

Neil Gehrels Memorial

Symposium

THE GEORGE
WASHINGTON
UNIVERSITY

WASHINGTON, DC

May 21-22, 2018



Blossing Leek



Clematis

Dieter H. Hartmann
Clemson University



On nuFnu and Time Domain Astronomy with the

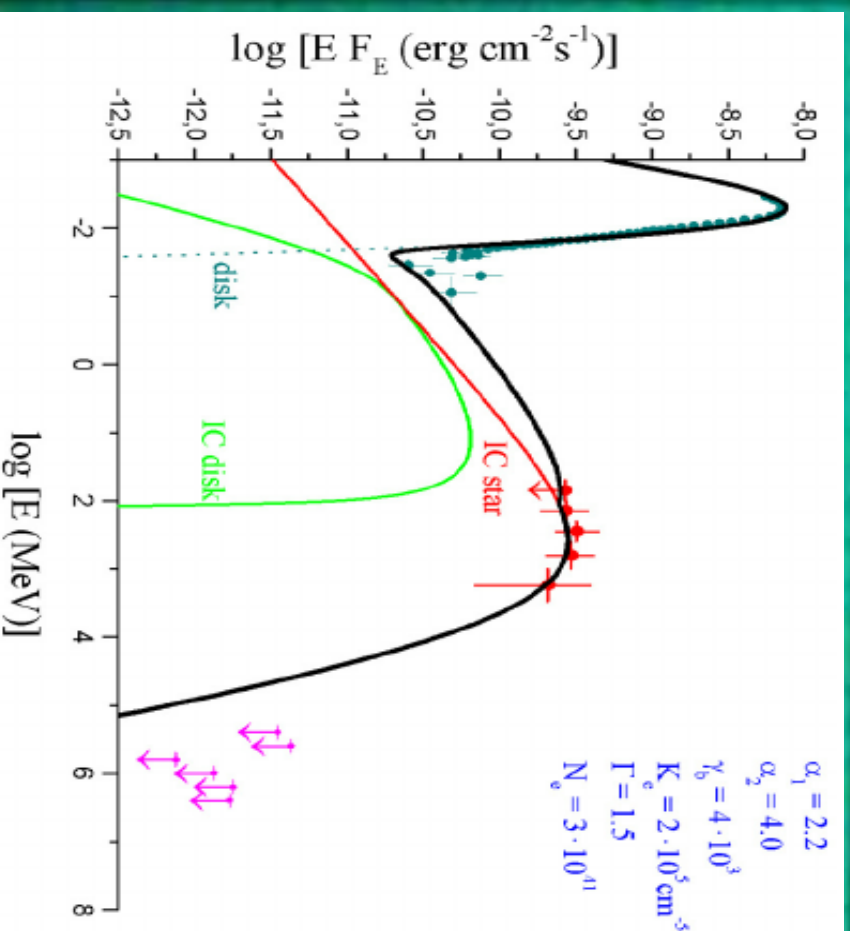
Neil Gehrels Swift Observatory



Multiwavelength

Astrophysics

Edited by France Córdova



TDA: Time Domain Astrophysics

All Sky Monitoring – Fast Response

MMA: Multi-Messenger Astrophysics

Electromagnetic radiation

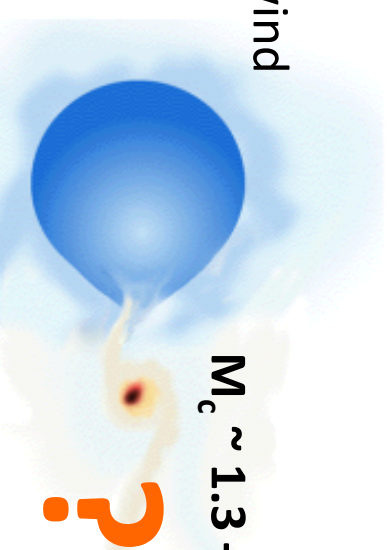
Gravitational waves

Neutrinos,

Cosmic Rays

Meteorites

WR wind



$M_c \sim 1.3 - 4.5 M_\odot$

F. Cordova

workshop:

Taos, NM,

August 1987

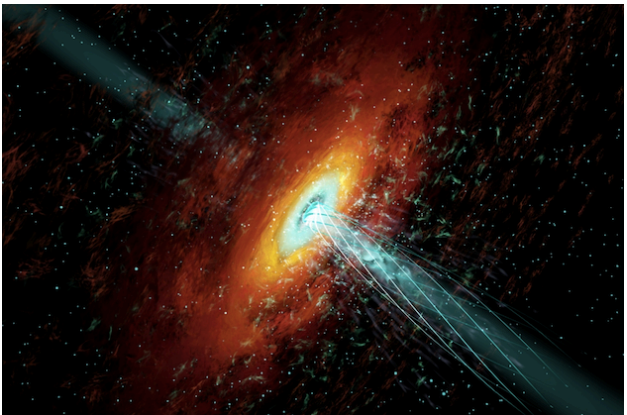
Cyg X-3

Giacconi et al. 1967

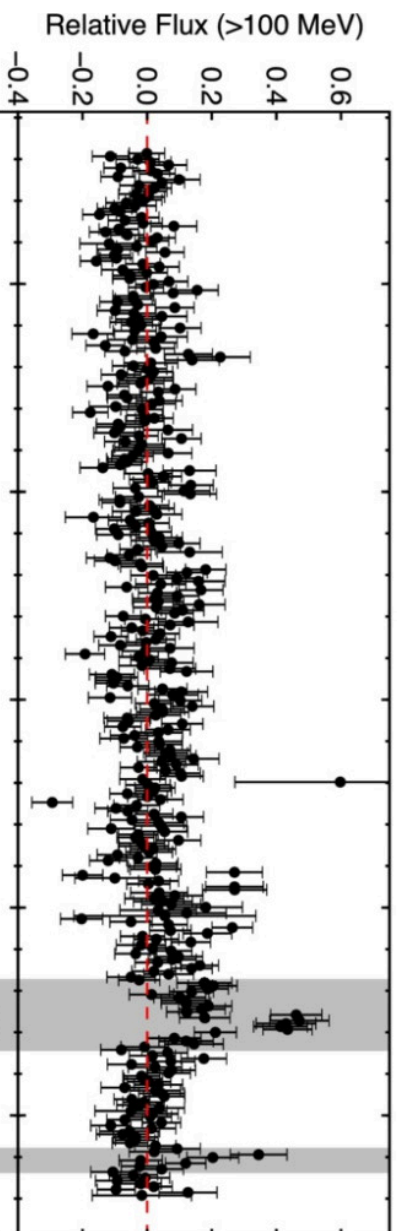
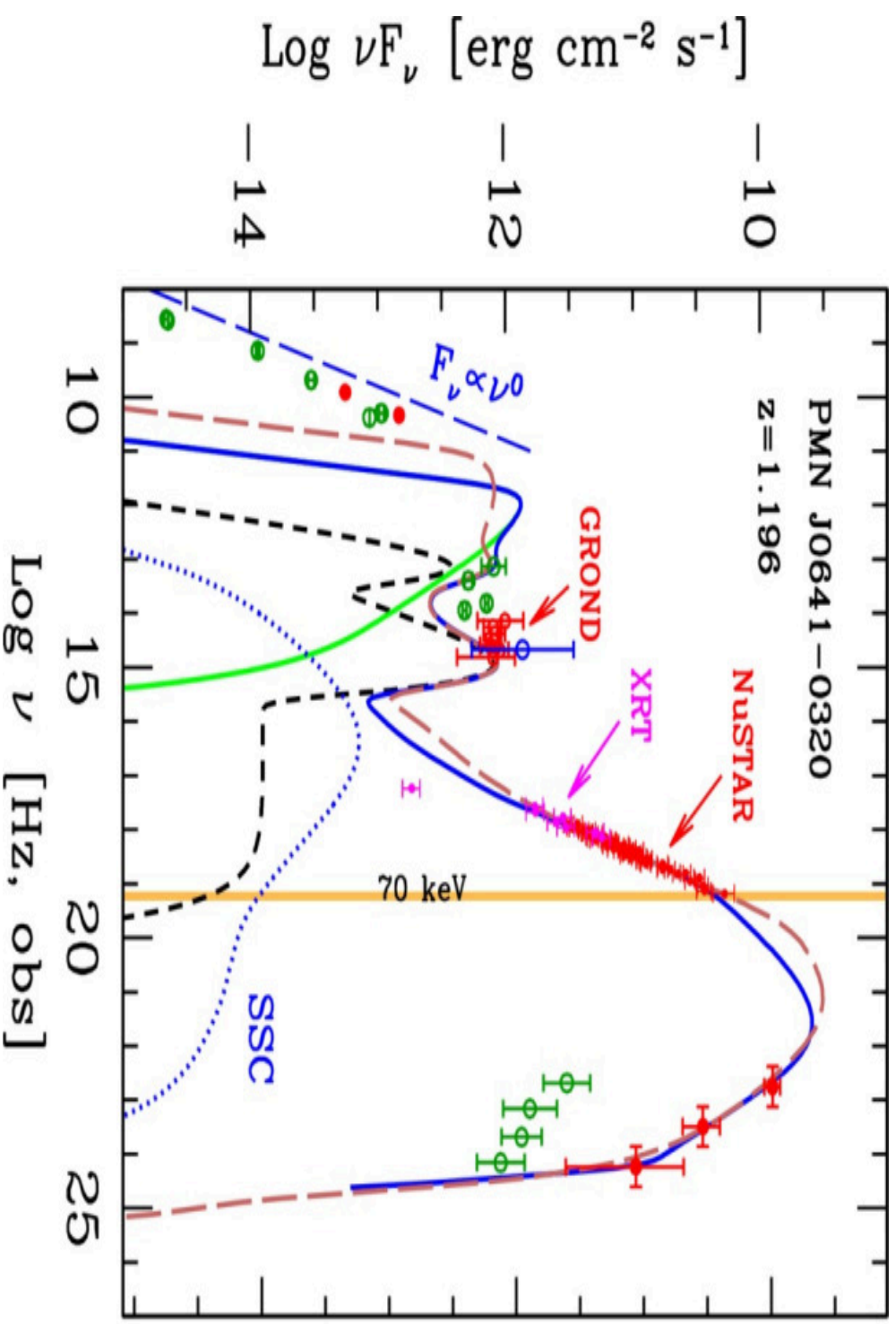
50 years ago! -

nuFnu:
flaring MeV blazar:

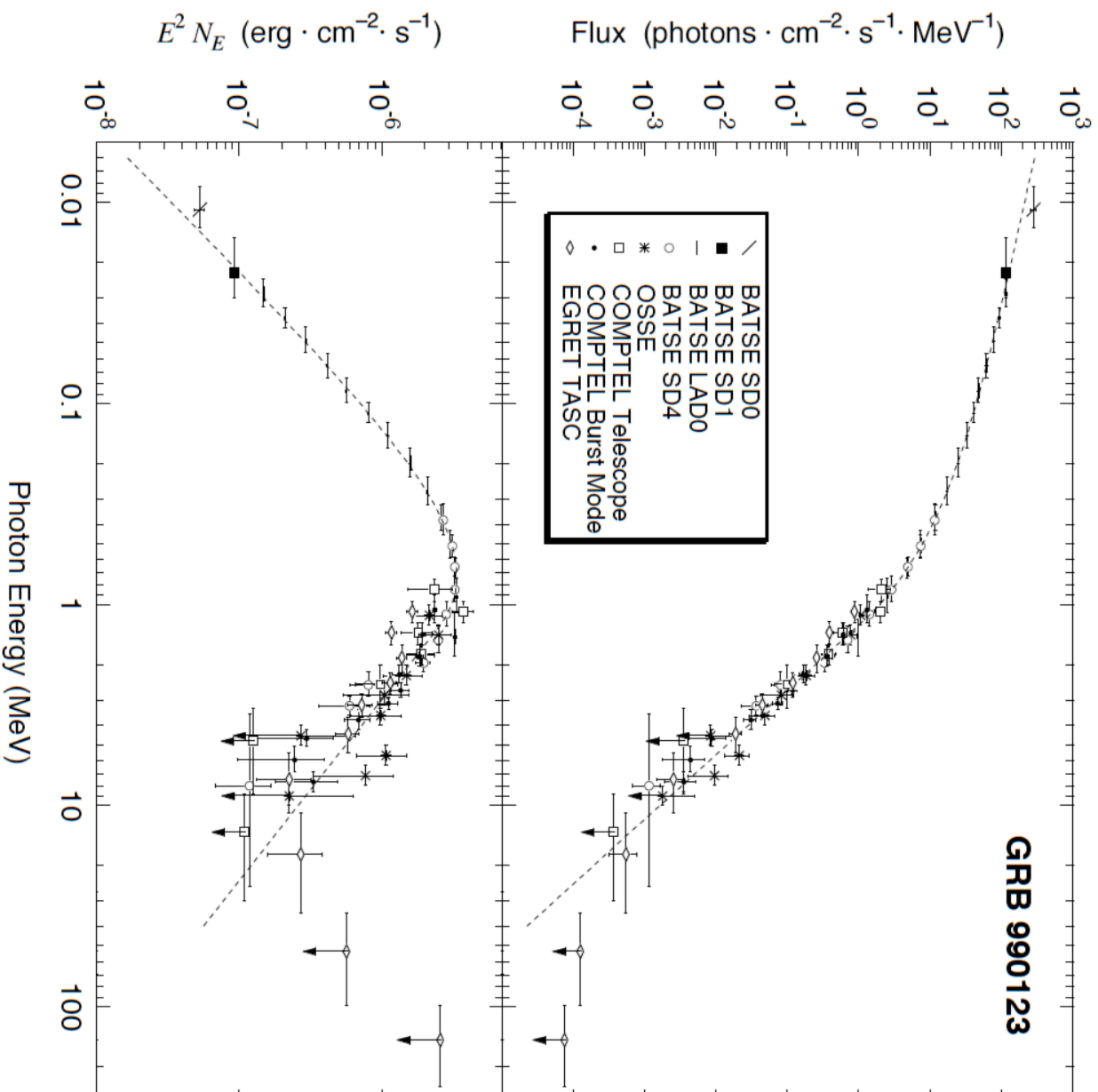
Ajello 2016, ApJ 826, 76



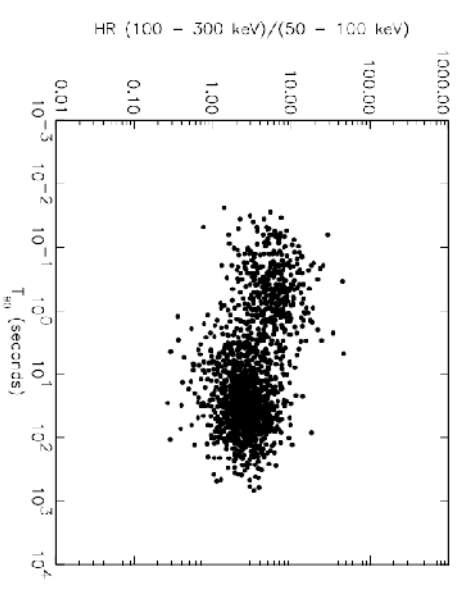
MOA: Multi-Observatory Astronomy



Long GRB Prompt emission



HR



T90



David Band:
 1957 - 2009

Since $d \ln v = dv/v$: No redshift effect on vFv – but....

