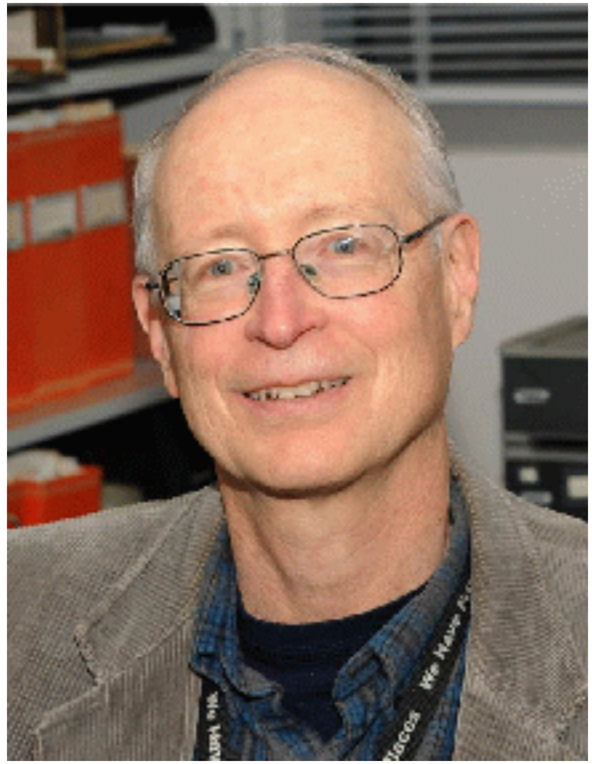
Remembering Three Projects I worked on with Neil

J. K. Cannizzo (UMBC & NASA/GSFC)

Gehrels Memorial Meeting, May 21-22, 2018

Many projects spanning ~2001 to present.
Some of the main ones:

--Ozone Depletion from Supernovae
--Integration & testing for BAT, XRT, & UVOT
--GRB Correlations
--3D Relativistic Hydrodynamics GRB calculation
--Strategy for LIGO-VIRGO Counterpart Searches
--Accretion Disk Fallback model for GRB emission
seen by XRT
--popular book on black holes



Charles Jackman (Code 900, Bldg. 33):
NASA/GSFC 2D photochemical transport code:
18 latitude bands, 58 log-spaced pressure levels
(~2 km in altitude)

Ozone

OZONE DEPLETION FROM NEARBY SUPERNOVAE

NEIL GEHRELS
NASA Goddard Space Flight Center, Laboratory for High Energy Astrophysics, Code 661, Greenbelt, MD 20771; gehrels@lheapop.gsfc.nasa.gov

CLAUDE M. LAIRD[1]
Department of Physics and Astronomy, University of Kansas, Lawrence, KS 66045; claird@ku.edu

CHARLES H. JACKMAN
NASA Goddard Space Flight Center, Laboratory for Atmospheres, Code 916, Greenbelt, MD 20771; charles.h.jackman@assess.gsfc.nasa.gov

JOHN K. CANNIZZO[2] AND BARBARA J. MATTSON[3]
NASA Goddard Space Flight Center, Laboratory for High Energy Astrophysics, Code 661, Greenbelt, MD 20771; cannizzo@stars.gsfc.nasa.gov, mattson@milkyway.gsfc.nasa.gov

AND

WAN CHEN
Sprint, IP Design, 12502 Sunrise Valley Drive, Reston, VA 20196; wan.w.chen@mail.sprint.com
Received 2002 May 31; accepted 2002 November 14

Ozone

ApJ, 585: 1169
2003 March 10

2.2. *Inclusion of SN-produced Gamma and Cosmic Rays*

The observed gamma-ray spectrum for SN 1987A is

$$\frac{dN}{dE} = 1.7 \times 10^{-3} \left(\frac{E}{1 \text{ MeV}} \right)^{-1.2} \text{cm}^{-2} \text{ s}^{-1} \text{ MeV}^{-1} \quad (1)$$

(Gehrels, Leventhal, & MacCallum 1988) between 0.02 and 2 MeV, lasting 500 days at 55 kpc, for a total energy 9.0×10^{46} ergs. For ease of modeling we set the incident monoenergetic gamma-ray photon flux N_i^0 by binning this differential flux into 66 evenly spaced logarithmic intervals from 0.001 to 10 MeV, for a net energy input of 3.3×10^{47} ergs. For a given distance $D_{\rm SN}$ we scale the empirically observed SN 1987A spectrum by $(5.5 \times 10^4 / D_{\rm SN})^2$, with $D_{\rm SN}$ in parsecs. In addition, in

