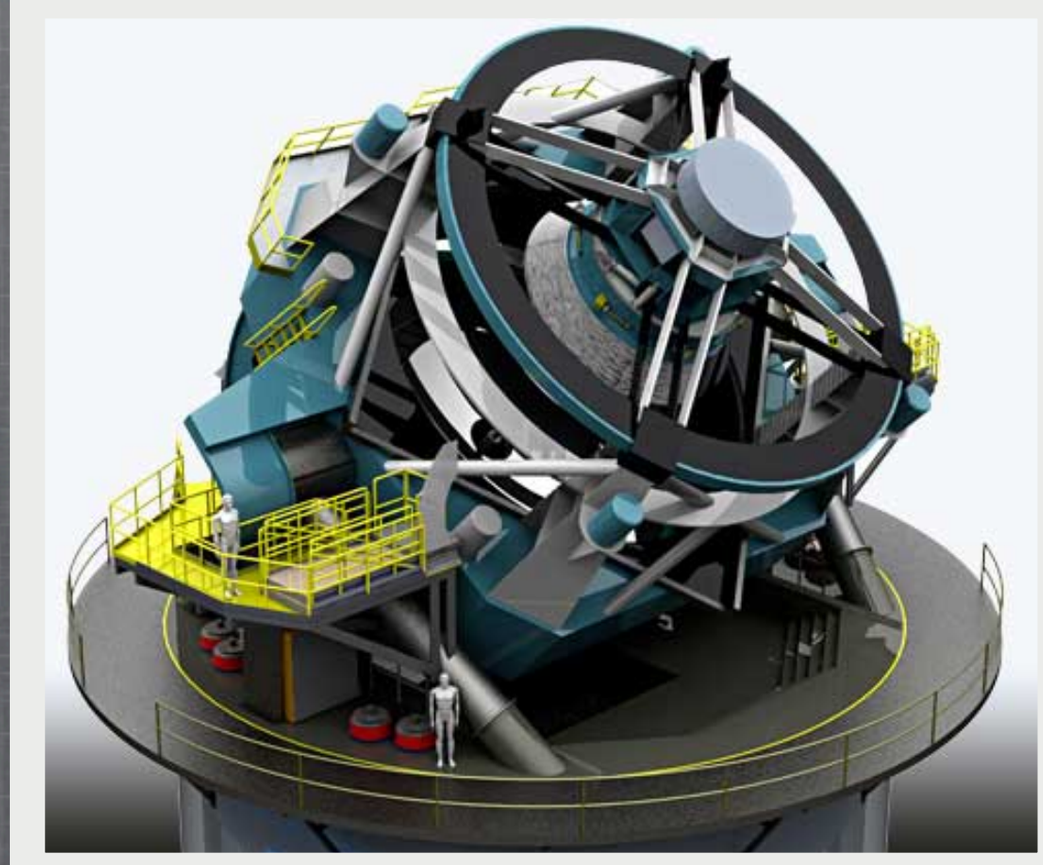
# PROBING SUPERMASSIVE BLACK HOLE GROWTH WITH NEXT GENERATION TELESCOPES


Steve Croft, UC Berkeley / UW Milwaukee

with Geoff Bower and the ATA Team
and David Kaplan

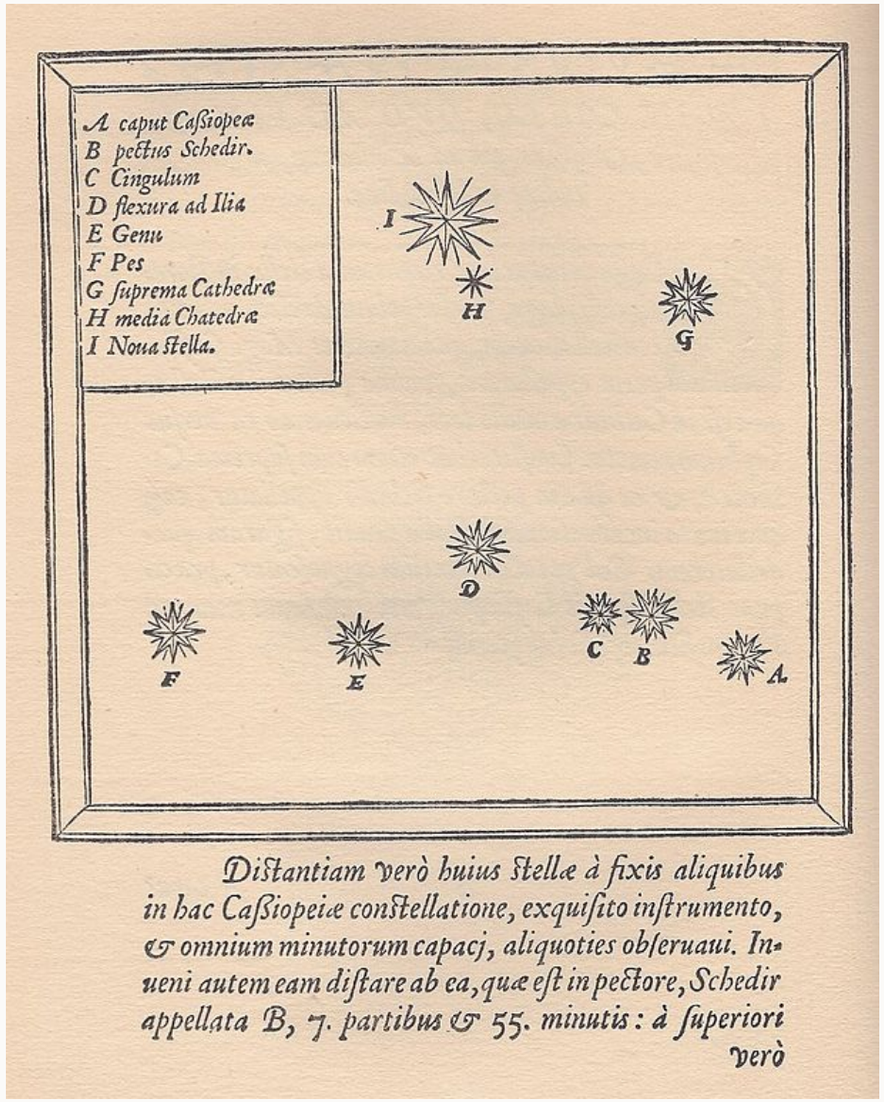



Images: SKA and LSST

# OPTICAL ASTRONOMY IN THE ELIZABETHAN ERA


Frontispiece to John Case, *Sphæra civitatis* (Oxford, 1588).

# THE CHANGING SKY

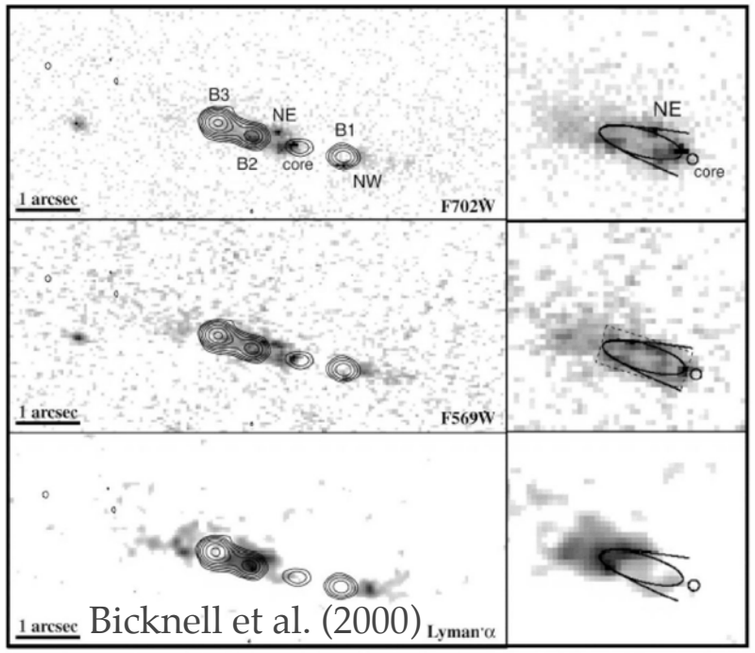



De nova et nullius aevi memoria prius visa stella (SN 1572)
Tycho Brahe, 1573

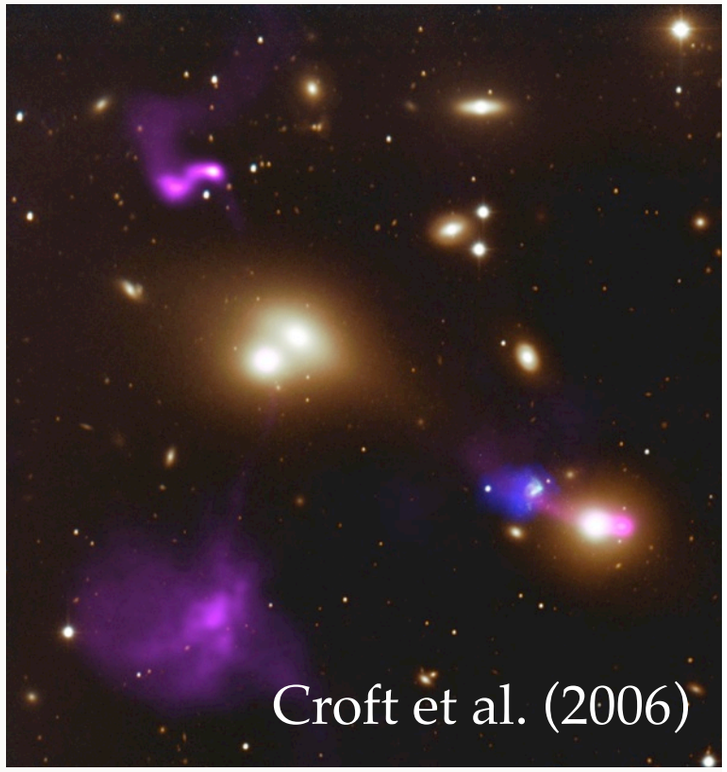
SN 1572 - Chandra, Spitzer, Calar Alto - Krause

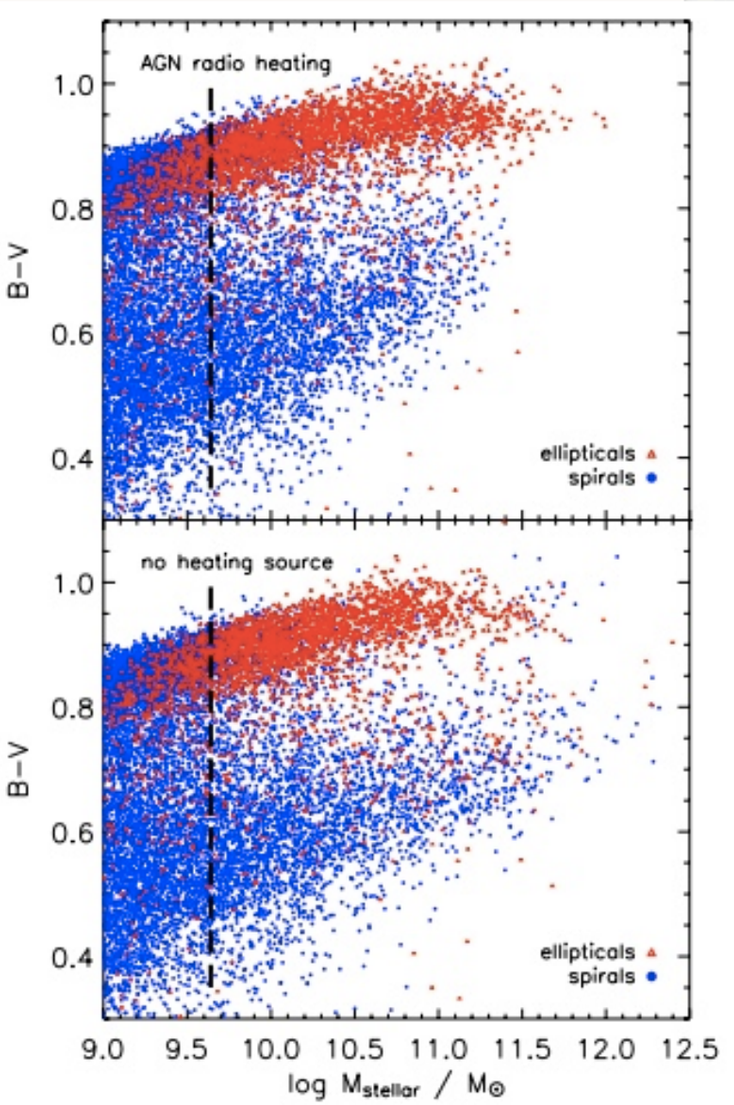
# A SNAPSHOT

# SNAPSHOTS

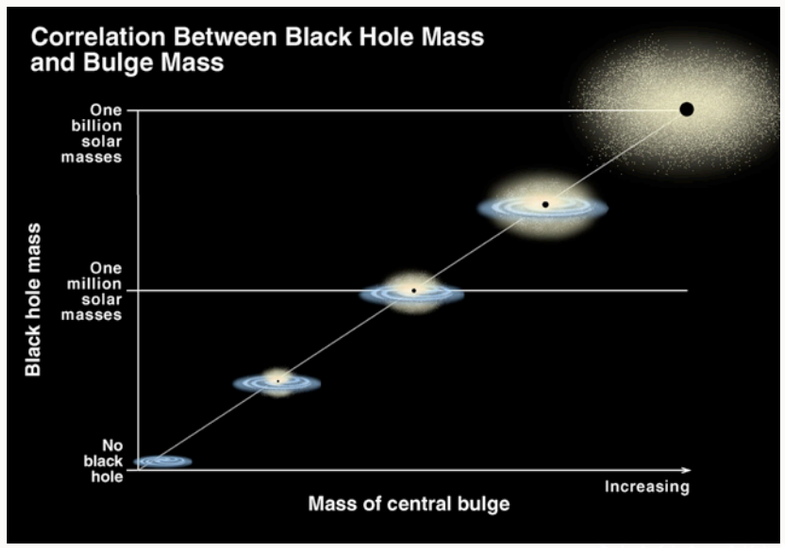


Bicknell et al. (2000)


