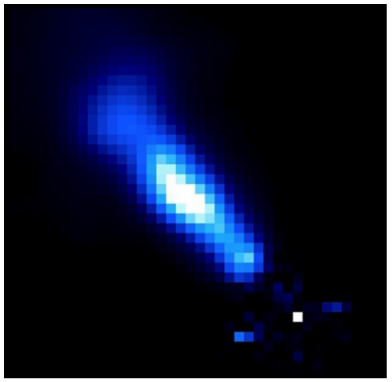
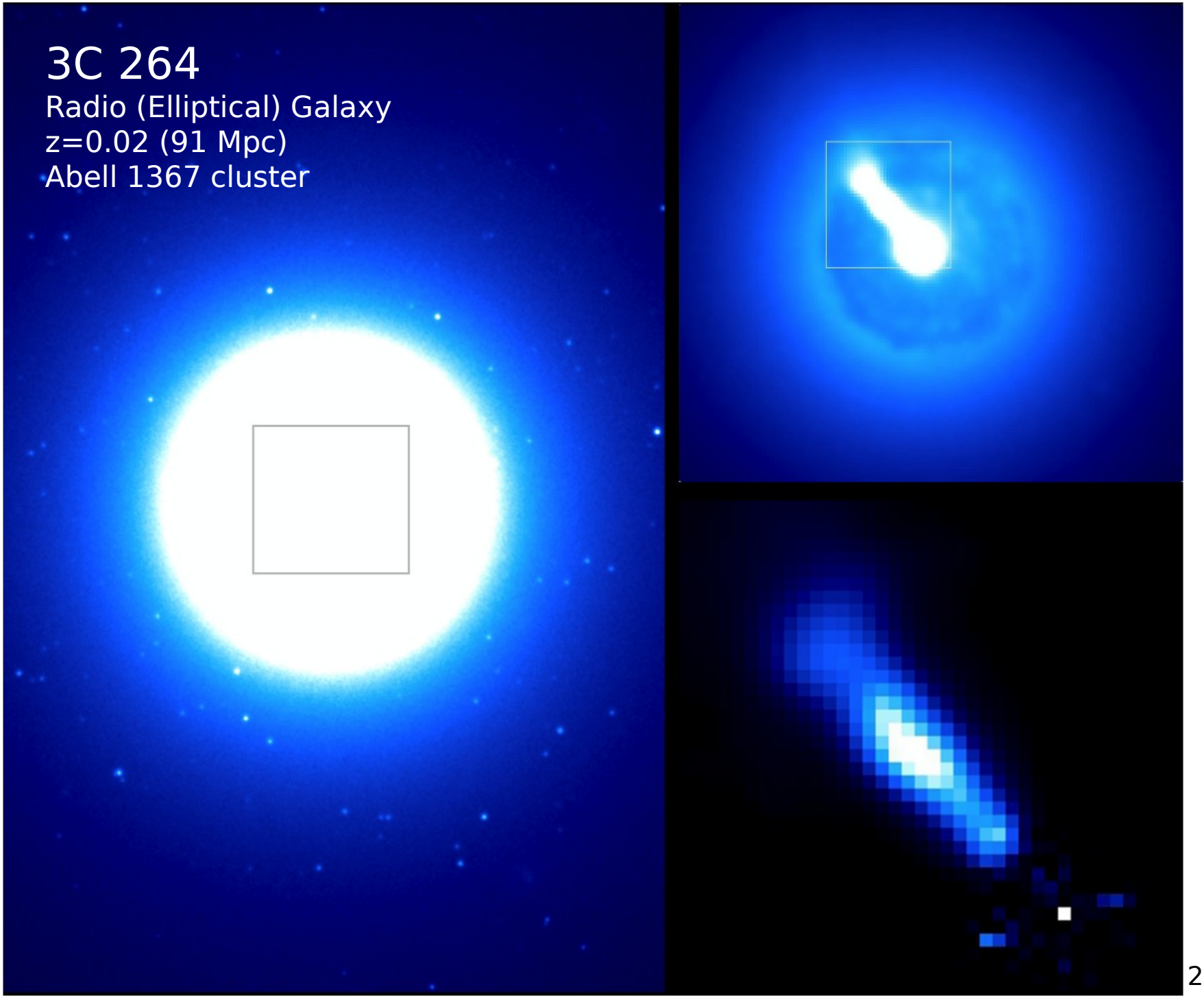
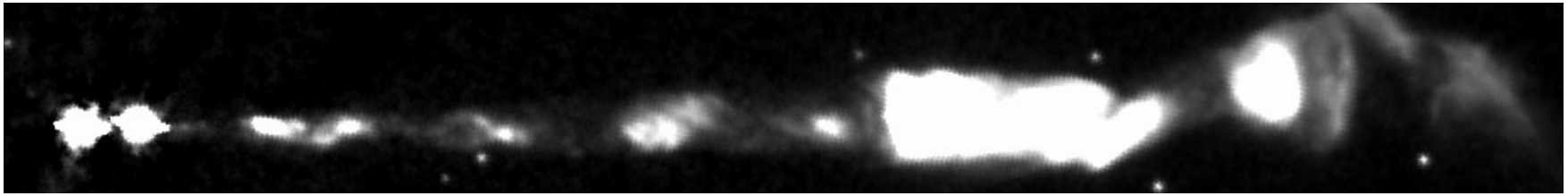
VERITAS detection & ongoing kinematic monitoring of Radio Galaxy 3C 264



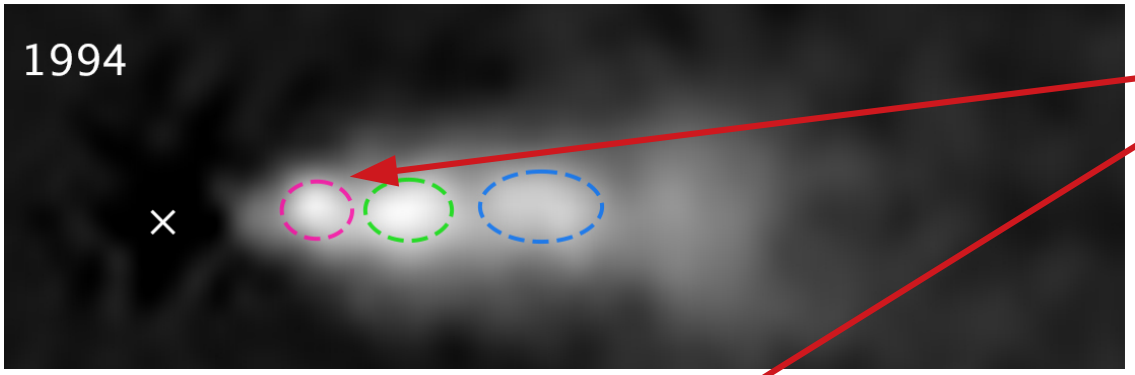
Eileen Meyer
University of Maryland Baltimore County
For the VERITAS Collaboration
Fermi Symposium 2018 | 16 Oct 2018


