Neil Gehrels Memorial Symposium


Clematis

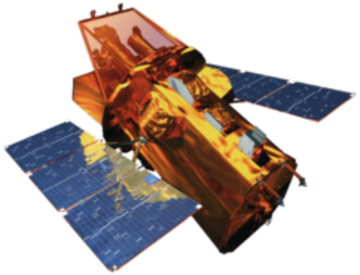
THE GEORGE
WASHINGTON
UNIVERSITY

WASHINGTON, DC

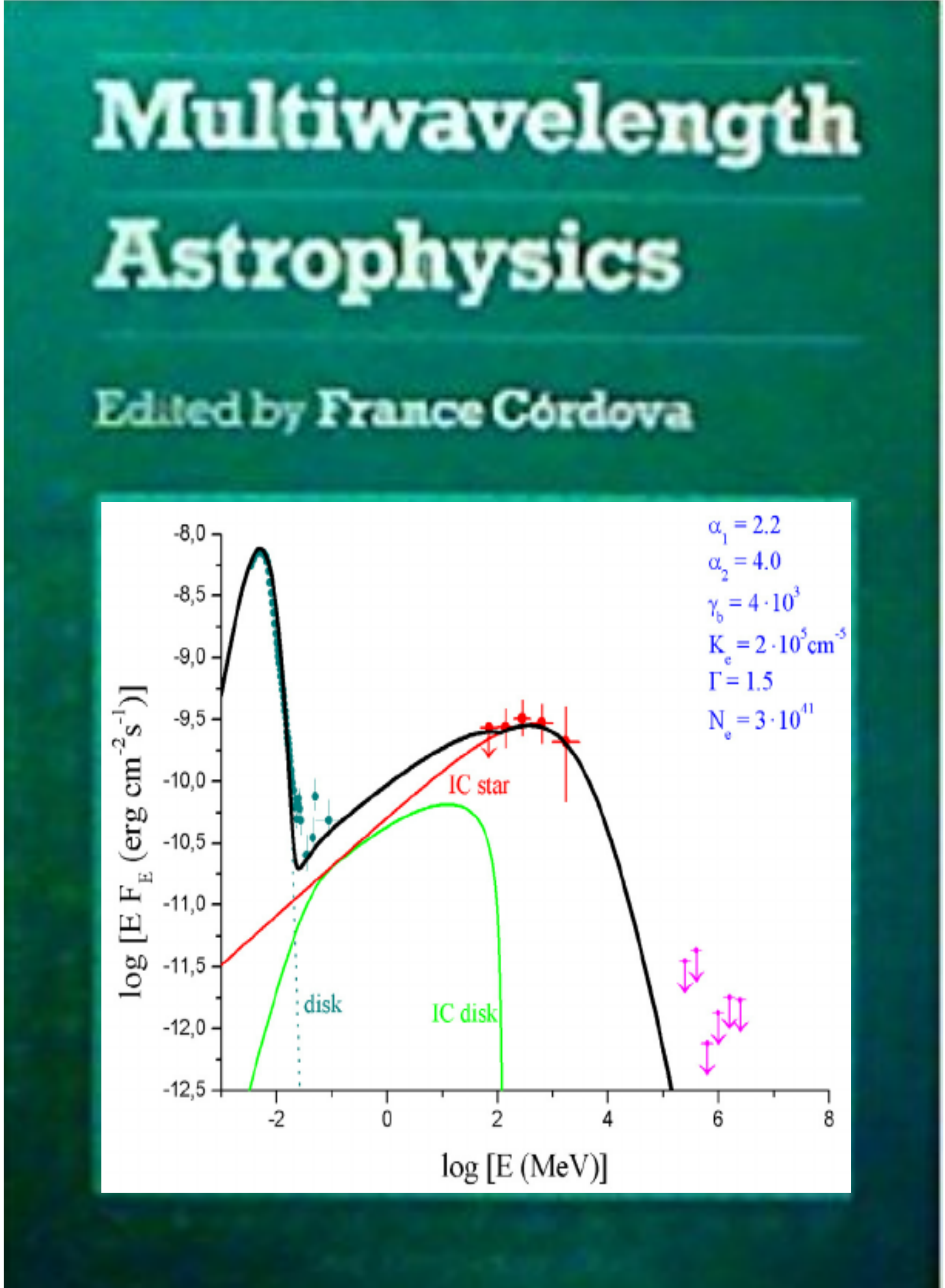
May 21-22, 2018


Blooming Leek

Dieter H. Hartmann
Clemson University

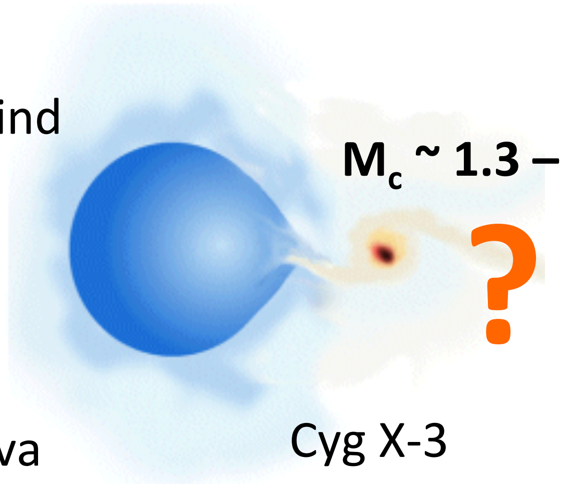


On nuFnu and Time Domain Astronomy with the



TDA: Time Domain Astrophysics
All Sky Monitoring – Fast Response

MMA: Multi-Messenger Astrophysics
Electromagnetic radiation
Gravitational waves
Neutrinos,
Cosmic Rays
Meteorites



WR wind

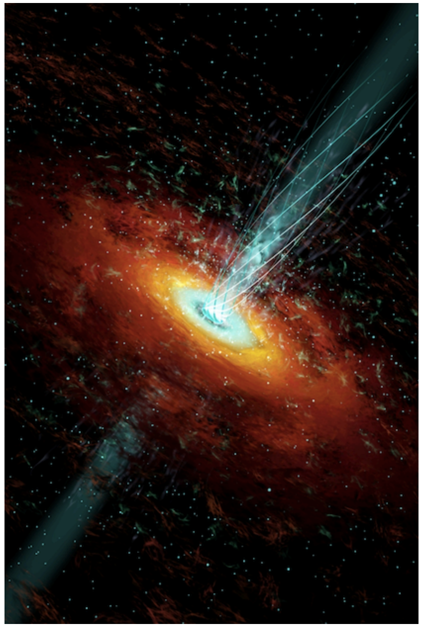
M_c ~ 1.3 – 4.5 $M_\odot$

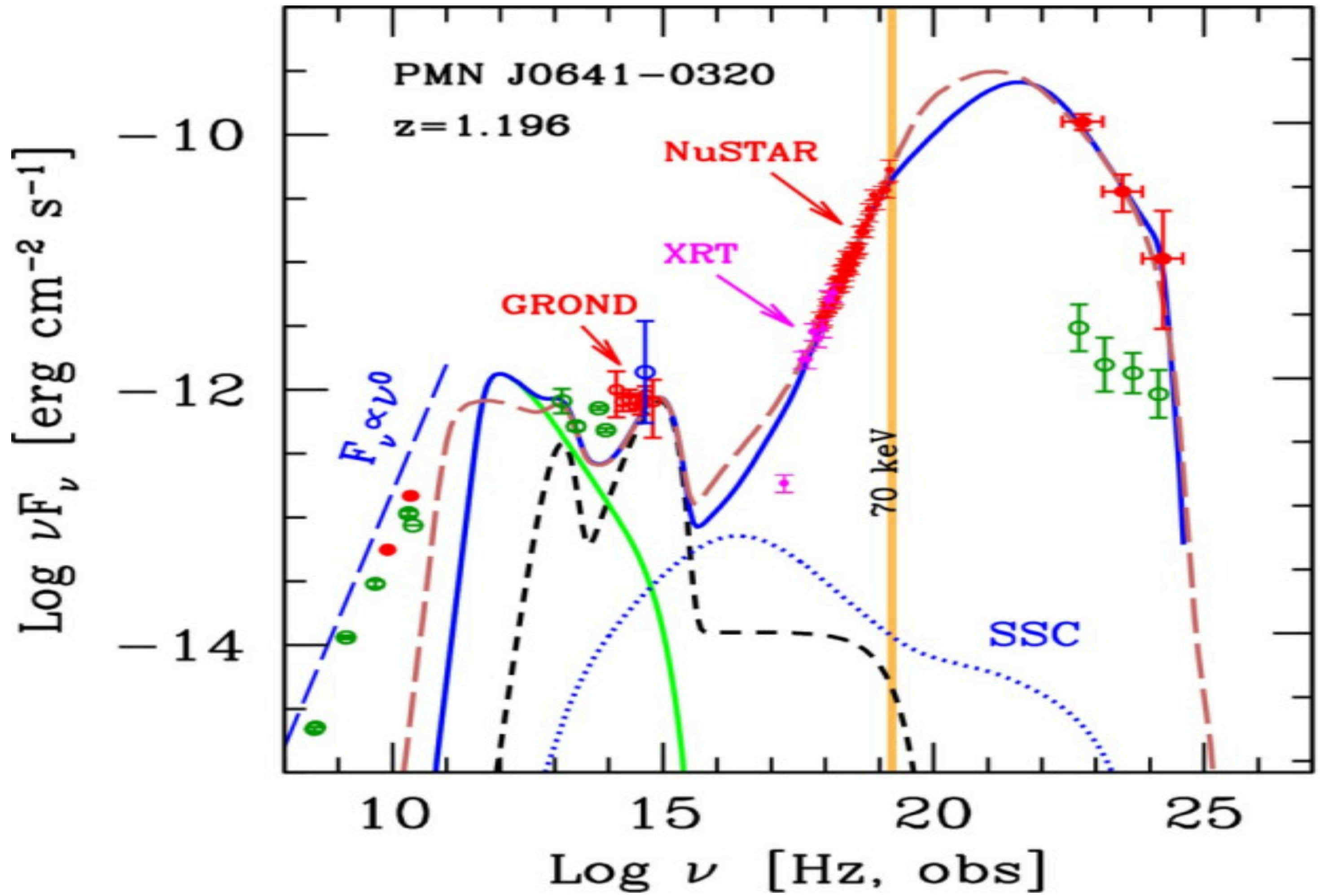
F. Cordova
workshop:
Taos, NM,
August 1987

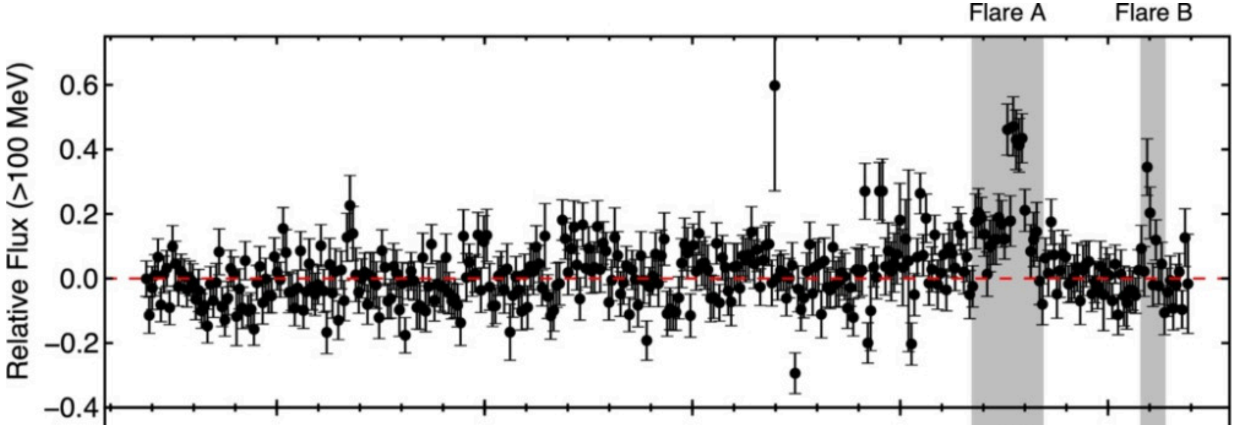
Cyg X-3
Giacconi et al. 1967
50 years ago! -

MOA: Multi-Observatory Astronomy

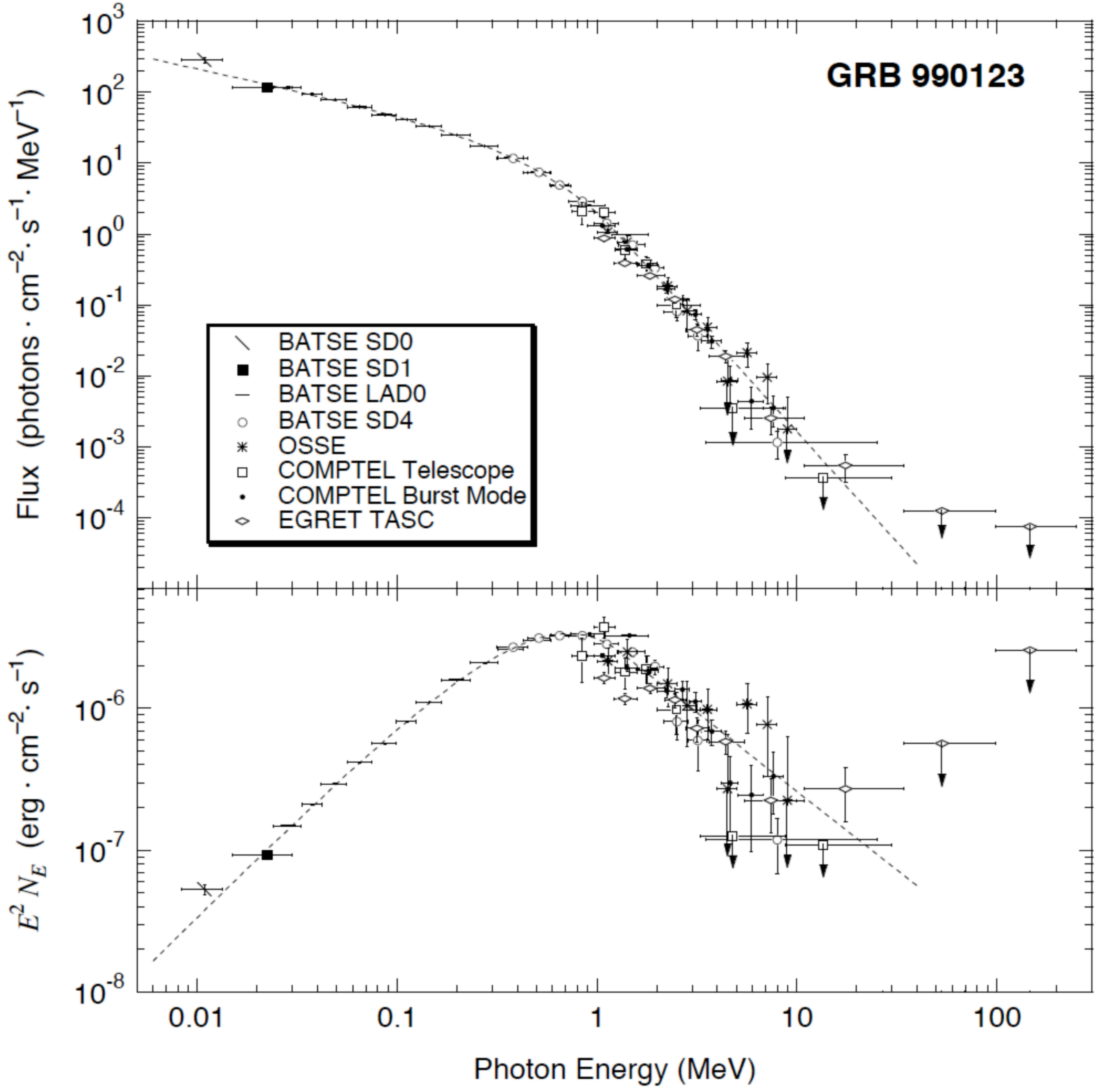
nuFnu:
flaring MeV blazar:
Ajello 2016, ApJ 826, 76

