

Skynet Virtual Observatory and Multi-Messenger Astronomy

Tom Finkenbinder,
September 8, 2018

Great to be With You –
Celebrating 14 Years of AHSP
at Spruce Knob



What “PROMPT”ed Skynet began with satellite missions to study Gamma Ray Bursts

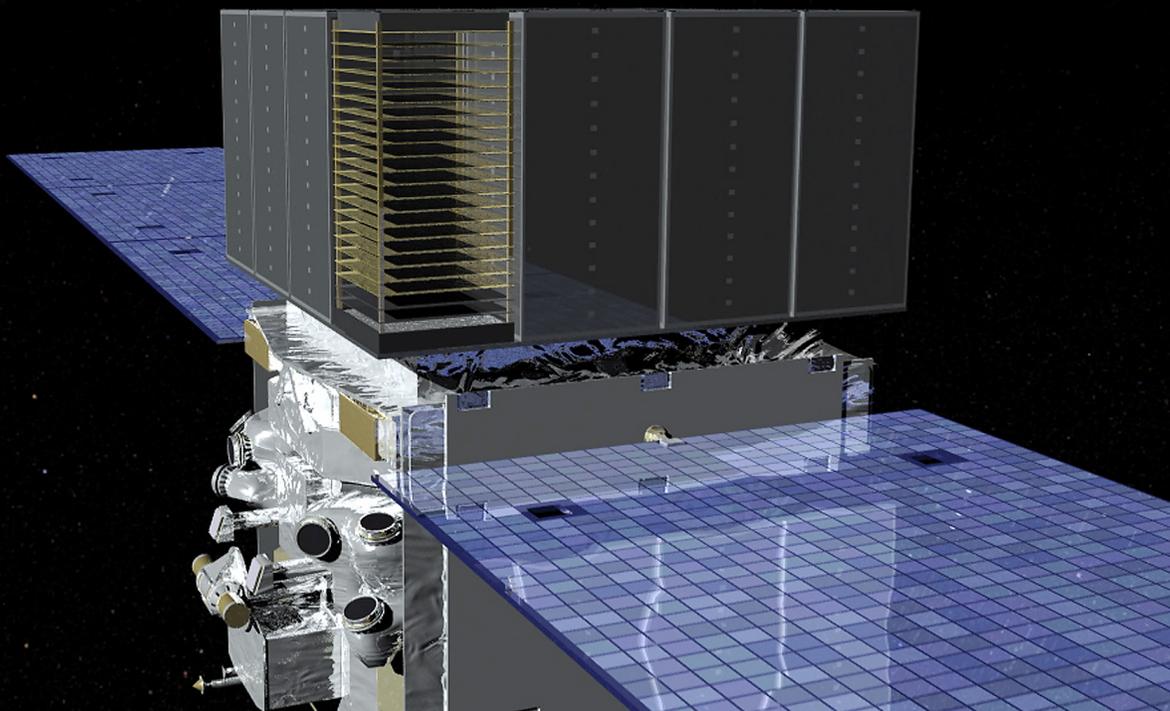
- High energy gamma photons scatter in Earth’s atmosphere so they can only be observed in space.
- Vela satellites (US Army) and SALT I & II Treaty Enforcement in the 1960’s.
- Early scientific missions included the Compton Gamma Ray Observatory and the Burst and Transient Source Explorer (BATSE).
- Current missions include Swift, FERMI and INTEGRAL, the earliest launched in 2004.



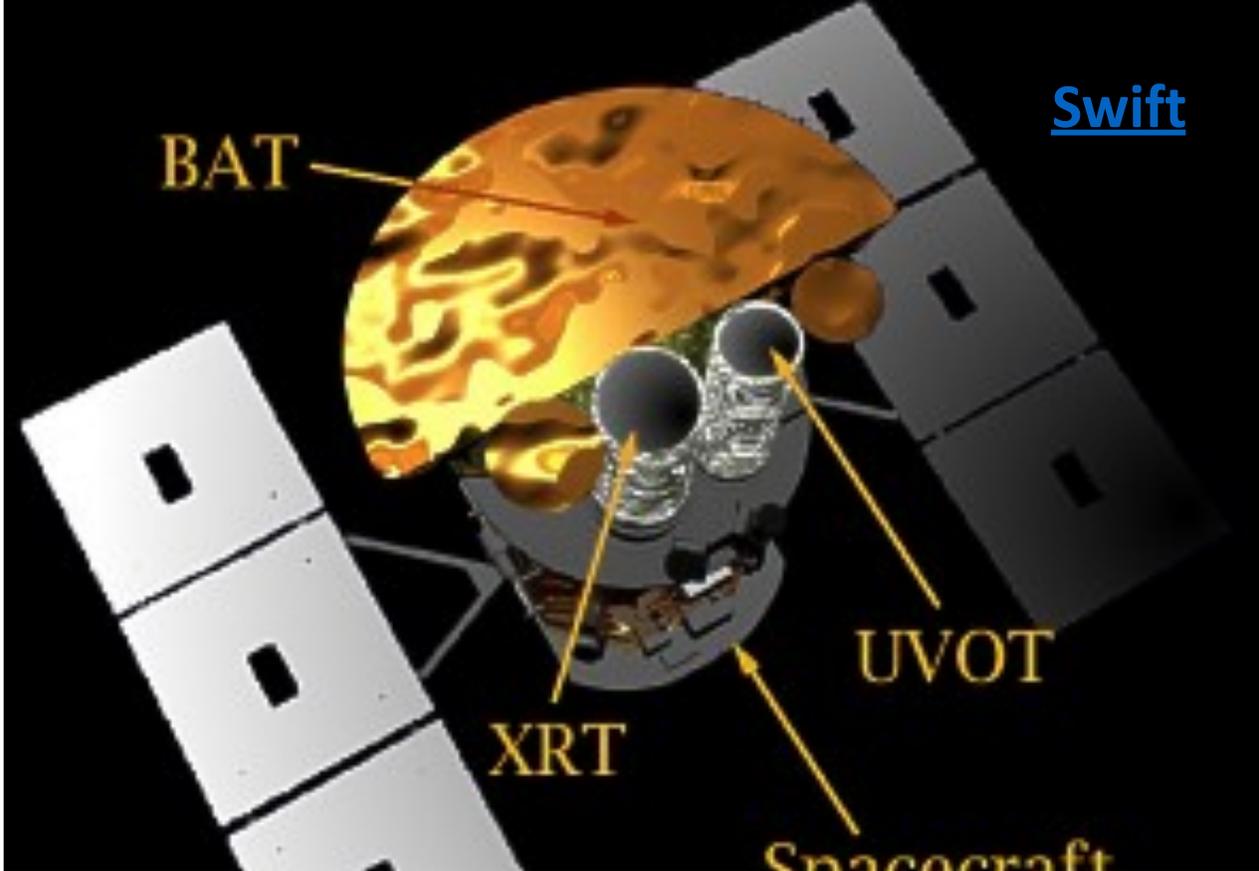
Photon Detection

- Gamma Ray Bursts don't produce observable photons elsewhere on the EM spectrum but they do many times light up everything around them for a short period of time, we call this 'afterglow'.
- PROMPT is an acronym for "Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes."
- The University of North Carolina won a grant from the NSF to build a group of robotic, and Internet-connected telescopes in the Chilean Andes.
- The mission is rapid response to observe GRB afterglow, the dust and gas impacted by the raw energy of the cataclysm in vicinity of the burst.

