Short Gamma-ray Bursts in the *Swift* Era

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Hubble Fellow, Northwestern University

Neil Gehrels Memorial Symposium

National Academy of Sciences, Washington DC, 5.22.2018

Reflections on Neil's Impact on Young Scientists

Image credit: NASA/GSFC

Contributions to Women in Astronomy

Women in Astronomy Blog contributions:

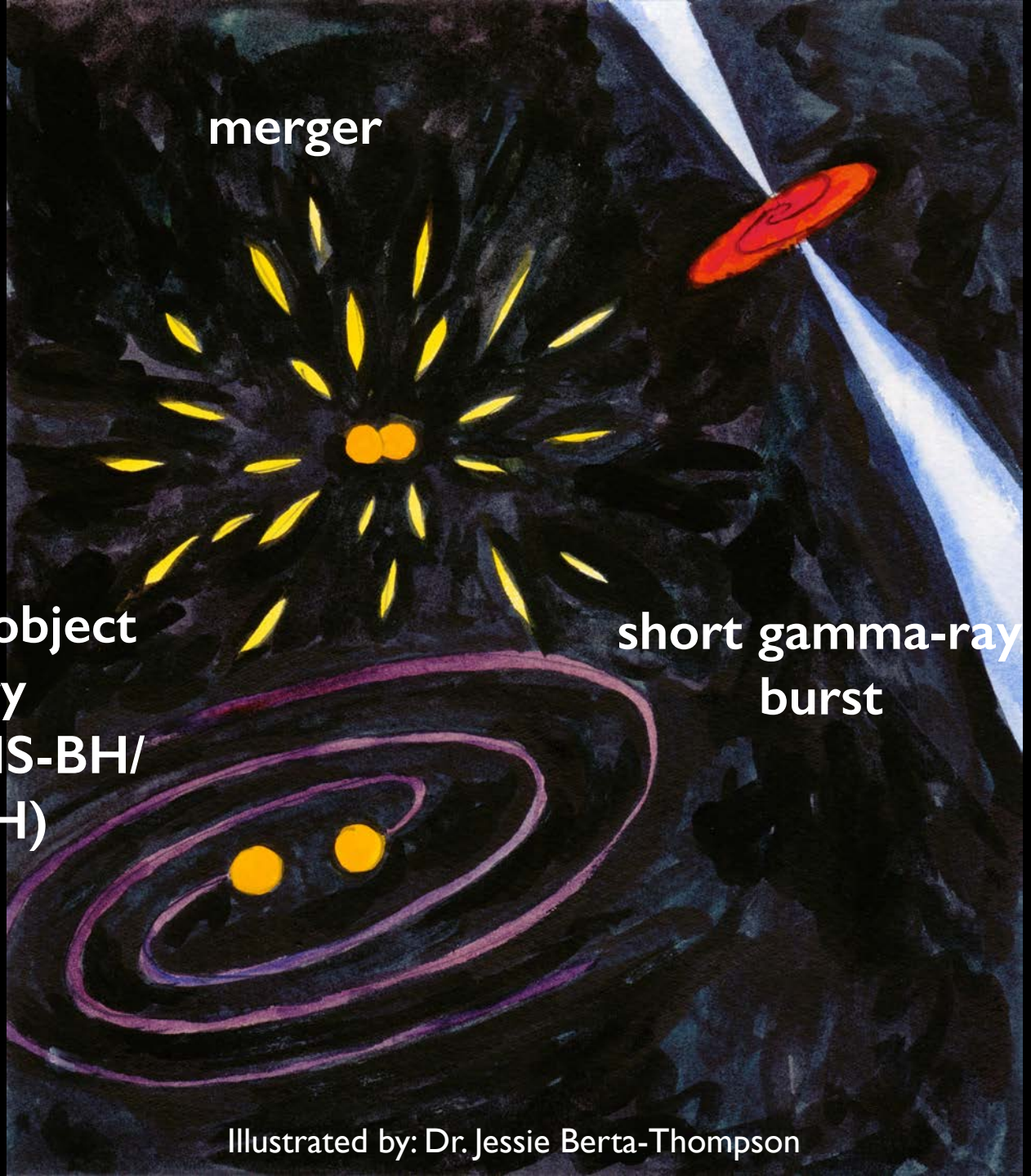
6/28/2012: My Daughter's Experience with Math and Science

1/23/2013: Report from the Southwest Conference for Undergraduate Women in Physics

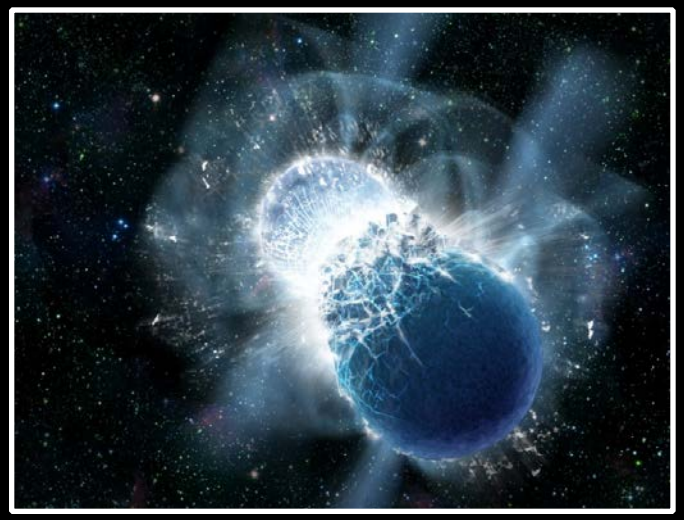
4/15/2013: First Woman Astronomer Hypatia: Paying Dearly for Her Beliefs

