DESGW PROJECT

Marcelle Soares-Santos
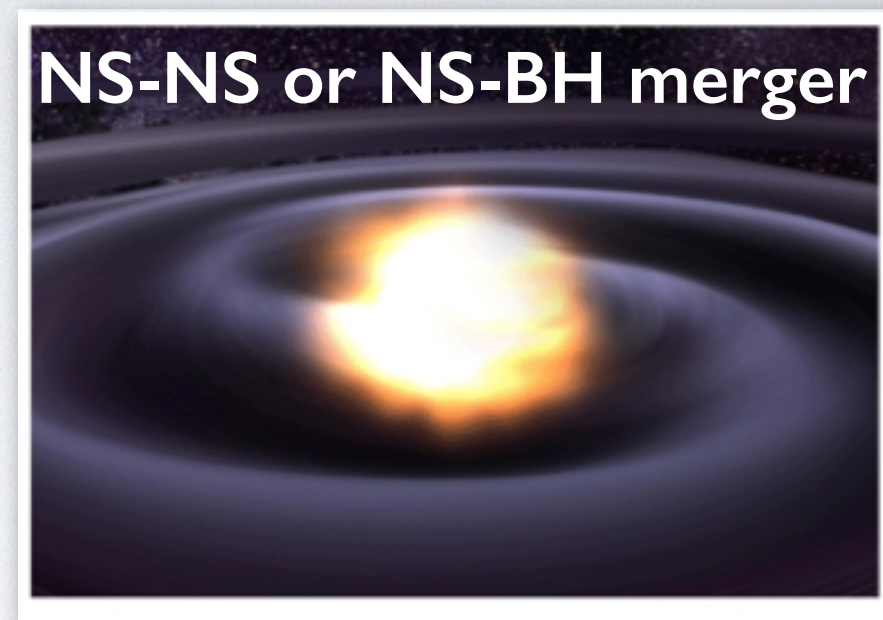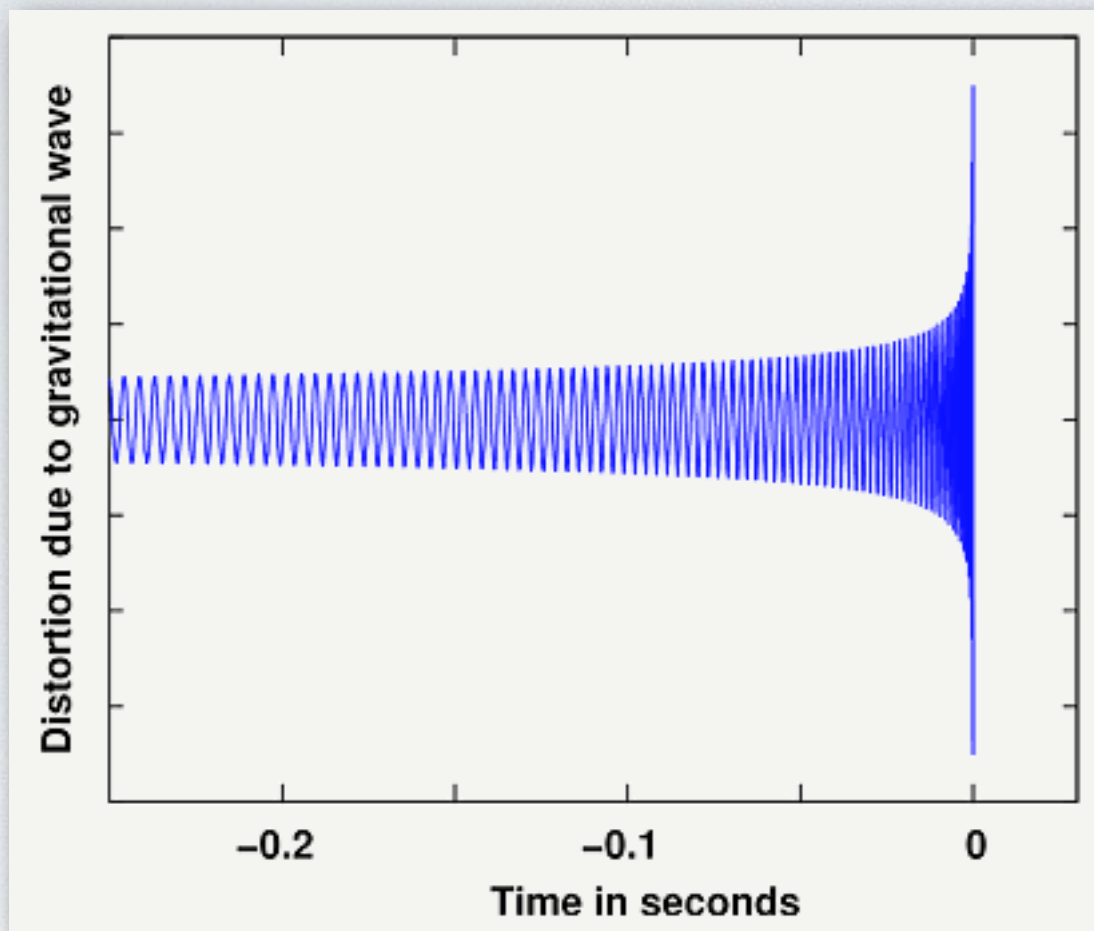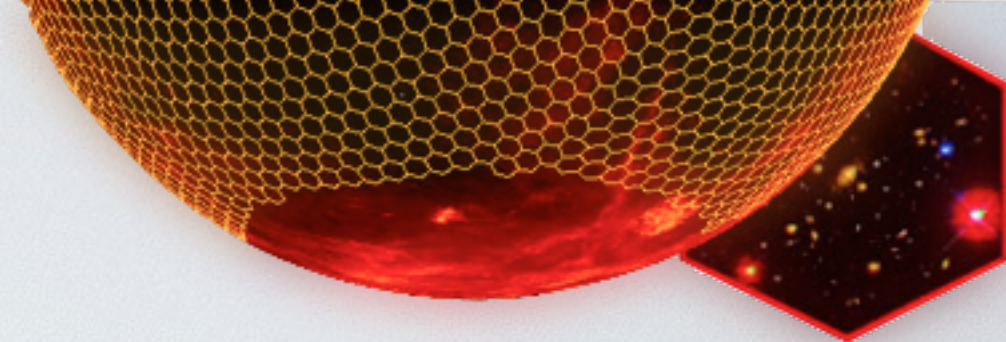
Fermilab