Use of νF_ν , spectral energy distributions for multiwavelength astronomy

N. GEHRELS

*Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center
Greenbelt, MD, USA*

(ricevuto il 6 Novembre 1995; approvato il 23 Luglio 1996)

Summary. — Spectral Energy Distribution (SED) plots of $\log(\nu F_\nu)$ vs. $\log(\nu)$ have become popular for multiwavelength astronomy because they give the source power per logarithmic frequency interval and thereby directly show the relative energy output in each frequency band. They also allow easy manipulation and integration of black-body spectra. However, usage can be tricky and misuse is common. This paper derives equations for manipulating SEDs.

PACS 95.75.Fg – Spectroscopy and spectrophotometry.

27182818284590452353602874713526624
977527470396995959574966676272724076
6303554758457138217882516642742746
63919320030599218174135066290435729
0033429260595630738132328627943490
7632338298807531955551157383418
793070215408914088477411092447614
60668082264800008477411042345442
4371075390777097520242345442
62613313845007520242345442
66969772093007520242345442
6763711320007520242345442
746377211007520242345442
897844280569536967707
854499699006864454905987931636889
230098793011782154229922957635
148220826908223288893984
94465105829008933203629709
4430163012391423901161403901983507
0330652842306494807239310023891950
9961878915930116001592986851924580
729386693858942987922824998920689058
2574927926104841584443634632449692285
400692285

Line/Continuum
“1 Crab @ 6 keV
= 1 milli Jansky”

When is νf_ν useful?

S. R. Kulkarni

August 1, 2007 (some modifications since then)
Further modification on 4 June 2005 (§5)

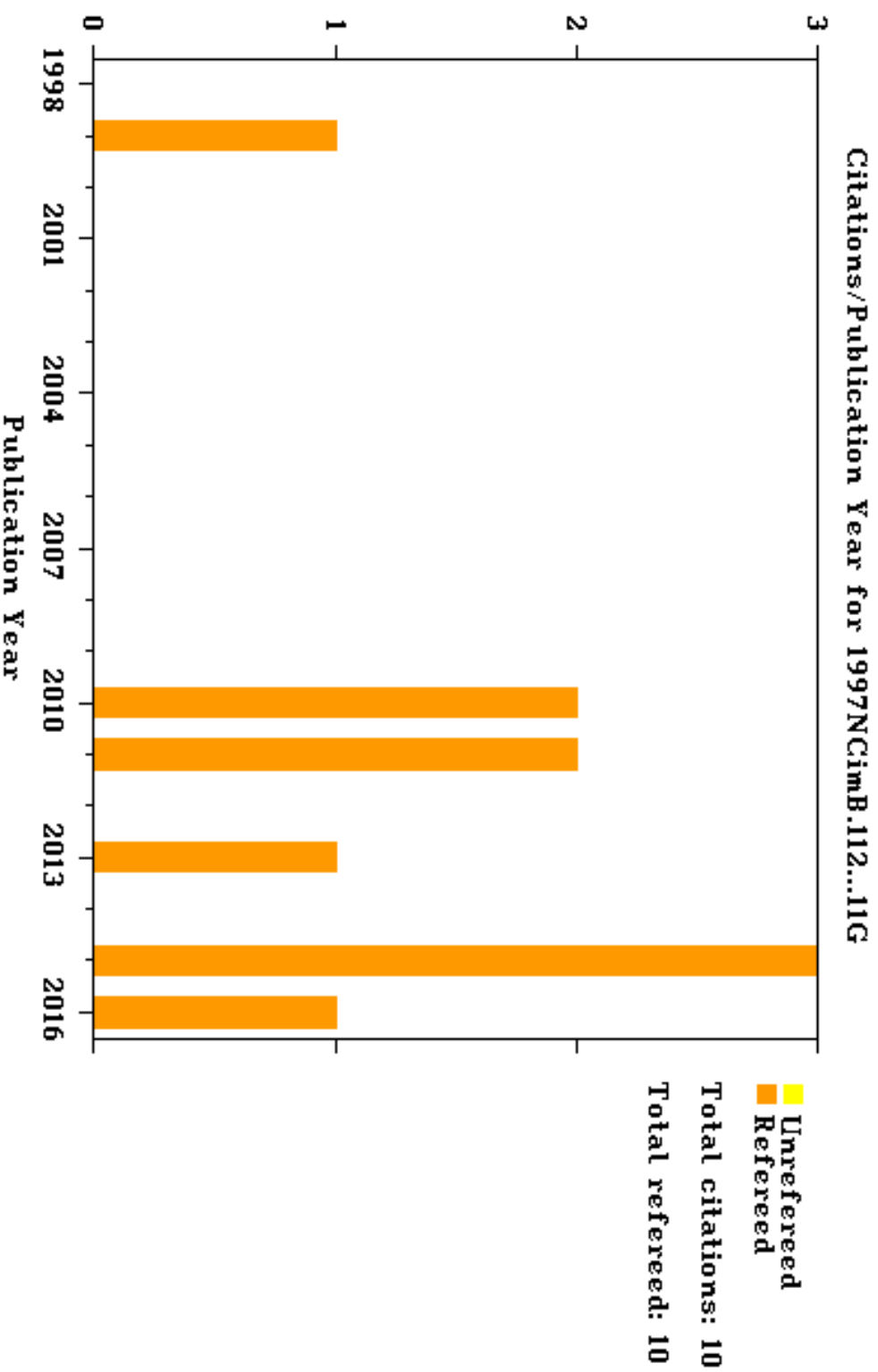
Gehrz, Ney, Strecker & Woolf 1970, ApJ

Title: Use of ν_F spectral energy distributions for multiwavelength astronomy.

Authors: [Gehrels, N.](#)

Publication: Nuovo Cimento B, Vol. 112B, No. 1, p. 11 - 15 ([NCimB Homepage](#))

Publication Date: 01/1997



H. Steinle S. Guieiec

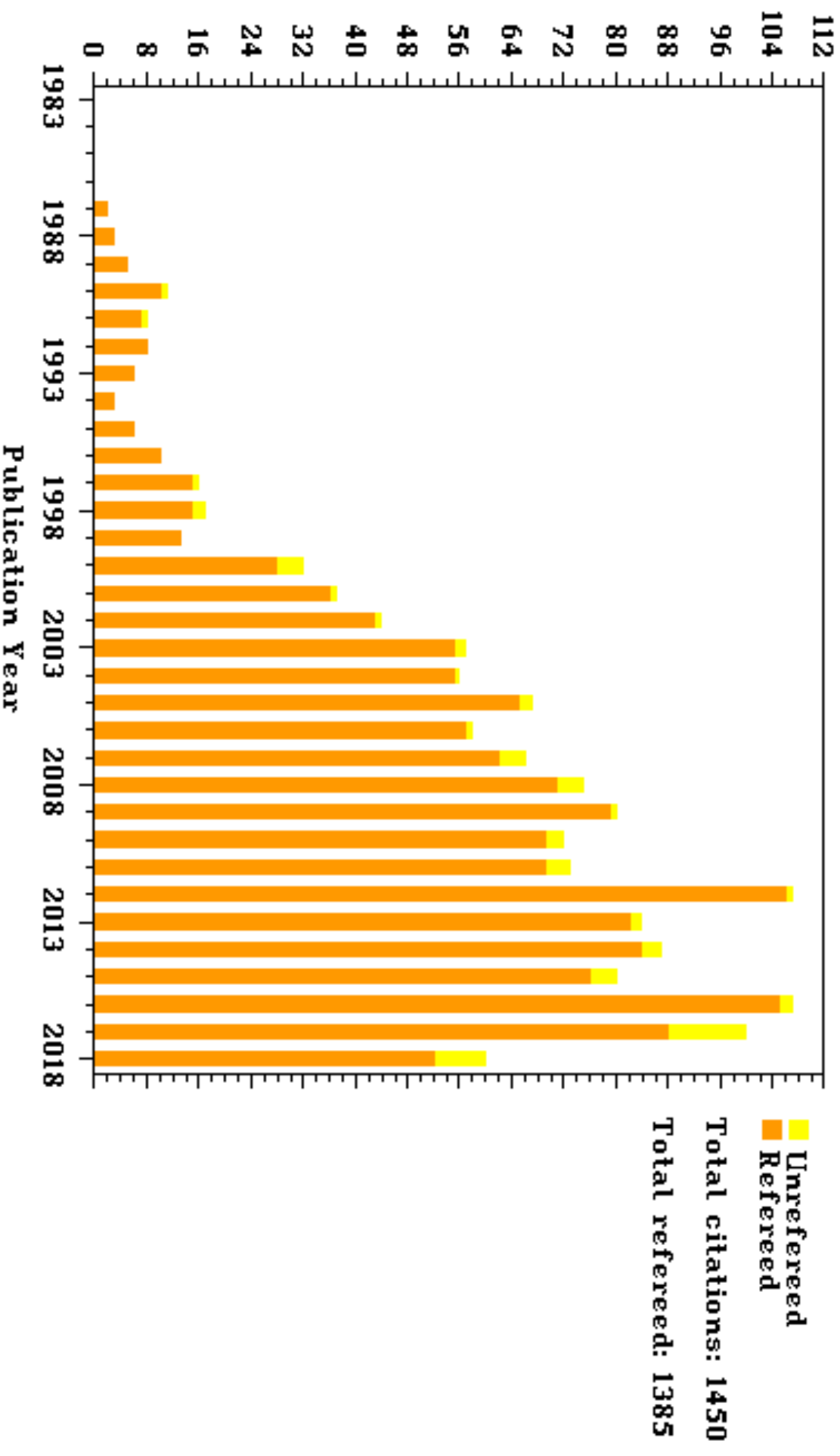
Title: Confidence limits for small numbers of events in astrophysical data

Authors: [Gehrels, N.](#)

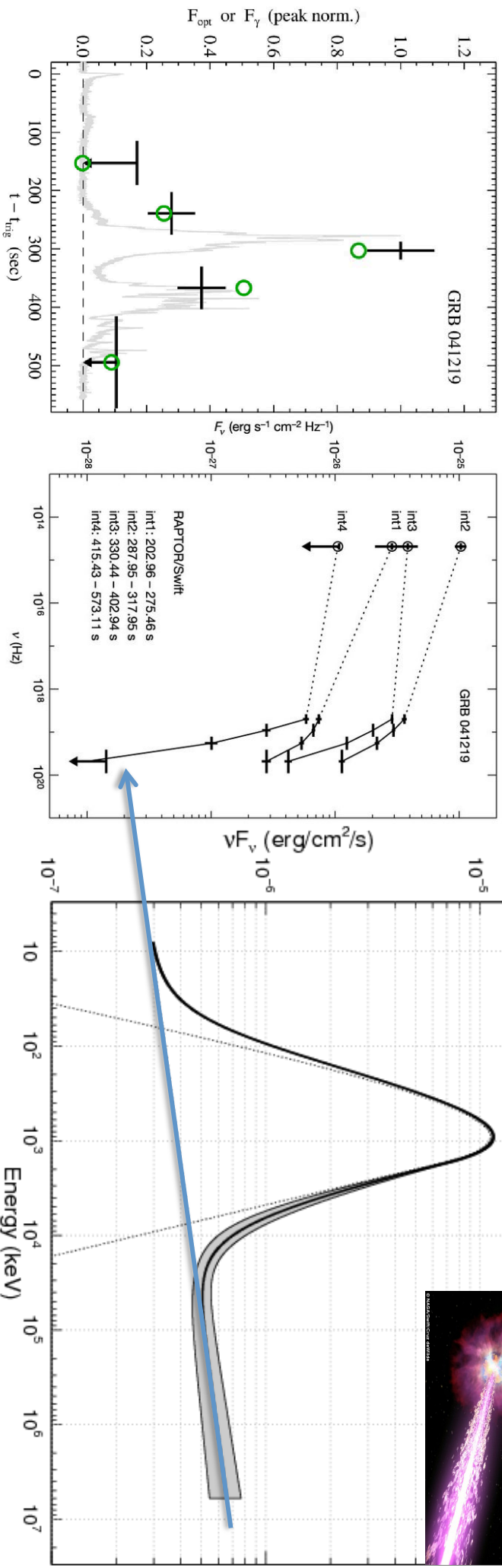
Affiliation: AA(NASA, Goddard Space Flight Center, Greenbelt, MD)

Publication: Astrophysical Journal, Part 1 (ISSN 0004-637X), vol. 303, April 1, 1986, p. 336-346