4/3/2014: Career profile

7/20/2015: The Fight for Women's Suffrage


merger
compact object binary (NS-NS/NS-BH/ BH-BH)
short gamma-ray burst
Illustrated by: Dr. Jessie Berta-Thompson

Early predictions in support of a neutron star merger origin



Nucleosynthesis, neutrino bursts and γ-rays from coalescing neutron stars

David Eichler*, Mario Livio†, Tsvi Piran‡ & David N. Schramm§

1989

GAMMA-RAY BURSTS AS THE DEATH THROES OF MASSIVE BINARY STARS

RAMESH NARAYAN,[1] BOHDAN PACZYŃSKI,[2] AND TSVI PIRAN[3]

1992

Received 1992 March 24; accepted 1992 June 5

ABSTRACT

We propose that gamma-ray bursts are created in the mergers of double neutron star binaries and black hole neutron star binaries at cosmological distances. Two different processes provide the electromagnetic

Image credit: Dana Berry, SkyWorks Digital, Inc.

Benchmark studies in short GRBs

A short γ-ray burst apparently associated with an elliptical galaxy at redshift z = 0.225

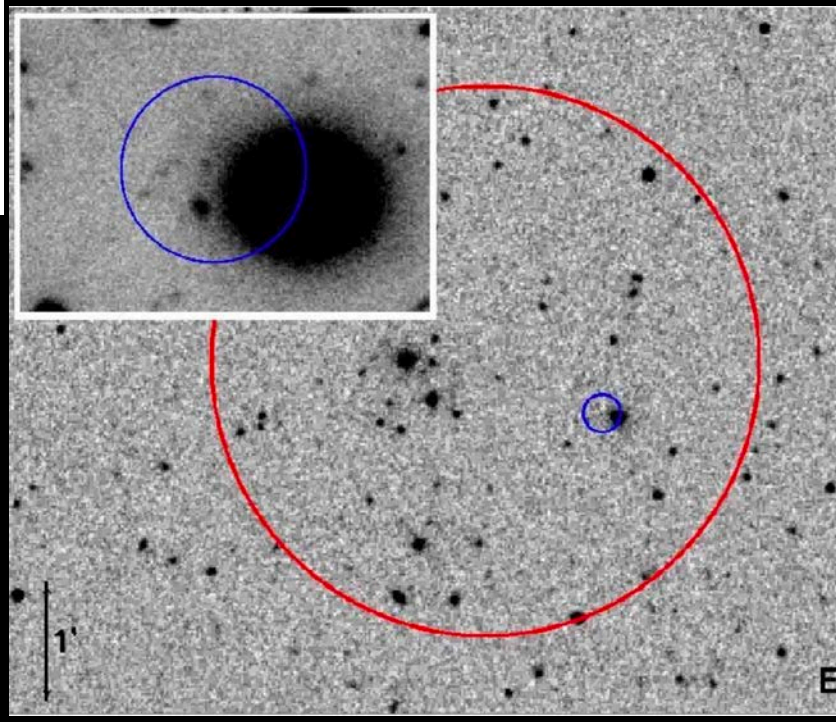
N. Gehrels ✉, C. L. Sarazin, P. T. O'Brien, B. Zhang, L. Barbier, S. D. Barthelmy, A. Blustin, D. N. Burrows, J. Cannizzo, J. R. Cummings, M. Goad, S. T. Holland, C. P. Hurkett, J. A. Kennea, A. Levan, C. B. Markwardt, K. O. Mason, P. Meszaros, M. Page, D. M. Palmer, E. Rol, T. Sakamoto, R. Willingale, L. Angelini, A. Beardmore, P. T. Boyd, A. Breeveld, S. Campana, M. M. Chester, G. Chincarini, L. R. Cominsky, G. Cusumano, M. de Pasquale, E. E. Fenimore, P. Giommi, C. Gronwall, D. Grupe, J. E. Hill, D. Hinshaw, J. Hjorth, D. Hullinger, K. C. Hurley, S. Klose, S. Kobayashi, C. Kouveliotou, H. A. Krimm, V. Mangano, F. E. Marshall, K. McGowan, A. Moretti, R. F. Mushotzky, K. Nakazawa, J. P. Norris, J. A. Nousek, J. P. Osborne, K. Page, A. M. Parsons, S. Patel, M. Perri, T. Poole, P. Romano, P. W. A. Roming, S. Rosen, G. Sato, P. Schady, A. P. Smale, J. Sollerman, R. Starling, M. Still, M. Suzuki, G. Tagliaferri, T. Takahashi, M. Tashiro, J. Tueller, A. A. Wells, N. E. White & R. A. M. J. Wijers

nature
International journal of science

Gehrels et al. 2005 (see also Bloom et al. 2006)

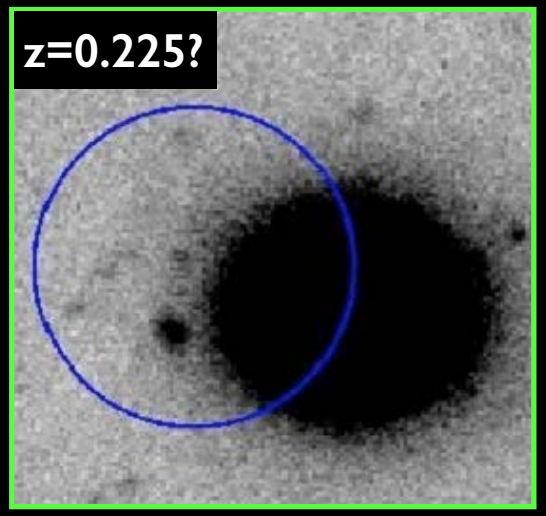
First X-ray afterglow in a short GRB and in an elliptical (old) galaxy!