Croft et al. (2006)



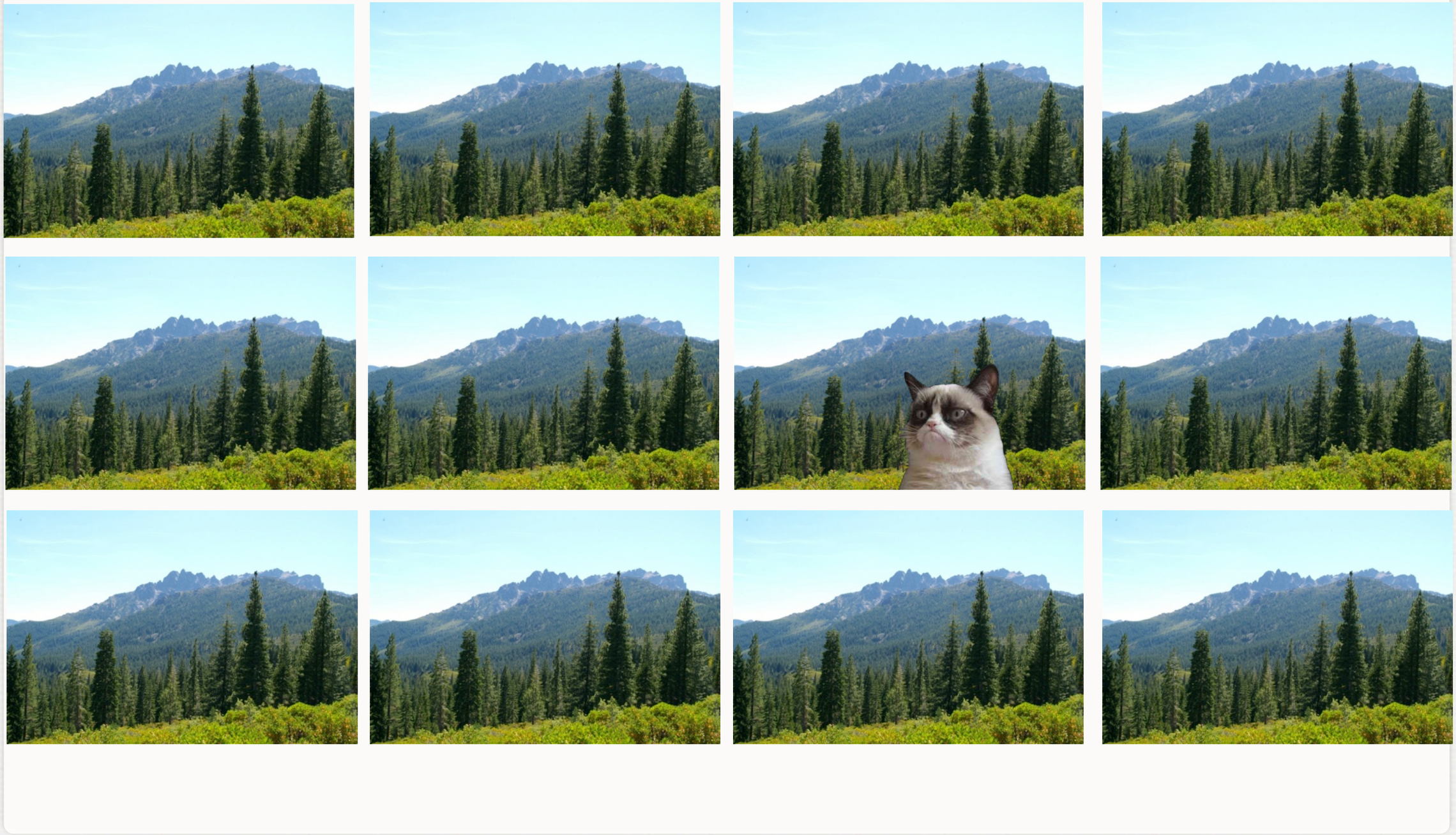
Croton et al. (2006)




NASA, ESA, CXC, STScI, NRAO, B. McNamara, L. Birzan and team

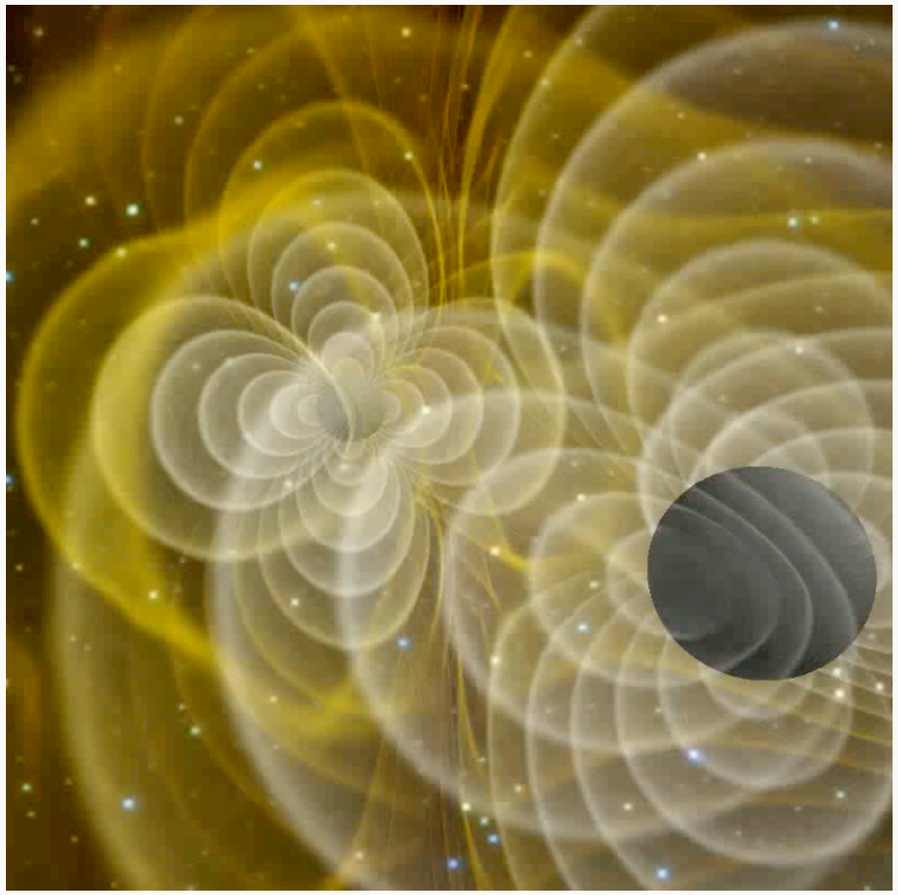
# SNAPSHOTS MISS THE ACTION

# TRANSIENTS

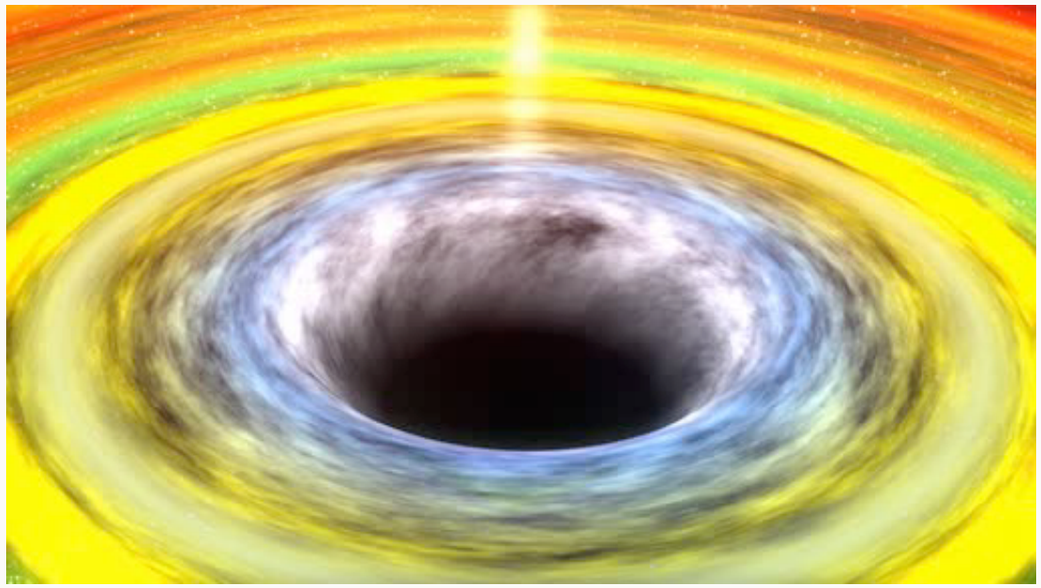


# BLACK HOLE GROWTH

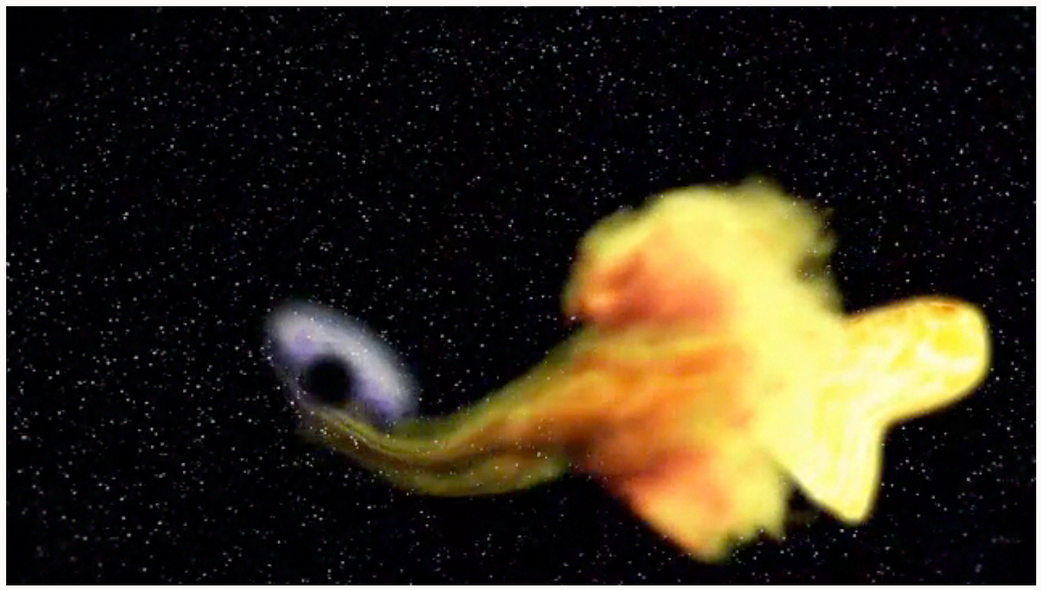
## Mergers, Gas Accretion, and Tidal Disruptions