Ozone

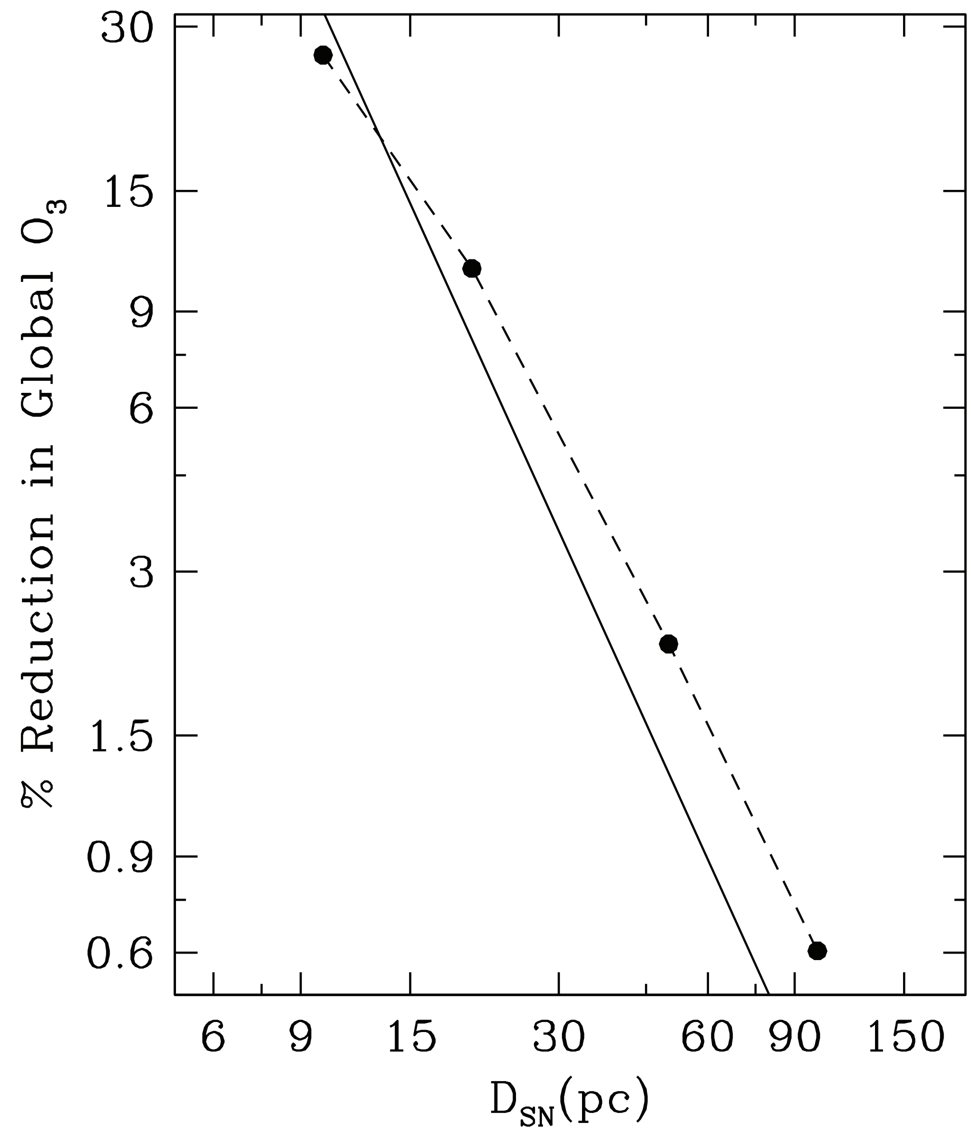
Odd nitrogen, NO_y, is primarily created through natural processes. The major source of NO_y is the oxidation of biologically produced N_2O in the stratosphere (e.g., Vitt & Jackman 1996). The NO_y constituents can destroy ozone through the catalytic reaction cycle

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (6)$$

$$NO_2 + O \rightarrow NO + O_2 \quad (7)$$

$$\text{net}: \quad O_3 + O \rightarrow O_2 + O_2\ . \quad (8)$$

Ozone



Ozone

FIG. 3.—Annual average reduction in global ozone from gamma irradiation from an SN as a function of D_{SN}, assuming $i_{SN} = 0°$ (average over year 2). The solid line indicates a dependency of D_{SN}^{-2}.

Our primary finding is that a core-collapse SN would need to be situated approximately 8 pc away to produce a combined ozone depletion from both gamma rays and cosmic rays of ∼47%, which would roughly double the globally averaged, biologically active UV reaching the ground. The rate of core-collapse SNe occurring within 8 pc is ∼1.5 Gyr^{-1}. As noted earlier, our calculated ozone depletion is significantly less than that found by Ruderman (1974) and consistent with Whitten et al. (1976). Given the ∼0.5 Gyr timescale for multicellular life on Earth, this extinction mechanism appears to be less important than previously thought.

It is a pleasure to acknowledge stimulating conversations with Tom Armstrong, Frank Asaro, Narciso Benítez, Adam Burrows, Enrico Cappellaro, Aimee Hungerford, Sasha Madronich, Frank McDonald, Joan Rosenfield, John Scalo, David Smith, Floyd Stecker, Sidney van den Bergh, Francis Vitt, William Webber, Craig Wheeler, and Stan Woosley.

Ozone

Brian Fields (U. Illinois):
Goddard Tuesday Astrophysics Colloquium
May 23, 2017
When Stars Attack! Confirmation, Identification, and Location of a Recent Near-Earth Supernova

"Neil still owns the kill radius" - referring to 8pc

Ozone

Date: Wed, 11 Mar 2015
From: Neil Gehrels
Subject: help with paper

Hi John,

Would you be able to help me tex up a skeleton of an ApJ paper by this weekend? It is a paper I would like you to join on the galaxy strategy for searching counterparts of a gravitational wave event. …

Attached is an outline and some comments. … Could you gin something up on Thursday and Friday?

Neil

Galaxies

Comment from Jonah 2-23-15

To pounce on one particular detail: while I think the plot we published a few years ago is basically right, I've always worried that the scaling law for "number of galaxies" may be problematic for the large number of faint galaxies that are presumably hard to find. Maybe this effect is important, and maybe its not – but it would be an interesting idea to explore. Mansi's insight would be very helpful. My guess is that we could convolve detection efficiency with a Scheter luminosity curve and get more realistic numbers.