DES Chicagoland Meeting ◆ Argonne ◆ Dec 9, 2014
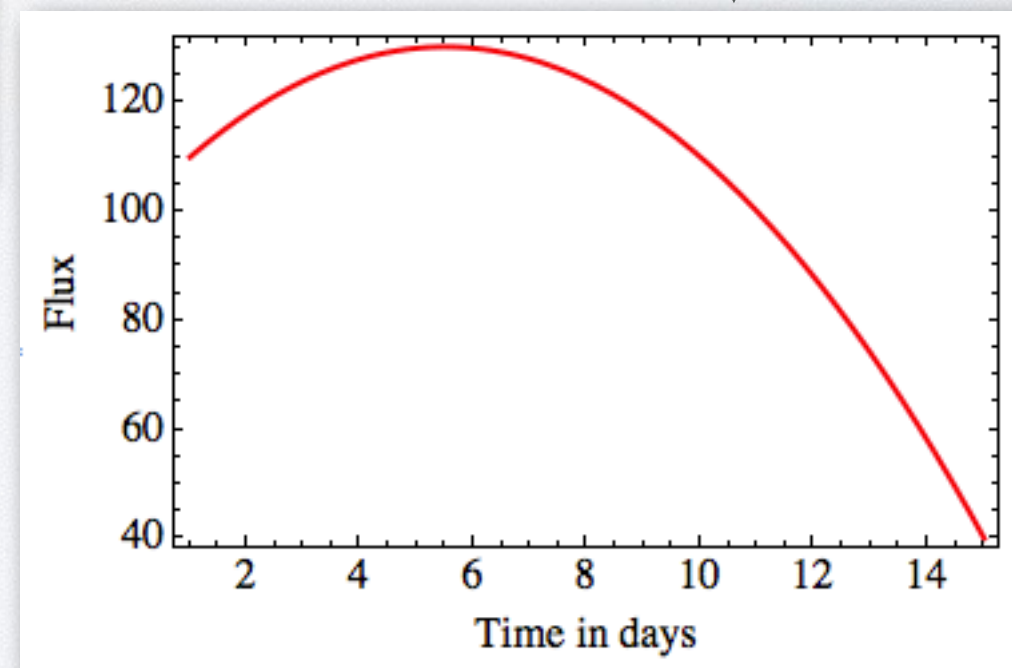
SCIENCE DRIVER

GW

NS-NS or NS-BH merger

↓ EM

ToF experiment
Standard Sirens

GW DETECTORS

The Advanced GW Detector Network

LIGO

Advanced LIGO Hanford 2015

Advanced LIGO Livingston 2015

GEO600 (HF) 2011

Advanced Virgo 2016

LIGO-India ~2021

KAGRA 2017
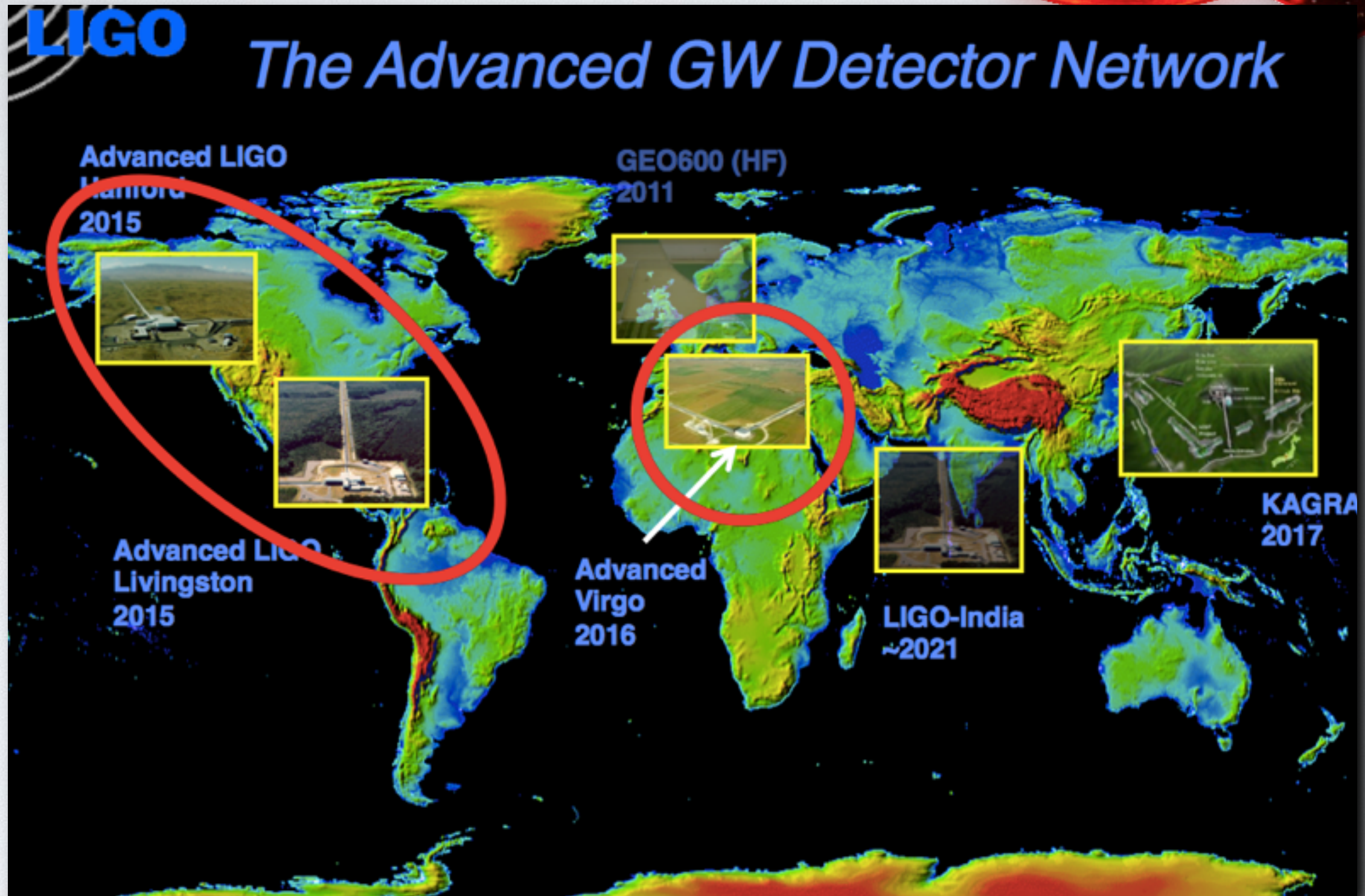
KILONOVAE
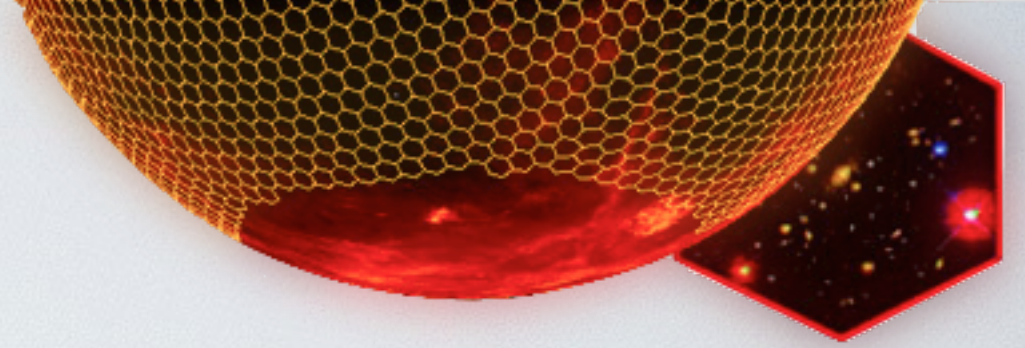
Type Ia supernova light curves are powered by the decay of 56 Ni and 56 Co.