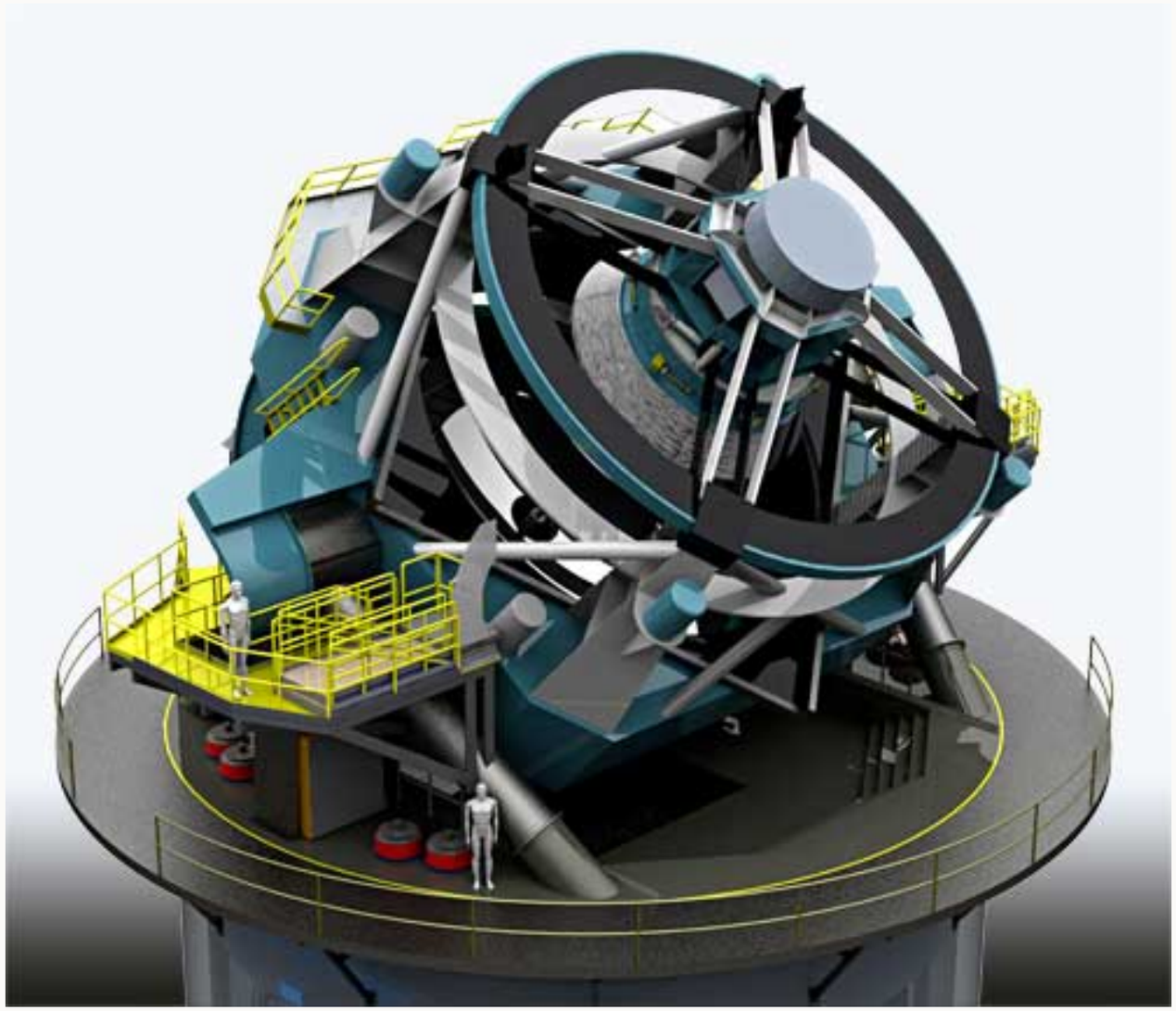
NASA / C. Henze



NASA GSFC



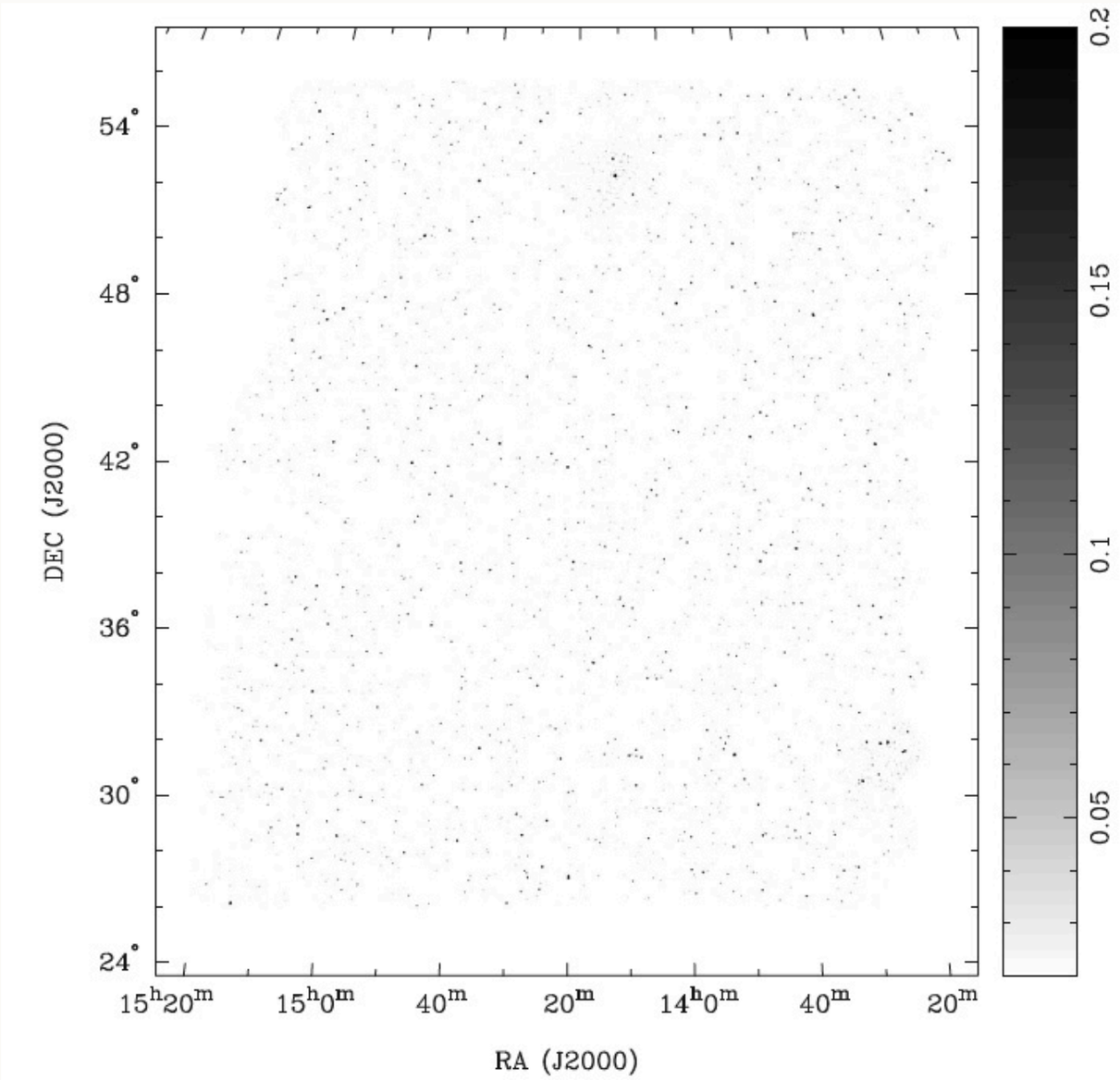
# PROBING SHORT TIMESCALES WITH SURVEYS

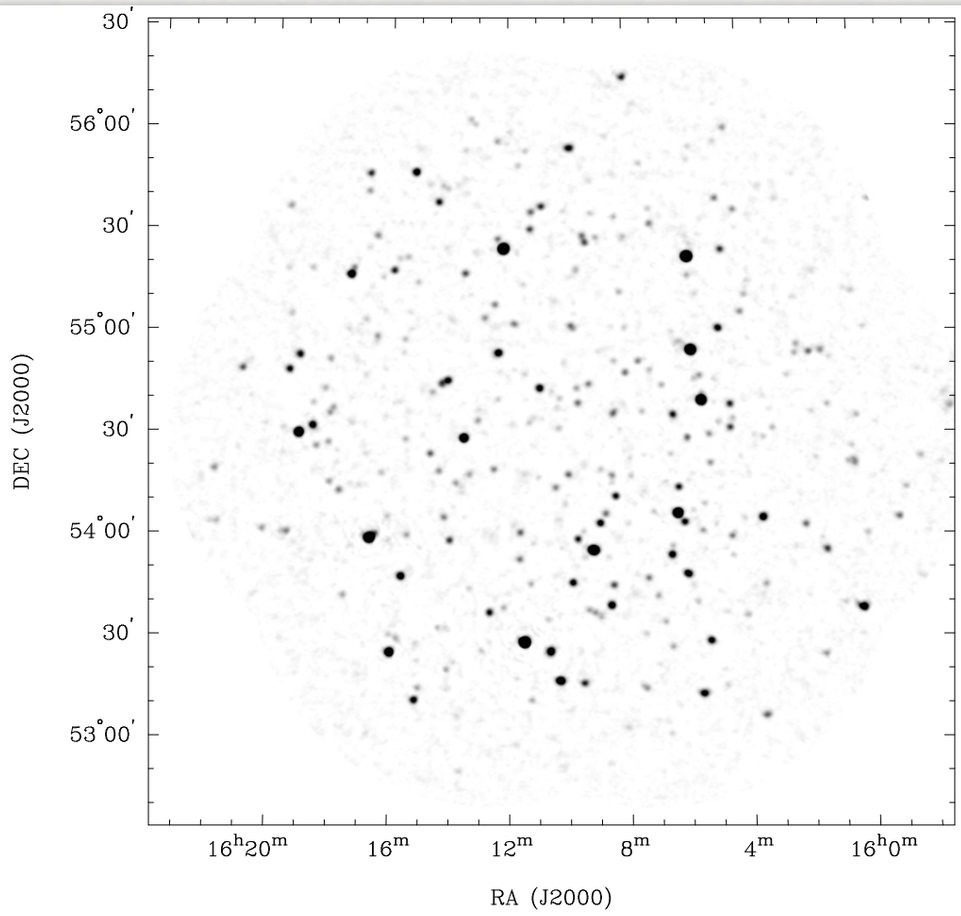


Large Synoptic Survey Telescope

Allen Telescope Array

# WIDE-FIELD RADIO SURVEYS



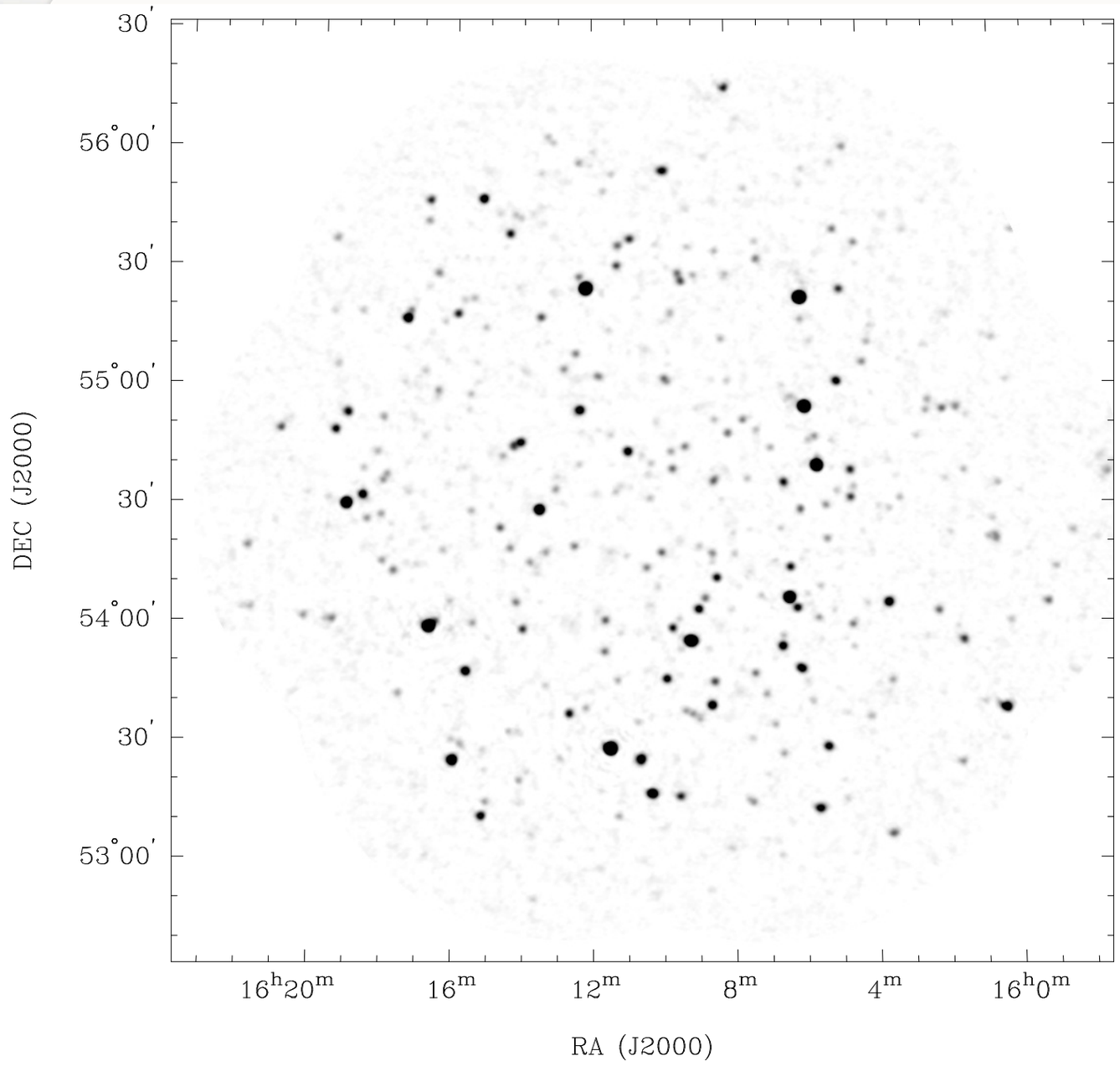

Bower et al. 2010, ApJ, 725, 1792
Bower et al. 2011, ApJ, 739, 76
Croft et al. 2010, ApJ, 719, 45
