

TXS 0128+554: A Young Gamma-Ray Emitting AGN With Episodic Jet Activity

Prof. Matt Lister

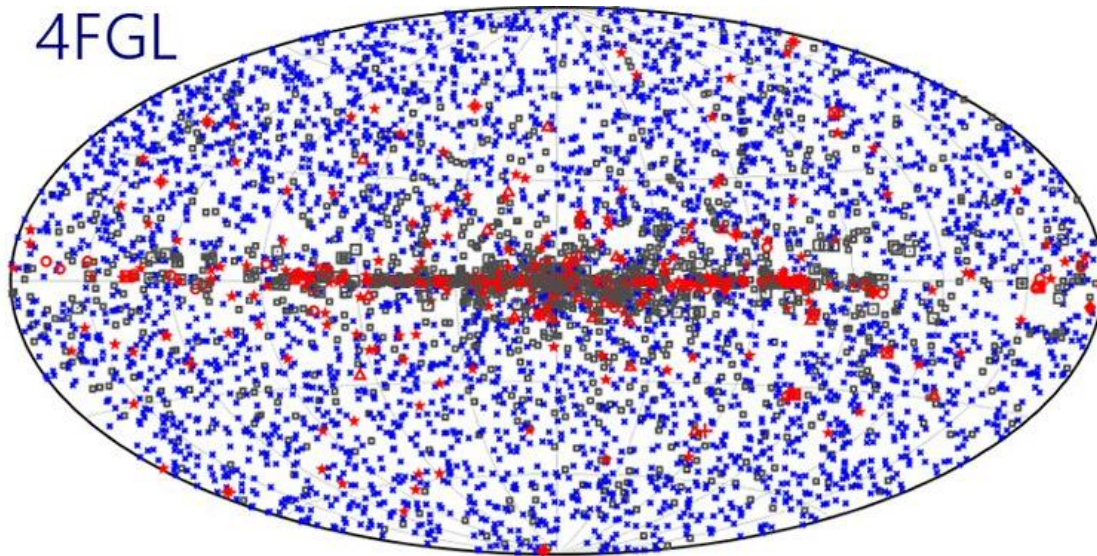
Department of Physics & Astronomy, Purdue University, USA

TXS 0128+554: A Young Gamma-Ray Emitting AGN With Episodic Jet Activity, M. L. Lister, D. C. Homan, Y. Y. Kovalev, S. Mandal, A. B. Pushkarev, & A. Siemiginowska,
Astrophysical Journal, **899**, id. 141, 15 pages (2020)

Artist Impression (NASA GSFC)

The Fermi LAT Gamma-Ray Sky

4FGL



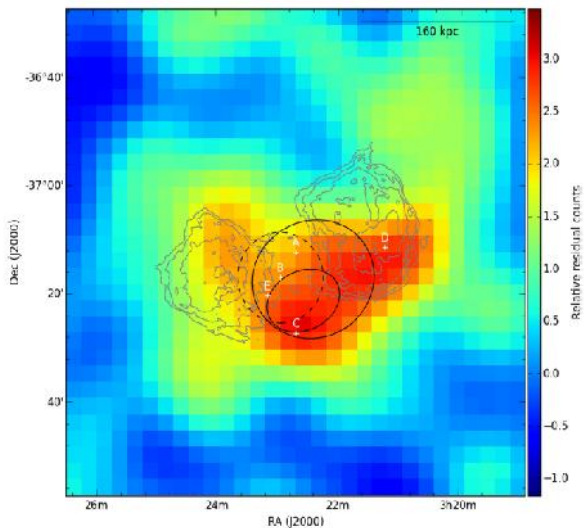
• No association	■ Possible association with SNR or PWN	• AGN
★ Pulsar	▲ Globular cluster	◆ PWN
■ Binary	+ Galaxy	○ SNR
★ Star-forming region	□ Unclassified source	● Nova

- **4FGL-DR2: Broadband all-sky catalog (0.1 GeV – 300 GeV) of ~5800 gamma-ray sources.**
- **~ 95% of sources with known associations are AGN.**
- **98% of the 4LAC AGN catalog are highly beamed blazars.**