Fermi



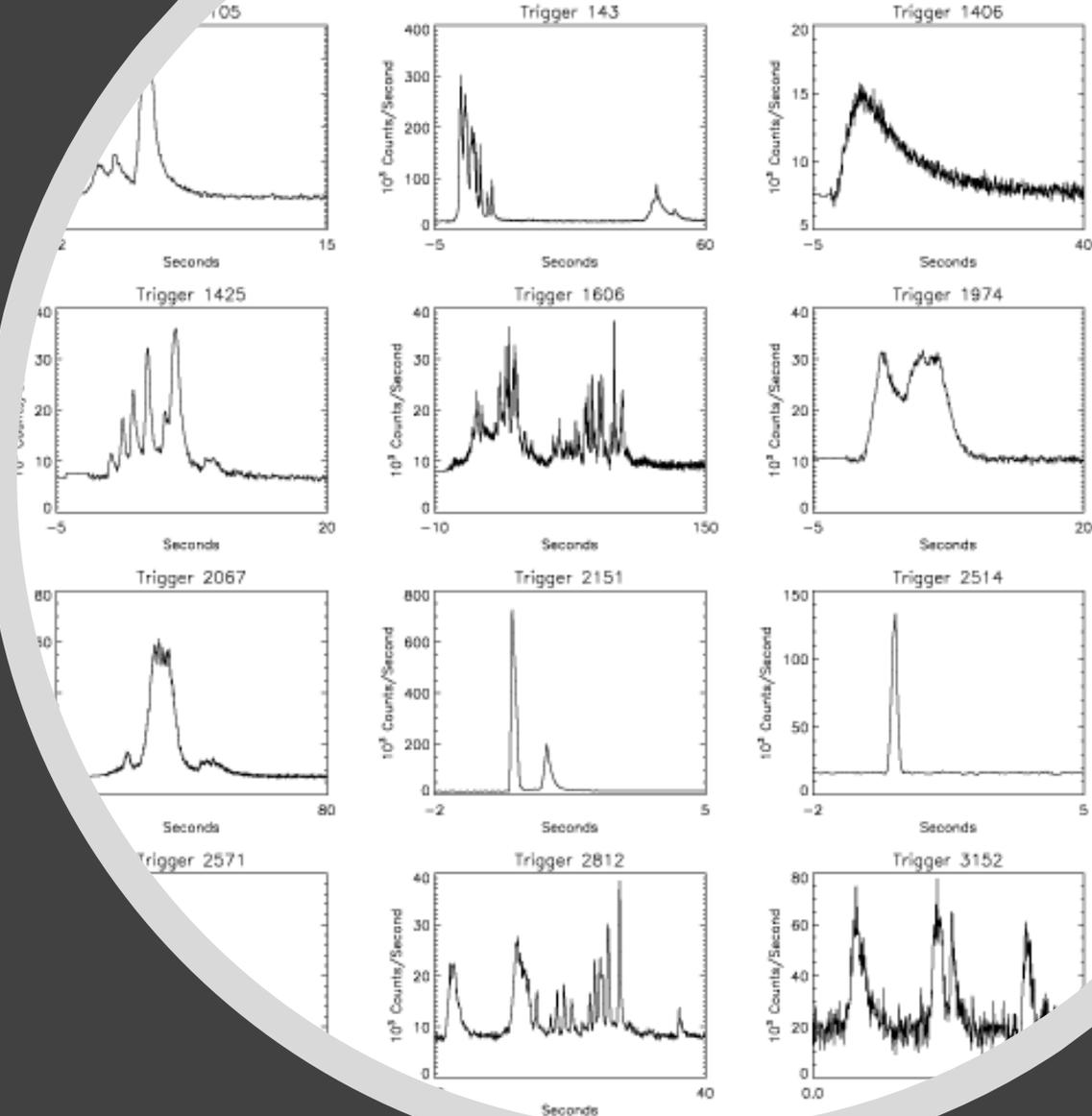
Swift



HEASARC - NASA's High Energy Astrophysics Science Archive and Research Center

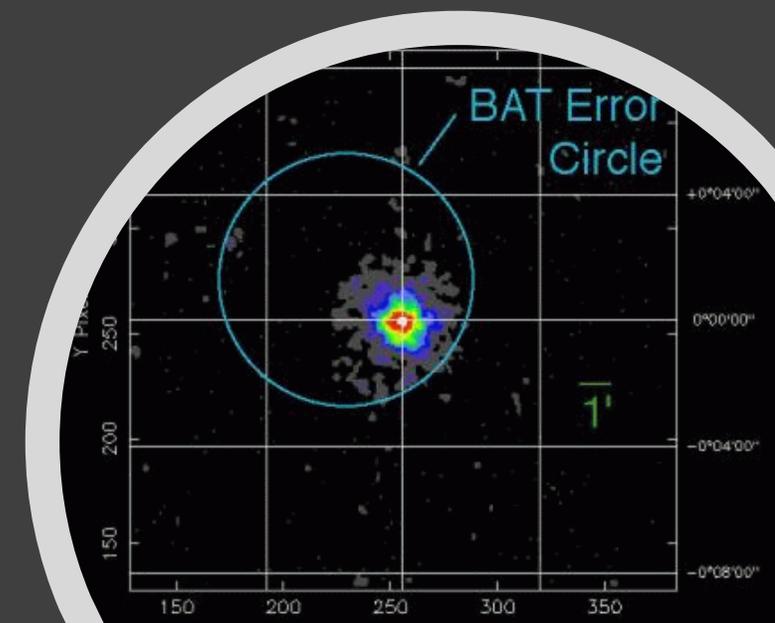
Swift BAT Light Curves

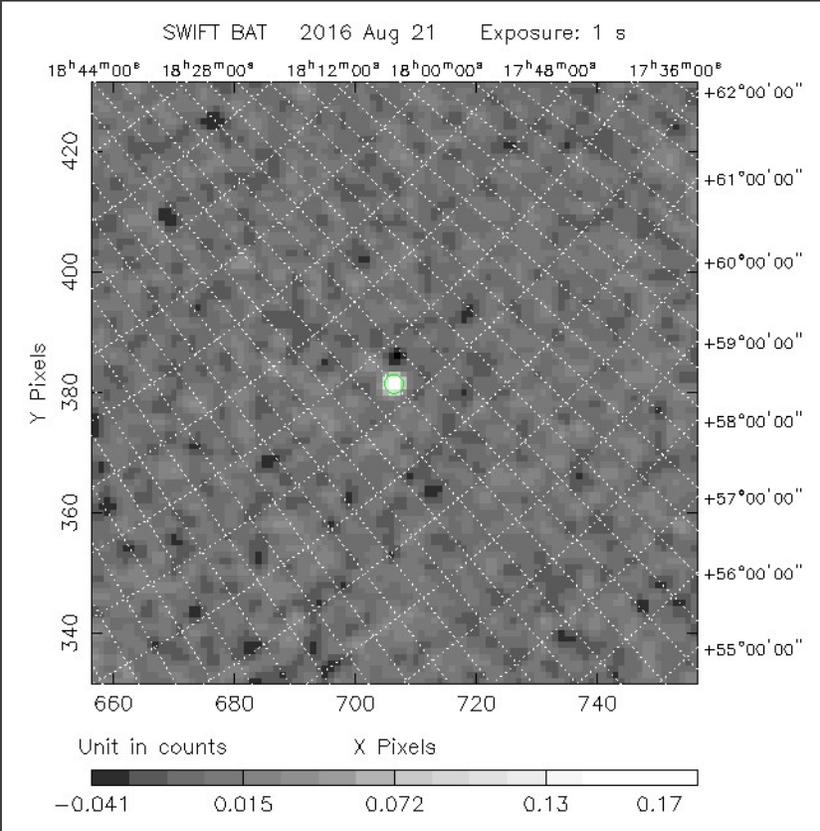
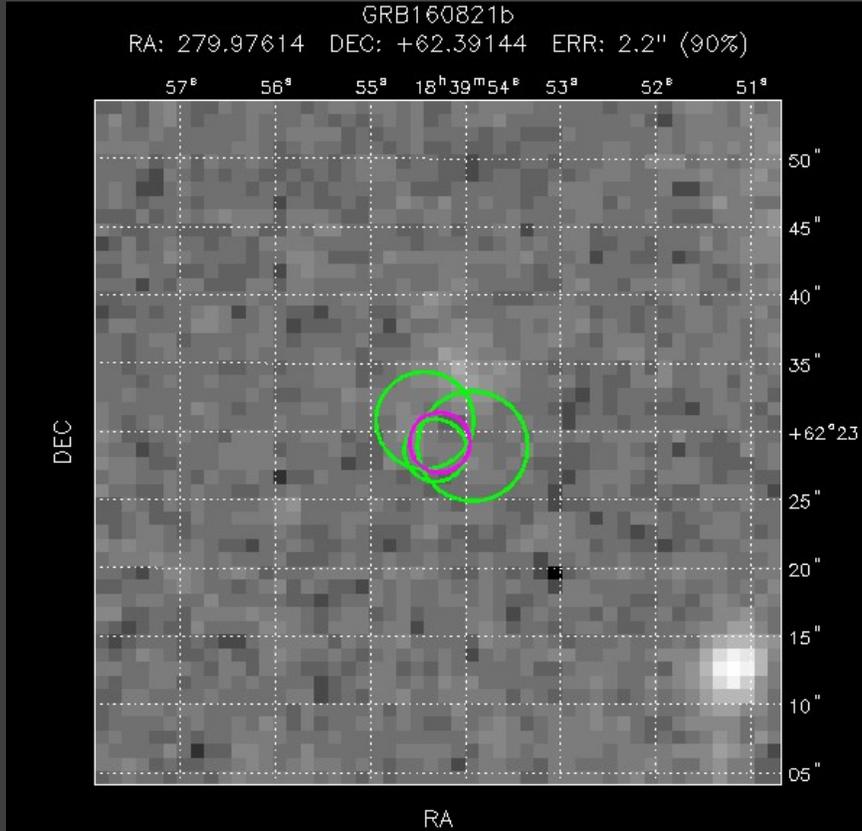
- Like snowflakes, no two are alike.
- There are however categories:
 - Long Bursts – a few seconds to a few minutes,
 - Short, Hard Bursts – a few milliseconds,
 - Afterglow can last much longer – days.
- Signatures indicate supernova, binary BH mergers, binary neutron star mergers, and combos.
- Widely accepted, these transient sources are among the most energetic/cataclysmic in the universe.
- Lucky us - in a much younger universe, “A Long Time Ago in Galaxies Far, Far Away.”



The BAT on Swift – Core Element of Rapid GRB Detection from Space

- Swift was launched in 2004 with planned life of 2 years, it's been in operation contributing to science now for 13 years.
- The array has 15 – 350 keV detection sensitivity: Hard X-ray.
- By comparison, Fermi LAT has 20 MeV – 300 GeV detection.
- This is significant because the core function of Swift is to detect a burst, locate it within an error circle, and slew to point the spacecraft with an X-ray and UV/visual camera at the burst.
- Coordinates and bulk data are radioed to the ground for a more precise location of the burst before settling on a field for observation from the spacecraft and the ground.



