Fermilab

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Dark Energy Survey on the OSG

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OSG All-Hands Meeting

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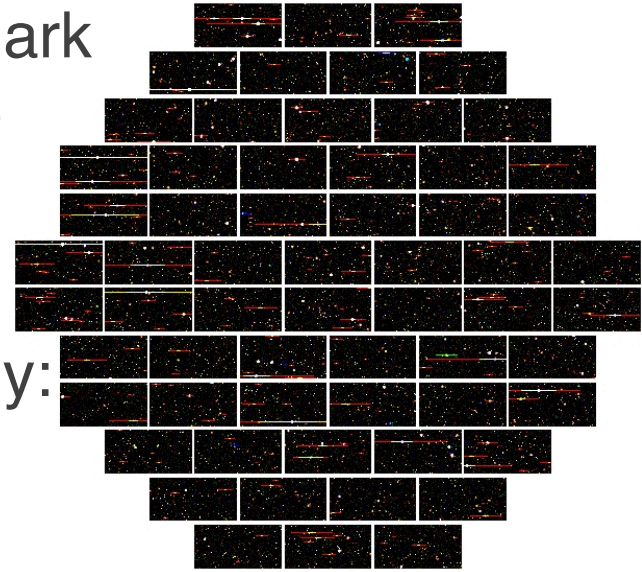
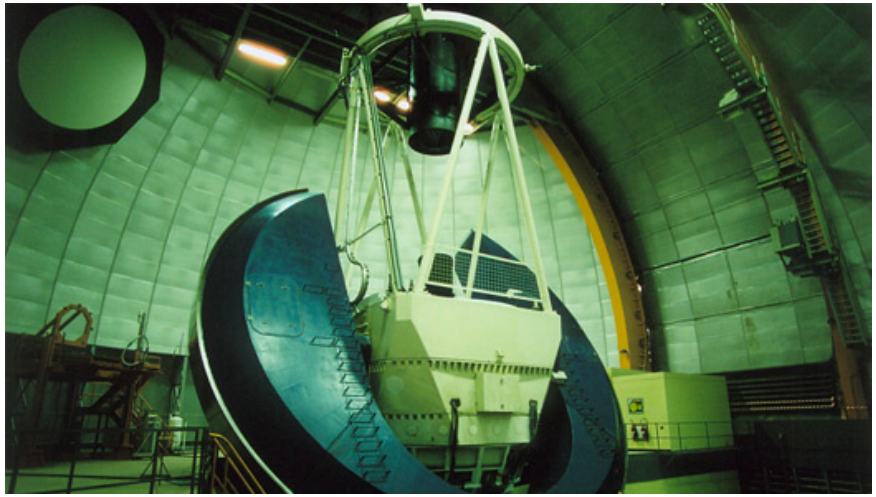
Credit: T. Abbott and NOAO/AURA/NSF

The Dark Energy Survey: Introduction

THE DARK ENERGY SURVEY

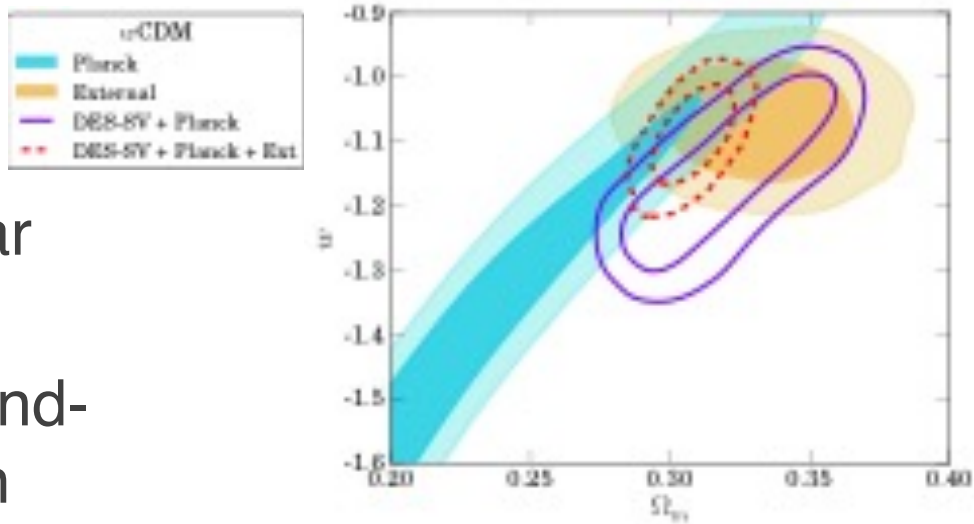
- Collaboration of 400 scientists using the Dark Energy Camera (DECam) mounted on the 4m Blanco telescope at CTIO in Chile
- Currently in fourth year of 5-year mission
- Main program is four probes of dark energy:
  - Type Ia Supernovae
  - Baryon Acoustic Oscillations
  - Galaxy Clusters
  - Weak Lensing
- A number of other projects e.g.:
  - Trans-Neptunian/ moving objects