Citations/Publication Year for 1986ApJ...303..336G



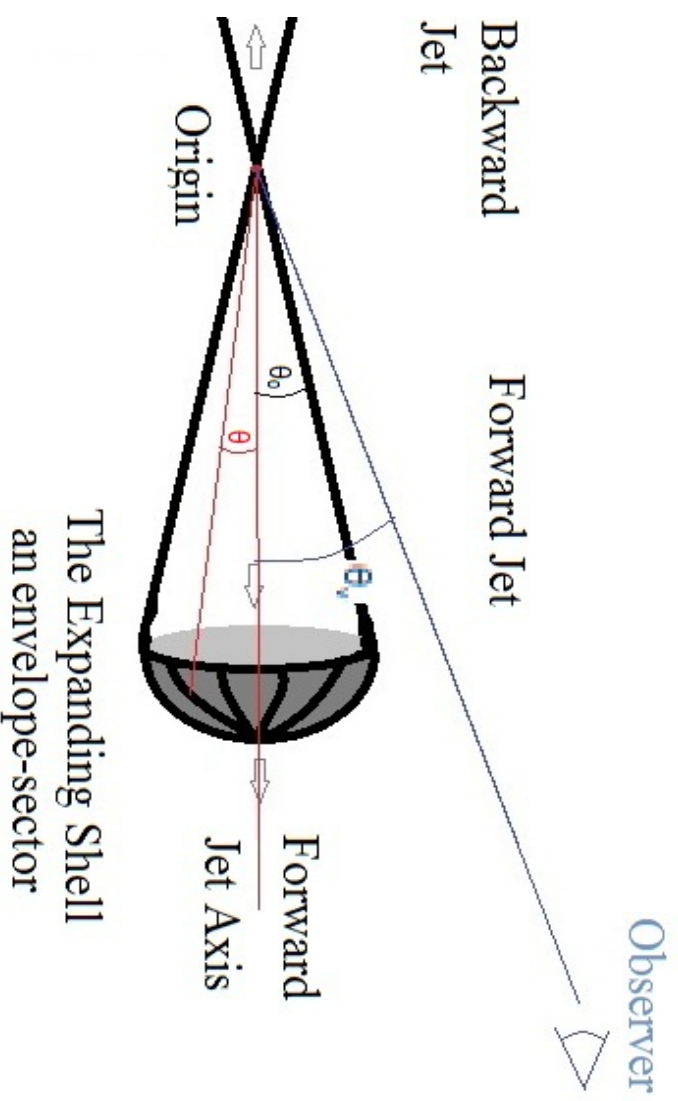
nuFnu: prompt emission: Long GRBs



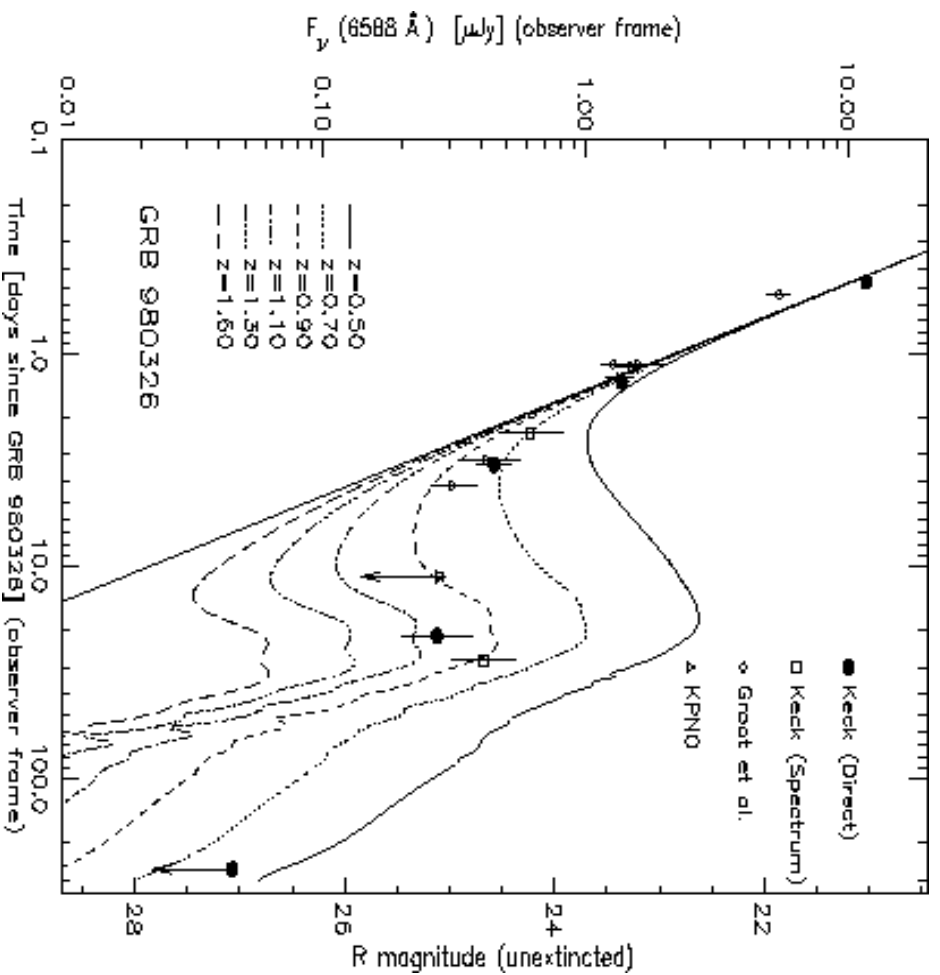
T. Vestrand, et al 2005, Nature

Time-dependent multi-component models:
 (un)correlated prompt optical emission may hold the key and allow GRBs to serve as standard candles:

S. Guiriec et al. 2016, ApJ Letters, 831, 8

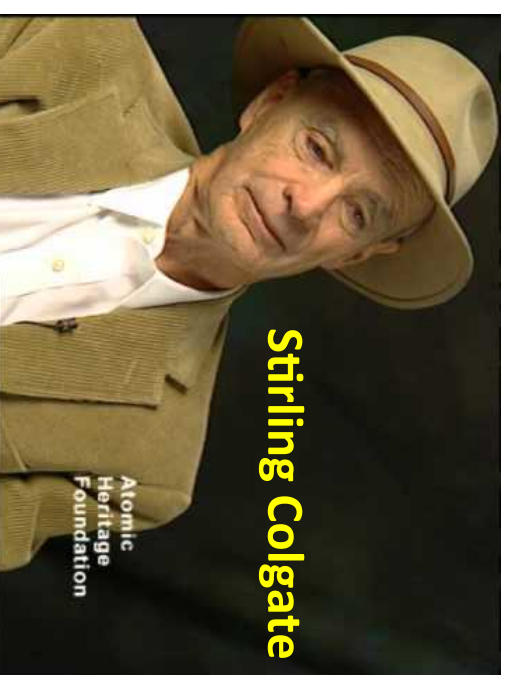
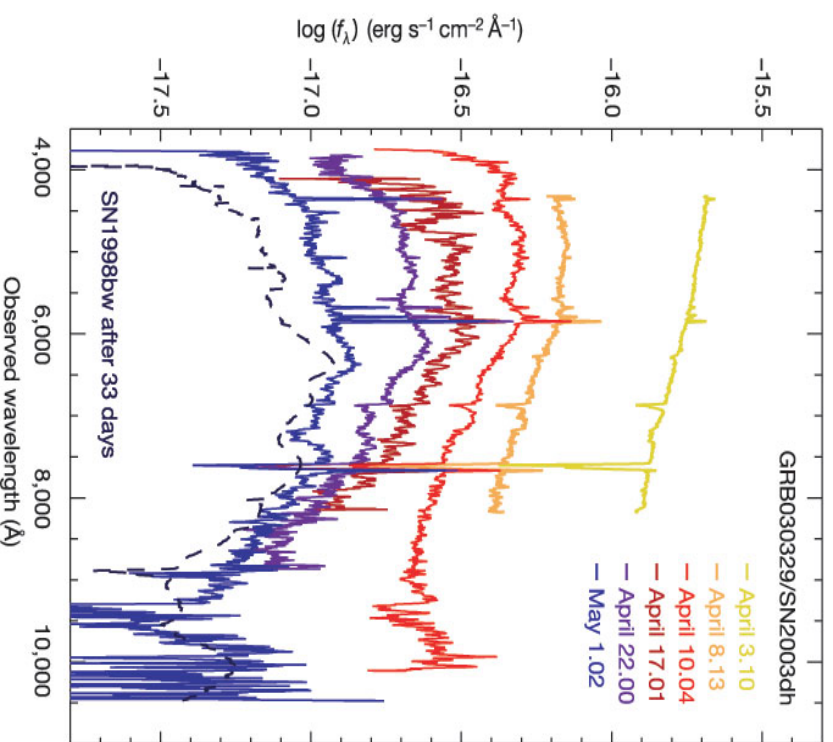


Afterglow of GRB980326: Bloom+99



NOT νF_{ν}

$$m_{\nu} \div -2.5 \text{Log}_{10}(f_{\nu})$$

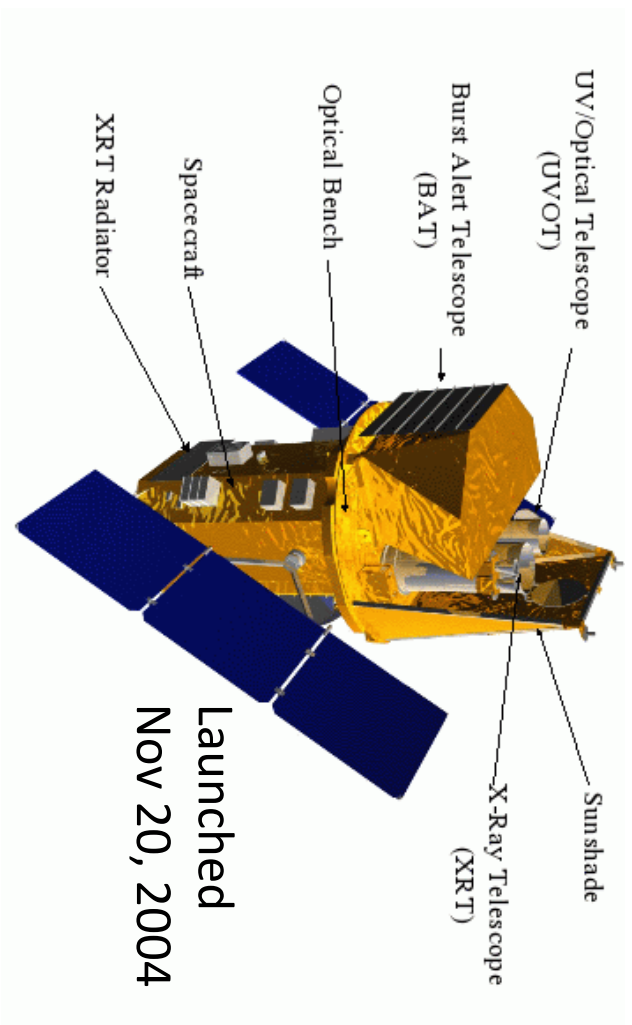


Stirling Colgate

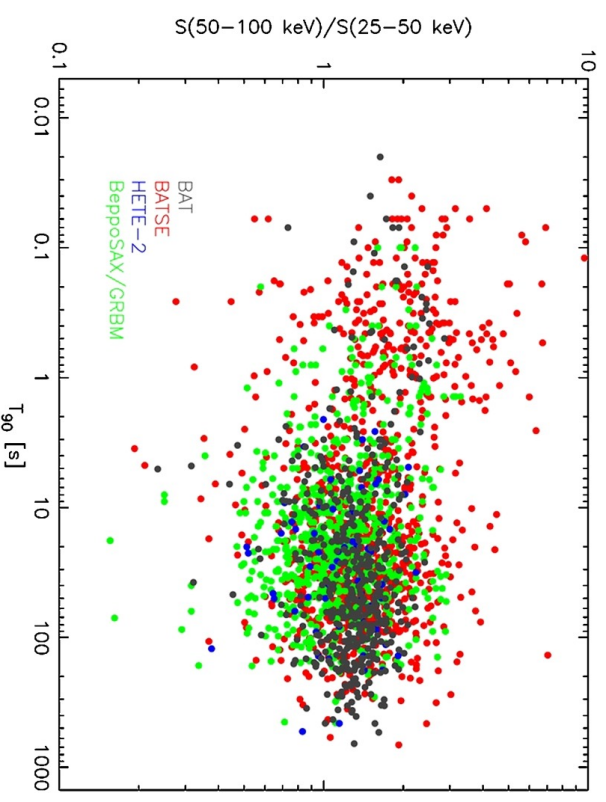
Atomic
Heritage
Foundation

1925 - 2013

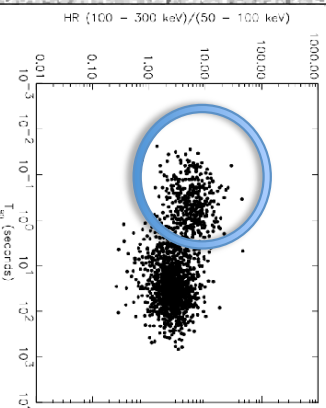
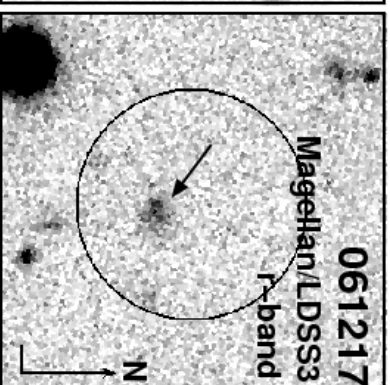
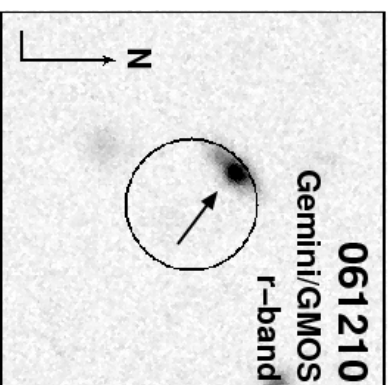
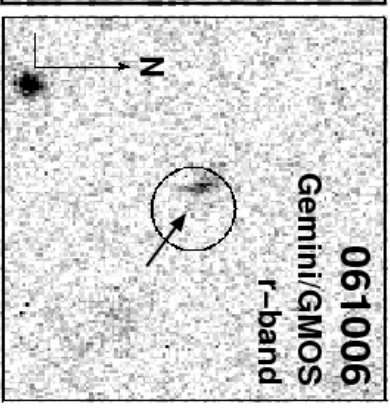
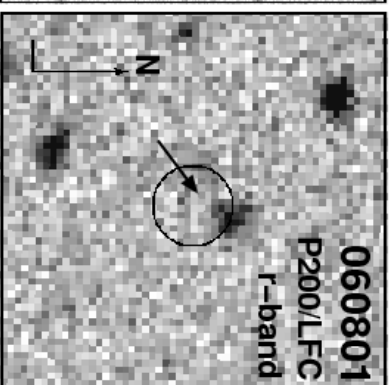
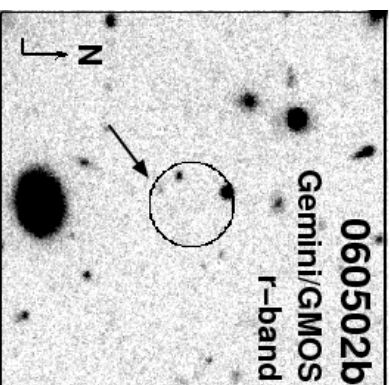
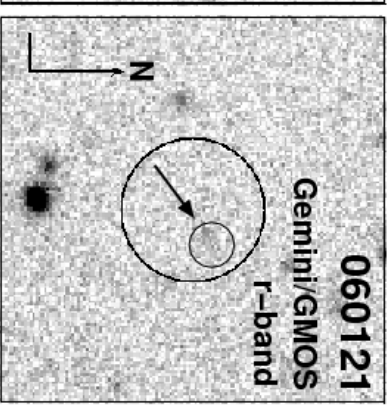
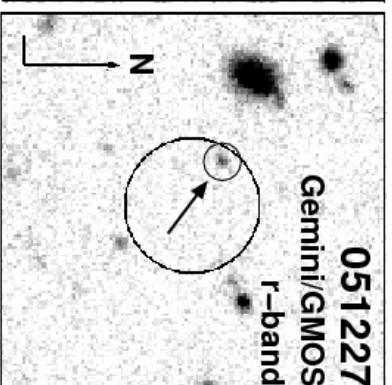
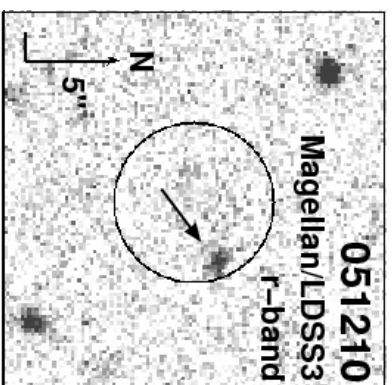
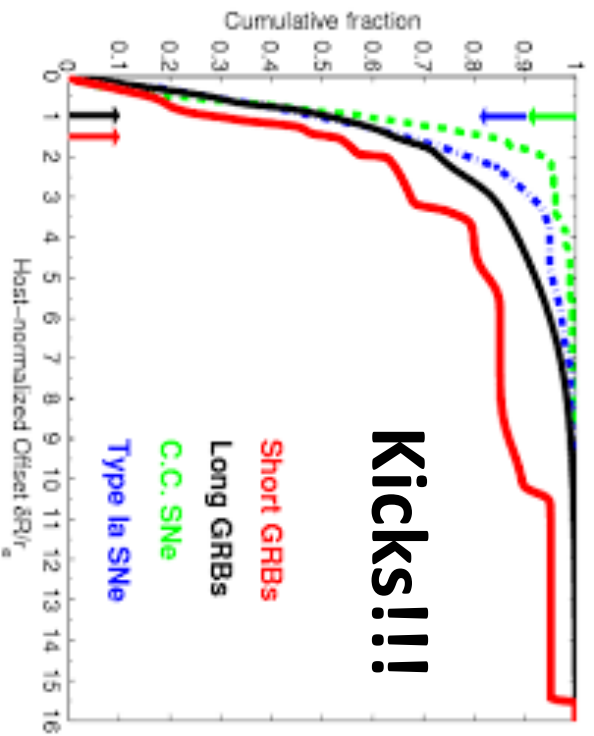
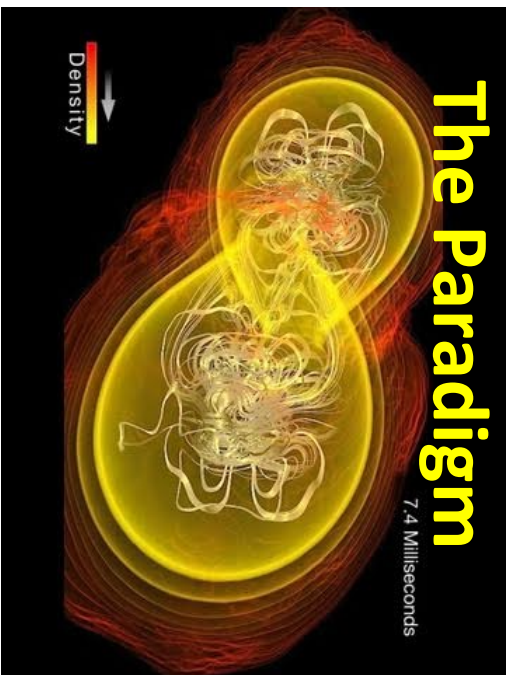
Short GRBs