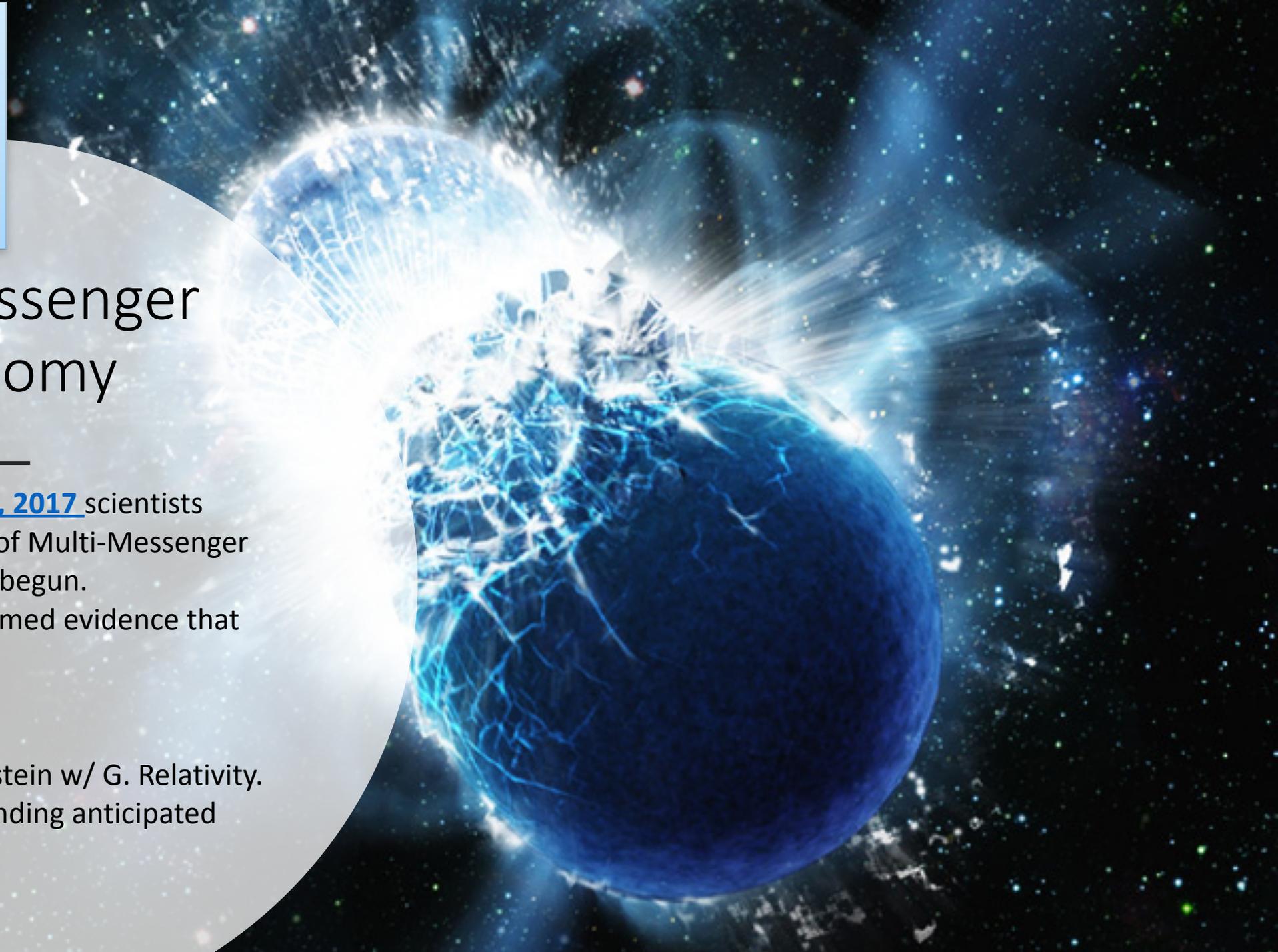


Additional Swift BAT/XRT Products

ref GW170817/GRB170817A (lookup 'standard siren' to discuss/compare. Announcement 10/16 the importance of the arrival time of the GW and the electromagnetic counterpart which was

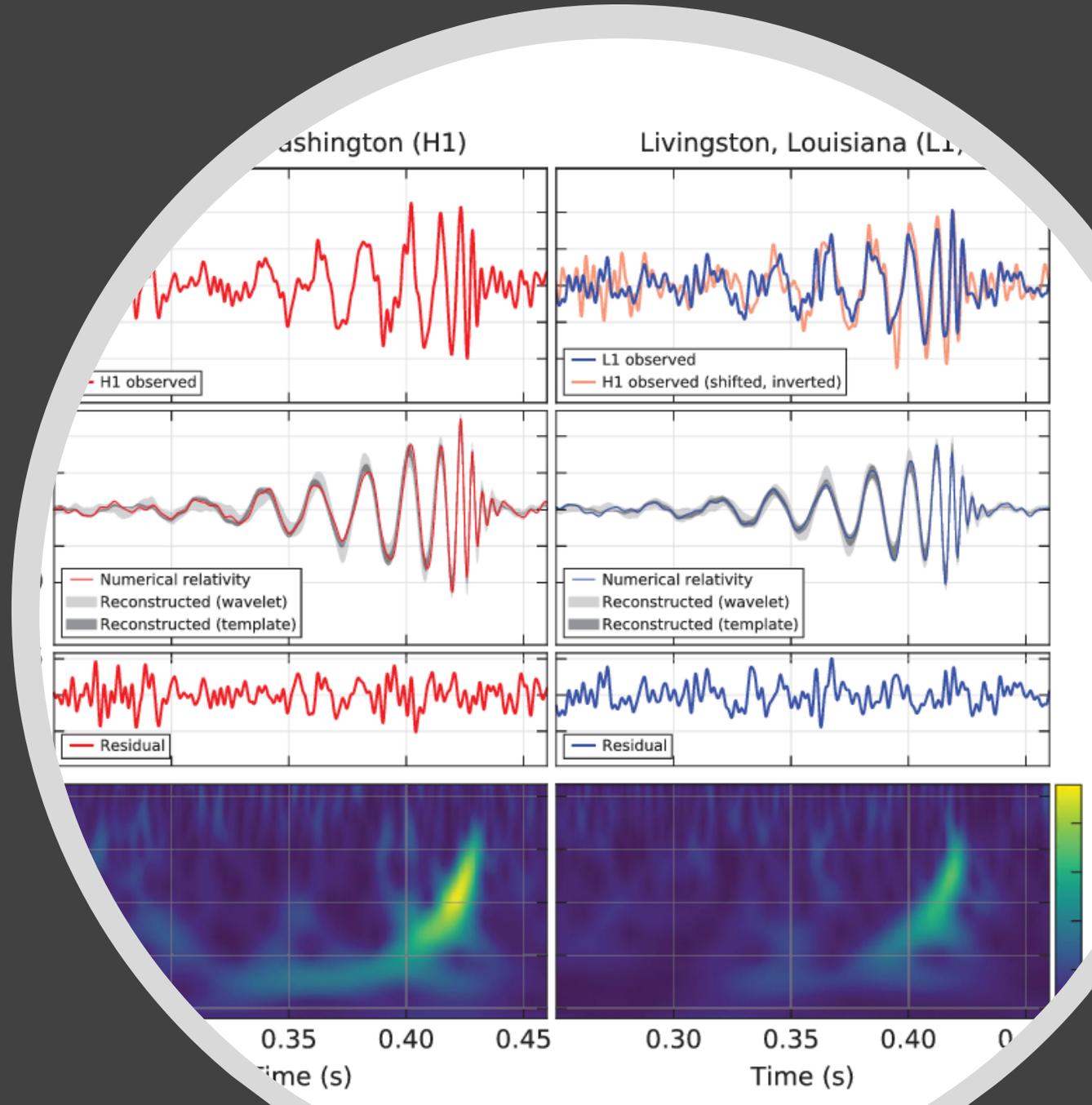
Multi-Messenger Astronomy

[On Monday, October 16, 2017](#) scientists announced that the era of Multi-Messenger astronomy had officially begun. Now that we have confirmed evidence that gravity travels in waves...
... as does light ...
... at the speed of light ...
... as predicted by A. Einstein w/ G. Relativity. Decades of study and funding anticipated these discoveries.



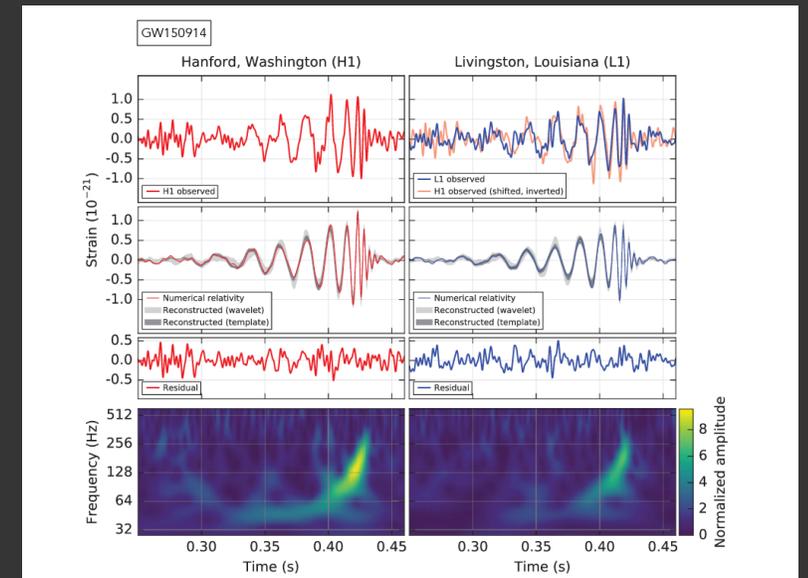
GW150914

- The discovery of this first gravitational wave, that confirmed Einstein's prediction from General Relativity, was announced February 11, 2016 at a conference in Washington, DC.
- The Nobel Prize in Physics was awarded in 2017 jointly to Rainer Weiss, Barry Barish and Kip Thorne – “for decisive contributions to the LIGO detector and the observation of gravitational waves.”
- [Click the image to the right](#) for an animation.



LIGO/Virgo and Sub-Atomic Studies

- This is the essence of multi-messenger astronomy:
 - A handful of high-energy satellites on scientific missions,
 - Hundreds of ground-based telescopes equipped for observing transients in optical and infrared bands, spectrography, polarization,
 - Specialty telescope networks like PROMPT designed for rapid response since burst afterglow fade quickly,
 - And now, LIGO/Virgo.
- Can high-energy transients be observed with other methods?
 - Yep.. now with ability to seek gravitational waves (GW),
 - Neutrino and subsequent muon detection [available with IceCube](#),
 - Radio Astronomy, infrared signatures, synchrotron radiation.



The Skynet Collection of Robotic Telescopes

[Amateur Astronomy Online](#) published in the June 2017 issue of *Reflector Magazine* – Astronomical League.

This article provides history of the program including funding, begins on page 16.