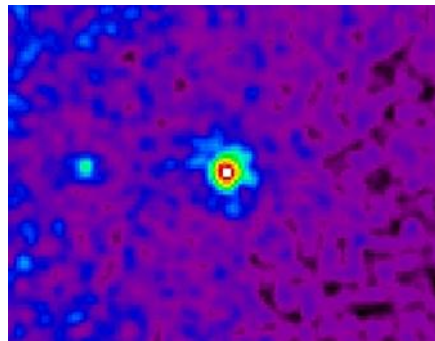
Image credit: <http://www.ssdsc.asi.it>

Gamma-rays from Nearby Radio Galaxies

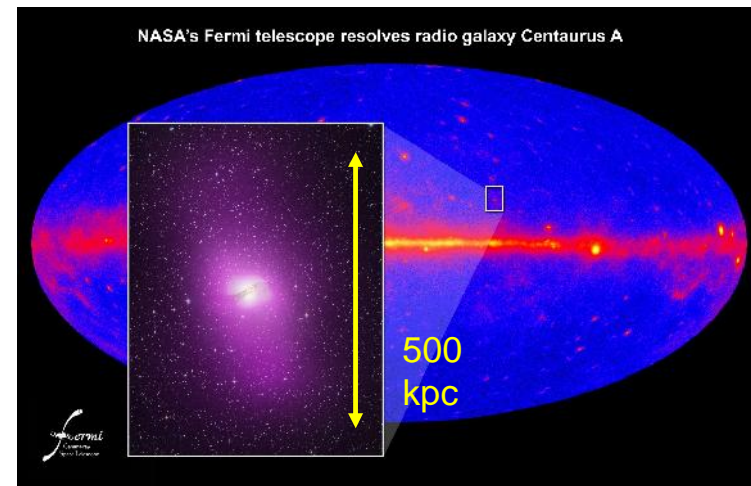
- Only a few detections to date, all within 70 Mpc.
- Non-beamed lobe emission detected.
- Inverse-Compton scattering of CMB photons by relativistic electrons and/or cosmic ray interactions with lobe plasma.



Fornax A (Ackermann et al. 2016 ApJ, 826)



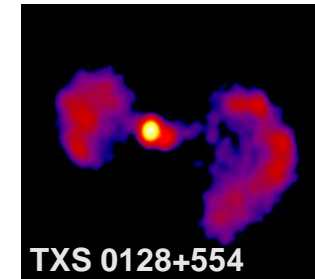
Perseus A (Abdo et al. 2009, ApJ 699,31)



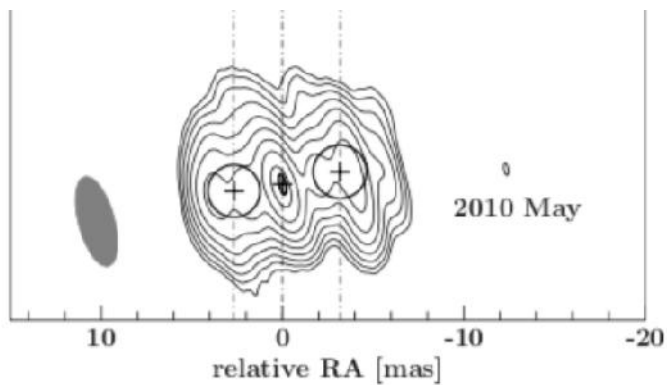
Centaurus A (Abdo et al. 2010, Science 328, 725)

Gamma-rays from Young AGN

- Only a handful of gamma-ray detections among ~100 known CSOs.
- Non-blazar (misaligned) jets with sub-luminal speeds.
- Sizes range from 7 pc to 56 pc.
- Three have compact core features.

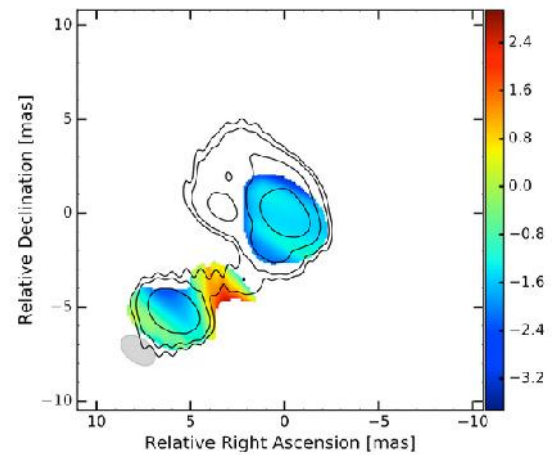


(Lister et al. 2020, ApJ 899, 141)