Comments from Mansi 3-2-15

- I agree that cherry-picking galaxies in the error circle may be the only option for searches at many non-optical wavelengths. So we should quantify where the sweet spot in reasonable returns here is.
-In addition to light, we should consider stellar mass and specific star formation rate. The NS-NS rate likely depends on a combination of the three parameters. Dwarfs may have high sSFR.
-Completeness of galaxy catalogs is much better for the brightest and most massive galaxies, so this should simplify the follow-up immensely.
-It would be good to involve Samaya. From our simulation work, localization "volumes" (instead of areas) were most interesting for the nearest detections but needed three detectors.
-We should factor in galaxy clustering in the local universe as well. Local galaxies are not uniformly distributed on the sky.
-We should make big circles around each galaxy (~100 kpc) so as to include kicked systems when computing tiling.

Comments from Samaya 3-9-15

Regarding the paper, I would be very happy to join the paper, especially in contributing to the aspect of GW volumes. I also think that it would be interesting to correct (statistically) for the incompleteness in galaxy catalog in both B-band luminosity and HI & am happy to develop some zero-th order algorithms to do so.

Galaxies

THE ASTROPHYSICAL JOURNAL, 820:136 (9pp), 2016 April 1 doi:10.3847/0004-637X/820/2/136

GALAXY STRATEGY FOR LIGO-VIRGO GRAVITATIONAL WAVE COUNTERPART SEARCHES

NEIL GEHRELS[1], JOHN K. CANNIZZO[2,3], JONAH KANNER[4], MANSI M. KASLIWAL[5], SAMAYA NISSANKE[6], AND LEO P. SINGER[1,7]
[1] NASA Goddard Space Flight Center, Mail Code 661, Greenbelt, MD 20771, USA
[2] CRESST and Astroparticle Physics Laboratory, NASA/GSFC, Greenbelt, MD 20771, USA
[3] Department of Physics, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250, USA
[4] LIGO, California Institute of Technology, Pasadena, CA 91125, USA
[5] Observatories of the Carnegie Institution for Science, 813 Santa Barbara Street, Pasadena, CA 91101, USA
[6] Institute of Mathematics, Astrophysics and Particle Physics, Radboud University, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands
Received 2015 August 14; accepted 2016 February 5; published 2016 March 30

ABSTRACT

In this work we continue a line of inquiry begun in Kanner et al. which detailed a strategy for utilizing telescopes with narrow fields of view, such as the *Swift* X-ray Telescope (XRT), to localize gravitational wave (GW) triggers from LIGO/Virgo. If one considers the brightest galaxies that produce ~50% of the light, then the number of galaxies inside typical GW error boxes will be several tens. We have found that this result applies both in the early years of Advanced LIGO when the range was small and the error boxes were large, and will apply in the later years when the error boxes will be small and the range will be large. This strategy has the beneficial property of reducing the number of telescope pointings by a factor of 10–100 compared with tiling the entire error box. Additional galaxy count reduction will come from a GW rapid distance estimate which will restrict the radial slice in search volume. Combining the bright galaxy strategy with a convolution based on anticipated GW localizations, we find that the searches can be restricted to about 18 ± 5 galaxies for 2015, about 23 ± 4 for 2017, and about 11 ± 2 for 2020. This assumes a distance localization at the putative neutron star–neutron star merger range μ for each target year, and these totals are integrated out to the range. Integrating out to the horizon would roughly double the totals. For localizations with $r \ll \mu$ the totals would decrease. The galaxy strategy we present in this work will enable numerous sensitive optical and XRTs with small fields of view to participate meaningfully in searches wherein the prospects for rapidly fading afterglow place a premium on a fast response time.

Key words: galaxies: statistics – gamma-ray burst: general – gravitational waves – X-rays: general