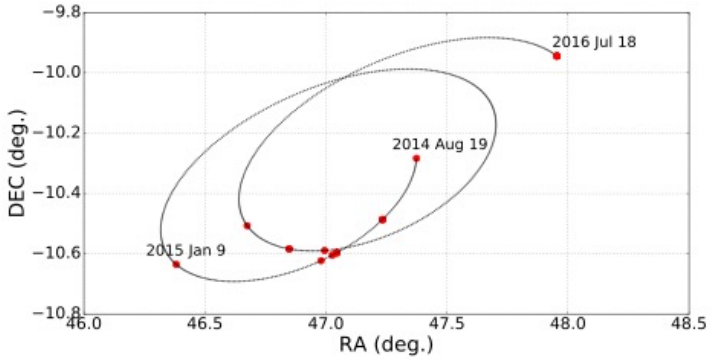


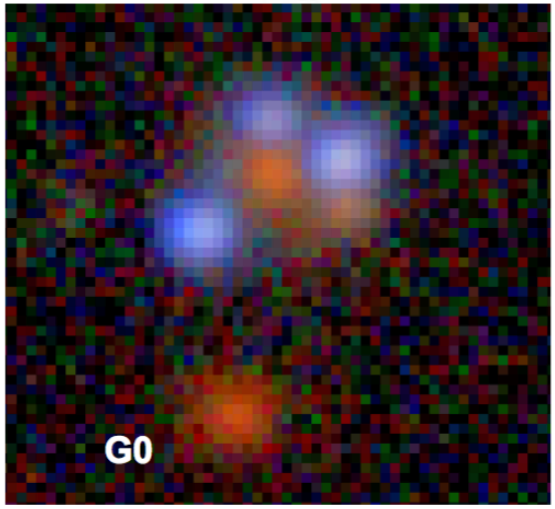


Recent DES Science Highlights (not exhaustive)

- Cosmology from large-scale galaxy clustering and cross-correlation with weak lensing
- First DES quad-lensed quasar system
- Dwarf planet discovery (second-most distant Trans-Neptunian object)
- Optical Follow-up of GW triggers