Talks by Josh Bloom, Paul O'Brien, Peter Meszaros



Firsts for short GRB afterglows
long: 1997, short: 2005

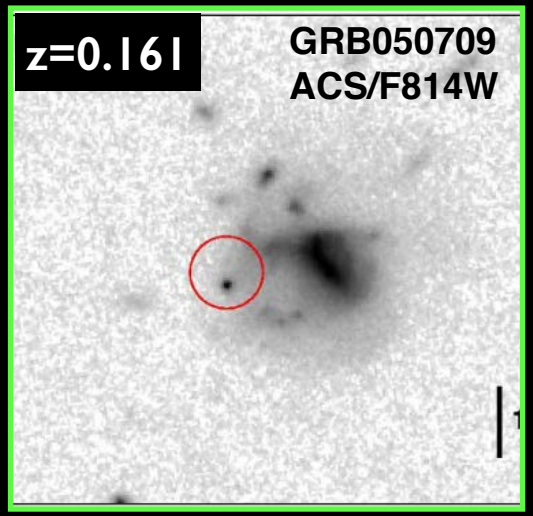
First X-ray afterglow



Gehrels et al. 2005, Bloom et al. 2006

~few arcsec

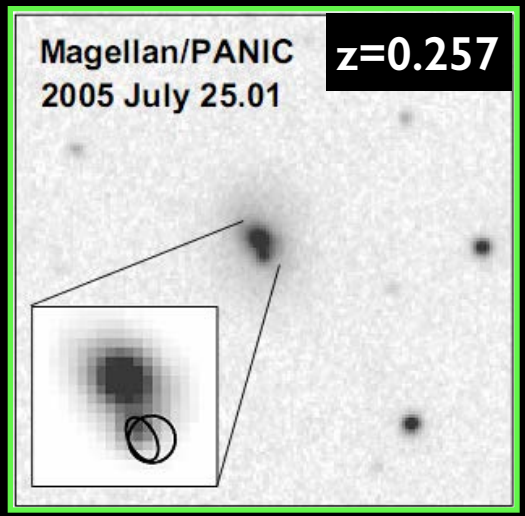
First optical afterglow



Fox et al. 2005; Hjorth et al. 2005

<1 arcsec

First radio afterglow



Berger et al. 2005; Panaitescu 2006

<1 arcsec

Key to <u>localization</u> and <u>placement</u> within a host

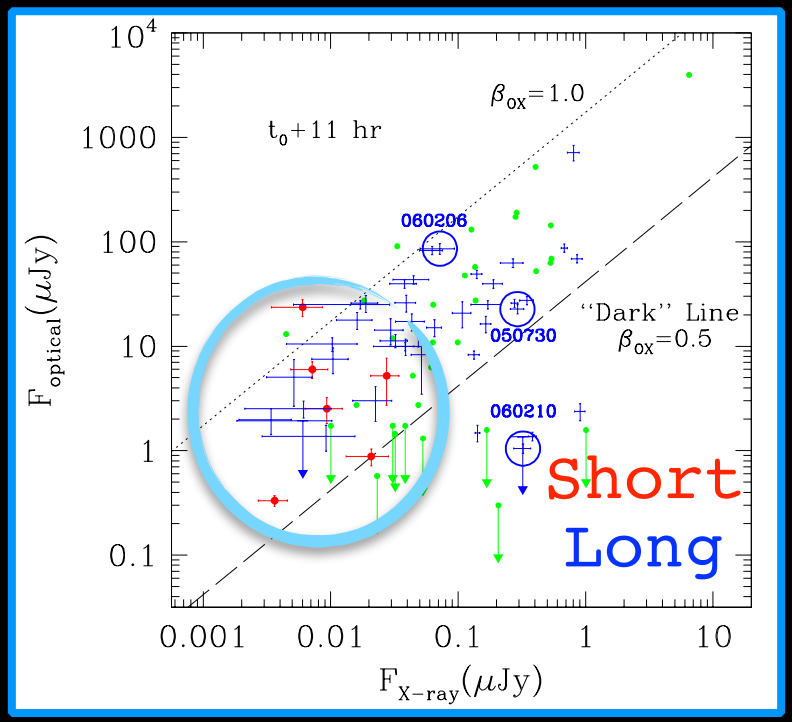
Benchmark studies in short GRBs

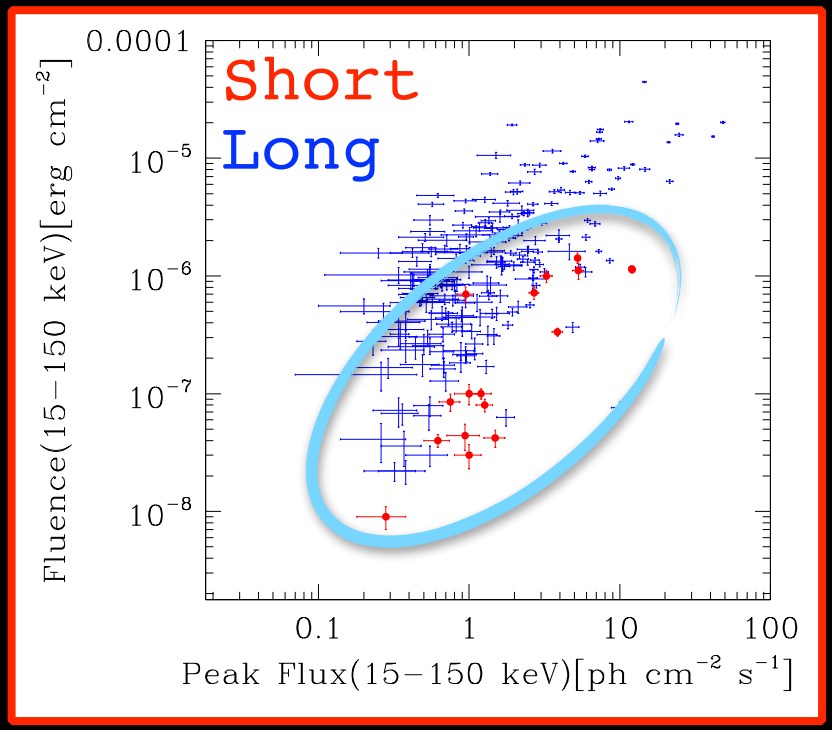
CORRELATIONS OF PROMPT AND AFTERGLOW EMISSION IN *SWIFT* LONG AND SHORT GAMMA-RAY BURSTS

