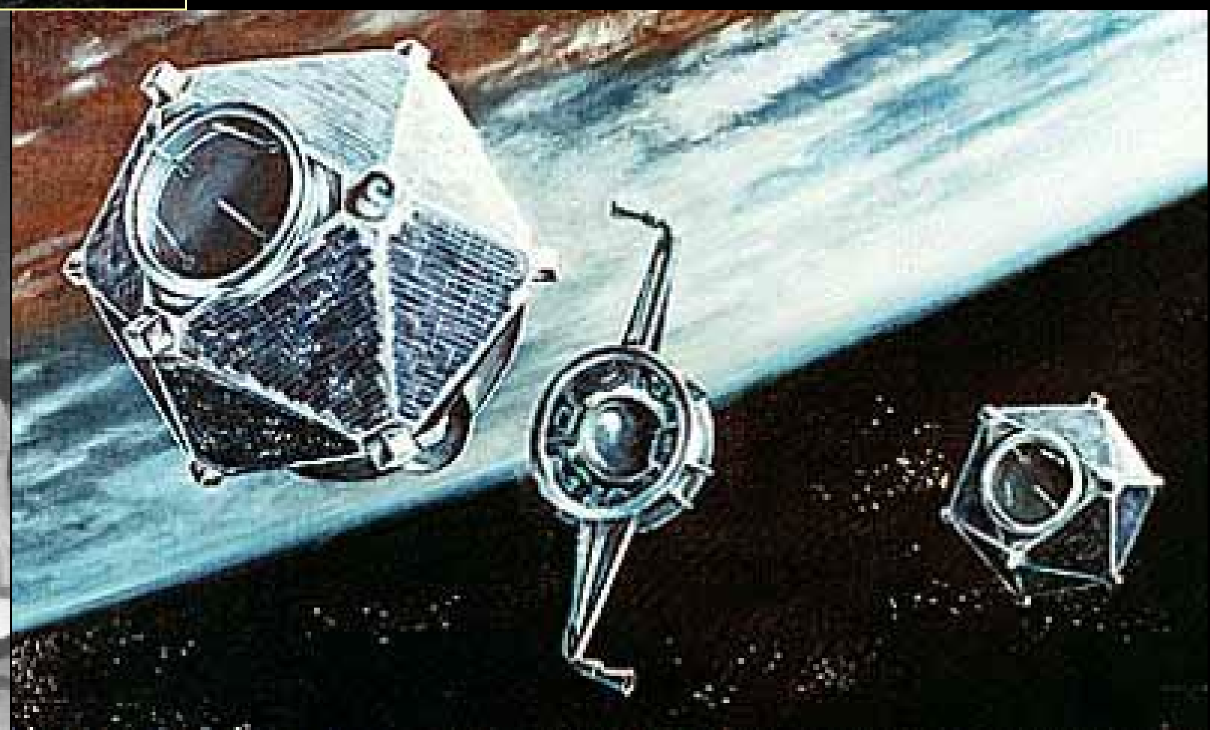
(a) in the atmosphere; beyond its limits, including outer space; or under water …

The Vela Satellites (1963-1970)

Velar [vay-lar’]:

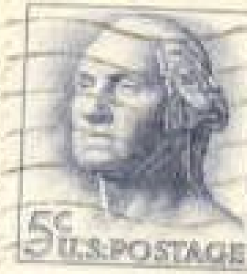
To watch; to guard

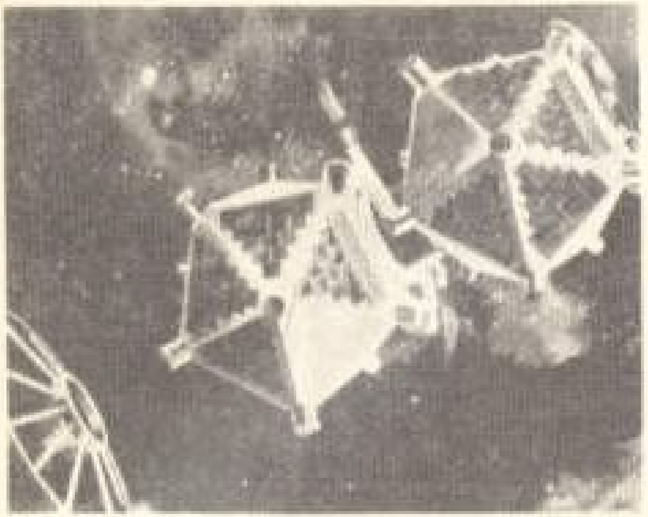




CAPE KENNEDY VELA TWINS

CAPE CANAVERAL
JUL 17
AM
1964
FLA.



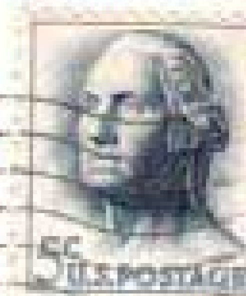


The United States has just fired a pair of watchdog satellites capable of scanning 200 million miles into space to identify a Russian nuclear blast if a test should be held despite a treaty ban to the contrary.

CLYDE J. SARZIN
PORT WASHINGTON, L. I.
NEW YORK, U.S.A.

NUCLEAR SPY
TWIN SATELLITES
VELA HOTEL PROJECT

CAPE CANAVERAL
11-AM
OCT 17
1963
FLA.



57,000 MILE HIGH ORBIT TWIN SENTINELS THEIR INSTRUMENTS CAPABLE OF SPOTTING A NUCLEAR BLAST MORE THAN 180 MILLION MILES AWAY. TO SERVE AS A WARNING THAT THE UNITED STATES IS DETERMINED TO FIND OUT IF ANY NATION VIOLATES THE NUCLEAR TEST BAN TREATY OF PRESIDENT KENNEDY AND THE SOVIET.


VELA
4
RESEARCH
MOONLETS
NUCLEAR
DETECTION
SATELLITES
On Patrol..........
Protection from
clandestine atomic
blasts in space
PATRICK AIR FORCE BASE, FL
APR 28
AM
1967
32925
5c
Launched by
Titan 3C
5:01 A.M. EST
One of the trio of hitchhiking Environmental
Research Satellites will be looking at some
of the death dealing radiation emitted by the sun
BOX 2296, HUNTINGTON, W. VA. 25724

The First Gamma-Ray Burst

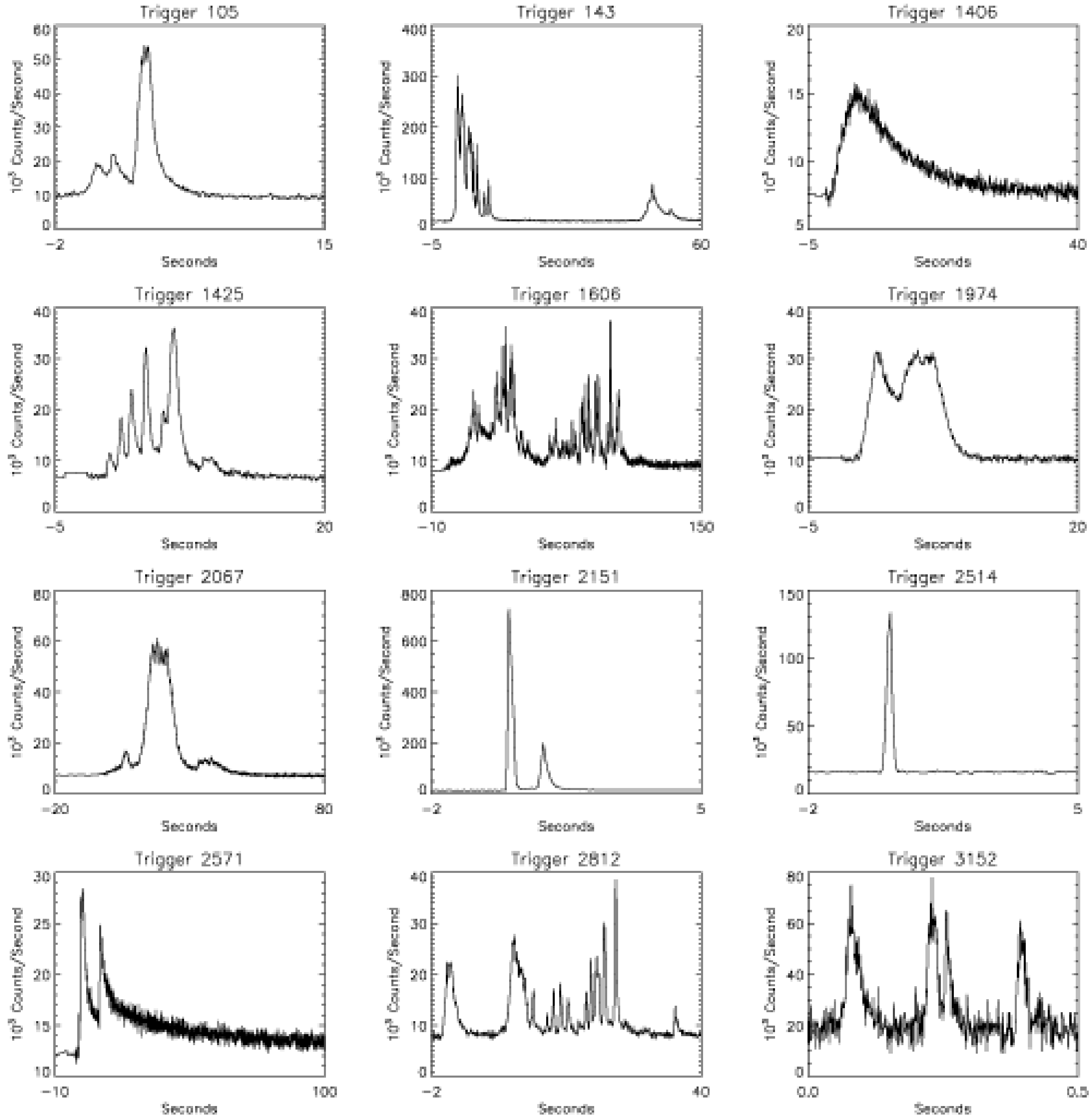
OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

RAY W. KLEBESADEL, IAN B. STRONG, AND ROY A. OLSON

University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico
Received 1973 March 16; revised 1973 April 2

ABSTRACT

Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to $\sim$30 s, and time-integrated flux densities from $\sim 10^{-5}$ ergs cm^{-2} to $\sim 2 \times 10^{-4}$ ergs cm^{-2} in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.


Trigger 105
Trigger 143
Trigger 1406
Trigger 1425
Trigger 1606
Trigger 1974
Trigger 2067
Trigger 2151
Trigger 2514
Trigger 2571
Trigger 2812
Trigger 3152
10³ Counts/Second
Seconds

Theories (1973-1993)