NS-NS merger light curves should be powered by heavier radioactive elements (the Lanthanides) formed via neutron capture by nuclei (r-process nucleosynthesis) as the ejecta decompresses from nuclear densities.

Strong line blanketing at optical wavelengths push the photosphere outward to a cooler layer at T~2500 K where the lanthanides recombine and become more transparent. This causes the SED to be red and peak near 1 micron.

The optical emission is expected to be ~1000 times that of a nova, hence kilo-nova.

The kilonova emission peaks on timescale of 0.5-10 days, optical luminosity of 10^{41}-$10^{42.5}$ ergs/sec and thus r ~ 19-22 mag at the edge of aLIGO/VIRGO volume.

THE OPPORTUNITY

LIGO/VIRGO GW advanced detectors are ramping up over the same time scale of DES observations.

DECam is the only imager capable of timely 24th mag searches over ~60 sq-deg regions in the southern sky.

DES already has "templates" for thousands of sq-deg.

DES has a transient detection pipeline (for SNe) and experience in adaptive scheduling of DECam observations.
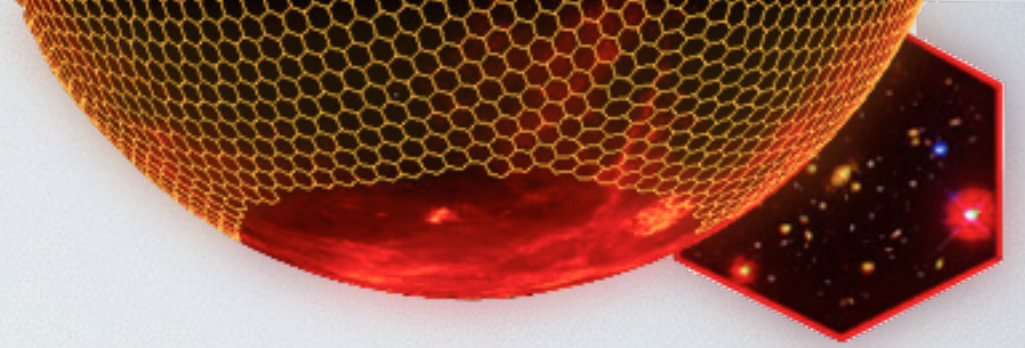
DESGW PROJECT

Initiated in June 2013 (response to LIGO call for LOIs)

Became a DES project in June 2014 (~20 people)

Annis, Bernstein, Desai, Diehl, Finley, Flaugher, Frieman, Gerdes, Goldstein, Gruendl, Kessler, Lin, March, Marriner, Neilsen, Sako, Scolnic, Soares-Santos, Sobreira, Yanny
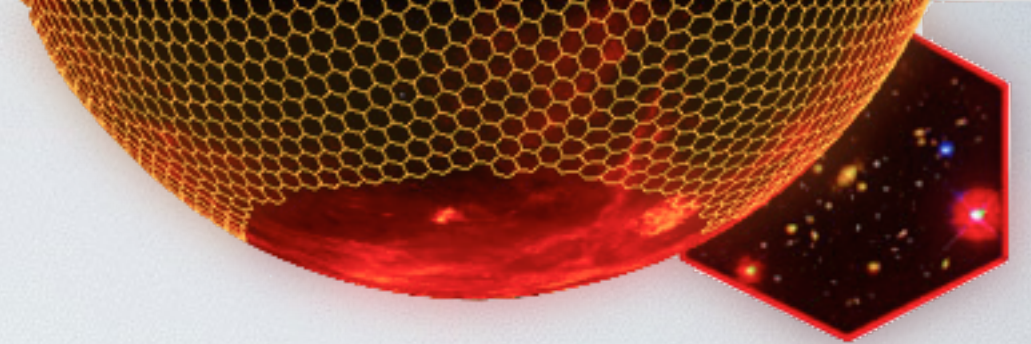
Collaborating w/ Daniel Holz, Hsin-Yu Chen (U Chicago)