Galaxies

Berger (2014)
ARAA

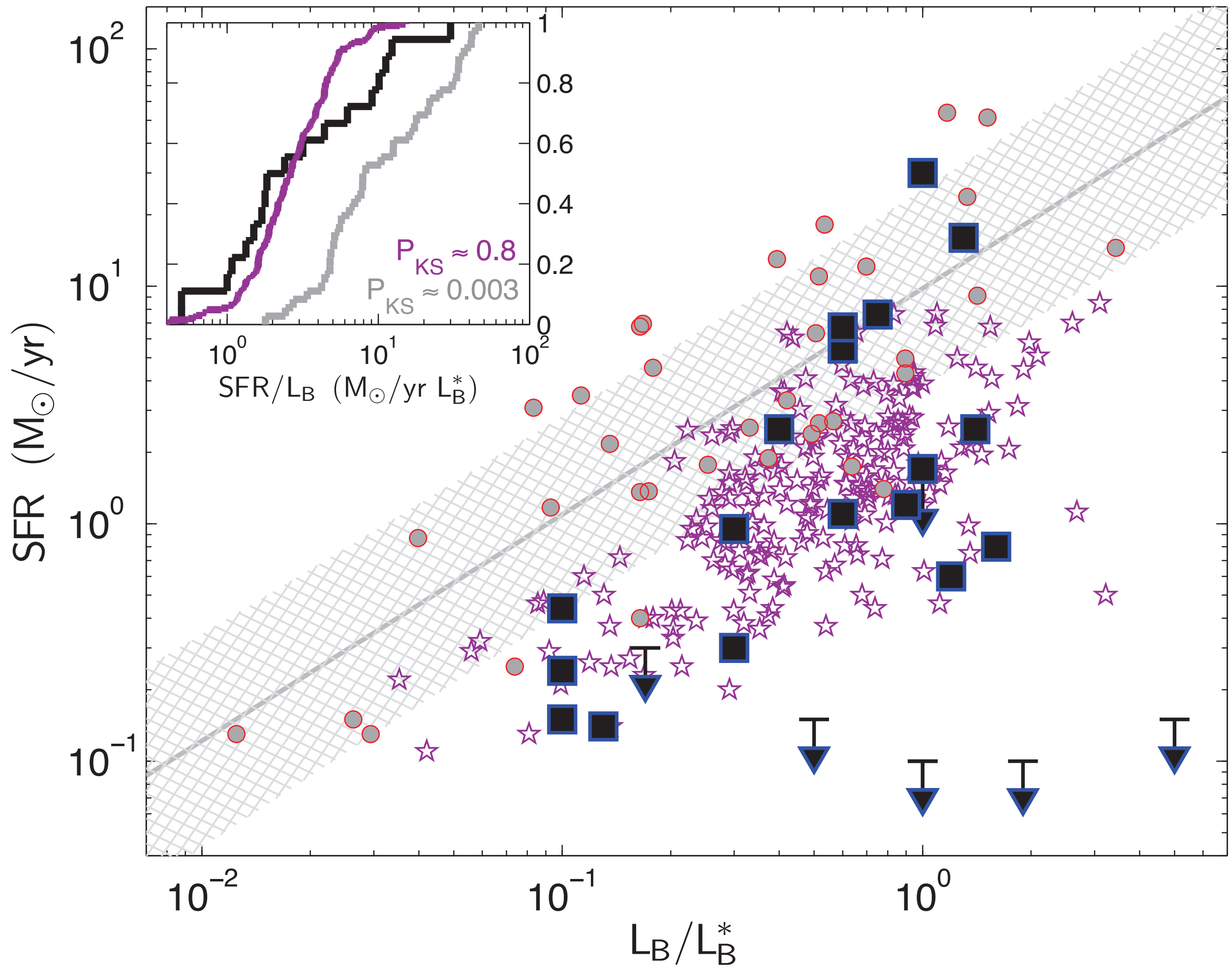


Figure 8:

Star formation rate as a function of rest-frame *B*-band luminosity for the host galaxies of short GRBs (squares), long GRBs (circles), and field star-forming galaxies at similar redshifts to short GRB hosts (pentagrams; Kobulnicky & Kewley 2004). The gray line and hatched region delineate the correlation (and standard deviation) for long GRB host galaxies. Short GRB host galaxies have substantially lower star formation rates as a function of luminosity than long GRBs hosts (i.e., they have lower specific star formation rates), but they closely track the field galaxy population (inset).