Model #	Author	Year Pub	Reference	Main Body	2nd Body	Place	Description
1.	Colgate	1968	CJPhys, 46, S476	ST		COS	SN shocks stellar surface in distant galaxy
2.	Colgate	1974	ApJ, 187, 333	ST		COS	Type II SN shock brem, inv Comp scat at stellar surface
3.	Stecker et al.	1973	Nature, 245, PS70	ST		DISK	Stellar superflare from nearby star
4.	Stecker et al.	1973	Nature, 245, PS70	WD		DISK	Superflare from nearby WD
5.	Harwit et al.	1973	ApJ, 186, L37	NS	COM	DISK	Relic comet perturbed to collide with old galactic NS
6.	Lamb et al.	1973	Nature, 246, PS52	WD	ST	DISK	Accretion onto WD from flare in companion
7.	Lamb et al.	1973	Nature, 246, PS52	NS	ST	DISK	Accretion onto NS from flare in companion
8.	Lamb et al.	1973	Nature, 246, PS52	BH	ST	DISK	Accretion onto BH from flare in companion
9.	Zwicky	1974	Ap&SS, 28, 111	NS		HALO	NS chunk contained by external pressure escapes, explodes
10.	Grindlay et al.	1974	ApJ, 187, L93	DG		SOL	Relativistic iron dust grain up-scatters solar radiation
11.	Brecher et al.	1974	ApJ, 187, L97	ST		DISK	Directed stellar flares on nearby stars
12.	Schlovskii	1974	SovAstron, 18, 390	WD	COM	DISK	Comet from system's cloud strikes WD
13.	Schlovskii	1974	SovAstron, 18, 390	NS	COM	DISK	Comet from system's cloud strikes NS
14.	Bisnovatyi- et al.	1975	Ap&SS, 35, 23	ST		COS	Absorption of neutrino emission from SN in stellar envelope
15.	Bisnovatyi- et al.	1975	Ap&SS, 35, 23	ST	SN	COS	Thermal emission when small star heated by SN shock wave
16.	Bisnovatyi- et al.	1975	Ap&SS, 35, 23	NS		COS	Ejected matter from NS explodes
17.	Pacini et al.	1974	Nature, 251, 399	NS		DISK	NS crustal starquake glitch; should time coincide with GRB
18.	Narlikar et al.	1974	Nature, 251, 590	WH		COS	White hole emits spectrum that softens with time
19.	Tsygan	1975	A&A, 44, 21	NS		HALO	NS corequake excites vibrations, changing E & B fields
20.	Chanmugam	1974	ApJ, 193, L75	WD		DISK	Convection inside WD with high B field produces flare
21.	Prilutski et al.	1975	Ap&SS, 34, 395	AGN	ST	COS	Collapse of supermassive body in nucleus of active galaxy
22.	Narlikar et al.	1975	Ap&SS, 35, 321	WH		COS	WH excites synchrotron emission, inverse Compton scattering
23.	Piran et al.	1975	Nature, 256, 112	BH		DISK	Inv Comp scat deep in ergosphere of fast rotating, accreting BH
24.	Fabian et al.	1976	Ap&SS, 42, 77	NS		DISK	NS crustquake shocks NS surface
25.	Chanmugan	1976	Ap&SS, 42, 83	WD		DISK	Magnetic WD suffers MHD instabilities, flares
26.	Mullan	1976	ApJ, 208, 199	WD		DISK	Thermal radiation from flare near magnetic WD
27.	Woosley et al.	1976	Nature, 263, 101	NS		DISK	Carbon detonation from accreted matter onto NS
28.	Lamb et al.	1977	ApJ, 217, 197	NS		DISK	Mag gating of accret disk around NS causes sudden accretion
29.	Piran et al.	1977	ApJ, 214, 268	BH		DISK	Instability in accretion onto rapidly rotating BH
30.	Dasgupta	1979	Ap&SS, 63, 517	DG		SOL	Charged intergal rel dust grain enters sol sys, breaks up
31.	Tsygan	1980	A&A, 87, 224	WD		DISK	WD surface nuclear burst causes chromospheric flares
32.	Tsygan	1980	A&A, 87, 224	NS		DISK	NS surface nuclear burst causes chromospheric flares
33.	Ramaty et al.	1981	Ap&SS, 75, 193	NS		DISK	NS vibrations heat atm to pair produce, annihilate, synch cool
34.	Newman et al.	1980	ApJ, 242, 319	NS	AST	DISK	Asteroid from interstellar medium hits NS
35.	Ramaty et al.	1980	Nature, 287, 122	NS		HALO	NS core quake caused by phase transition, vibrations
36.	Howard et al.	1981	ApJ, 249, 302	NS	AST	DISK	Asteroid hits NS, B-field confines mass, creates high temp
37.	Mitrofanov et al.	1981	Ap&SS, 77, 469	NS		DISK	Helium flash cooled by MHD waves in NS outer layers
38.	Colgate et al.	1981	ApJ, 248, 771	NS	AST	DISK	Asteroid hits NS, tidally disrupts, heated, expelled along B lines
39.	van Buren	1981	ApJ, 249, 297	NS	AST	DISK	Asteroid enters NS B field, dragged to surface collision
40.	Kuznetsov	1982	CosRes, 20, 72	MG		SOL	Magnetic reconnection at heliopause
41.	Katz	1982	ApJ, 260, 371	NS		DISK	NS flares from pair plasma confined in NS magnetosphere
42.	Woosley et al.	1982	ApJ, 258, 716	NS		DISK	Magnetic reconnection after NS surface He flash
43.	Fryxell et al.	1982	ApJ, 258, 733	NS		DISK	He fusion runaway on NS B-pole helium lake
44.	Hameury et al.	1982	A&A, 111, 242	NS		DISK	e- capture triggers H flash triggers He flash on NS surface
45.	Mitrofanov et al.	1982	MNRAS, 200, 1033	NS		DISK	B induced cyclo res in rad absorp giving rel e-s, inv C scat
46.	Fenimore et al.	1982	Nature, 297, 665	NS		DISK	BB X-rays inv Comp scat by hotter overlying plasma
47.	Lipunov et al.	1982	Ap&SS, 85, 459	NS	ISM	DISK	ISM matter accum at NS magnetopause then suddenly accretes
48.	Baan	1982	ApJ, 261, L71	WD		HALO	Nonexplosive collapse of WD into rotating, cooling NS
49.	Ventura et al.	1983	Nature, 301, 491	NS	ST	DISK	NS accretion from low mass binary companion
50.	Bisnovatyi- et al.	1983	Ap&SS, 89, 447	NS		DISK	Neutron rich elements to NS surface with quake, undergo fission
51.	Bisnovatyi- et al.	1984	SovAstron, 28, 62	NS		DISK	Thermonuclear explosion beneath NS surface
52.	Ellison et al.	1983	A&A, 128, 102	NS		HALO	NS corequake + uneven heating yield SGR pulsations
53.	Hameury et al.	1983	A&A, 128, 369	NS		DISK	B field contains matter on NS cap allowing fusion
54.	Bonazzola et al.	1984	A&A, 136, 89	NS		DISK	NS surface nuc explosion causes small scale B reconnection
55.	Michel	1985	ApJ, 290, 721	NS		DISK	Remnant disk ionization instability causes sudden accretion
56.	Liang	1984	ApJ, 283, L21	NS		DISK	Resonant EM absorp during magnetic flare gives hot synch e-s
57.	Liang et al.	1984	Nature, 310, 121	NS		DISK	NS magnetic fields get twisted, recombine, create flare
58.	Mitrofanov	1984	Ap&SS, 105, 245	NS		DISK	NS magnetosphere excited by starquake
59.	Epstein	1985	ApJ, 291, 822	NS		DISK	Accretion instability between NS and disk
60.	Schlovskii et al.	1985	MNRAS, 212, 545	NS		HALO	Old NS in Galactic halo undergoes starquake
61.	Tsygan	1984	Ap&SS, 106, 199	NS		DISK	Weak B field NS spherically accretes, Comptonizes X-rays
62.	Usov	1984	Ap&SS, 107, 191	NS		DISK	NS flares result of magnetic convective-oscillation instability
63.	Hameury et al.	1985	ApJ, 293, 56	NS		DISK	High Landau e-s beamed along B lines in cold atm. of NS
64.	Rappaport et al.	1985	Nature, 314, 242	NS		DISK	NS + low mass stellar companion gives GRB + optical flash
65.	Tremaine et al.	1986	ApJ, 301, 155	NS	COM	DISK	NS tides disrupt comet, debris hits NS next pass
66.	Muslimov et al.	1986	Ap&SS, 120, 27	NS		HALO	Radially oscillating NS
67.	Sturrock	1986	Nature, 321, 47	NS		DISK	Flare in the magnetosphere of NS accelerates e-s along B-field
68.	Paczynski	1986	ApJ, 308, L43	NS		COS	Cosmo GRBs: rel e+/- opt thk plasma outflow indicated
69.	Bisnovatyi- et al.	1986	SovAstron, 30, 582	NS		DISK	Chain fission of superheavy nuclei below NS surface during SN
70.	Alcock et al.	1986	PRL, 57, 2088	SS	SS	DISK	SN ejects strange mat lump craters rotating SS companion
71.	Babul et al.	1987	ApJ, 316, L49	CS		COS	GRB result of energy released from cusp of cosmic string
72.	Livio et al.	1987	Nature, 327, 398	NS	COM	DISK	Oort cloud around NS can explain soft gamma-repeaters
73.	McBreen et al.	1988	Nature, 332, 234	GAL	AGN	COS	G-wave bkgrd makes BL Lac wiggle across galaxy lens caustic
74.	Curtis	1988	ApJ, 327, L81	WD		COS	WD collapses, burns to form new class of stable particles
75.	Melia	1988	ApJ, 335, 965	NS		DISK	Be/X-ray binary sys evolves to NS accretion with recurrence
76.	Ruderman et al.	1988	ApJ, 335, 306	NS		DISK	e+/- cascades by aligned pulsar outer-mag-sphere reignition
77.	Paczynski	1988	ApJ, 335, 525	CS		COS	Energy released from cusp of cosmic string (revised)
78.	Murikami et al.	1988	Nature, 335, 234	NS		DISK	Absorption features suggest separate colder region near NS
79.	Melia	1988	Nature, 336, 658	NS		DISK	NS + accretion disk reflection explains GRB spectra
80.	Blaes et al.	1989	ApJ, 343, 839	NS		DISK	NS seismic waves couple to magnetospheric Alfen waves
81.	Trofimenko et al.	1989	Ap&SS, 152, 105	WH		COS	Kerr-Newman white holes
82.	Sturrock et al.	1989	ApJ, 346, 950	NS		DISK	NS E- field accelerates electrons which then pair cascade
83.	Fenimore et al.	1988	ApJ, 335, L71	NS		DISK	Narrow absorption features indicate small cold area on NS
84.	Rodrigues	1989	AJ, 98, 2280	WD	WD	DISK	Binary member loses part of crust, through L1, hits primary
85.	Pineault et al.	1989	ApJ, 347, 1141	NS	COM	DISK	Fast NS though Oort clouds, fast WD bursts only optical
86.	Melia et al.	1989	ApJ, 346, 378	NS		DISK	Episodic electrostatic accel and Comp scat from rot high-B NSs
87.	Trofimenko	1989	Ap&SS, 159, 301	WH		COS	Different types of white, "grey" holes can emit GRB
88.	Eichler et al.	1989	Nature, 340, 126	NS	NS	COS	NS - NS binary members collide, coalesce
89.	Wang et al.	1989	PRL, 63, 1550	NS		DISK	Cyclo res & Raman scat fits 20, 40 keV dips, magnetized NS
90.	Alexander et al.	1989	ApJ, 344, L1	NS		DISK	QED mag resonant opacity in NS atmosphere
91.	Melia	1990	ApJ, 351, 601	NS		DISK	NS magnetospheric plasma oscillations
92.	Ho et al.	1990	ApJ, 348, L25	NS		DISK	Beaming of radiation necessary from magnetized neutron stars
93.	Mitrofanov et al.	1990	Ap&SS, 165, 137	NS	COM	DISK	Interstellar comets pass through dead pulsar's magnetosphere
94.	Dermer	1990	ApJ, 360, 197	NS		DISK	Compton scattering in strong NS magnetic field
95.	Blaes et al.	1990	ApJ, 363, 612	NS	ISM	DISK	Old NS accretes from ISM, surface goes nuclear
96.	Paczynski	1990	ApJ, 363, 218	NS	NS	COS	NS-NS collision causes v collisions to drive super-Ed wind
97.	Zdziarski et al.	1991	ApJ, 366, 343	RE	MBR	COS	Scattering of microwave background photons by rel e-s
98.	Pineault	1990	Nature, 345, 233	NS	COM	DISK	Young NS drifts through its own Oort cloud
99.	Trofimenko et al.	1991	Ap&SS, 178, 217	WH		HALO	White hole supernova gave simul burst of g-waves from 1987A
100.	Melia et al.	1991	ApJ, 373, 198	NS		DISK	NS B- field undergoes resistive tearing, accelerates plasma
101.	Holcomb et al.	1991	ApJ, 378, 682	NS		DISK	Alfen waves in non-uniform NS atmosphere accelerate particles
102.	Haensel et al.	1991	ApJ, 375, 209	SS	SS	COS	Strange stars emit binding energy in grav. rad. and collide
103.	Blaes et al.	1991	ApJ, 381, 210	NS	ISM	DISK	Slow interstellar accretion onto NS, e- capture starquakes result
104.	Frank et al.	1992	ApJ, 385, L45	NS		DISK	Low mass X-ray binary evolves into GRB sites
105.	Woosley et al.	1992	ApJ, 391, 228	NS		HALO	Accreting WD collapses to NS
106.	Hojman et al.	1993	ApJ, 411, 541	NS		HALO	NS popul at MW halo boundary expected by hydro density jump
107.	Dar et al.	1992	ApJ, 388, 164	WD		COS	WD accretes to form naked NS, GRBs, cosmic rays
108.	Thompson et al.	1993	ApJ, 408, 194	NS		COS	Sudden NS convection with high B drives e- pairs, gammas.
109.	Hanami	1992	ApJ, 389, L71	NS	PLAN	COS	NS - planet magnetospheric interaction unstable
110.	Meszaros et al.	1992	ApJ, 397, 570	NS	NS	COS	NS - NS collision produces anisotropic fireball
111.	Eichler et al.	1992	Science, 257, 937	NS		HALO	High vel halo pulsars accrete after being kicked from disk
112.	Eichler et al.	1992	Science, 257, 937	WD	WD	HALO	WD merger yields GRB
113.	Carter	1992	ApJ, 391, L67	BH	ST	COS	Normal stars tidally disrupted by galactic nucleus BH
114.	Usov	1992	Nature, 357, 472	NS		COS	WD collapses to form NS, B-field brakes NS rotation instantly
115.	Blaes et al.	1992	ApJ, 399, 634	NS		GAL	Old NS accretes from mol cloud, R-T instab at crust
116.	Narayan et al.	1992	ApJ, 395, L83	NS	NS	COS	NS - NS merger gives optically thick fireball
117.	Narayan et al.	1992,	ApJ, 395, L83	BH	NS	COS	BH-NS merger gives optically thick fireball
118.	Brainerd	1992	ApJ, 394, L33	AGN	JET	COS	Synchrotron emission from AGN jets
119.	Smith et al.	1993	ApJ, 410, 315	NS		DISK	e- beams accel by E-fields near NS with high B
120.	Meszaros et al.	1992	MNRAS, 257, 29P	BH	NS	COS	BH-NS have vs collide to γs in clean fireball
121.	Meszaros et al.	1992	MNRAS, 257, 29P	NS	NS	COS	NS-NS have vs collide to γs in clean fireball
122.	Fatuzzo et al.	1993	ApJ, 407, 680	NS		COS	Alfen waves accel particles which upscatter soft photons
123.	Bisnovatyi-Kogan	1993	A&A Sup, 97, 65	NS		GAL	Absorption by cloud of heavy elements around NS
124.	McBreen et al.	1993	A&A Sup, 97, 81	AGN		COS	Relativistic jets from cocooned AGN
125.	Cline et al.	1992	ApJ, 401, L57	BH		DISK	Primordial BHs evaporating could account for short hard GRBs
126.	Woosley	1993	ApJ, 405, 273	BH		COS	Spinning Wolf-Ray star collapses, failed SN, emitts beamed fireball
127.	Melia et al.	1992	ApJ, 398, L85	NS		COS	Crustal adjustments by extragal radio pulsars
128.	Rees et al.	1992	MNRAS, 258, 41P	NS	ISM	COS	Relativistic fireball reconverted to radiation when hits ISM
129.	Kundt et al.	1993	Ap&SS, 200, 151	NS		GAL	Spasmodic NS accretion causes beamed cooling 'sparks'
130.	Meszaros et al.	1993	ApJ, 405, 278	NS	BH	COS	Compact binary coalesces, fireball hits external medium
131.	Cheng et al.	1993	MNRAS, 262, 1037	NS		GAL	NS glitch reignites magnetosphere of dead pulsar
132.	Melia et al.	1993	ApJ, 408, L9	NS		COS	NS structural readjustments explain both SGRs and GRBs
133.	Piran et al.	1993	ApJ, 403, L67	NS		GAL	Galactic fireball requires rel ejecta, low T, possible but unlikely
134.	Fabian et al.	1993	MNRAS, 263, 49	NS		LMC	NS accretes after ejected from Meg Cloud by companion SN
135.	Fatuzzo et al.	1993	ApJ, 414, L89	NS		COS	Sheared Alfen waves in NS magsphere dissipate focused power

135 theories, less than 100 GRBs!

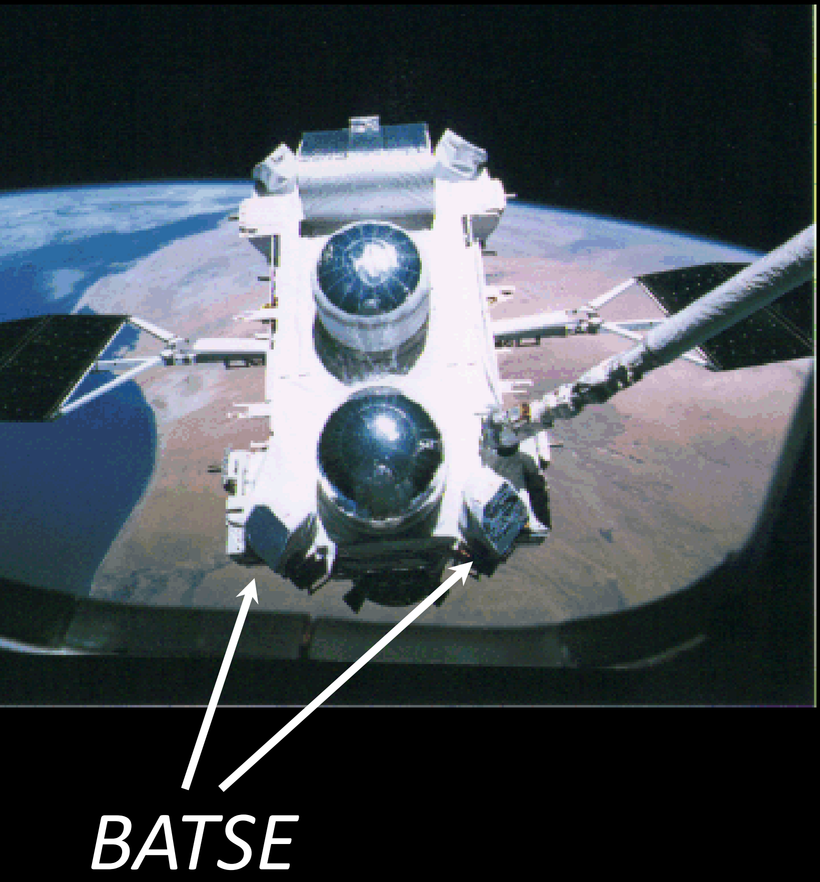
Short duration & high energy:

- New type of supernova?
- Giant stellar flares?
- Matter/anti-matter annihilation?
- Meteor/comet impacts on compact objects?
- Neutron stars? Colliding, merging, collapsing?
- Black holes? Colliding, merging, evaporating?