Croft et al. 2011, ApJ, 731, 34
Croft et al. 2013, ApJ, 762, 93
Croft et al. 2013, in prep.

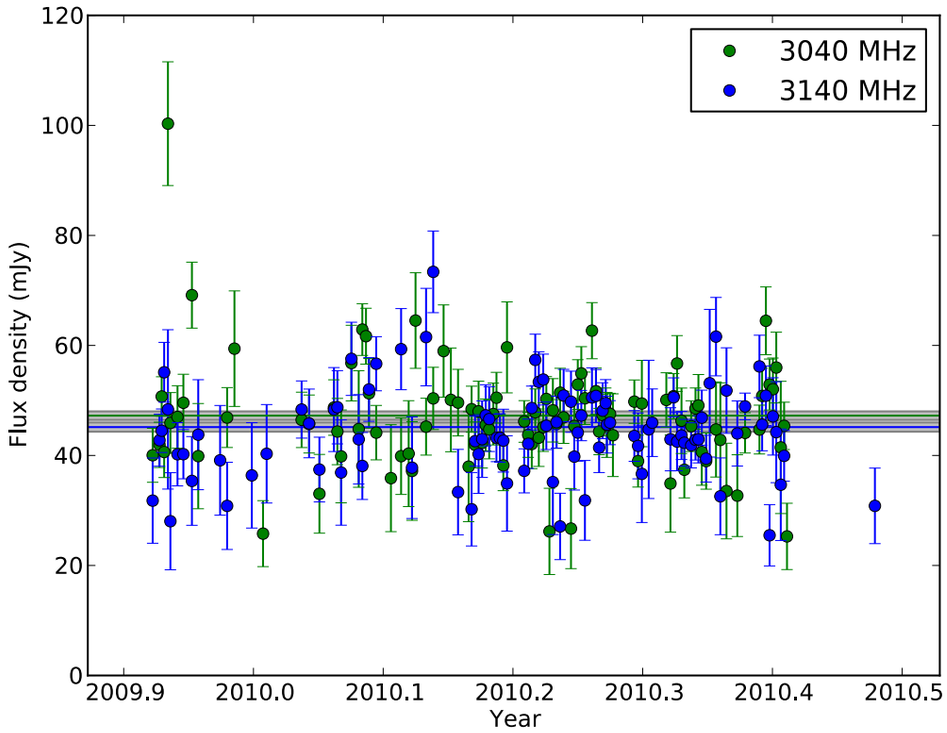
# PIGSS ELAIS



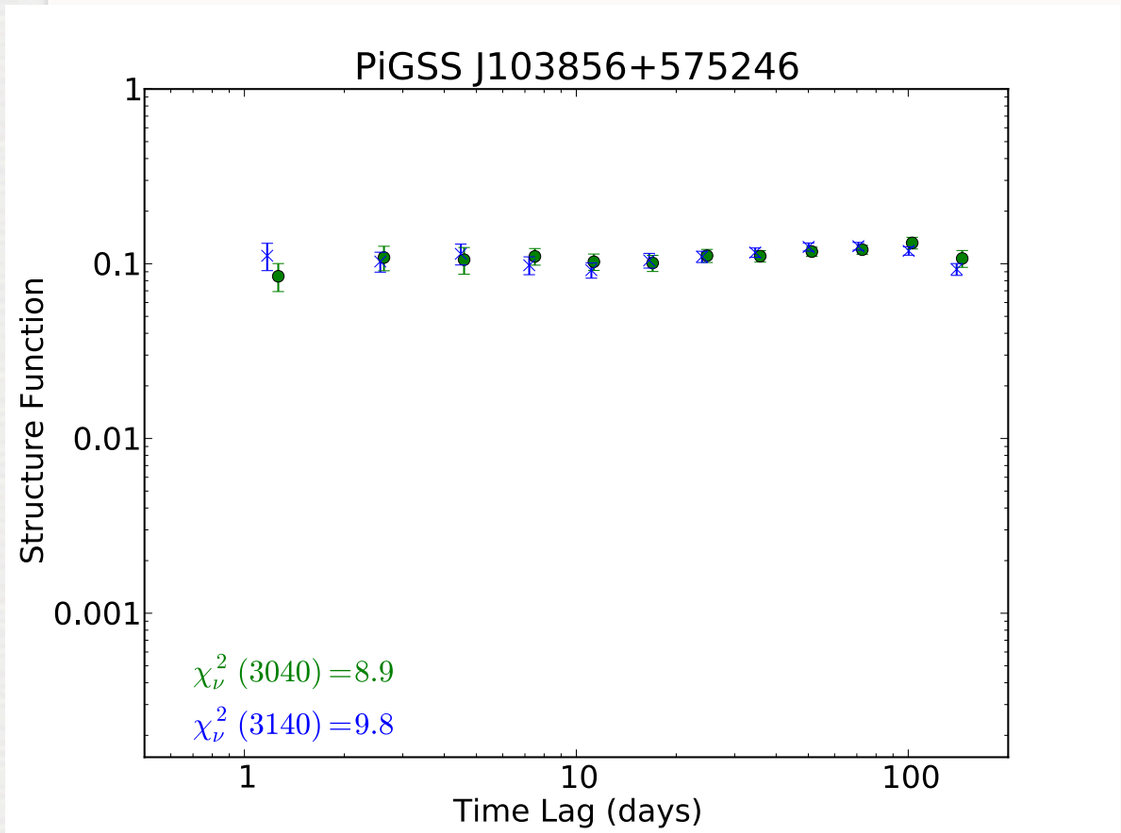

RA, DEC, FREQ = 16:12:42.243, 53:48:31.02, 3.03997350E+00 GHz at pixel (621.00, 513.00, 1.00)
Spatial region : 1,1 to 1432,1356
Pixel map image: mos3040-01-01-11.cm (eliasn1-0001) Min/max=-0.01334/0.1865 Range = $4\times10^{-3}$ to 0.02 JY/BEAM (lin)