N. GEHRELS,[1] S. D. BARTHELMY,[1] D. N. BURROWS,[2] J. K. CANNIZZO,[1,3] G. CHINCARINI,[4,5] E. FENIMORE,[6] C. KOUVELIOTOU,[7] P. O'BRIEN,[8] D. M. PALMER,[6] J. RACUSIN,[2] P. W. A. ROMING,[2] T. SAKAMOTO,[1,3] J. TUELLER,[1] R. A. M. J. WIJERS,[9] AND B. ZHANG[10]

Received 2008 February 4; accepted 2008 August 21

Gehrels et al. 2008





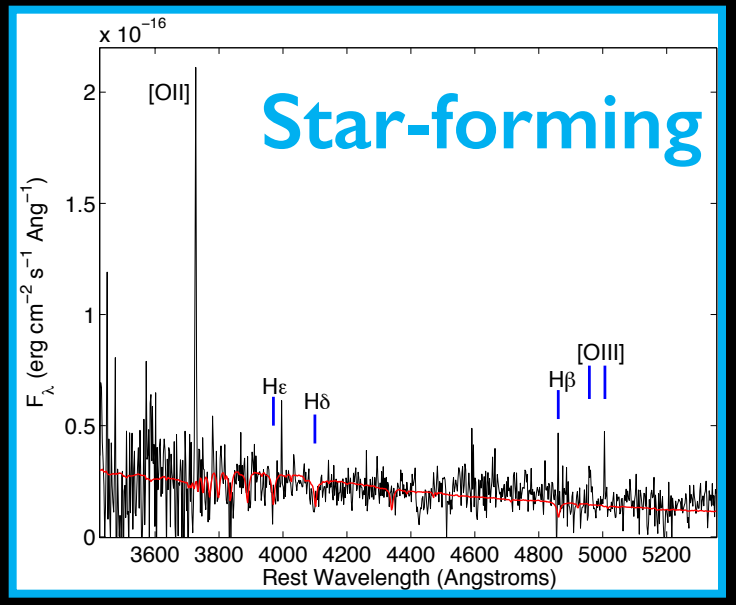
Short GRBs are fainter across the electromagnetic spectrum

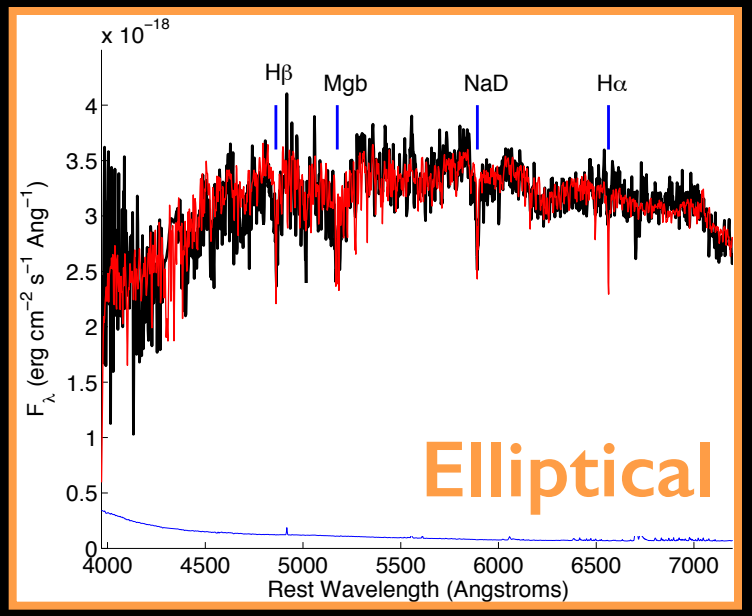
Building upon Neil's discovery: Hosts of Short GRBs

Why study environments?

Crucial context!