3C 264
Radio (Elliptical) Galaxy
z=0.02 (91 Mpc)
Abell 1367 cluster

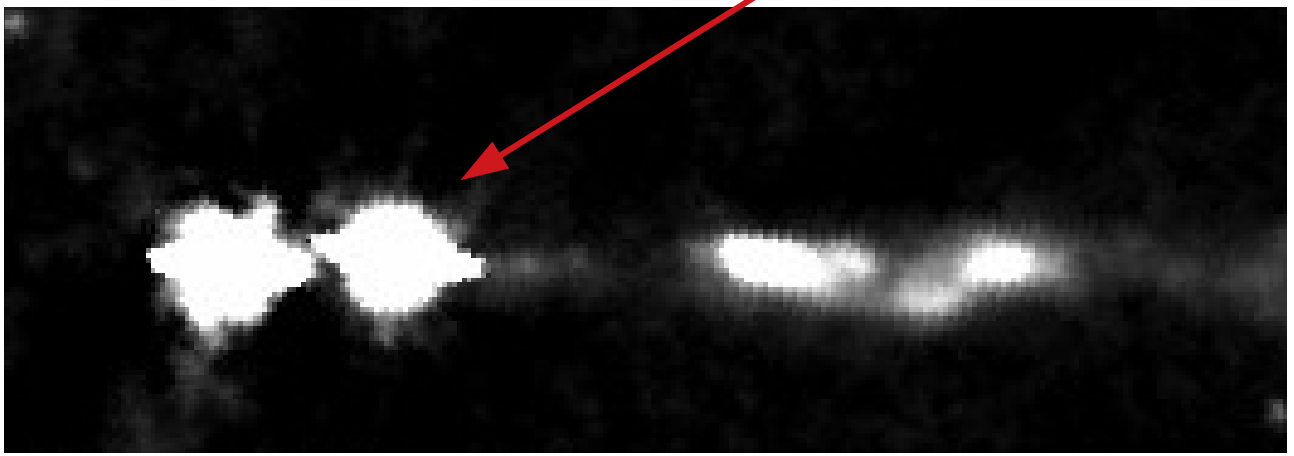
M87 – d=22 Mpc, 106 pc/”



3C264 – d=91 Mpc, 442 pc/”

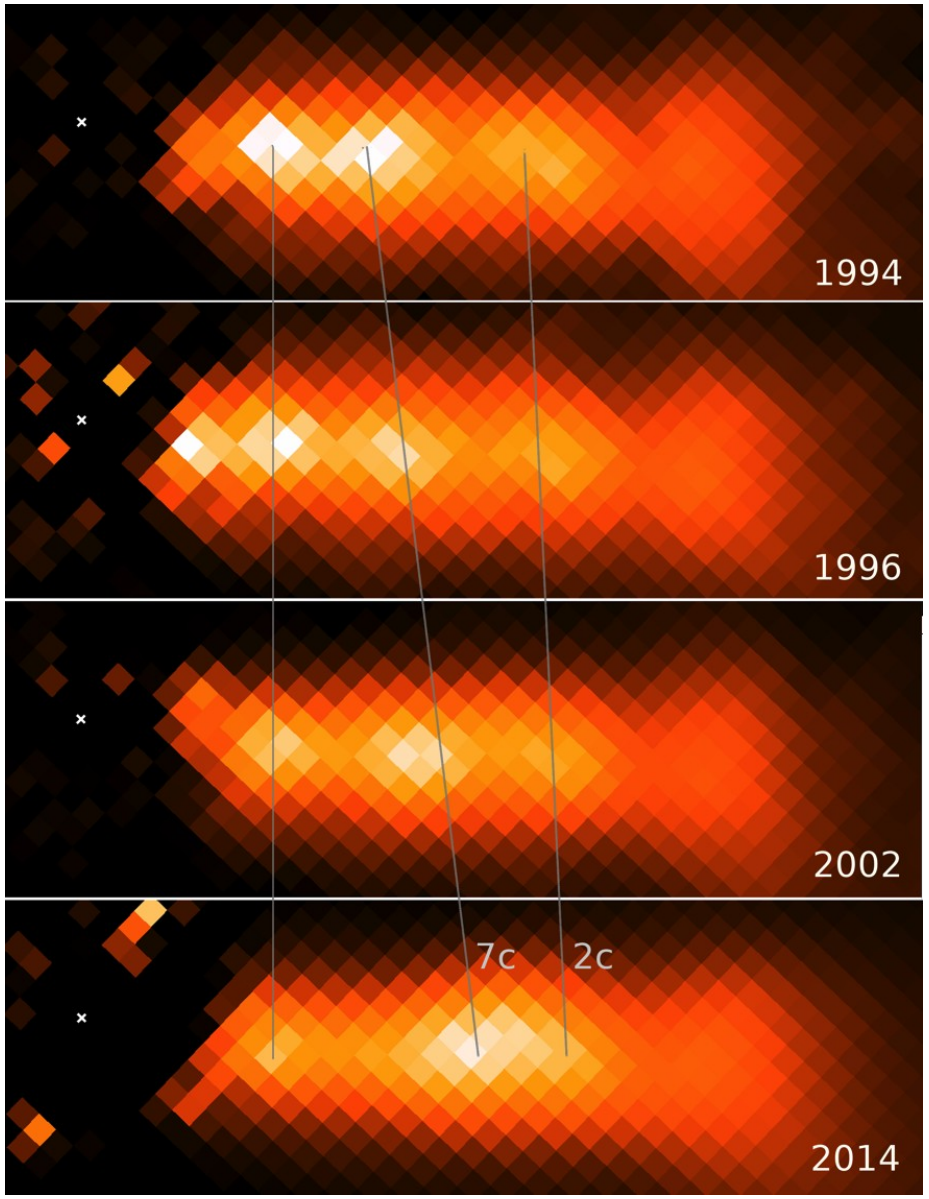


Stationary shock/feature



← M87 at equivalent scale to 3C264

HST Proper Motions Result - Meyer+2015



3C 264 – 91 Mpc (5x M87 distance)

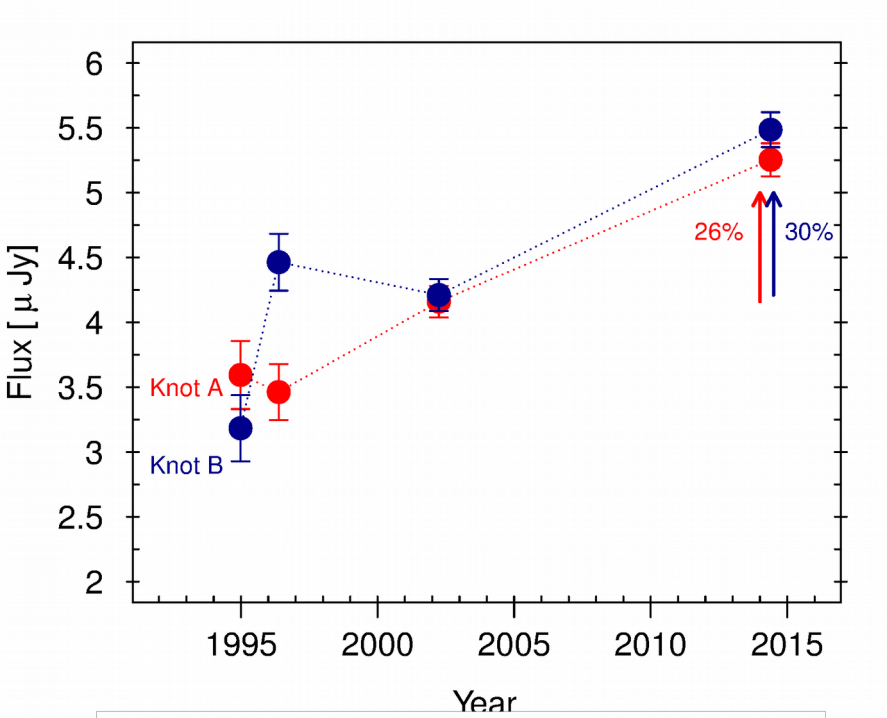
Jet is 0.4 kpc in length

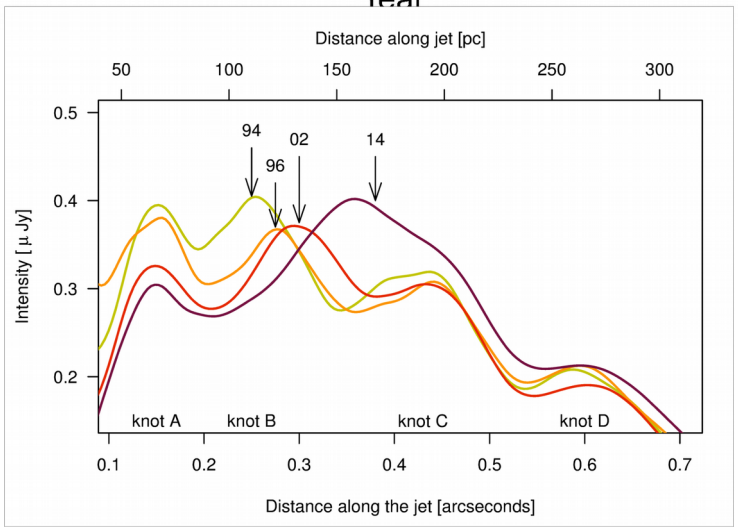
Knot B has apparent speed of 7+/-0.8 c *(highest ever measured at these distances)*