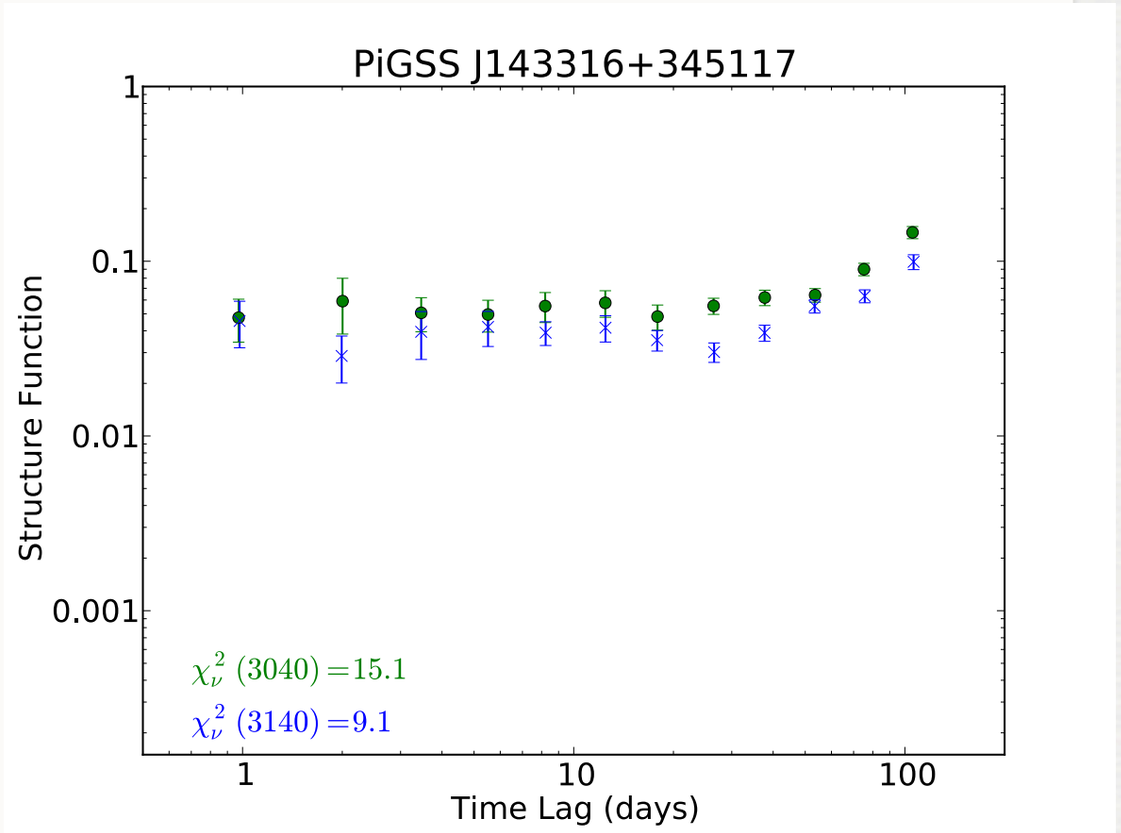
# PIGSS AGN VARIABILITY



# PIGSS AGN VARIABILITY

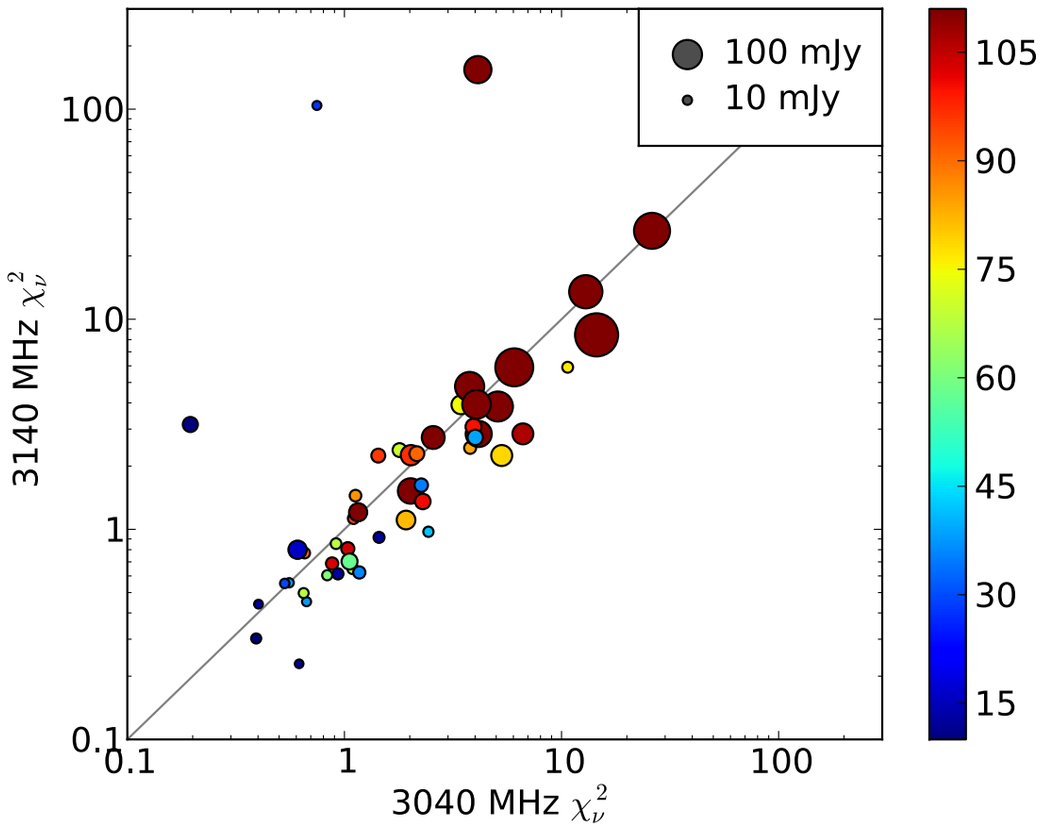


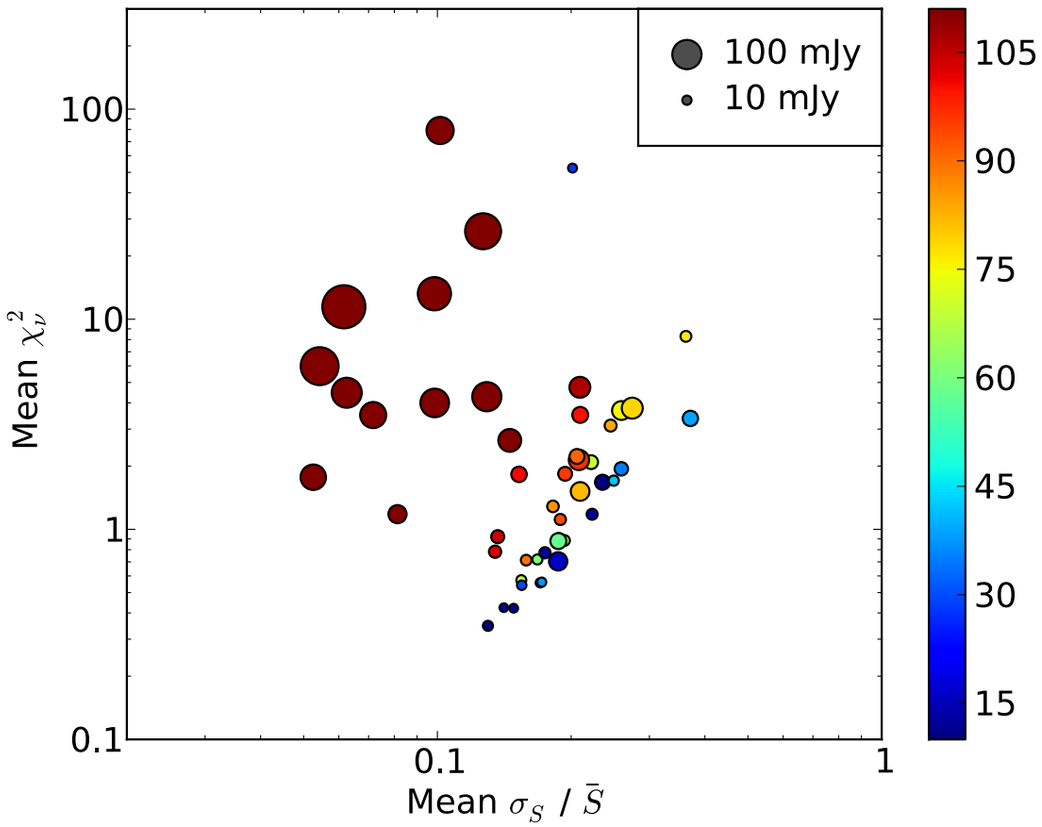




$$D_\nu(\tau) = \frac{1}{N_\tau} \sum_{j,k} \left(S_{\nu,j} - S_{\nu,k}\right)^2$$

Croft et al. 2013, ApJ, 762, 93

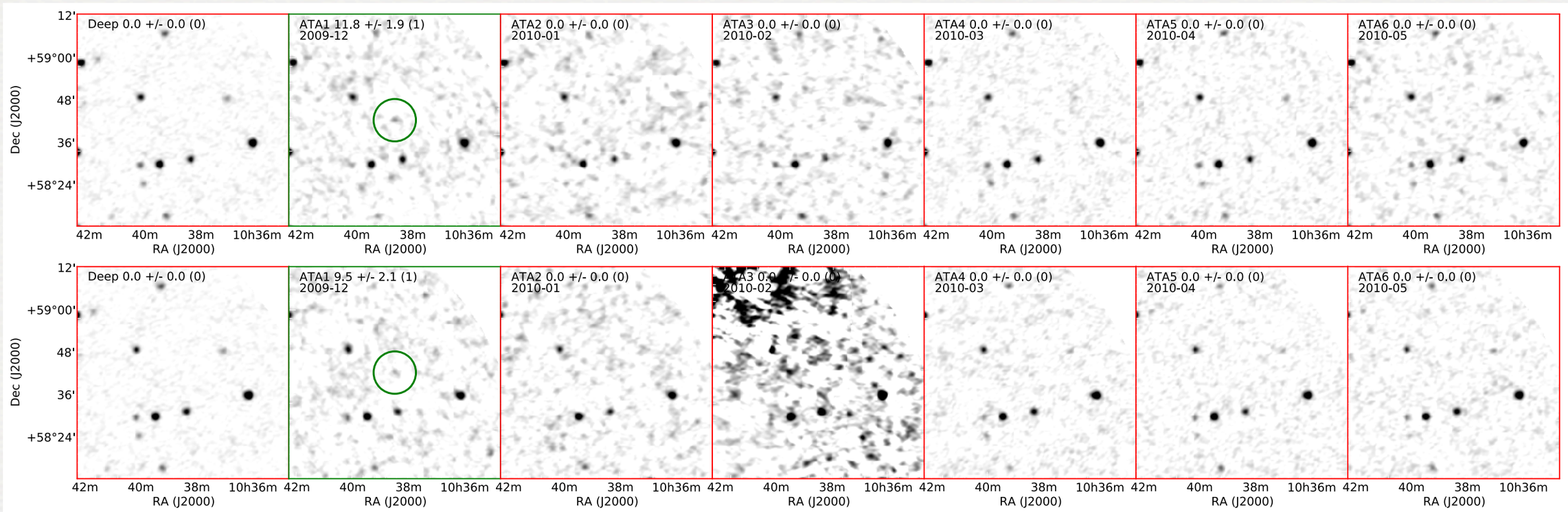
# PIGSS AGN VARIABILITY

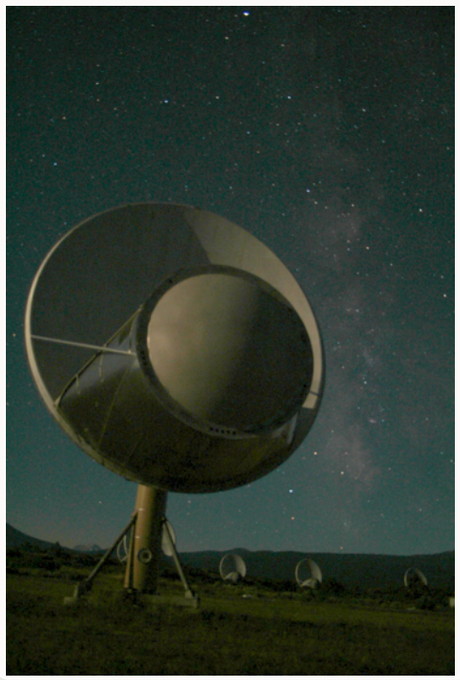



Croft et al. 2013, ApJ, 762, 93

# PIGSS TRANSIENTS



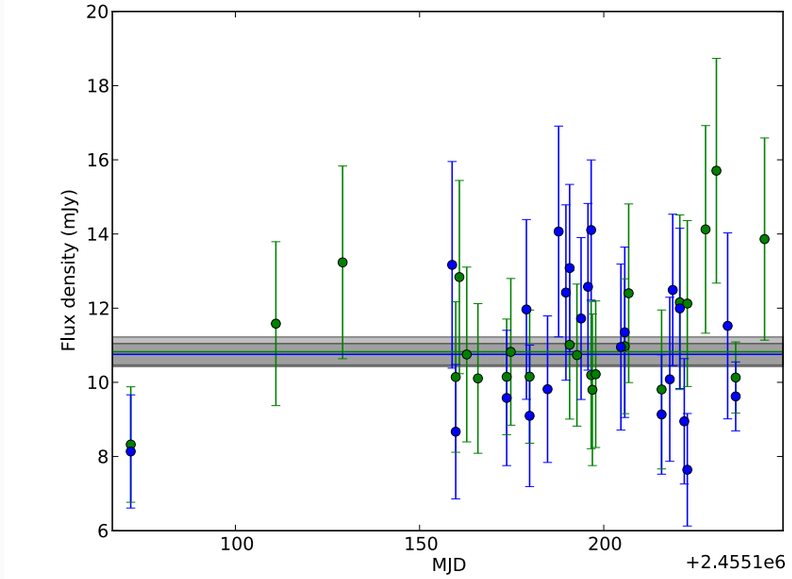



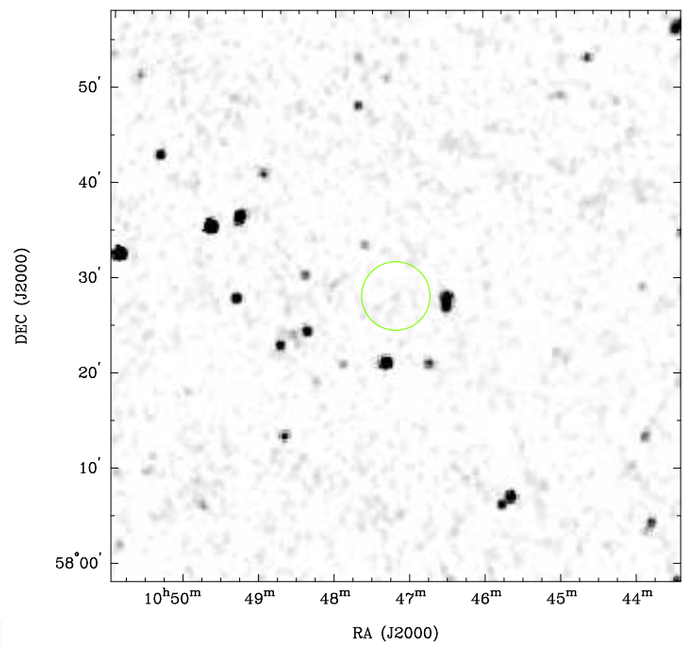
Nothing confirmed to vary by > factor 10
One source brightens by at least a factor 6 in monthly averages