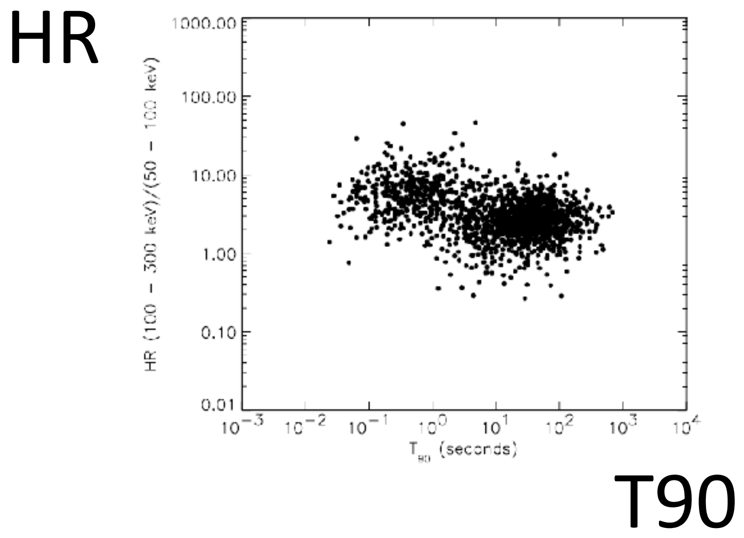




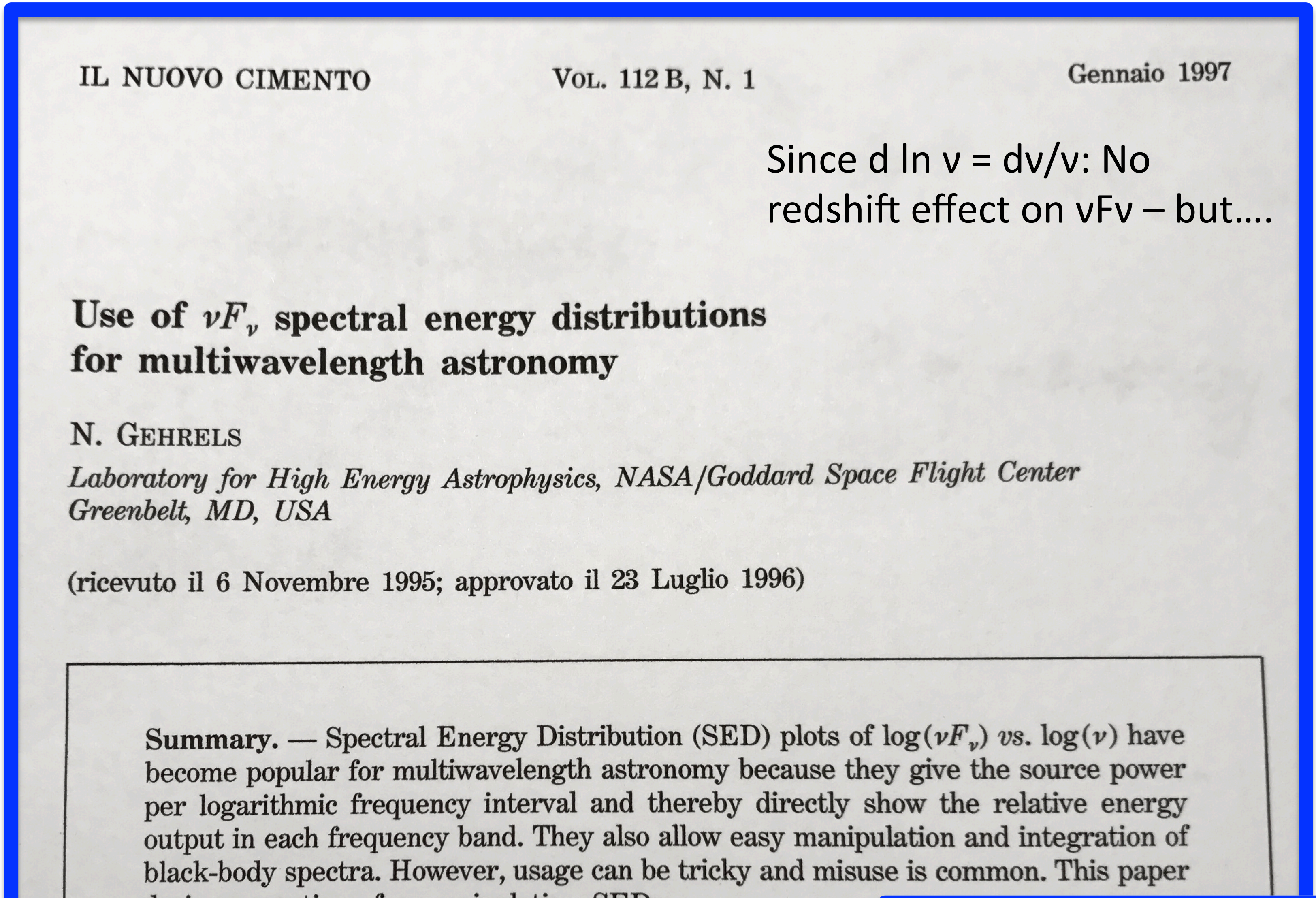


Long GRB Prompt emission





David Band:
1957 - 2009



IL NUOVO CIMENTO Vol. 112 B, N. 1 Gennaio 1997

Use of νF_ν spectral energy distributions for multiwavelength astronomy

N. Gehrels

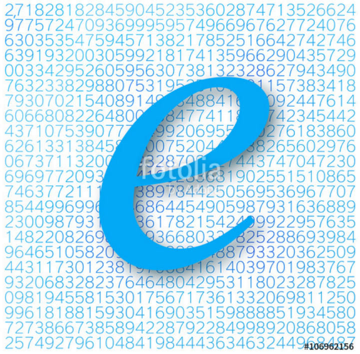
Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center
Greenbelt, MD, USA

(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.

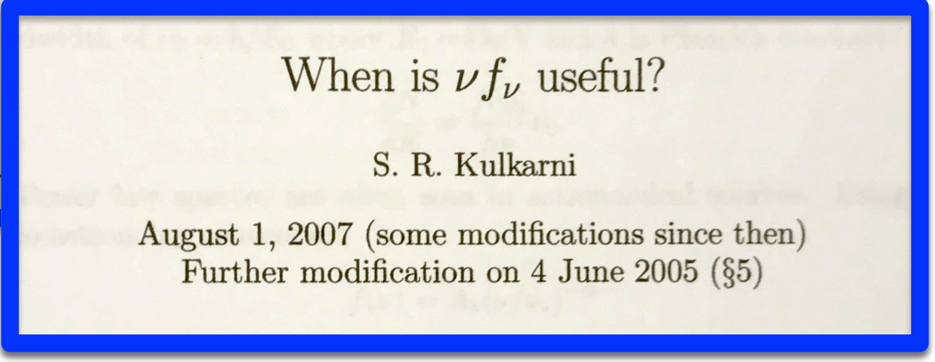
PACS 95.75.Fg – Spectroscopy and spectrophotometry.

Since d ln ν = dν/ν: No redshift effect on νFν – but….



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

Gehrz, Ney, Strecker& Woolf 1970, ApJ

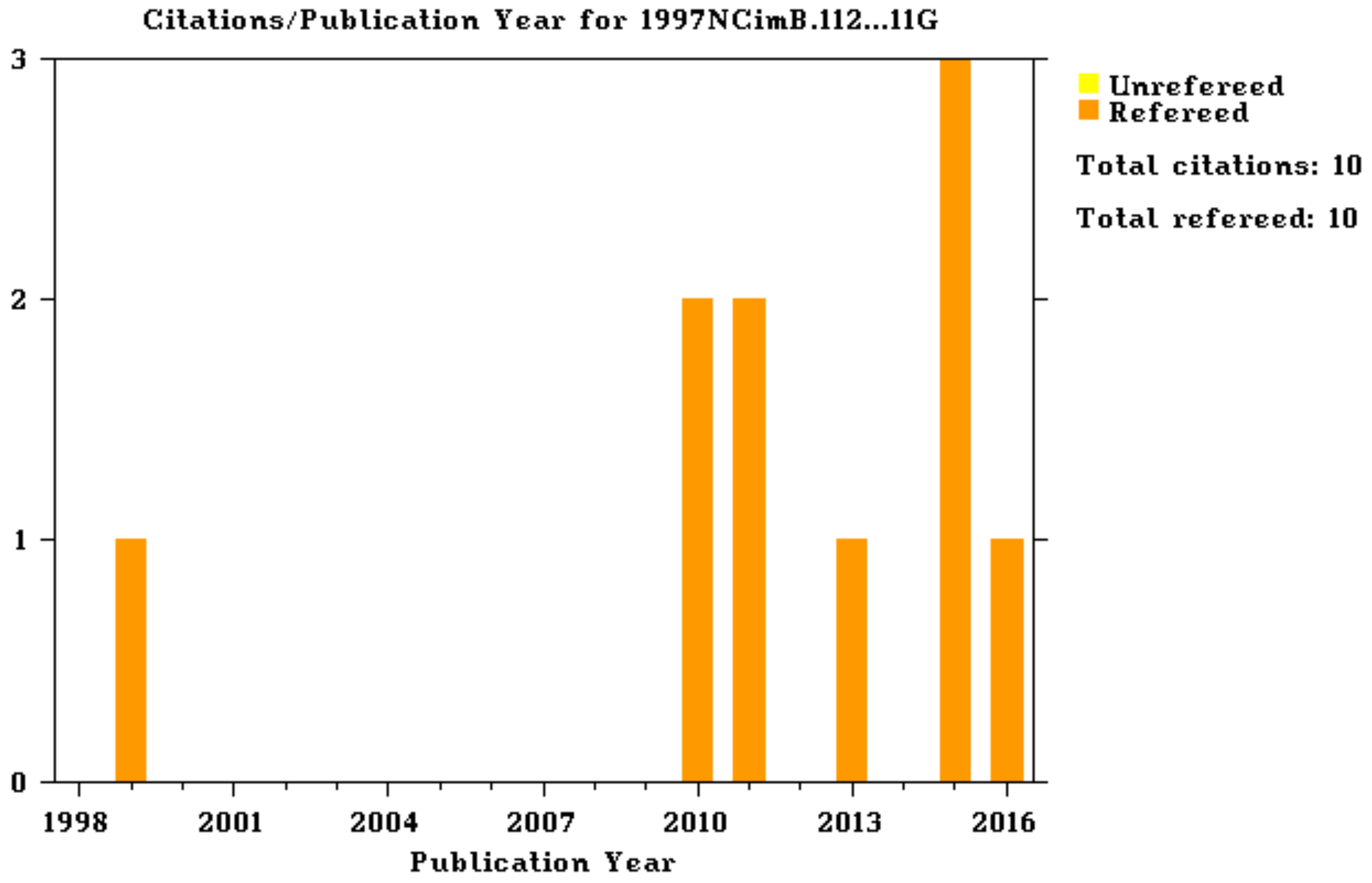


When is νf_ν useful?

S. R. Kulkarni

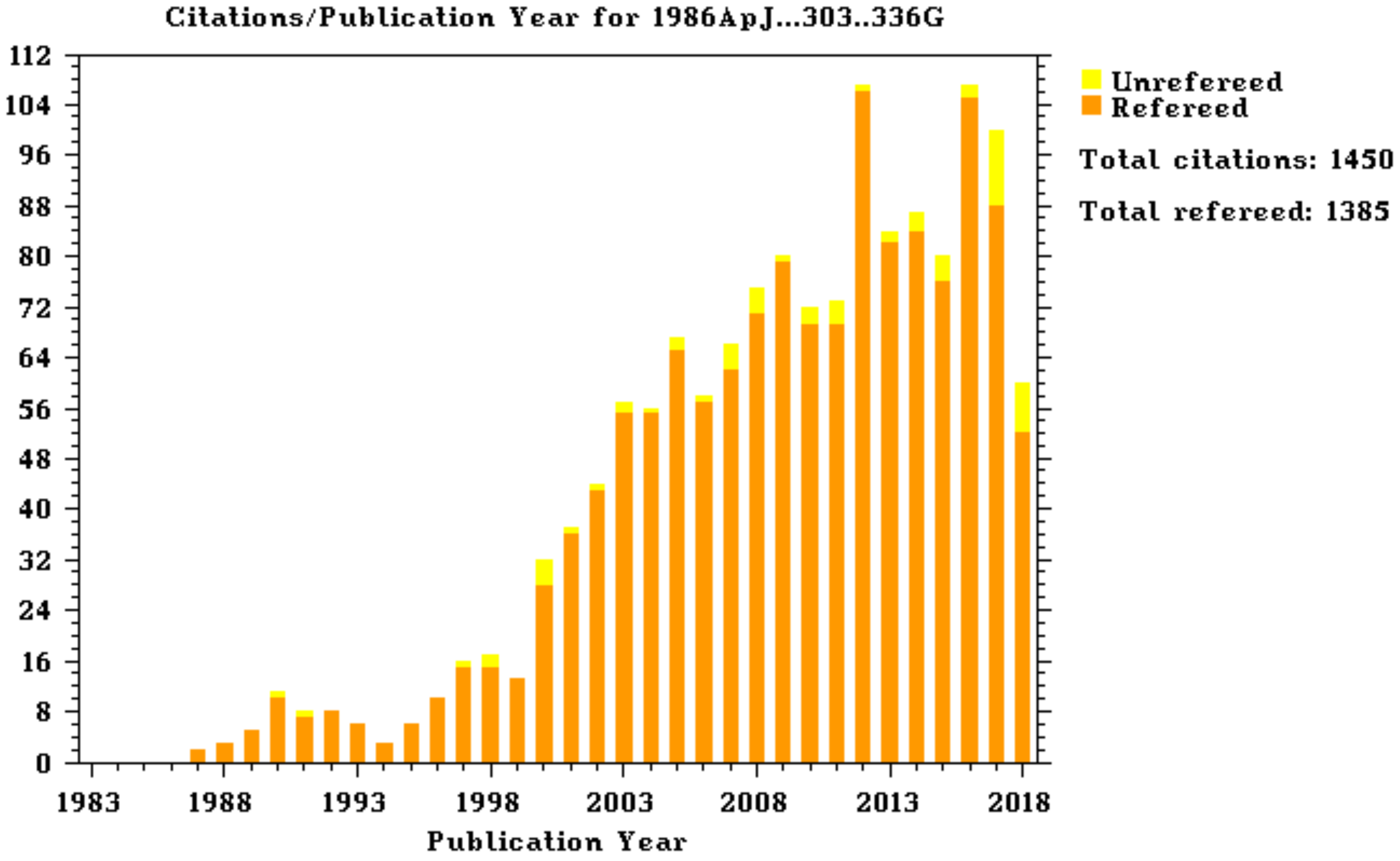
August 1, 2007 (some modifications since then)
Further modification on 4 June 2005 (§5)

