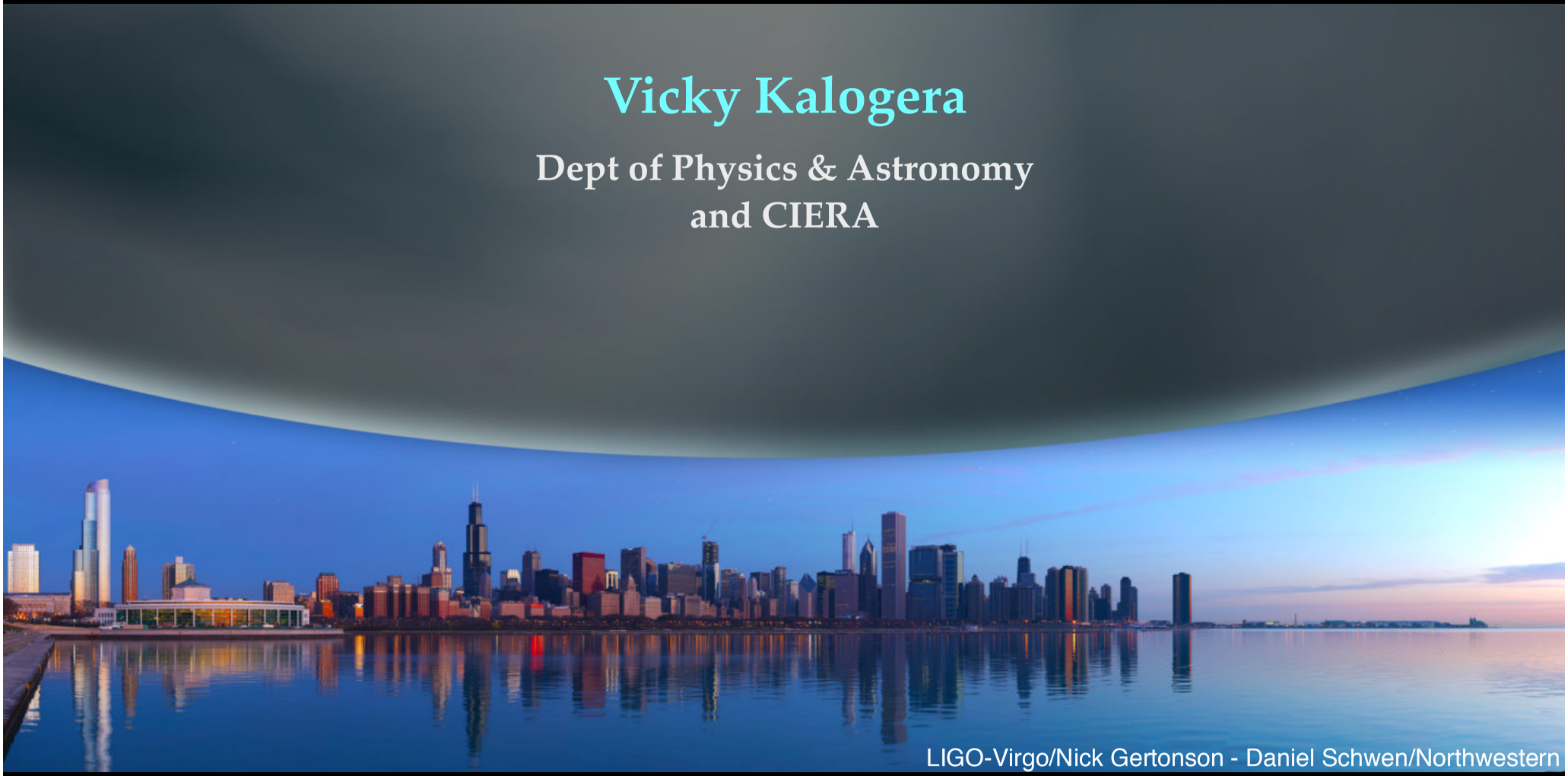
Neil's connection to GW170817
and
Near-term GW detection expectations

Vicky Kalogera

Dept of Physics & Astronomy
and CIERA



LIGO-Virgo/Nick Gertonson - Daniel Schwen/Northwestern

Neil Gehrels Memorial Meeting

National Academy of Sciences

May 20-21, 2018

NORTHWESTERN UNIVERSITY

CIERA

Neil's interface with the GW community

Thanks to Peter Shawhan & Gaby Gonzalez

2006 - 2008: LIGO PAC (Program Advisory Committee)

~ 2008:

— Joint search for sub-prime GRB candidates and deep LIGO triggers

— His first LSC paper: "Search for GW Bursts from Soft Gamma Repeaters"

— Early efforts of Swift follow-up of LIGO triggers

2011: Joined the LIGO Scientific Collaboration

2012 - 2015: LVC Diversity Committee

— LSC Statement on Diversity

— Anti-Harassment Guidelines

2013 - 2014: LVC GW-EM MOU Committee

2015 - 2017: Co-chair of LVC Diversity Committee

Collaboration focused on X-ray follow-up of GW triggers

Daryl Haggard
McGill

as PI
co-Is: Neil G and VK

Cycle 18 Approved TOO Proposal:

"Bringing Gravitational-Wave Astronomy to Light:
Chandra X-ray Localization of LIGO-Virgo GW Sources"

MOU with the LVC

"Targeting LIGO-Virgo Candidates with X-Ray Imaging"

Around January 2017
Dealing with a BH-BH trigger …

-------- Forwarded Message --------
Subject: Re: Possible GW trigger for Proposal 18400410
Resent-From: daryl.haggard@mcgill.ca
Date: Sat, 7 Jan 2017 20:23:26 +0000
From: Gehrels, Neil (GSFC-6610) <neil.gehrels@nasa.gov>
To: Vicky Kalogera <vicky@northwestern.edu>
CC: Daryl Haggard <daryl.haggard@mcgill.ca>, Neil Gehrels
<gehrels@milkyway.gsfc.nasa.gov>

Vicky,

I am happy to stay in the loop on this interesting object, but don't
have a strong opinion one way or the other. I would hate to miss the
big big detection. However, the odds are so small for it if it is the
BH-BH LIGO counterpart as you point out. I am slightly opposed.

Neil

> On Jan 7, 2017, at 1:00 PM, Vicky Kalogera <vicky@northwestern.edu> wrote:
>
> Neil, any opinions? should we go ahead without your input ?
> do we want to trigger - it is definitely a BH-BH, so I am not sure whether I buy the validity of
> the counterparts reported as LIGO source counterparts …
>
> > On Jan 7, 2017, at 11:57 AM, Daryl Haggard <daryl.haggard@mcgill.ca> wrote:
> >
> > Thanks Belinda,
> >
> > The visibility looks good in ProVis, as do the roll and pitch angles --
> > I know your team will do a more thorough assessment. Coordinates are
> > proprietary, so I'll wait to share those only if we officially trigger.
> >
> > I am waiting to touch base with the Swift team, but will follow up soon,
> > -Daryl

Thanks to Daryl Haggard for finding this.