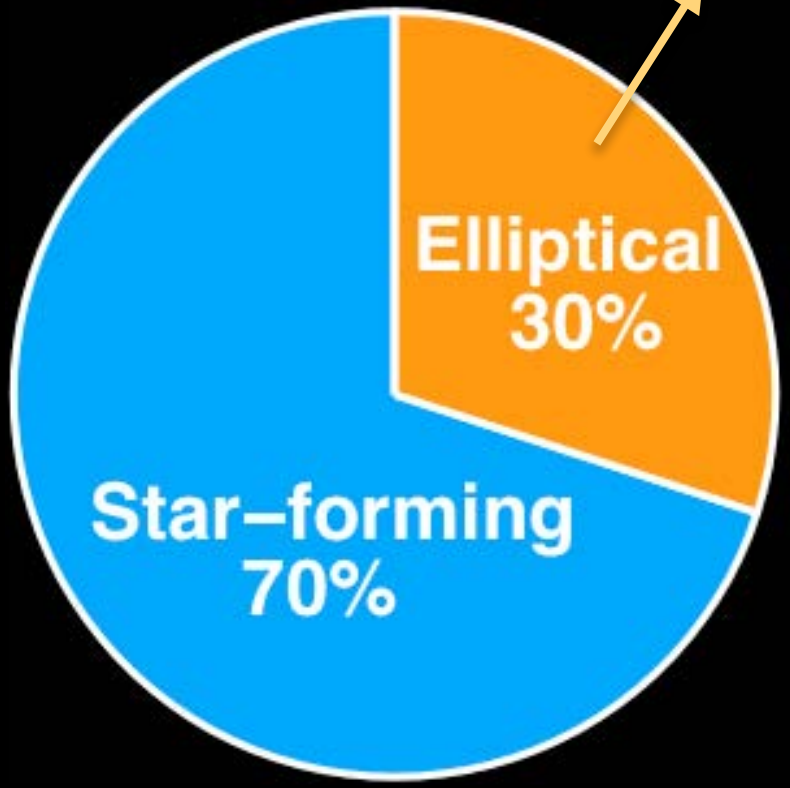
Building upon Neil's discovery: Hosts of Short GRBs





Building upon Neil's discovery: Hosts of Short GRBs

GRB 050509B in an Elliptical:
The first discovery is not always the norm!