Project link in DES wiki: https://cdcvs.fnal.gov/redmine/projects/desgw/wiki

GW DETECTORS

Timeline, detection range, expected # of detections
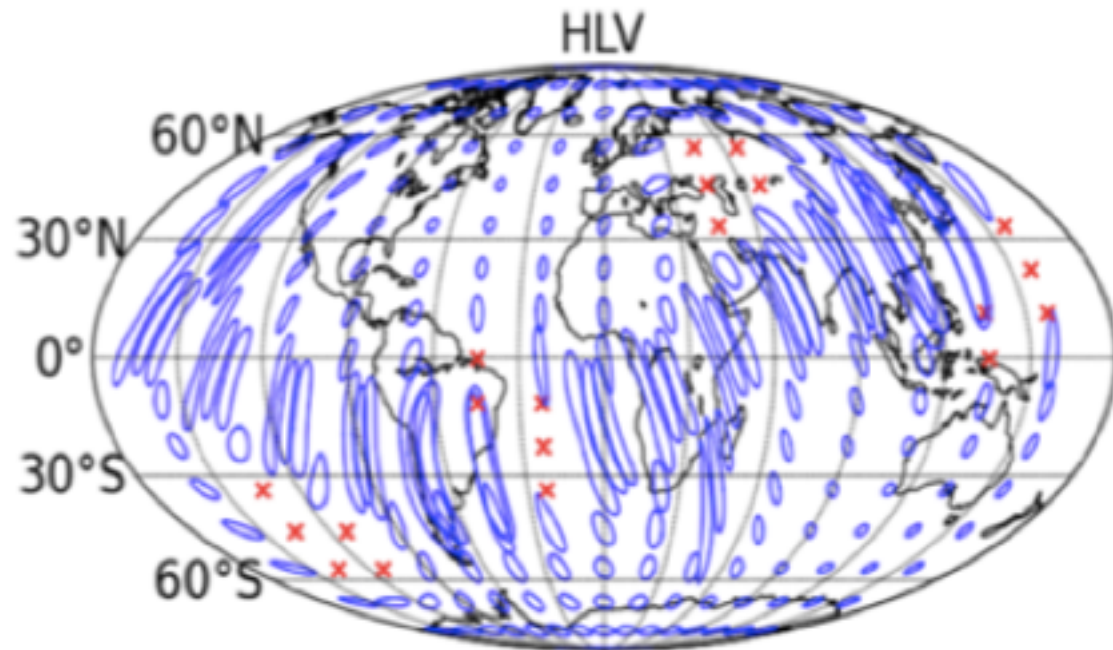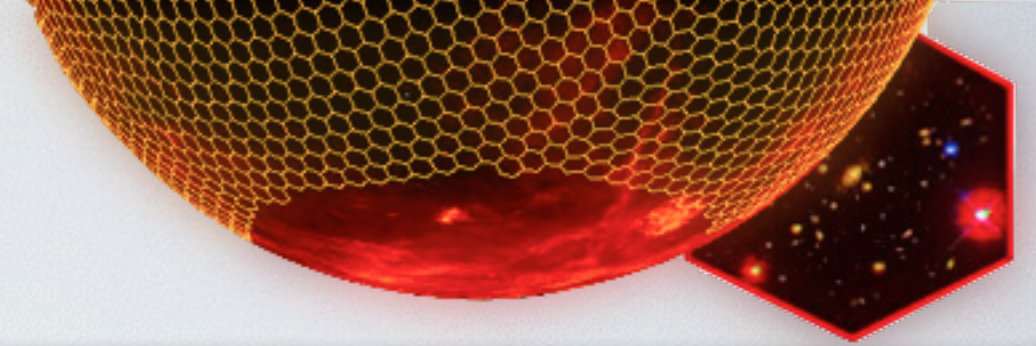
LIGO: arXiv:1304.0670

	Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections	% BNS Localized within	
			LIGO	Virgo	LIGO	Virgo		$5 \deg^2$	$20 \deg^2$
aLigo	2015	3 months	40 − 60	−	40 − 80	−	0.0004 − 3	−	−
aLigo	2016–17	6 months	60 − 75	20 − 40	80 − 120	20 − 60	0.006 − 20	2	5 − 12
aVirgo + aLigo	2017–18	9 months	75 − 90	40 − 50	120 − 170	60 − 85	0.04 − 100	1 − 2	10 − 12
aVirgo + aLigo	2019+	(per year)	105	40 − 80	200	65 − 130	0.2 − 200	3 − 8	8 − 28
	2022+ (India)	(per year)	105	80	200	130	0.4 − 400	17	48