... interstellar warfare?

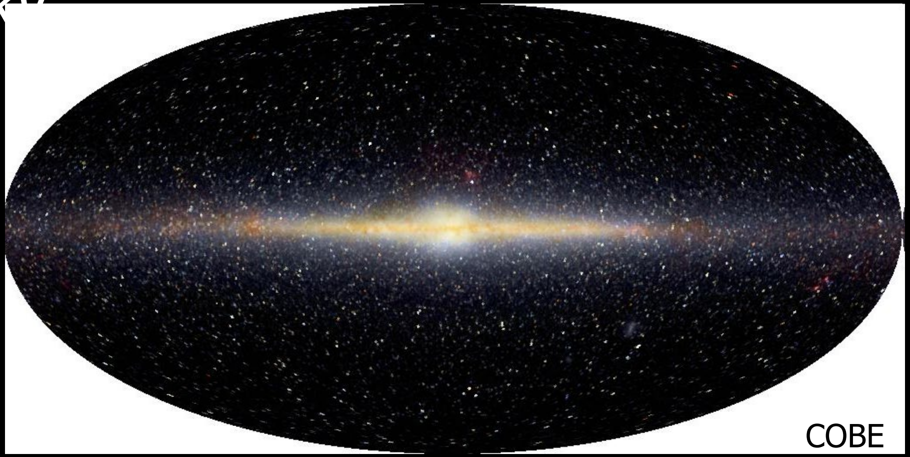
Uncertainty in distance by a ~10^{12}

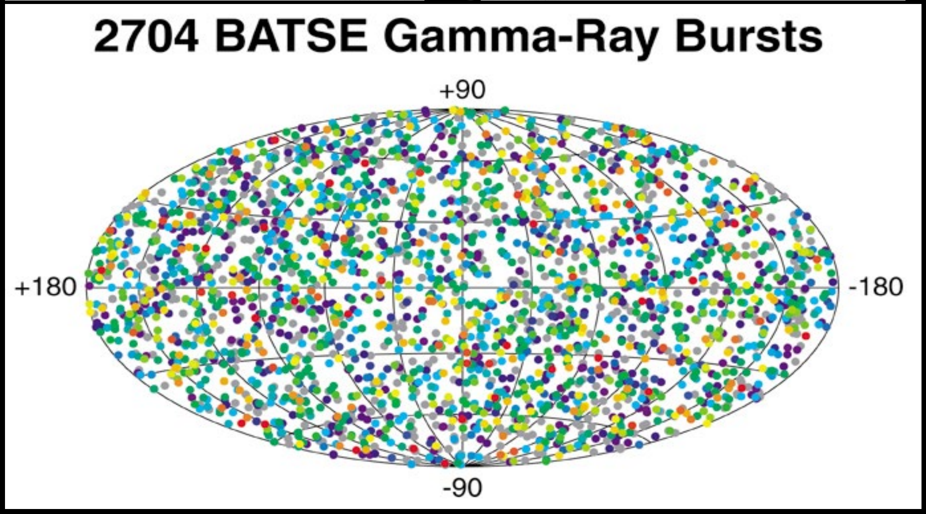
Compton γ-Ray Observatory (1993)



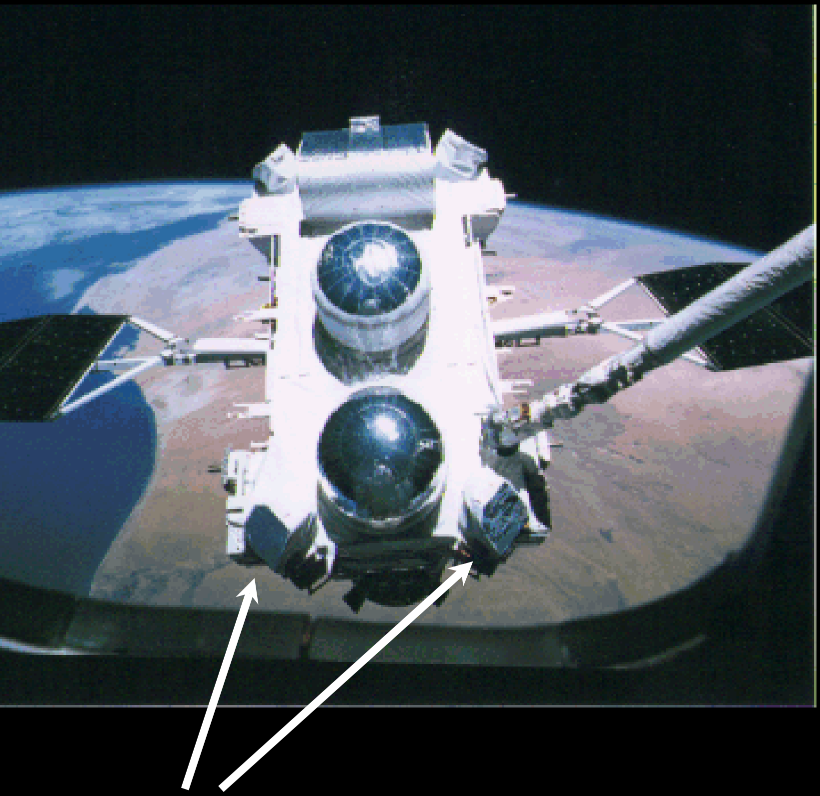
Result 1:

GRBs uniformly distributed on the sky





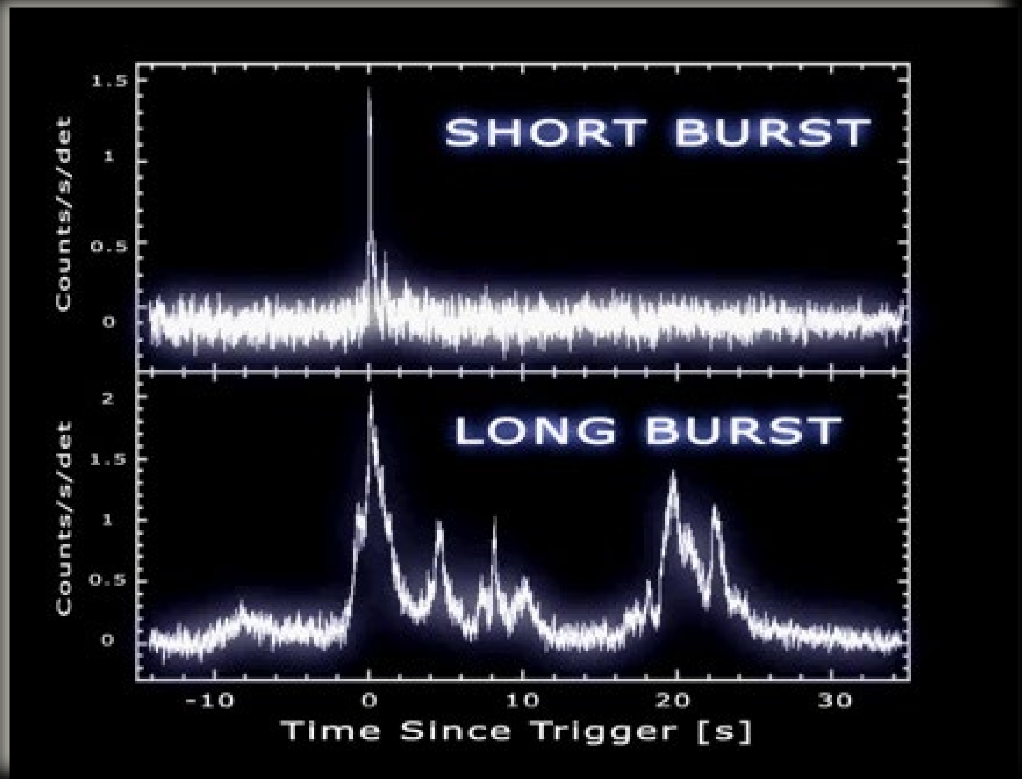
Compton γ-Ray Observatory (1993)



BATSE

Result 2:

Two types of GRBs: long and short



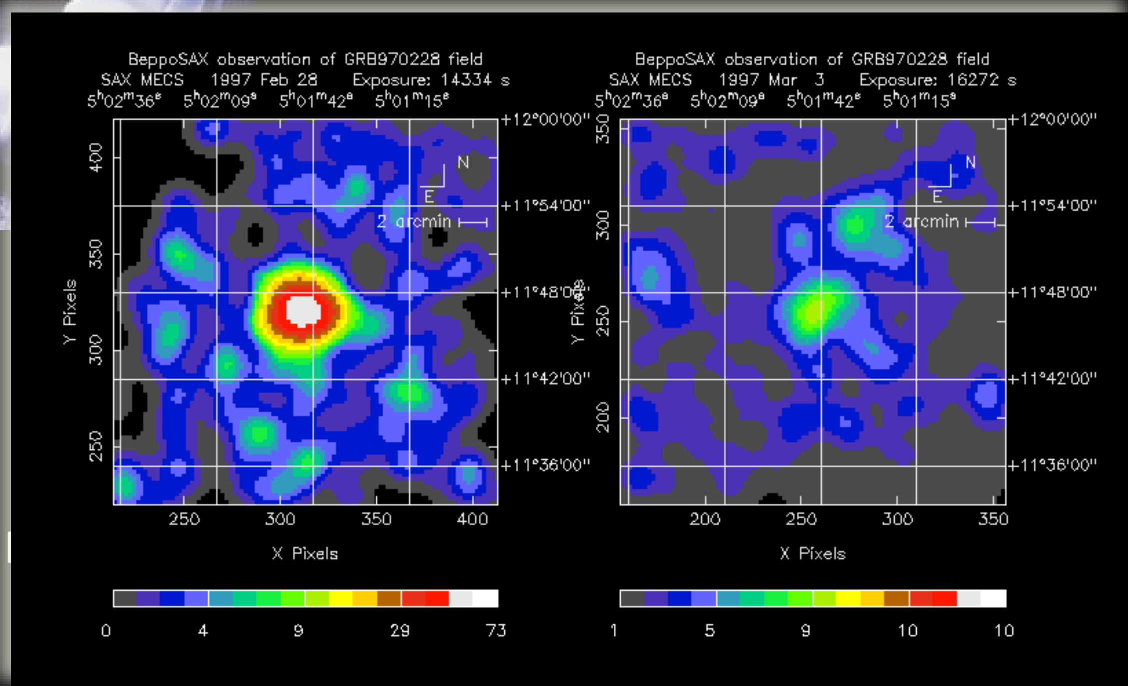
Prompt Emission vs. Afterglow

GRB

Afterglow

The Discovery of Afterglows

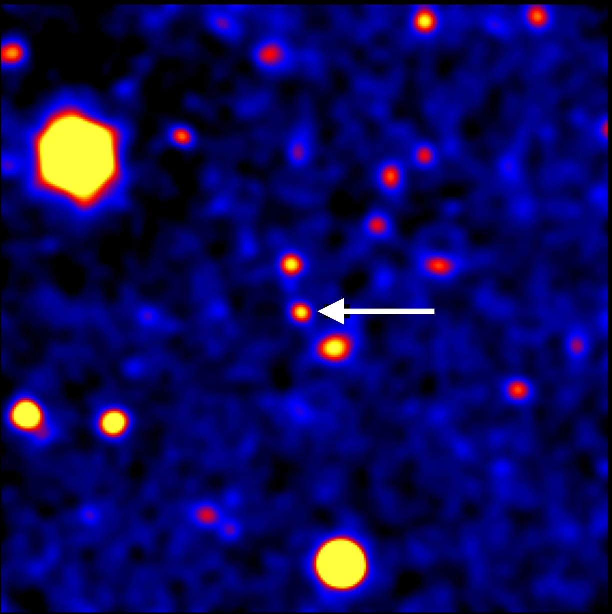
February 28, 1997

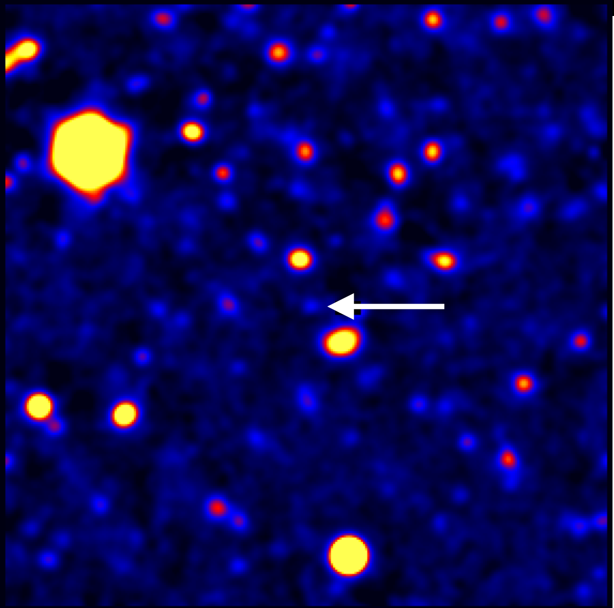


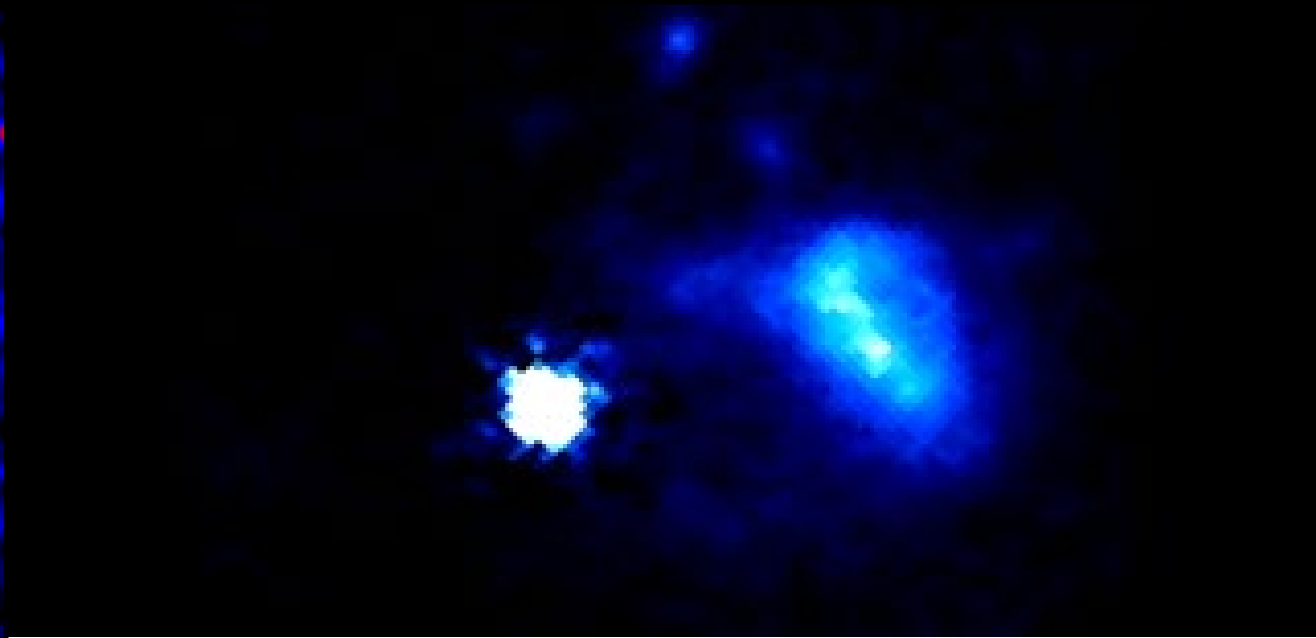
BeppoSAX (April 30,

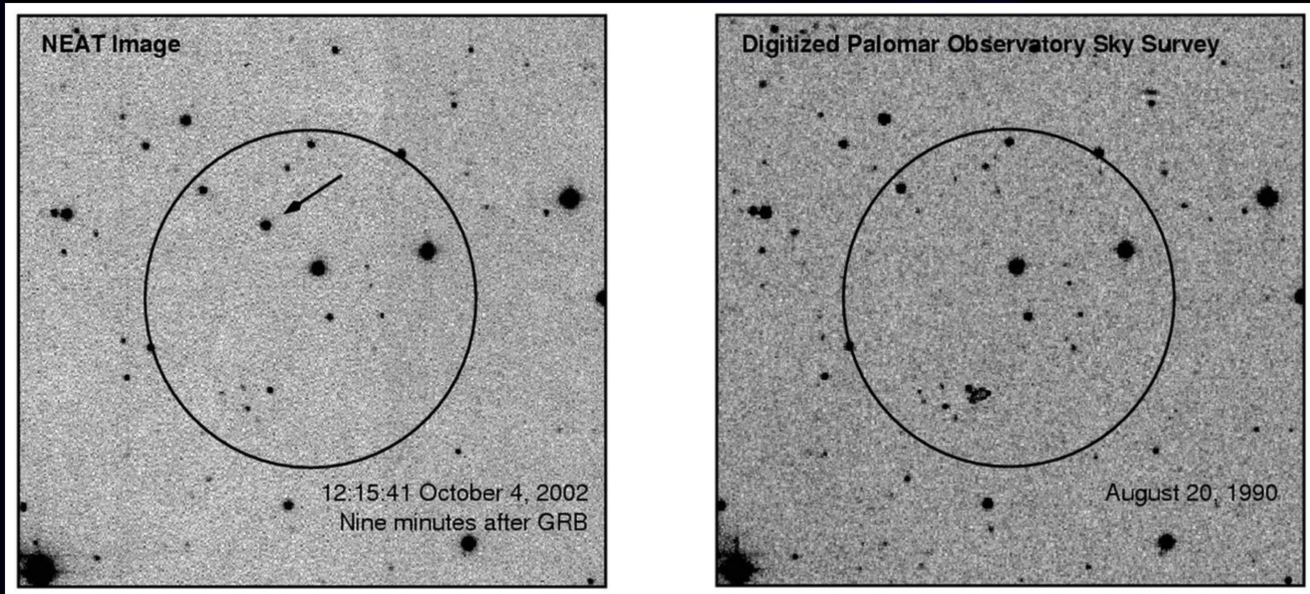
- Soft X-ray response
- 100× more accurate thar
- Delivery time of ~hours

Optical Afterglows

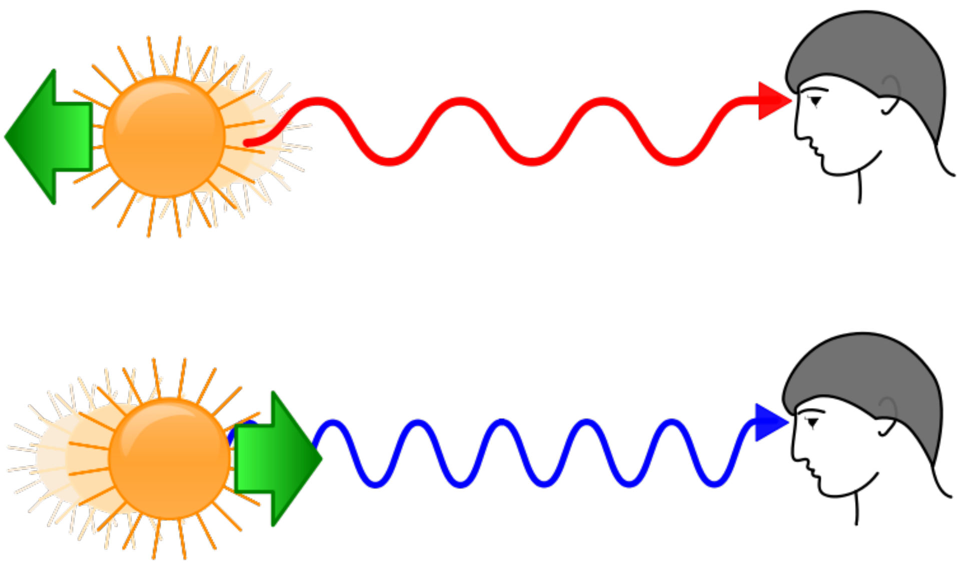


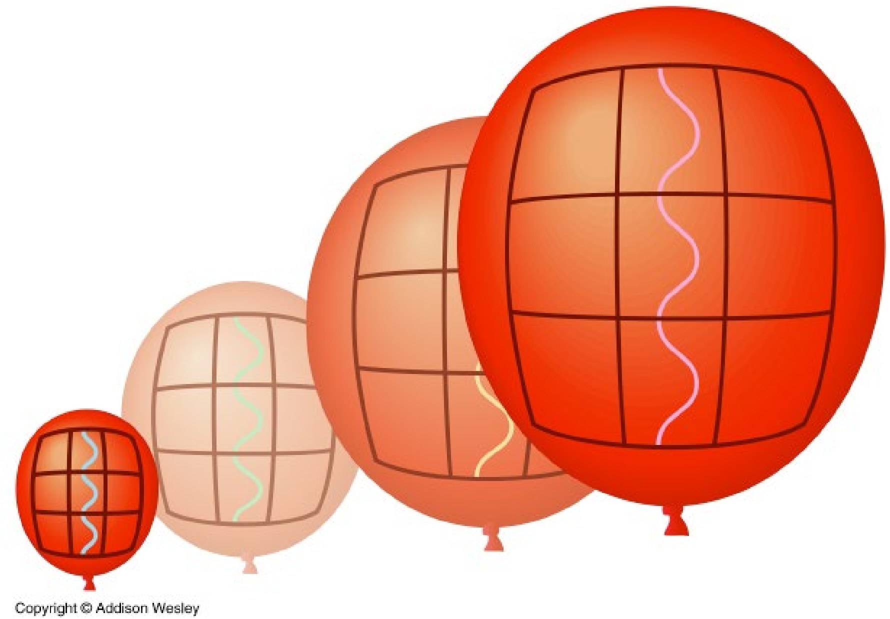


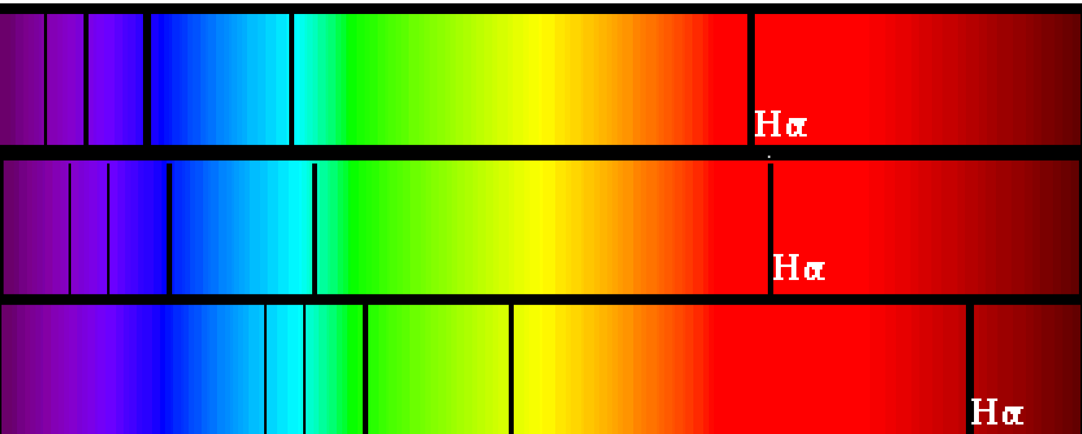




Redshift: A Distance Indicator







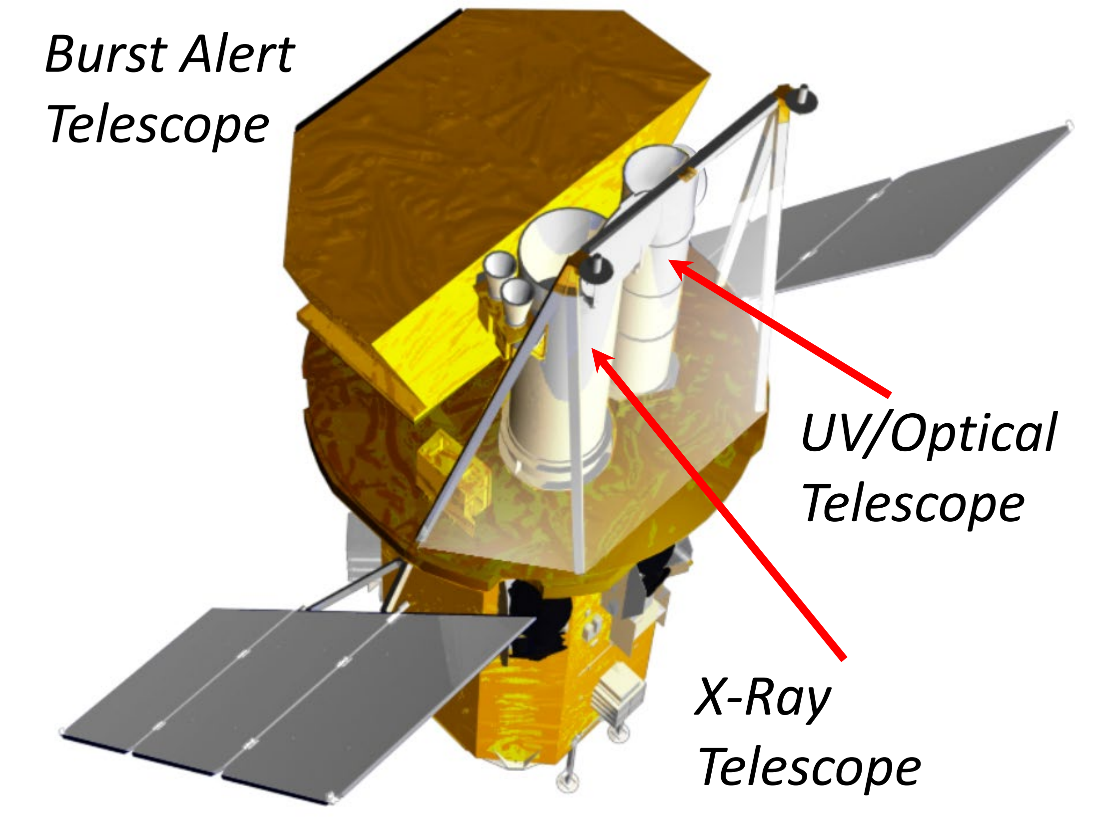
At rest

Low velocity (nearby)

High velocity (far away)

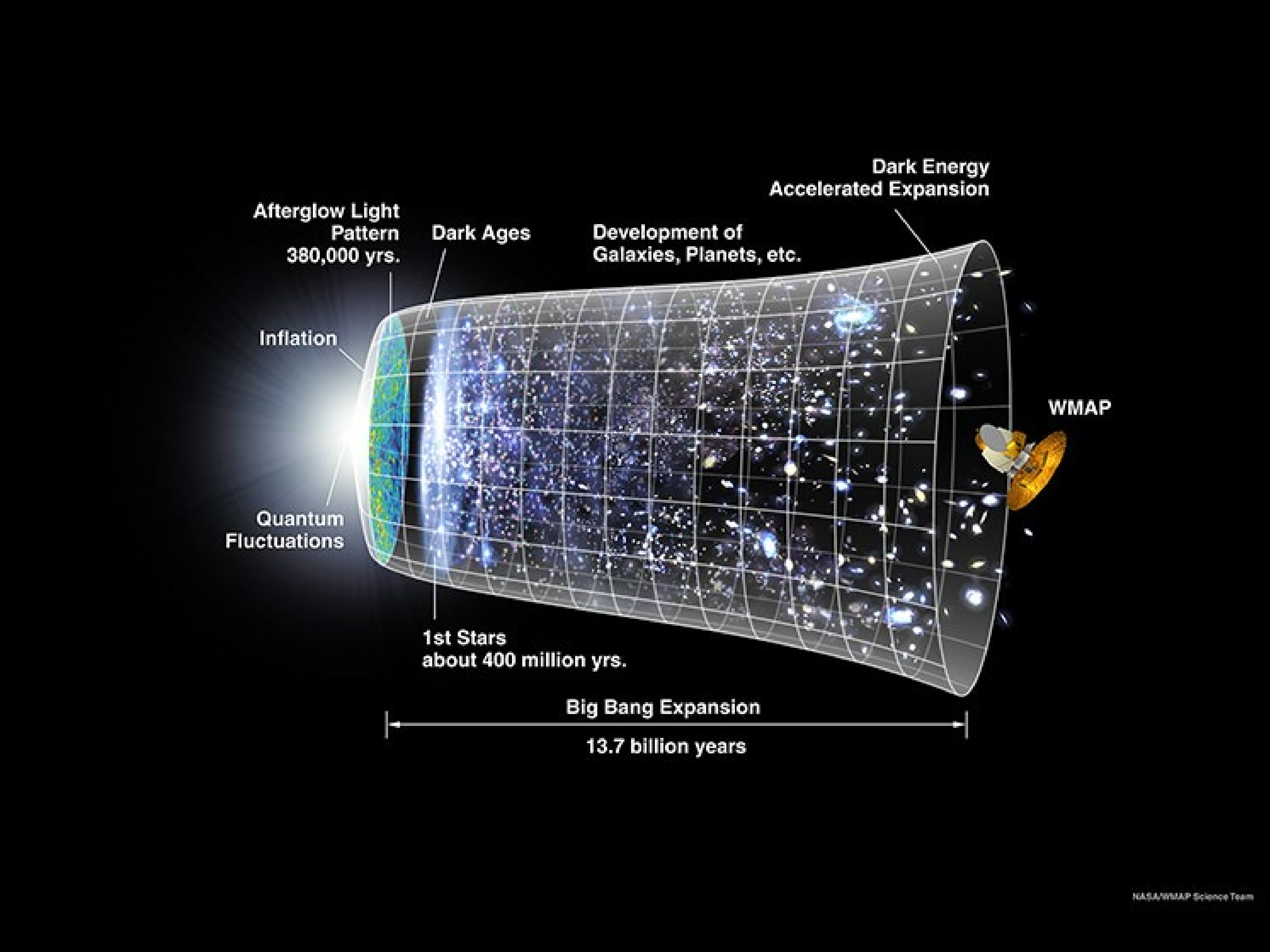
$z = (\lambda_{obs} - \lambda_{em})/\lambda_{em}$ $cz = H_0 \times d$