SFR $\lesssim$ 0.1-1 M_{sun}/yr

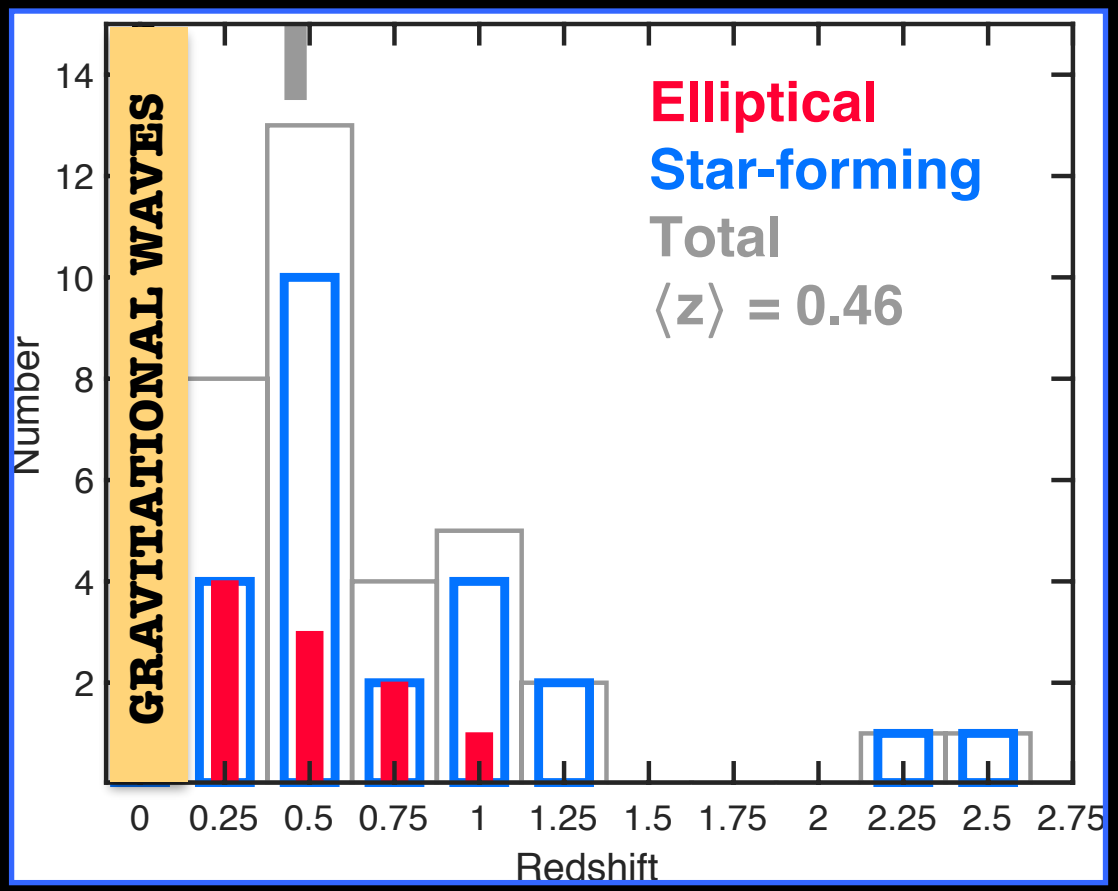
$M_* \sim 10^{10.1}$ M_{sun}

$L_B \sim 0.1\text{-}5 L_B^*$

age~0.06-4.4 Gyr

Commensurate with older stellar progenitor with a wide range of timescales

Steep drop-off in redshift distribution beyond z~1.3



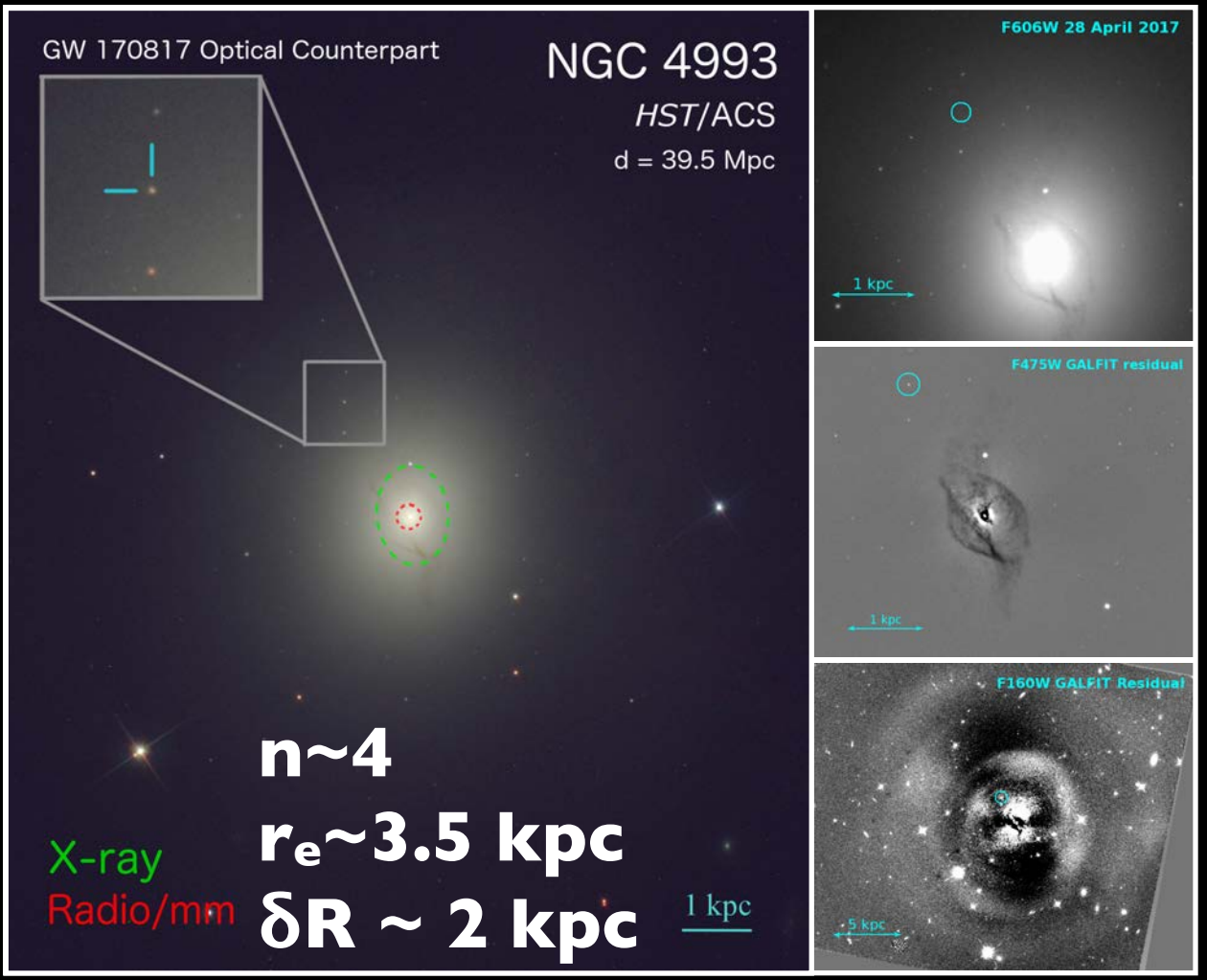
Number

Redshift

True redshift distribution important for constraining delay time distribution

Fong et al. 2017; Berger 2014 (refs therein)

GW170817 Host Overview



Blanchard, Berger, Fong et al. 2017

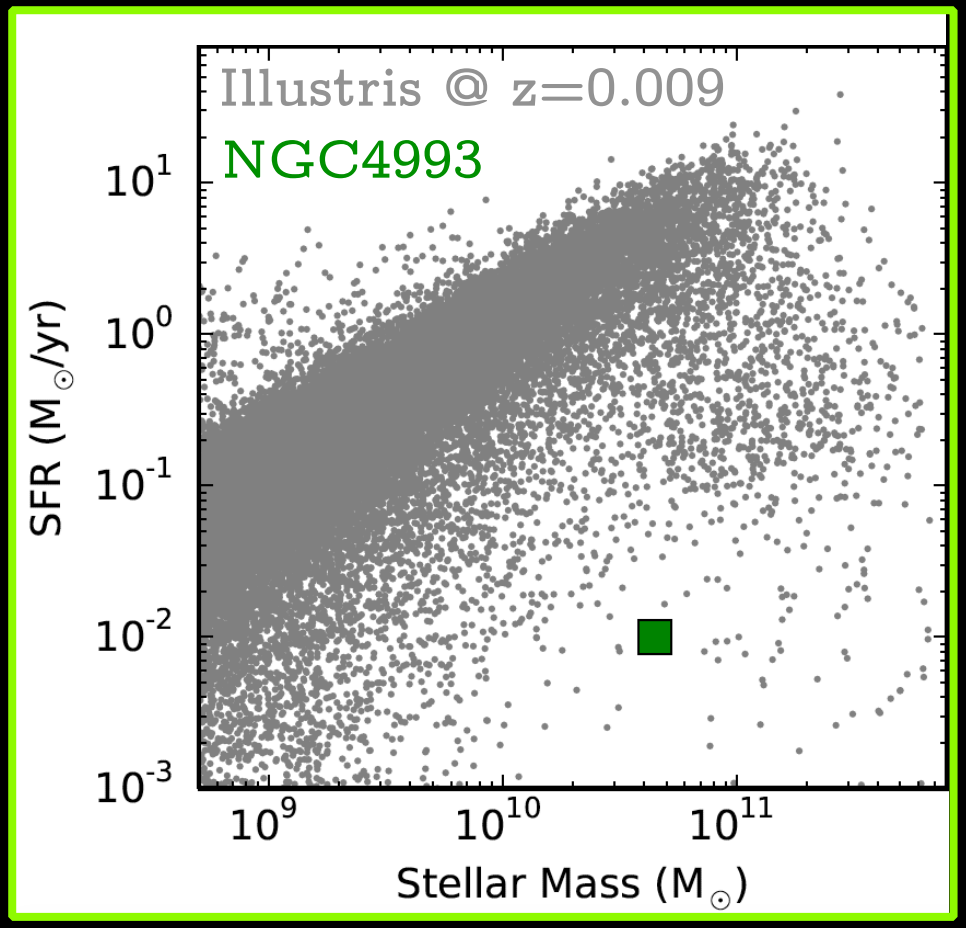
Pre-explosion: m>27 AB mag (PI: Bellini)