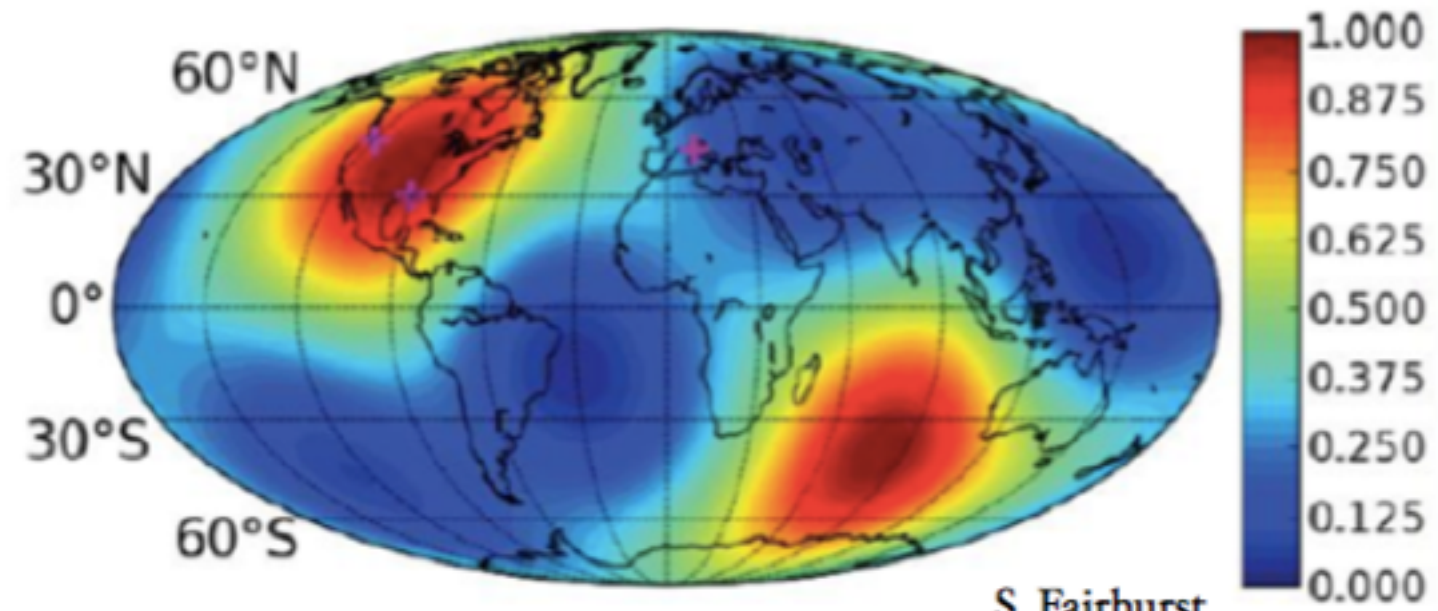There is a (small) chance that LIGO/Virgo will make their first GW detection during Y3-5 of DES observations.

GW TRIGGERS

HLV

LIGO: arXiv:1304.0670

Position localizations

S. Fairhurst

Detection rates

GW events happening during CTIO day have the best chance of being detected and have better localization information.

8-12 hours later, the region of interest will be overhead during the night for DECam observations.

DESGW PROGRAM CONCEPT

GW trigger

time stamp
sky region
distance

DES search system

build template image
schedule observations
take new images
perform image subtraction
detect, model counterpart

- <u>Near term goal</u>: background rate studies, preparations for a 'pilot search' in 2015-2016

- <u>Long term goal</u>: a large scale program for 2016-2019 and beyond

  - DECam — still available after the DES 5-year run

  - LSST — to start in ~2022, faster than DECam

  - Synergy with future neutrino experiments — ToF experiment including neutrinos?

DES & GW PROJECT

Current focus of activities:

Background rate study (w/ SNe data, SNANA simulations)

Use simulated data to develop search strategy

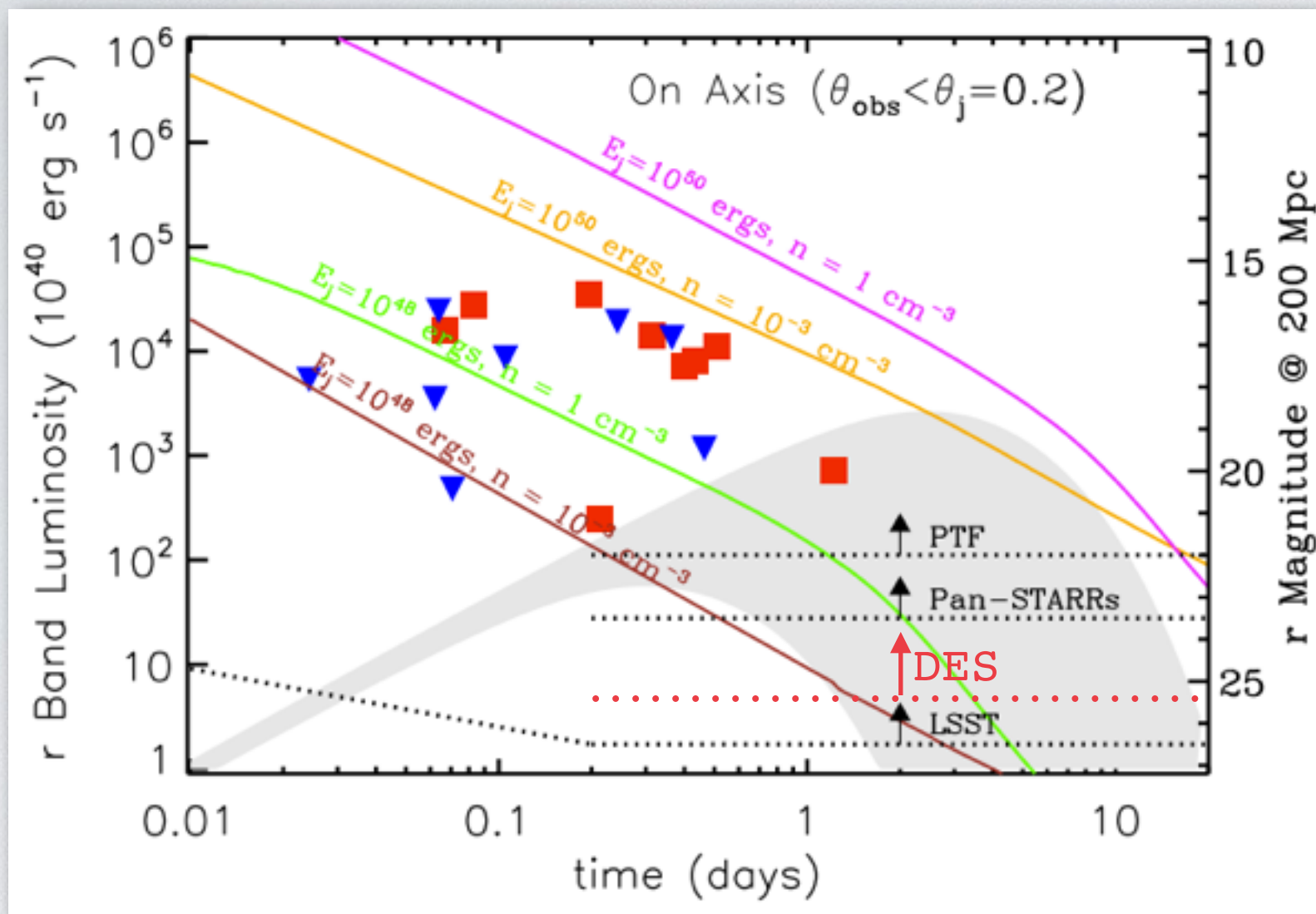Build a search pipeline (image diff in wide survey)