The Swift Satellite

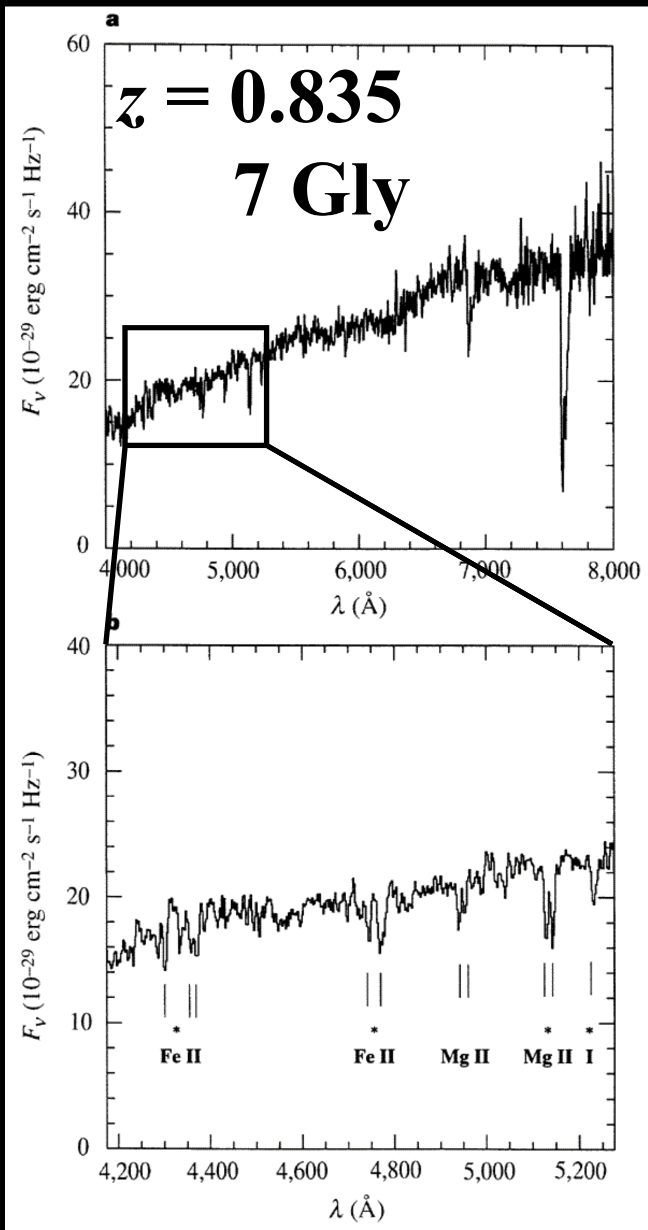


- Event rate ~100/yr
- Positions ~1-5″
- Alerts within ~60 sec
- Lifetime ~2015

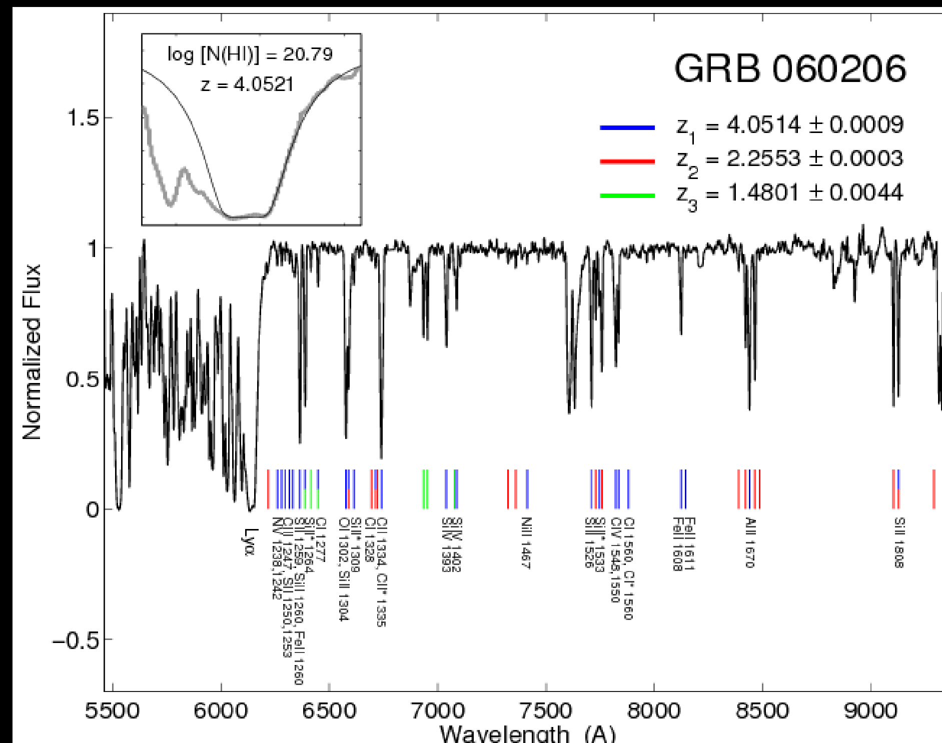
November 20, 2004


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years
NASA/WMAP Science Team

GRB Redshifts: Cosmological Origin

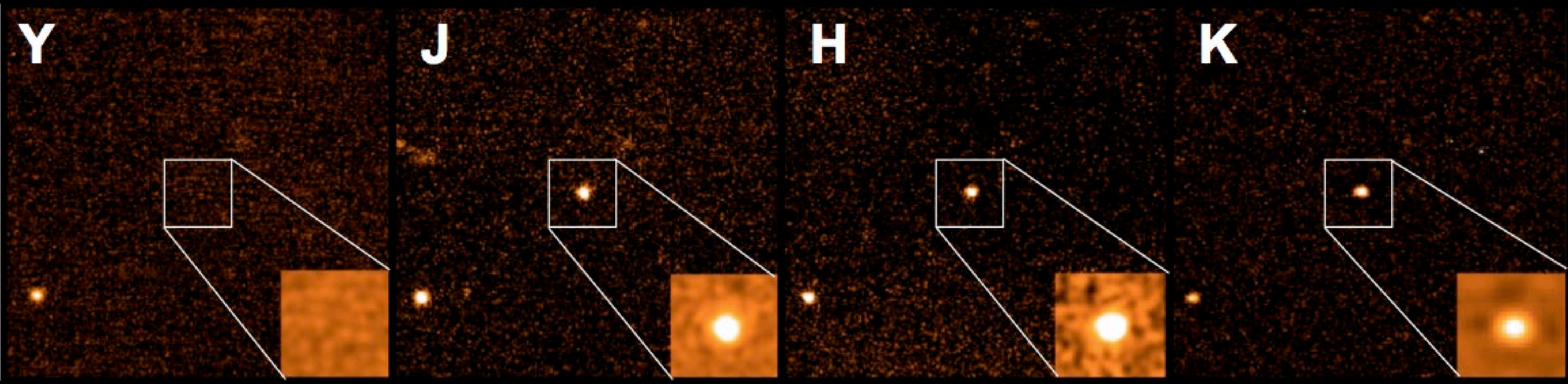


z = 4.0514   12.1 Gly



- GRBs are cosmological
- The energy release is ~10^{54} erg = rest-mass of a solar-mass object

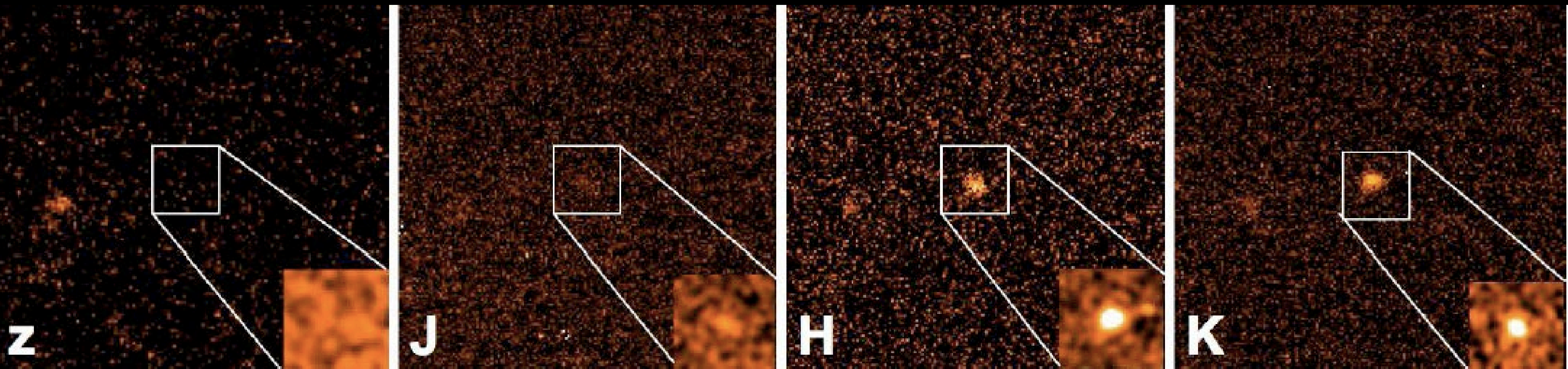
GRBs as Probes of First Galaxies



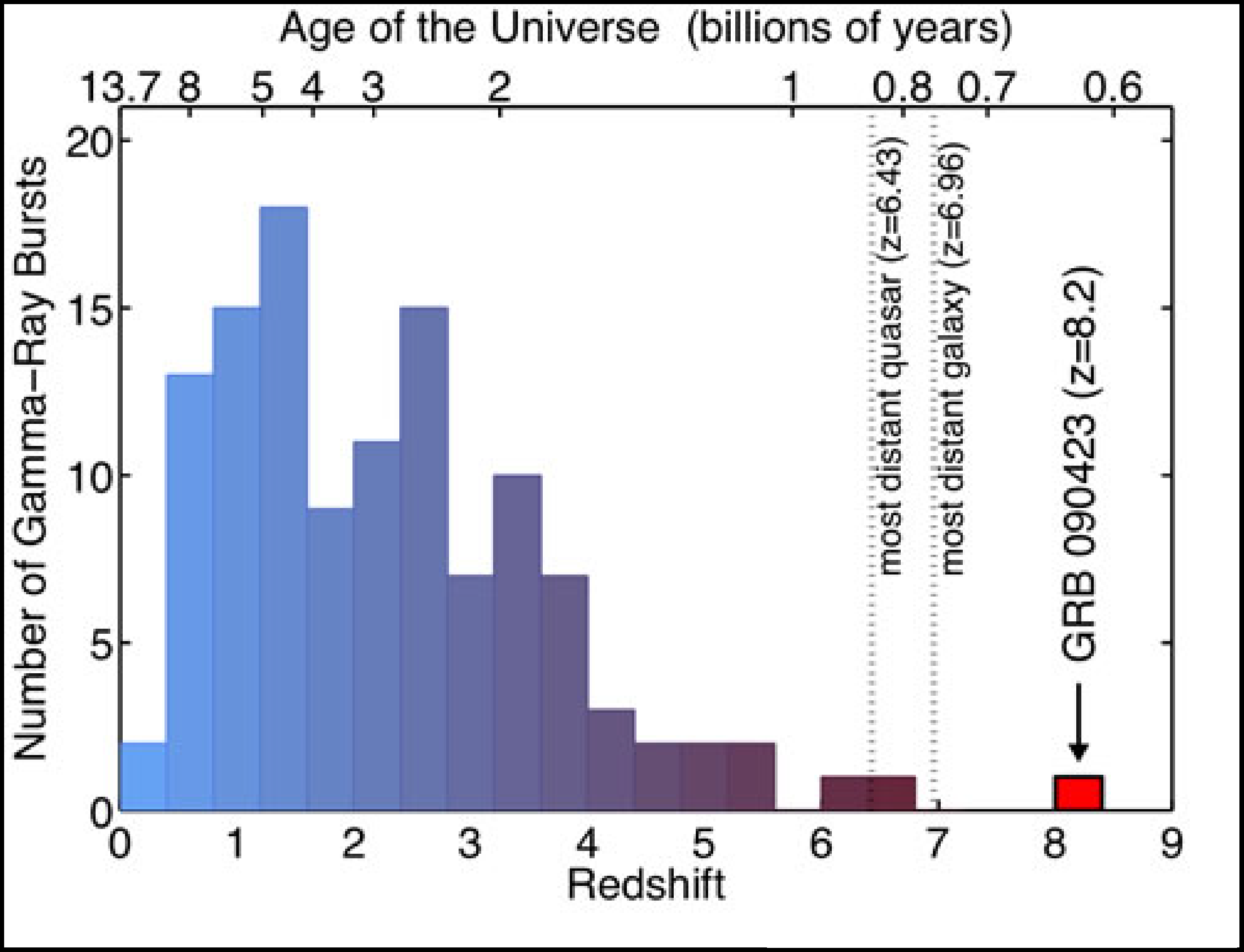
$z \approx 8.26$ (625 Myr)

GRBs can be used as "flashlights" to probe the composition of high redshift galaxies

$z \approx 9.4$ (525 Myr)