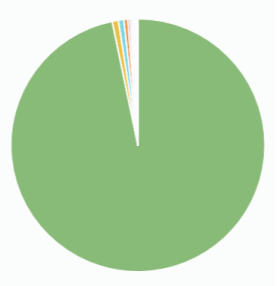






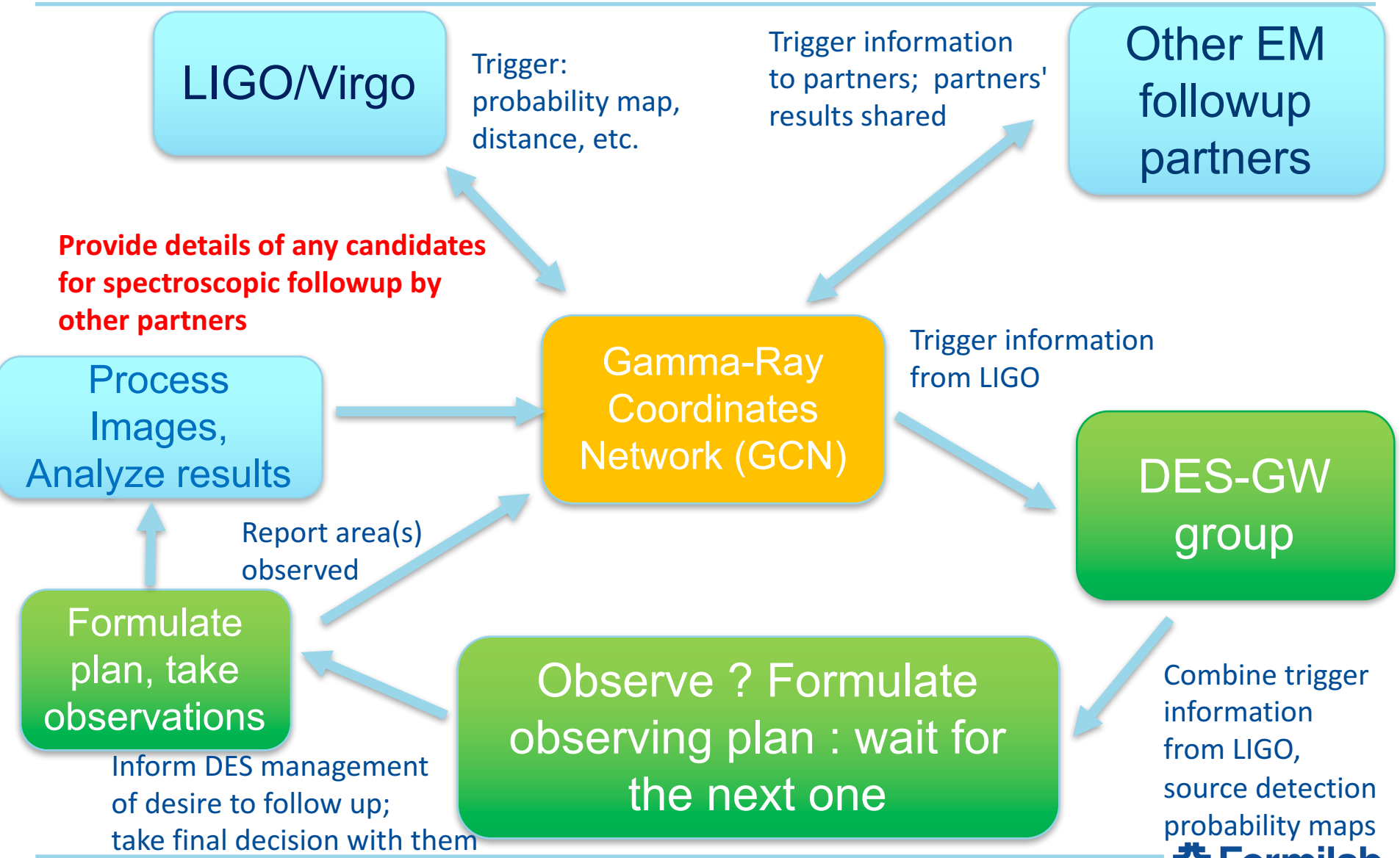
Overview of DES computing resources

- About 3 dozen rack servers, 32-48 cores each, part of FNAL GPGrid but DES can reserve them. used for nightly processing, reprocessing campaigns, and deep coadds (64+ GB RAM)using direct submission from NCSA.
- Allocation of 980 "slots" (1 slot = 1 cpu 2 GB RAM) on FNAL GPGrid, plus opportunistic cycles
- OSG resources (all sites where Fermilab VO is supported)
- NERSC (not for all workflows)
- Various campus clusters
- Individuals have access to FNAL Wilson (GPU) Cluster
  - Difficult to run at scale due to overall demand
- By the numbers:
  - 2016: 1.98 M hours; 92% on GPGrid
  - 2.42 M hours last 12 months; 97% GPGrid
  - Does not count NERSC/campus resources
  - Does not count NCSA->FNAL direct submission



GPGrid	2339150
CIT_CMS_T2	19071
GLOW	16686
USCMS-FNAL-WC1	11923
Clemson-Palmetto	6933
AGLT2	5567
Nebraska	3351
SU-OG-CE	2553
MWT2	2321
SU-OG-CE1	2207
Crane	1609
HOSTED_STANFORD	1371
Sandhills	1295
MIT_CMS	955
Fermicloud	819
SU-OG	777
Tusker	498
UCSDT2	271
NYSGRID_CORNELL_NYS1	234
FNAL_HEPCLOUD	84

Overview of GW EM followup



Difference Imaging Software (GW Follow-up and TNOs)

- Originally developed for Supernova studies
- Several ways to get GW events
- DES is sensitive to neutron star mergers or BH-NS mergers (get an optical counterpart), core collapse
- Main analysis: use “difference imaging” pipeline to compare search images with same piece of sky in the past (i.e. look for objects that weren’t there before)