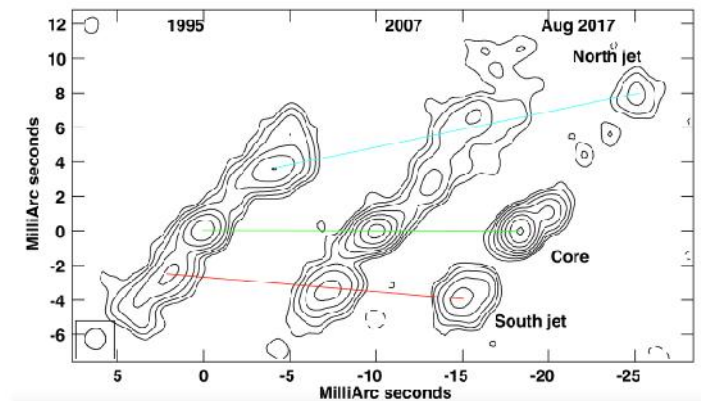
PMN J1603-4904

(Müller et al., 2014, A&A 562,4)



PKS 1718-649

(Angioni et al. 2019, A&A 627, 148,
Migliori et al. 2016, ApJ 821, L31)



NGC 3894

(Principe et al. 2020, A&A 535,185)

Compact Radio Source TXS 0128+554

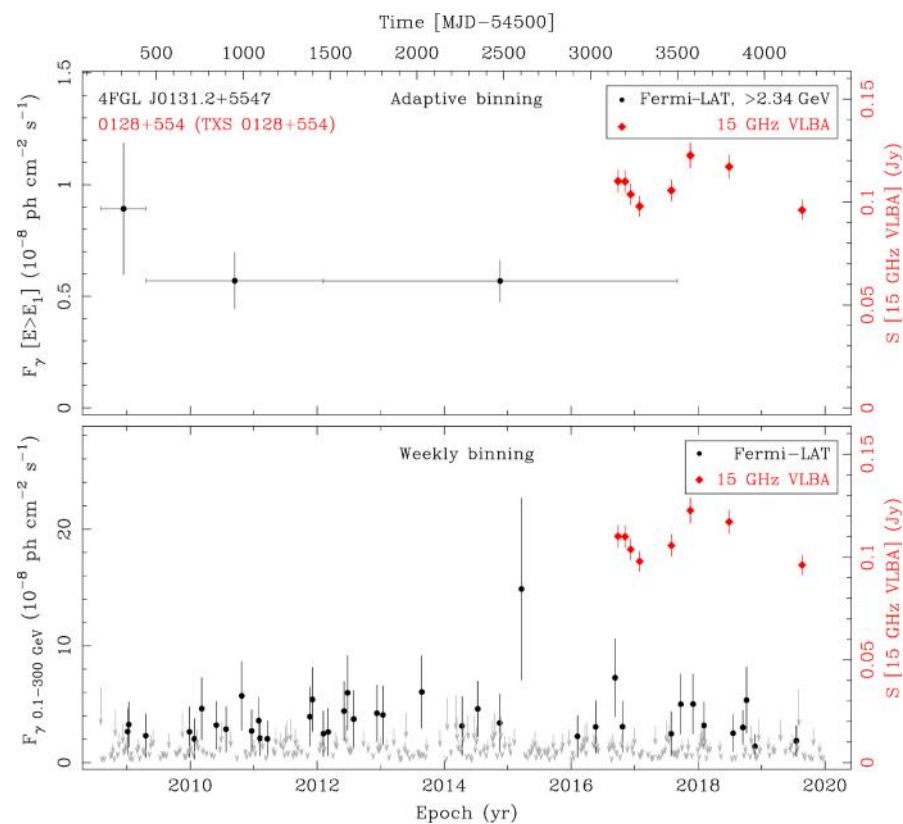
AGN Host: LEDA 2513233

Elliptical galaxy at $z = 0.036$ ($D = 160$ Mpc)