Galaxies

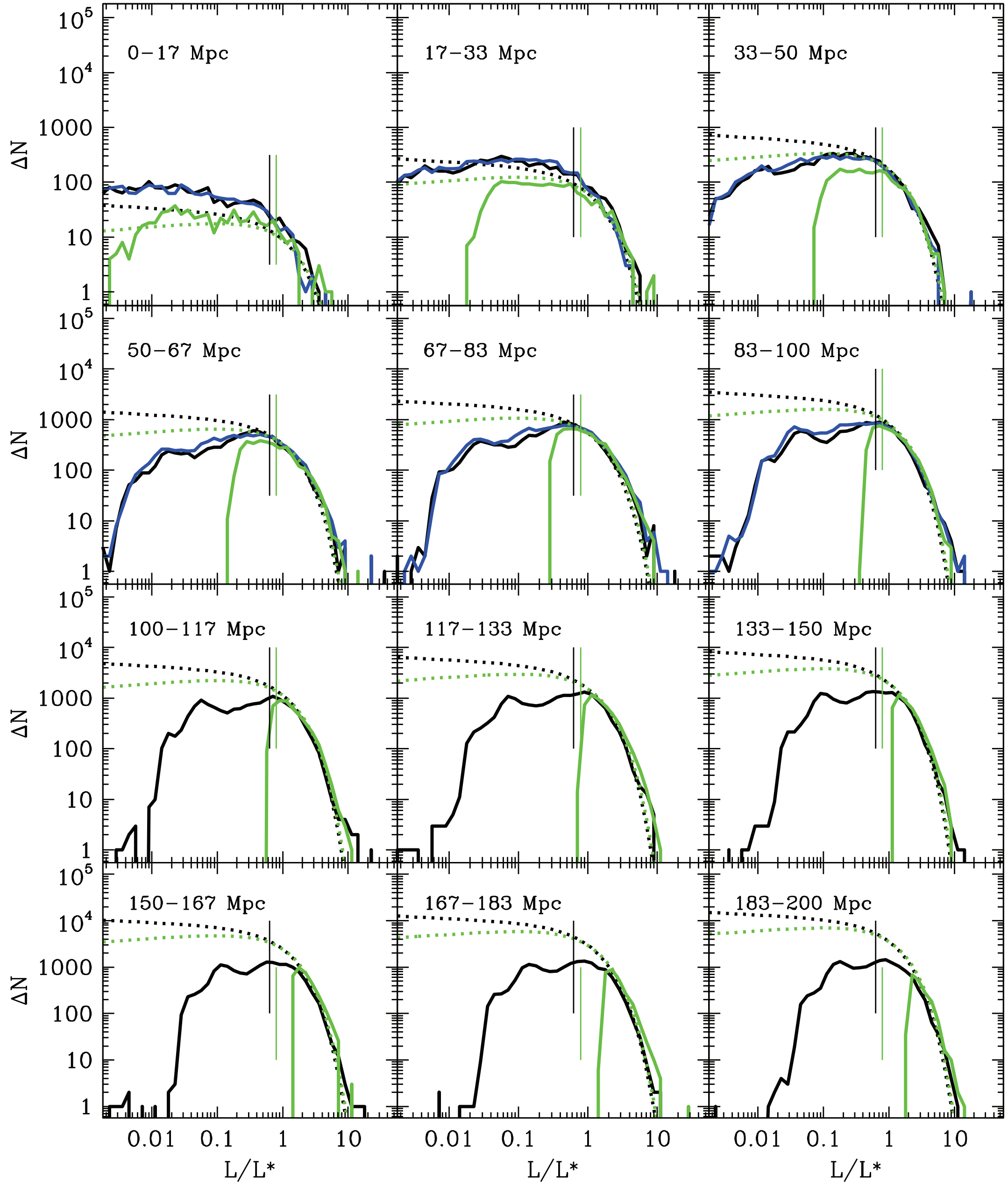


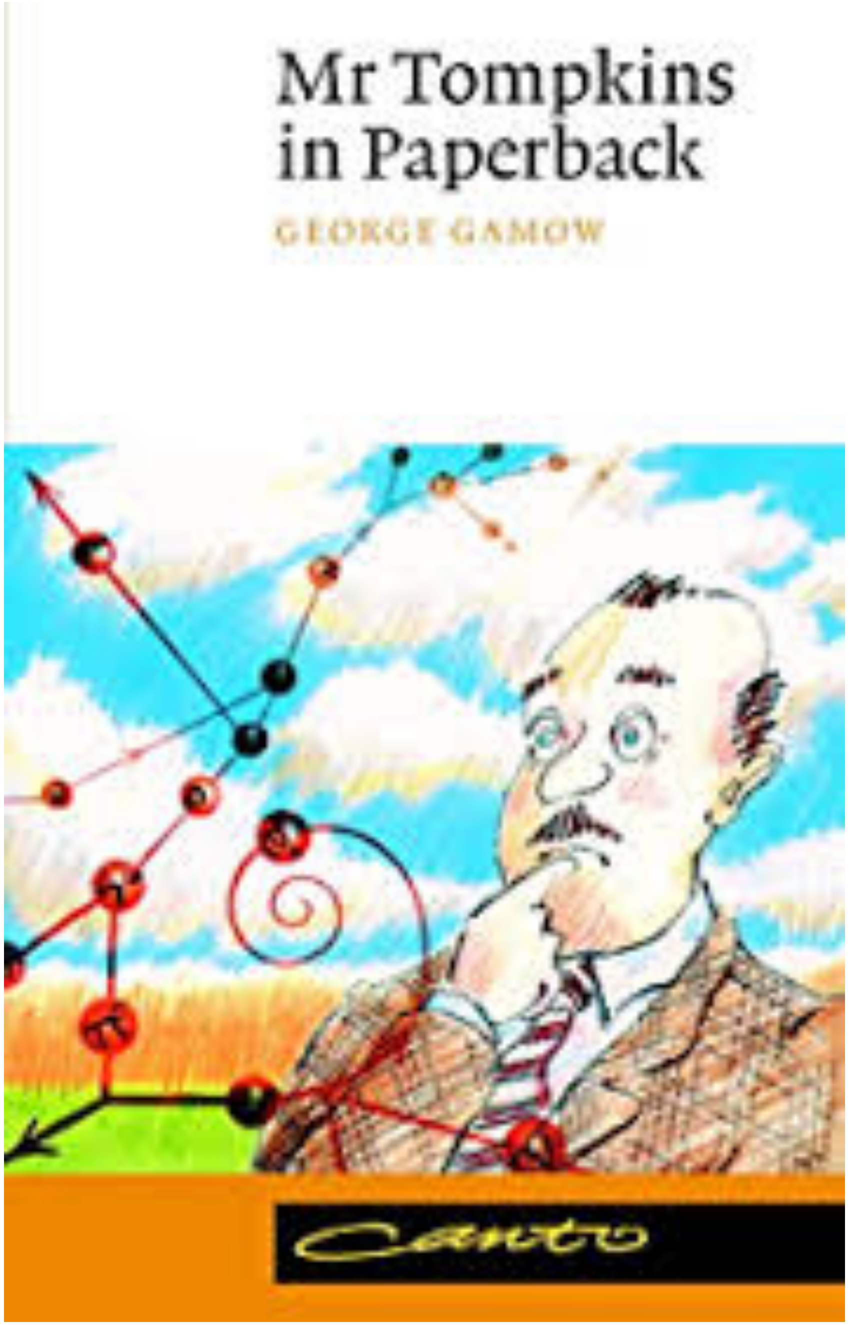
Figure 2. A comparison of the completeness measures of the CLU catalog (black) with GWGC (blue) and the 2MASS redshift survey (green) is given by showing differential frequency histogram distributions for 12 distance slices (solid) vs. $x = L/L^*$, using bins of width 0.1 dex in x. For CLU and GWGC $x = L_B/L_B{}^*$, whereas for 2MASS $x = L_K/L_K{}^*$. Shown also is the Schechter function $\phi^* x^a e^{-x} \Delta V dx$ (dotted), where the volume element ΔV is that for the given distance slice. For the 2MASS data, which are in the K-band, $\alpha = -0.9$ and $x_{1/2} = 0.790$. The vertical line segments in each panel indicate $x = x_{1/2}$.