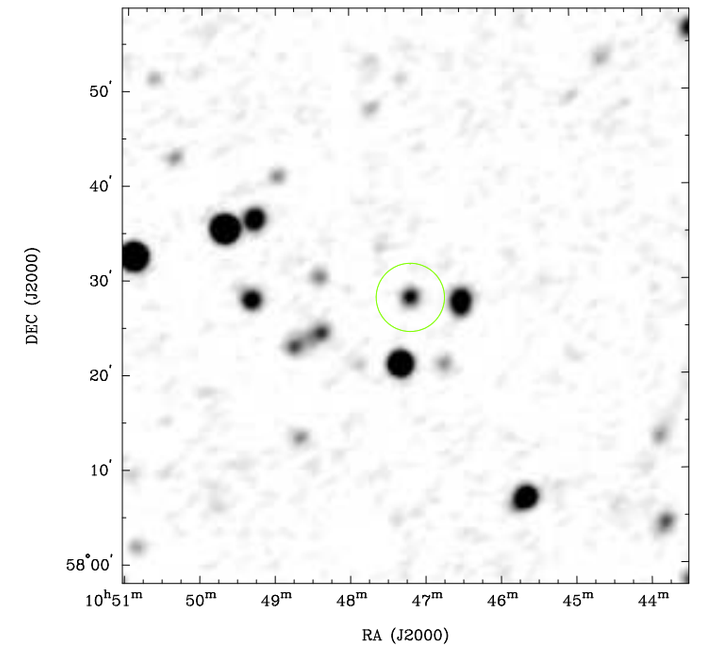
Croft et al. 2013, ApJ, 762, 93

variables

# PIGSS ~~TRANSIENTS~~



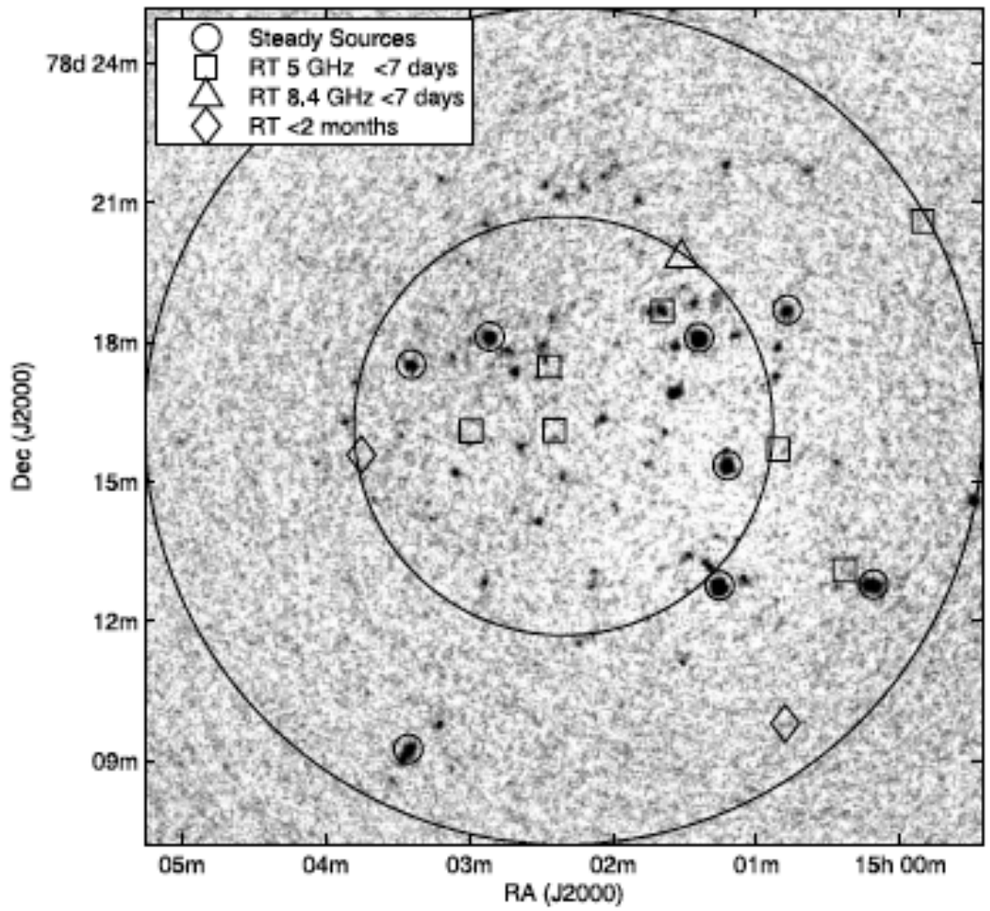




Croft et al. 2013, ApJ, 762, 93

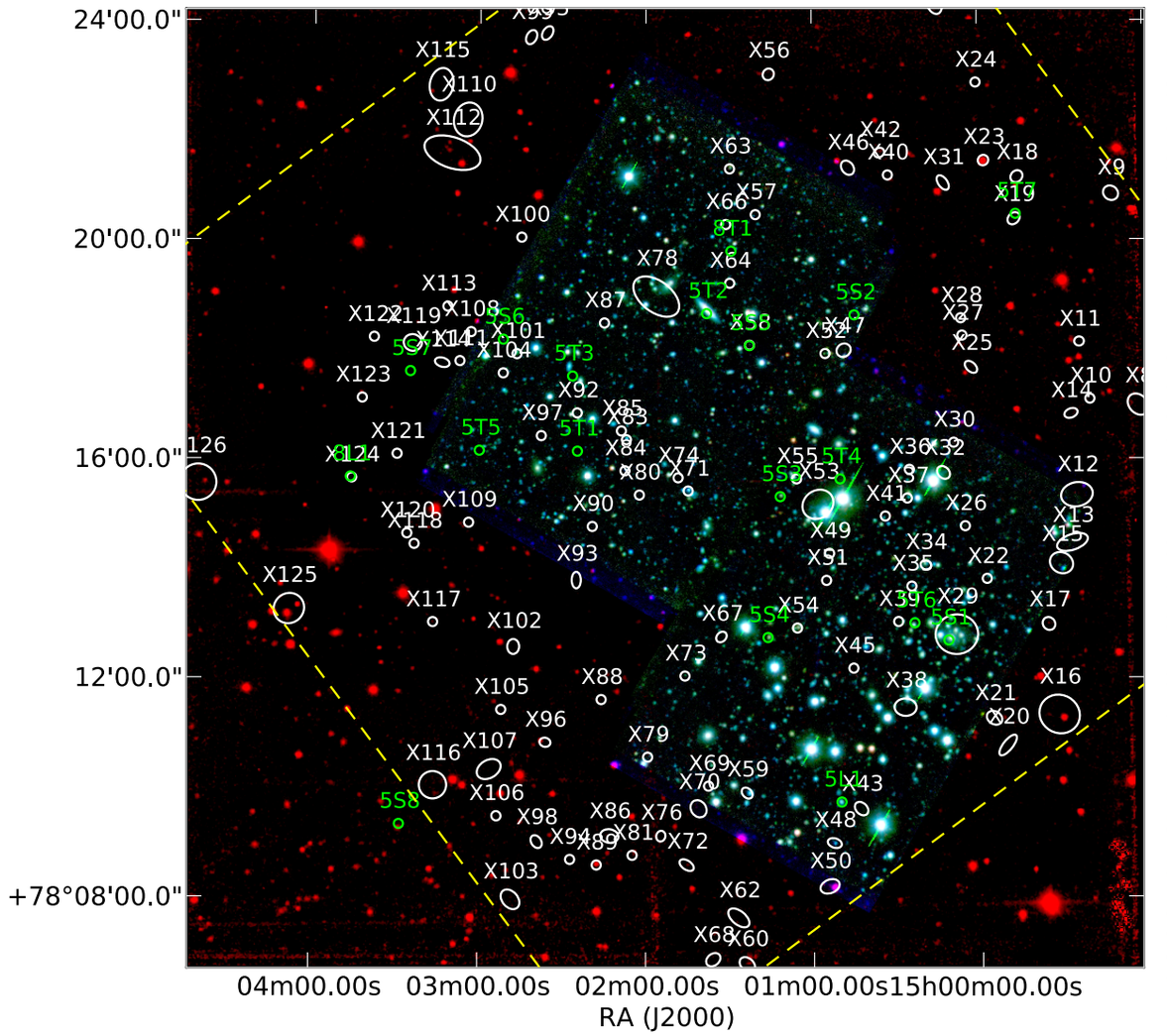
z = 0.6 quasar, brightened by a factor ~3

# BLIND RADIO SEARCHES

Bower et al. (2007) VLA archival 5 and 8.4 GHz

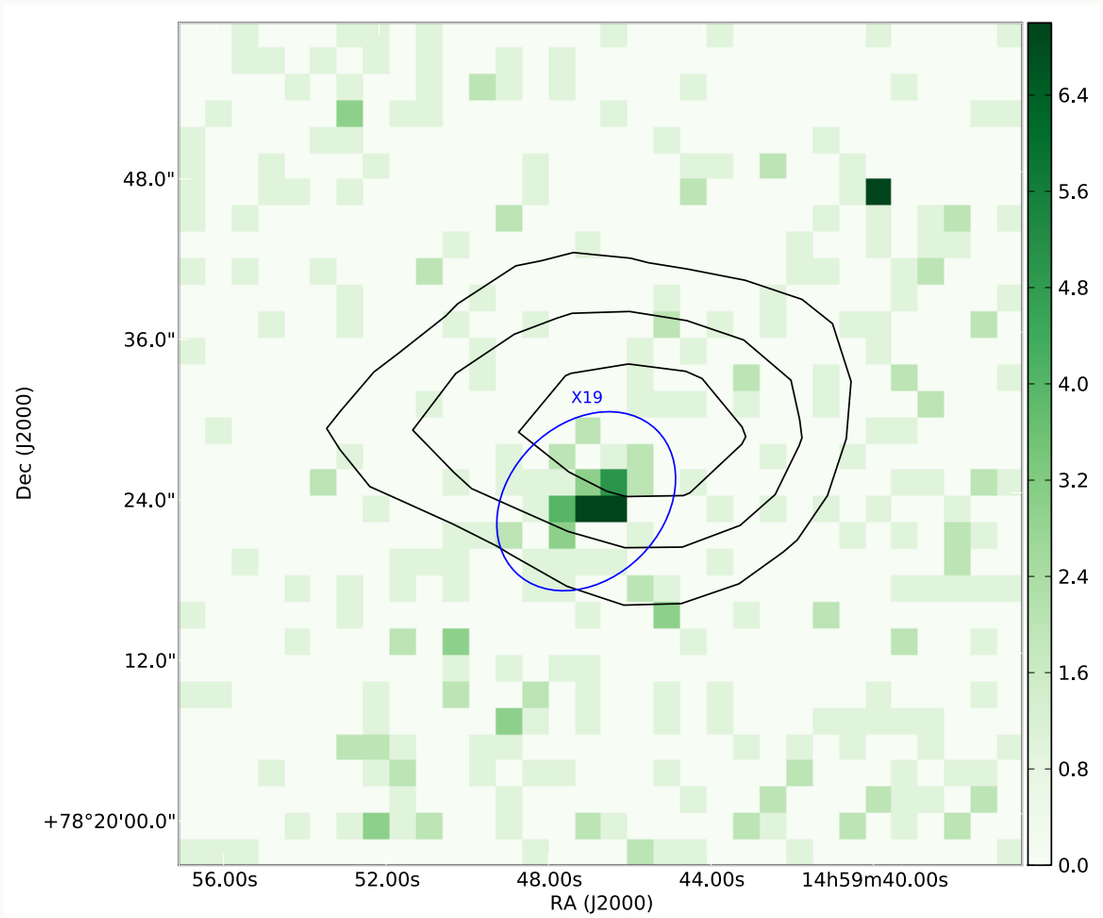


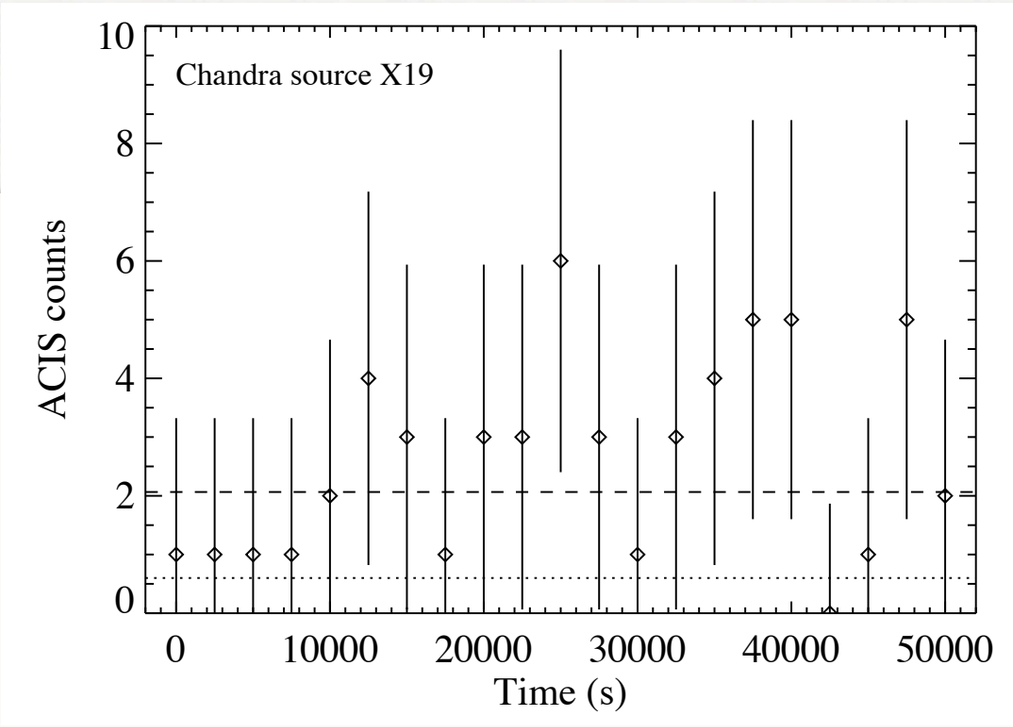

944 epochs, 10 transient candidates ≲ 2 mJy
(5 are artifacts, 1 good detection, 4 marginal - Frail et al. 2012)