Title: Use of νF_ν 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

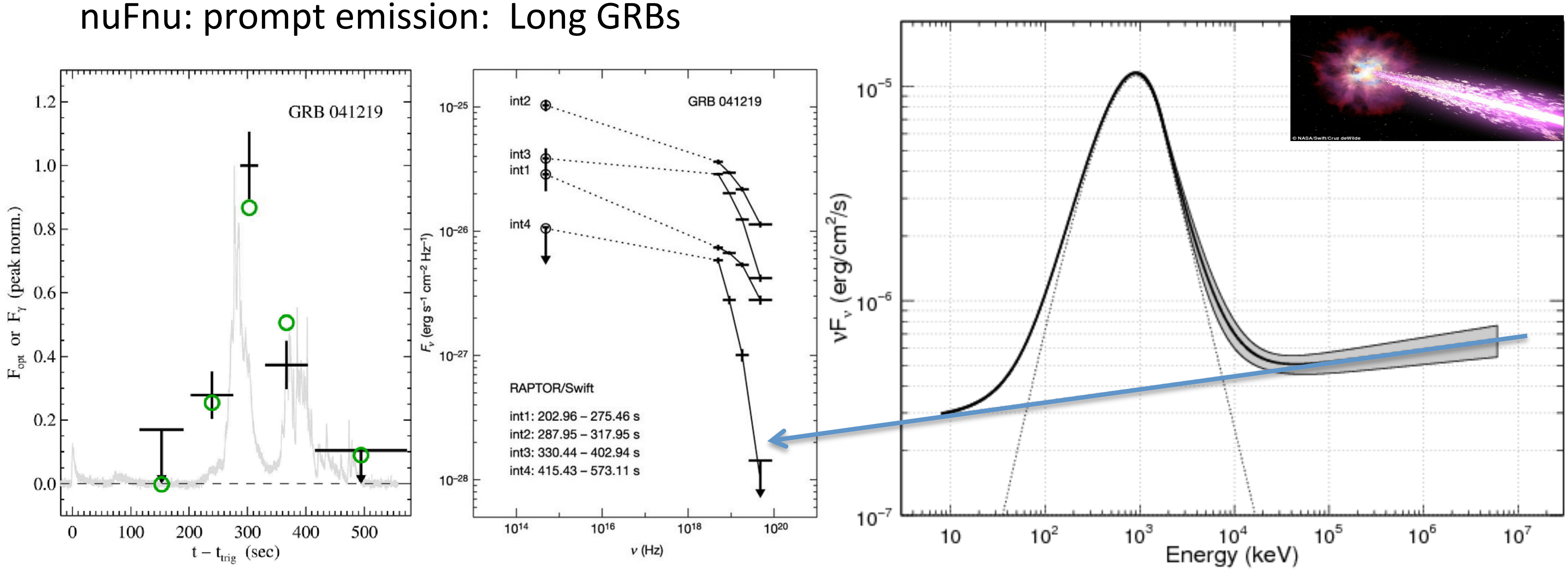


H. Steinle   S. Guieiec

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



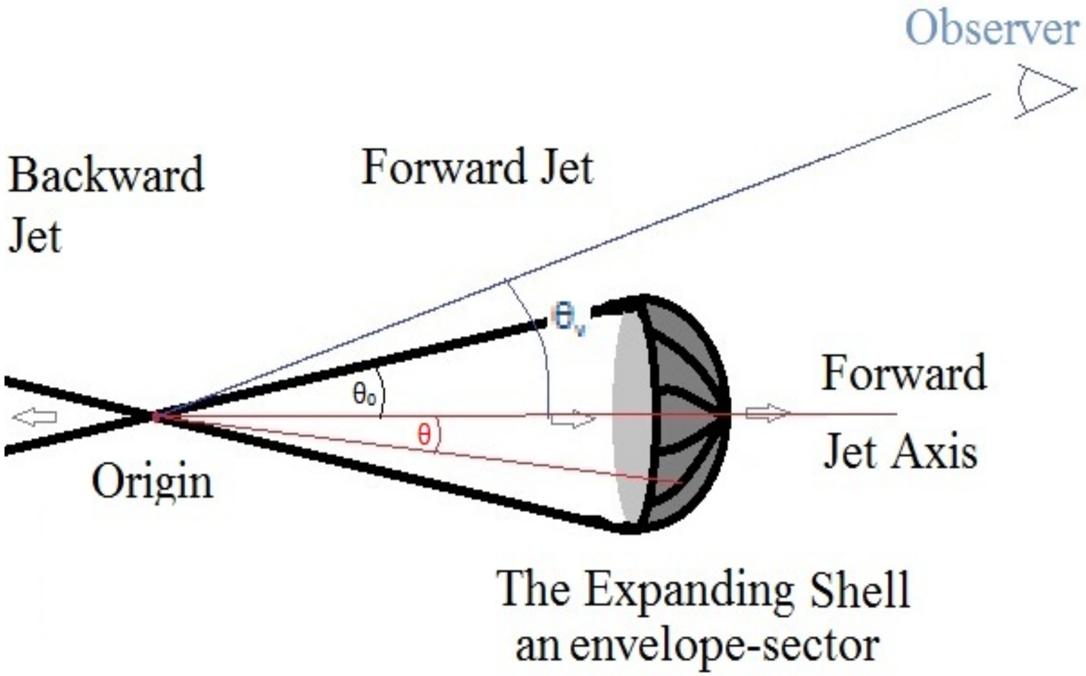
nuFnu: prompt emission: Long GRBs



T. Vestrand, et al 2005, Nature

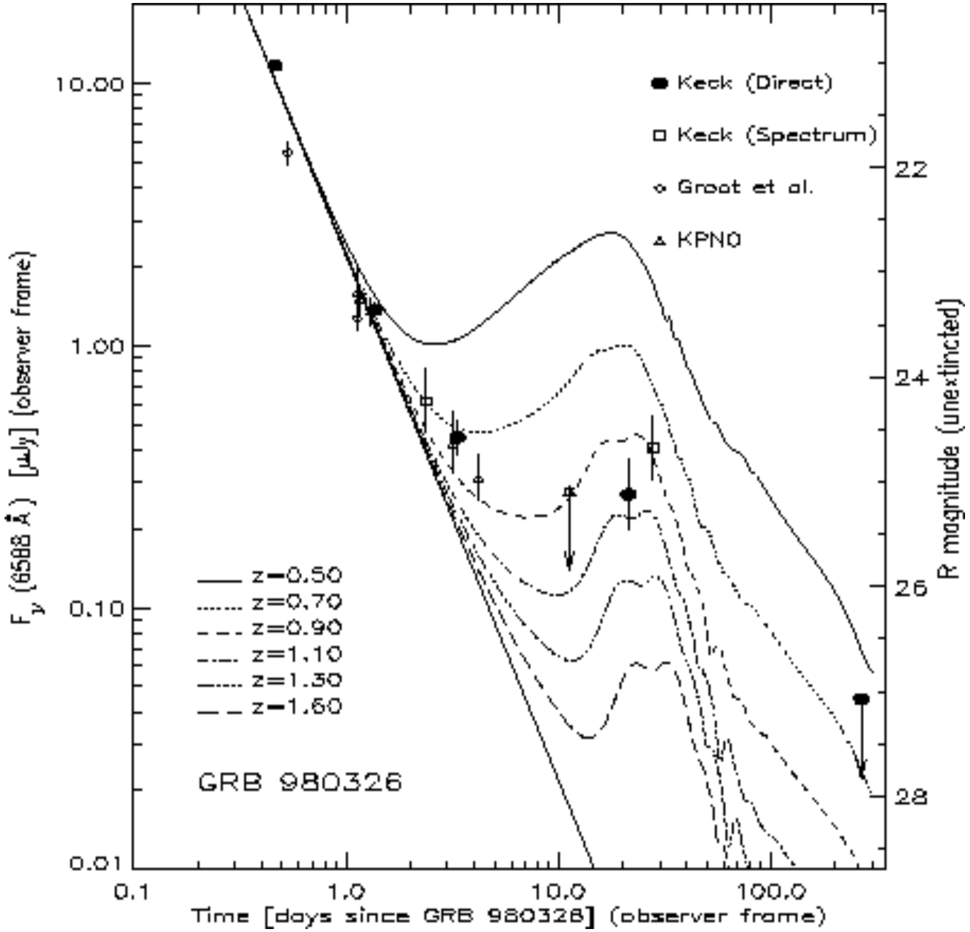
Time-dependent multi-component models:
(un)correlated prompt optical emission may hold the key and allow GRBs to serve as standard candles:

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



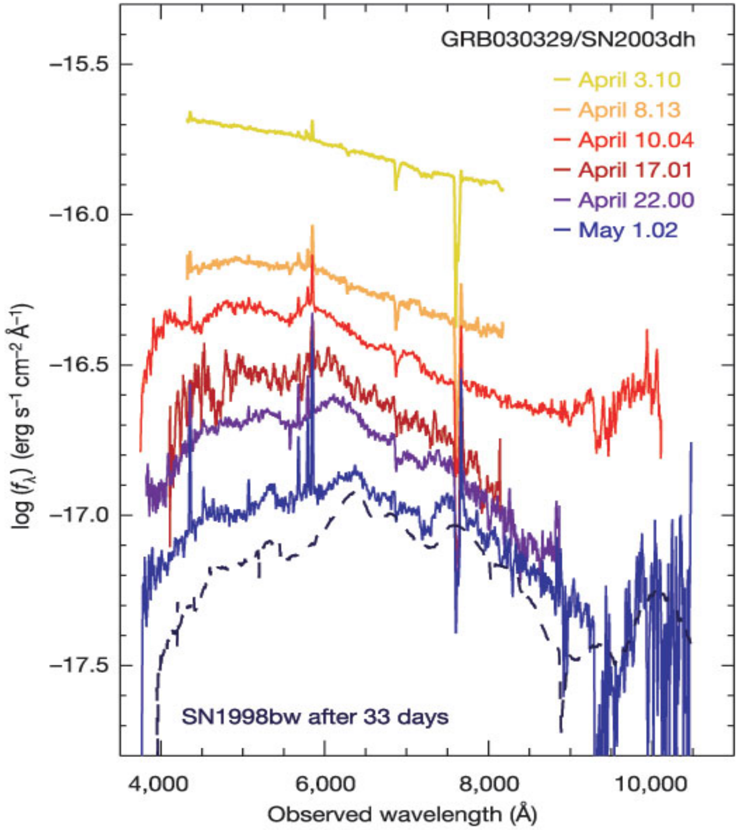
Ofek Birnholtz & Tsvi Piran 2013, PRD.87.123007

Afterglow of GRB980326: Bloom+99



NOT nuFnu

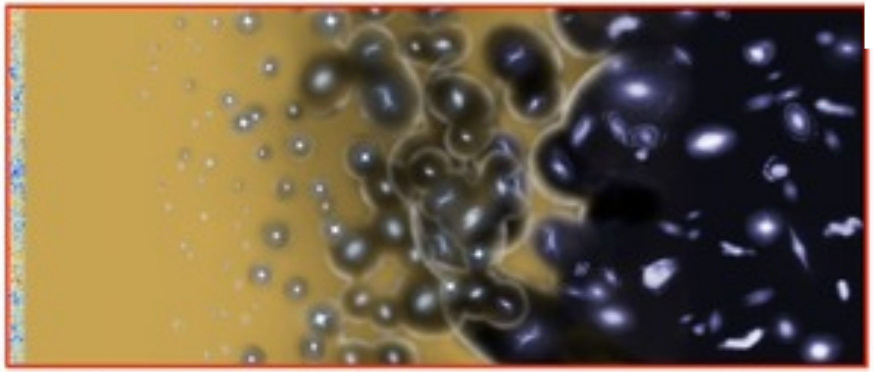
$m_\nu \div -2.5\ \mathrm{Log}_{10}(f_\nu)$



1925 - 2013

GRBs as cosmological TOOLS
AG Spectroscopy

From local chemical evolution
to
cosmic chemical evolution



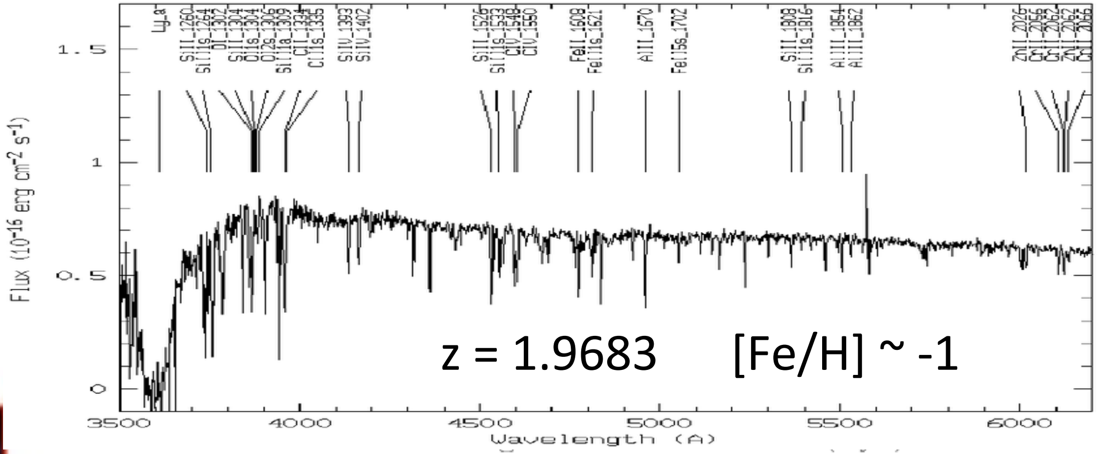
Credit ESA/Planck

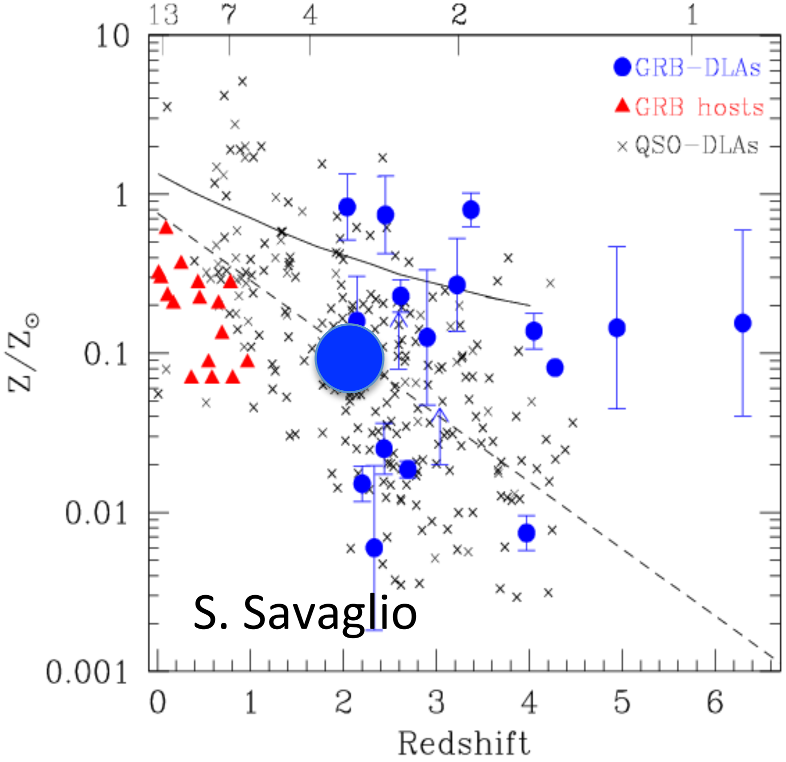
Elisabeth Vangioni
IAP/CNRS France

Minneapolis May, 2017

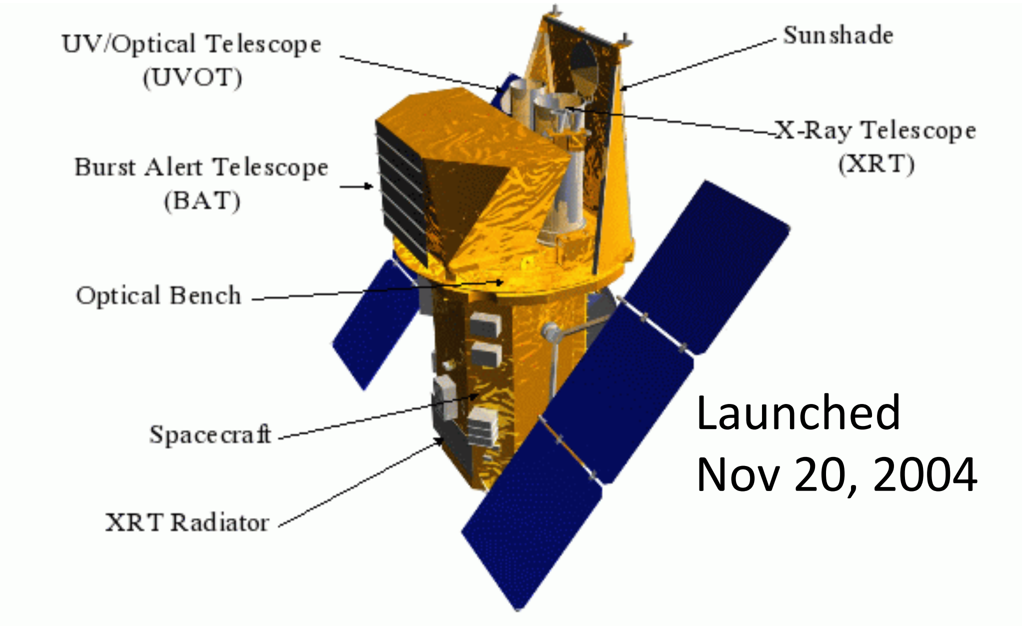
Cosmic Chemical Evolution

GRB081008; Swift/BAT
VLT/UVES FORS2 spectroscopy
~ 5 hours later D'Elia et al.