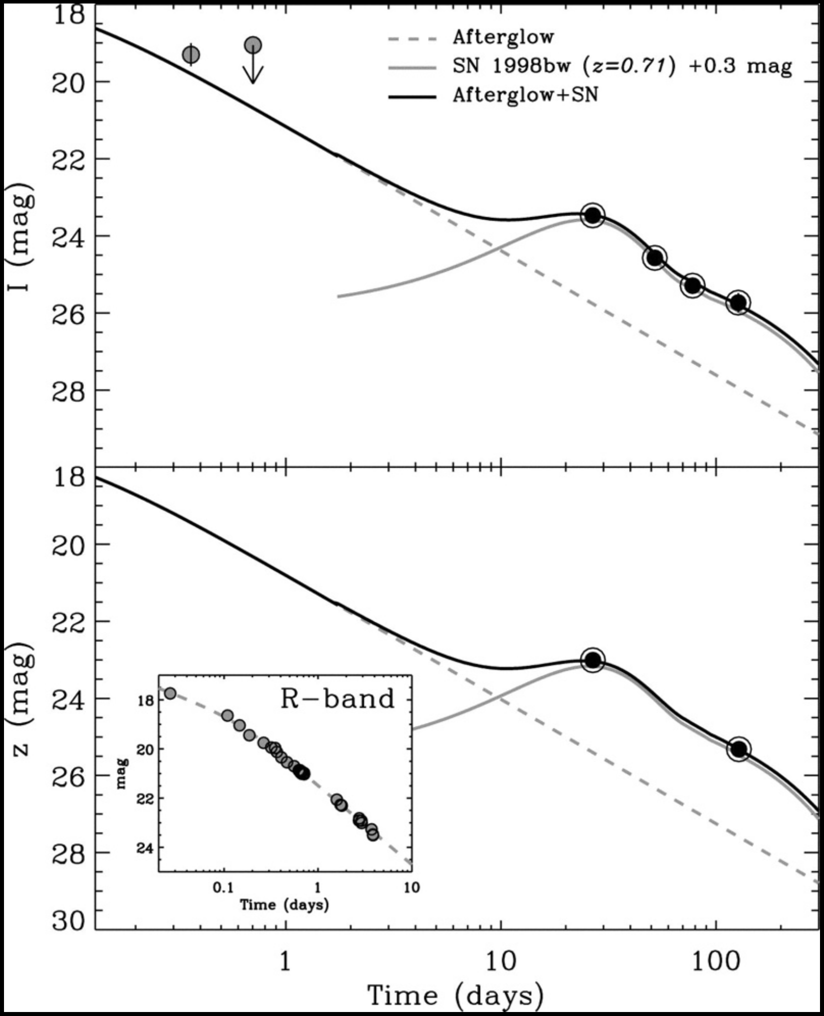


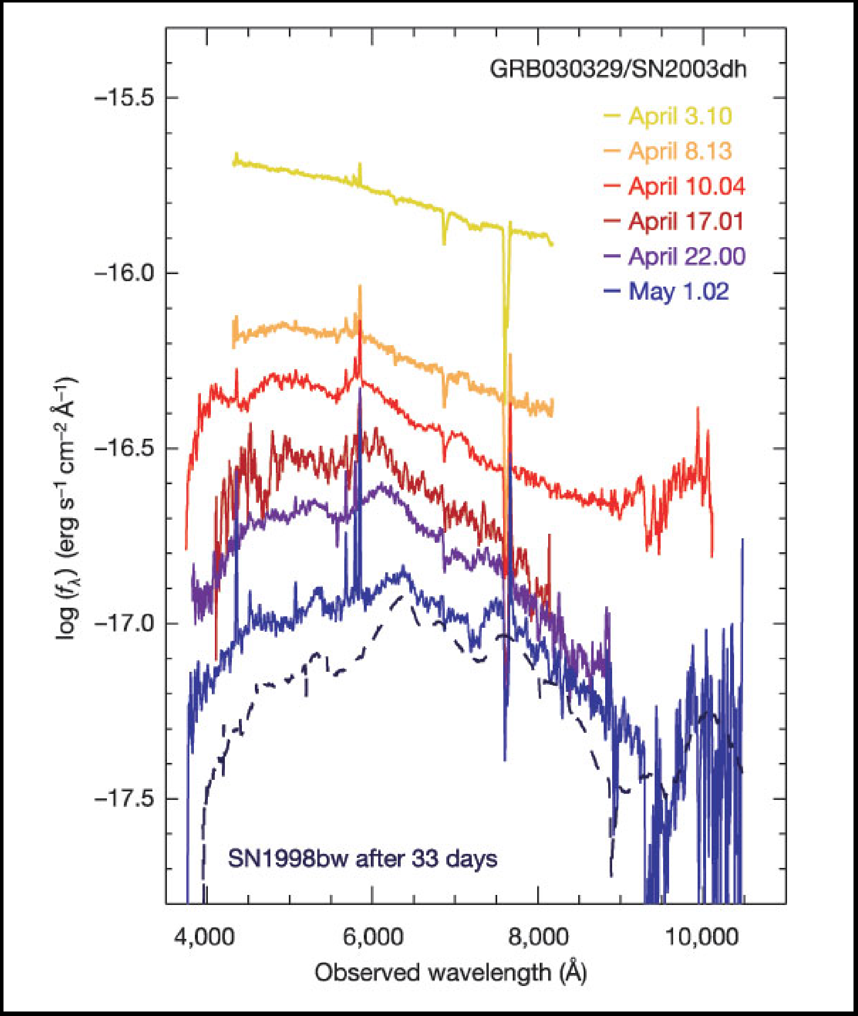
z = 8.2 ⇒ 630 Myr after the Big Bang
4.6% of the current age of the Universe



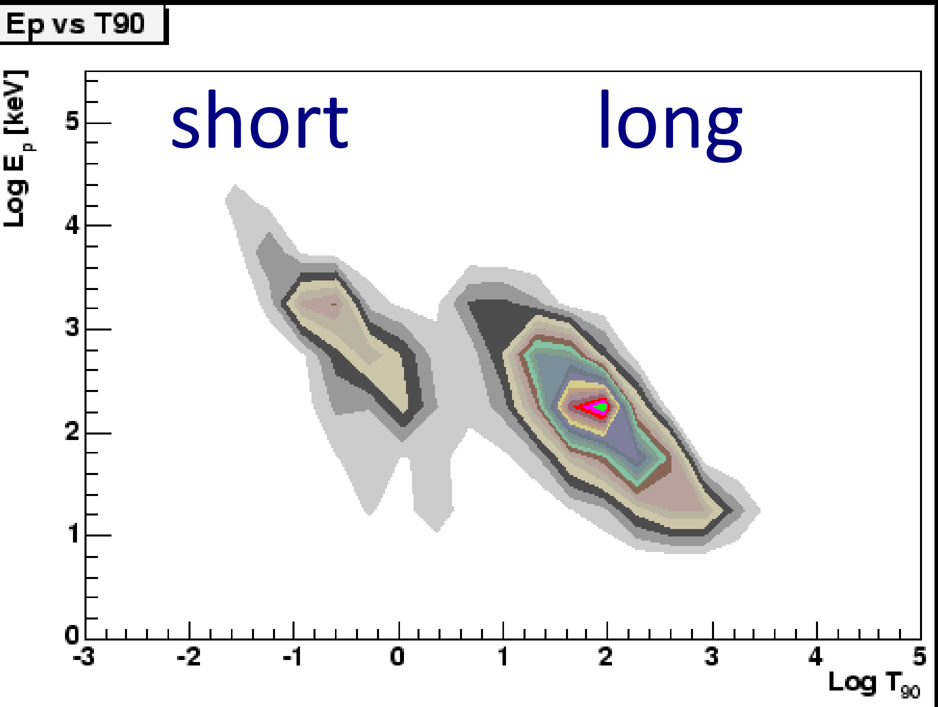
Long GRBs: The Death of Massive Stars

2. Association with core-collapse supernovae



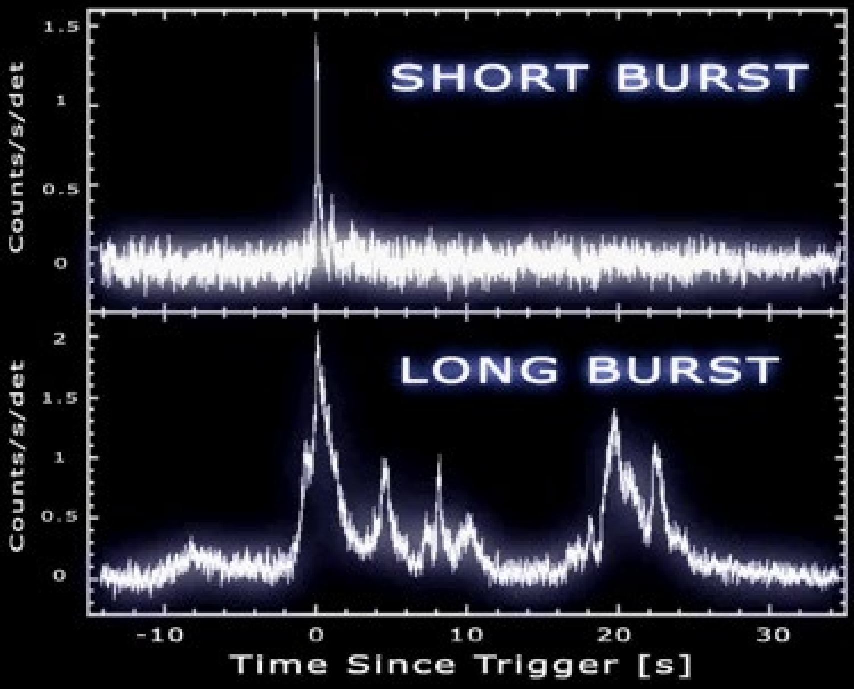


Short GRBs



Short GRBs have a similar flux to long GRBs, but short duration leads to less photons

⇒ *more difficult to localize*

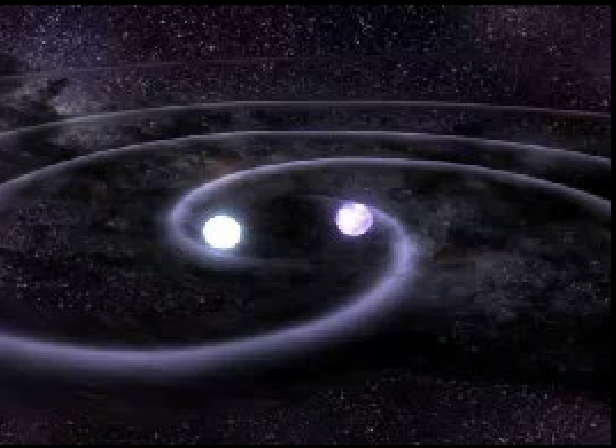


- No active star formation (?)
- Stellar population >1 Gyr

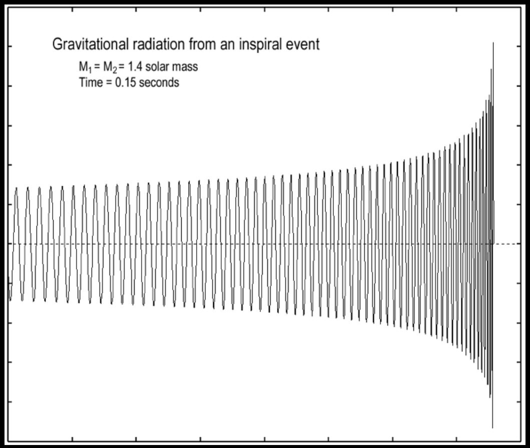
⇒ short GRBs are produced by an old stellar population

NS-NS binaries?