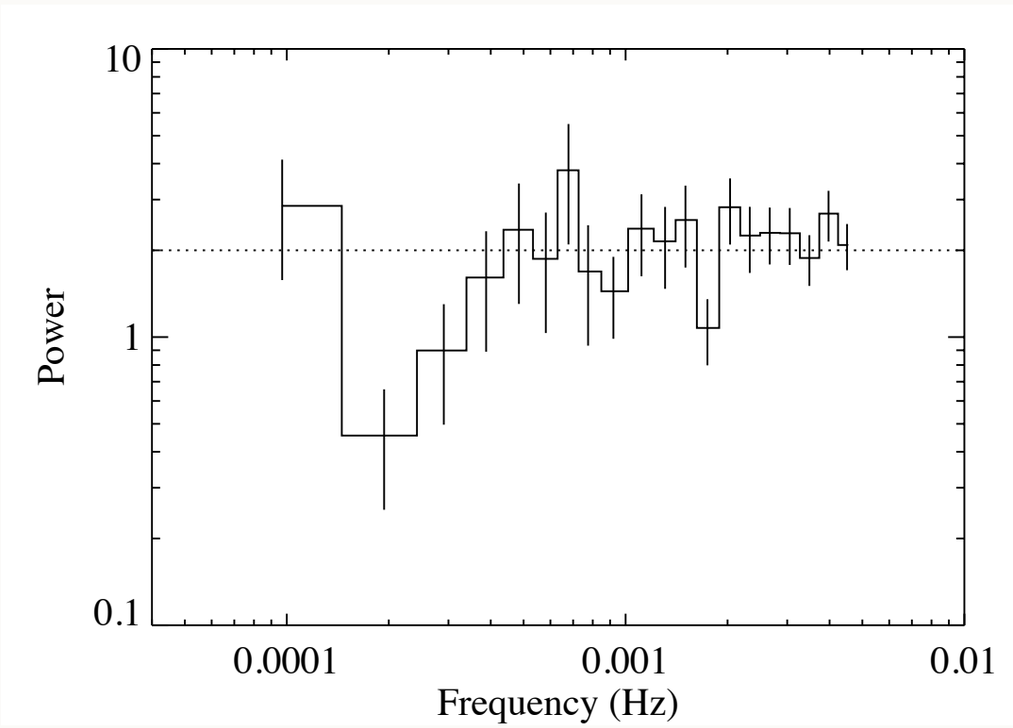



Croft, Tomsick & Bower 2011
ApJ, 740, 87

# X-RAY COUNTERPARTS?

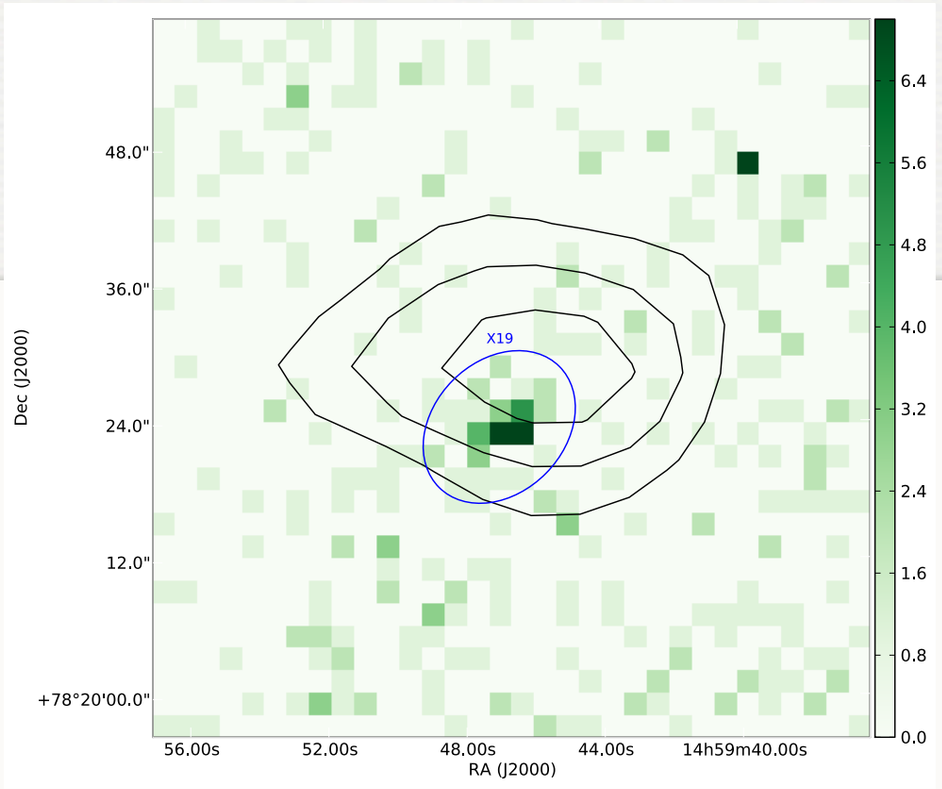


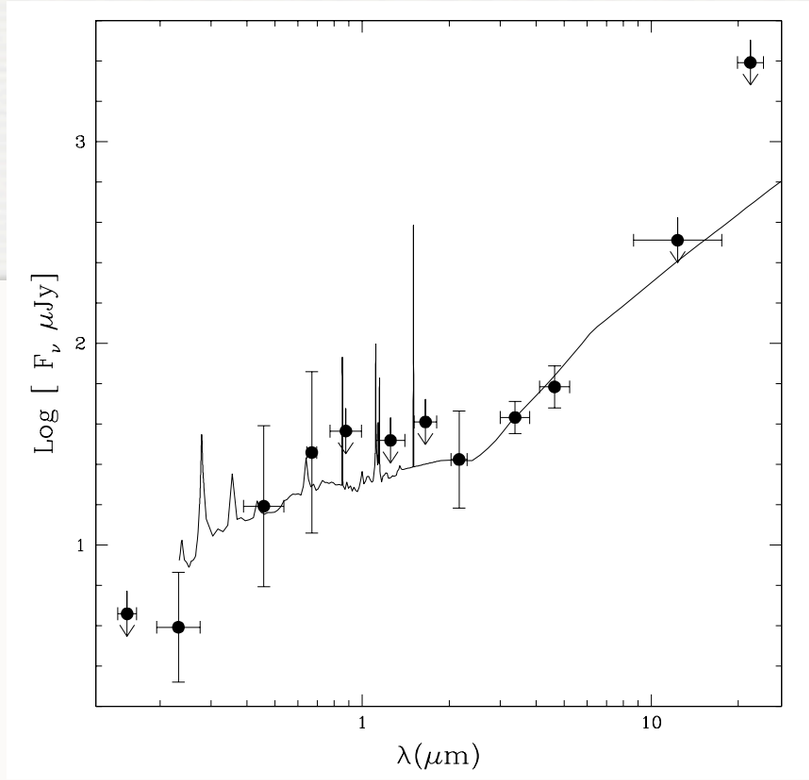



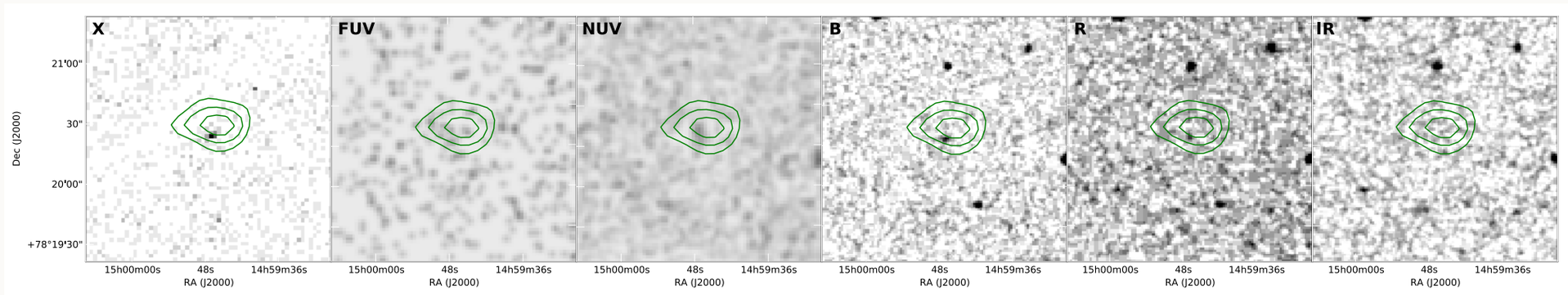



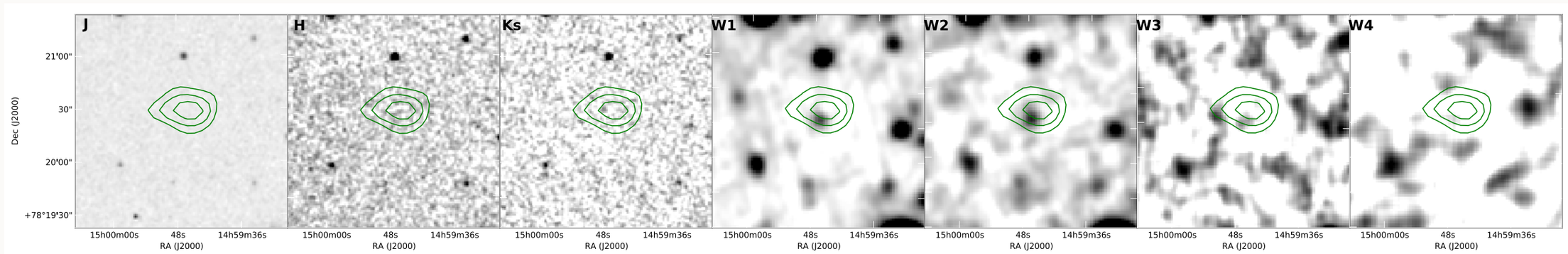

Croft, Tomsick & Bower 2011, ApJ, 740, 87

# Z = 1.29 AGN



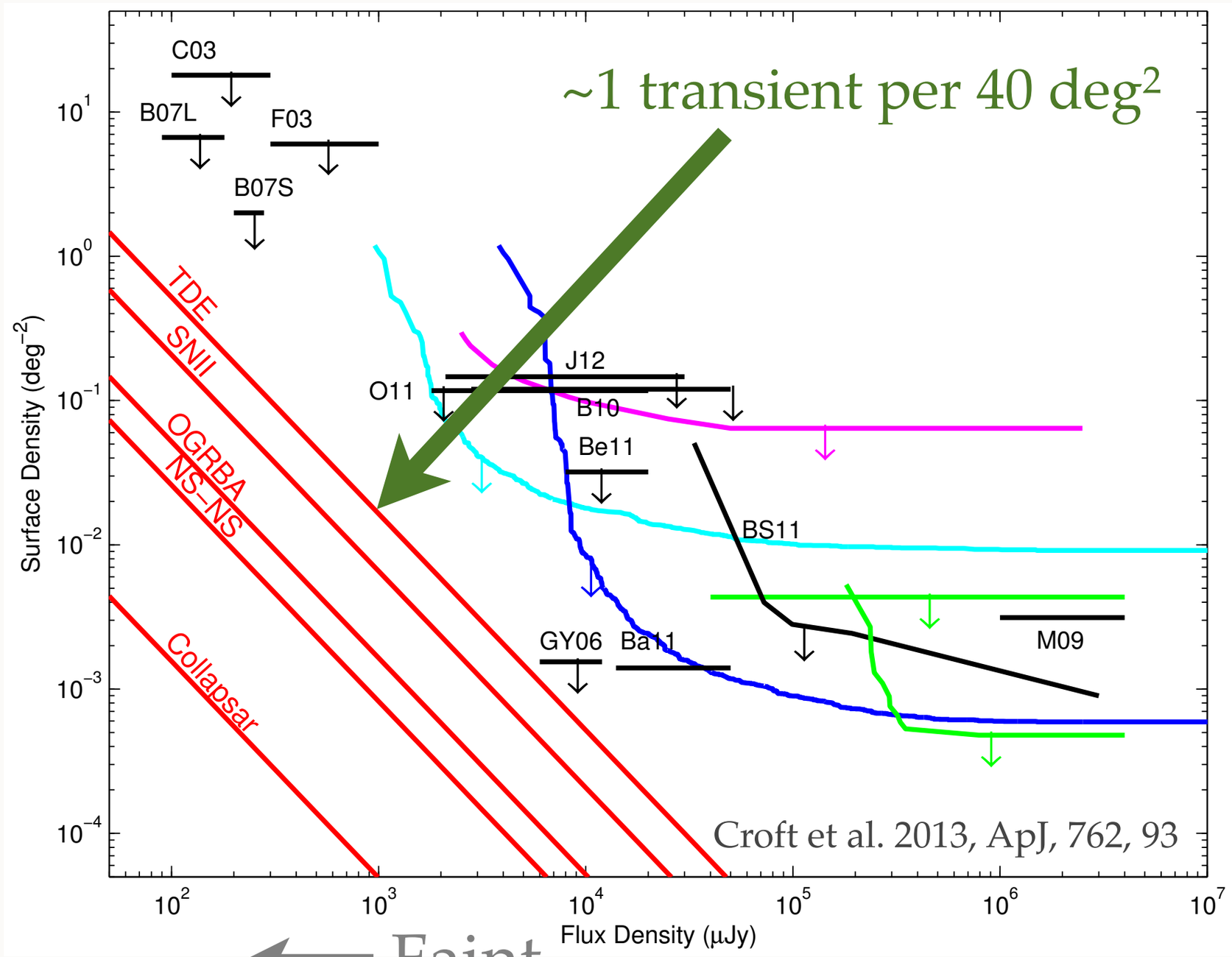




Croft, Tomsick & Bower 2011, ApJ, 740, 87

# PUSHING SENSITIVITY AND AREA

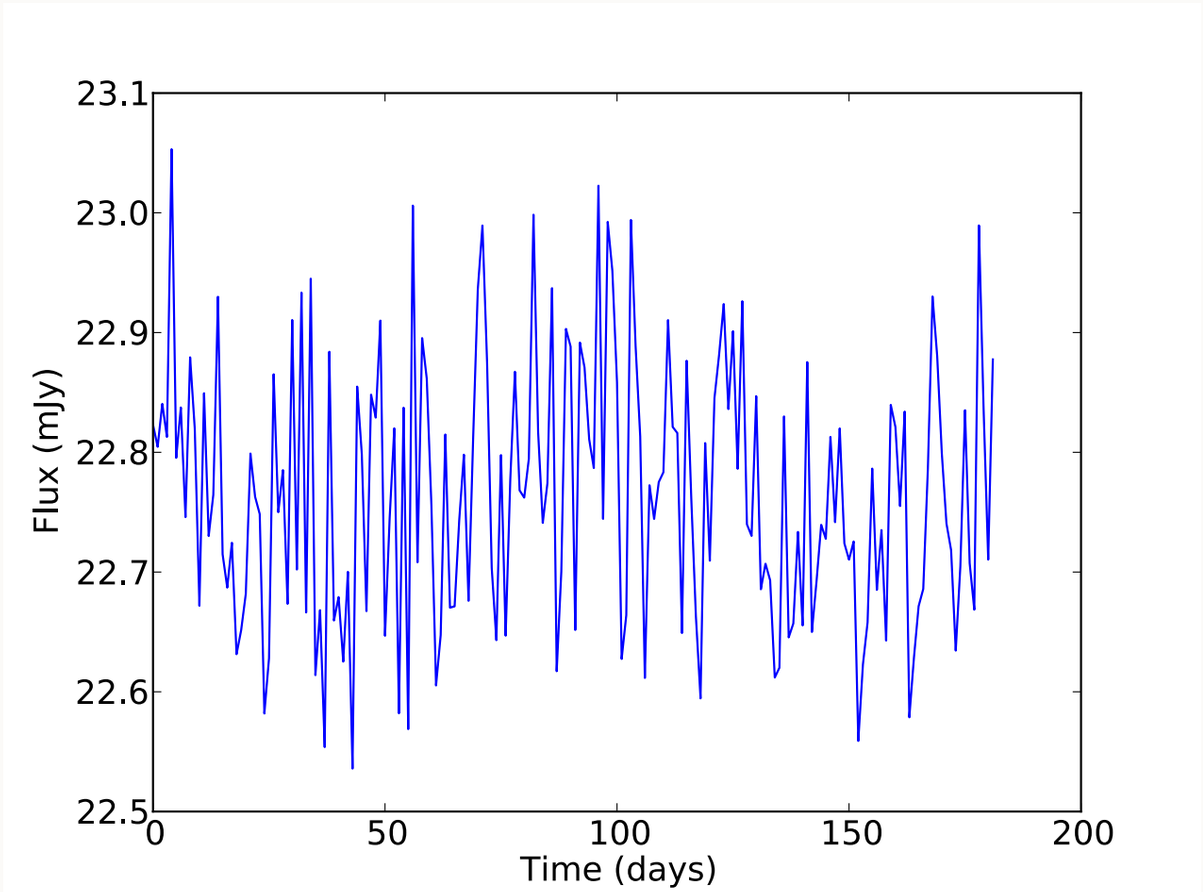



Rare

Faint

# INSPIRAL SIGNATURES

- Unlikely to see flares hours before merger
- Could maybe see modulation of emission at earlier times

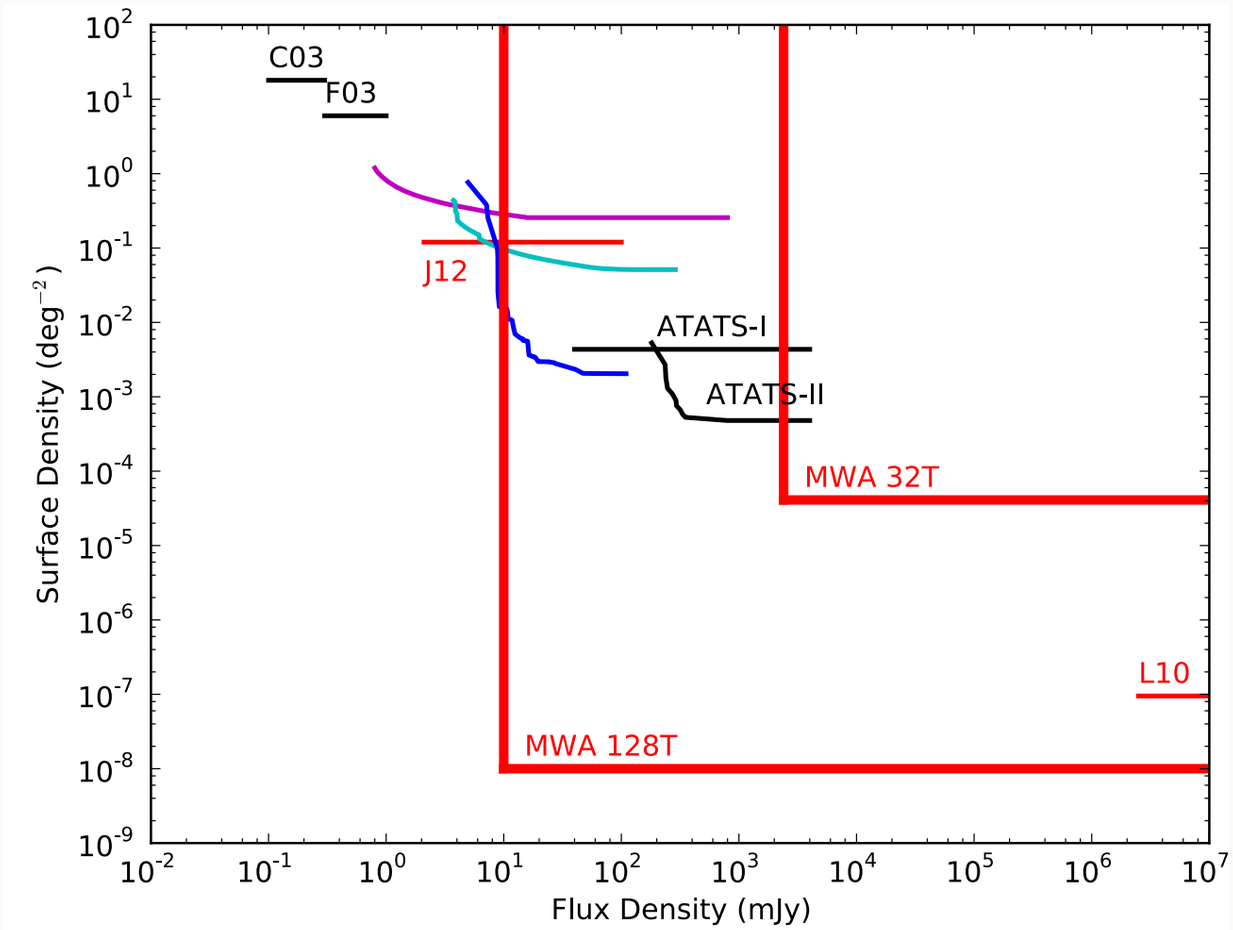




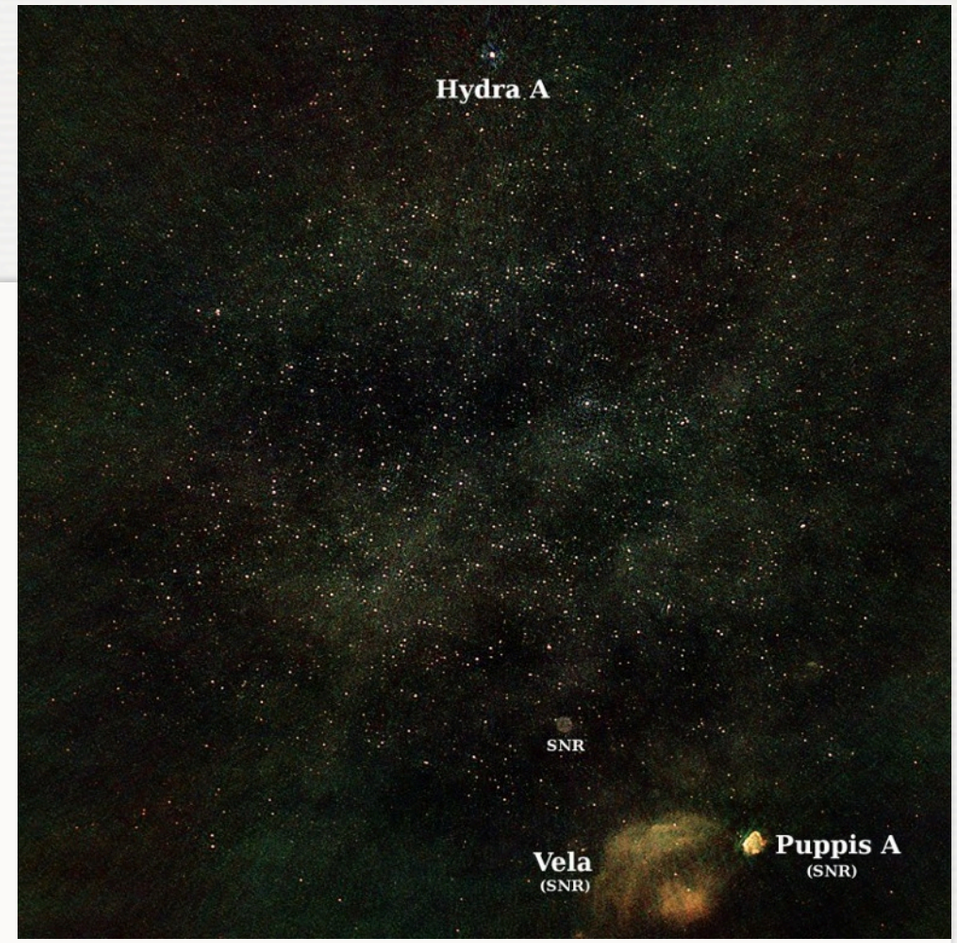


O'Shaughnessy, Croft & Kaplan in prep.

# MWA




Kaplan, Croft proposed 1000h commensal survey




MWA collaboration

# ASKAP

- VAST: 10,000 deg$^2$ daily to 6$\sigma$ = 3 mJy / beam
- Survey speed: 230x ATA-42, with 10x better resolution
- Combining 10 daily images gives good cadence, 1 mJy detection threshold
- 60 *new* TDEs per 10-epoch image, plus 20 RSNII and a handful of OGRBA and NSNS
- Few tens of inspirals
- 250,000 radio AGNs brighter than 5 mJy monitored daily

# THE FUTURE

- Large surveys will see AGNs, TDEs, and inspirals
- MWA, LWA, ASKAP, LOFAR, MeerKAT, WSRT Apertif, and ultimately SKA in the radio
- Multi-wavelength, multi-messenger, archival as well as triggered follow-up
- Consider cadence, and look for multi-epoch or multi-telescope confirmation