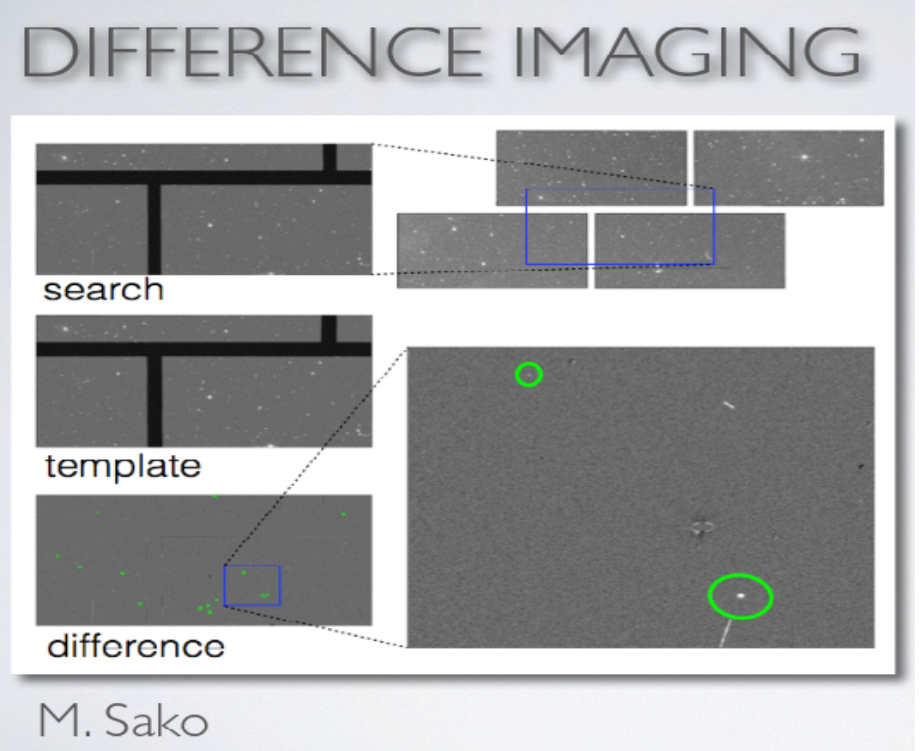


Image analysis pipeline

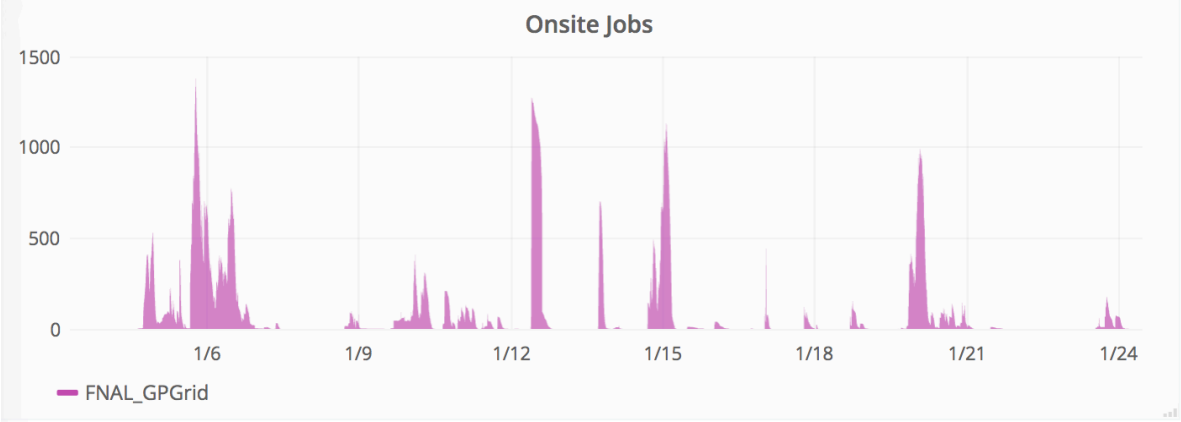
- Each search and template image first goes through “single epoch” processing (few hours per image). About 10 templates per image on average (some overlap of course)
  - New since last AHM: SE code somewhat parallelized (via joblib package in Python.) Now uses 4 cpus and 3.5 – 4GB memory; up to 100 GB local disk. **Run time is similar or shorter despite additional new processing/calibration steps.**
  - Increased resource requirements don't hurt as much because memory per core actually went down.
- Once done, run difference imaging (template subtraction) on each CCD individually (around 1 hour per job, 2 GB RAM, ~50 GB local disk)
- Totals for first event: about 240 images for main analysis *59 CCDs per image (3 unusable) over three nights = about 5000 CPU-hours for diffimg runs needed per night
  - Recent events have been similar
- File I/O is with Fermilab dCache