Very special thanks to the astronomy departments at Penn State (Swift, Gamma Ray Bursts) and the University of North Carolina (Skynet).

[NASA/GSFC makes real time notices of GRB transients available to anyone with interest.](#)

UNC, NASA, others provisioning the network to support multi-messenger astronomy and current fields of interest; exoplanets, NEO's.

Background
If you were sixteen years old in 1984 and a fan of science fiction, you have seen Arnie Schwartzenegger in the *Terminator* franchise, probably more than once. Well, of course, the *Star Wars* generation. The first *Terminator* sequel, *Judgment Day*, was released seven years later, which is a lifetime for a sequel. Release of the franchise was released, and another twelve years afterwards—a testament to the enduring nature of that franchise.

I have no doubt that the faculty in the Department of Physics and Astronomy at the University of North Carolina were inspired by the first robotic telescopes were manufactured by 3C Optical Systems. The UNC astronomy faculty and grad students began building the PPODMFT network—meaning “Panoramic Robotic Optical Monitoring and Follow-up Telescopes”—in 2004. The figures show that Skynet has taken over 16 million images for tens of thousands of users worldwide.

Most of the funding for Skynet has been awarded through the Major Research Instrumentation (MRI) Program at the NSF, NASA and other collaborators have also contributed to the network. The first Skynet proposal, submitted in 2003, was turned down, although some of the scopes were already being assembled. The grant was used to build telescopes and the claim she dunes at the Cerro Tololo Inter-American Observatory above La Serena, Chile, 20 degrees south of sea level. A second proposal asked NSF to fund the construction of six 7-inch robotic telescopes, figured with hypothesis of military suitable for professional astronomy, at \$10,000 per telescope. The first NSF award was made in 2004. Dr. Dan Reicherth leads the program at UNC-Crispel Hill.

Two million dollars was raised via the American Recovery and Reinvestment Act (ARRA), awarded through NSF and allocated to several projects between 2010 and 2012. This included the addition of four new 7-inch RC scopes at the Siding Springs Observatory in New South Wales, Australia. Some award was used to collect the relinquishment of the National Radio Astronomy Observatory to escape in Great Virginia.

Typical of NSF grants, funding will rely on the self-funded Skynet's operation in a pay-for-use model. PPODMFT is a 24-inch R. added in 2013 in partnership with the Government of Thailand pays for most of its use, paid time on the other Skynet telescopes cover support operating expenses for PPODMFT to escape was ab

AMATEUR ASTRONOMY ONLINE
By Tom Finkenbinder

telescopes; they conceived a project called “Skynet”—a nod to the reality of a world increasingly served by computers and the Internet. Not quite machines that are self-aware, Skynet is a collection of telescopes, filters, cameras, and retractable-roof observatories installed in remote mountainous locations that employ robotics to study the sky at night.

Skynet headquarters is in the Monroeth Observatory building on campus at UNC in Chapel Hill, North Carolina. Skynet is funded by the National Science Foundation (NSF), NASA, and private donors. Skynet observatories—span four continents. New sites in North America are up for consideration every year, as the outreach curriculum written by UNC professors garners interest from other colleges and universities, foreign government science programs, K-12, youth groups, and adult amateur astronomer communities—like us.

Skynet is truly a global scientific resource available to the public and academia through a web portal for PCs, laptops, tablets, and cell phones; a variety of related websites; and a Facebook page. The

16 *Reflector* • JUNE 2017



PROMPT Telescopes

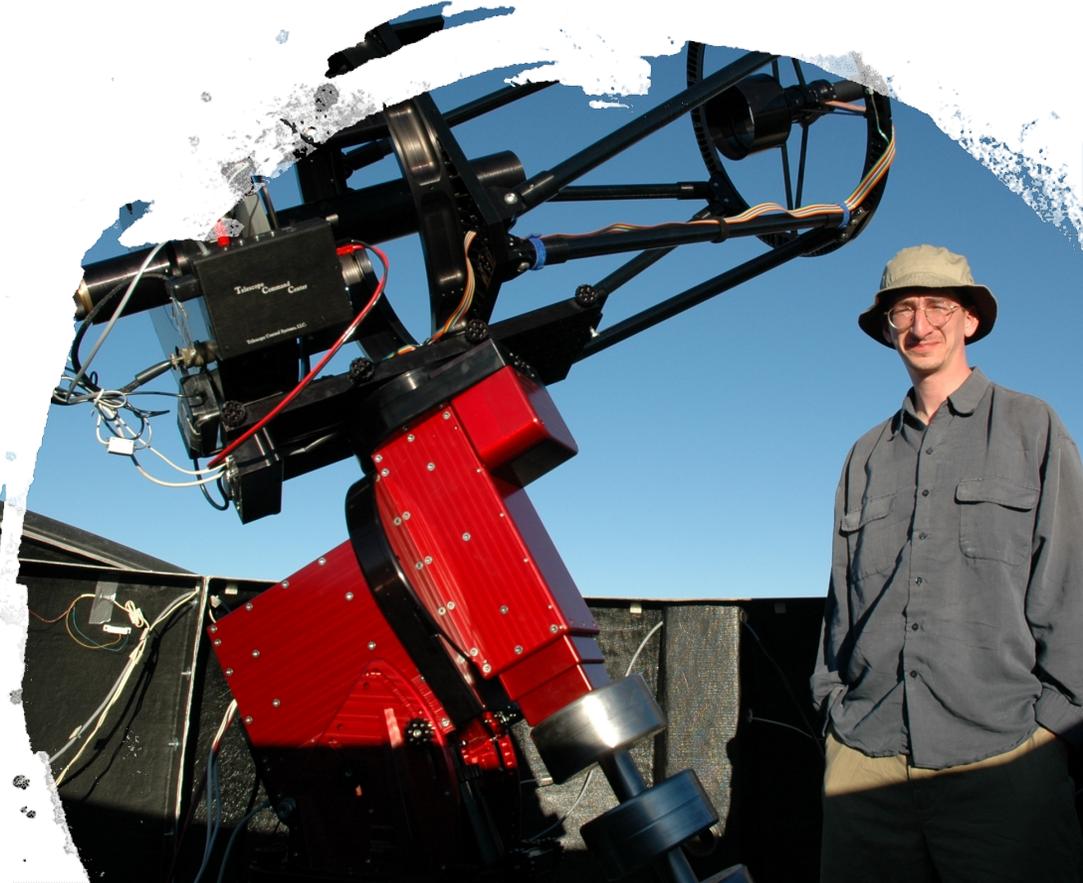
Originally RC Optics 16" Ritchey Chretien design, primary with coated emulsions akin to built-in filters in optical and IR wavelengths.

Now, eight clamshell domes. Grants, NASA and private funding are allowing aperture upgrades, over half are at least 24" aperture.

Astro Optik donated a 32" scope, used for astrophotography and spectrography of supernovae.

One dome recently provisioned to the UNC Evrscope project, studying exoplanets.

Original equipment installed all over the world, connected to Skynet w same comms and robotics.



Now
16"



Now
4 17"
Proposed
17" + 28"
or 40"

Now
3 16" + 3 24" +
32" + 40"
In Dev
Polarimeter,
Spectrograph
Proposed
60"

Now
16"

Skynet: PROMPT

Allocation of CTIO Scopes When Not Chasing Bursts or in Skynet Queue

PROMPT 1 – 24"
PlaneWave, NASA use
with NEO studies,
complement LSST

PROMPT 2 – 16"
original RC Optics,
used for
astrophotography

PROMPT 3 – 24"
PlaneWave, NASA use
with NEO studies,
complement LSST

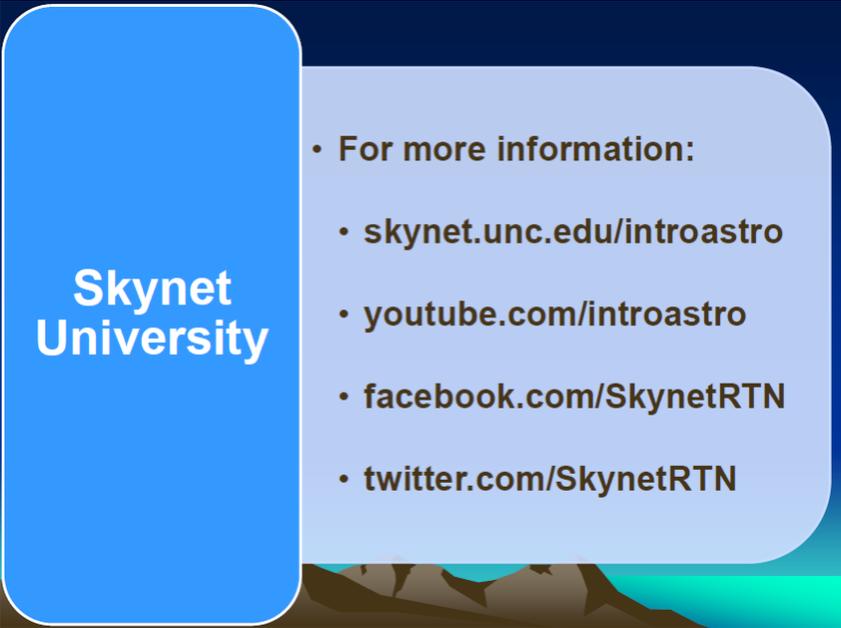
PROMPT 4 –
Allocated for new
installation of
Evryscope

PROMPT 5 – 16"
original RC Optics,
used for DLT40
Supernova Study

PROMPT 6 – 16" RC
Optics being replaced
w/ 24", GRB
Polarization Study

PROMPT 7 – 32"
Astro Optik,
astrophotography and
SN spectrography

PROMPT 8 – 0.7m
(27") installed, owned
by Government of
Thailand

The logo for Skynet University is a blue rounded rectangle with the text "Skynet University" in white. To its right is a light blue rounded rectangle containing a list of links. The background of the entire slide is dark grey with a white curved shape on the left side.