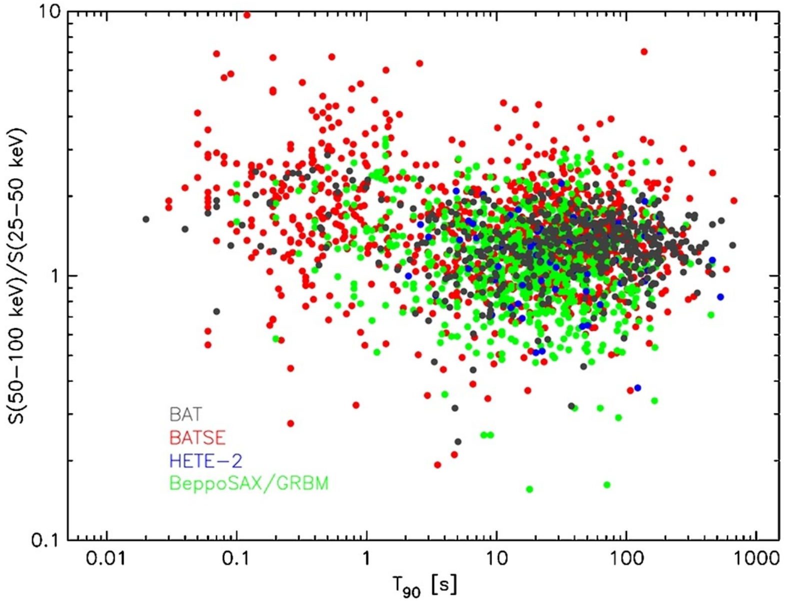


Short GRBs



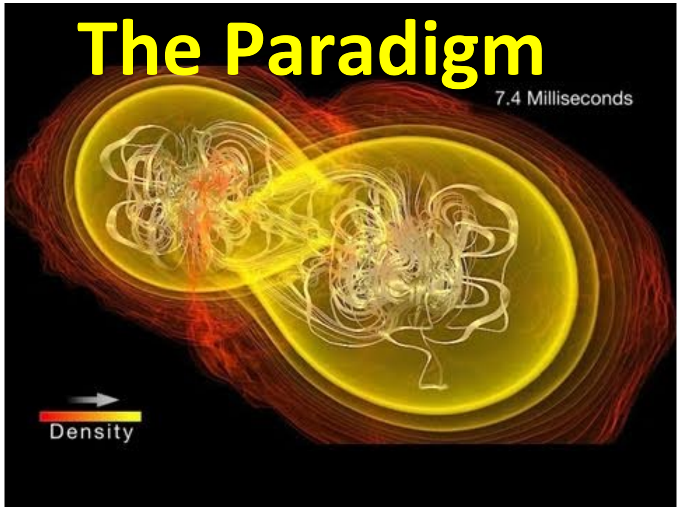
Launched
Nov 20, 2004

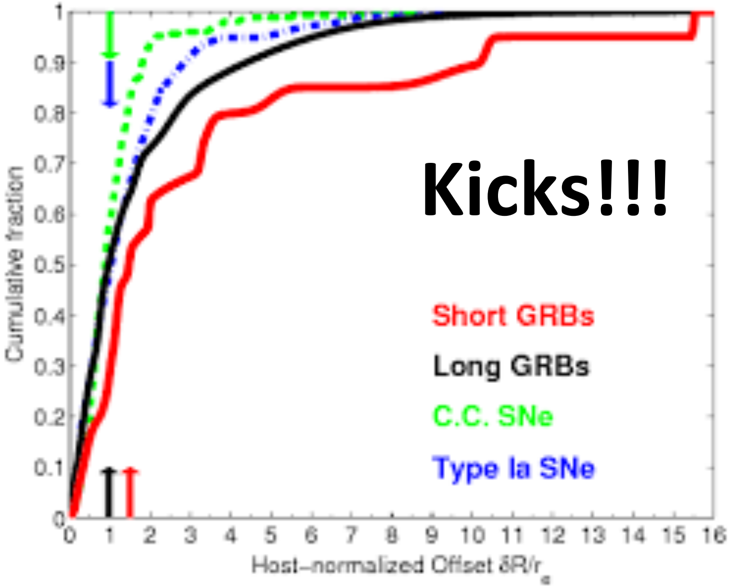
X-ray afterglows of SHBs
were discovered quickly,
but at a low rate.

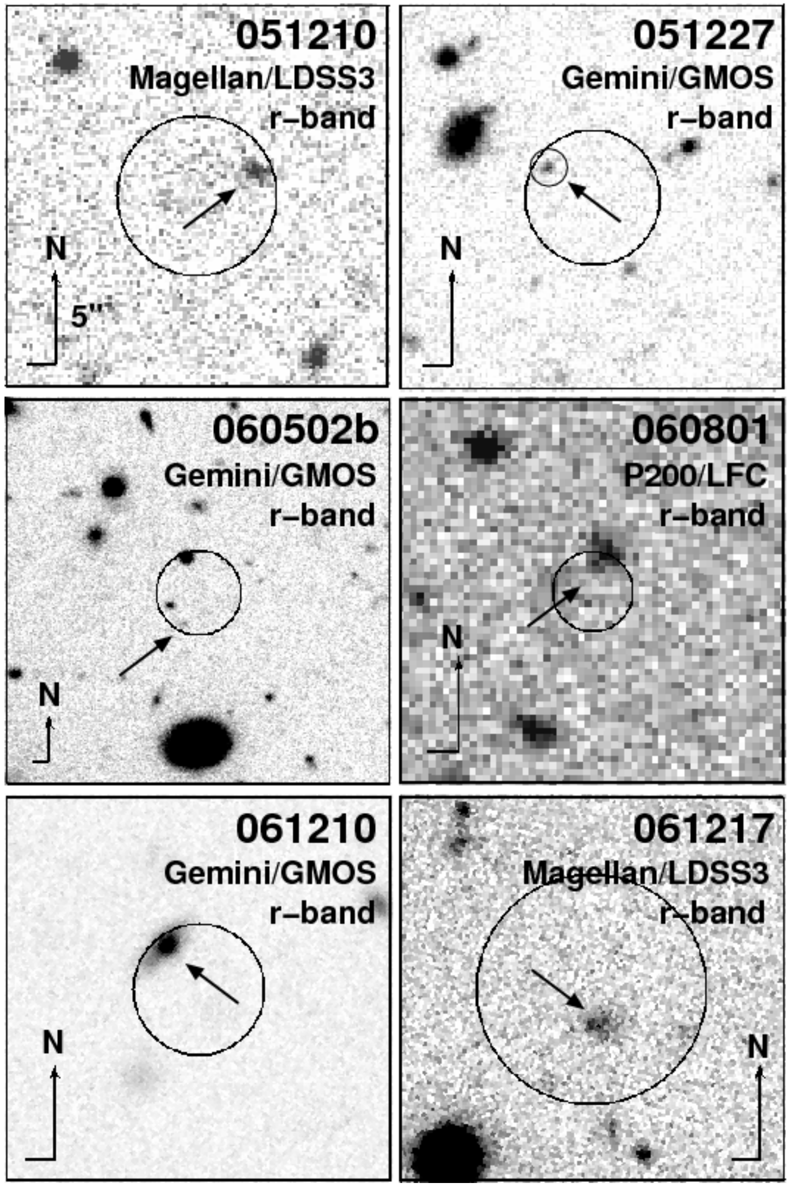


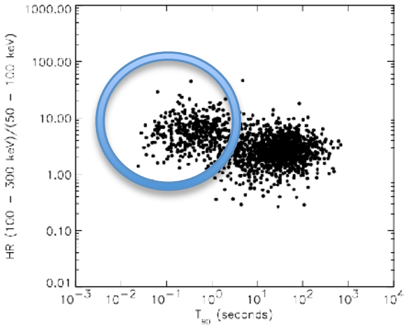
HR-T90 plot of GRBs detected by different missions (from Sakamoto et al. 2011). For interpretation of color in this figure, see Ghirlanda et al. 2015, JHEA 7, 81.)

The Paradigm



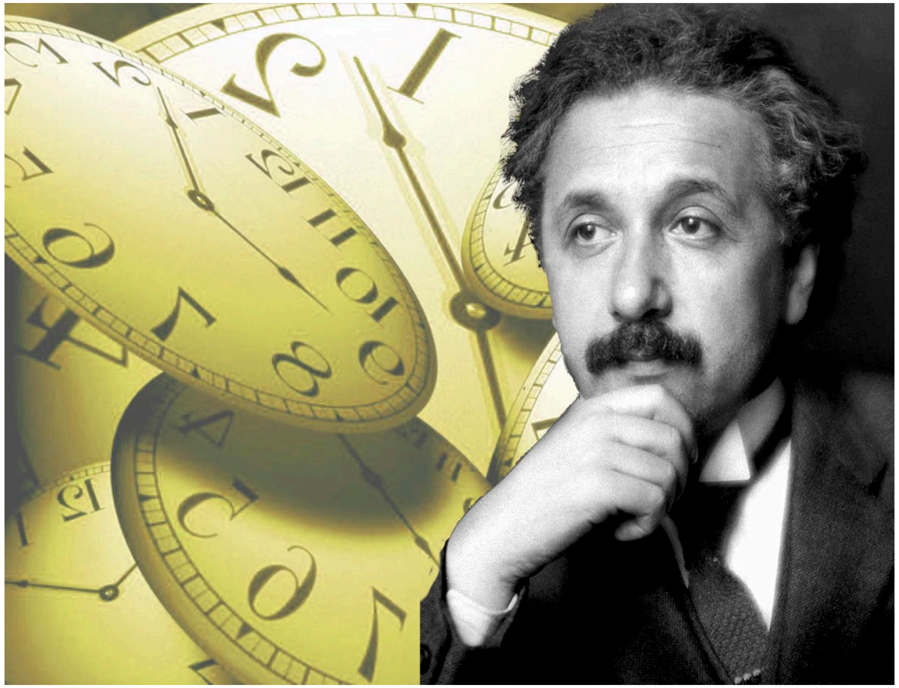


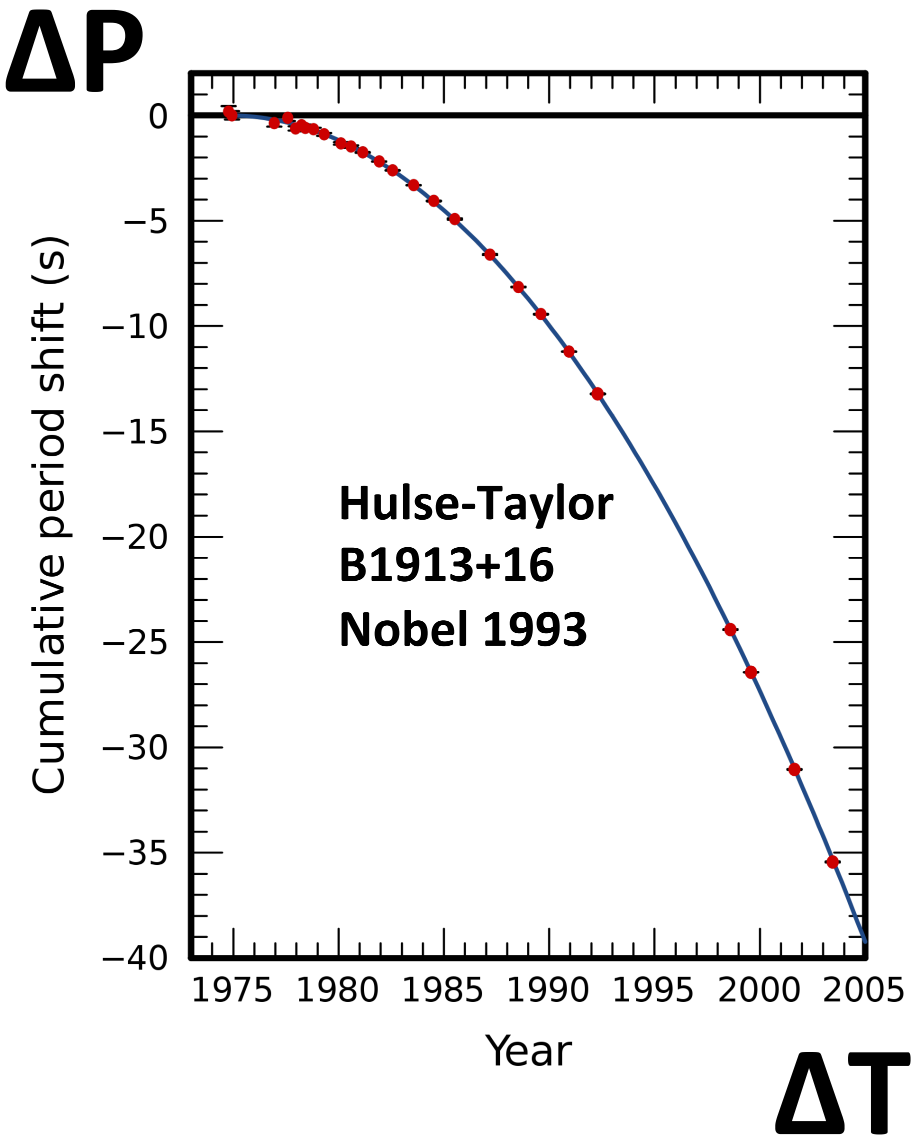




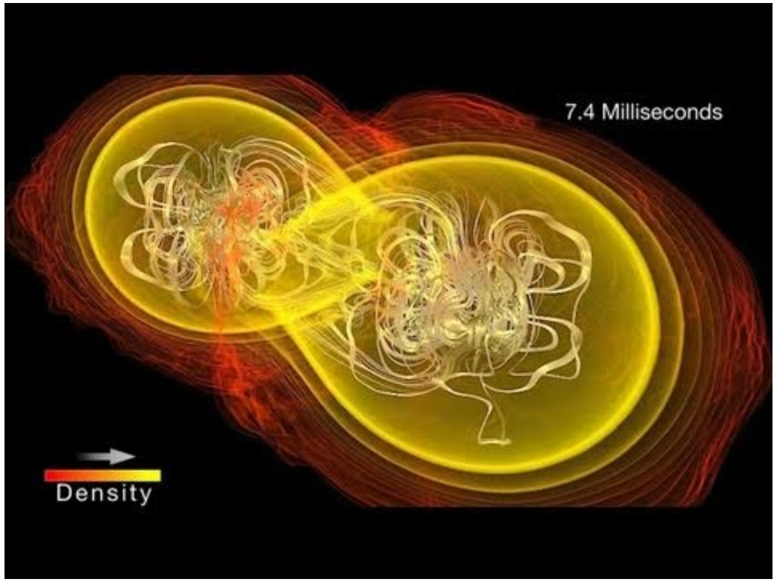
E. Berger et al.