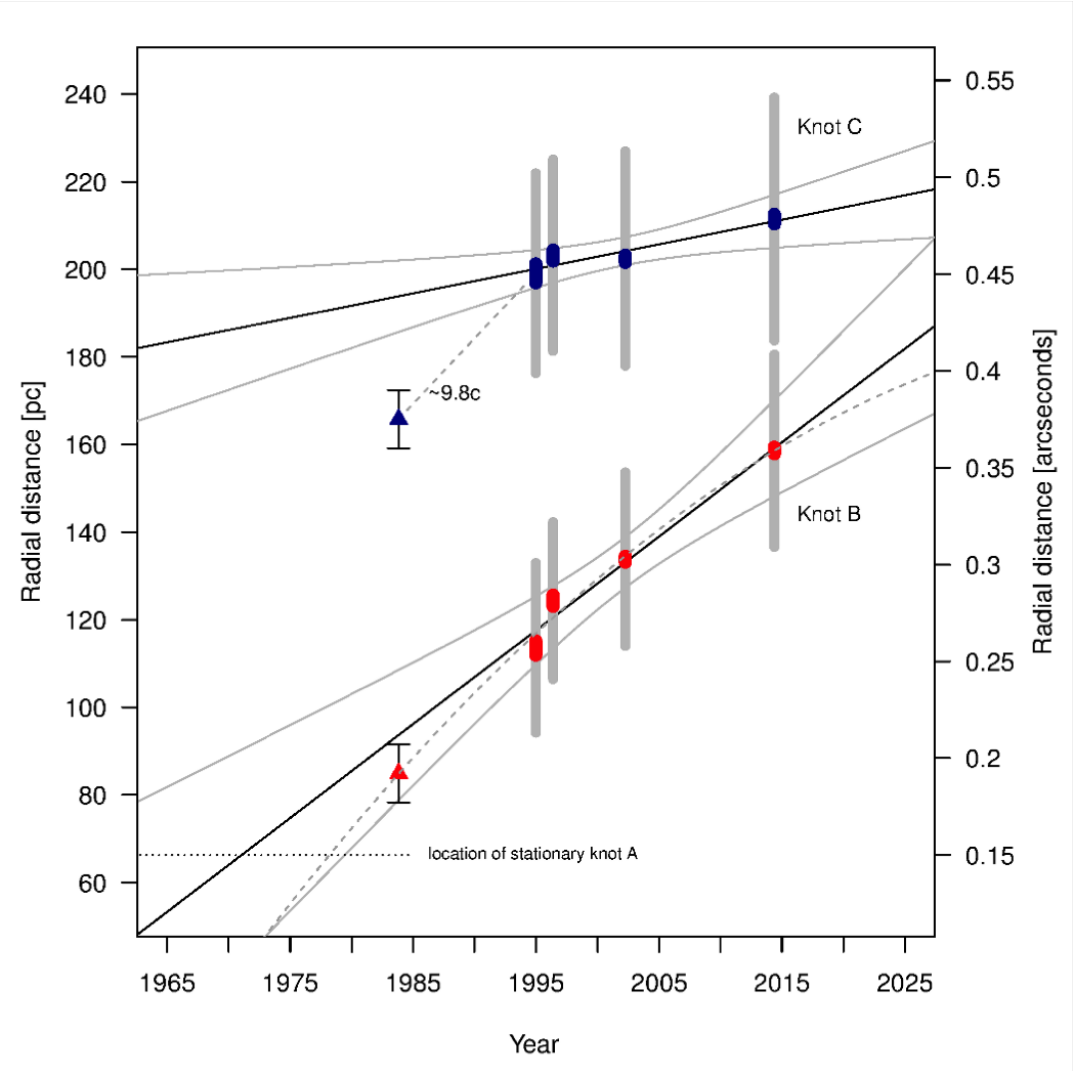
Colliding with Knot C in final epoch

Significant Brightening Observed

HST Proper Motions Result - Meyer+2015







Efficiency of the Internal Shock in 3C 264

We estimate ~30 years for the collision to go to completion

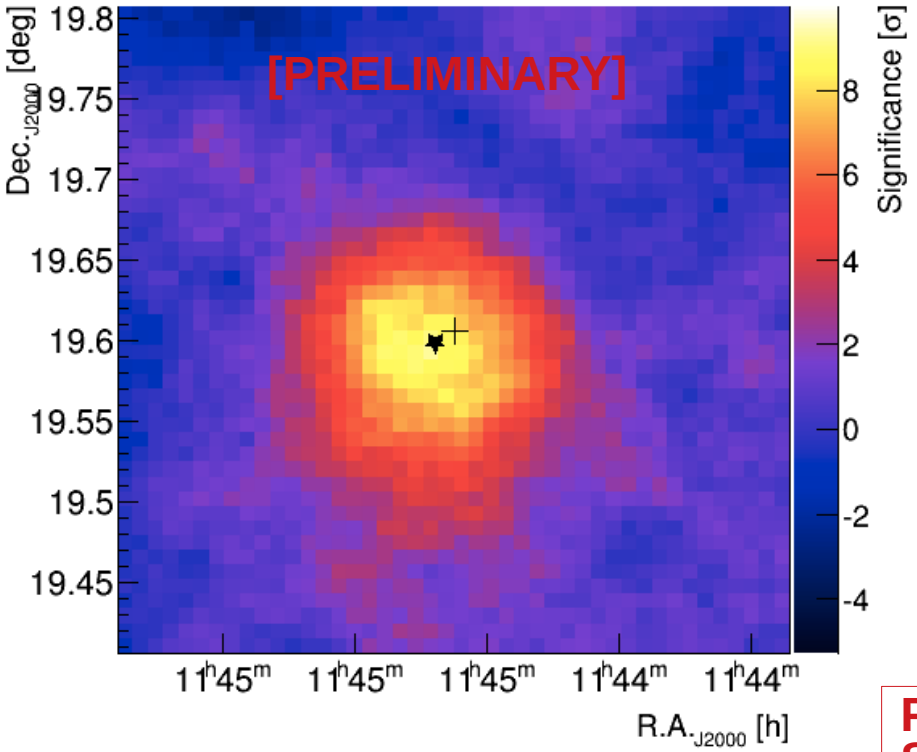
Pessimistically, assume flux steady at 2014 level

Taking minimum Lorentz factors Γ_B=7.1, Γ_C = 2.8 (angle of 8.1°) produces Γ_m = 3.7 for the combined knot post-collision

Assume cooling time << collision time (radiates 30 years)

$E_{diss}=2.6\times10^{51}$ erg → $\eta = 10^{-3}$ *minimum*

VERITAS Detection of 3C 264 in 2018



VERITAS discovery of VHE emission from the FRI radio galaxy 3C 264

ATel #11436; ***Reshmi Mukherjee (Barnard College) for the VERITAS Collaboration***
*on **17 Mar 2018; 00:25 UT***
Credential Certification: Reshmi Mukherjee (muk@astro.columbia.edu)