X-ray afterglows of SHBs were discovered quickly, but at a low rate.

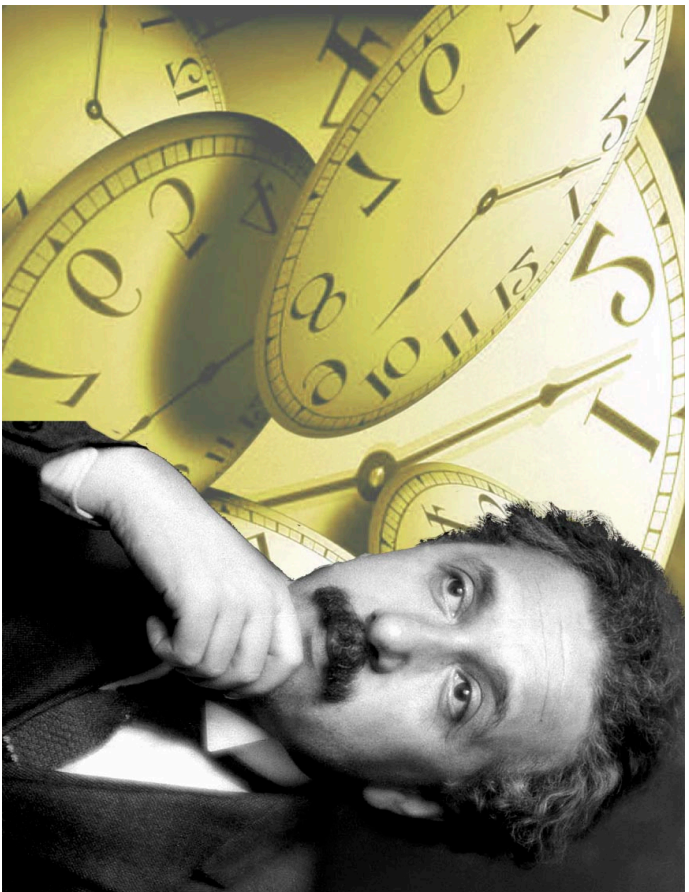


HR-T90 plot of GRBs detected by different missions (from Sakamoto et al. 2011). For interpretation of color in this figure, see Ghirlanda et al. 2015, JHEA 7, 81.)

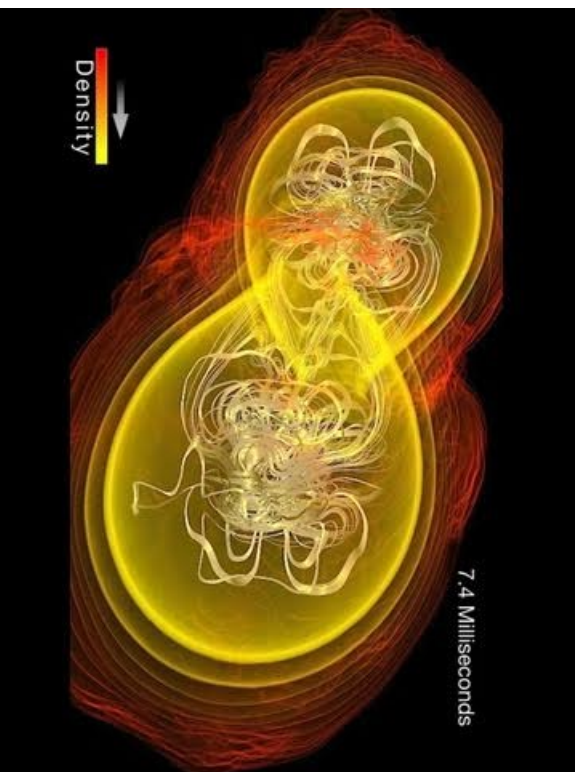


E. Berger et al.

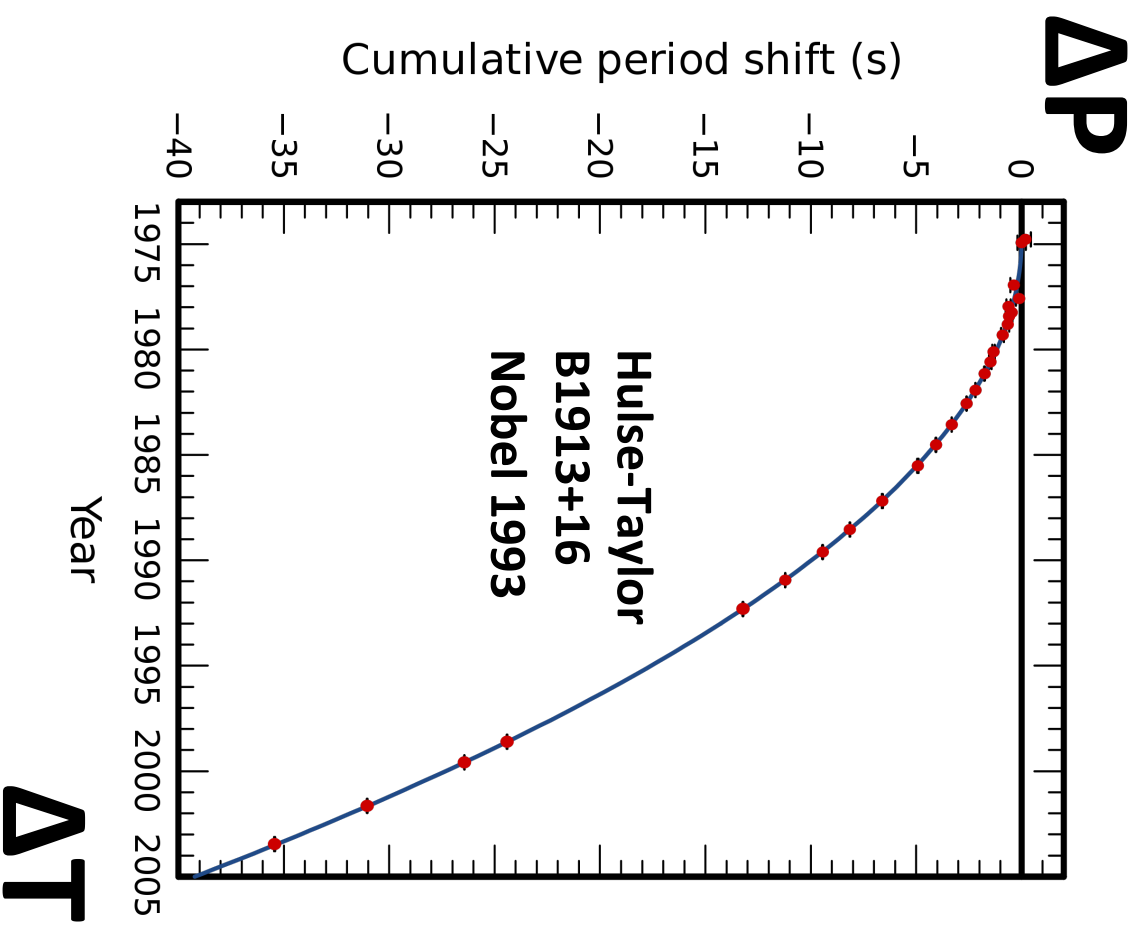
Confirming the The paradigm: BNS merger – GW – short GRB



GRMHD not yet ready in the late 90th



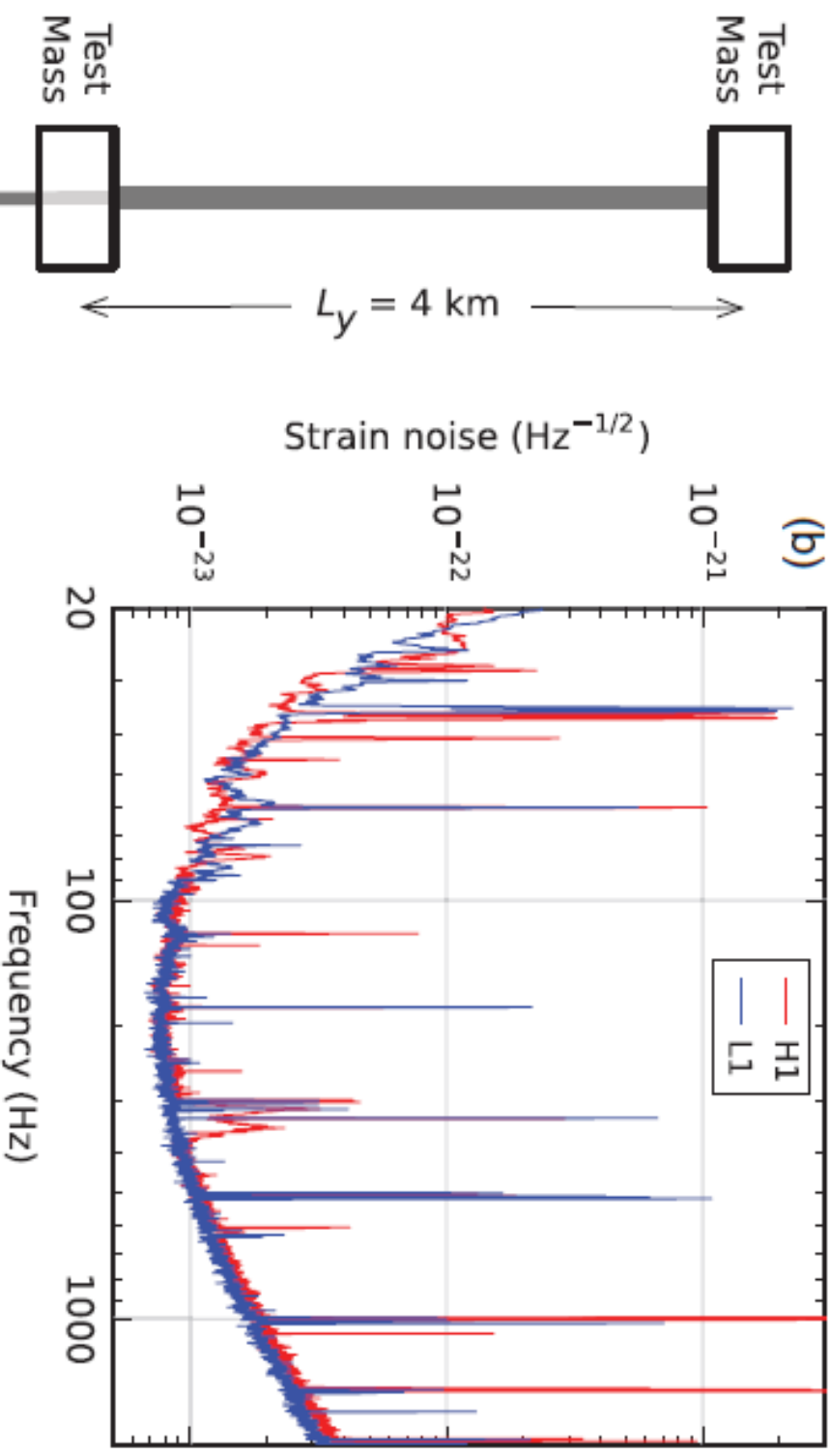
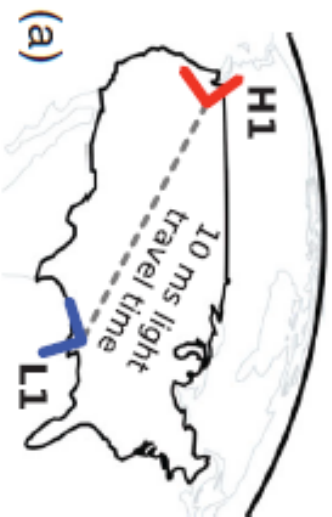
Today:
Numerical GRMHD can predict quality templates