Gravitational Waves



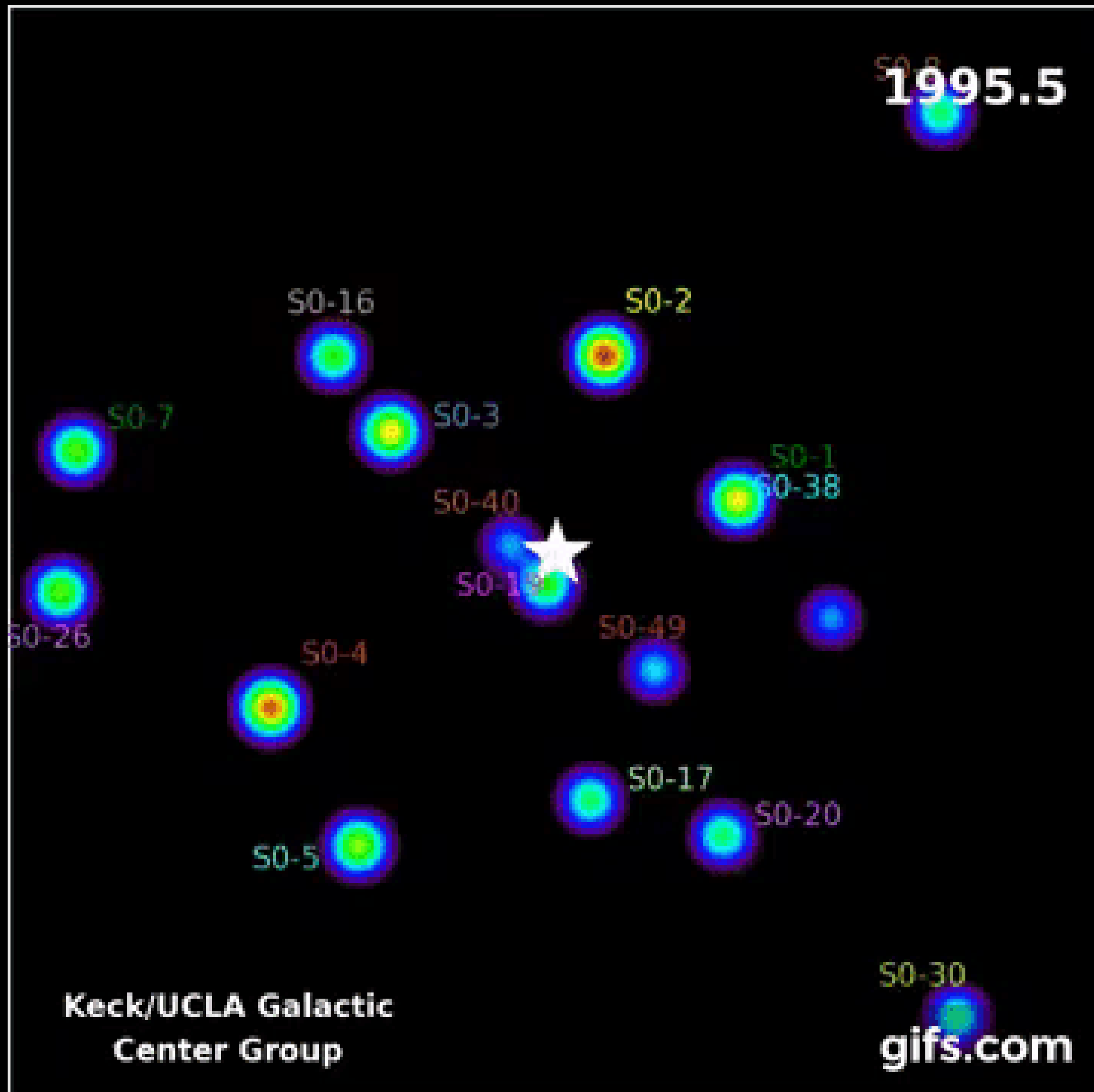
⇒



⇖

LIGO

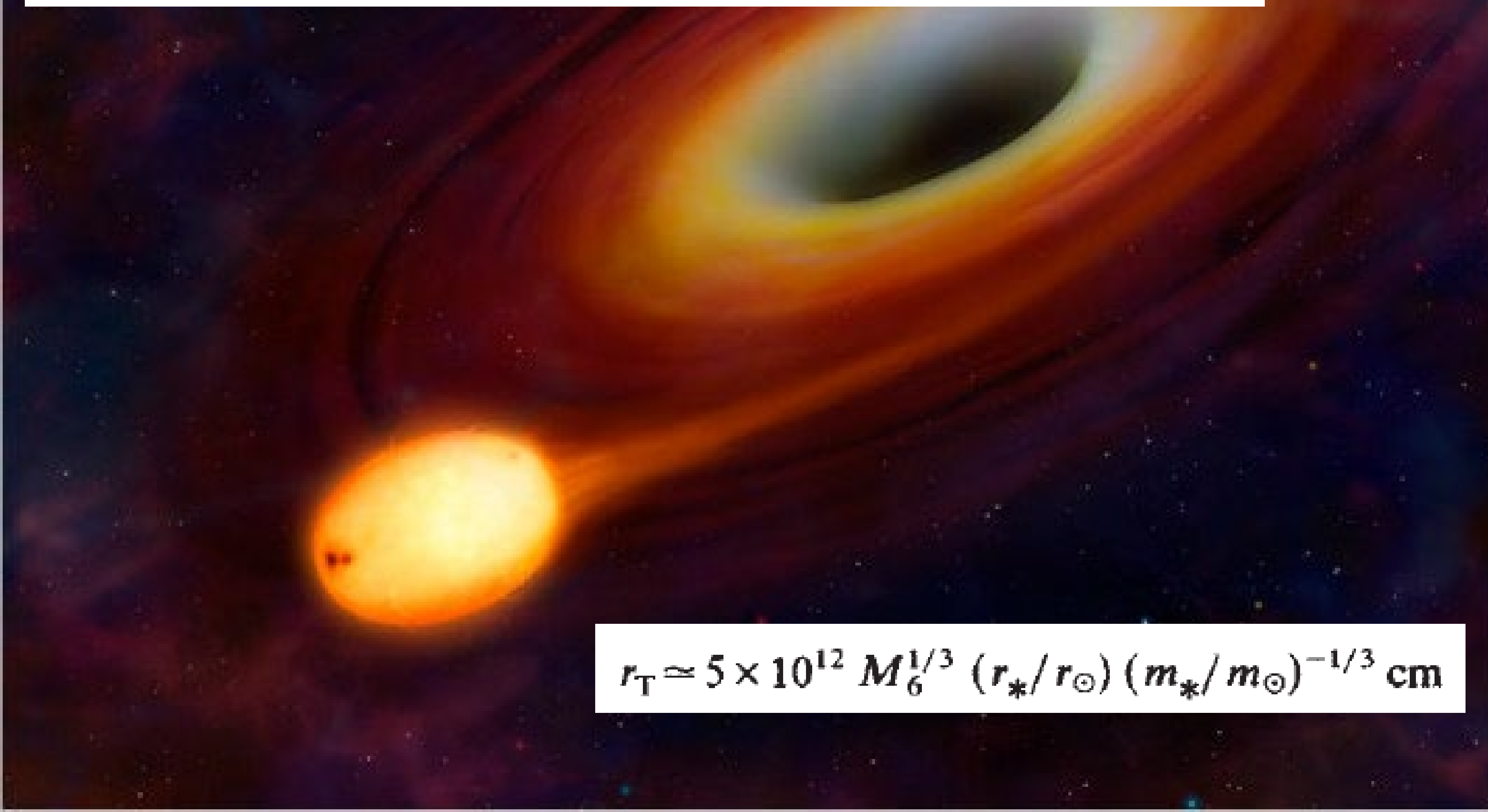
Probing Black Holes…


1995.5
S0-16
S0-2
S0-7
S0-3
S0-1
S0-38
S0-40
S0-26
S0-4
S0-49
S0-17
S0-20
S0-5
S0-30
Keck/UCLA Galactic
Center Group
gifs.com

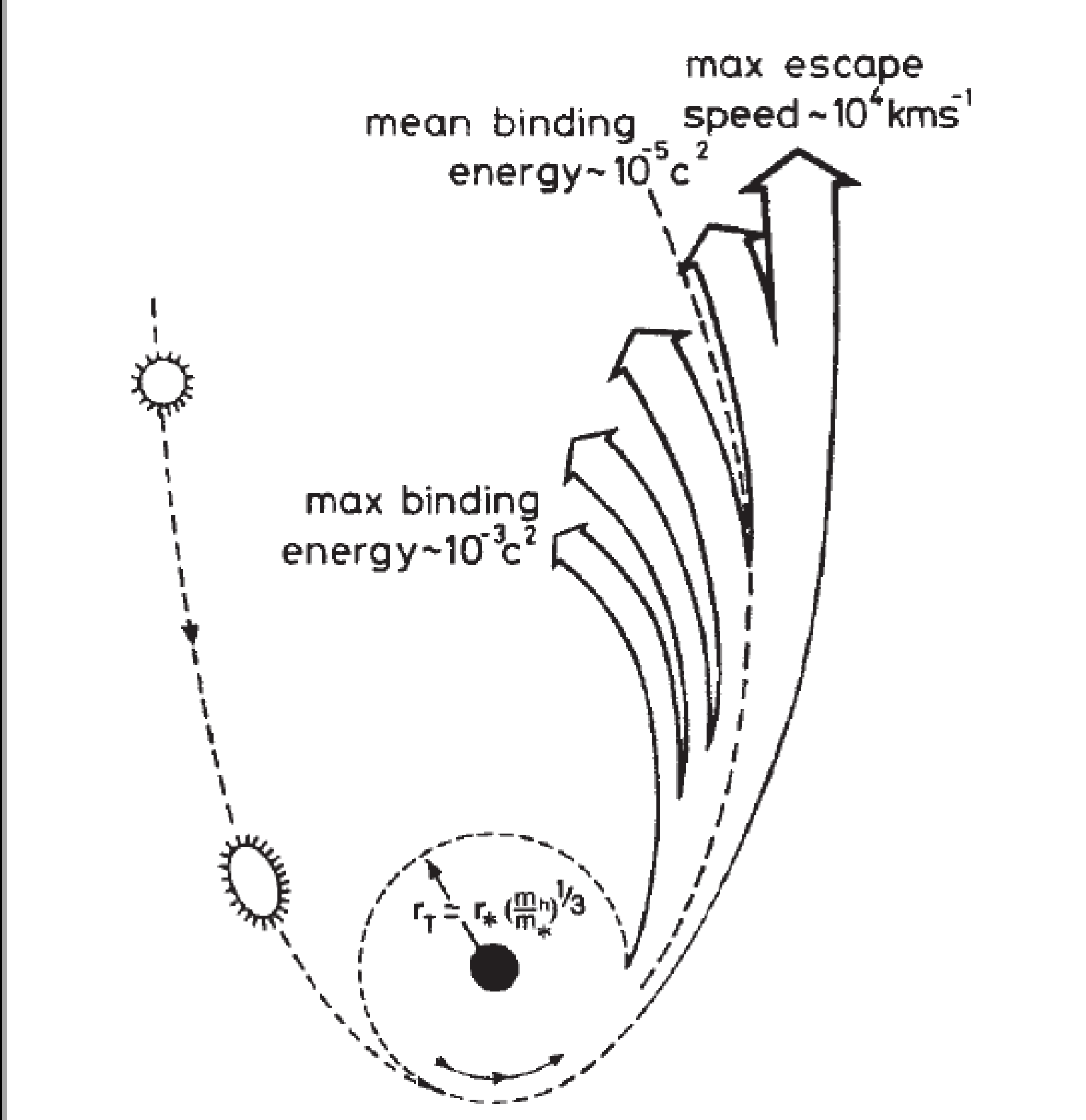
NATURE VOL. 333 9 JUNE 1988 ARTICLES 523

Tidal disruption of stars by black holes of 10^6–10^8 solar masses in nearby galaxies

Martin J. Rees

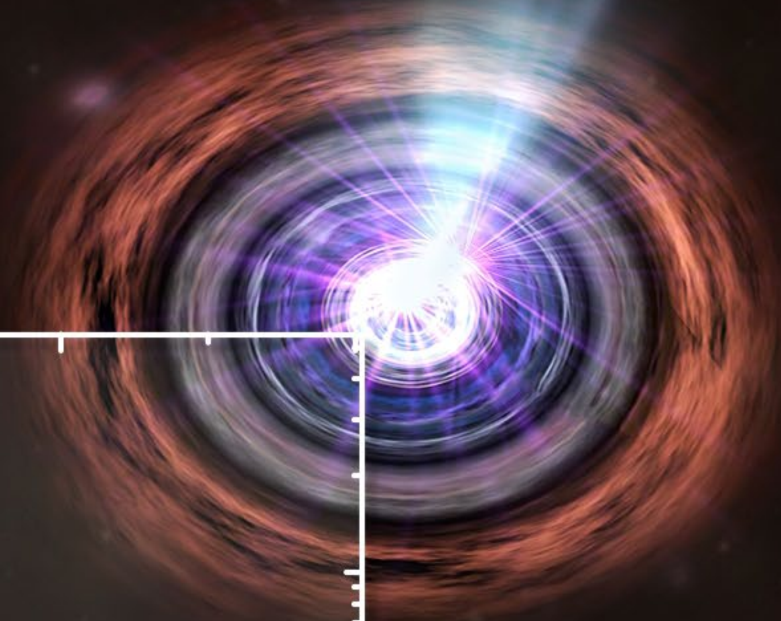


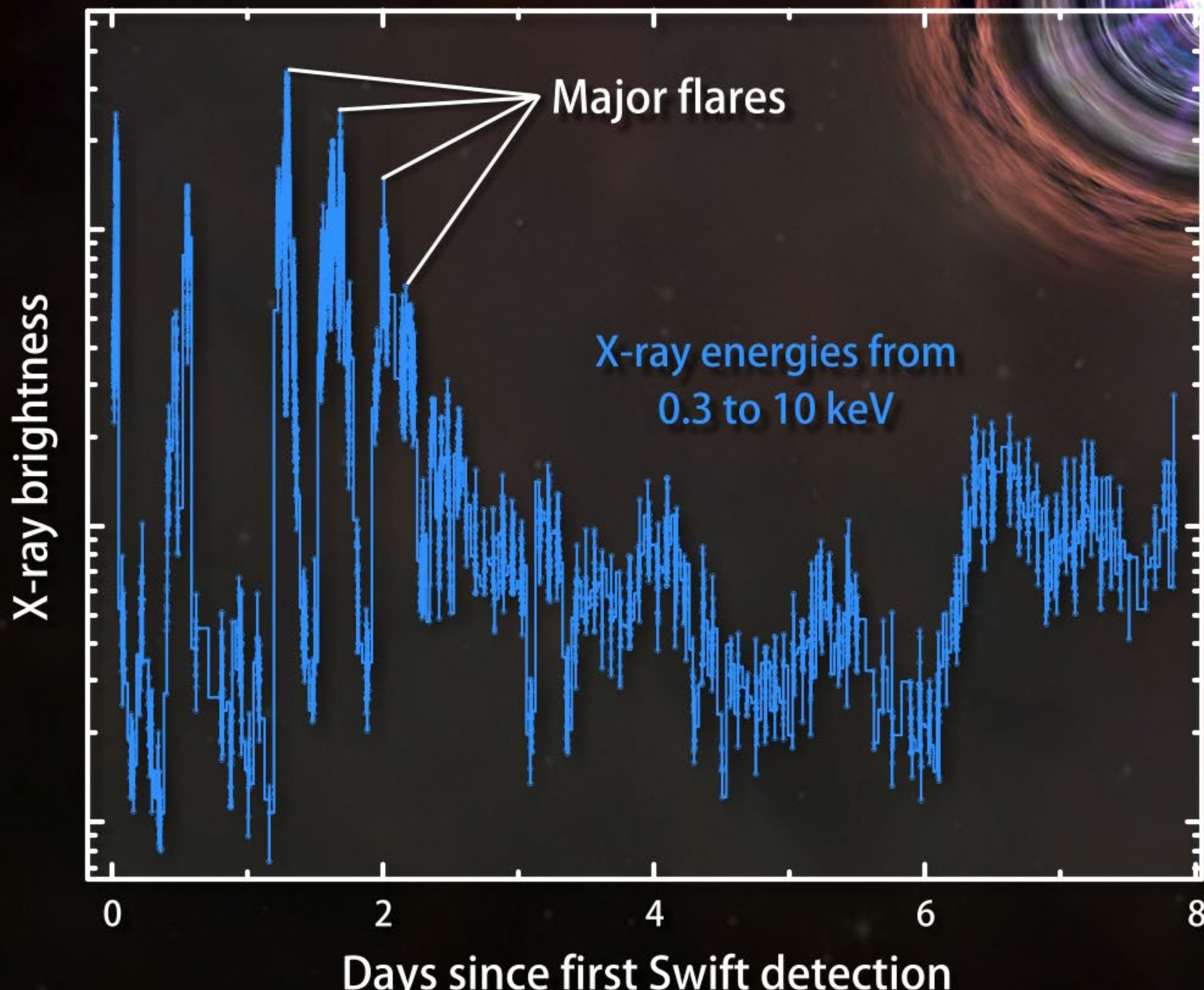
$$r_T \simeq 5 \times 10^{12}\, M_6^{1/3}\, (r_*/r_\odot)\, (m_*/m_\odot)^{-1/3}\ \mathrm{cm}$$