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





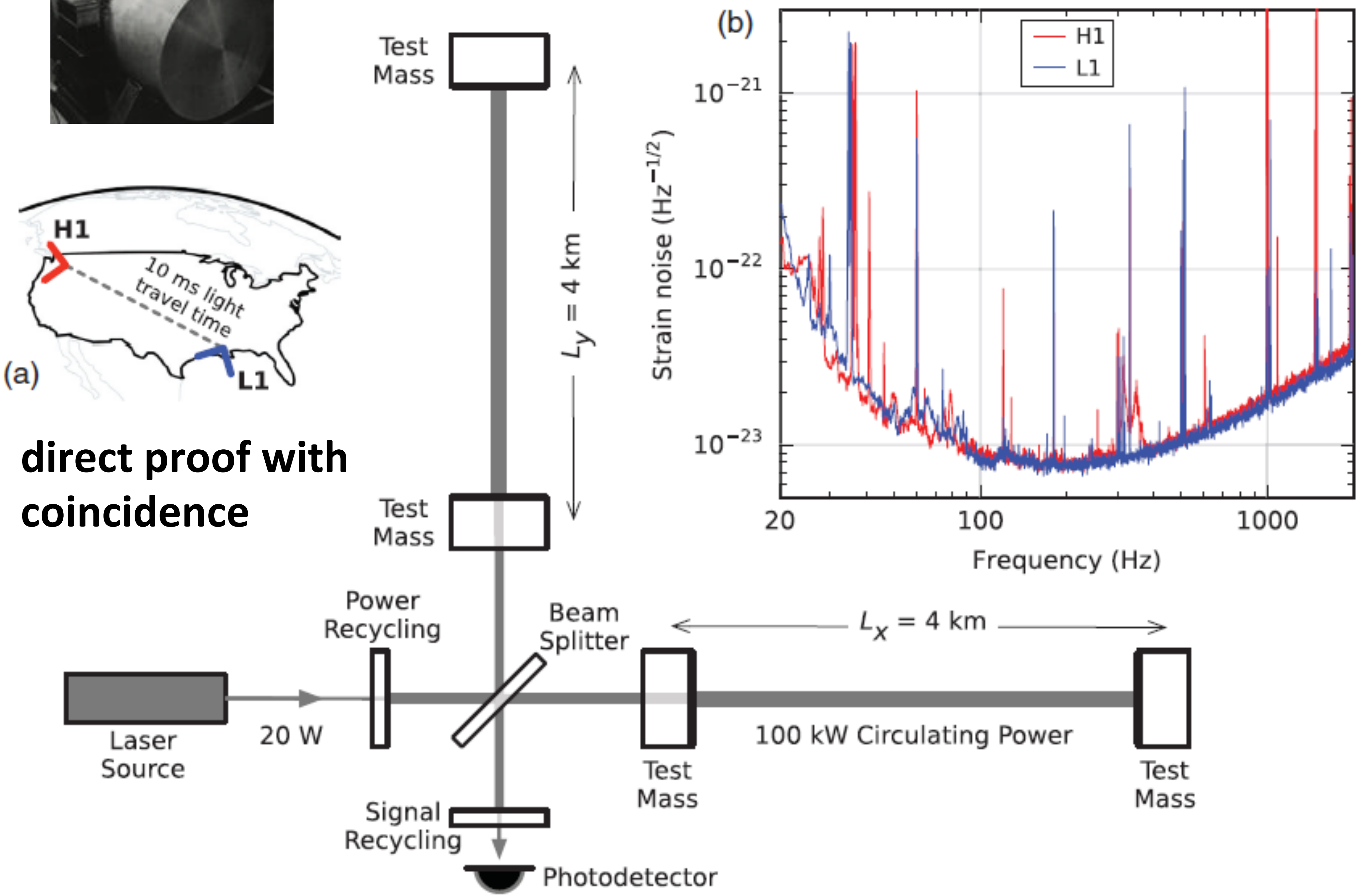
GRMHD not yet ready in the late 90th



Today:
Numerical GRMHD can predict quality templates

Joe Weber’s bar
1960 …. 1972 “Detection”

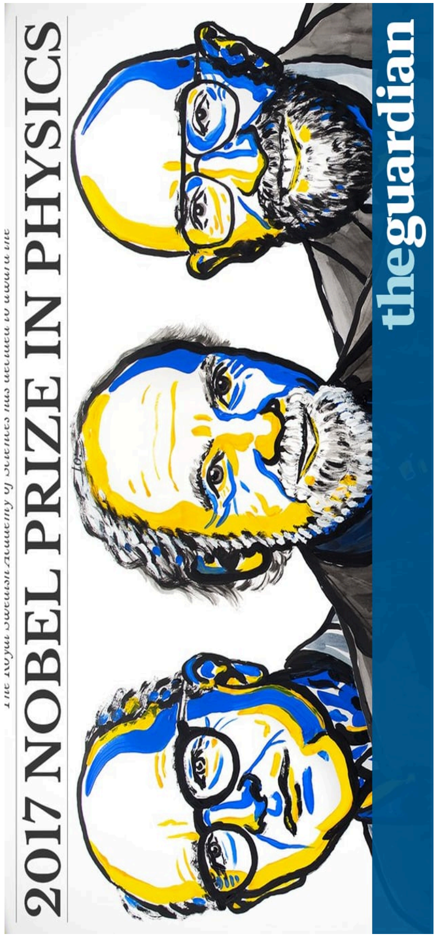
Detectors have come a long way



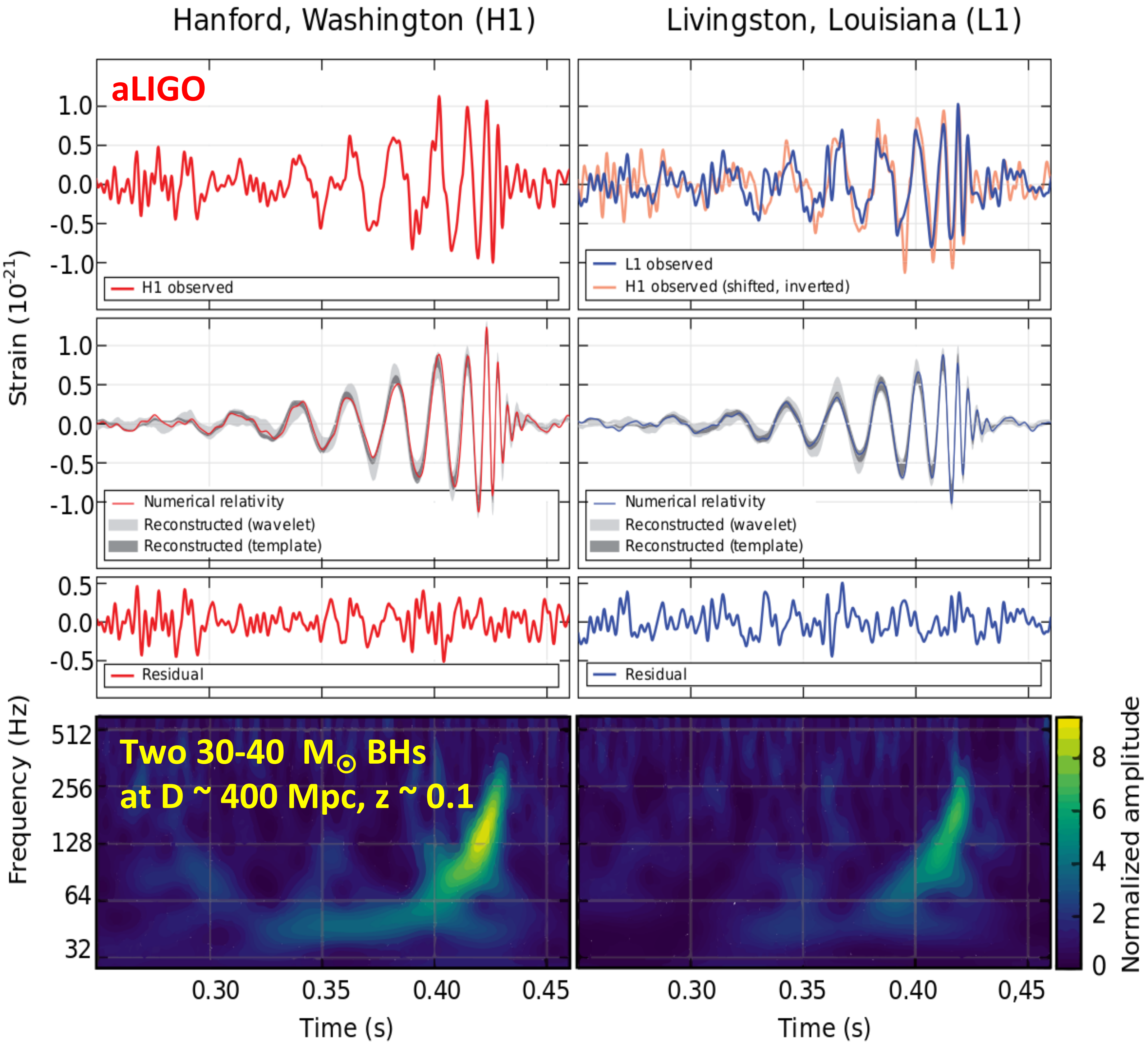
direct proof with coincidence

GW150914

2-11-2016 PR



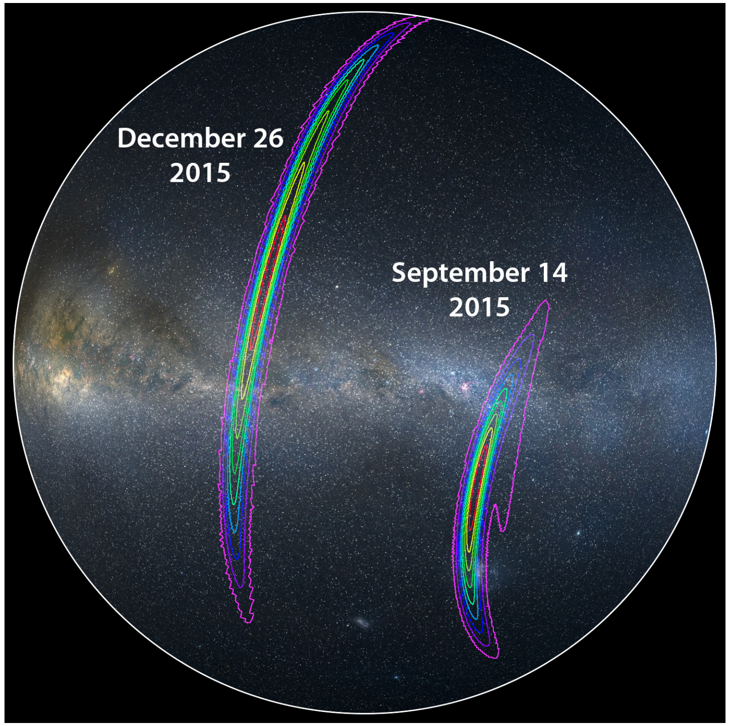
Rainer Weiss
Barry C Barish
Kip S. Thorne



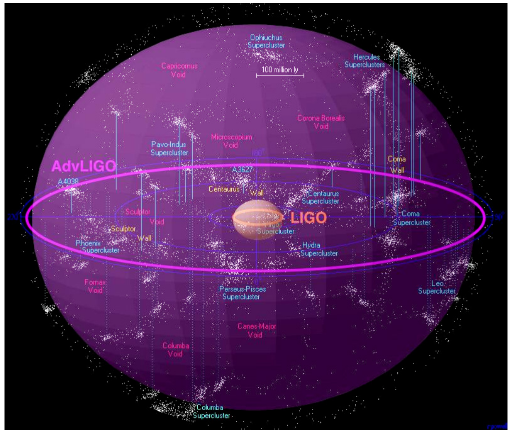
Two 30-40 $M_{\odot}$ BHs
at D ~ 400 Mpc, z ~ 0.1

Fermi/GBM blip

More BBH mergers followed …



But what about binary neutron stars



Horizon (S/N = 8)

aLIGO(Liv) (218 Mpc)

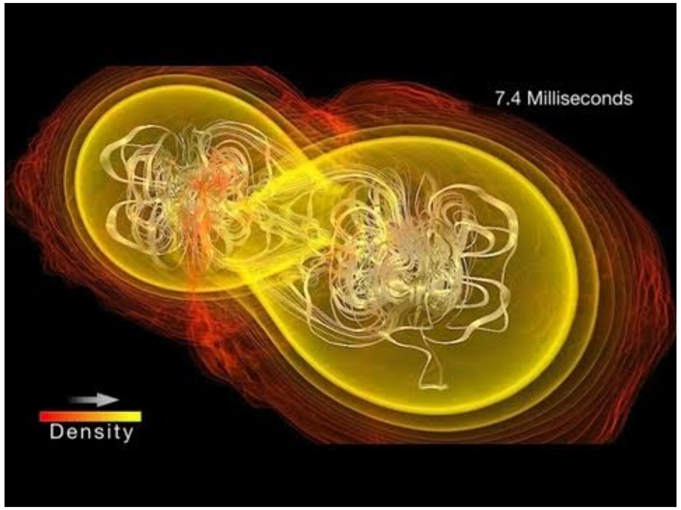
LIGO(Han) (107 Mc)

Virgo (58 Mpc)

Paradigm: BNS merger = Short GRB

Rates: 10^{-2} Mpc^{-3} 10^{-5} yr^{-1} (4π/3) (200 Mpc)^3 ~ few per year

Scaling from known sGRB rates or population synthesis



Paradigm Confirmed:

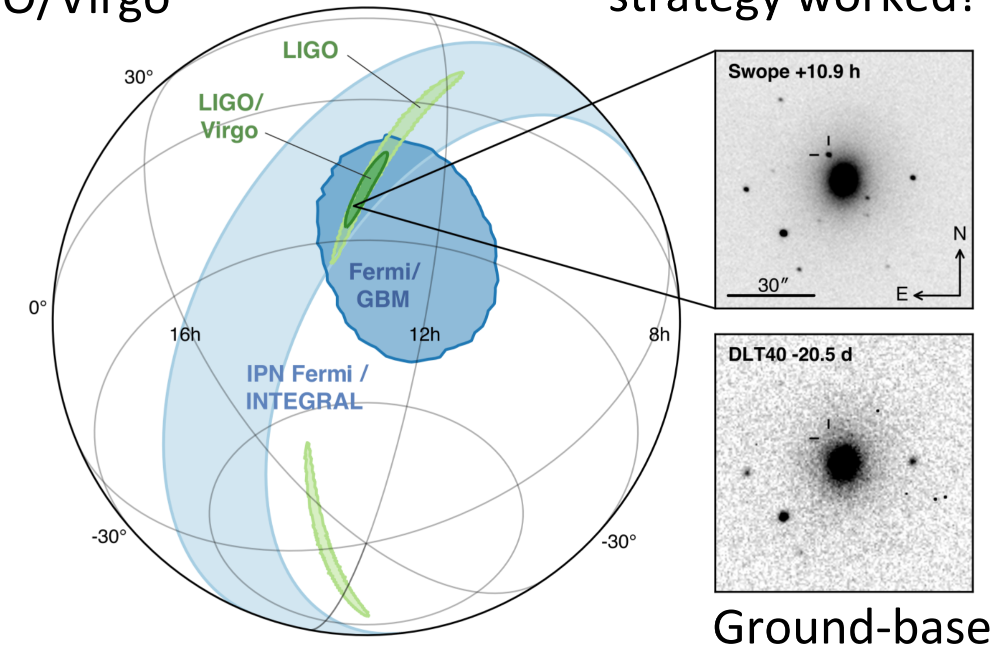
BNS merger – GW – sGRB

D ~ 40 Mpc

GW170817

LIGO/Virgo

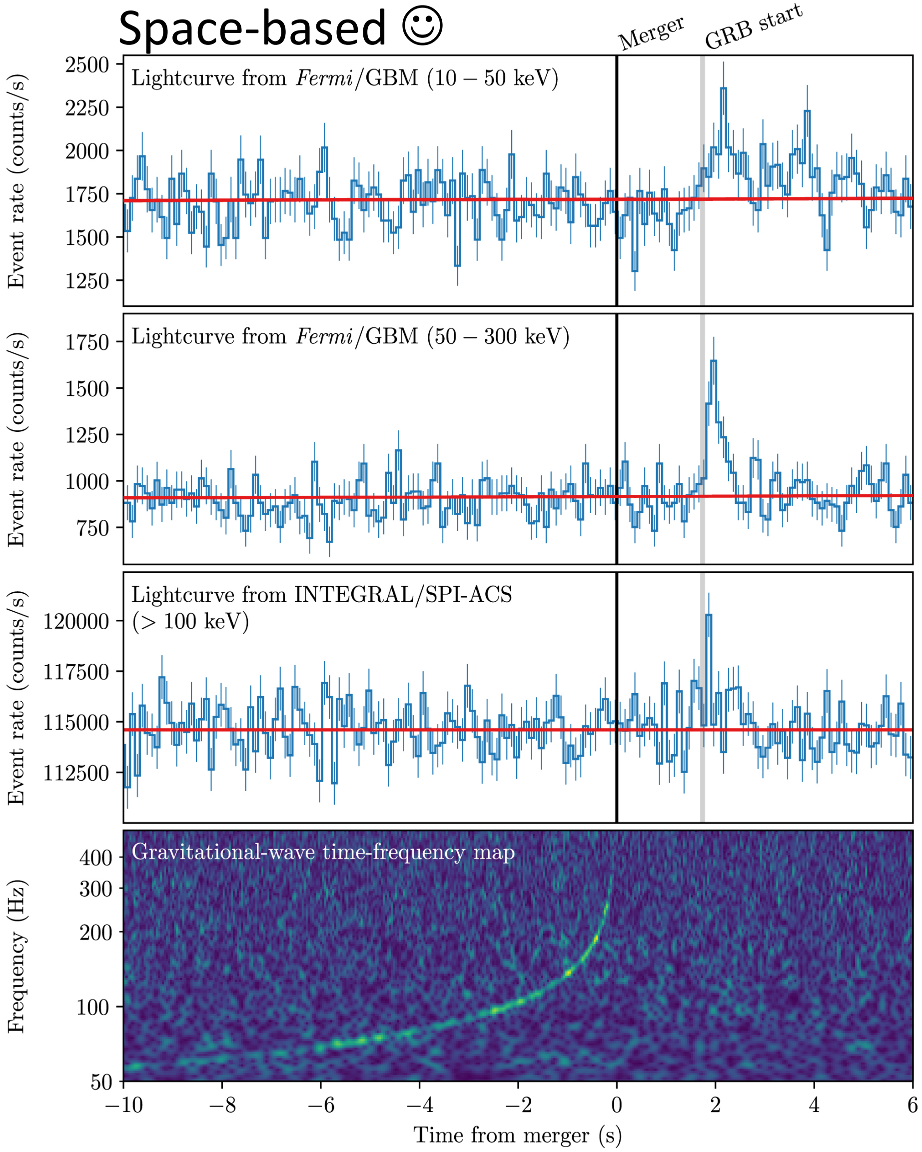
Neil's search strategy worked!



Ground-based With small telescopes ☺

Neutrinos no detection ☹

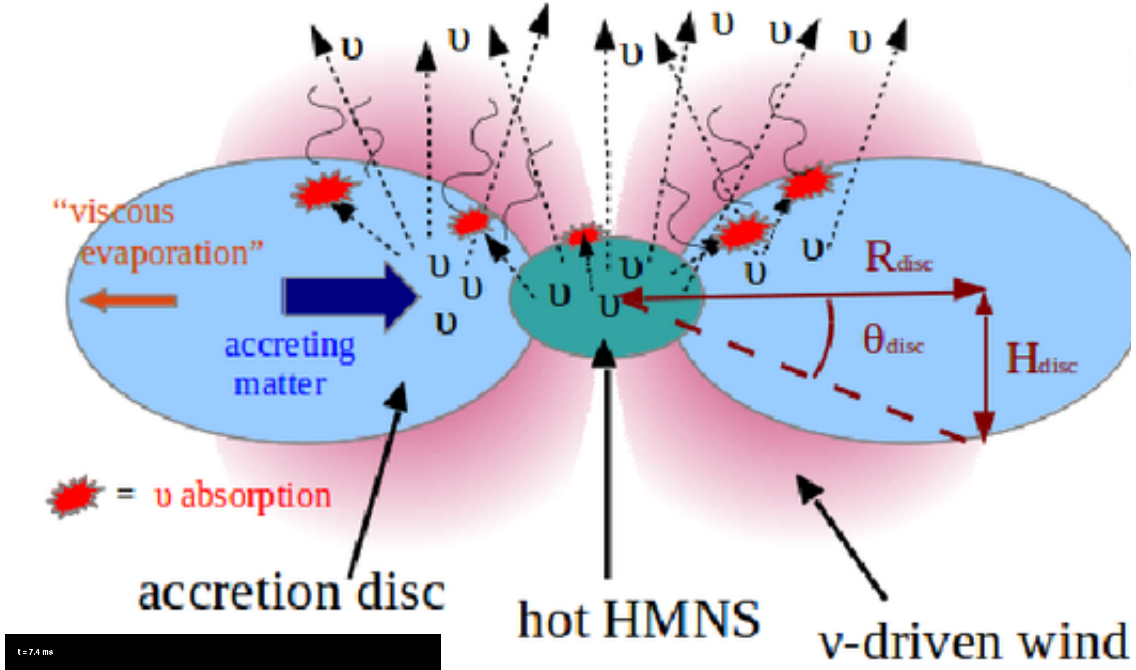
Space-based ☺

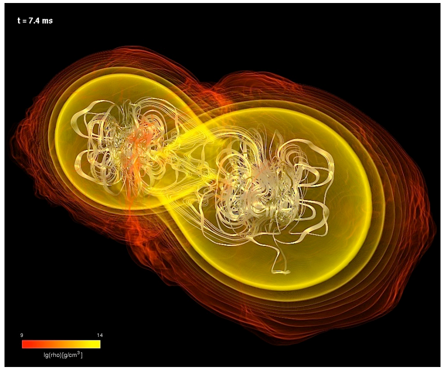


Abbott, B. P., et al. "Gravitational Waves and Gamma Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A." 2017, ApJL, 848, L13.

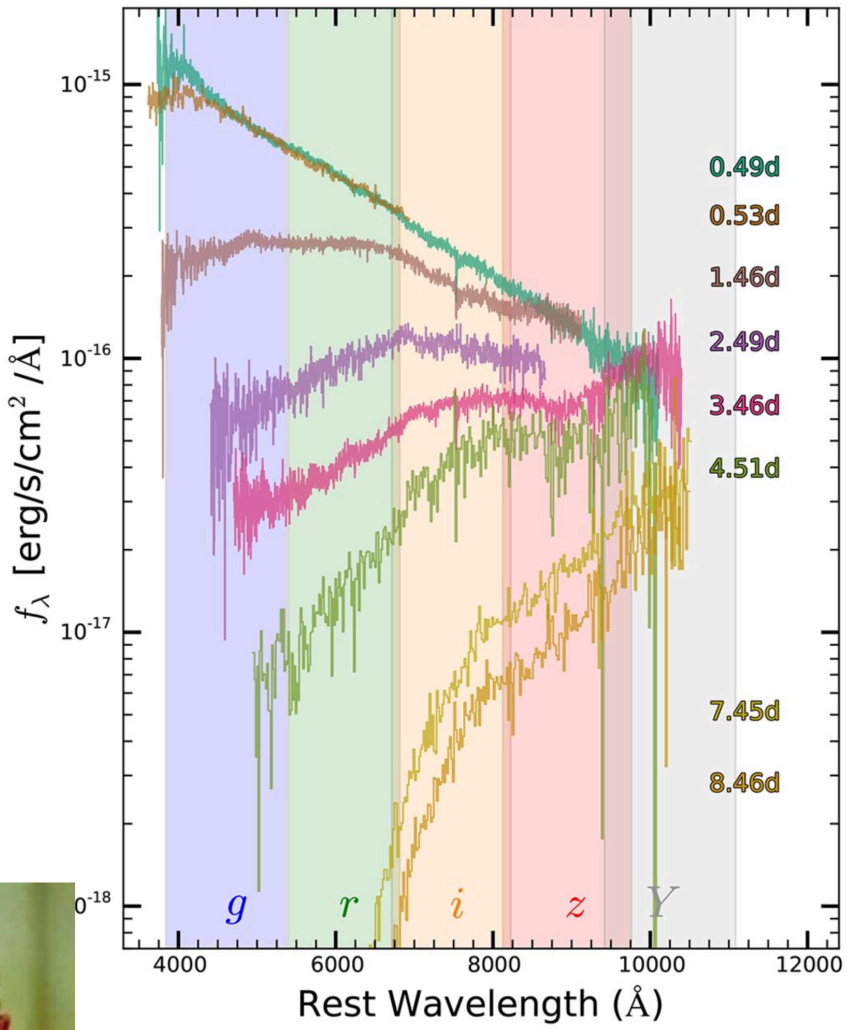
> 3,000 authors ☺

Kilonova (B. Metzger 2010)



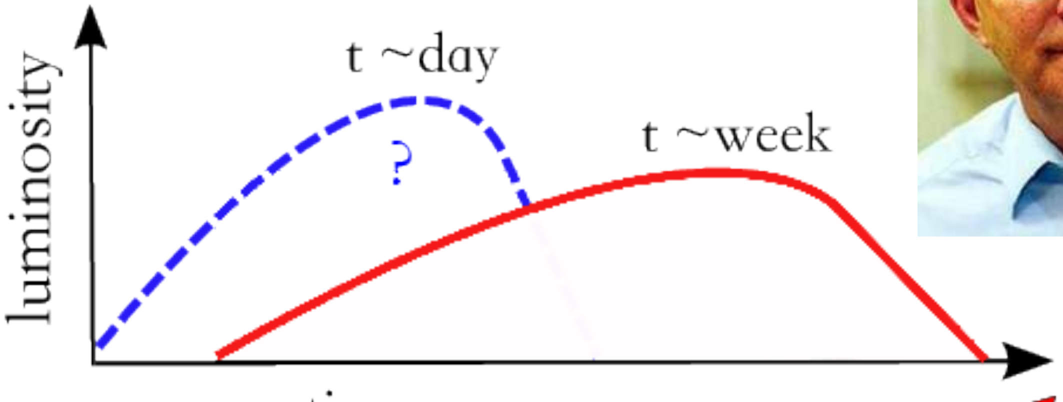


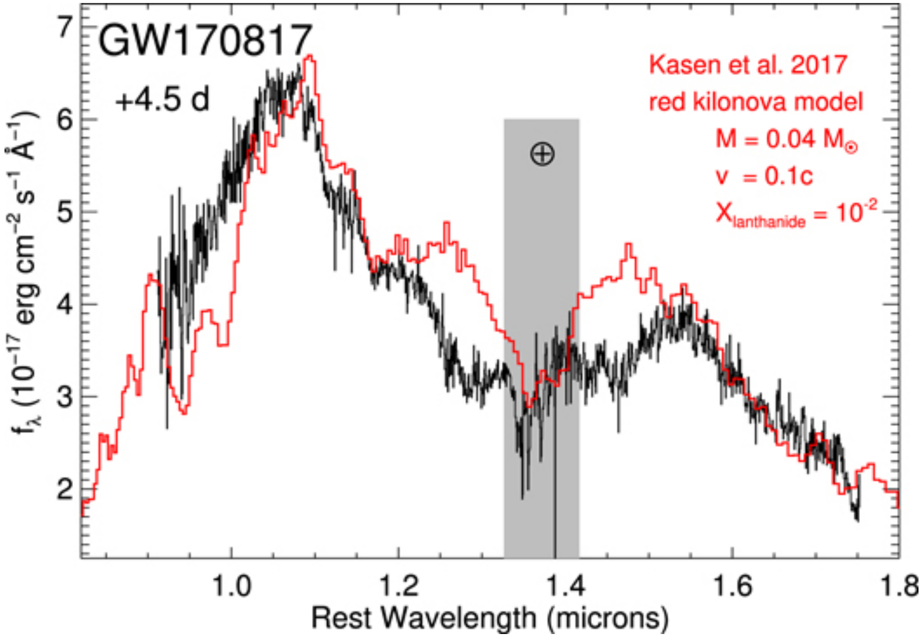
$$p^+ + \overline{\nu}_e \rightarrow e^+ + n^0$$