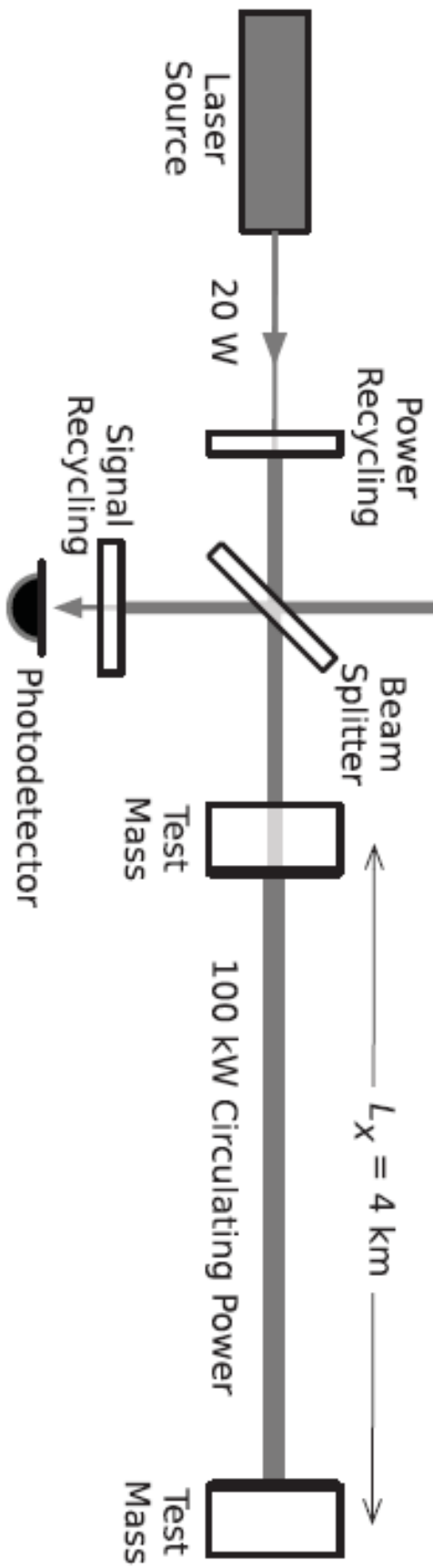
Joe Weber's bar
1960 ... 1972 "Detection"



Detectors have come a long way



direct proof with
coincidence



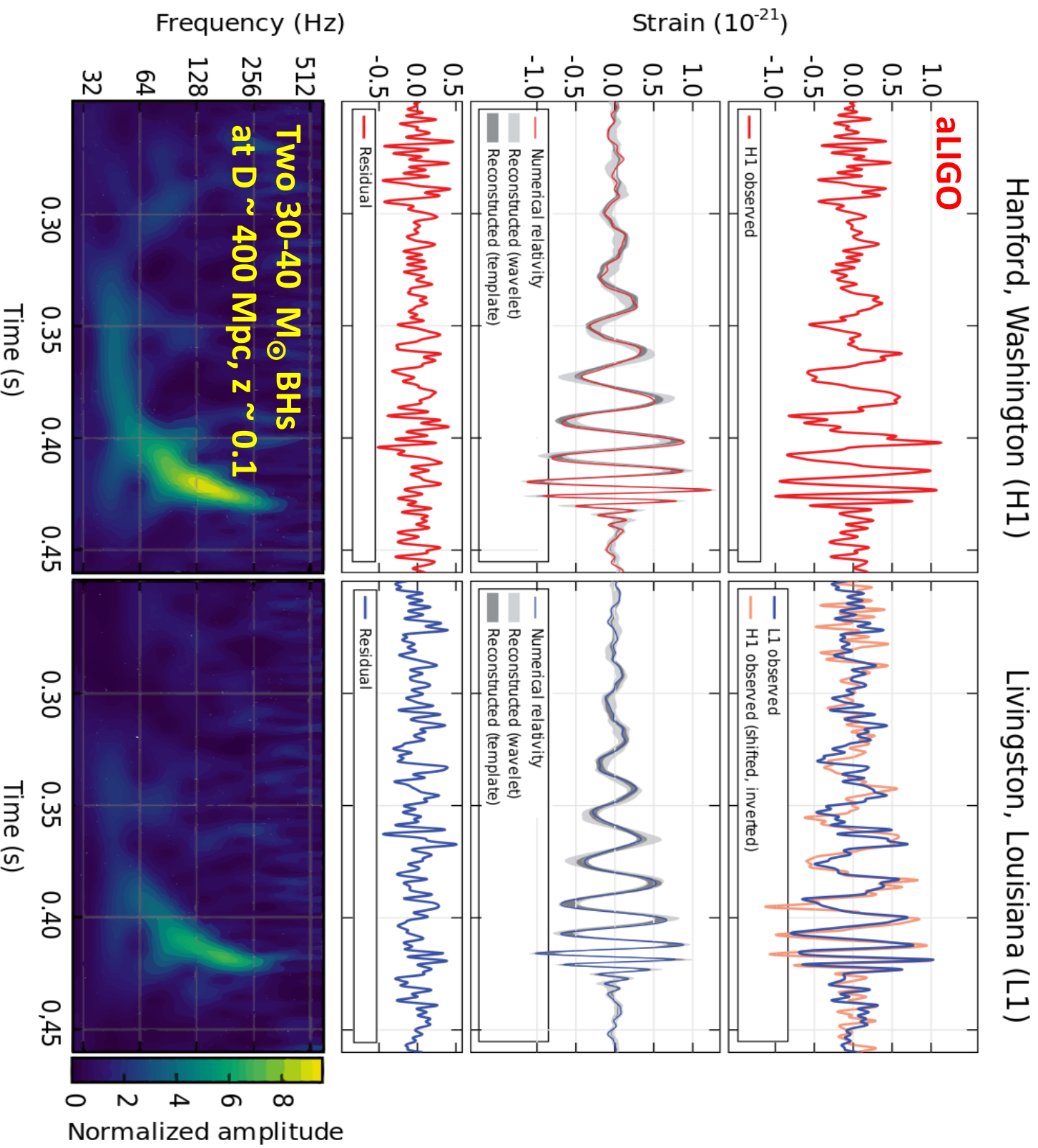
GW150914

2-11-2016 PR

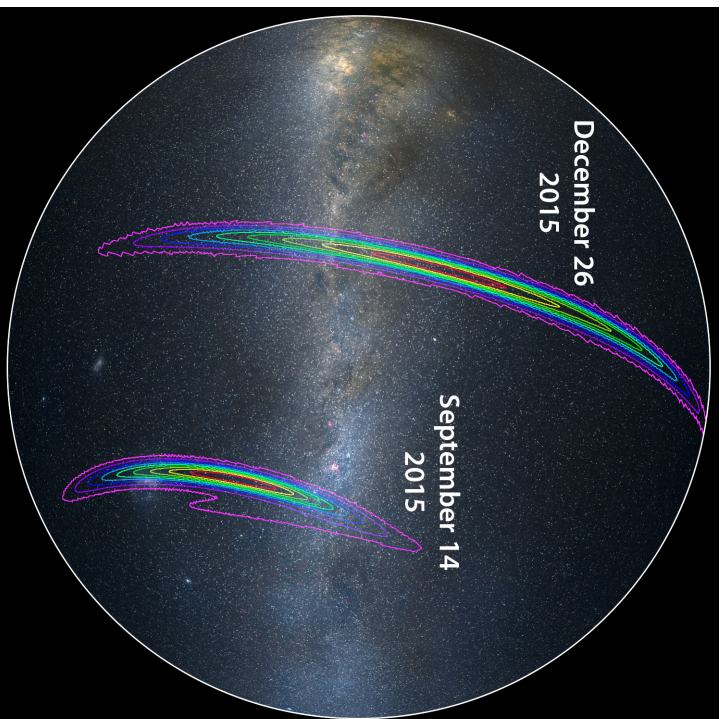


Rainer Weiss
Barry C Barish
Kip S. Thorne

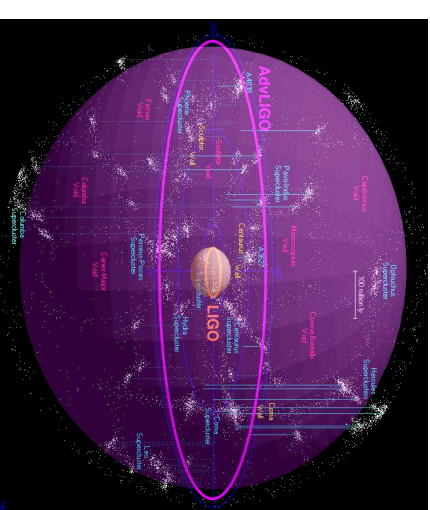
Fermi/GBM blip



More BBH mergers followed ...



**But what about binary
neutron stars**



Horizon (S/N = 8)

aLIGO(Liv) (218 Mpc)

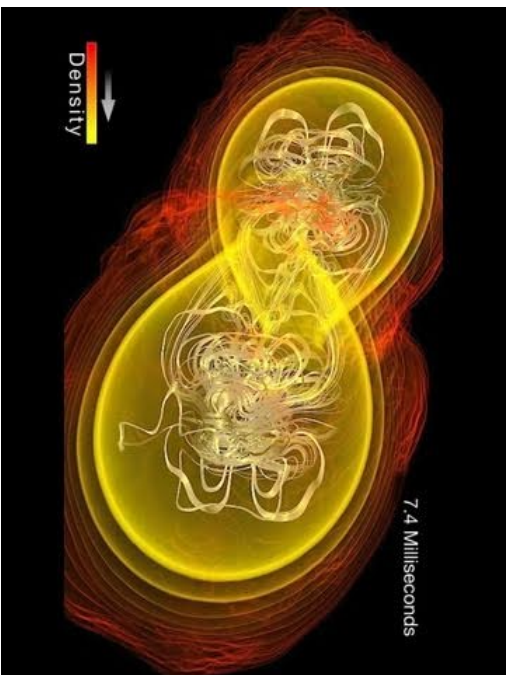
LIGO(Han) (107 Mc)

Virgo (58 Mpc)

Paradigm: BNS merger = Short GRB

Rates: $10^{-2} \text{ Mpc}^{-3} 10^{-5} \text{ yr}^{-1}$ ($4\pi/3$) (200 Mpc)³ \sim few per year

Scaling from known SGRB rates or population synthesis



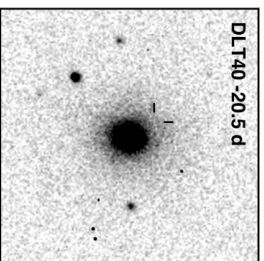
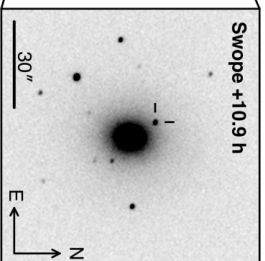
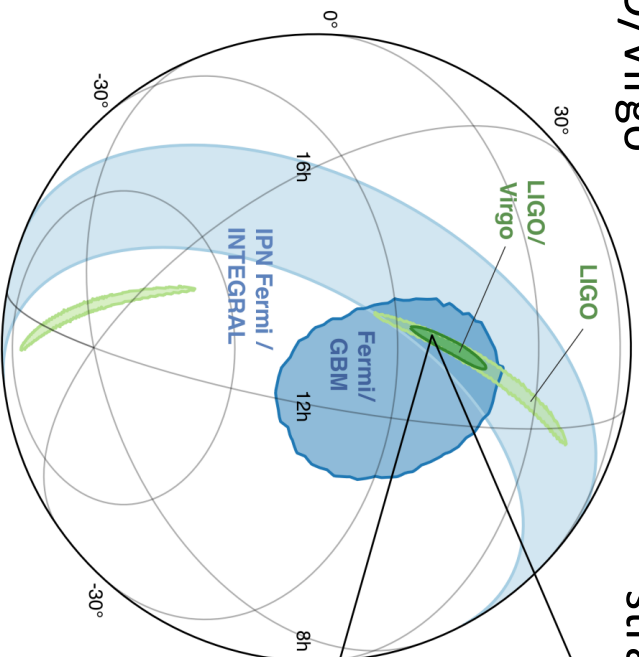
Paradigm Confirmed:
BNS merger
– GW – sGRB

D ~ 40 Mpc

GW170817

LIGO/Virgo

Neil's search strategy worked!