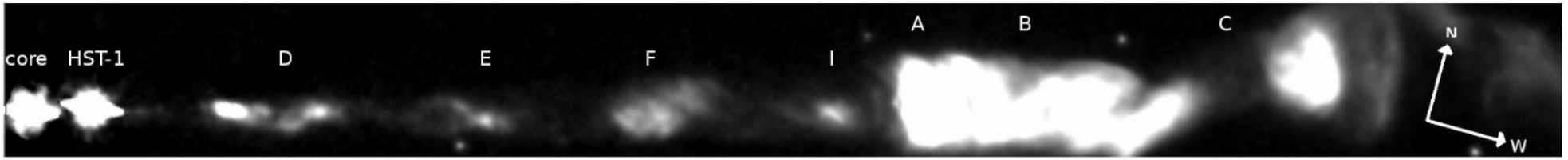
Subjects: Gamma Ray, TeV, VHE, Request for Observations, AGN, Blazar

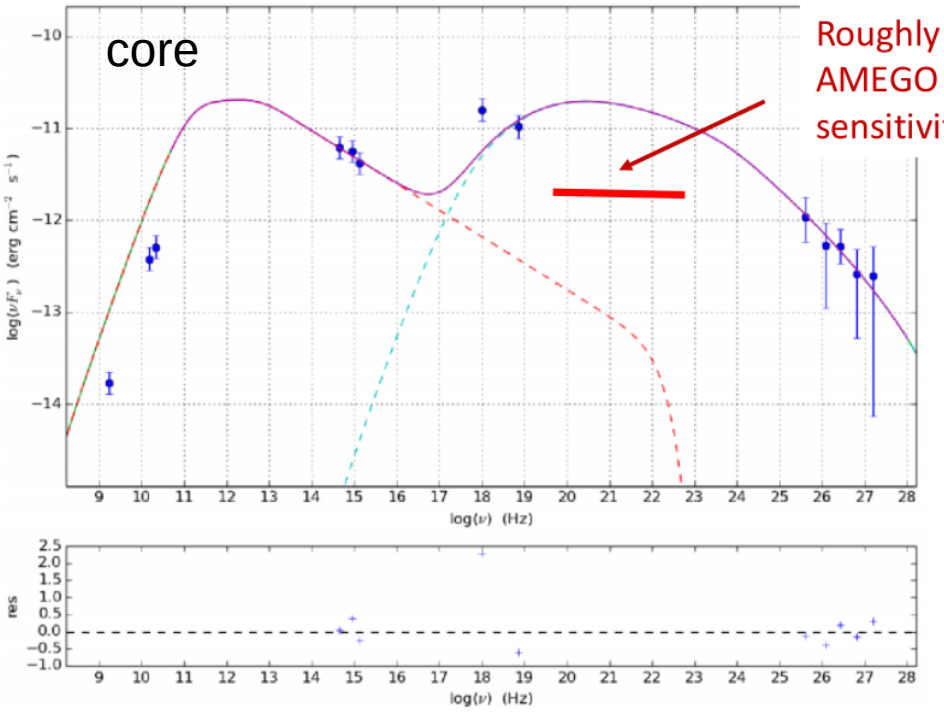
Tweet Recommend 50

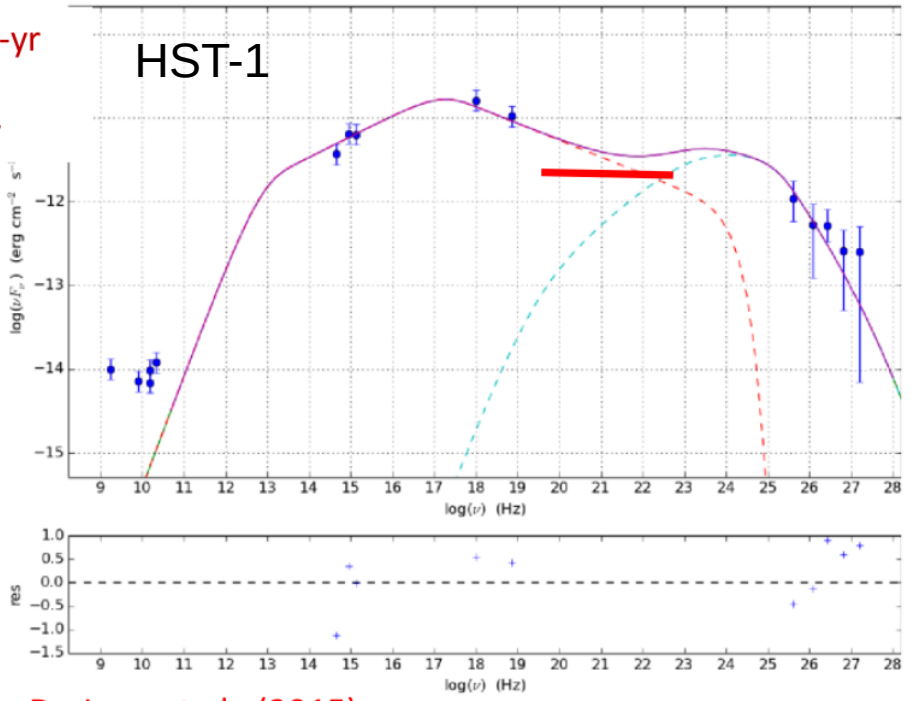
We report the VERITAS discovery of very-high-energy emission (VHE; >100 GeV) from the FRI radio galaxy 3C 264, also known as NGC 3862. Nearly 12 hours of quality selected data, collected by VERITAS between 09 February 2018 and 16 March 2018 (UTC), were analyzed. Preliminary results yield an excess of 60 gamma-ray events above background at the position of the source, corresponding to a statistical significance of 5.4 standard deviations. Our preliminary flux estimate (E>300 GeV) is (1.3 ± 0.2)e-12 cm^-2 s^-1, or approximately 1% of the Crab Nebula flux above the same threshold. The Fermi-LAT 3FHL catalog (Ackermann et al. 2017 ApJS 232, 18) lists a photon index of 1.65 ± 0.33 for 3C 264 which, when extrapolated to the VHE band, is consistent with the VERITAS detection. At a redshift of 0.0217, 3C 264 is a

Follow-Up Observations Scheduled:
VLA (DD - 2018 April 02)
HST (GO, PI: Meyer – 2018 Mar 24)
VLBI (MOJAVE + DD – 2018 Mar 30)
Chandra (DD – 2018 April 04)
Swift
Ground-based Optical

M87: Core versus HST-1 (100 pc downstream)







De Jong et al., (2015)