TXS 0128+554: A New Gamma-ray CSO

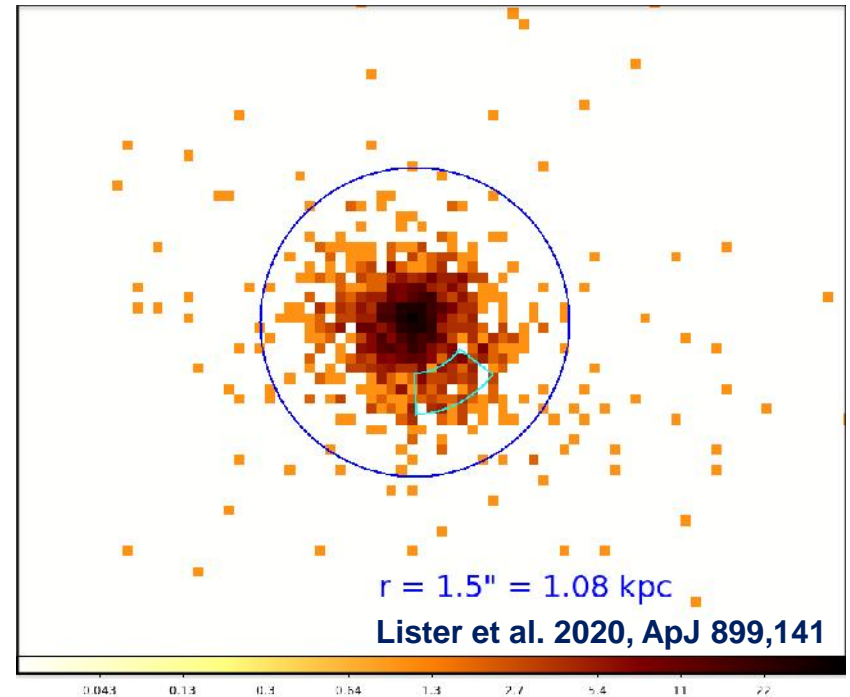
- Added to the MOJAVE VLBA program in 2016.
- Compact radio-loud AGN (0.1 Jy at 15 GHz) located within 95% confidence ellipse of a hard spectrum ($\Gamma = 2.1$) LAT gamma-ray source in 3LAC and 3FHL catalogs.
- No kpc-scale radio emission, but not classified as GPS/CSO due to flat radio spectrum.
- Detected by ROSAT in keV X-ray regime.
- WISE infrared colors place it in the blazar color-color strip but outside the gamma-ray blazar region (Massaro et al. 2012).



Pushkarev et al. (MOJAVE website)

Chandra X-ray Observations

- Observed in March 2019 with Chandra ACIS-S.
- Data fit with absorbed power law model, photon index $\Gamma = 2.4$ between 0.5 keV and 10 keV.