Future steps:

Propose to perform searches in 2015B

KN MODELS

Metzger & Berger 2012

Solid lines: GRB afterglow models

Gray region: KN models range

Fitting function:

$$f(t) = C \frac{(t/t_o)^b}{1 + \exp\left(\frac{t - t_o}{t_c}\right)}$$

KN 'SEARCH'

Initial cuts:
— event duration < 22 days
— 3+ detections @ S/N > 3.5

Characteristic decay time cuts:
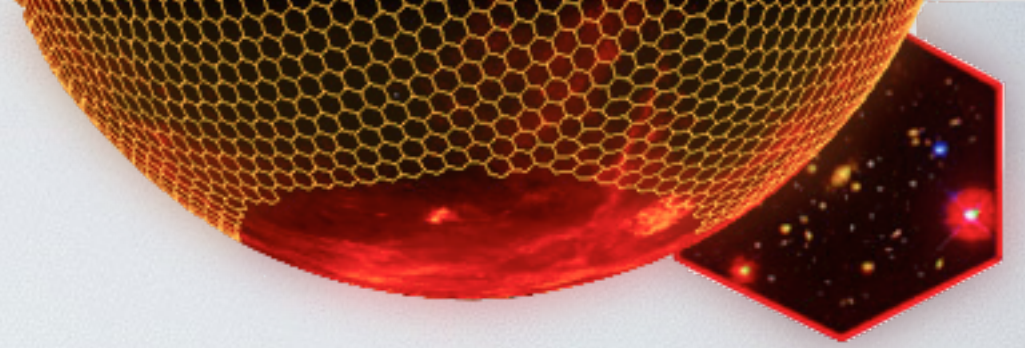— $0.1 < tc < 3$
— $tc\_err < 0.2$

i-band magnitude cuts:
— $i > 22.0$ @ $z = 0.05$
— $i > 23.5$ @ $z = 0.1$

Candidates in SN field E1:

— **1255** after initial cuts

— **28** after tc cuts

  – **26** simulated SN
  – **2** real new events

— **0** after mag cuts

Next step:
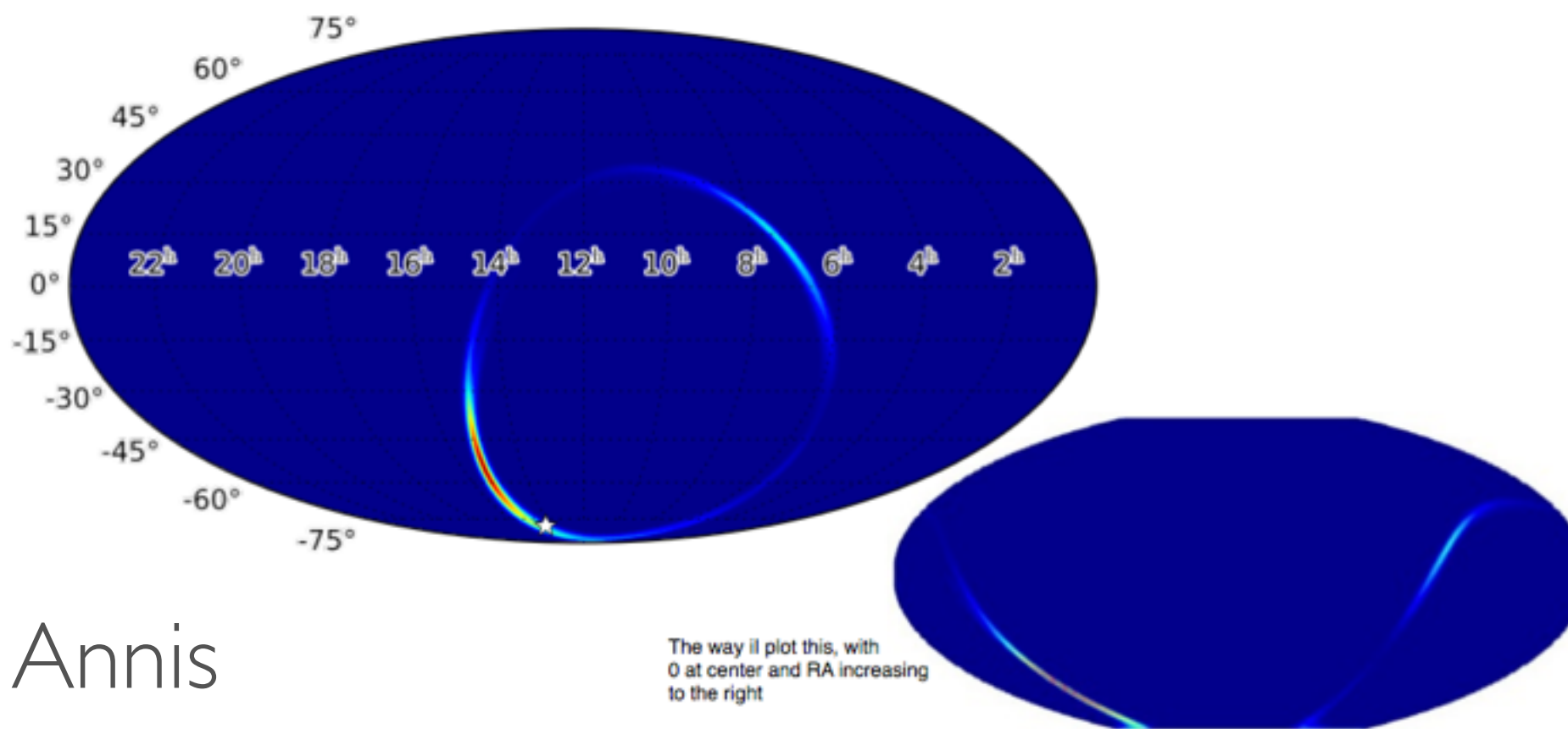Determine the background rate using simulated KN events.