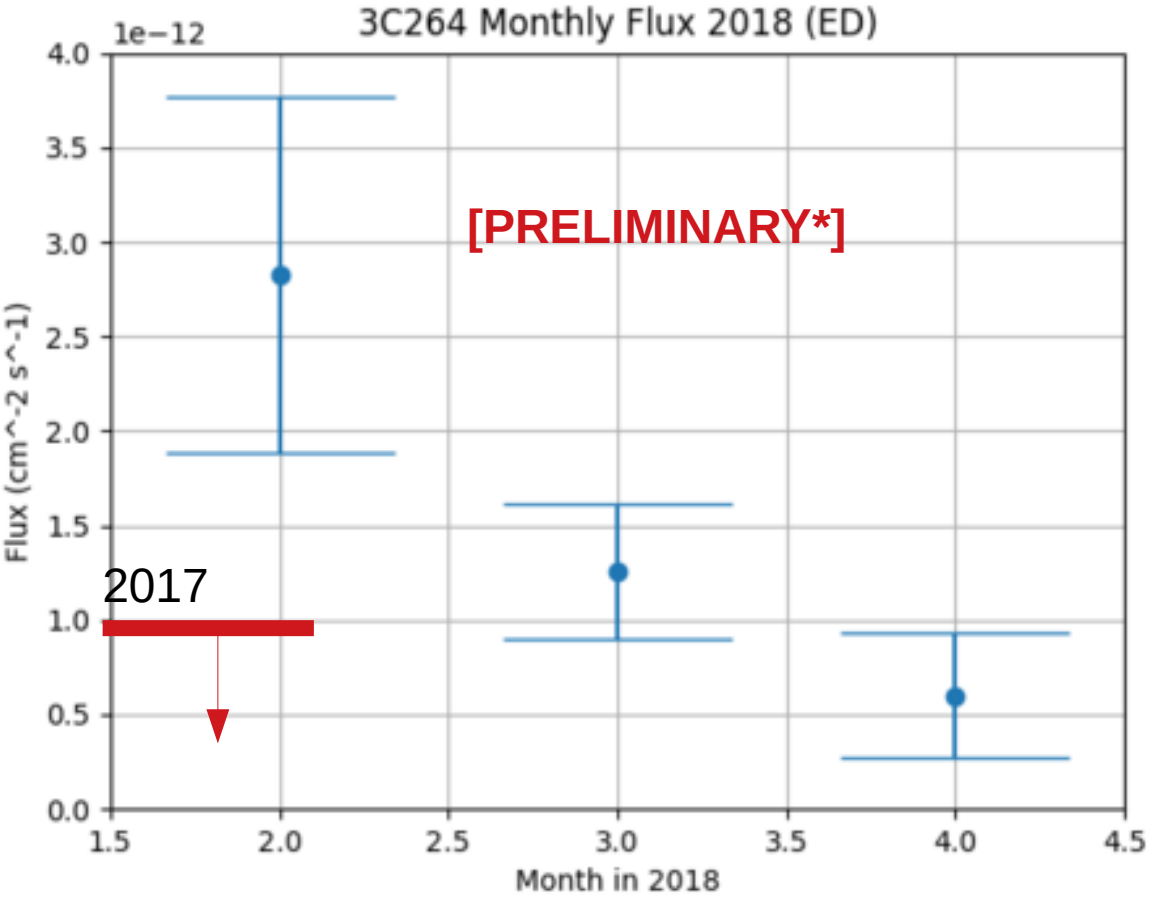
VERITAS Detection of 3C 264 in 2018

2017 Observations:

- 9.205 hrs live time
- 27 Feb – 20 May
- only upper limit
- 224 GeV – 30 TeV flux
  < 1.03e-12 cm^{-2} s^{-1}

2018 Observations:

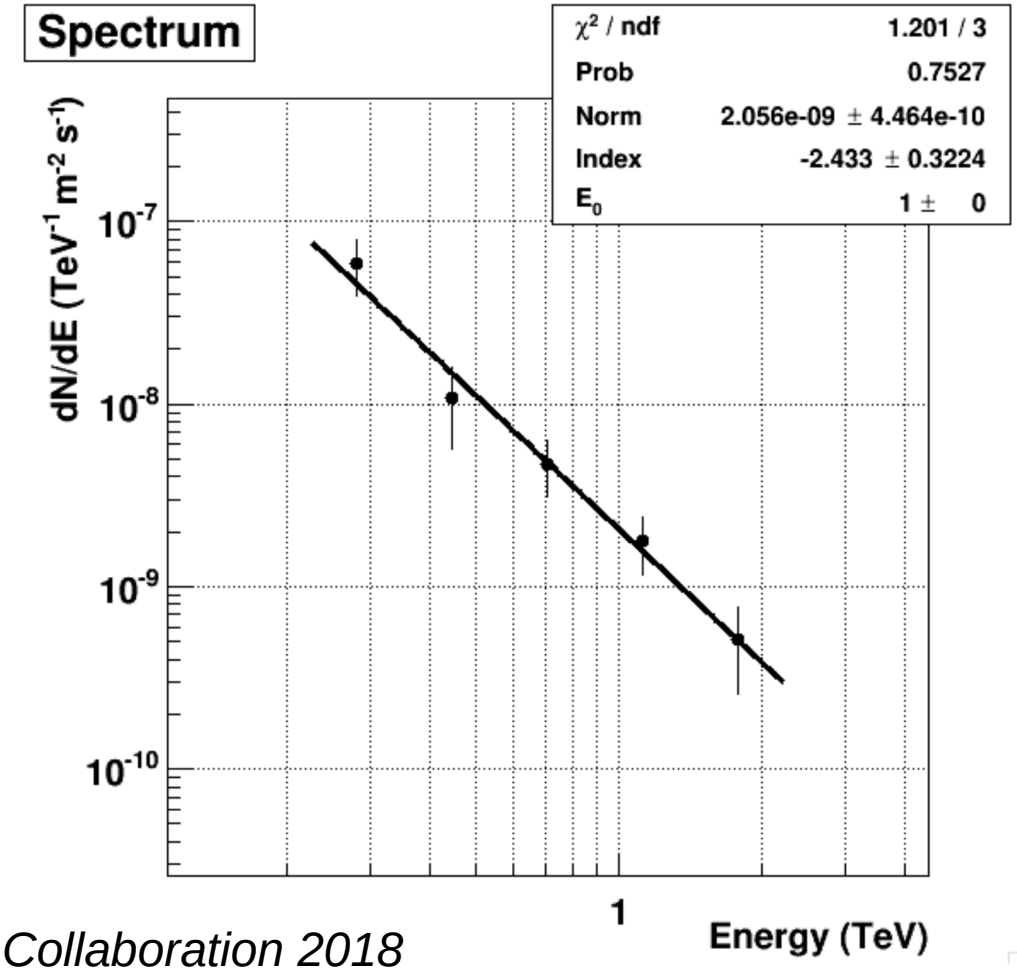
- 37.85 hrs live time
- 28 Feb – 21 Mar
- 7.6 sigma (ITM analys.)
- flux > 224 GeV is
  1.32±0.29e-12 cm^{-2} s^{-1}
- Spectral index -2.43