Optical: Dust structure traces ionized gas (Levan et al. 2017)

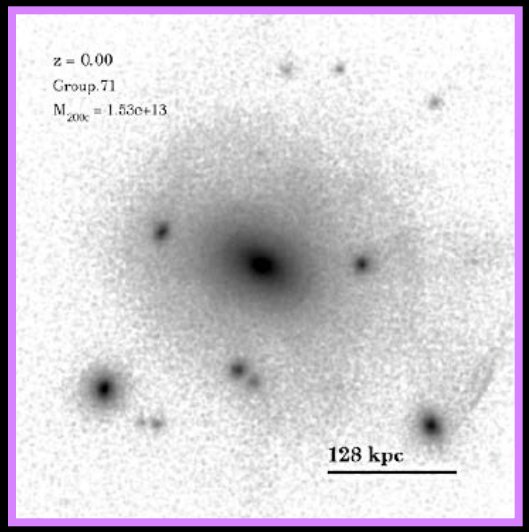
Near-infrared: Concentric shells indicate galaxy merger

Other HST PIs: Tanvir, Kasliwal, Troja, Levan

NGC4993: An outlier in the context of galaxies at similar redshift?



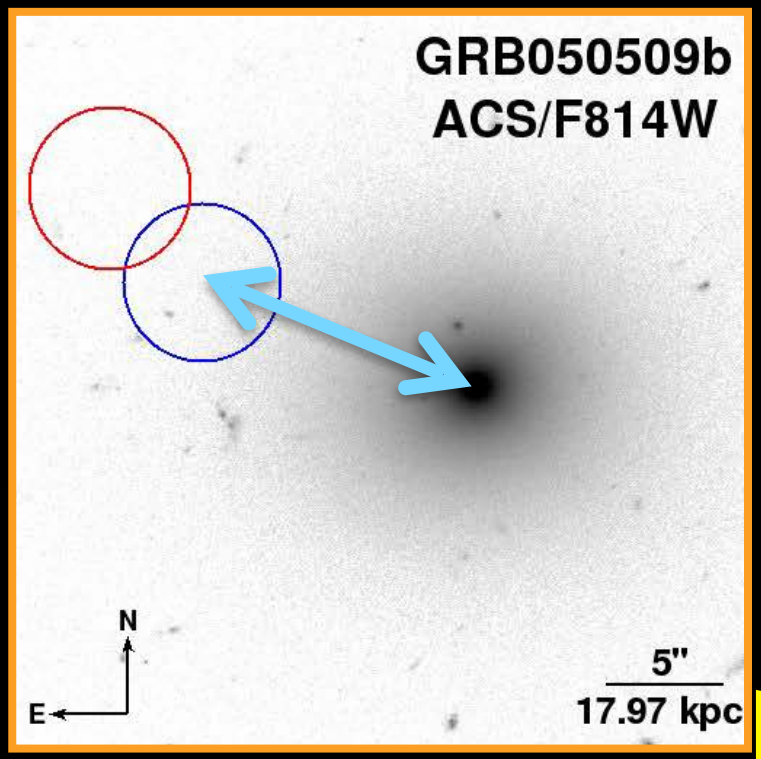
Expected incidence of shells is **<15%**
(Pop et al. 2017)



Credit: Sarah Wellons (NU)

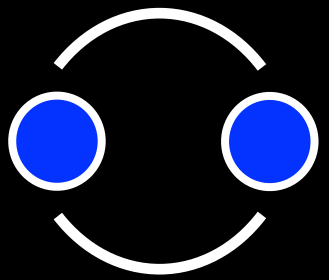
Short GRB locations: GRB 050509B (and friends) re-visited

Hubble Space Telescope

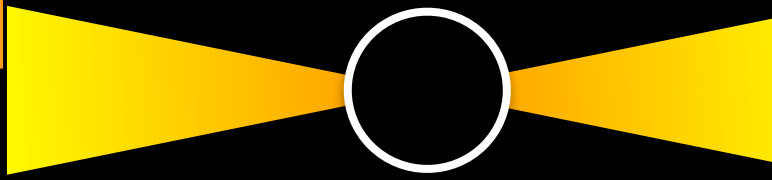


"offset"