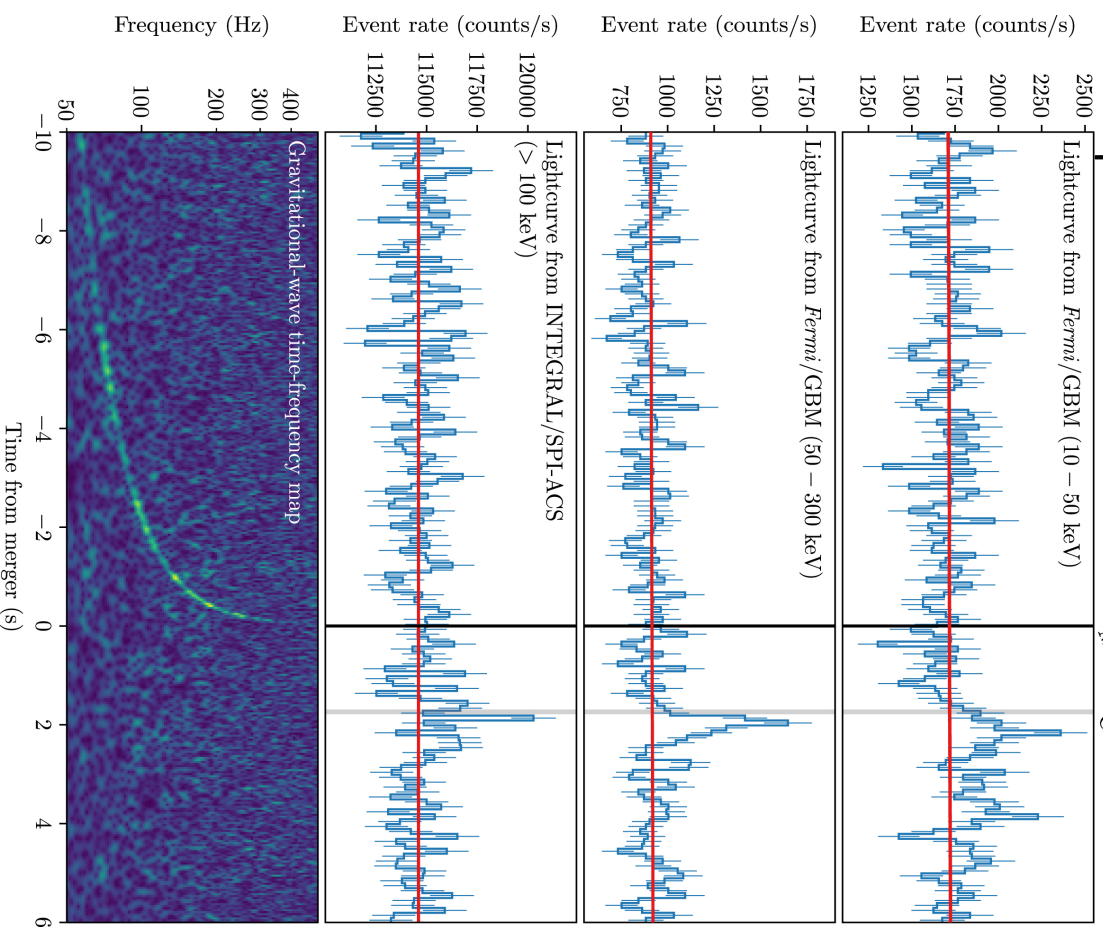


Ground-based
 With small
 telescopes 😊

Neutrinos no detection 😞

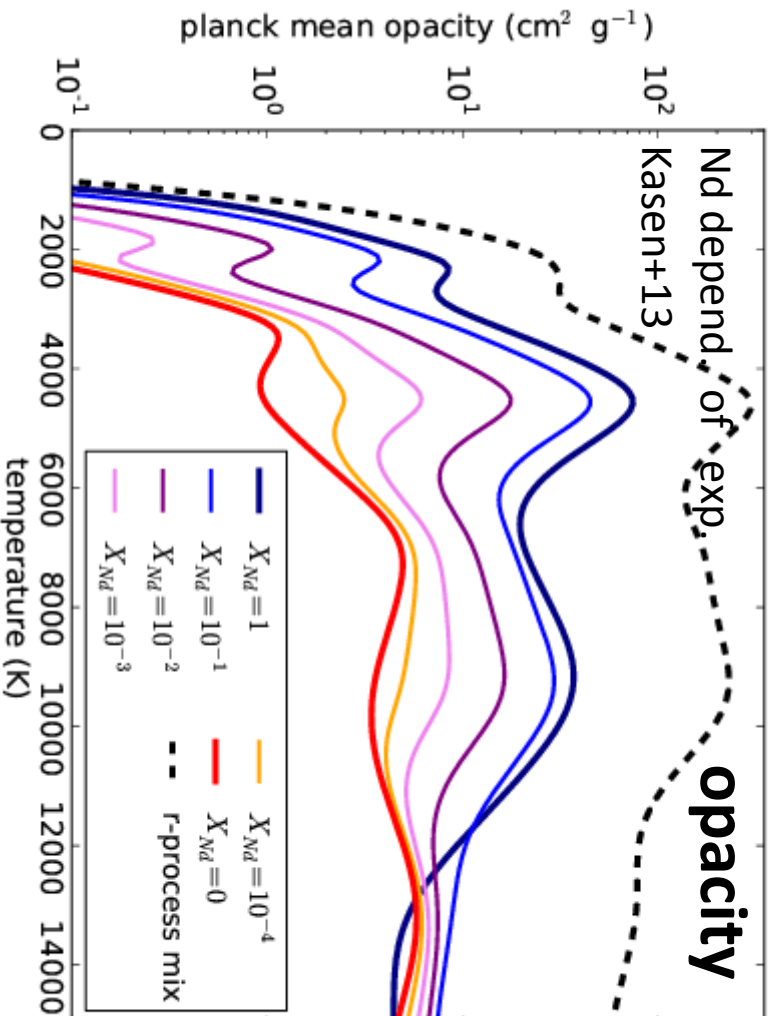
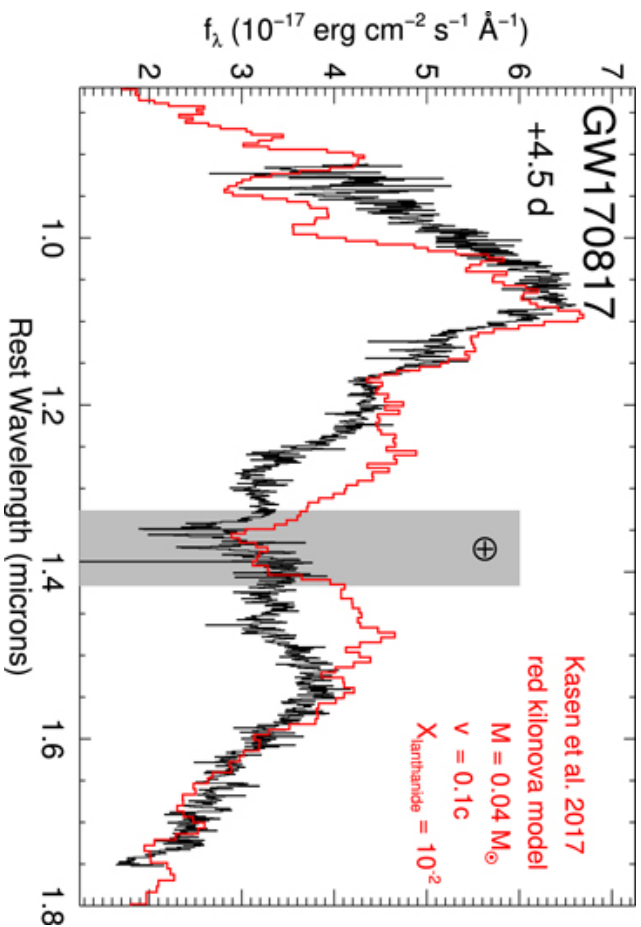
Space-based 😊

Merger
 GRB start



Abbott, B. P., et al. "Gravitational Waves and Gamma Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A." 2017, *ApJL*, [848](#), [L113](#).

> 3,000 authors 😊

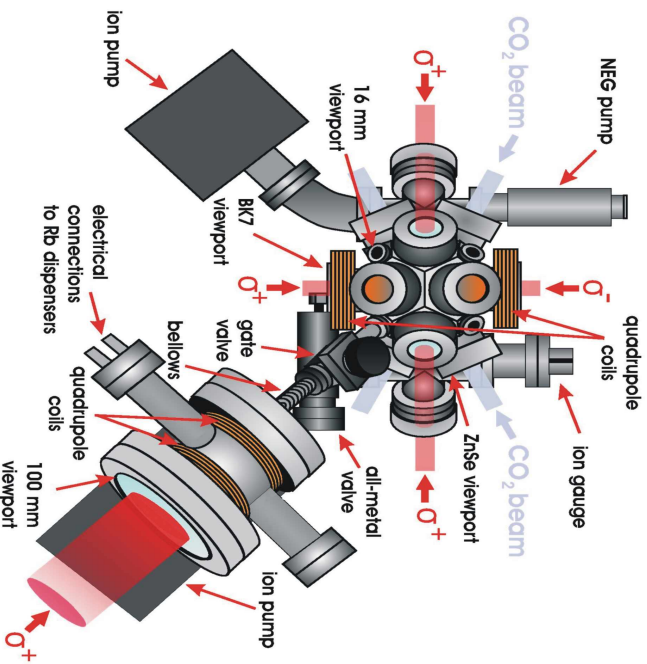


$$Y_e(\text{Nd}) = Z/A = 60/144 \sim 0.4$$

IA	1	H	1.008	IIA	2	He	4.003
	3	Li	6.941		3	B	10.811
	4	Be	9.012	IIIA	4	C	12.011
	11	Na	22.990	IIIV	5	N	14.007
	12	Mg	24.305	V	6	O	15.999
	13	Al	26.982	VI	7	F	18.998
	14	Si	28.086	VII	8	Ne	20.180
	15	P	30.974	VIII	9	Na	22.990
	16	S	32.06	IX	10	Mg	24.305
	17	Cl	35.453	X	11	Al	26.982
	18	Ar	39.948	XI	12	Si	28.086
	19	K	39.098	XII	13	P	30.974
	20	Ca	40.078	XIII	14	S	32.06
	21	Sc	44.956	XIV	15	Cl	35.453
	22	Ti	47.88	XV	16	Ar	39.948
	23	V	50.942	XVI	17	K	39.098
	24	Cr	51.996	XVII	18	Ca	40.078
	25	Mn	54.938	XVIII	19	Sc	44.956
	26	Fe	55.845	XIX	20	Ti	47.88
	27	Co	58.933	XX	21	V	50.942
	28	Ni	58.693	XXI	22	Cr	51.996
	29	Cu	63.546	XXII	23	Mn	54.938
	30	Zn	65.38	XXIII	24	Fe	55.845
	31	Ga	69.723	XXIV	25	Co	58.933
	32	Ge	72.63	XXV	26	Ni	58.693
	33	As	74.922	XXVI	27	Cu	63.546
	34	Se	78.96	XXVII	28	Zn	65.38
	35	Br	79.904	XXVIII	29	Ga	69.723
	36	Kr	83.80	XXIX	30	Ge	72.63
	37	Rb	85.468	XXX	31	As	74.922
	38	Sr	87.62	XXXI	32	Se	78.96
	39	Y	88.906	XXXII	33	Br	79.904
	40	Zr	91.224	XXXIII	34	Kr	83.80
	41	Nb	92.906	XXXIV	35	Rb	85.468
	42	Mo	95.94	XXXV	36	Sr	87.62
	43	Tc	98.906	XXXVI	37	Y	88.906
	44	Ru	101.07	XXXVII	38	Zr	91.224
	45	Rh	102.905	XXXVIII	39	Nb	92.906
	46	Pd	106.42	XXXIX	40	Mo	95.94
	47	Ag	107.868	XL	41	Tc	98.906
	48	Cd	112.414	XLI	42	Ru	101.07
	49	In	114.818	XLII	43	Rh	102.905
	50	Sn	118.710	XLIII	44	Pd	106.42
	51	Sb	121.757	XLIV	45	Ag	107.868
	52	Te	127.6	XLV	46	Cd	112.414
	53	I	126.905	XLVI	47	In	124.404
	54	Xe	131.29	XLVII	48	Sn	126.905
	55	Ba	137.327	XLVIII	49	Sb	127.6
	56	La	138.905	XLIX	50	Te	131.29
	57	Ce	140.12	L	51	I	126.905
	58	Pr	140.908	LI	52	Xe	131.29
	59	Nd	144.242	LII	53	Ba	137.327
	60	Pm	144.913	LIII	54	La	138.905
	61	Sm	150.36	LIV	55	Ce	140.12
	62	Eu	151.964	LV	56	Pr	140.908
	63	Gd	157.25	LVI	57	Nd	144.242
	64	Tb	158.925	LVII	58	Pm	144.913
	65	Dy	162.50	LVIII	59	Sm	150.36
	66	Ho	164.930	LIX	60	Eu	151.964
	67	Er	167.259	LX	61	Gd	157.25
	68	Tm	168.930	LXI	62	Tb	162.50
	69	Yb	173.054	LXII	63	Dy	164.930
	70	Lu	174.967	LXIII	64	Ho	167.259
	71	Hf	178.49	LXIV	65	Er	168.930
	72	Ta	180.948	LXV	66	Tm	173.054
	73	W	183.84	LXVI	67	Yb	174.967
	74	Re	186.207	LXVII	68	Lu	176.93
	75	Os	190.23	LXVIII	69	Hf	178.49
	76	Ir	192.22	LXIX	70	Ta	180.948
	77	Pt	195.084	LXX	71	W	183.84
	78	Au	196.967	LXXI	72	Re	186.207
	79	Hg	200.59	LXXII	73	Os	190.23
	80	Tl	204.38	LXXIII	74	Ir	192.22
	81	Pb	207.2	LXXIV	75	Pt	195.084
	82	Bi	208.98	LXXV	76	Au	196.967
	83	Po	209	LXXVI	77	Hg	200.59
	84	At	210	LXXVII	78	Tl	204.38
	85	Rn	222	LXXVIII	79	Pb	207.2
	86	Fr	223	LXXIX	80	Bi	208.98
	87	Ra	226	LXXX	81	Po	209
	88	Ac	227	LXXXI	82	At	210
	89	Th	232.038	LXXXII	83	Rn	222
	90	Pa	231.036	LXXXIII	84	Fr	223
	91	U	238.029	LXXXIV	85	Ra	226
	92	Np	237.048	LXXXV	86	Ac	227
	93	Pu	244.064	LXXXVI	87	Th	232.038
	94	Am	243.061	LXXXVII	88	Pa	231.036
	95	Cm	247.045	LXXXVIII	89	U	238.029
	96	Bk	247.071	LXXXIX	90	Np	244.064
	97	Cf	251.083	LXXXX	91	Pu	243.061
	98	Es	252.083	LXXXXI	92	Am	247.045
	99	Fm	253.081	LXXXXII	93	Cm	247.045
	100	Md	258.10	LXXXXIII	94	Bk	251.083
	101	No	259.10	LXXXXIV	95	Cf	252.083
	102	Lr	260.10	LXXXXV	96	Es	253.081
	103	Uu	261.10	LXXXXVI	97	Fm	254.08
	104	Uu	262.10	LXXXXVII	98	Md	258.10
	105	Uu	263.10	LXXXXVIII	99	No	259.10
	106	Uu	263.10	LXXXXIX	100	Lr	260.10
	107	Uu	263.10	LXXXXX	101	Uu	261.10
	108	Uu	263.10	LXXXXXI	102	Uu	262.10
	109	Uu	263.10	LXXXXXII	103	Uu	263.10
	110	Uu	263.10	LXXXXXIII	104	Uu	263.10
	111	Uu	263.10	LXXXXXIV	105	Uu	263.10
	112	Uu	263.10	LXXXXXV	106	Uu	263.10
	113	Uu	263.10	LXXXXXVI	107	Uu	263.10
	114	Uu	263.10	LXXXXXVII	108	Uu	263.10
	115	Uu	263.10	LXXXXXVIII	109	Uu	263.10
	116	Uu	263.10	LXXXXXIX	110	Uu	263.10
	117	Uu	263.10	LXXXXXX	111	Uu	263.10
	118	Uu	263.10	LXXXXXXI	112	Uu	263.10
	119	Uu	263.10	LXXXXXXII	113	Uu	263.10
	120	Uu	263.10	LXXXXXXIII	114	Uu	263.10
	121	Uu	263.10	LXXXXXXIV	115	Uu	263.10
	122	Uu	263.10	LXXXXXXV	116	Uu	263.10
	123	Uu	263.10	LXXXXXXVI	117	Uu	263.10
	124	Uu	263.10	LXXXXXXVII	118	Uu	263.10
	125	Uu	263.10	LXXXXXXVIII	119	Uu	263.10
	126	Uu	263.10	LXXXXXXIX	120	Uu	263.10
	127	Uu	263.10	LXXXXXXX	121	Uu	263.10
	128	Uu	263.10	LXXXXXXXI	122	Uu	263.10
	129	Uu	263.10	LXXXXXXXII	123	Uu	263.10
	130	Uu	263.10	LXXXXXXXIII	124	Uu	263.10
	131	Uu	263.10	LXXXXXXXIV	125	Uu	263.10
	132	Uu	263.10	LXXXXXXXV	126	Uu	263.10
	133	Uu	263.10	LXXXXXXXVI	127	Uu	263.10
	134	Uu	263.10	LXXXXXXXVII	128	Uu	263.10
	135	Uu	263.10	LXXXXXXXVIII	129	Uu	263.10
	136	Uu	263.10	LXXXXXXXIX	130	Uu	263.10
	137	Uu	263.10	LXXXXXXX	131	Uu	263.10
	138	Uu	263.10	LXXXXXXXI	132	Uu	263.10
	139	Uu	263.10	LXXXXXXXII	133	Uu	263.10
	140	Uu	263.10	LXXXXXXXIII	134	Uu	263.10
	141	Uu	263.10	LXXXXXXXIV	135	Uu	263.10
	142	Uu	263.10	LXXXXXXXV	136	Uu	263.10
	143	Uu	263.10	LXXXXXXXVI	137	Uu	263.10
	144	Uu	263.10	LXXXXXXXVII	138	Uu	263.10
	145	Uu	263.10	LXXXXXXXVIII	139	Uu	263.10
	146	Uu	263.10	LXXXXXXXIX	140	Uu	263.10
	147	Uu	263.10	LXXXXXXX	141	Uu	263.10
	148	Uu	263.10	LXXXXXXXI	142	Uu	263.10
	149	Uu	263.10	LXXXXXXXII	143	Uu	263.10
	150	Uu	263.10	LXXXXXXXIII	144	Uu	263.10
	151	Uu	263.10	LXXXXXXXIV	145	Uu	263.10
	152	Uu	263.10	LXXXXXXXV	146	Uu	263.10
	153	Uu	263.10	LXXXXXXXVI	147	Uu	263.10
	154	Uu	263.10	LXXXXXXXVII	148	Uu	263.10
	155	Uu	263.10	LXXXXXXXVIII	149	Uu	263.10
	156	Uu	263.10	LXXXXXXXIX	150	Uu	263.10
	157	Uu	263.10	LXXXXXXX	151	Uu	263.10
	158	Uu	263.10	LXXXXXXXI	152	Uu	263.10
	159	Uu	263.10	LXXXXXXXII	153	Uu	263.10
	160	Uu	263.10	LXXXXXXXIII	154	Uu	263.10
	161	Uu	263.10	LXXXXXXXIV	155	Uu	263.10
	162	Uu	263.10	LXXXXXXXV	156	Uu	263.10
	163	Uu	263.10	LXXXXXXXVI	157	Uu	263.10
	164	Uu	263.10	LXXXXXXXVII	158	Uu	263.10
	165	Uu	263.10	LXXXXXXXVIII	159	Uu	263.10
	166	Uu	263.10	LXXXXXXXIX	160	Uu	263.10
	167	Uu	263.10	LXXXXXXX	161	Uu	263.10
	168	Uu	263.10	LXXXXXXXI	162	Uu	263.10
	169	Uu	263.10	LXXXXXXXII	163	Uu	263.10
	170	Uu	263.10	LXXXXXXXIII	164	Uu	263.10
	171	Uu	263.10	LXXXXXXXIV	165	Uu	263.10
	172	Uu	263.10	LXXXXXXXV	166	Uu	263.10
	173	Uu	263.10	LXXXXXXXVI	167	Uu	263.10
	174	Uu	263.10	LXXXXXXXVII	168	Uu	263.10
	175	Uu	263.10	LXXXXXXXVIII	169	Uu	263.10
	176	Uu	263.10	LXXXXXXXIX	170	Uu	263.10
	177	Uu	263.10	LXXXXXXX	171	Uu	263.10
	178	Uu	263.10	LXXXXXXXI	172	Uu	263.10
	179	Uu	263.10	LXXXXXXXII	173	Uu	263.10
	180	Uu	263.10	LXXXXXXXIII	174	Uu	263.10
	181	Uu	263.10	LXXXXXXXIV	175	Uu	263.10
	182	Uu	263.10	LXXXXXXXV	176	Uu	263.10
	183	Uu	263.10	LXXXXXXXVI	177	Uu	263.10
	184	Uu	263.10	LXXXXXXXVII	178	Uu	263.10
	185	Uu	263.10	LXXXXXXXVIII	179	Uu	263.10
	186	Uu	263.10	LXXXXXXXIX	180	Uu	263.10
	187	Uu	263.10	LXXXXXXX	181	Uu	263.10
	188	Uu	263.10	LXXXXXXXI	182	Uu	263.10
	189						