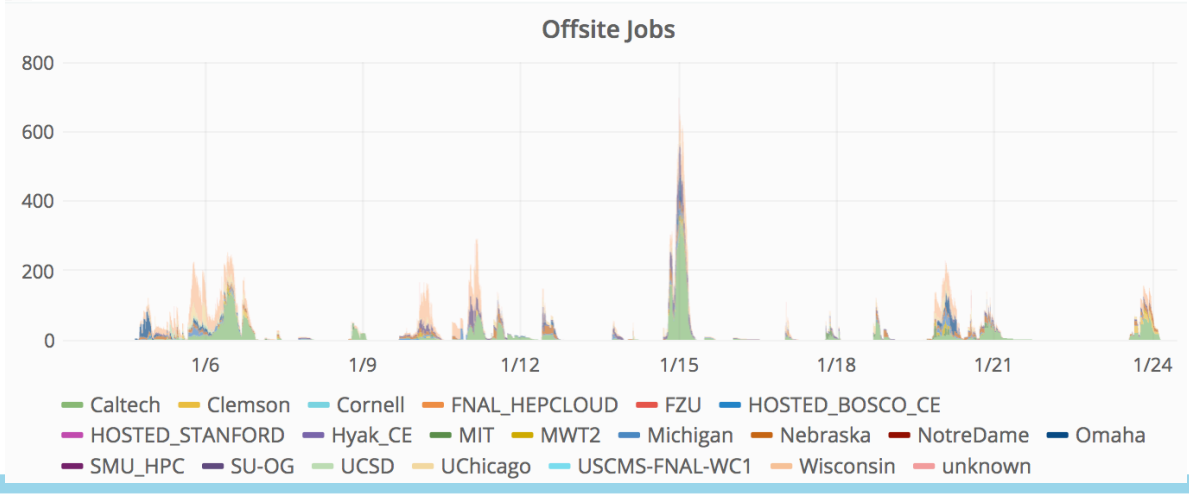
The Need for Speed

- 6k CPUs is not that much in one day, but one can't wait a long time for them. Want to process images within 24 hours (15 is even better) **allowing DES to send alerts out for even more followup while object is still visible.** First event was over a longer period.
- Necessitates opportunistic resources (OSG); possibly Amazon/Google at some point if opportunistic resources unavailable
  - Did a successful AWS test last summer within FNAL HEPCloud demo

Current GW Follow-up Analysis

- Followup analysis ongoing for most recent public LIGO trigger.
- OSG job fraction somewhat higher than last year (increased GPGrid usage by FIFE/DES? More multicore jobs? Both?)





Peak OSG fraction about 40%

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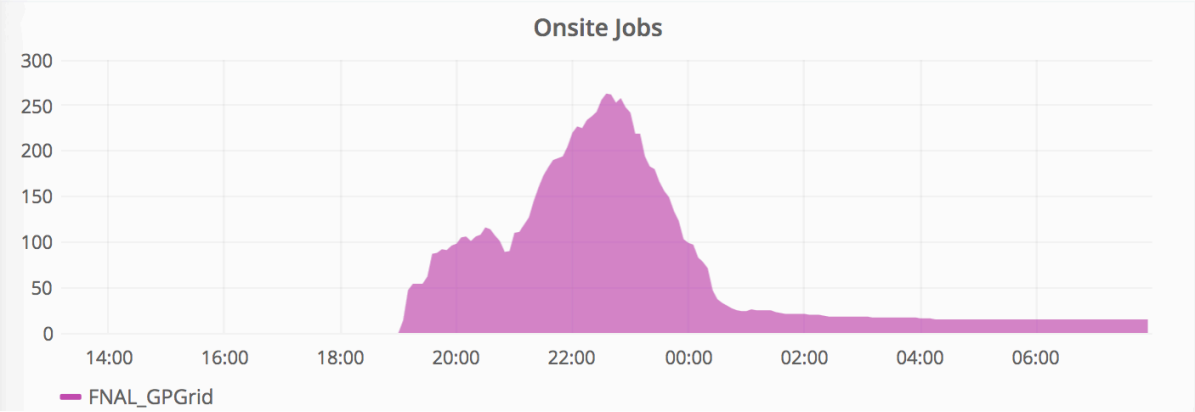
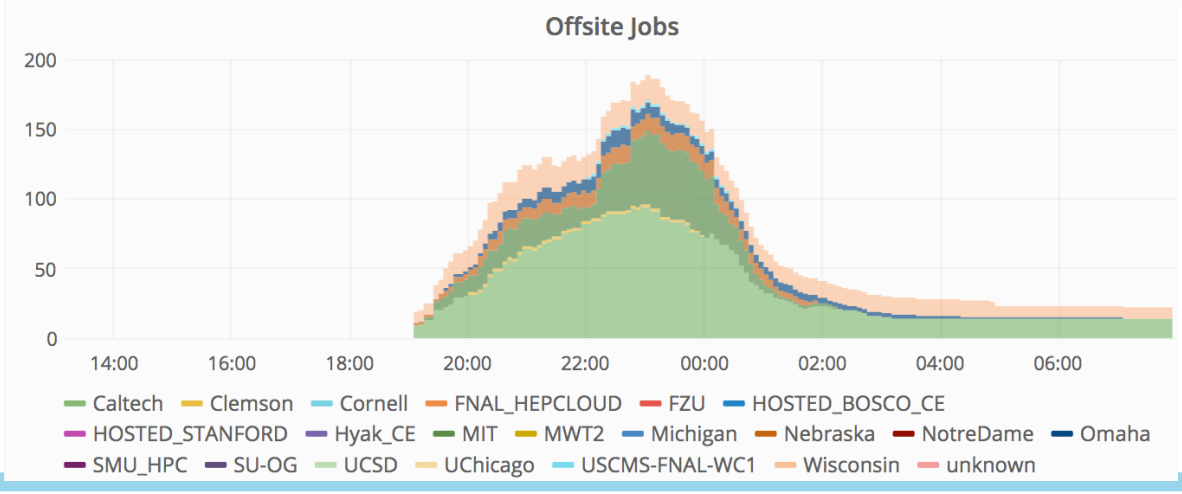