**Skynet
University**

- For more information:
- skynet.unc.edu/introastro
- youtube.com/introastro
- facebook.com/SkynetRTN
- twitter.com/SkynetRTN

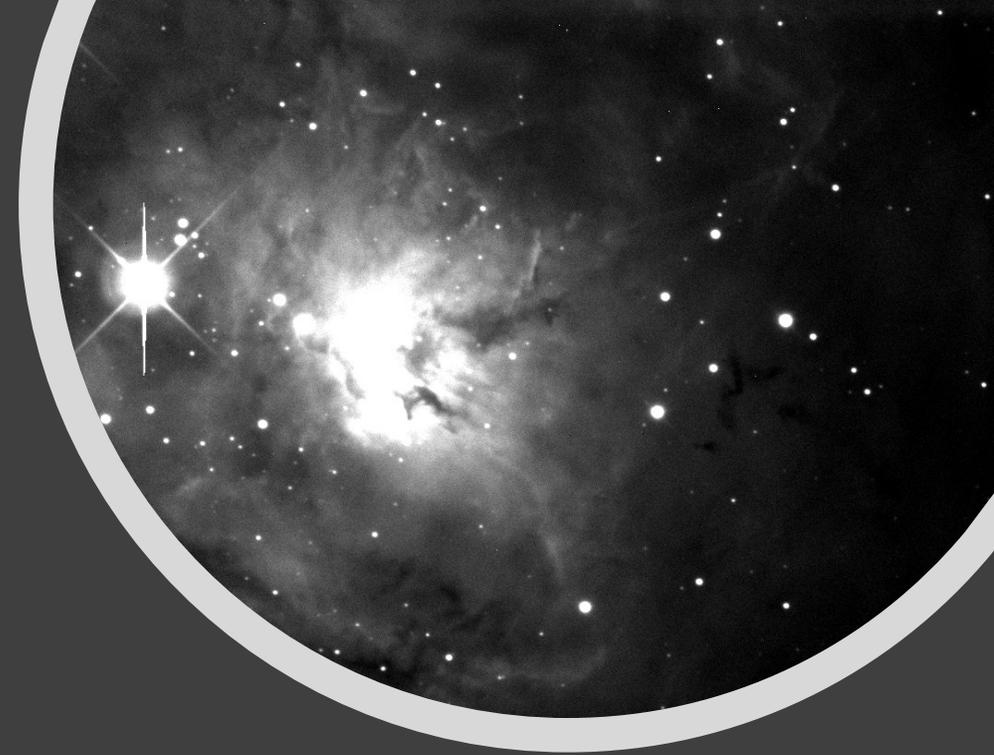
Start With Skynet University

Click panel on the left to begin.

[Click here](#), to go to the Skynet Portal.

Basic Imaging

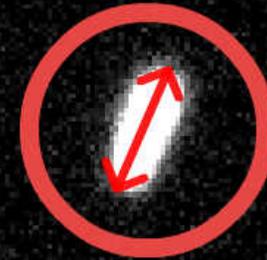
- [View the tutorials](#) and lab samples before you commit.
- [Lab 1 – Observing with Skynet](#), explores object classifications.
- Structure of the labs guides students up the cosmic ladder:
 - parallax,
 - Cepheid and Lyra variables,
 - Hubble redshift.
- It promotes understanding planetary systems and Kepler's Laws.
- Newton's conceptual relationship of mass and gravity are visited.



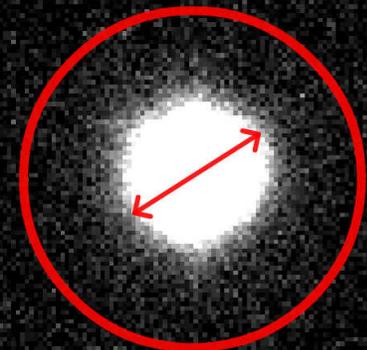
Asteroids, Minor Planets, and Meteors – Oh My!

- [Afterglow allows measurements:](#)
 - angular separation,
 - angular diameter,
 - illumination/brightness magnitude measurements,
 - contrast setting for best viewing.
- Near Earth Orbit science is now well-funded.
- Measuring changes in position and size with Skynet to interpret orbits – learn some techniques.
- [Center for Near Earth Orbit Studies](#)
- [The Minor Planet Center](#)
- [American Meteor Society](#)

Ceres 18.11 arcsec



Vesta 21.9 arcsec



Congress mandated NASA catalog earth crossing objects greater than 100m. Civil defense project funded by NSF is called Skywatch. JPL has a project called NEAT.

Supporting LSST

Large Synoptic Survey Telescope

Mission: Metadata project similar to Kepler mission

Near Earth Orbit Studies

Two 24" PROMPT scopes supporting LSST

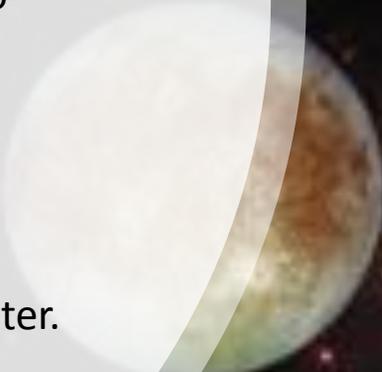
Two NASA funded scopes (1~1.5m) at CTIO

Skynet to participate with candidate follow up



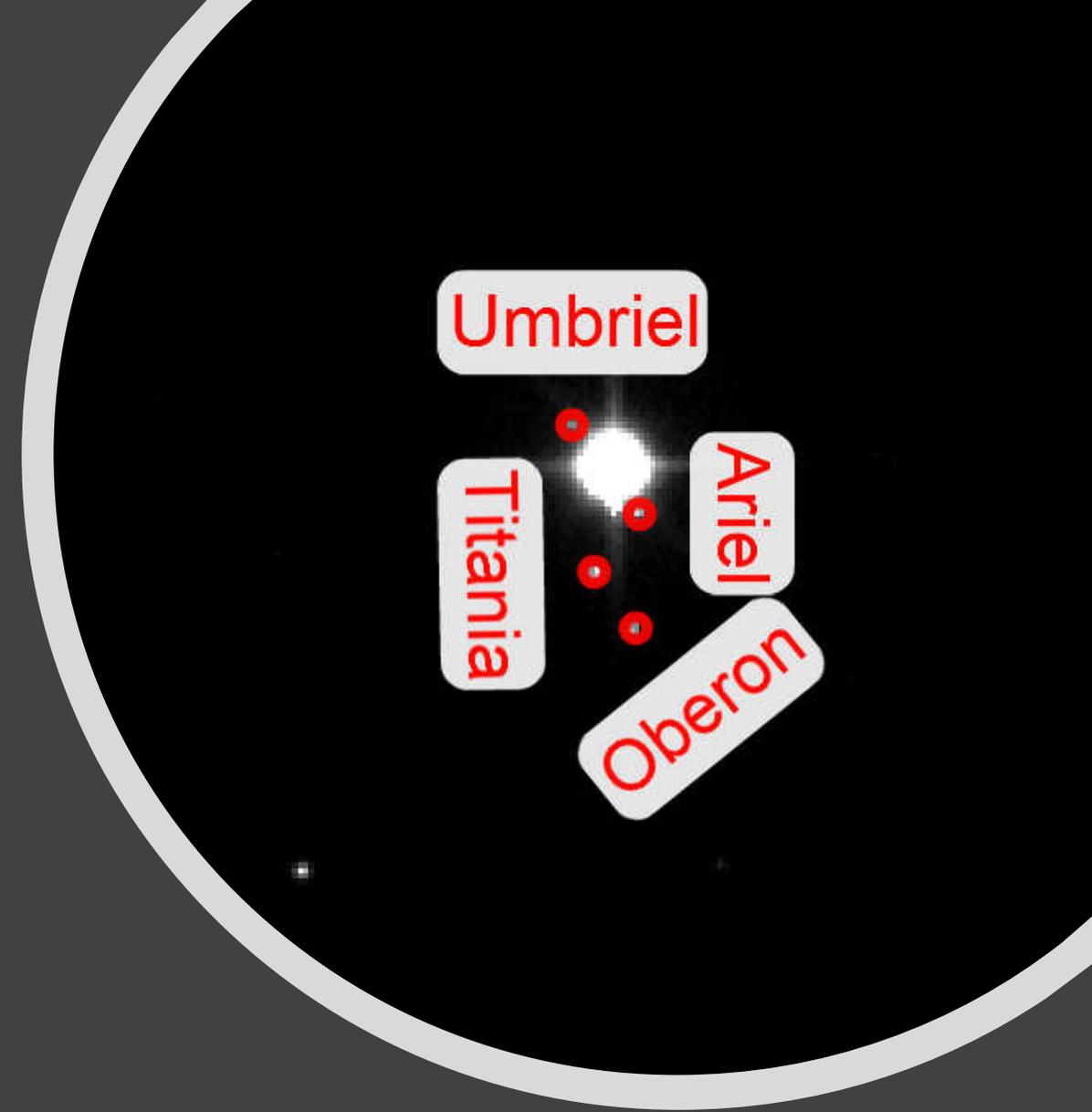
The Galilean Revolution

- [Lab 3](#) takes the student into our heliocentric view of the universe.
- Promotes an understanding of what Galileo contributed to astronomy.
- Here, Newton and Kepler's math are applied.
- The labs allow viewing moons of Jupiter.
- Phases of Venus illustrate the heliocentric model.