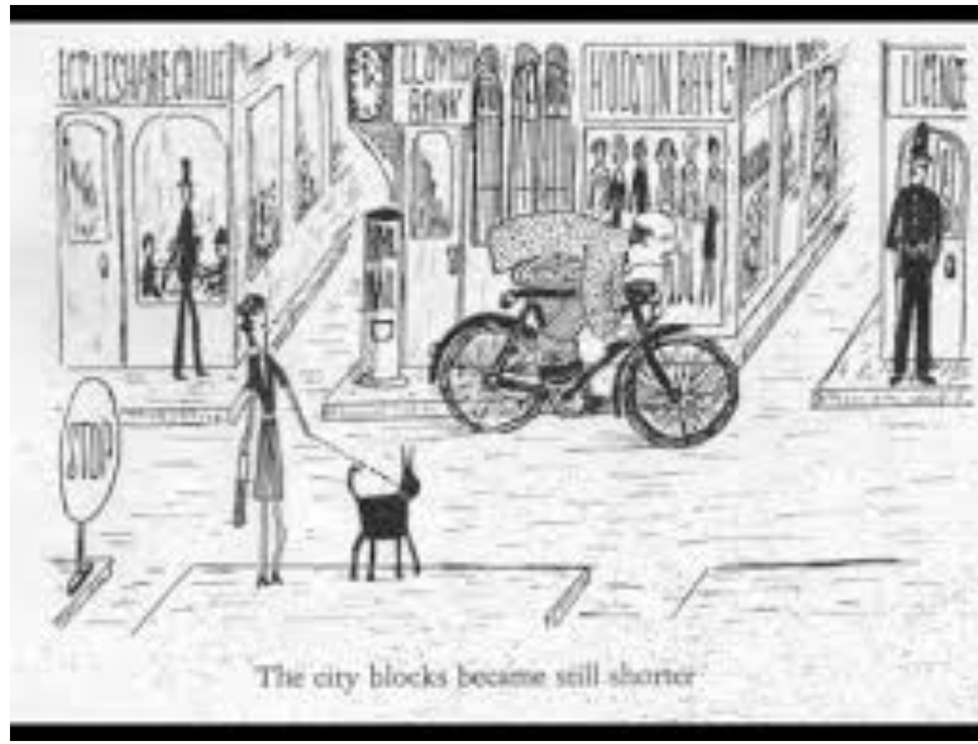
Galaxies

Multimessenger Observations of a Binary Neutron Star Merger (2017, ApJL, 848, L12):

The One-Meter, Two-Hemisphere (1M2H) team was the first to discover and announce (August 18 01:05 UTC; Coulter et al. 2017a) a bright optical transient in an *i*-band image acquired on August 17 at 23:33 UTC ($t_c + 10.87$ hr) with the 1 m Swope telescope at Las Campanas Observatory in Chile. The team used an observing strategy (Gehrels et al. 2016) that targeted known galaxies (from White et al. 2011b) in the three-dimensional LIGO-Virgo localization taking into account the galaxy stellar mass and star formation rate (Coulter et al. 2017). The transient, designated Swope Supernova Survey 2017a (SSS17a), was $i = 17.057 \pm 0.018$ mag[962] (August 17 23:33 UTC, $t_c + 10.87$ hr) and did not match any known asteroid or supernova. SSS17a (now with the IAU designation AT 2017gfo) was located at α(J2000.0) = $13^h09^m48\overset{s}{.}085 \pm 0.018$, δ(J2000.0) = $-23°22'53\overset{''}{.}343 \pm 0.218$ at a projected distance of $10\overset{''}{.}6$ from the center of NGC 4993, an early-type galaxy in the ESO 508 group at a distance of $\simeq$40 Mpc (Tully–Fisher distance from Freedman et al. 2001), consistent with the gravitational-wave luminosity distance (LIGO Scientific Collaboration & Virgo Collaboration et al. 2017b).

Galaxies





The city blocks became still shorter

Book

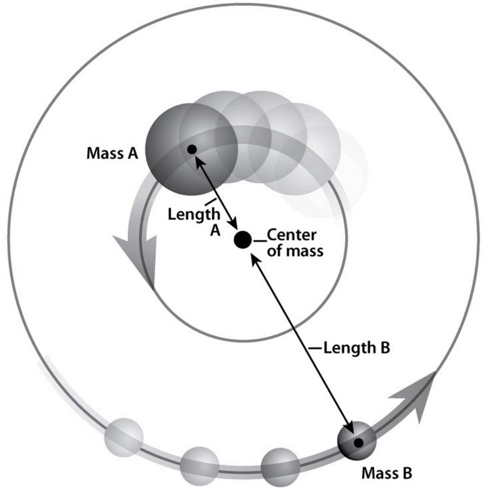
About the illustrator

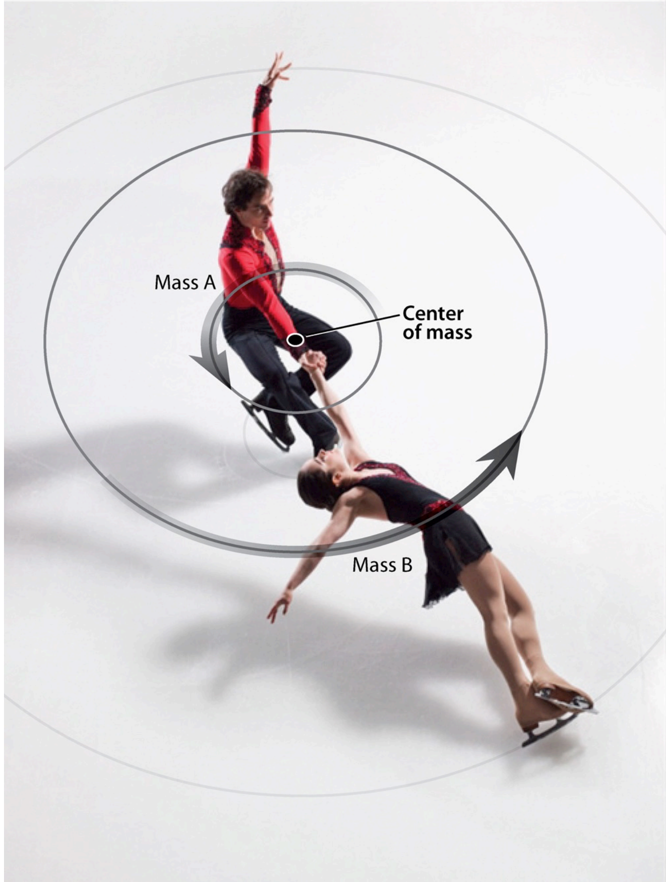
Figure 3: Roen Kelly.