- Possible thermal component present with $kT < 0.08$ keV.
- N_{H} column density of $6.7 \times 10^{21} \text{ cm}^{-2}$ consistent with $N_{\text{HI}} - \text{linear size relation for CSOs}$ (Philström et al. 2003), but at high end of scatter.
 - may indicate an atypically dense neutral medium.



The galaxy is a point-source X-ray emitter in a 19 ksec Chandra exposure.

Multifrequency VLBA Observations: 2.3 GHz to 23 GHz

- Observed with VLBA in June 2018 with spatial resolution ranging from 4 pc to 0.3 pc.
- Relativistic jets are inflating an ellipsoid plasma cocoon ~ 16 pc in diameter.
- Strong flat spectrum core ($T_b \sim 10^{10}$ K) is indicative of current jet activity.

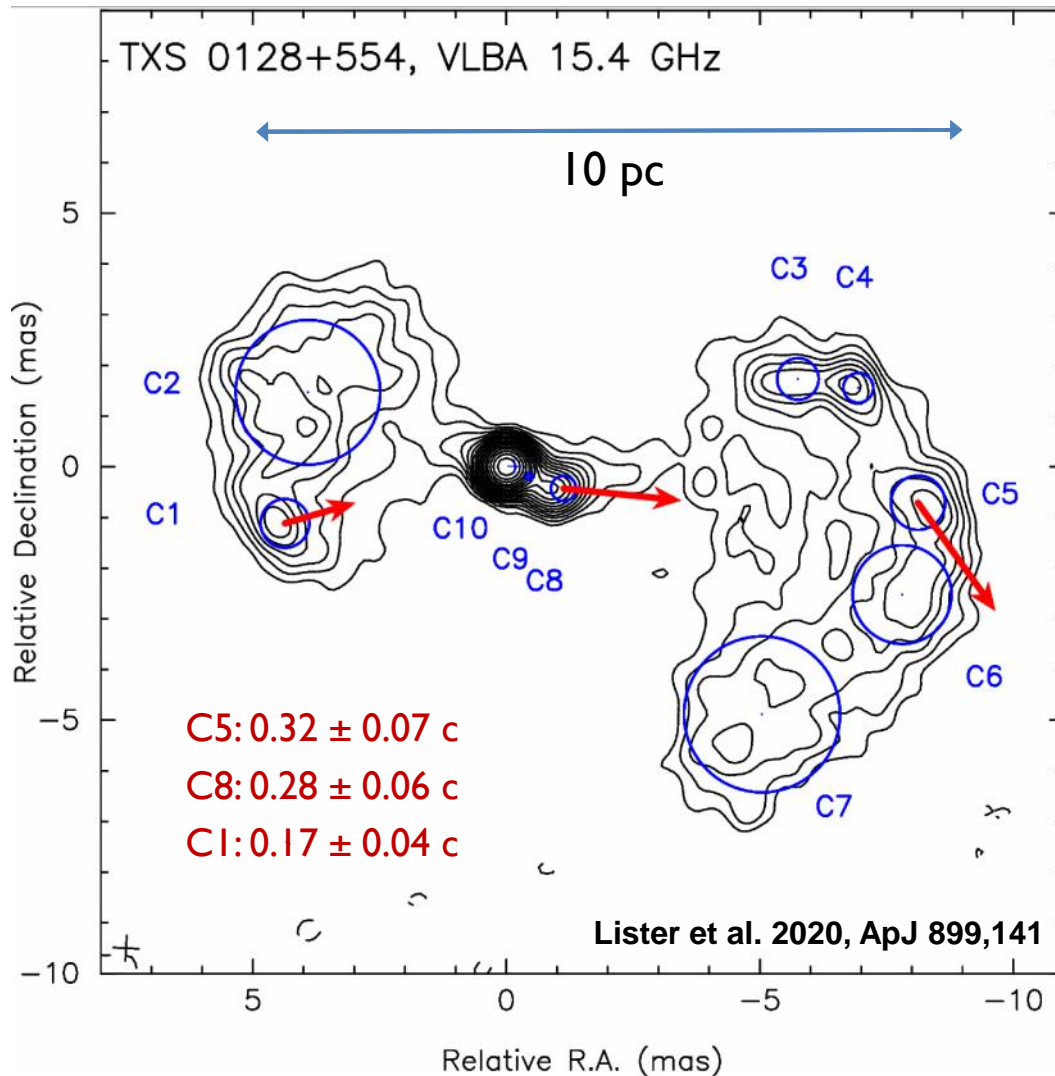
<https://public.nrao.edu/news/stop-start-jets/#PRimage1>