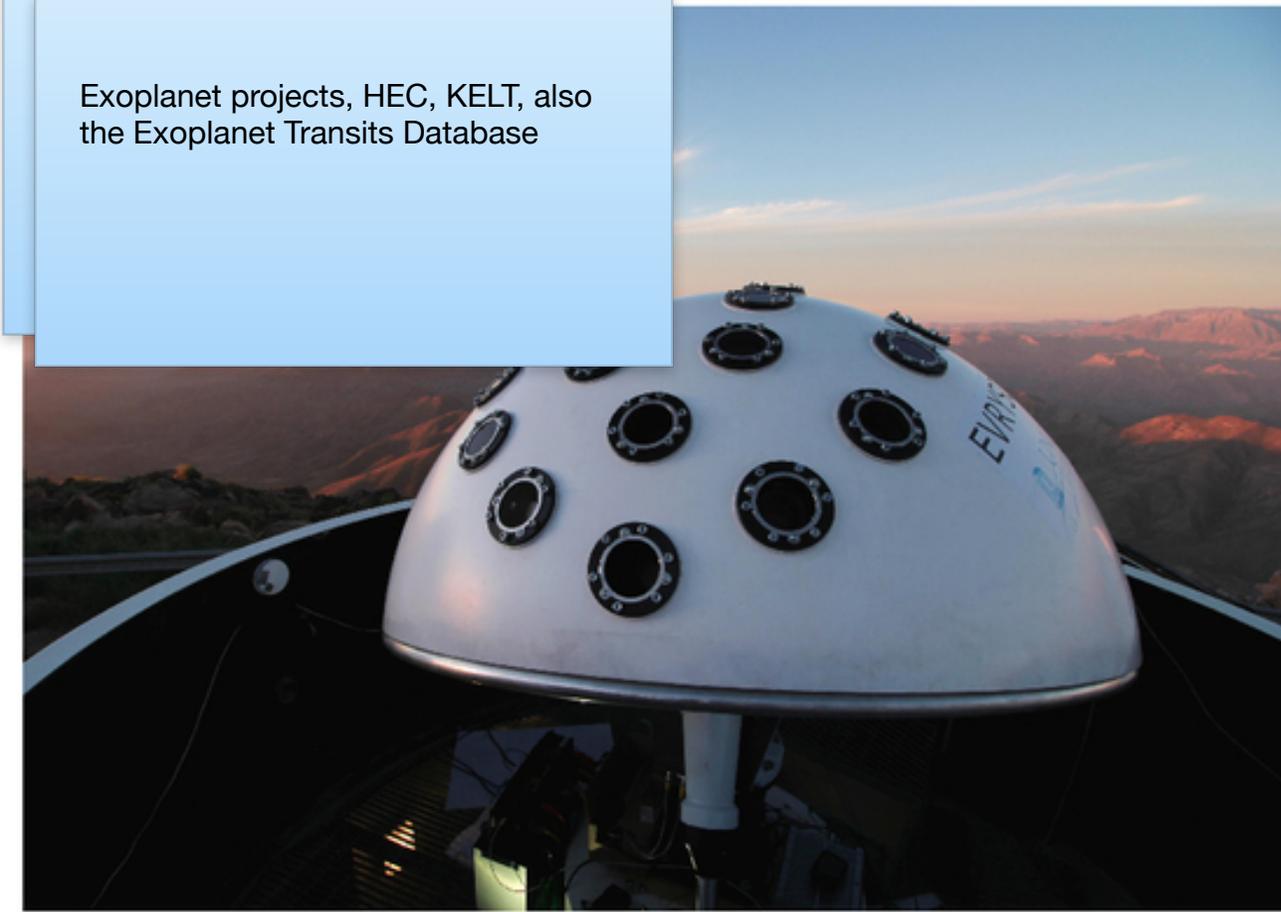


Observing a System

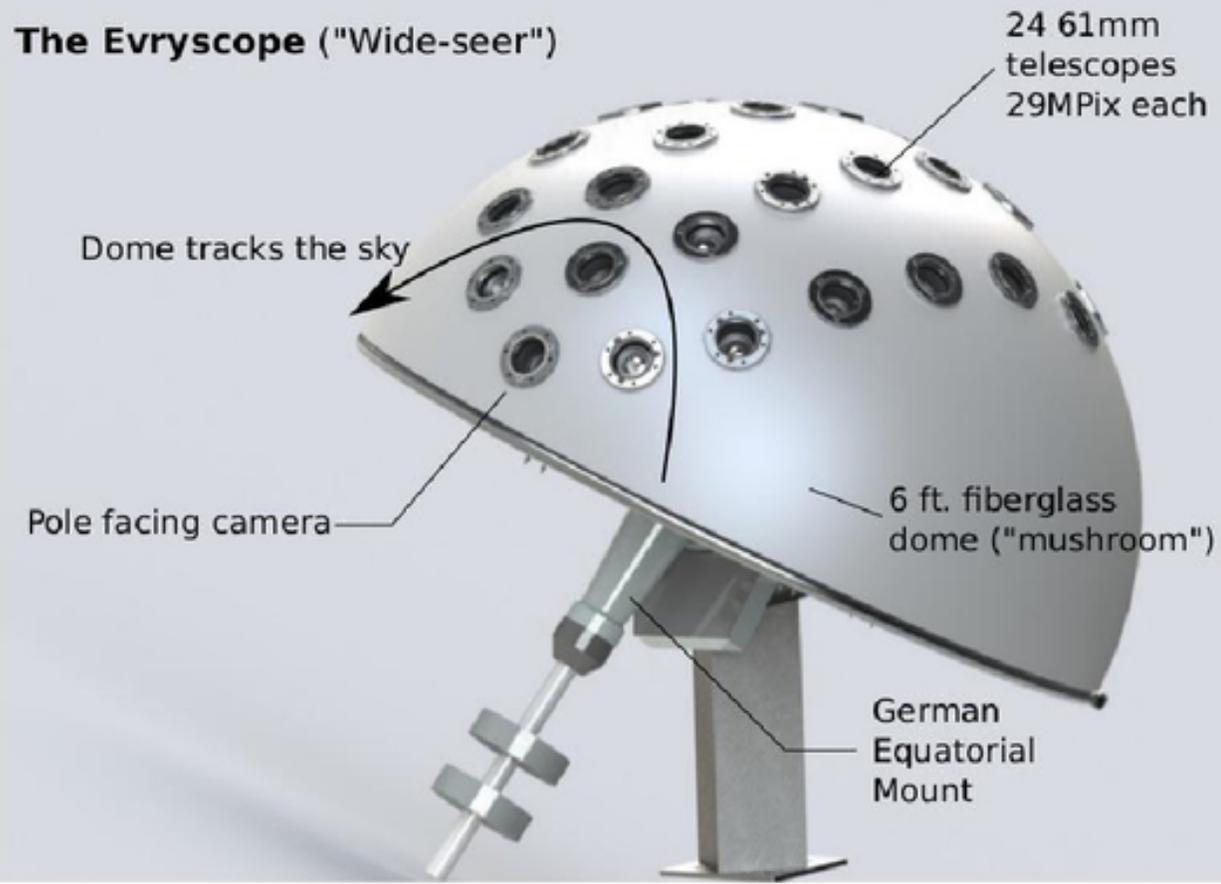
- Here is an example of observing a system:
 - Uranus and four prominent moons.
- Afterglow is the astrometry and photometry app:
 - custom programmed used to evaluate Skynet images with the labs provided.
- These are labeling features.
- Some labs use imaging data to calculate mass.
- Some labs use multiple images to calculate orbits.
- Some labs use imaging [to show rotation](#).



Exoplanet projects, HEC, KELT, also the Exoplanet Transits Database



The Evryscope ("Wide-seer")



Evryscope

[Exoplanet All Sky Surveys](#)

Radio Astronomy

\$2M was awarded to Skynet through the American Recovery and Reinvestment Act, some in a collaboration used to refurbish the NRAO 20 meter radio telescope in Greenbank, WV.

Once mechanically refurbished, the pointing system to drive the scope was connected to Skynet's scheduling application in Chapel Hill.

Later came modifications to existing systems and the creation of scanning algorithms, also produced in Chapel Hill, to make useful data products accessed through the Skynet portal.