VERITAS Collaboration 2018

**Do NOT use preliminary results presented here in any presentation or publication without contacting the VERITAS team*

VERITAS Detection of 3C 264 in 2018

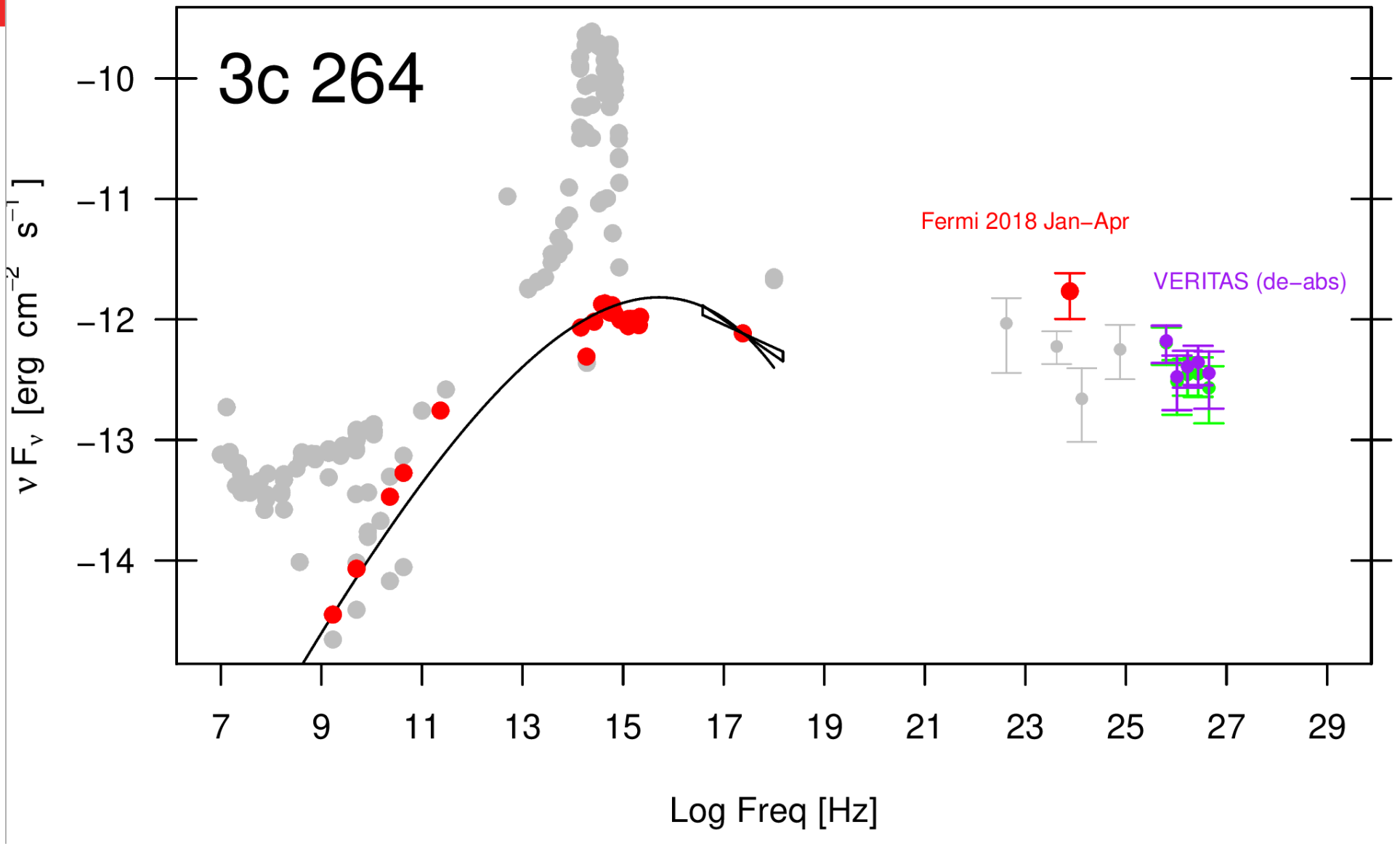


[PRELIMINARY*]

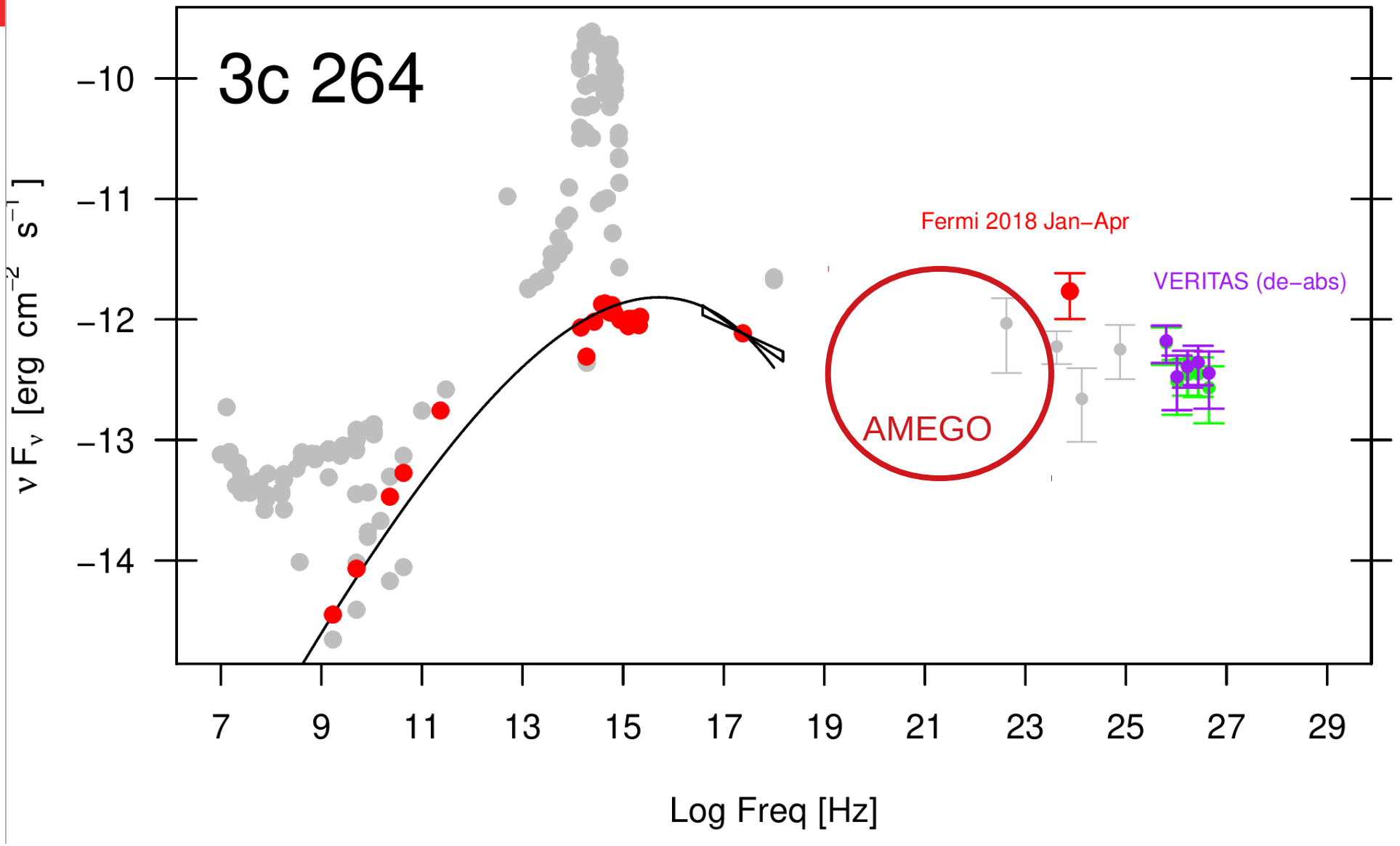
VERITAS Collaboration 2018

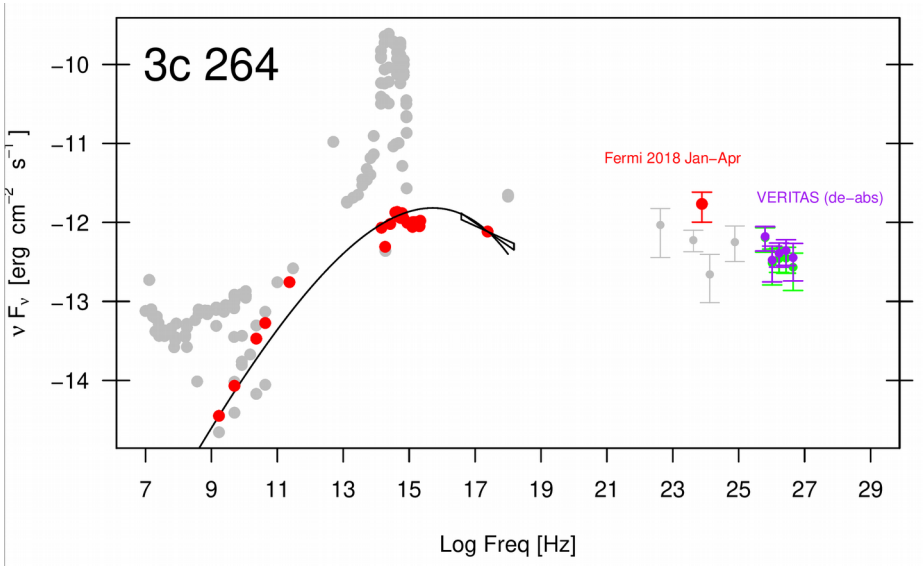
**Do NOT use preliminary results presented here in any presentation or publication without contacting the VERITAS team*