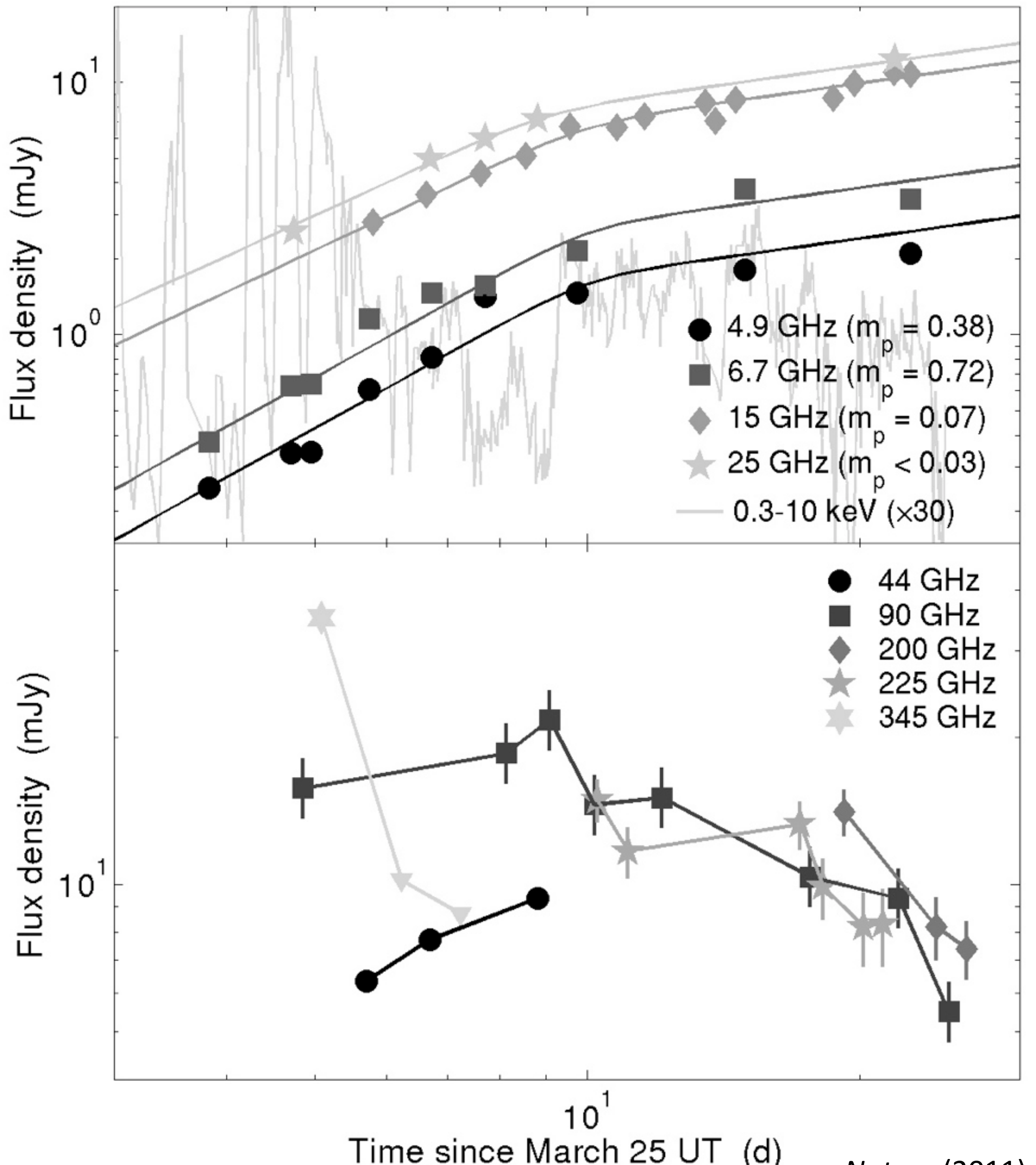
Rees 1988 (Nature)

GRB 110328A





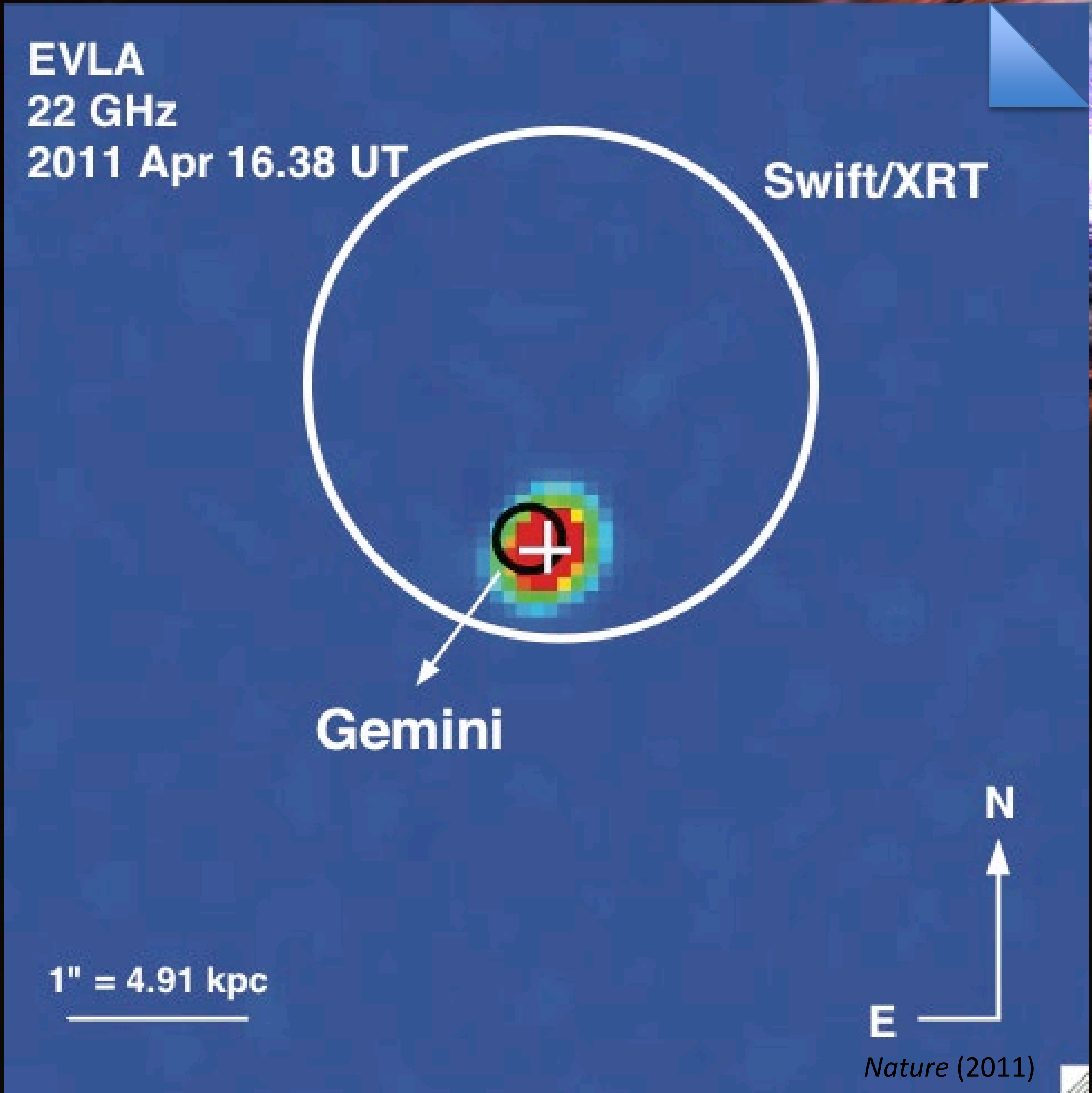
NASA/CXC/Warwick/A.Levan et al.



Flux density (mJy)
4.9 GHz (m_p = 0.38)
6.7 GHz (m_p = 0.72)
15 GHz (m_p = 0.07)
25 GHz (m_p < 0.03)
0.3-10 keV (×30)
44 GHz
90 GHz
200 GHz
225 GHz
345 GHz
Flux density (mJy)
Time since March 25 UT (d)

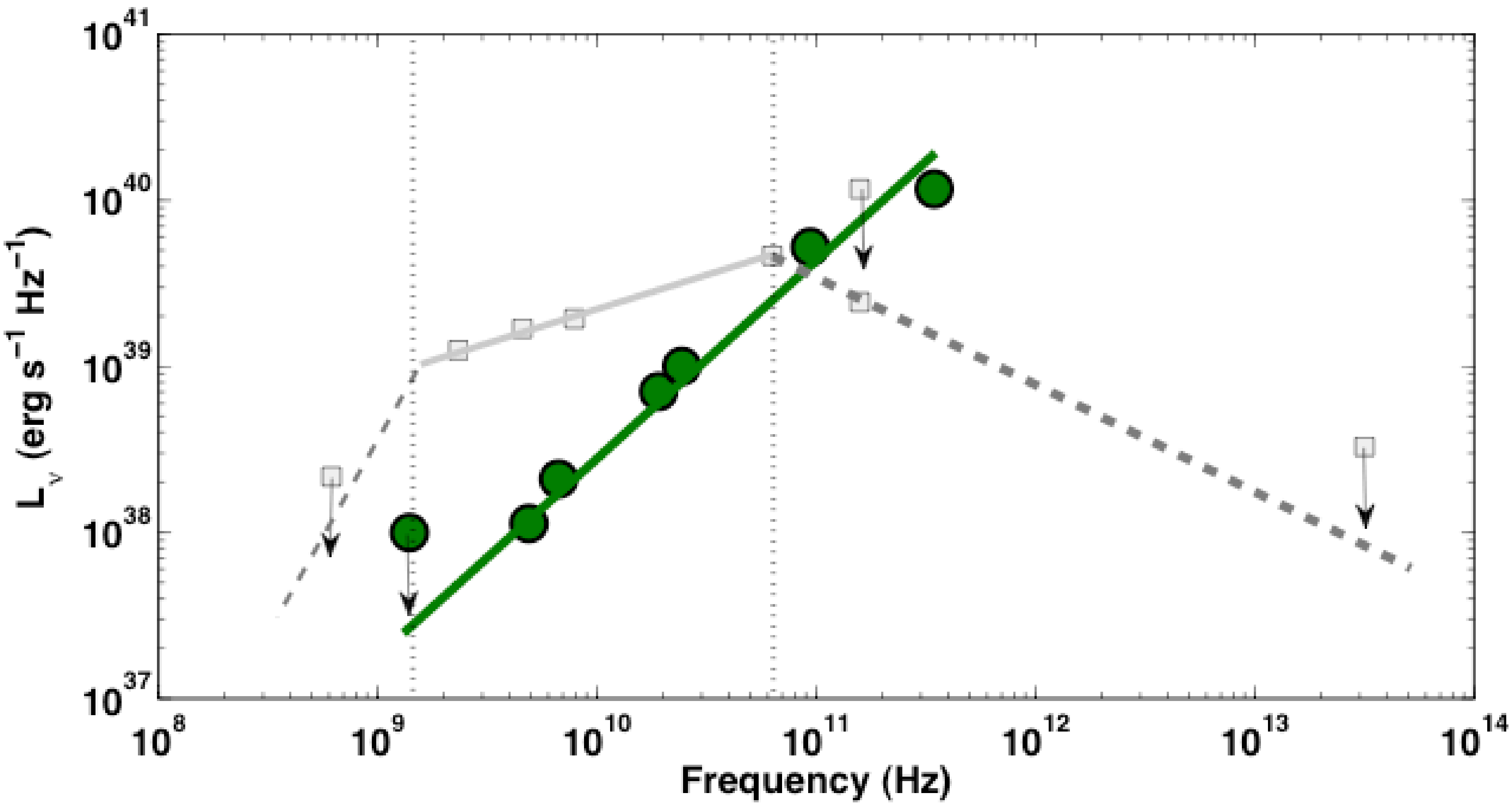
Nature (2011)

Positional Alignment

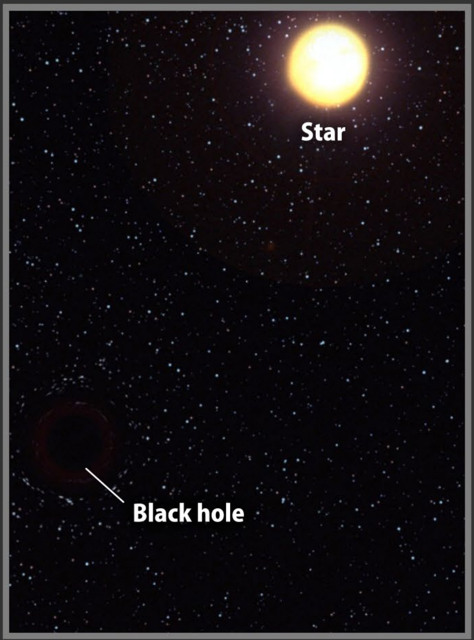


Nature (2011)

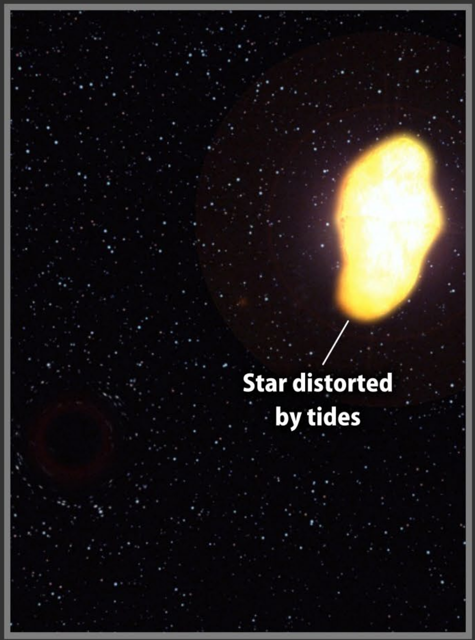
Why radio astronomers need to observe at many frequencies!



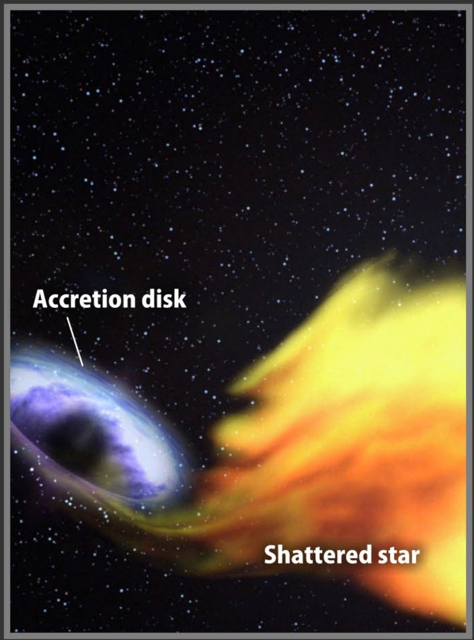
Swift J1644+57: Onset of a relativistic jet



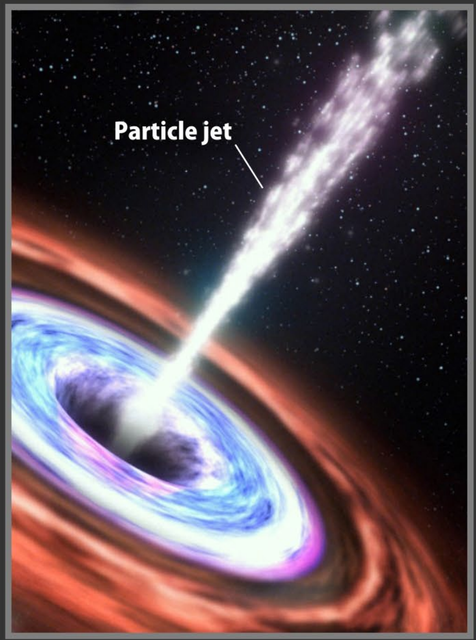
1. A sun-like star on an eccentric orbit plunges toward the supermassive black hole of distant galaxy.



2. Strong tidal forces near the black hole increasingly distort the star. If the star passes too close, it shatters in two.



3. The half of the star facing the black hole streams toward it and forms an accretion disk. The other half of the star just expands into space.



4. Near the black hole, magnetic fields power a narrow jet of particles moving near the speed of light. Viewed head-on, the jet is a brilliant X-ray source.

Credit: NASA/Goddard Space Flight Center/Swift

Thanks!