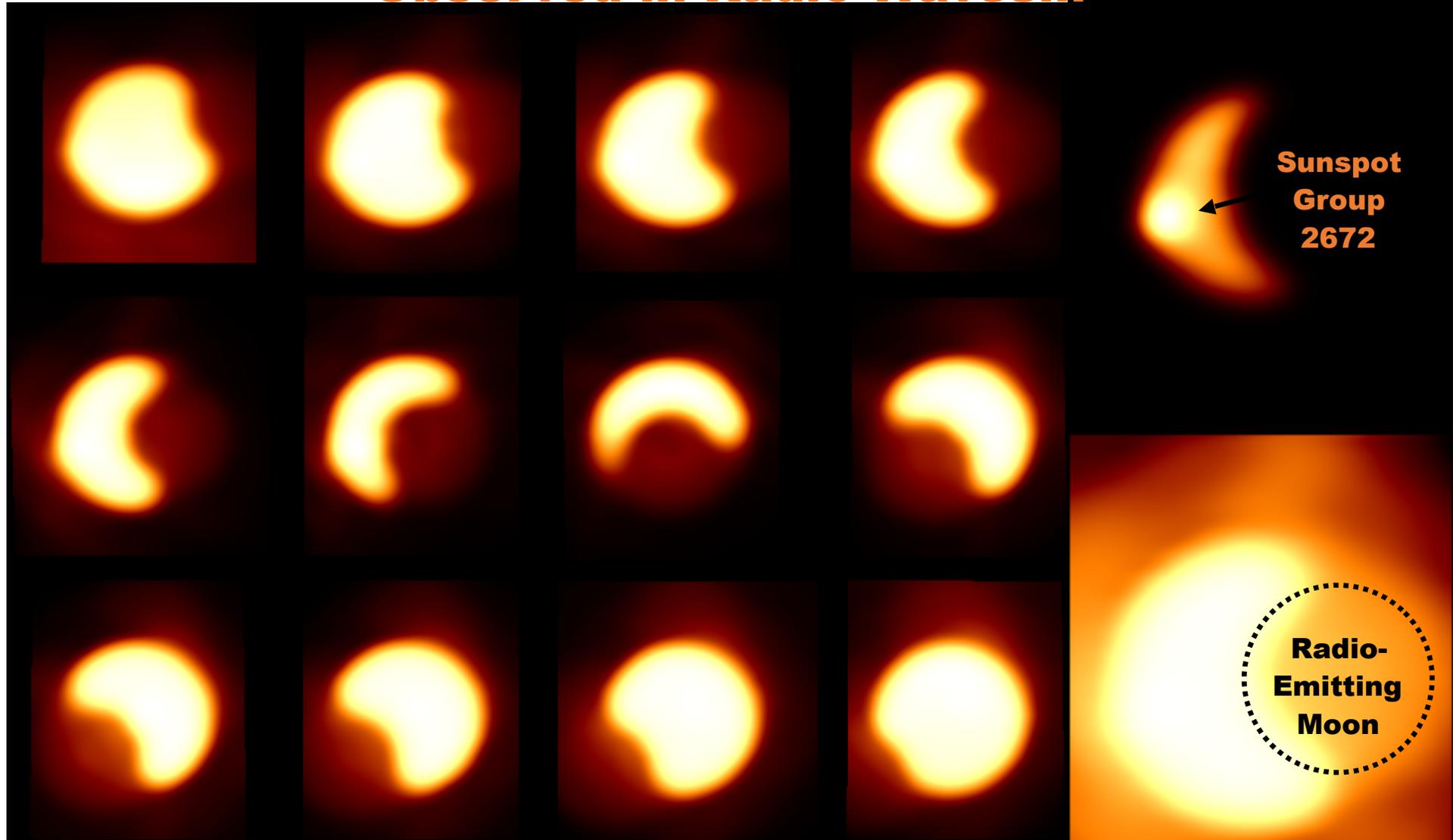


ARP 153 in Visual and Radio X Bands

Credit UNC Dept. of Astronomy and Astrophysics

The Great American Eclipse of 2017

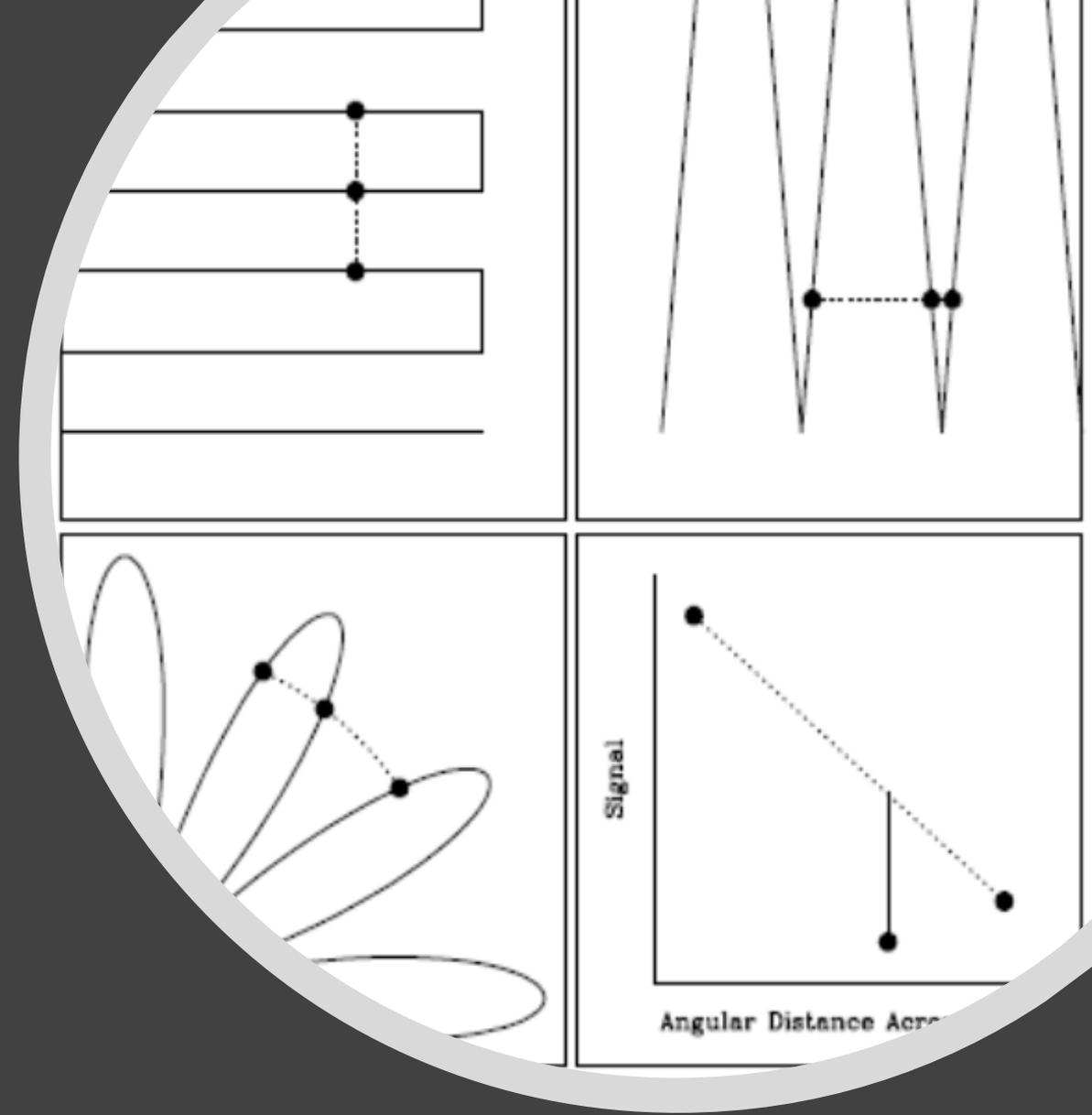
Observed in Radio Waves!!!



Green Bank Observatory 20-Meter Telescope (J. Brandt, D. Reichart, D. Dutton, J. Martin)

Scanning Algorithms

- The G20 arrived at Greenbank in 1994, its original receiver built/installed in late 1995.
- The G20 was operated by the USNO for, among other tasks, measurement of wobbling motion of the Earth's polar axis and orbital peculiarities.
- The scope went dormant in 2000 due to funding cutbacks and more capable NRAO radio array installations, the VLA in New Mexico for example.
- In 2008, an L-Band receiver was installed. UNC and NRAO began recommissioning the scope in 2012.
- An X-Band receiver has since been added.
- UNC wrote the computer code to enable the telescope scanning patterns needed to image radio objects.



Radio Adventures



34482, Virgo A, 4 petals, 40s total (10s per petal)

First try on a really bright radio source, actually, Cas A several years ago.



34496, M87, 12 petals, 40s total, sloppy scan, hydrogen 1420 MHz



34598, M87, substantially better image, 12 petals, 480s (40s/petal)

Synchrotron radiation at the center of the galaxy, free electrons orbiting BH

M87 was the first naturally observed source of SR. It had been created in particle accelerators.

Not a large enough aperture to see anything wrt relativistic jet in M87



35180, Moon, map (raster), 6 passes, 2s per pass, sloppy scan



35181, Moon, map (raster), 20 passes, 8s per pass, oblong shape

See the scan pattern compared with beam size

Grayscale rendering good, 3D rendering good



35182, Moon, 12 petals, 240s (20s/petal)

Feedback from NRAO to adjust petal size, beam width really off

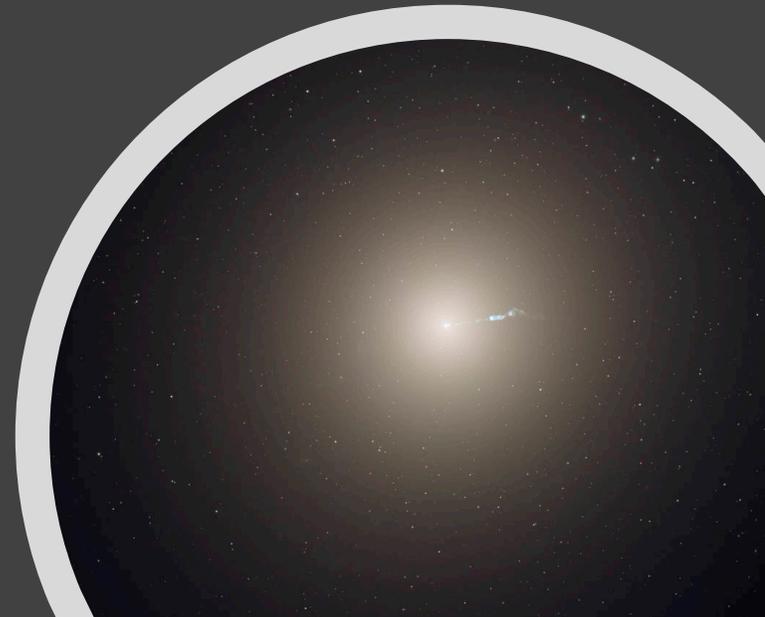
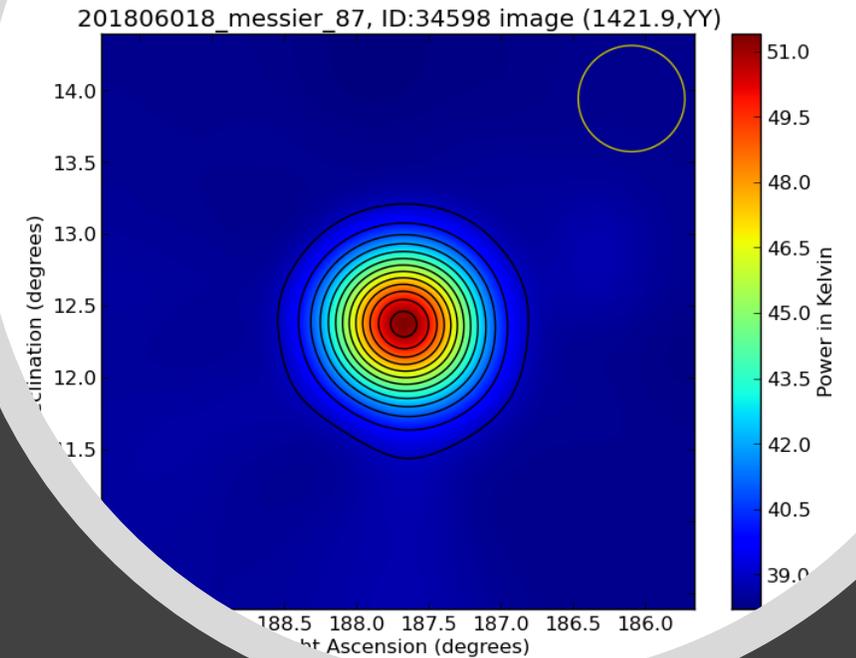
Grayscale rendering good, 3D rendering good