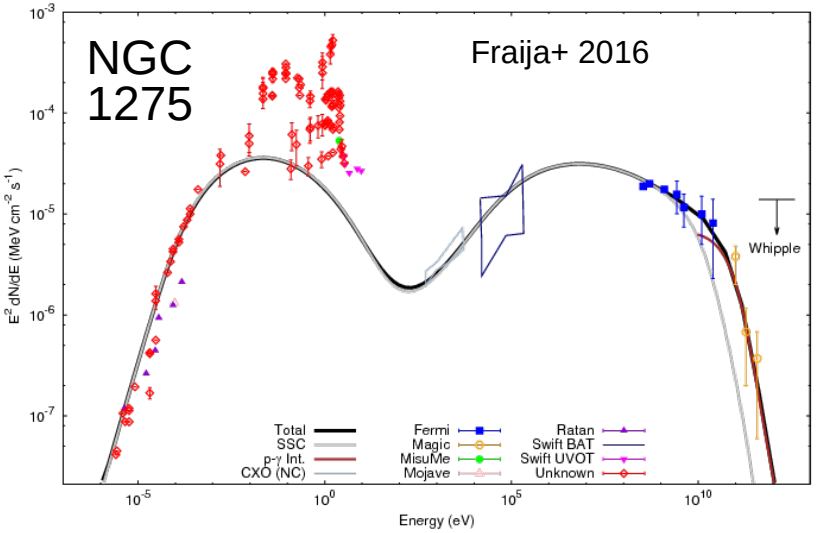
Broad-Band SED of 3C 264

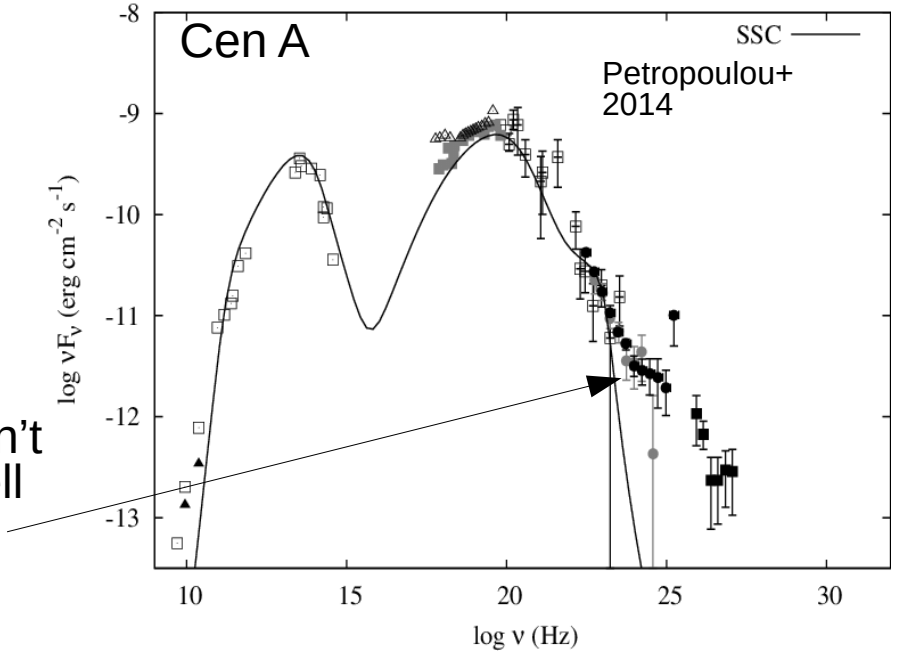


Broad-Band SED of 3C 264

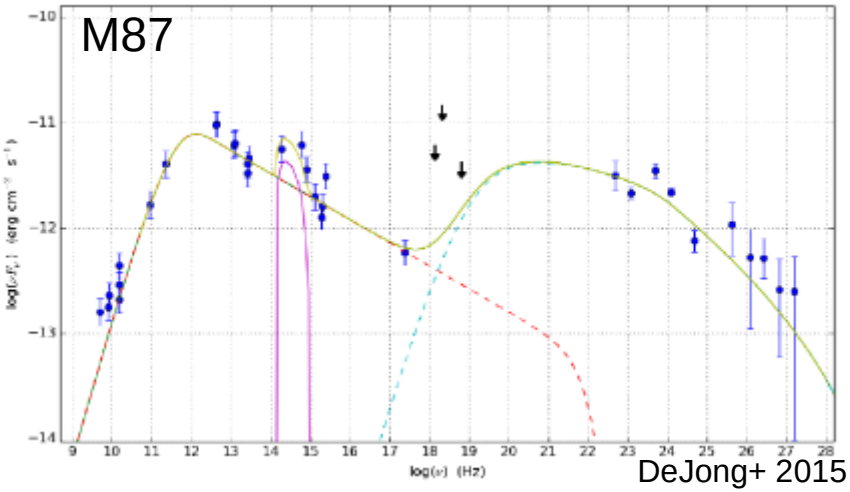








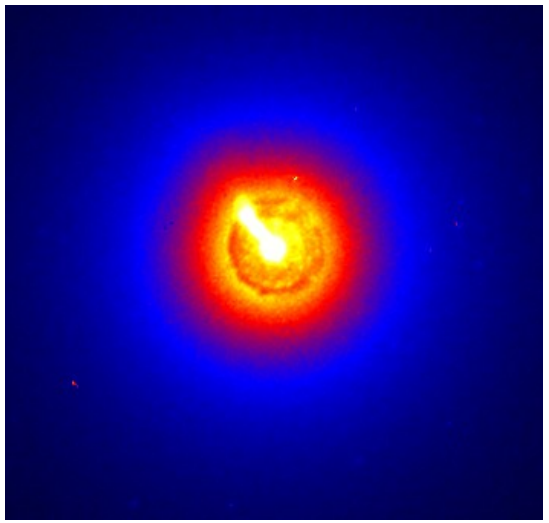
SSC doesn't explain well these "bumps"

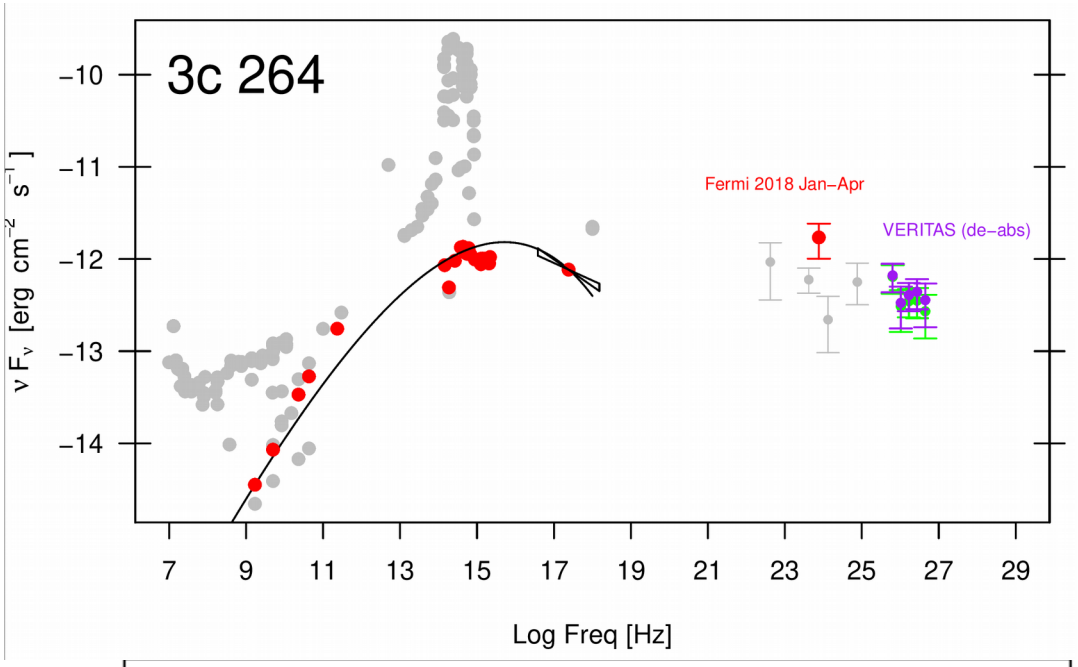


Previously (Meyer+2011) had argued that all radio galaxies have synchrotron peaks at low (~10^{12} Hz) frequencies. However 3c264 appears to have a peak ~10^{15} Hz