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Neil

Thanks to Daryl Haggard for finding this.

When GW170817 came …

Daryl Haggard
McGill

Melania Nynka
McGill

John Ruan
McGill

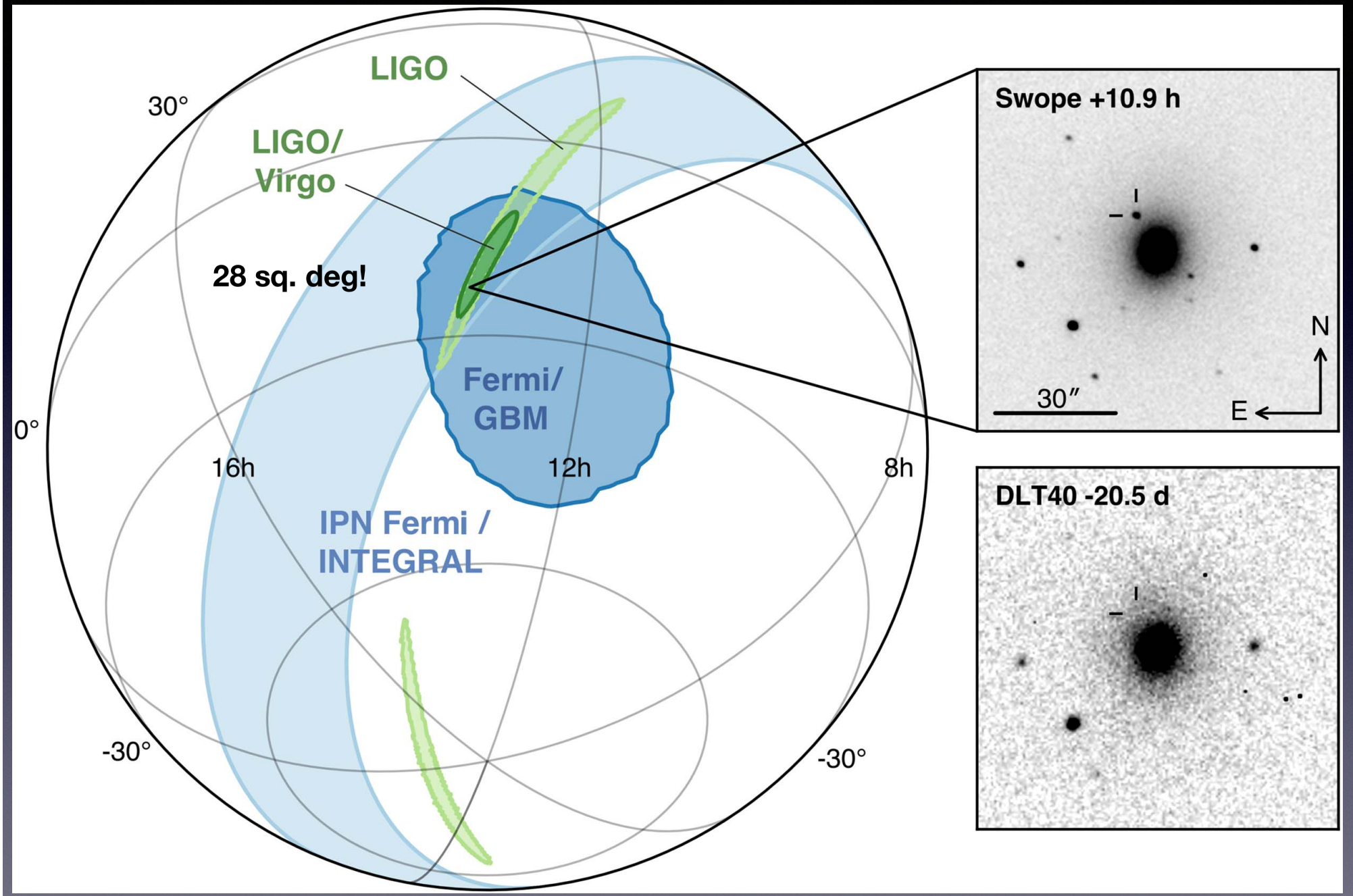
Brad Cenko
Goddard

Phil Evans
Leicester

plus VK
Northwestern

triggered that same approved TOO proposal originally submitted by the Haggard/Gehrels/Kalogera team

Once GW170817 was localized…

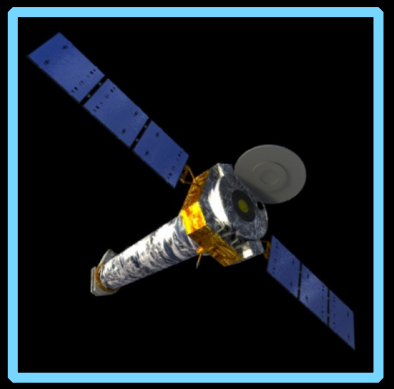


Multi-Messenger Astronomy paper, LVC+All EM teams, ApJ Letters, 2017

Timeline of early EM follow-up: The first 72 hours

12 hr: Optical discovery

1.5 days: First optical and near-infrared spectra



GW trigger

1

2

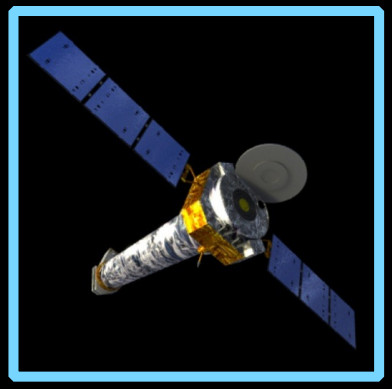
3

13.7 hr: First radio observations

2.4 days: First, deep X-ray observations

Courtesy Margutti & Fong

Timeline of early EM follow-up: The first two weeks



16 days: Radio comes into view!