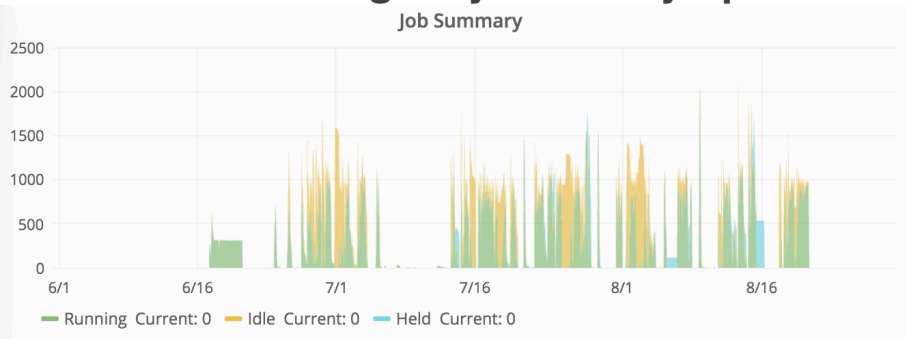


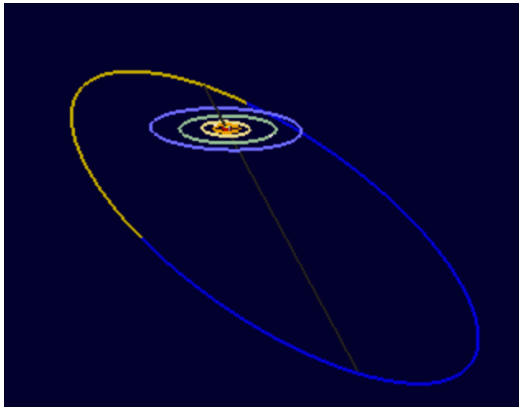
Peak OSG fraction about 40%

Here: SE jobs only (4 cpu)

Dwarf Planet Discovery

- DES researchers found dwarf planet candidate 2014 UZ224 (currently nicknamed DeeDee)
  - D Gerdes et al., https://arxiv.org/abs/1702.00731
- All code is OSG ready and is basically the same as SE + diffimg processing with very minor tweaks
  - After diffimg identifies candidates then other code makes "triplets" of candidates to verify that the same thing's seen in multiple images
  - Main processing burst was July-August when FNAL GPGrid was under light load, so >99% of jobs ended up on GPGrid
    - Required resources would have exhausted NERSC allocation; **FNAL w/OSG as contingency was only option**





Made at Minor Planet Center site:
http://www.minorplanetcenter.net/db_search/show_object?utf8=%E2%9C%93&object_id=2014+UZ224

Future Directions

- Have written tool to determine template images given only a list of RA,DEC pointings, and then fire off single-epoch processing for each one (run during day before first observations)
- Incorporate DAG generation/job submission script into automated image listener (re-write in Python?) so everything is truly hands-off
- Working on ways to reduce job payload (we are I/O limited)
  - A few more things now in CVMFS
  - Not sure cache hit rates would be high enough for StashCache to help with input images
- **Applying same techniques to Planet 9 search**