Roen Kelly is a scientific illustrator who lives in Milwaukee, Wisconsin. She works at Kalmbach Publishing Co. as a staff illustrator for *Astronomy* and *Discover* magazines. She received a Bachelor of Arts degree in drawing and painting from

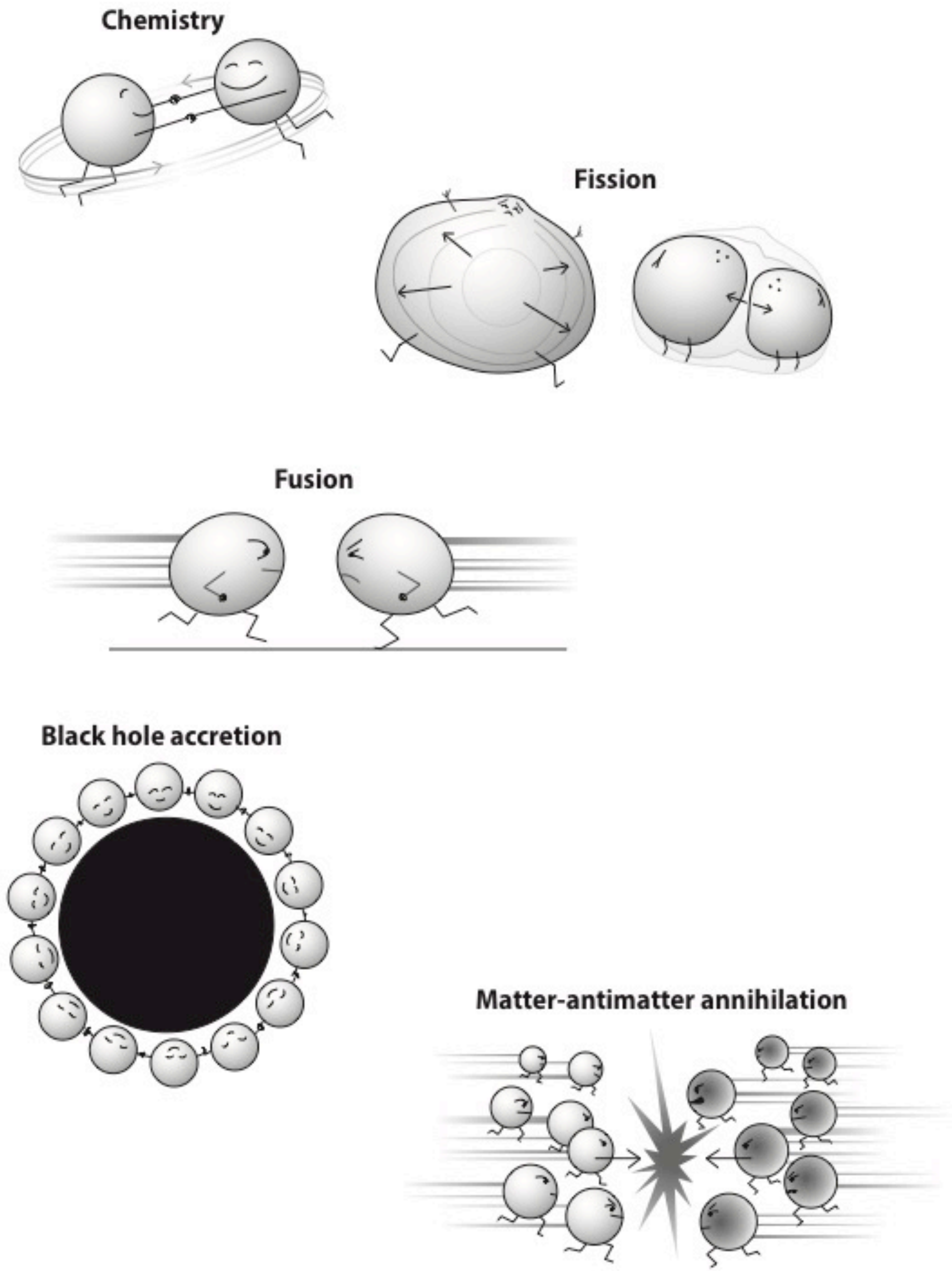
Book

Figure 1.10: Schwarzschild working in the trenches.


Mass A
Length A
Center of mass
Length B
Mass B


Mass A
Center of mass
Mass B

Book


Chemistry
Fission
Fusion
Black hole accretion
Matter-antimatter annihilation

Book

If anyone is interested in being a reader, please see me.

Book

Neil Gehrels 1952–2017

The high-energy astrophysicist, musician, adventurer and Swift PI is remembered by **John K Cannizzo**.