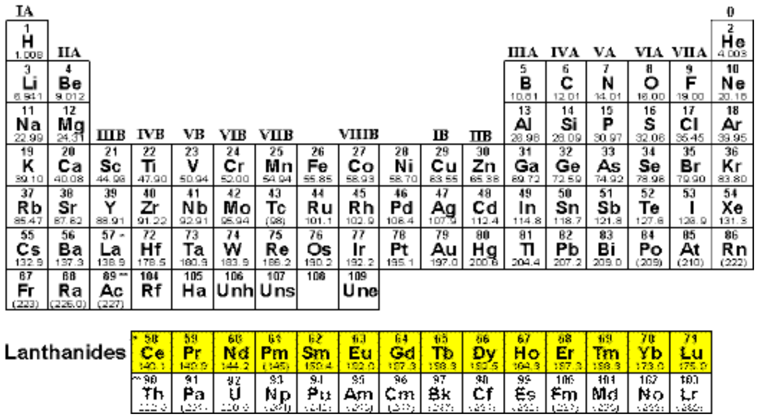


Shappee et al. 2017, Science

Original model by Li-Xin Li & Bohdan Paczynski 1998







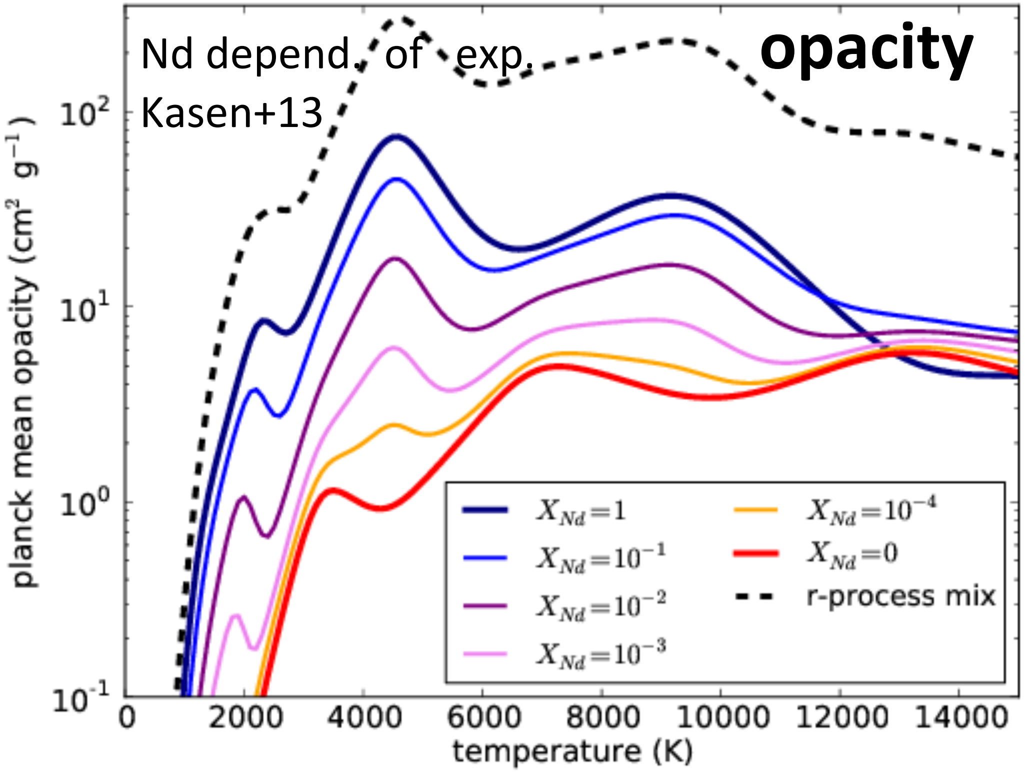
IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 * La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226.0)	89 ** Ac (227)	104 Rf	105 Ha	106 Unh	107 Uns	108	109 Une									

Lanthanides	* 58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
	** 90 Th [illegible]	91 Pa [illegible]	92 U [illegible]	93 Np [illegible]	94 Pu [illegible]	95 Am [illegible]	96 Cm [illegible]	97 Bk [illegible]	98 Cf [illegible]	99 Es [illegible]	100 Fm [illegible]	101 Md [illegible]	102 No [illegible]	103 Lr [illegible]

Lanthanides and Actinides

Large atomic complexity

–> Line opacity

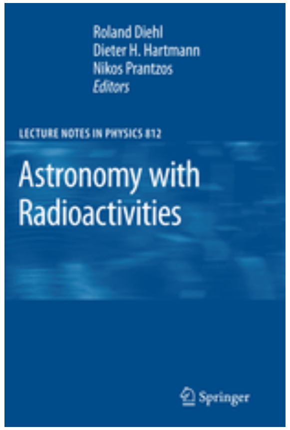


opacity

Nd depend. of exp.

Kasen+13

Y_e(Nd) = Z/A = 60/144 ~ 0.4

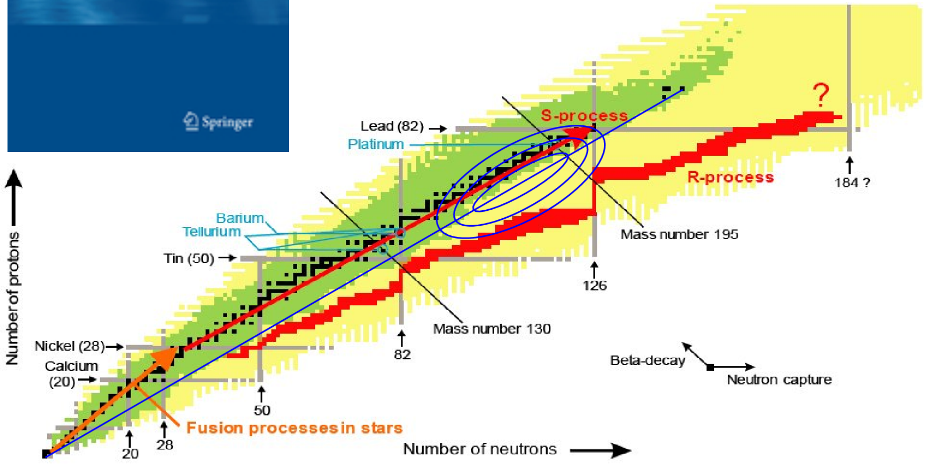


Roland Diehl
Dieter H. Hartmann
Nikos Prantzos
Editors

LECTURE NOTES IN PHYSICS 812

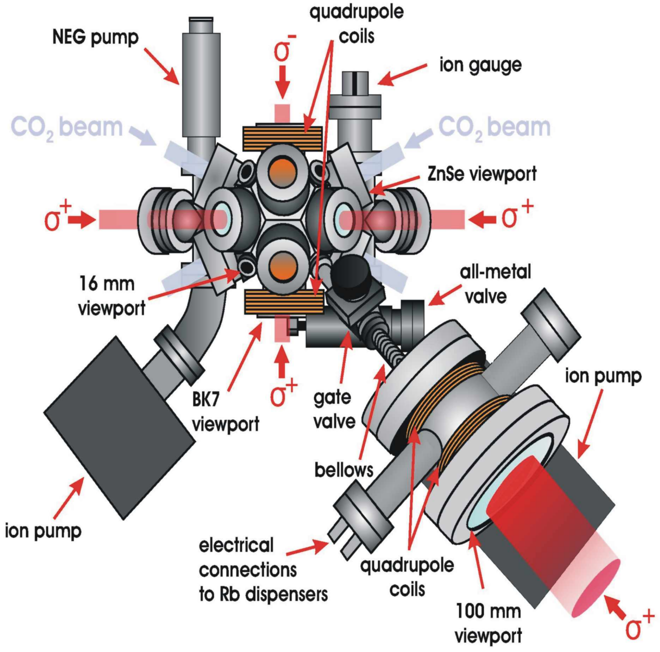
Astronomy with Radioactivities

Springer



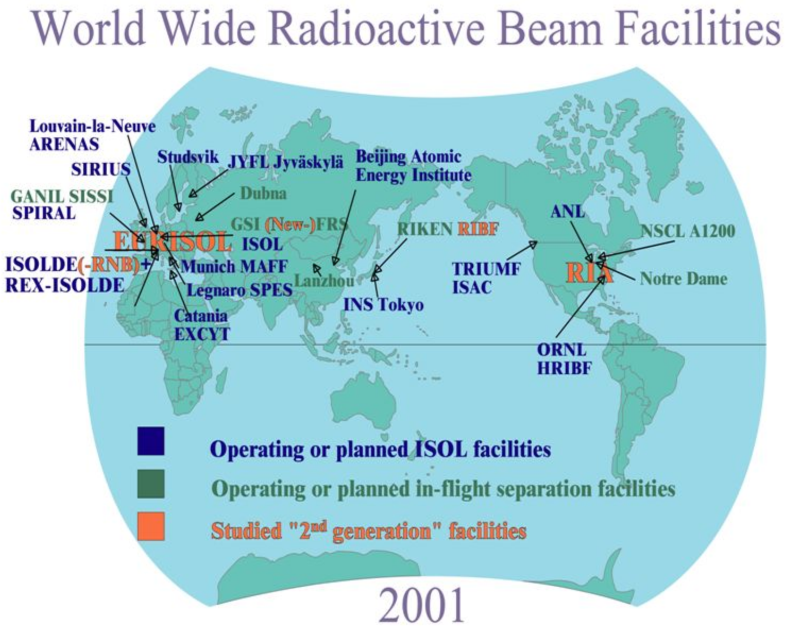
Nucleosynthesis studies need input from

Lab Astro: nuclear masses, lifetimes, etc.:

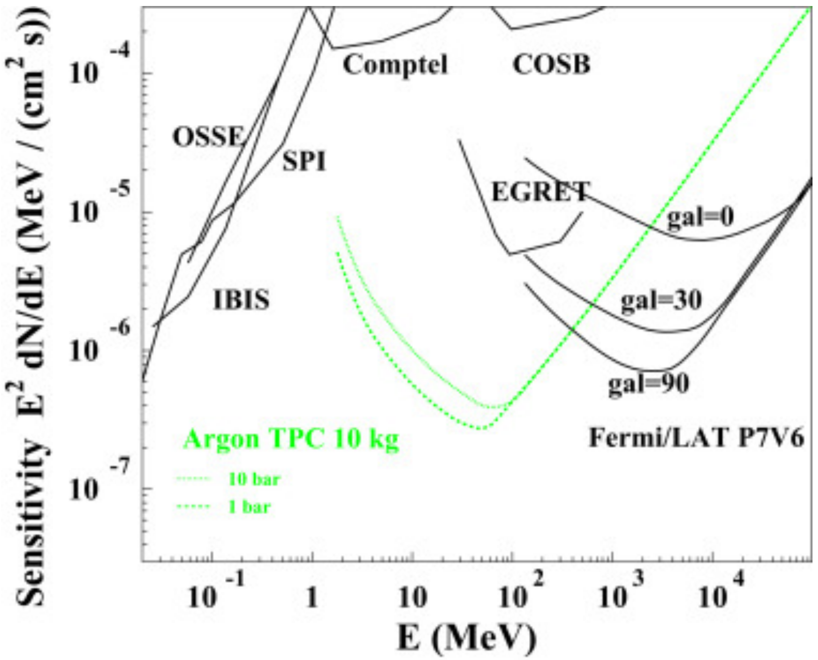


Full use of kN spectroscopy requires input from

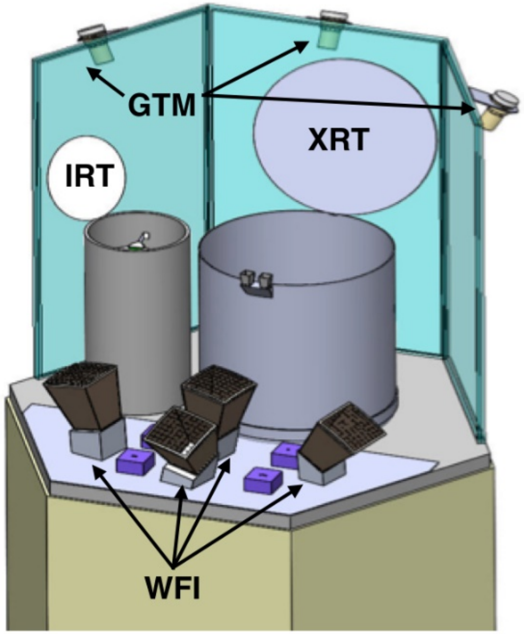
Lab Astro: EBITs etc



The MeV Gap

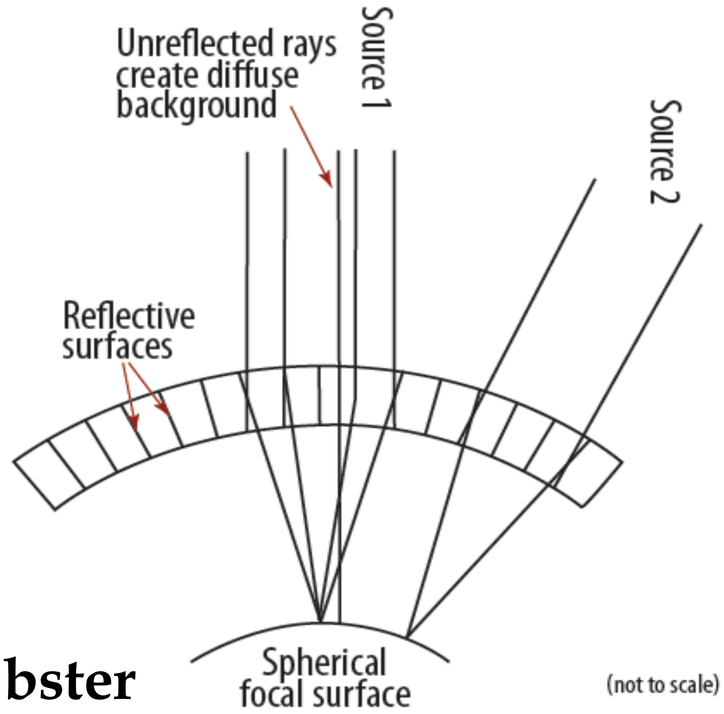


TAP Telescopes:
PI: Jordan Camp (GSFC)

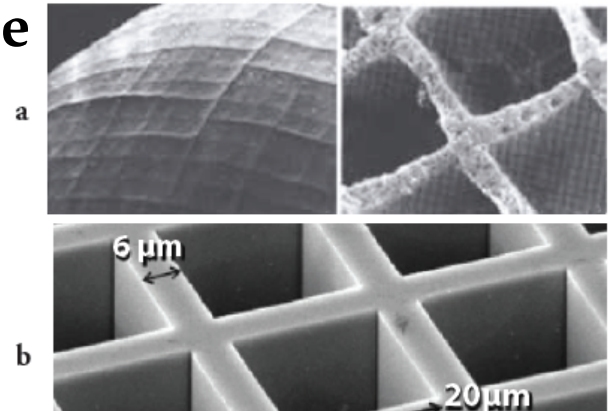


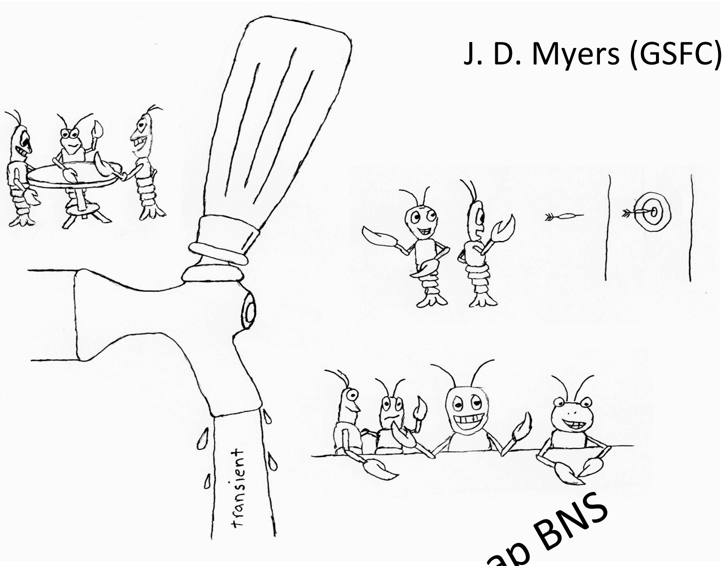
- WFI (Lobster) modules (4): 0.5-5keV
  - 2000 deg^2 (~0.5 sr) FoV, 1 arcmin loc.
  - 10^{-11} $erg/cm^2/sec$ in 2000 sec
- IR Telescope
  - 1 deg^2 FoV
  - 0.3 – 2.5 micron, D ~ 0.7 m, three bands, R ~30 spectroscopy
  - 23-24 Mag in 500 sec
- X-ray Telescope (single crystal silicon mirror): 0.5-5 keV
  - 1 deg^2 FoV
  - 3 x 10^{-15} $erg/cm^2/sec$ in 2000 sec
- **Gamma-ray Transient Monitor (8)**
  - **10 - 1000 keV, 4pi FoV**