Lister et al. 2020, ApJ 899,141

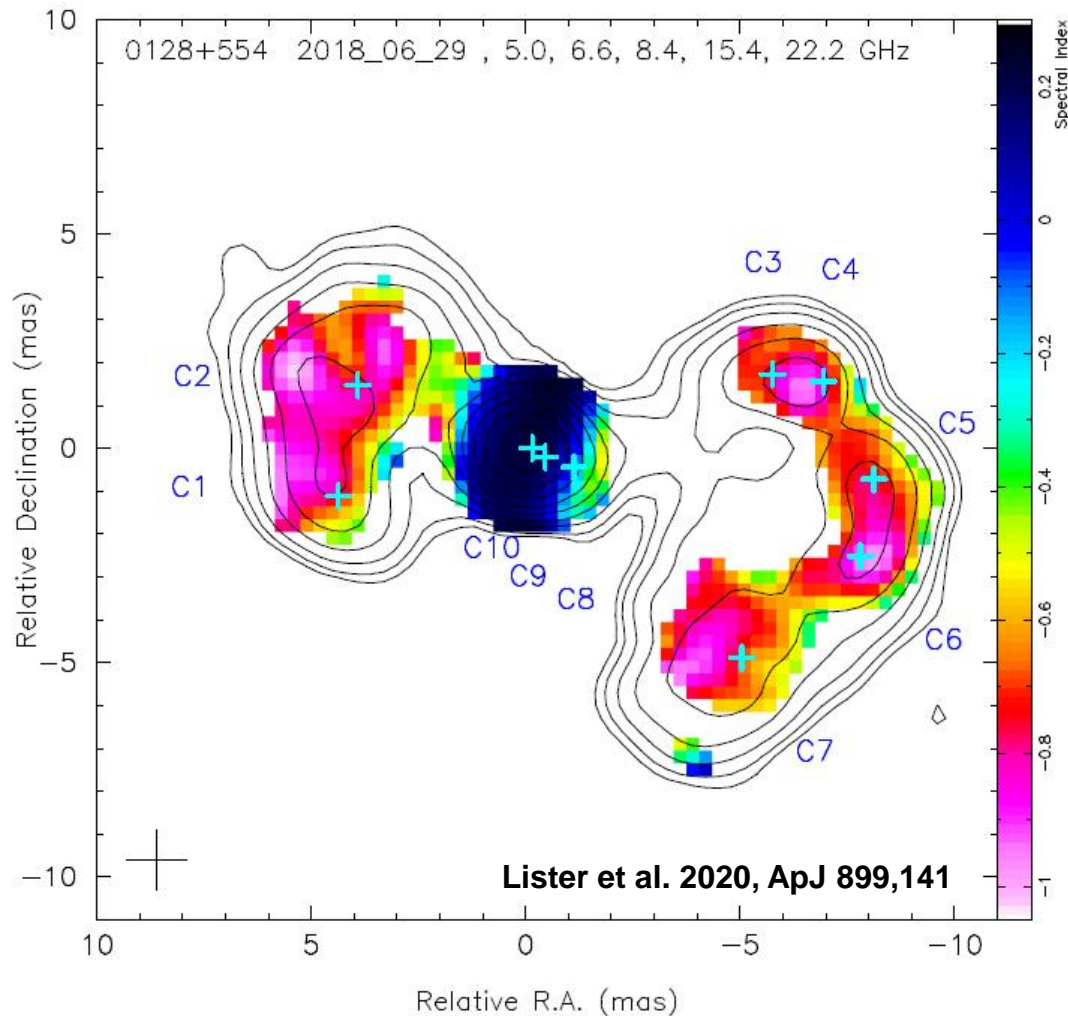
MOJAVE VLBA Monitoring

- 8 epochs at 15 GHz from 2016-2019.
- Cocoon expanding at 0.3 c
→ started growing $\sim 80\text{ yr}$ ago.
- Gap in emission between inner jet and outer shell.
- After going dormant, AGN launched a new inner jet a decade ago.



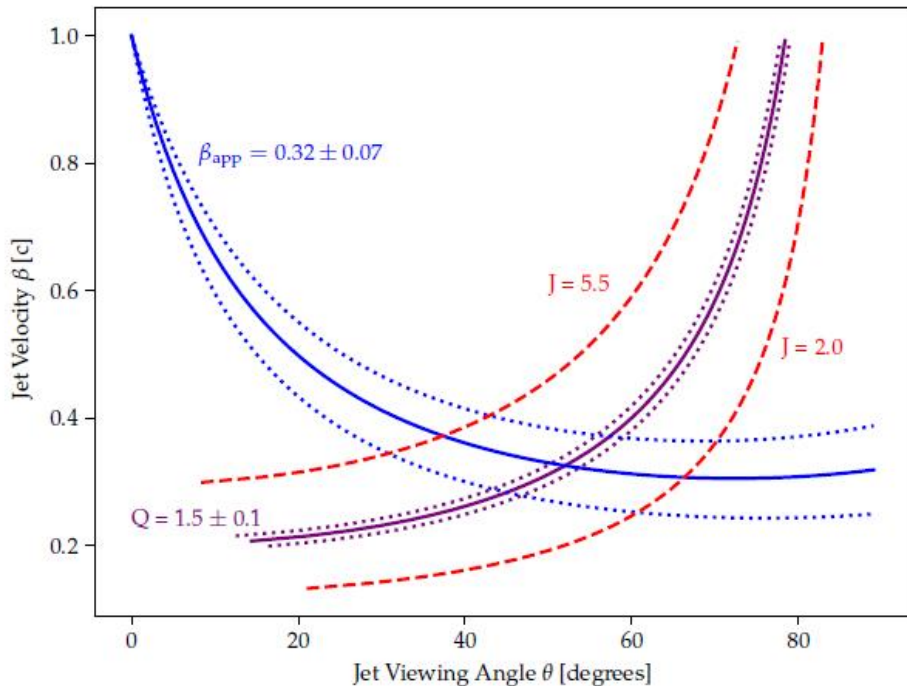
<http://www.physics.purdue.edu/MOJAVE>

Spectral Index Map



- Flat-spectrum core and inner jet region.
- No flat-spectrum (active) hotspots.
- C2 and C6 are aligned with inner jet direction.
- No detectable core shift between frequencies.
 - unusual for flat-spectrum AGN core.
 - may indicate core is a standing recollimation shock.