Nucleosynthesis studies need input from

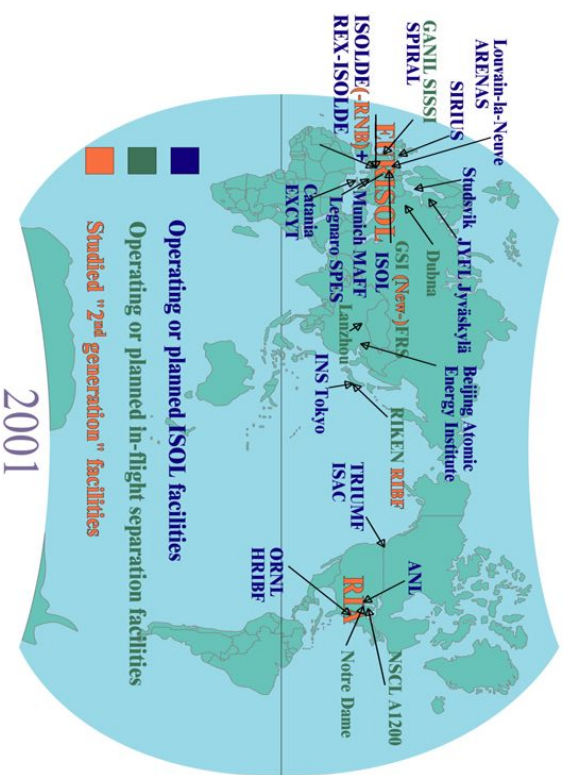
Lab Astro: nuclear masses, lifetimes, etc.:



Full use of KN spectroscopy requires input from

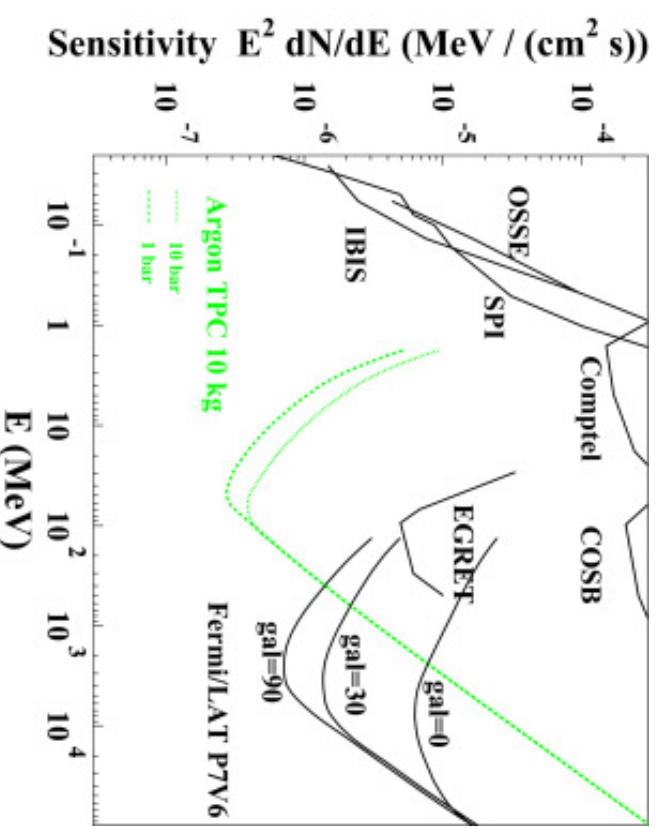
Lab Astro: EBITs etc

World Wide Radioactive Beam Facilities



2001

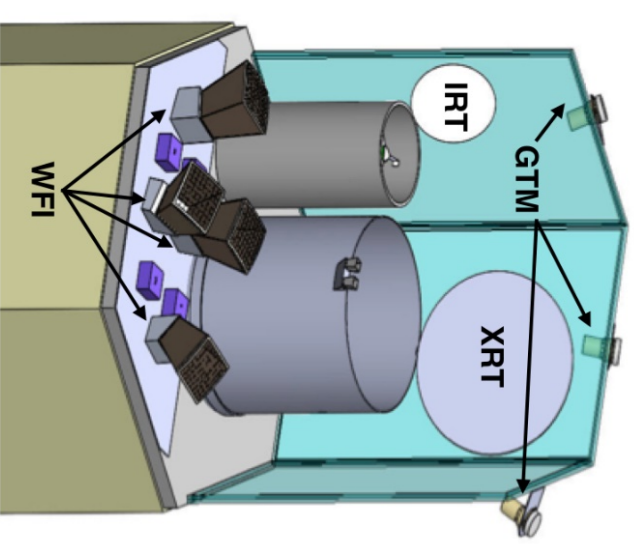
The MeV Gap



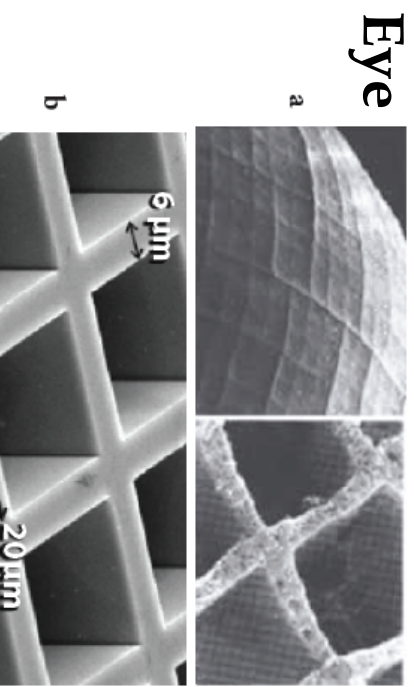
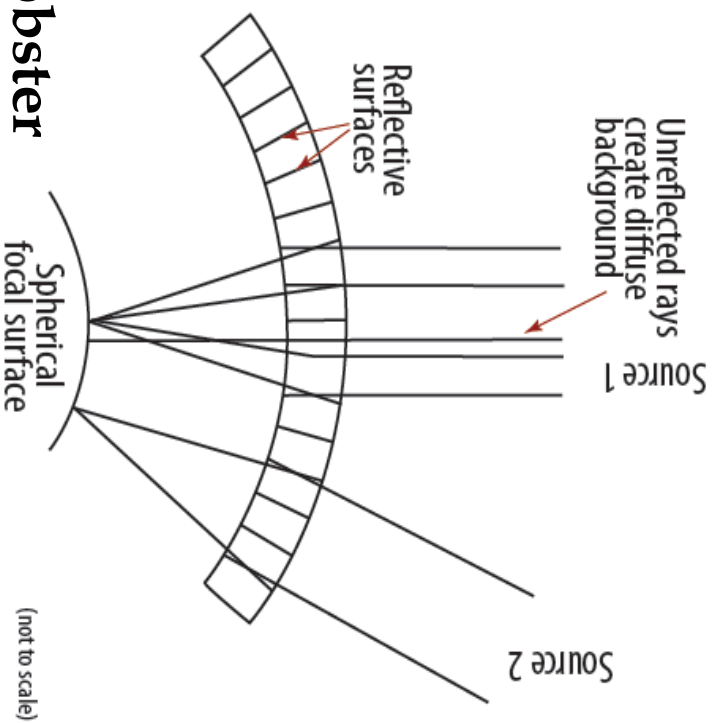
TAP Telescopes:

PI: Jordan Camp (GSFC)

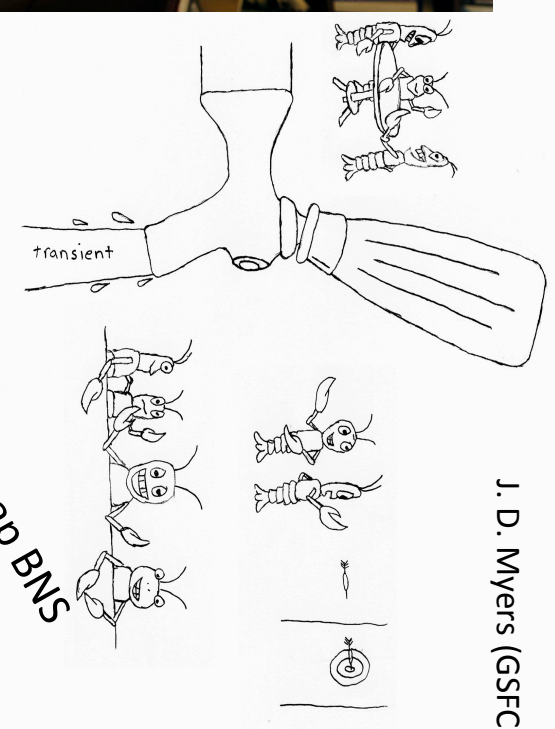
- WFI (Lobster) modules (4): 0.5-5keV
 - 2000 deg² (~0.5 sr) FoV, 1 arcmin loc.
 - 10⁻¹¹ erg/cm²/sec in 2000 sec
- IR Telescope
 - 1 deg²FoV
 - 0.3 – 2.5 micron, D ~ 0.7 m, three bands, R ~30 spectroscopy
 - 23-24 Mag in 500 sec
- X-ray Telescope (single crystal silicon mirror): 0.5-5 keV
 - 1 deg²FoV
 - 3 x 10⁻¹⁵ erg/cm²/sec in 2000 sec
- Gamma-ray Transient Monitor (8)
 - 10 - 1000 keV, 4pi FoV



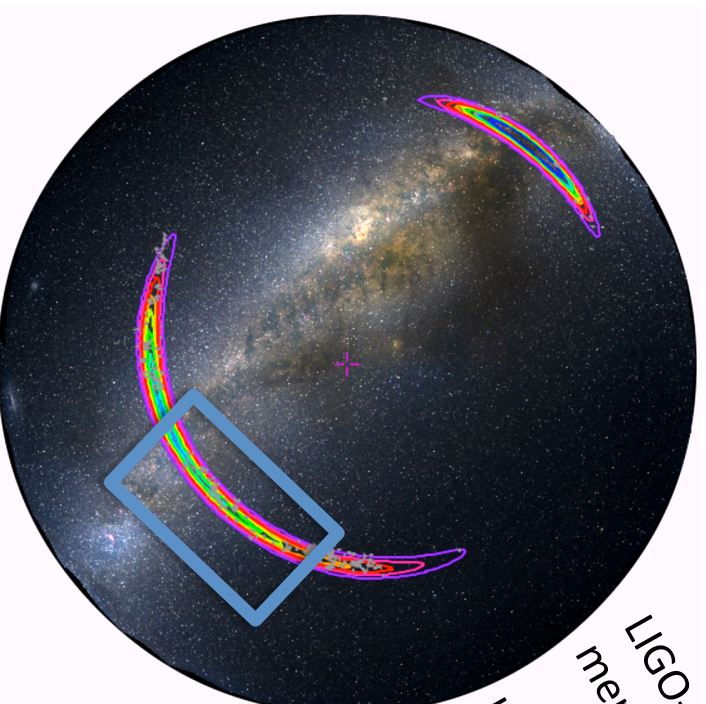
WFI: Lobster Eye Geometry microchannel optics



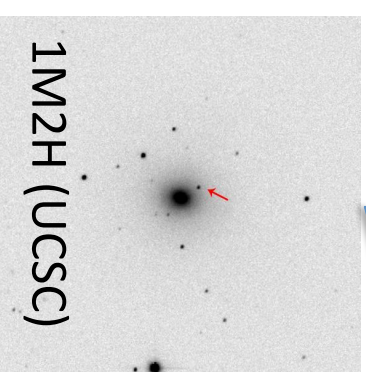
Lobster-Eye geometry: simultaneous large FoV, high position resolution and high sensitivity → Time Domain Astronomy