J. Annis
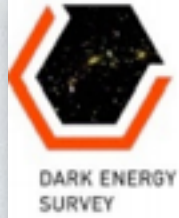
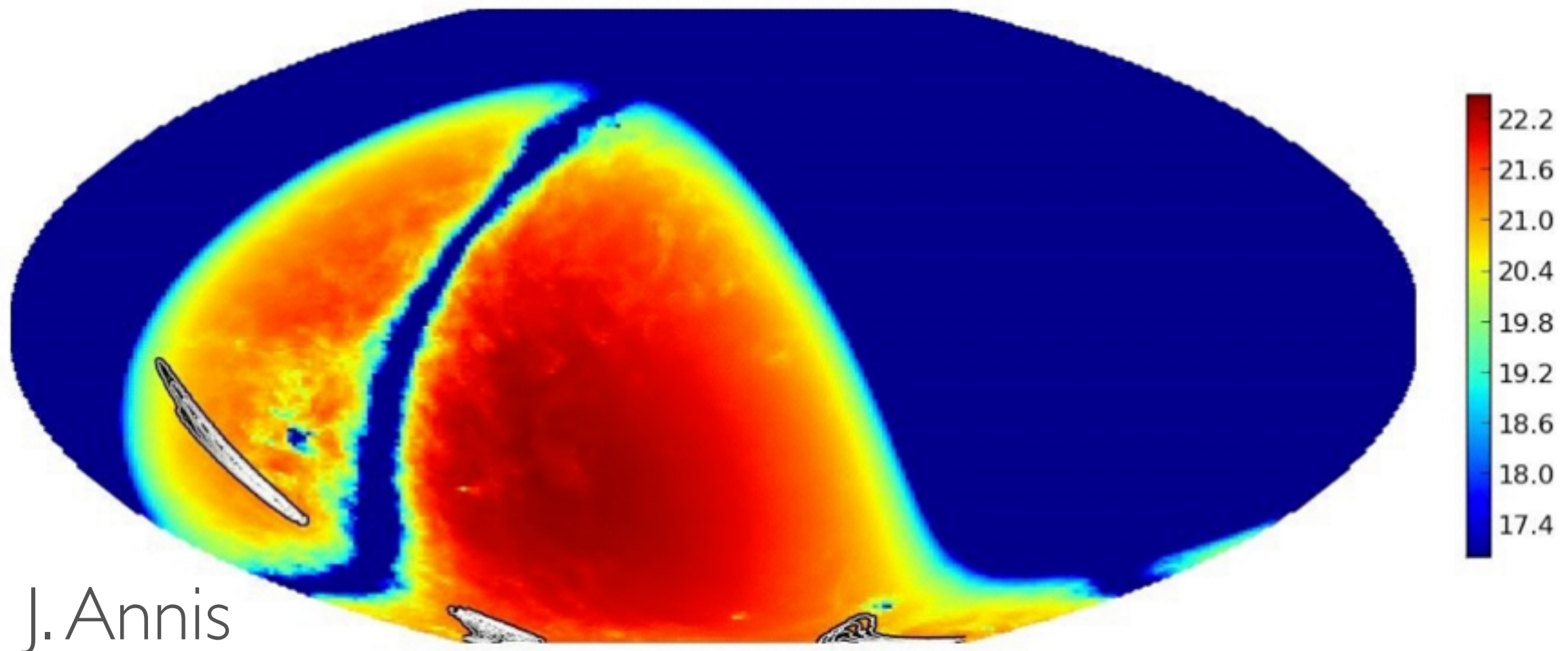Limiting mag map + Probability of finding contours

J. Annis

PROCESSING PIPELINE

— Image subtraction in the wide survey is of interest to various groups/projects in DES: SNe, KBO, GW…

— Ramping up on existing effort by Masao, Kessler and others in the SN working group.

— We have resources to make production processing happen at Fermilab, using the FermiGrid.

— Next steps: work on pipeline, test on SNe field, make a "mock observing run".