Neil was born in Lake Geneva, Wisconsin, on 3 October 1952, a year after his Dutch parents, Anton "Tom" and Aleida Gehrels (née de Stoppelaar), came to the US. Neil was the first of their three children. He was given the same name as an uncle, Cornelis A Gehrels, who sheltered a Jewish family in his basement during the second world war, but was caught and died in a concentration camp.

Neil's father was a well-known astronomer, which led to a peripatetic existence in Neil's formative years as the family followed Tom through various postdocs and visiting positions. These included a year living at McDonald Observatory atop Mount Locke when Neil was in first grade. Each day Neil went down the mountain to a small school in Fort Davis, where he found that "ranchers' kids don't like astronomers' kids".

When Neil was 14, the family finally settled in Tucson, Arizona. As a teenager he was keenly interested in music, from classical to rock-and-roll. He attended high school in Tucson, graduating as valedictorian in 1970. He went to college at the University of Arizona in Tucson (where his father worked) as a music major, but in July 1972 he had an epiphany that "music was a great hobby but a lousy profession". He already liked maths and science and was turned on to physics by Chang-Yun (Charlie) Fan, a cosmic-ray astrophysicist who flew instruments on satellites and balloons. Neil worked for four years in his lab, carrying out various tasks including soldering and writing computer programs. Neil received bachelors degrees in physics and music in 1976.

"Neil's greatest impact came from his role as principal investigator of the Swift mission"

Voyager, Caltech and Goddard

Neil attended Caltech for graduate school between 1976 and 1982, working in Ed Stone's cosmic-ray group on Voyager. Even before Voyager 1 and 2 arrived at Jupiter, it was decided Neil would be given data from their cosmic-ray subsystems for the Jupiter fly-by, which yielded an unexpected bonanza. Voyager detected a high flux of oxygen and sulphur ions, very different from the usual astrophysical mix of hydrogen, helium, carbon, sulphur and iron, while Voyager cameras saw volcanoes on Io spewing sulphur dioxide into the jovian magnetosphere. Neil wrote two papers (Gehrels *et al.* 1981, Gehrels & Stone 1983) predicting that aurorae on Jupiter are caused by oxygen and sulphur ions precipitating into the atmosphere, which was later shown to be correct.

While at Caltech, Neil met Ellen Williams, one of four women grad students who had been put into the men's dorms, and they married in 1980. In 1981, Neil came to NASA's Goddard Space Flight Center to join Frank McDonald's high-energy astrophysics group as a postdoc with Bonnard Teegarden; at the same time, Ellen came to the University of Maryland as a postdoc. After one-and-a-half years, Neil was hired as a civil servant. From 1995, he was chief of the Goddard Astroparticle Physics Laboratory.

In his early years at Goddard, Neil worked on the GRIS (Gamma-Ray Imaging Spectrometer) balloon payload, which observed SN 1987A and gamma-ray line emission. The detection of a gamma-ray signal a little over one year after the supernova, much sooner than expected, prompted theories that "fingers" of ejecta from the exploding core can penetrate the overlying, expanding stellar layers more rapidly than earlier, spherically symmetric estimates had indicated.

From 1991 to 2000, Neil was the Compton Gamma Ray Observatory (CGRO) project scientist. CGRO was one of NASA's Great Observatories and gave the first comprehensive observations of the gamma-ray sky. Its discoveries included revealing an isotropic distribution of gamma-ray bursts (GRBs) on the sky, showing that there exist two classes of GRBs (long and short), finding blazars with bright gamma-ray emission and detailed mapping of gamma-rays from ^{26}Al decay and of the 511 keV line from positron annihilation.

Swift

Neil's greatest scientific impact came from his role as principal investigator of the Swift mission (Gehrels *et al.* 2004), launched 20 November 2004. Neil led Swift from conception through hardware development. Swift has had many milestone findings, including the first localization of a short GRB (Gehrels *et al.* 2005), the discovery of flares and bright X-ray afterglows, the discovery of GRBs at redshift greater than 8 and the discovery of a jetted tidal disruption event. In later years, Swift has become instrumental in target-of-opportunity observations. Neil's benevolent leadership contributed to the great success of Swift, which received top ranking among the NASA Senior Review of active missions on multiple occasions.

Neil was an avid adventurer, whose activities included mountain climbing and hiking. In 1973, he hitchhiked around the world with his brother, getting as far as Istanbul, at which point they rode buses and trains. Also during his time in Arizona he took a long bicycle trip to the Panama Canal and back. In the mid-1980s, Neil summited Mt Aconcagua, and later Mt Tupingato. He climbed the Nose route on El Capitan in 2006 and 2015. He and his family were also volunteers in disadvantaged communities.

In his last few months, Neil was increasingly weakened as a result of pancreatic cancer, but continued to work until a couple of weeks before his death. He died at home on 6 February 2017, and is survived by his wife Ellen Williams, children Thomas and Emily, his mother Aleida, and siblings George and Jo-Ann.

Those of us who were fortunate to work with Neil know of his unwavering enthusiasm for science and unselfish generosity in mentoring others. ●

AUTHOR

John K Cannizzo is a research scientist at the University of Maryland, Baltimore County, USA.

REFERENCES

Gehrels N & Stone EC 1983 *J. Geophys. Res.* **88** 5537

Gehrels N *et al.* 1981 *J. Geophys. Res.* **86** 8906

Gehrels N *et al.* 2004 *Astrophys. J.* **611** 1005

Gehrels N *et al.* 2005 *Nature* **437** 851