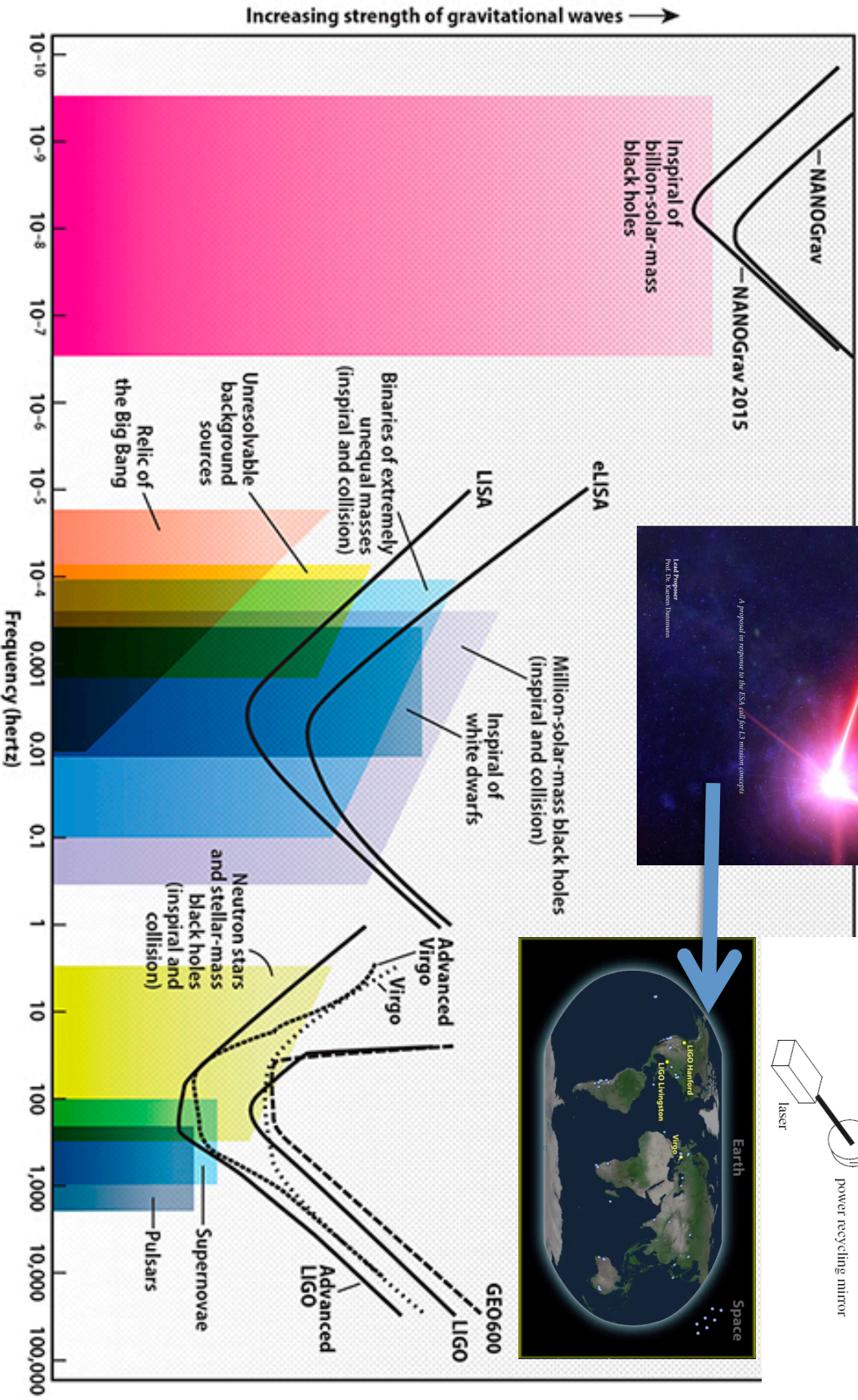
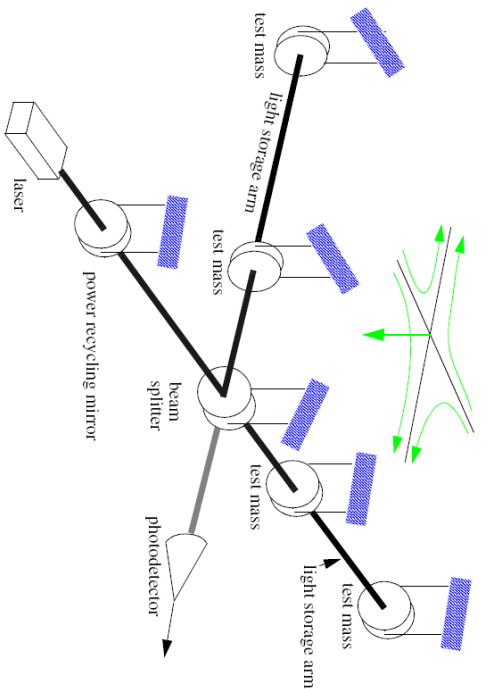
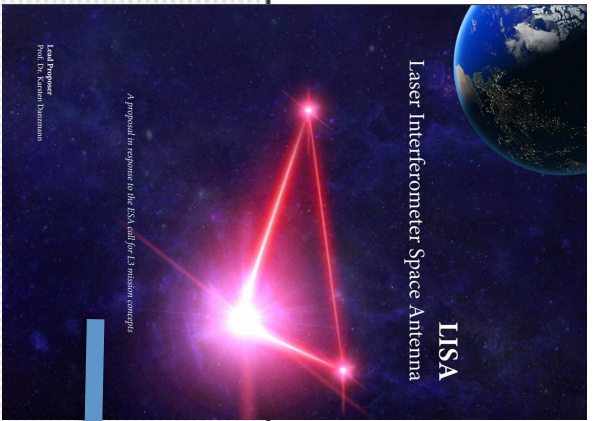
J. D. Myers (GSFC)



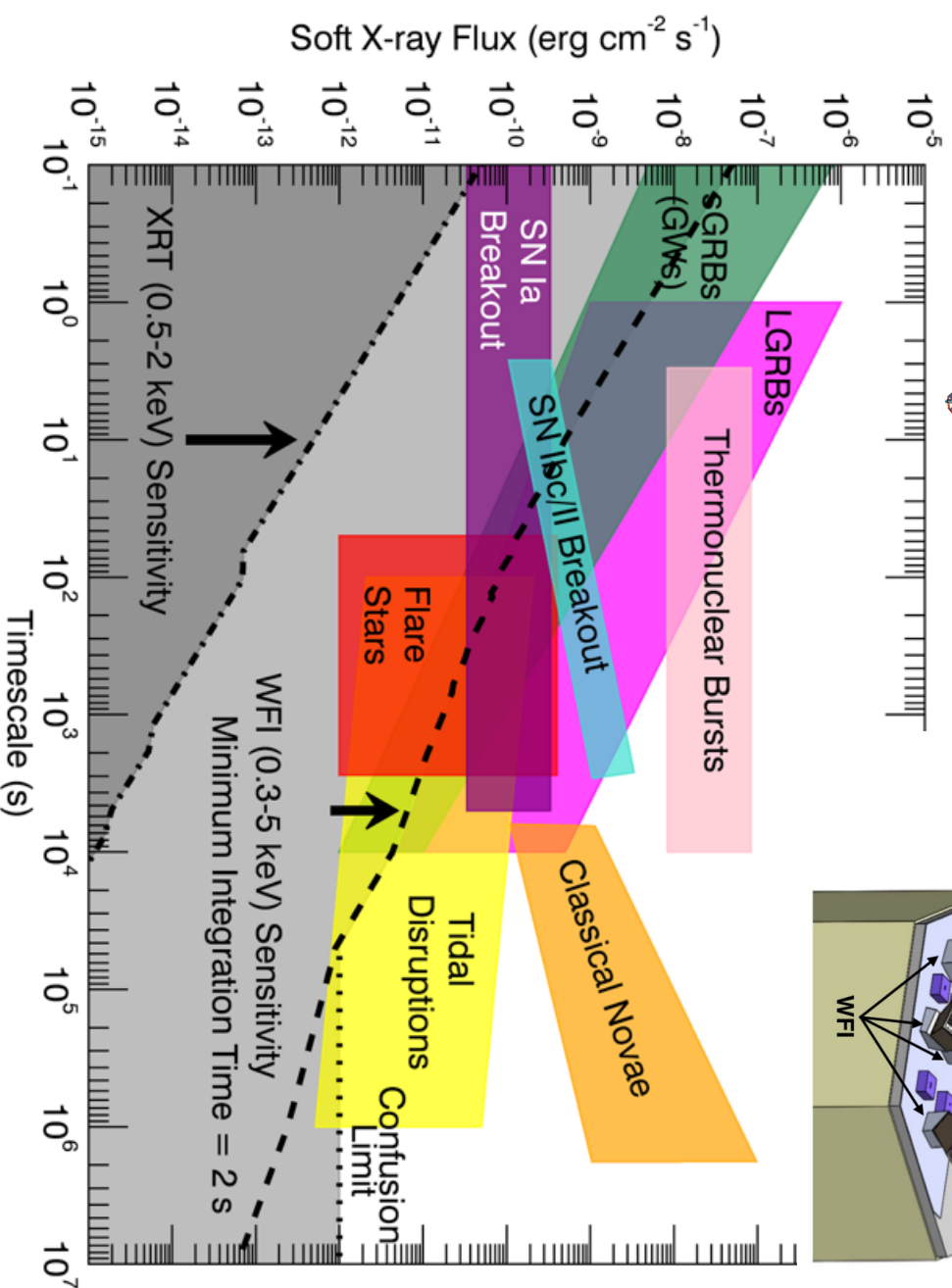
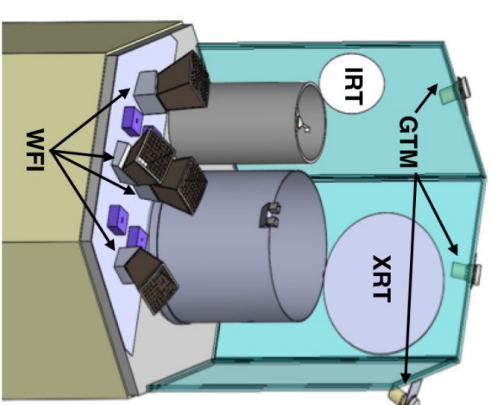
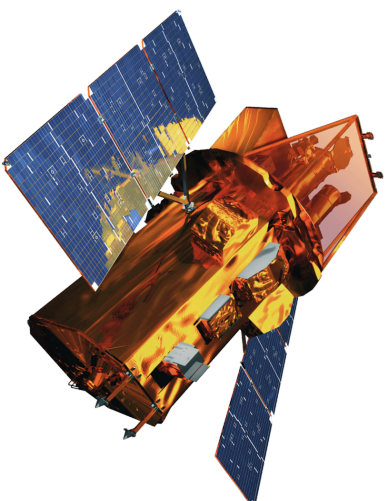
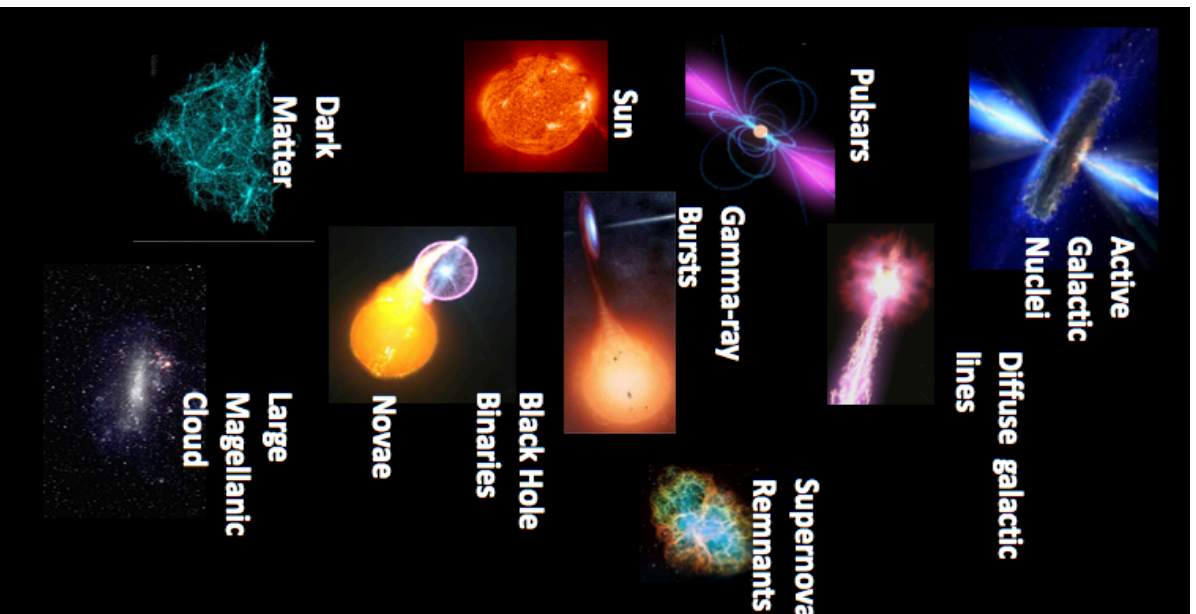
LIGO-Virgo sky map BNS
merger (100 □²)
Lobster FoV: Galaxy
Catalog Follow-up



1M2H (UCSC)



Time Domain Discovery Space



Time Domain Astrophysics

With **Swift**

Clemson University - October 24-26, 2011



In preparation for Senior Reviews, Neil gathered a large group of TDA enthusiasts, to discuss the status of the field and to aim in the forward direction with Swift in the context of ground- and space-based missions: We will miss him dearly when we gather again later this year.

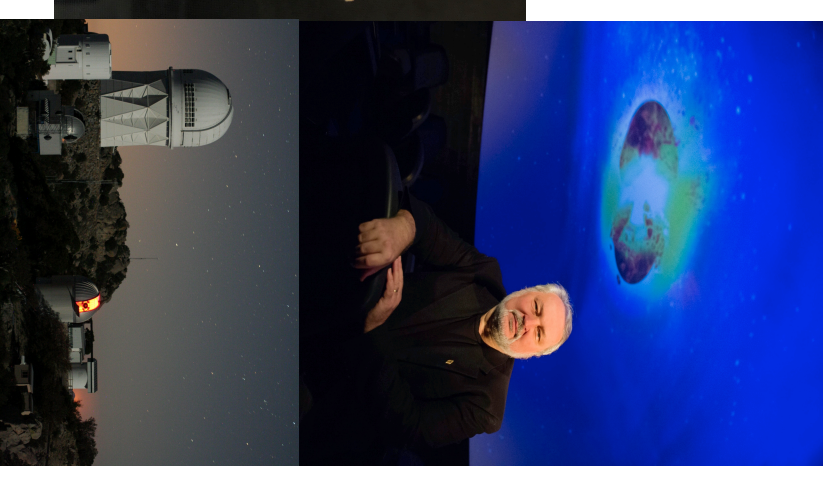
October 2015





from: Ken Nishikawa

I like this photo very much. It presents Neil's leadership and his beautiful smile, revealing his kind human nature. I had wonderful times with him at meetings. At GSFC, he hosted me and I had a fruitful time with him and his colleagues. I miss him.



Thank you Neil