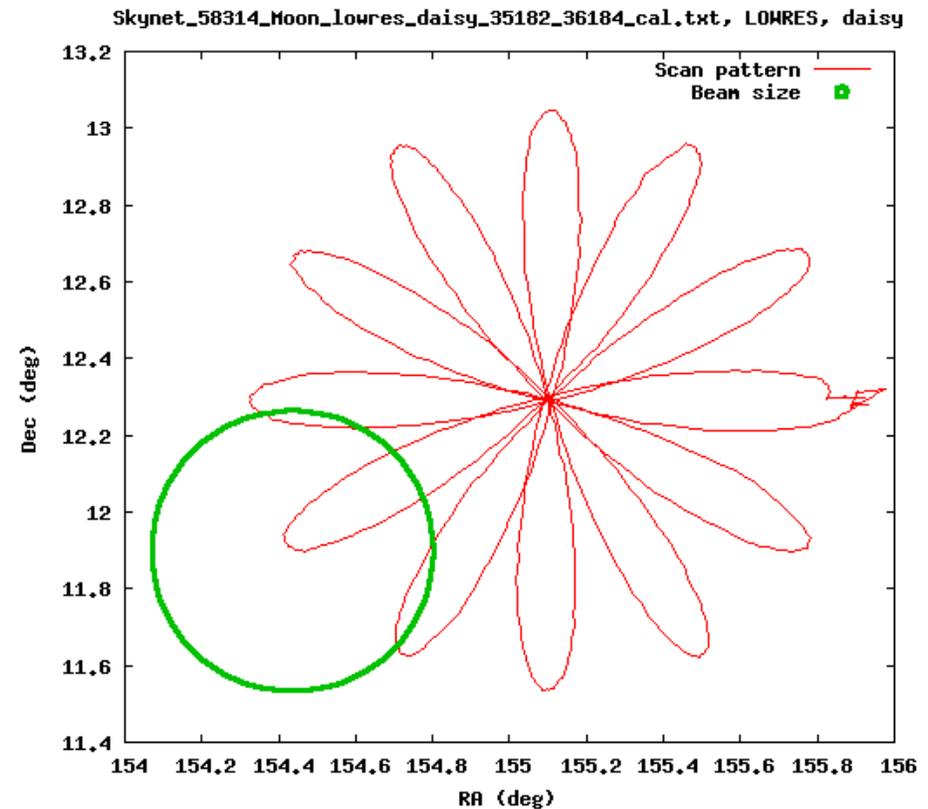
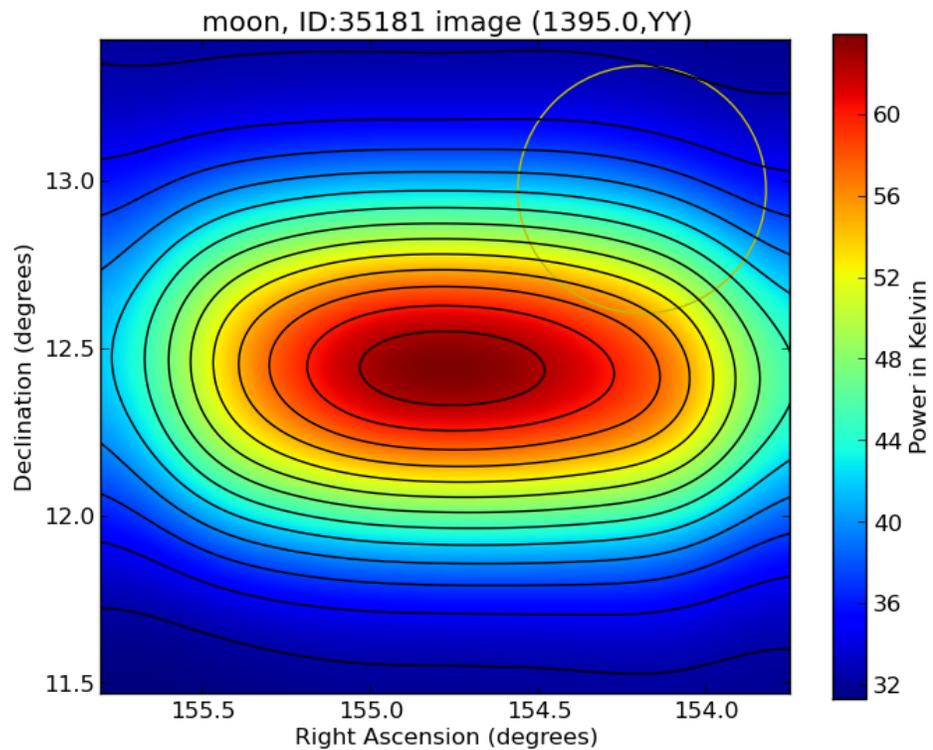
The moon was New – Q1 by the way. Looking for thermal signature. All the disc shows illumination in radio with each observation.

Conclude that the thermal energy is consistent whether the surface facing earth is illuminated by the sun or not.

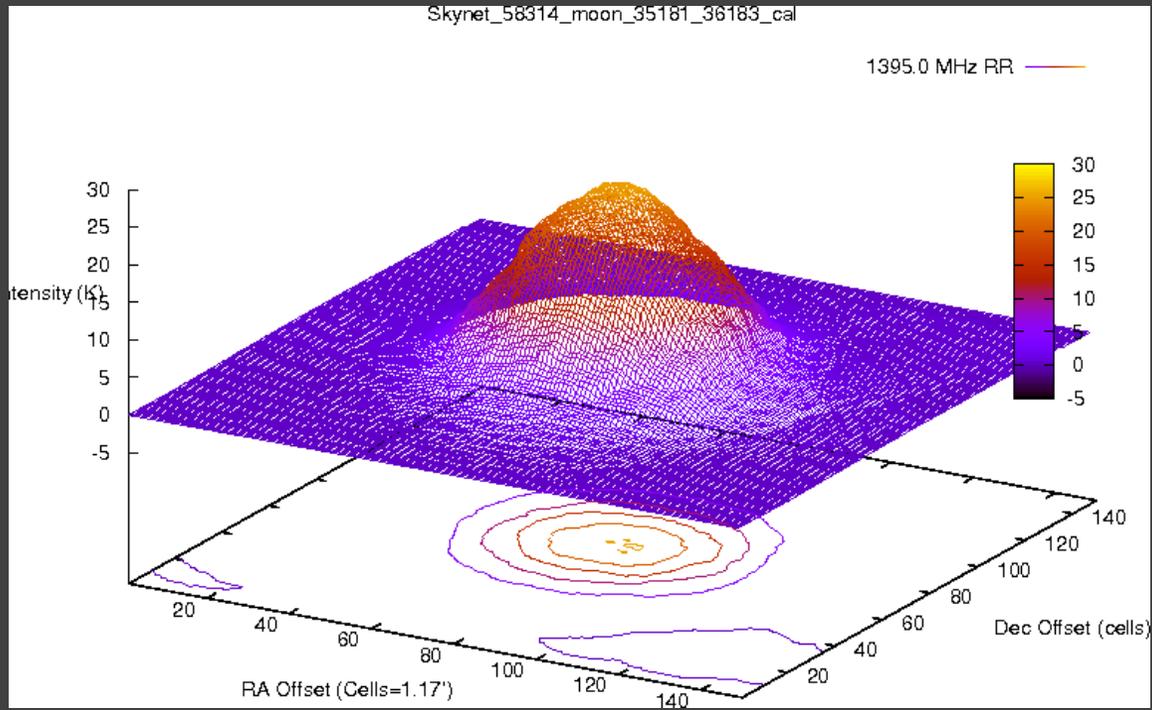
L Band M87 ObsID 34598

- M87, a favorite supergiant elliptical galaxy in the Virgo Cluster, first recorded by C. Messier.
- High energy plasma jet originates in the core and extends about 5000 light years into space, at relativistic speeds – near the speed of light.
- Stars and globular clusters are distributed evenly throughout its galactic envelope – a radius of 490kly.
- Black Hole at the center – about $7.22 \times 10^9 M_{\odot}$, rotating 1000k/s.
- One would expect that the radio image is thermal radiation from the core but it is in fact synchrotron radiation – first observed artificially with particle accelerators, but w M87, first confirmed in nature.
- Dust, gas and plasma accelerated around the BH at the event horizon, fed into and spun out of the jet/ejecta.





L Band Moon ObsID 35181
Thermal Imaging with Daisy Scan Pattern on the Greenbank 20m



L Band Moon ObsID 35181
3D Rendering with Image of Moon Phase,
10% Illuminated

Q&A



Many Thanks!

STEM Sub-Domain Planned for my Website

<https://www.newedgeanalytics.net/skilled-labor/>

If you have questions via NOVAC or for Chapel Hill:

Email me at tom@newedgeanalytics.net

Join me [on LinkedIn](#)

On Twitter [@TomFinkenbinder](#)

Skynet on Facebook <https://www.facebook.com/SkynetRTN/>