Jet Speed and Viewing Angle

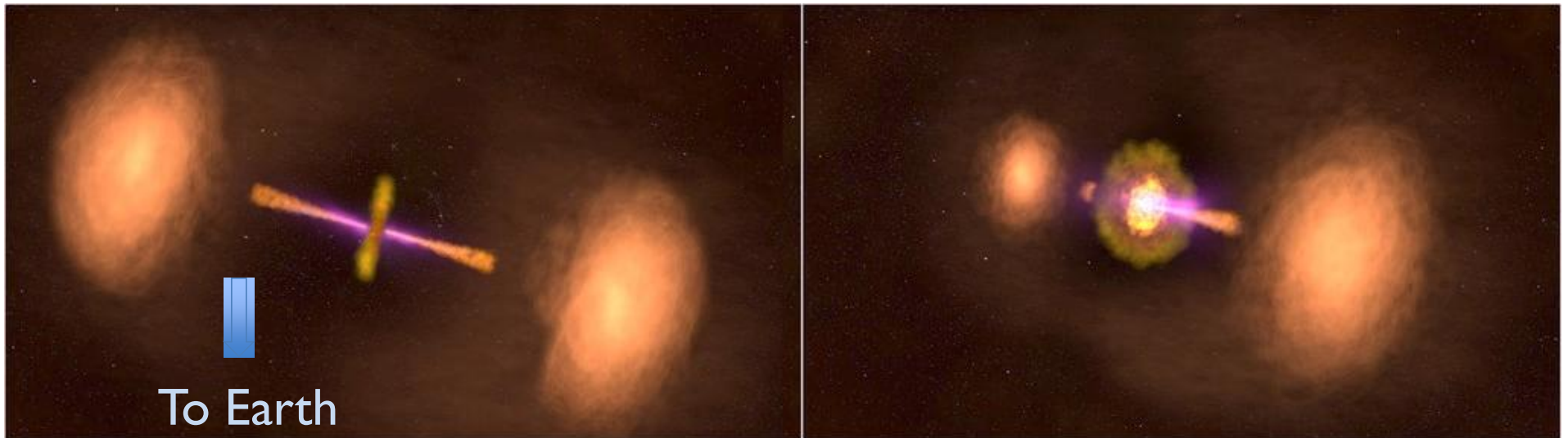


Lister et al. 2020, ApJ 899,141

- Constrained by:
 - i. western lobe expansion speed (blue)
 - ii. jet/counterjet flux ratio J (red)
 - iii. jet/counterjet length ratio Q (purple)
- Intersection point is $\theta = 52 \pm 8^\circ$, $v = 0.3 \pm 0.07 c$
- Doppler factors are $\delta = 1.2$ (approaching) and $\delta = 0.79$ (receding) jet.
- Kinematic age of W lobe is 82 ± 17 years.

“Twin Paradox”

- The eastern (receding) lobe looks smaller (and younger) since its light has travelled a longer distance to reach us.

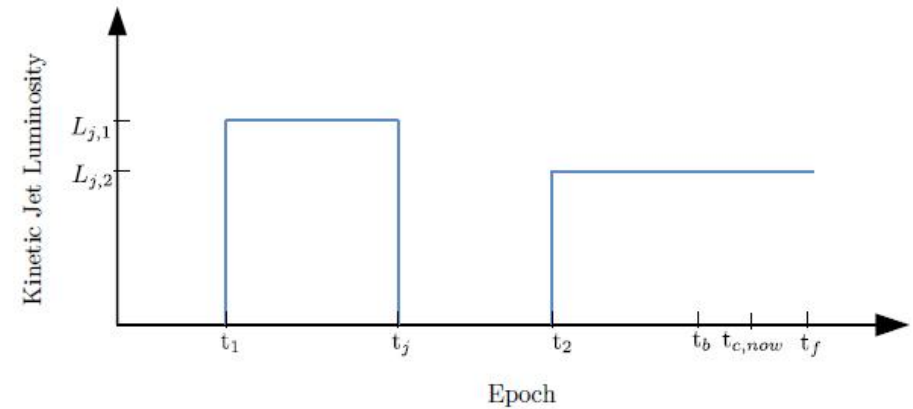


Top down view

What we see on the sky

Jet History

1. Outer lobes started forming 82 ± 17 years ago.
2. Jets turned off, creating an emission gap.
3. Outer shell no longer actively been fed by the AGN.
4. Inner jets re-launched roughly a decade ago.



- Stawarz et al. (2008) cocoon emission model:
 - predicts correct synchrotron luminosity ($L = 10^{41}$ erg/s), SSA turnover frequency (630 MHz), B field (5 – 20 mG)
 - underpredicts gamma-ray emission by three orders of magnitude
 - **gamma-rays are being emitted from the inner jet/core region.**