GW trigger

9 days

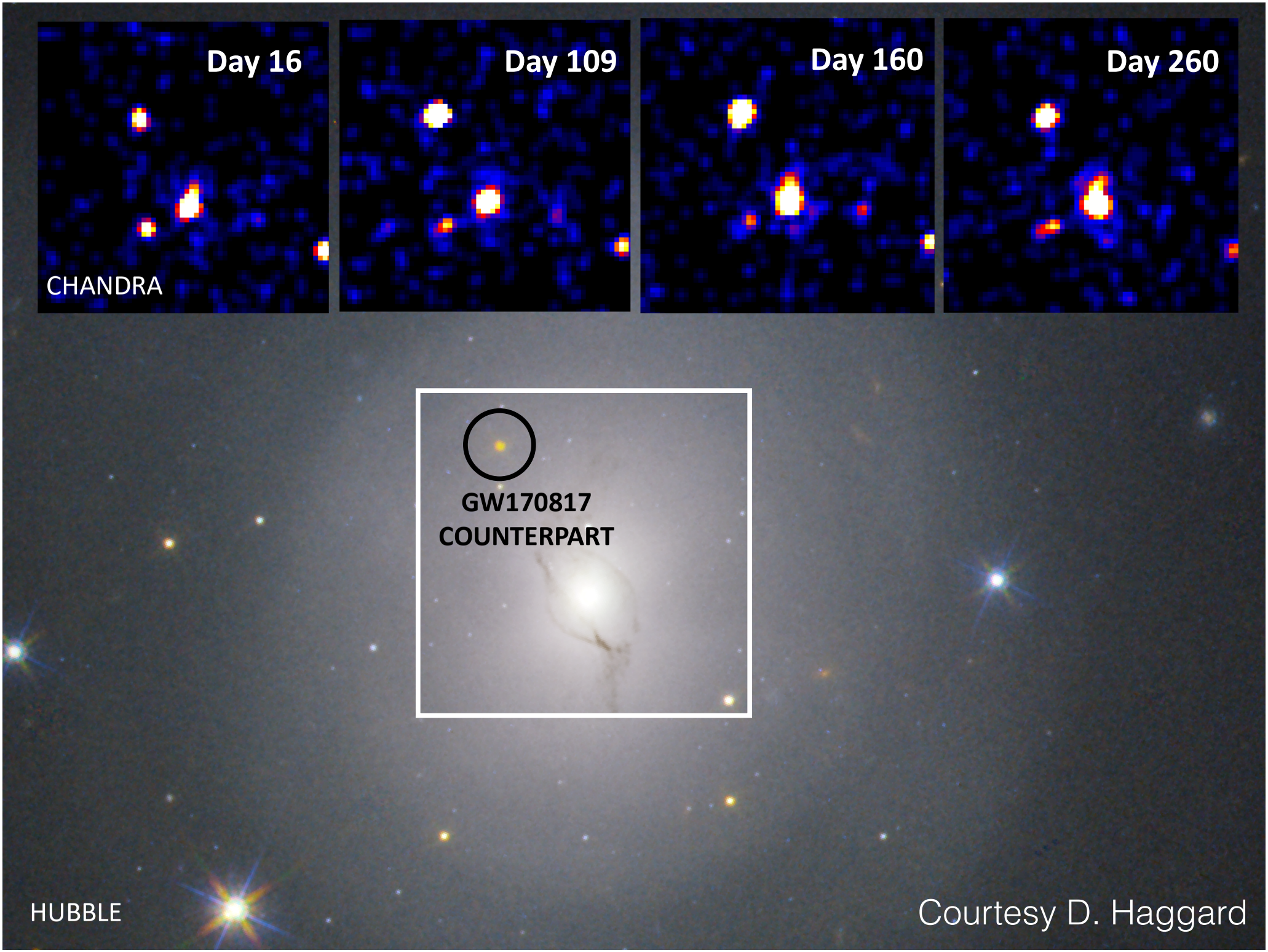
15 days

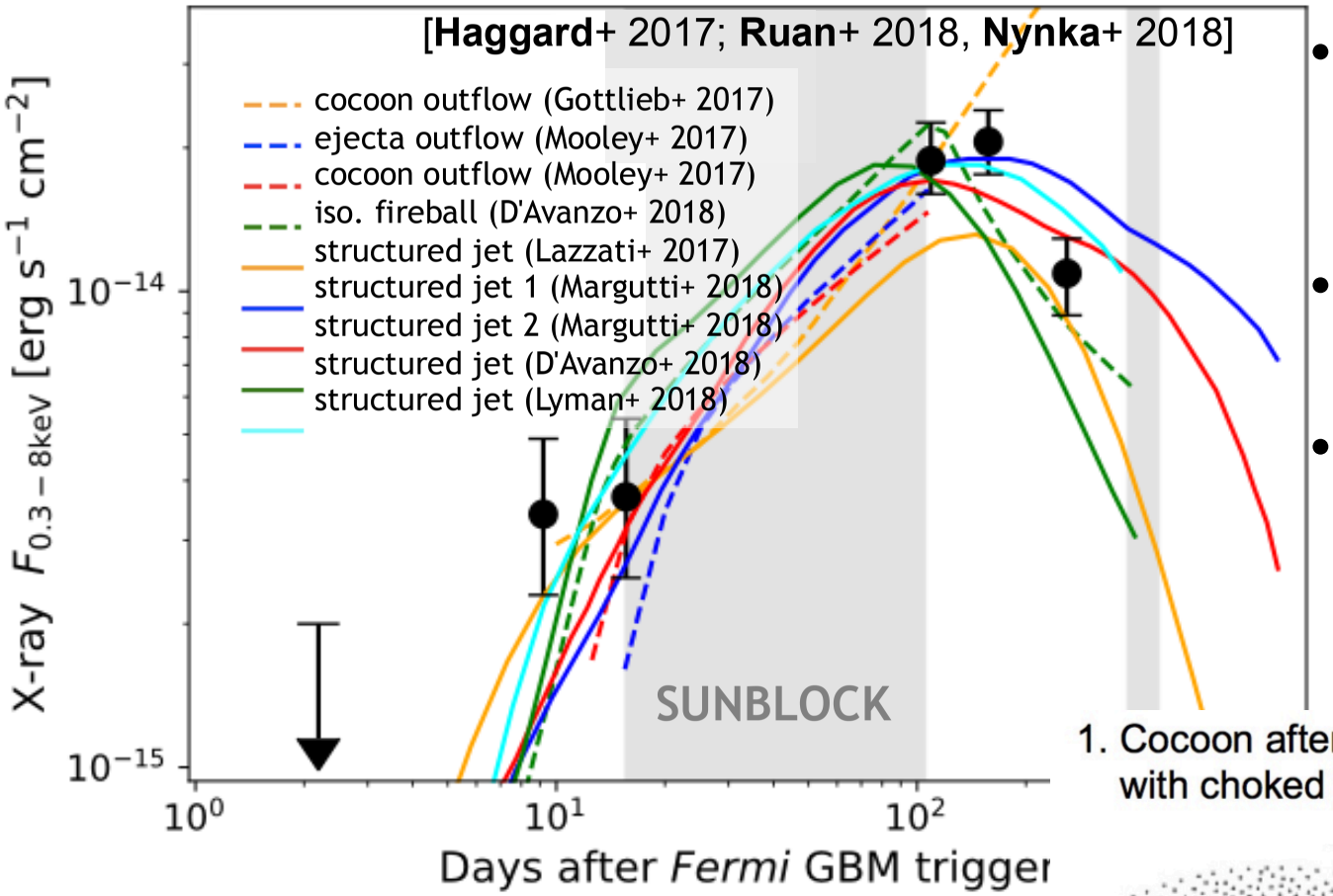
days

30 days

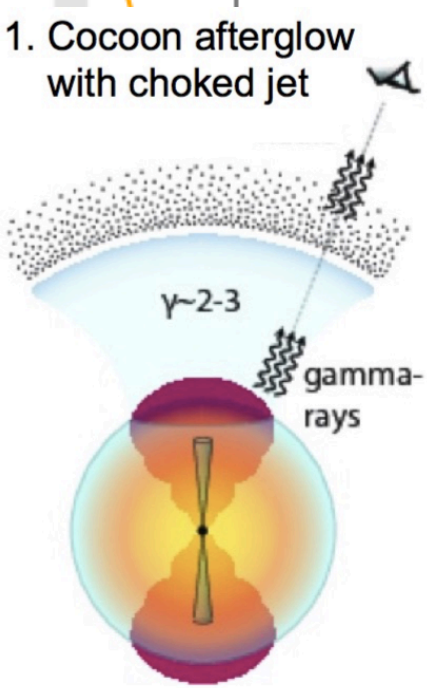
9-15 days: X-rays come into view!

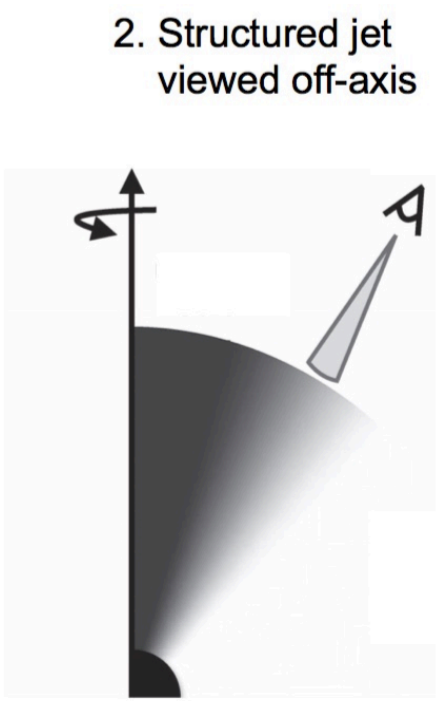
Courtesy Margutti & Fong


Day 16
Day 109
Day 160
Day 260
CHANDRA
GW170817
COUNTERPART
HUBBLE
Courtesy D. Haggard



- ***Chandra*** non-det. ~2 days; det. 9, 15, 109,160, & 260 days
- Upper limits from ***Swift*** & **NuSTAR**
- X-ray and radio initially pointed to off-axis GRB