Additional Workflows on the OSG

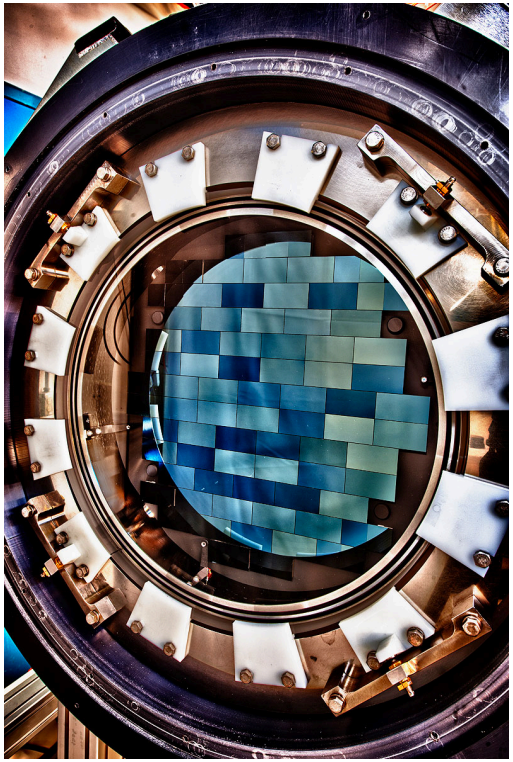
- Several new workflows now OSG-capable
  - SN analysis: < 2 GB memory, somewhat longer run times due to heavy I/O (tens of GB) requirements. Nearly always run on GPGrid now, but not necessary
  - Simulations (some fit into usual 2 GB RAM slots)
  - Other workflows require 4-8 GB memory; being run at FNAL right now. Not a requirement but difficult to get such high-mem slots in general
- Other workflows include:
  - Deep learning in galaxy image analysis
  - COSMOSIS (cosmological parameter estimation): http://arxiv.org/abs/1409.3409

OSG benefits to DES

- When it works, it's great!
- Biggest issues are the usual pre-emption, network bandwidth
  - Most DES workflows (at least so far) are **very** I/O limited: some workflows transfer several GB of input
  - expect StashCache to somewhat mitigate the problem, but only to a point
  - Still have to copy a lot of images around (currently most SW doesn't support streaming)
- HPC resources may make more sense for other workflows (though having easy ways to get to them is really nice!)
  - Some analyses have MPI-based workflows. Works well when able to get multiple machines (not set up for that right now)
- Strong interest in additional GPU resources. DES will work with FIFE expts on common tools for OSG GPU access

Summary

- Lots of good science coming out of DES right in multiple areas
- OSG is and will be an important resource provider for the collaboration
- Opportunistic resources are critical for timely GW candidate follow-ups and TNO searches (i.e. Planet 9)
- Trying to get additional workflows on to OSG resources now
- Very interested in additional non-HTC resources (MPI and GPUs especially.) OSG could be a great resource provider here



Credit: Raider Hahn, Fermilab

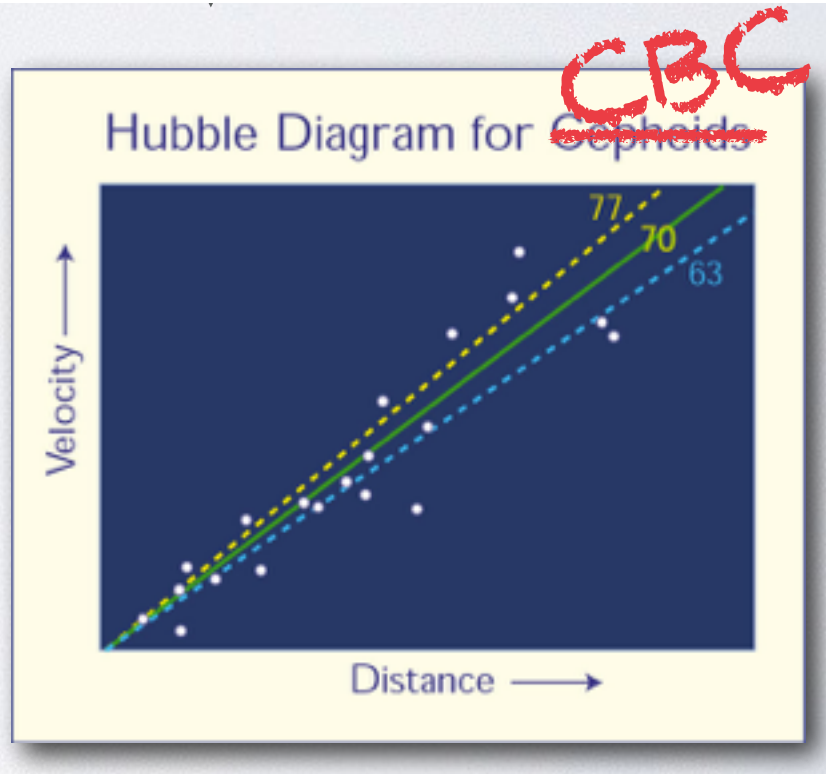
Dataflow and Day-to-Day Operations With Grid Resources