NS/BH kicks



ΔT **"delay time"**

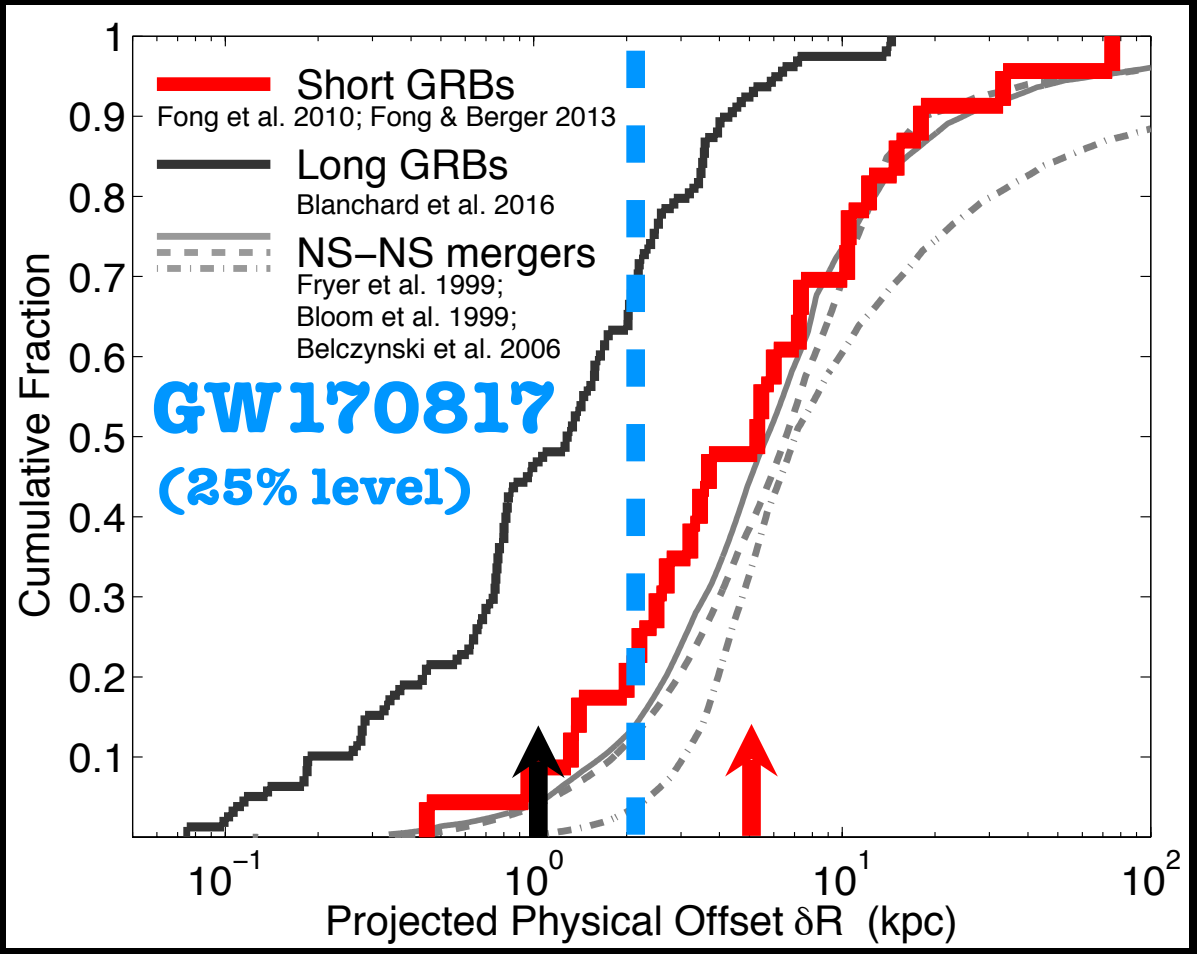


ground-based position from Gehrels et al. 2005
Fong et al. 2010, Fong & Berger 2013

Fryer & Kalogera 1997; Fryer et al. 1999; Bloom et al. 1999; Perna & Belczynski 2002; Belczynski et al. 2006; Zemp et al. 2009; Kelley et al. 2010

Short GRB locations

see also: talks by Josh Bloom, Peter Meszaros



Fong & Berger 2013
(see also: Pan et al. 2017, Levan et al. 2017)

Long GRBs: Blanchard et al. 2016
NS-NS models: Fryer et al. 1999; Bloom et al. 1999; Belczynski et al. 2006

Short ~ 5 kpc
Long ~ 1 kpc

host-normalized:
~20% are $>5r_e$
~20% are $<1r_e$

Weakly correlated with regions of stellar mass or star formation

Indicative of NS-NS/NS-BH merger progenitors!

Sun, Jul 14, 2013 @ 5:33PM

Hi Neil,

I hope all is well at GSFC! I'm sure you are as busy as ever...

I just wanted to let you know that we posted a paper to the arXiv last week about short GRB locations:
http://arxiv.org/abs/1307.0819
This is the latest sample, and more than doubles the sample from 2010.

Sun, Jul 14, 2013 @ 11:30PM

Hi Wen-fai,
Yes, I saw your nice paper on short bursts. The results are indeed important.

Dedications in the GW+GRB discovery

LIGO-Virgo Collaboration et al. 2017 (ApJL: 848, L13):
Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A

We dedicate this Letter to the memory of Neil Gehrels. His pioneering work in gamma-ray astronomy and his vision for multi-messenger astrophysics were instrumental to our discoveries.

Goldstein, Veres, Burns et al. 2017:
An Ordinary Short Gamma-Ray Burst with Extraordinary Implications: Fermi-GBM Detection of GRB 170817A

We dedicate this paper to the memory of Neil Gehrels who was an early and fervent advocate of multi-messenger time-domain astronomy and with whom we wish we could have shared the excitement of this tremendous observation.

On the origin of short GRBs

"We'll find out once this ground-based gravitational wave instrument called **LIGO** gets working... and if we see them at the same time that we see short bursts over the next few years, **we'll know we really nabbed it.**"

Neil Gehrels Maniac Lecture, September 29, 2015

https://www.youtube.com/watch?v=IG08SL8fDDk

On his own achievements

Audience Question: With all of these achievements, are you thinking about the **Nobel** at all?

Neil's Answer: Ehh, well, not the Nobel.
But, you wanna go with me to the **Himalayas**???

Neil Gehrels Maniac Lecture, September 29, 2015
https://www.youtube.com/watch?v=lG08SL8fDDk

thank you!