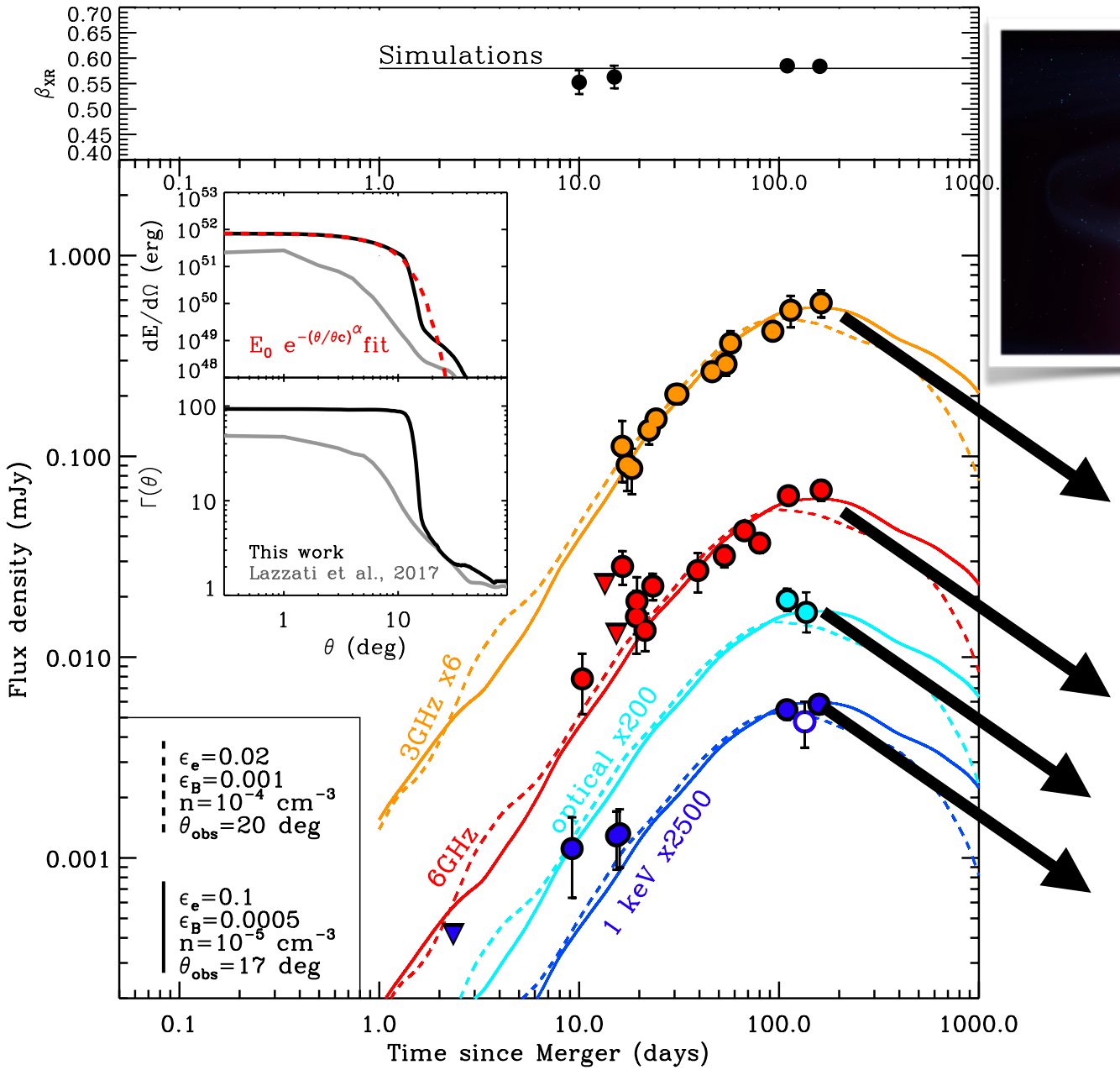


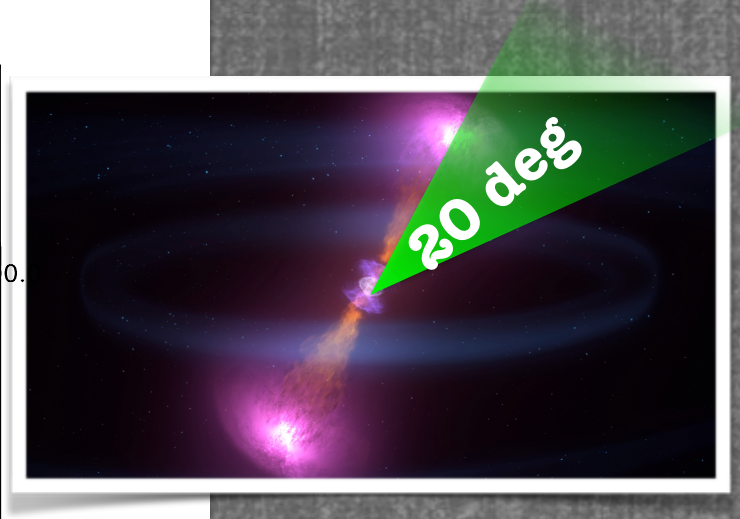


- Jet and/or cocoon afterglows supported by recent data
- X-ray and radio turn-over currently underway…

[*also* **Evans**+2017; **Margutti**+ 2017/2018; **Troja**+ 2017; **Kasliwal**+ et al. 2017; **Mooley**+ 2017, **Alexander**+ 2018]

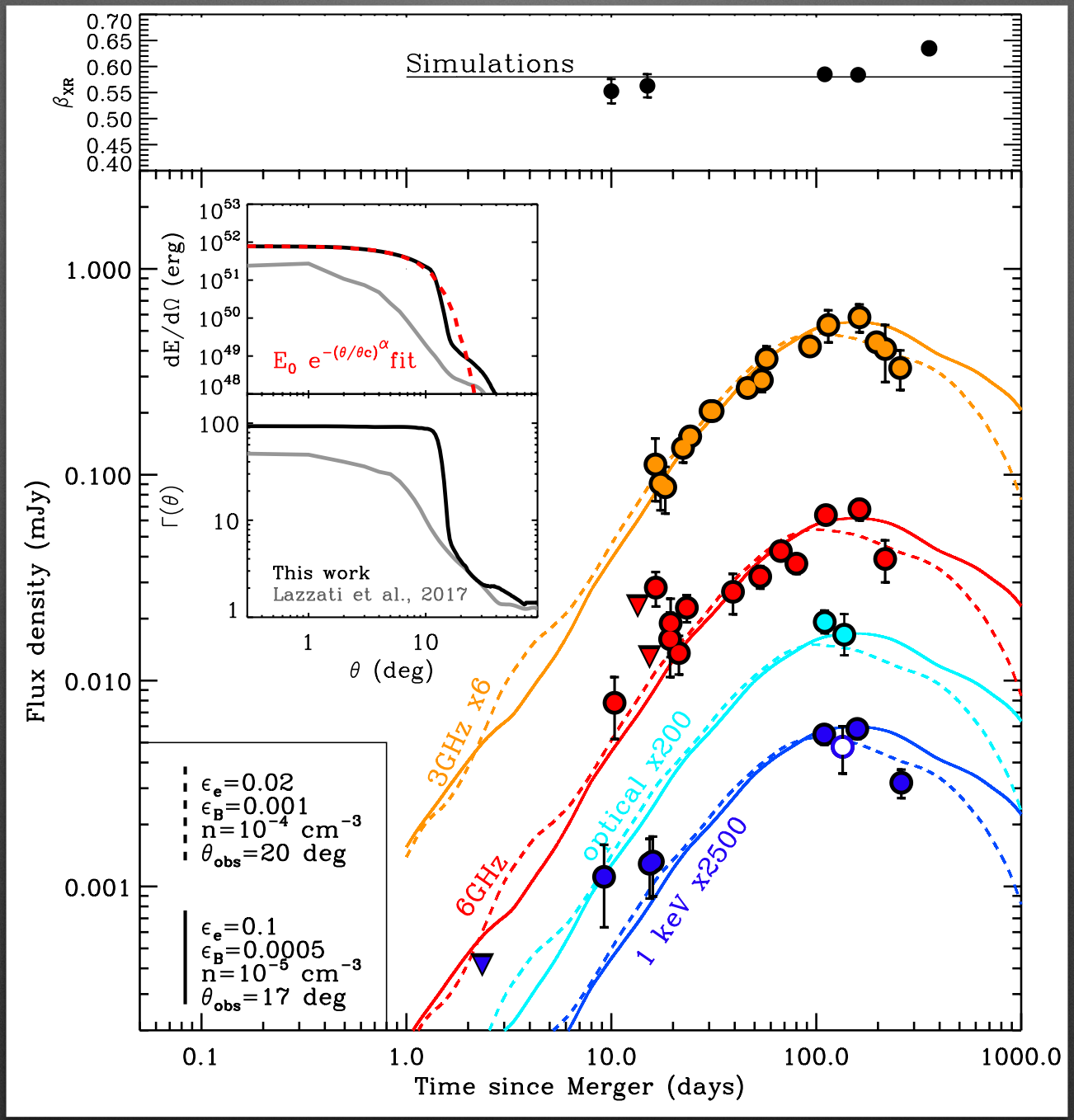
Off-axis Jet predictions:





Ultra-relativistic jet viewed from the side

Margutti et al. 2018

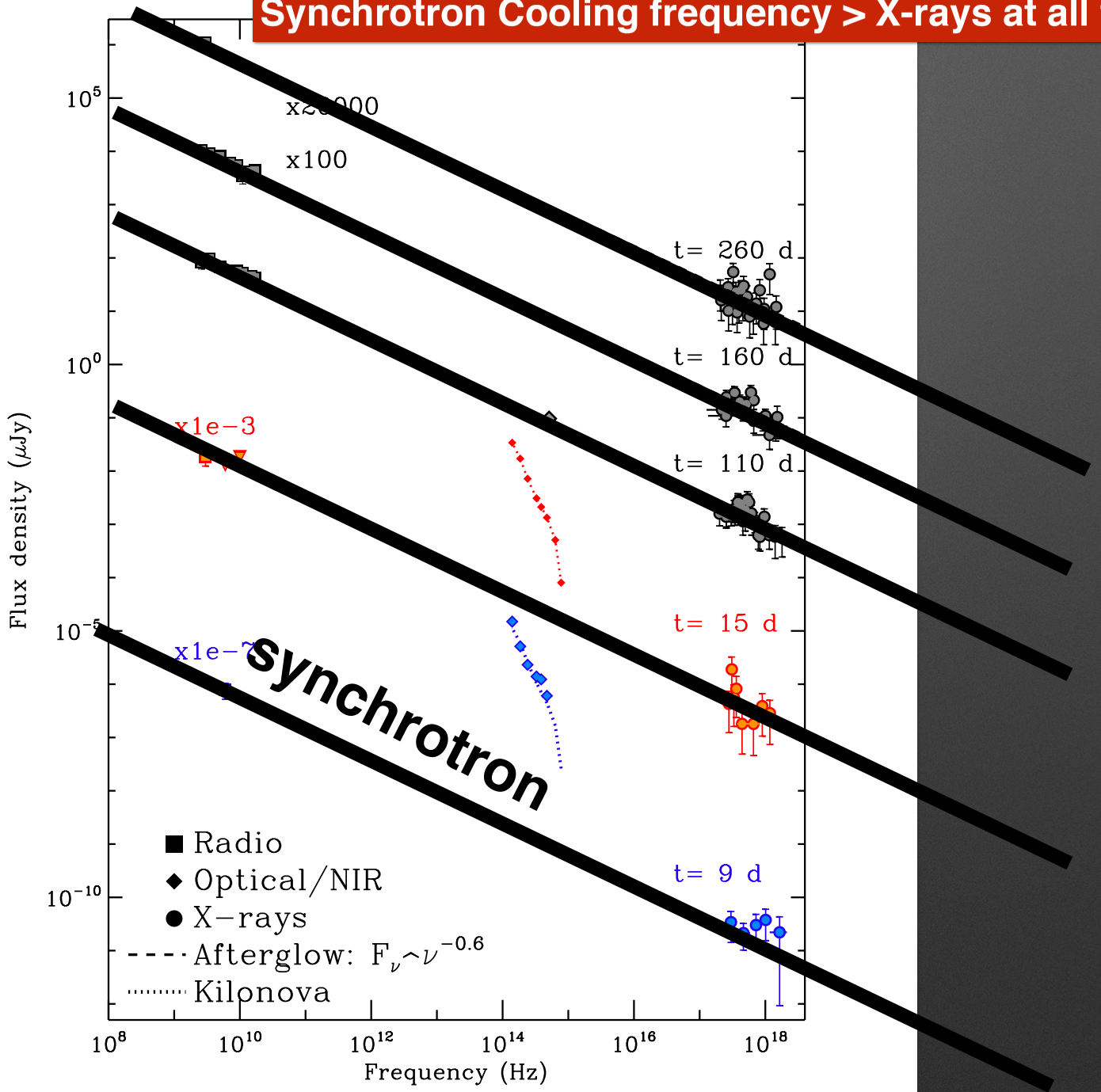


Alexander+2018

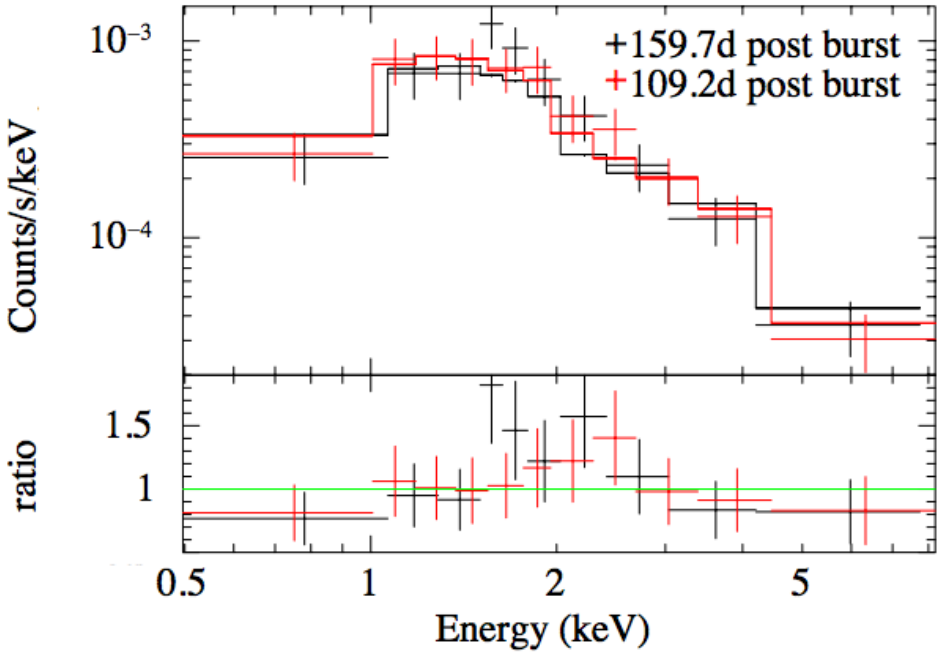
SAME spectrum (no spectral evolution)

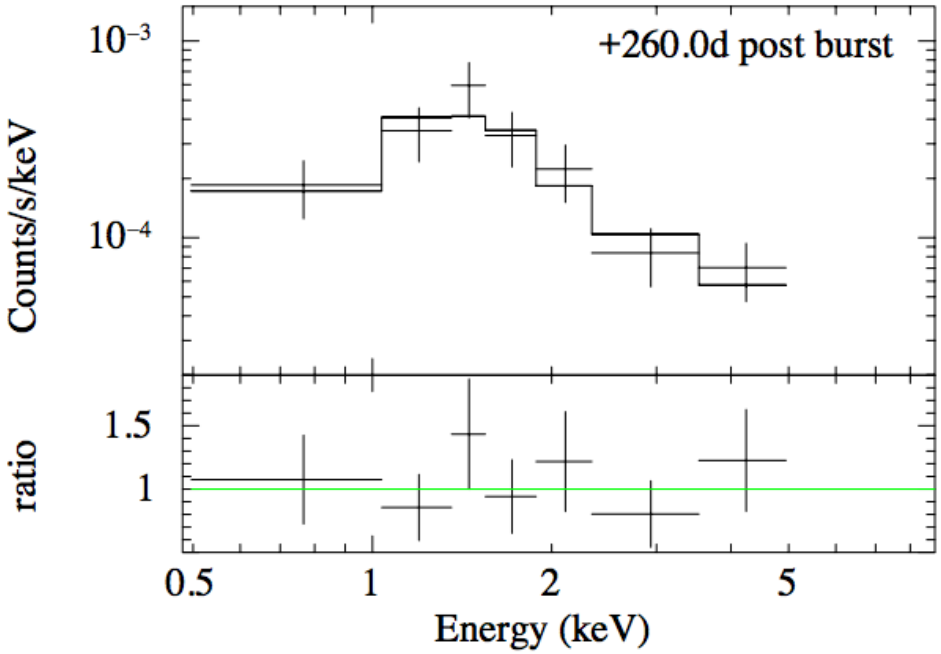
Synchrotron Cooling frequency > X-rays at all times