- Dedicated ground link between La Serena and main archive at NCSA (transfer is a few minutes per image)
- Nightly processing occurs at FNAL
  - Submitted from NCSA to FNAL GPGrid cluster via direct condor submission
  - Reprocessing campaigns (additional corrections, etc.) underway at FNAL

Motivation for Optical follow-up of GW events

- The "golden channel" is merger of two neutron stars, with the GW component detected by LIGO and the EM component detected by a telescope
- If one can observe both the GW and EM component, it opens up a lot of opportunities

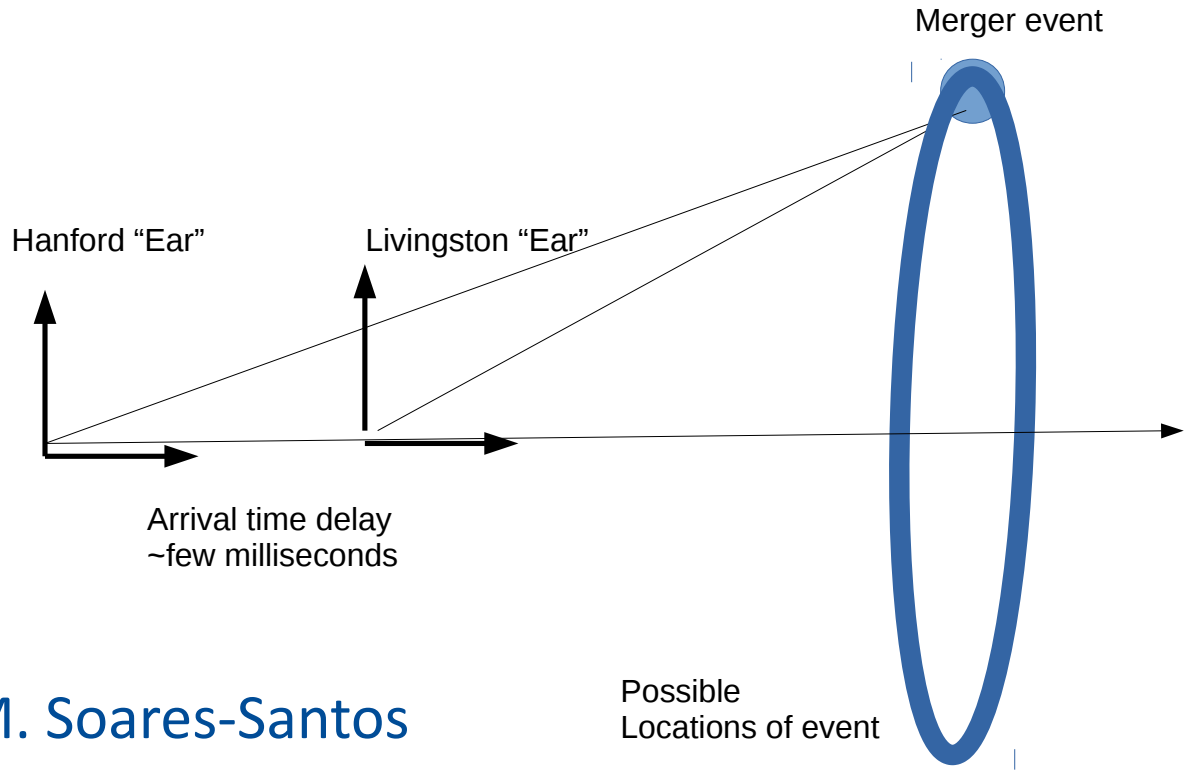
GW gives distance
EM counterpart gives redshift
(from host galaxy)
Together they give a new
way to measure Hubble parameter



CBC = Compact Binary Coalescence

Event Localization

- Similar to how our ears work
- With 2 detectors area can still be hundreds of sq. deg.
- With Virgo detector, would be localized to few tens of sq. deg.



M. Soares-Santos