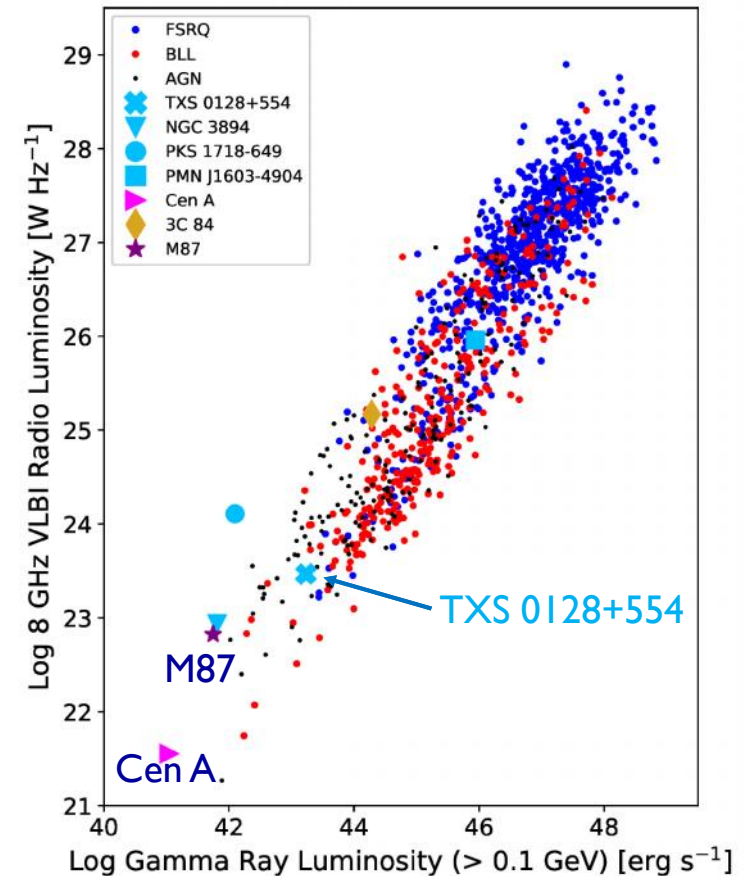
A New Class of Gamma-ray AGN

Source Name	z	D_L [Mpc]	Host Galaxy	kpc morph.	LLS [pc]	θ [°]	β_{app} [c]	Age [y]	ν_m [GHz]	f
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
<i>Fermi</i> -detected CSOs										
TXS 0128+554	0.036	159	Elliptical	C	12	52^{+7}_{-9}	0.32 ± 0.07	82 ± 17	0.66	0.48
NGC 3894	0.011	47	Elliptical	E	7	10–21	~ 0.1	59 ± 5	5	0.18
PKS 1718–649	0.014	62	Elliptical ^a	C	2.5	...	0.06 ± 0.03	70 ± 30	3.6	< 0.01
PMN J1603–4904	0.232	1148	Unknown ^b	E	56	...	< 3	> 54	0.39	0.37

^a Host has an elliptical nucleus with a prominent dust lane, surrounded by faint spiral structure.

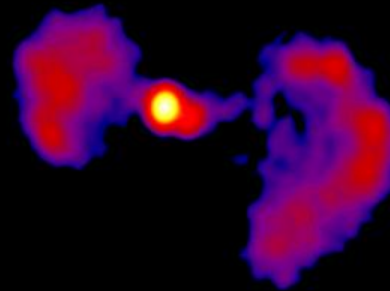
^b No indications of active star formation in optical spectrum (Goldoni et al. 2016).

- TXS 0128+554 lies at extreme low luminosity end of Fermi-detected AGNs.
- Similar properties to NGC 3894 and PKS 1718-649, but much higher 8 GHz radio core fraction ($f = 0.48$).
 - **All three have much lower luminosity than typical CSOs.**



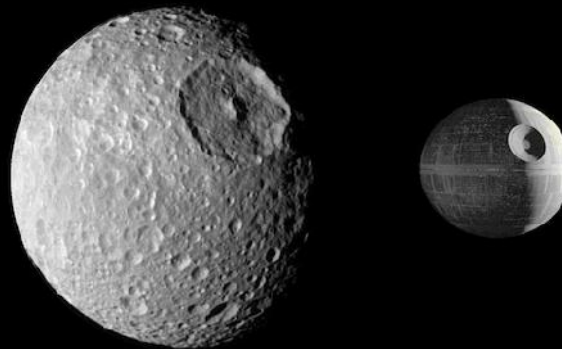
Summary

- Compact Symmetric Objects are a new (rare) class of misaligned gamma-ray emitting AGN.
- TXS 0128+554 is likely detected by Fermi due to a new jet producing powerful gamma-ray emission.



TXS 0128+554

TXS 0128+554: A Young Gamma-Ray Emitting AGN With Episodic Jet Activity,
M. L. Lister, D. C. Homan, Y. Y. Kovalev,
S. Mandal, A. B. Pushkarev, & A.
Siemiginowska,
Astrophysical Journal, **899**, id. 141, 15
pages (2020)



Darth Vader's TIE Fighter in Star Wars Episode IV (Credit: Lucasfilm)

Joins the 'Death Star' moon
Mimas in the Star Wars –
Astronomy pantheon.