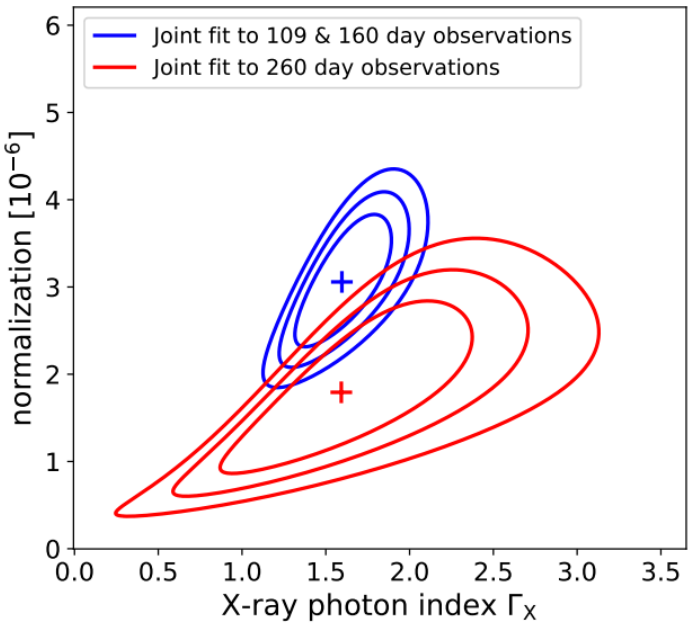
Margutti+2018 updated with new data from Alexander +2018



Chandra X-ray Spectral Fits







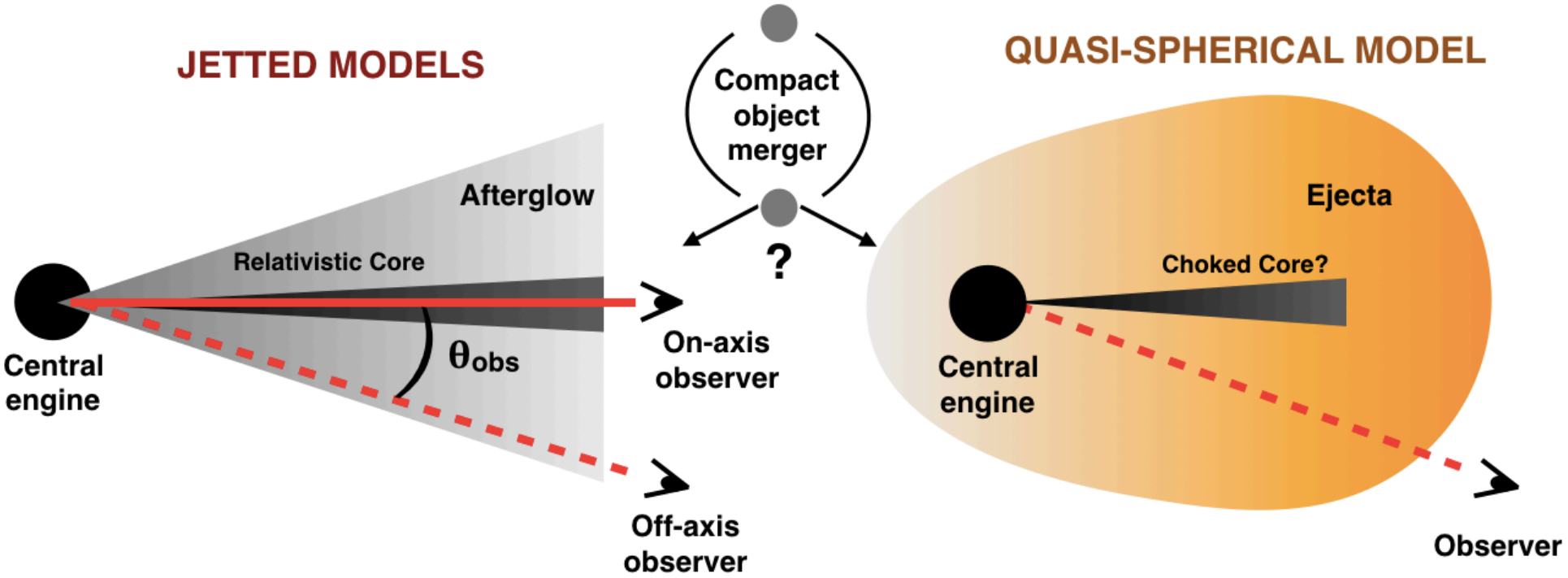
Absorbed power-law spectral models w/ $N_H = 7.5 \times 10^{20}$ cm^{-2}

- 109 days: $\Gamma_X = 1.53^{+0.24}_{-0.23}$
- 160 days: $\Gamma_X = 1.58^{+0.23}_{-0.22}$
- 260 days: $\Gamma_X = 1.57^{+0.38}_{-0.39}$

Lack of evolution in spectral index *disfavors* passing of synchrotron cooling break.

Nynka, Ruan, Haggard, et al. ApJL *submitted*

X-ray emission models



[Courtesy: Margutti, Fong, & Haggard]

Always looking into the future …

How many more NS mergers in O3?

GW170817: Most Accurate NS-NS Merger Rate Measurement

ApJ Letters, 832, 2
Phys. Rev. Lett. 119, 16110

NS-NS Rate Predictions:

Rates Review paper, LVC, CQG, 2010

TABLE IV: Compact binary coalescence rates per Mpc^3 per Myr.[a]

Source	R_{low}	R_{re}	R_{high}	R_{max}
NS-NS (Mpc^{-3} Myr^{-1})	0.01 [1]	1 [1]	10 [1]	50 [16]
NS-BH (Mpc^{-3} Myr^{-1})	6×10^{-4} [18]	0.03 [18]	1 [18]	
BH-BH (Mpc^{-3} Myr^{-1})	1×10^{-4} [14]	0.005 [14]	0.3 [14]	

[1] VK et al., ApJ Letters, 2004
" The Cosmic Coalescence Rates for Double Neutron Star Binaries"