WFI: Lobster Eye Geometry
microchannel optics

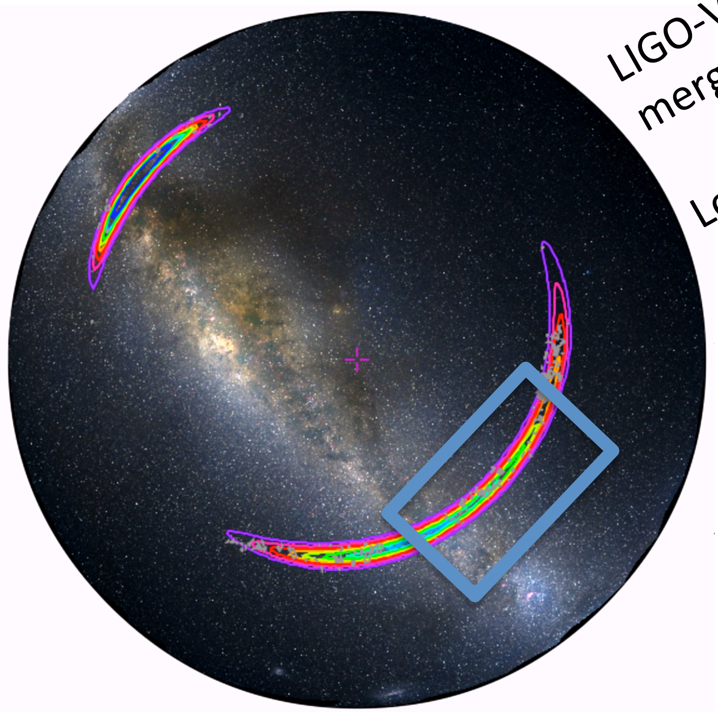


Lobster Eye



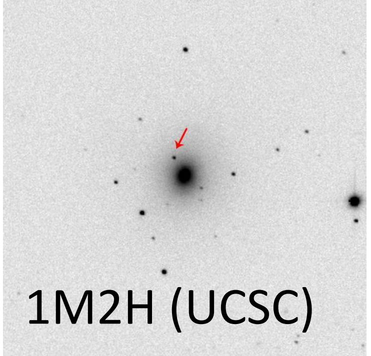


J. D. Myers (GSFC)



LIGO-Virgo sky map BNS merger (100 □²)

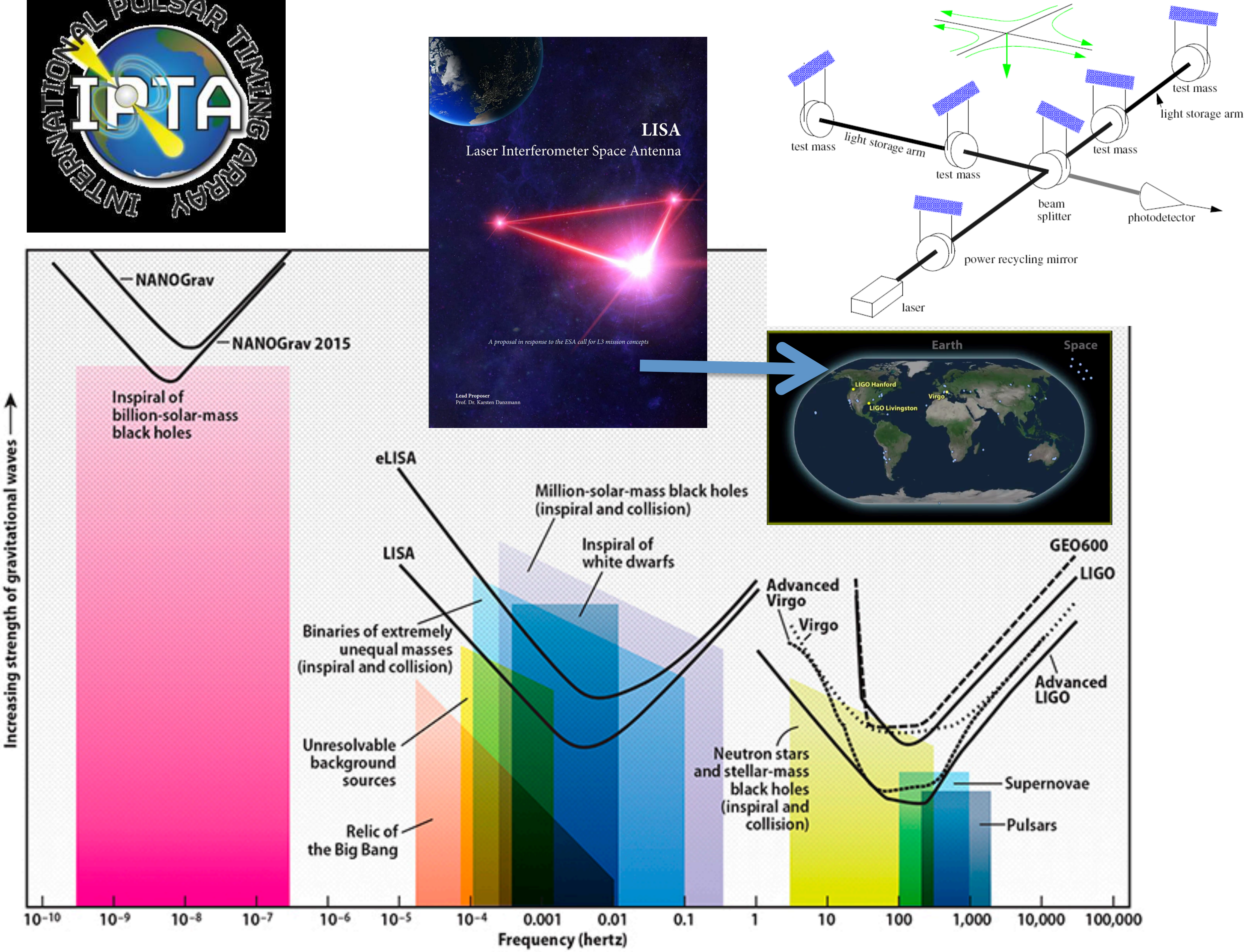
Lobster FoV: Galaxy Catalog Follow-up



1M2H (UCSC)

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

INTERNATIONAL PULSAR TIMING ARRAY
IPTA

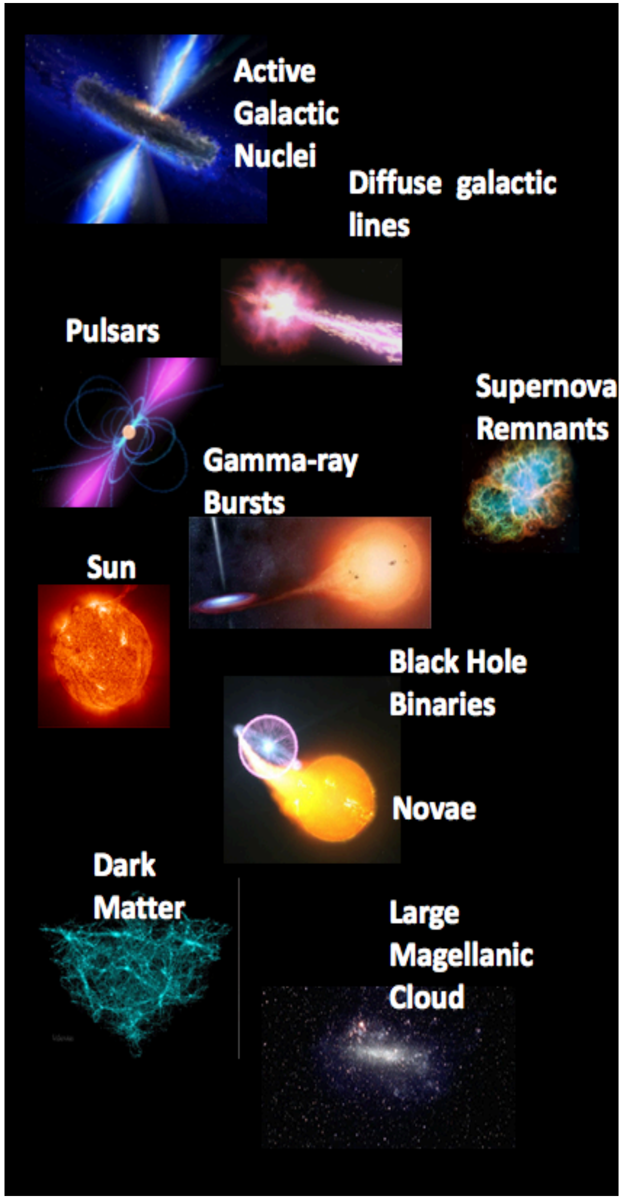


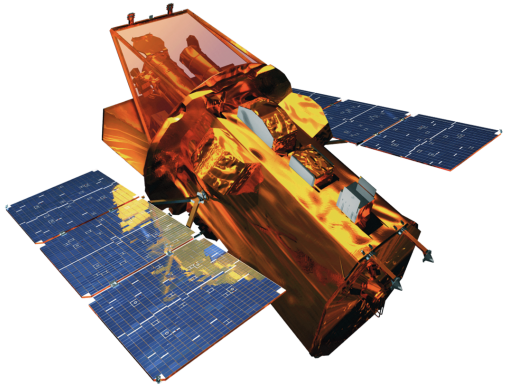
LISA
Laser Interferometer Space Antenna

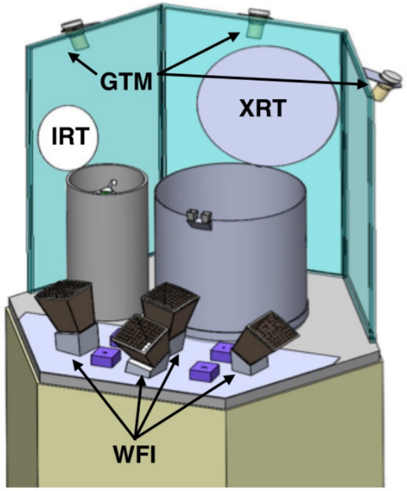
A proposal in response to the ESA call for L3 mission concepts

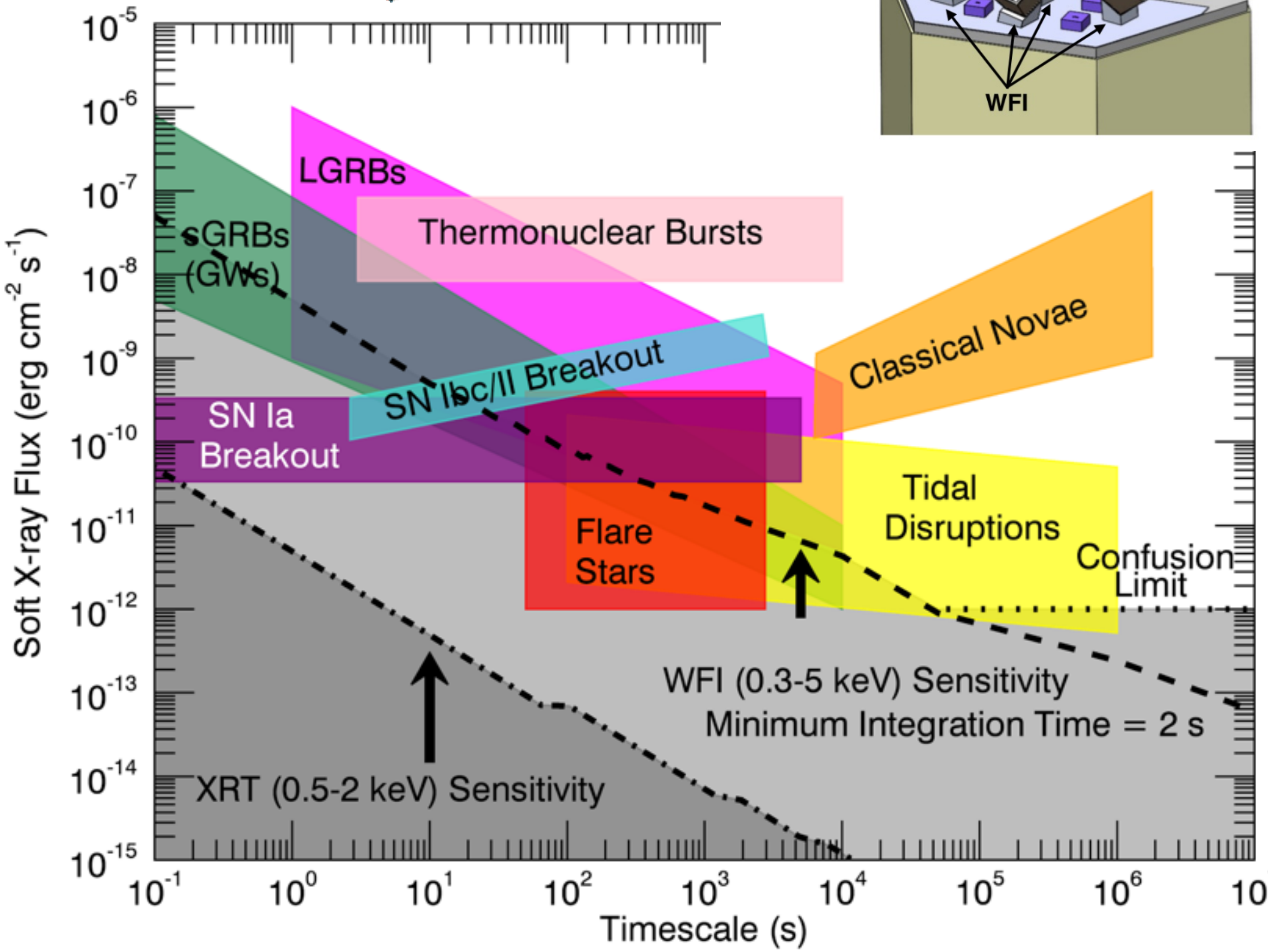
Lead Proposer
Prof. Dr. Karsten Danzmann

Time Domain
Discovery Space





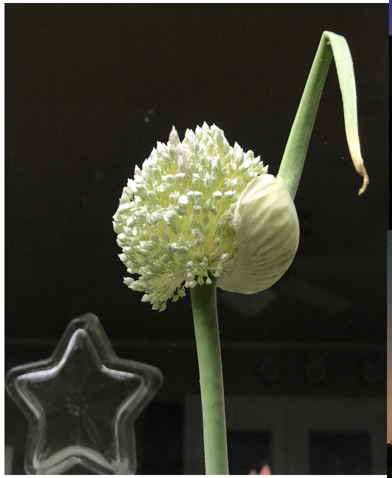


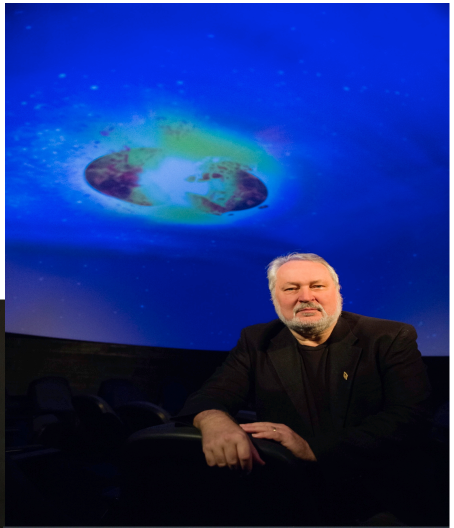


In preparation for Senior Reviews, Neil gathered a large group of TDA enthusiasts, to discuss the status of the field and to aim in the forward direction with Swift in the context of ground- and space-based missions: We will miss him dearly when we gather again later this year.

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