DIFF IMG EXAMPLE

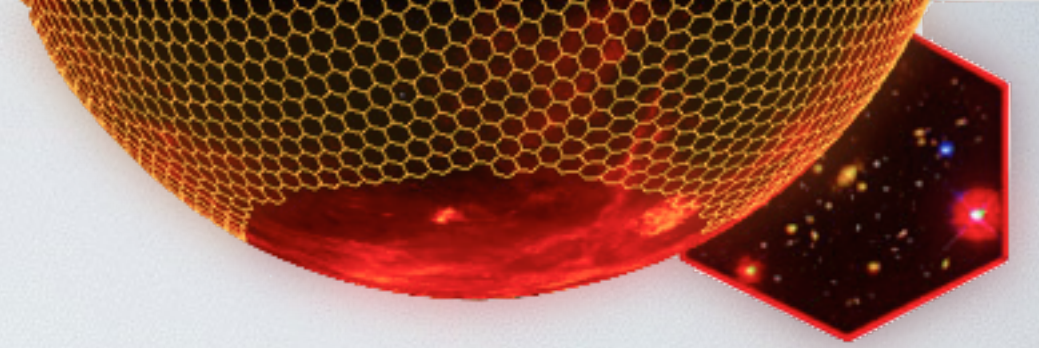search

template
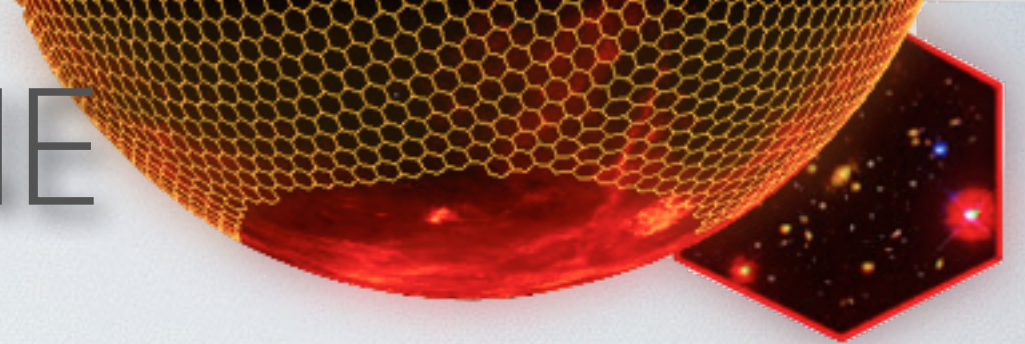
difference
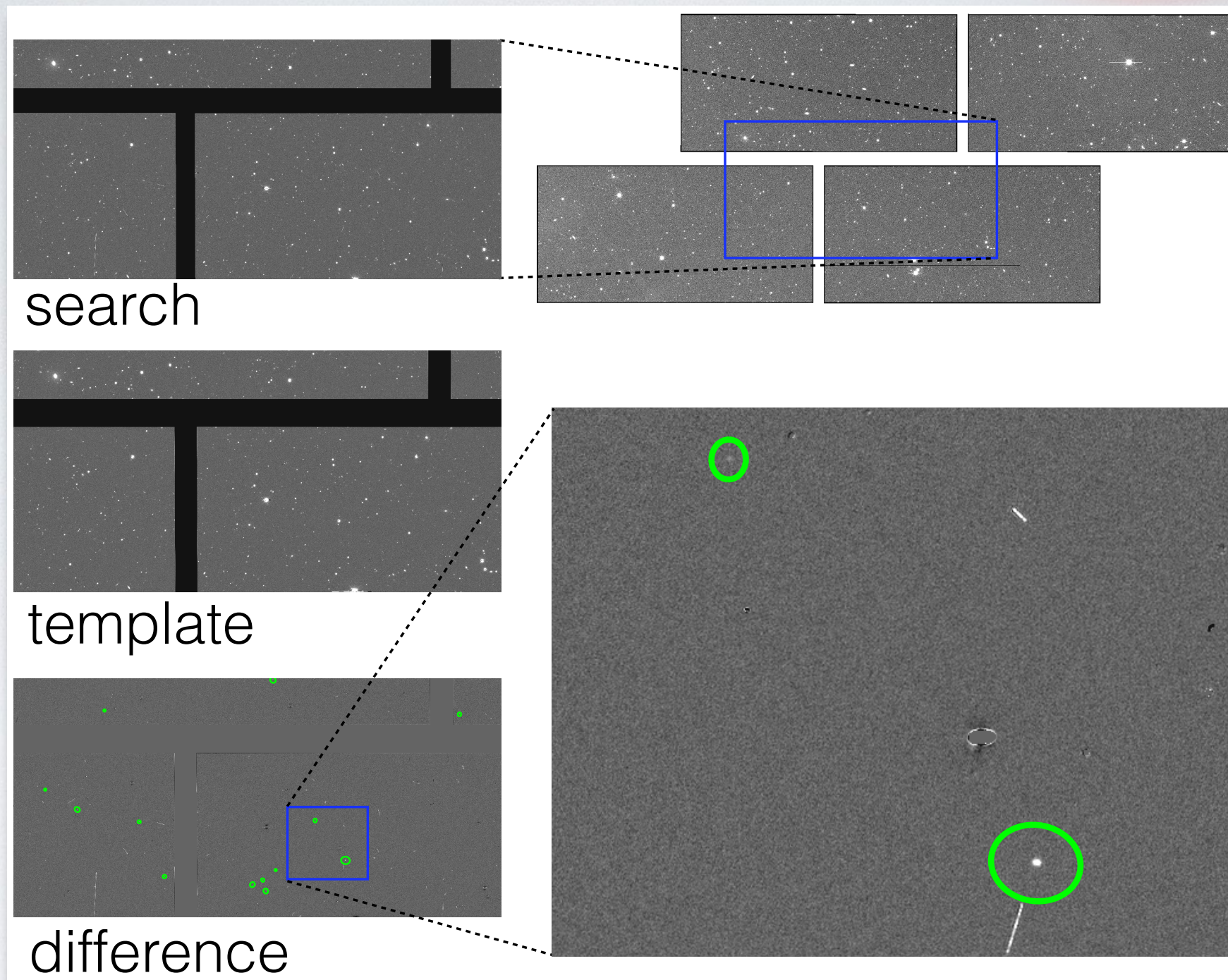
M. Sako

PROPOSAL

Ideal case: **TOO multi-year program**

A more conservative approach:
~5-10 nights added to nominal 105 DES nights in 2015B (interruptions handled internally by the collaboration)

Our current efforts should lead to a strong statement about our ability to accomplish the science goals in either case.

Deadline: March 2015.

DESGW WORKSHOP

— Spring 2015 (possibly pre-Michigan satellite meeting)

— Hosted at Fermilab

—Topics:
  — Results of background rate study (publication)
  — Progress on image subtraction pipeline
  — Proposals for pilot search program
  —LIGO/Virgo status and plans (invite a LIGO speaker)