[16] Kim, VK, Lorimer 2006

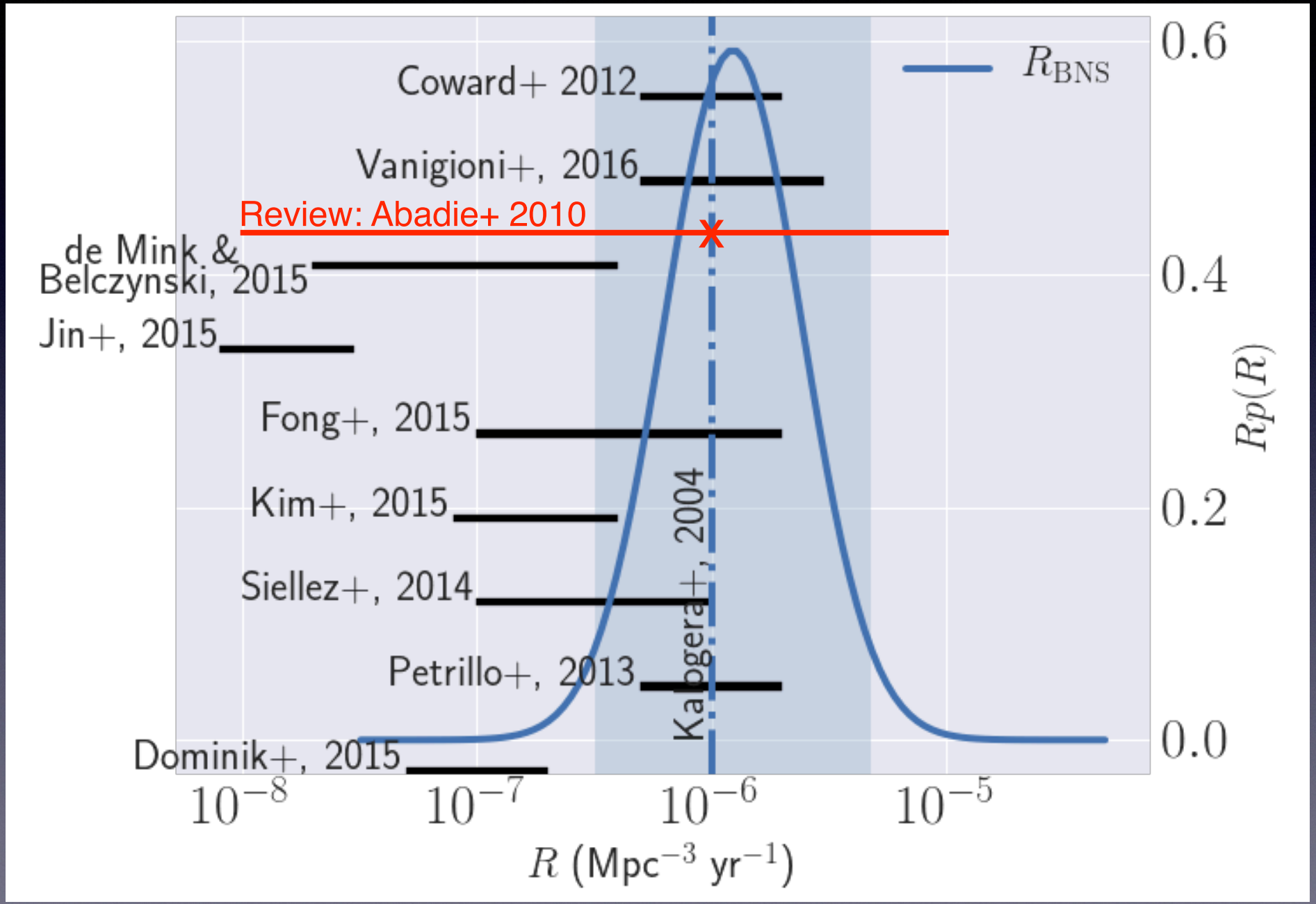
GW paper, LVC, PRL, 2017

NS-NS Rate Measurement: 1.54 $^{+3.2}_{-1.22}$ (0.3 - 5) per Mpc^3 per Myr

This rate distribution…

R_{BNS} ~ 3.2 x 10^{-7} — 4 x 10^{-6} $Mpc^{-3}yr^{-1}$

ApJ Letters, 832, 2
Phys. Rev. Lett. 119, 16110



O3 Event Rate Expectations

Courtesy: Pankow 2018

$\rho_{net} > 12$
T_{obs}: 1 yr with 50% duty cycle

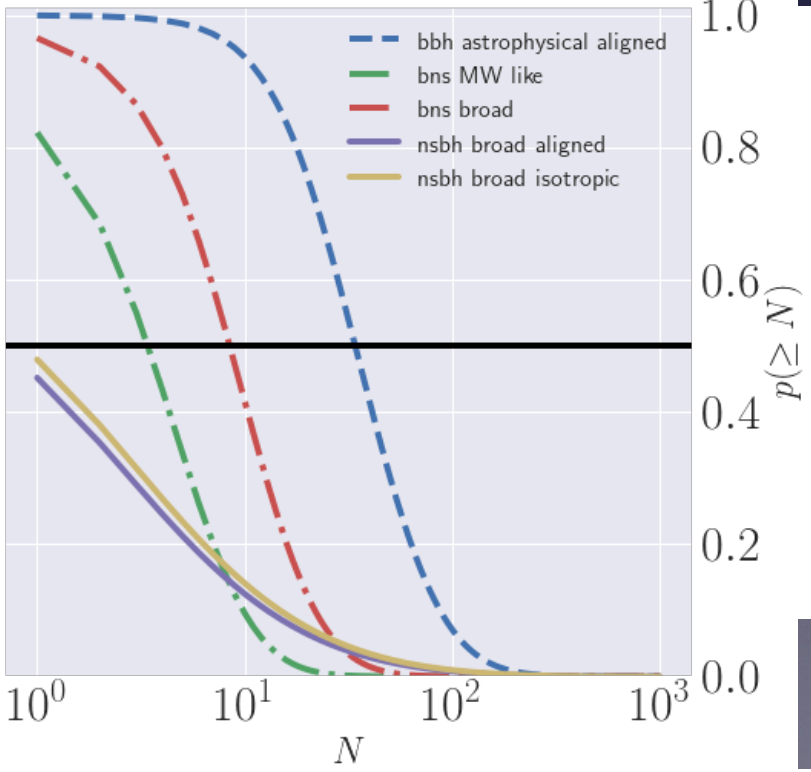
Take Aways

BH-BH rate will **dominate**, possibly by more than an order of magnitude, up to **~few/wk., at least ~few/mo.**

1-10 NS-NS, possibly up to **~1/mo.**

VT has **strong mass dependence** but **very mild dependence** on assumed spin distribution

NS-BH: N=0 not ruled out in any scenario, most give **~50% N>0**



source category	full year VT	N_d
BBH / bbh_astrophysical_aligned	6.8×10^8 Mpc^3 yr	35^{+78}_{-26}
BNS / bns_mw_like	3.2×10^6 Mpc^3 yr	4^{+9}_{-4}
BNS / bns_broad	7.3×10^6 Mpc^3 yr	9^{+19}_{-7}
NSBH / nsbh_broad_aligned	4.9×10^7 Mpc^3 yr	1^{+24}_{-1}
NSBH / nsbh_broad_isotropic	5.7×10^7 Mpc^3 yr	1^{+28}_{-1}

SEE ALSO:
Living Reviews in Relativity (in press)