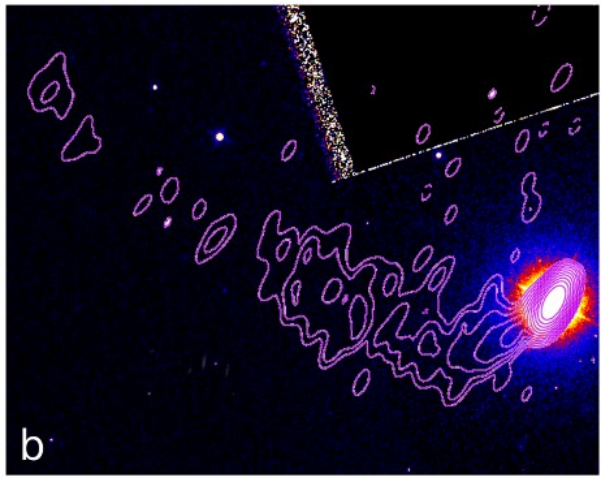
Do radio galaxies show the same great variety in ν_{syn} as blazars?

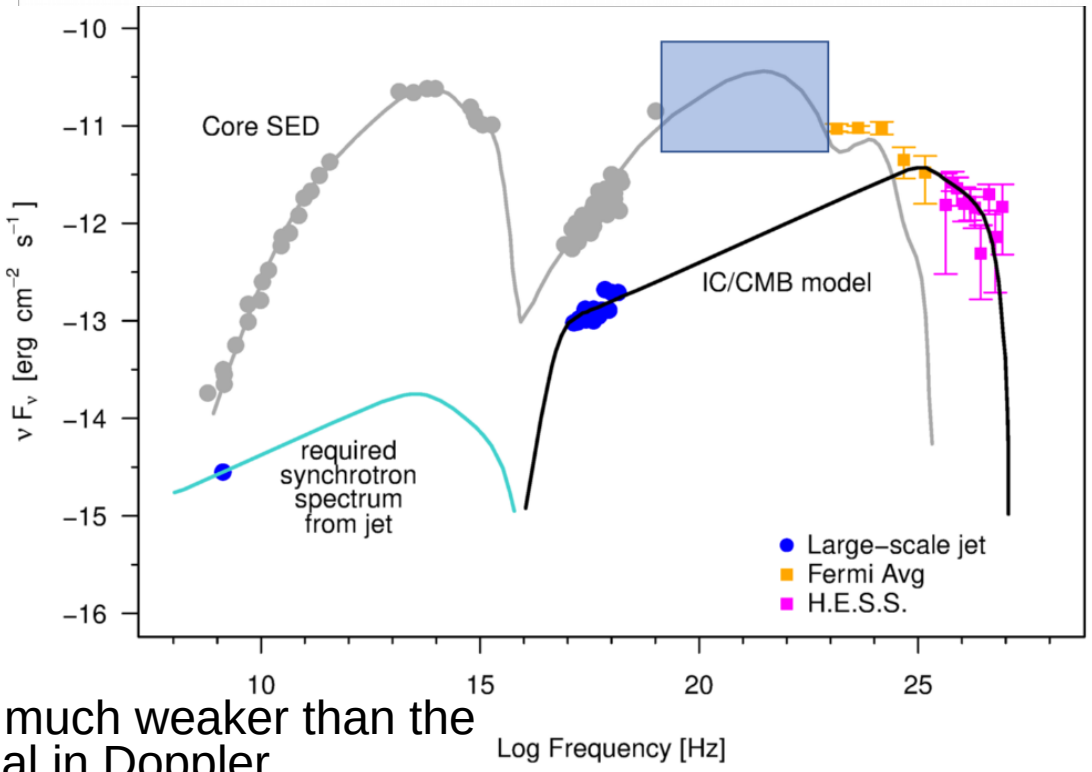
3C 264





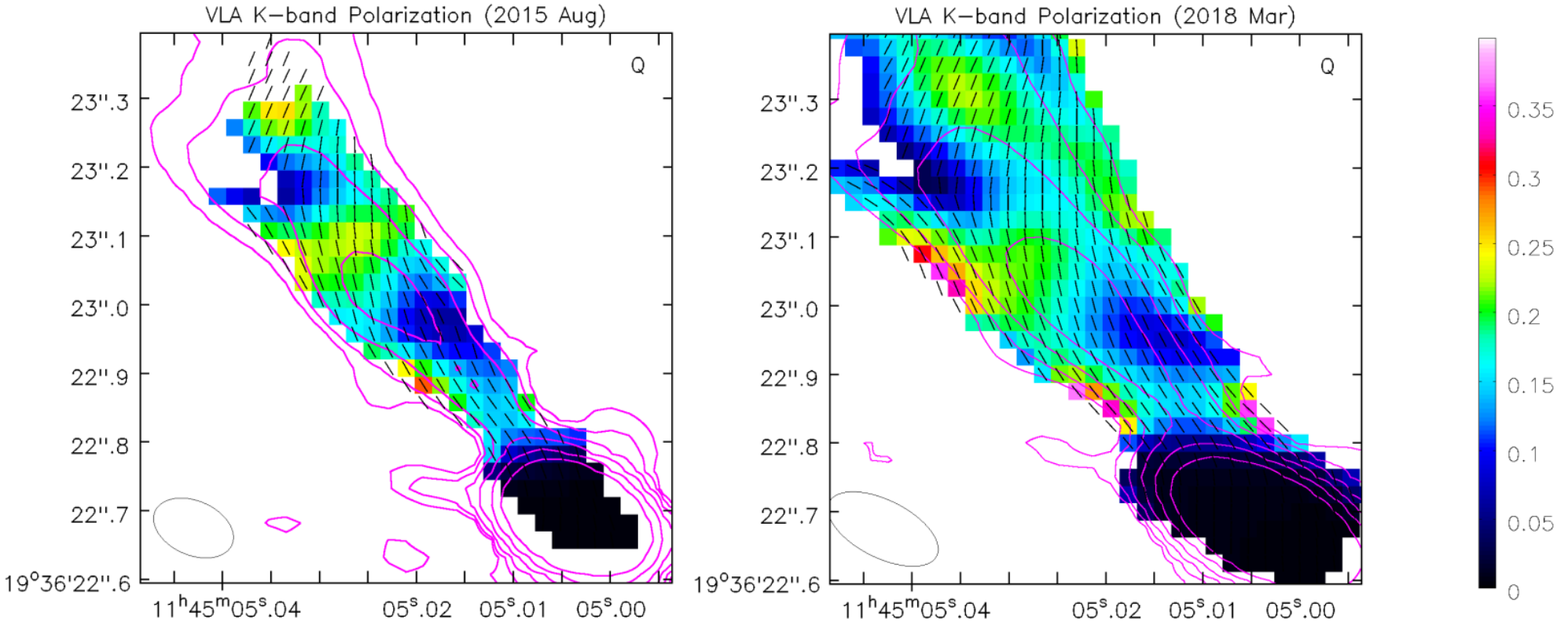
AP Librae





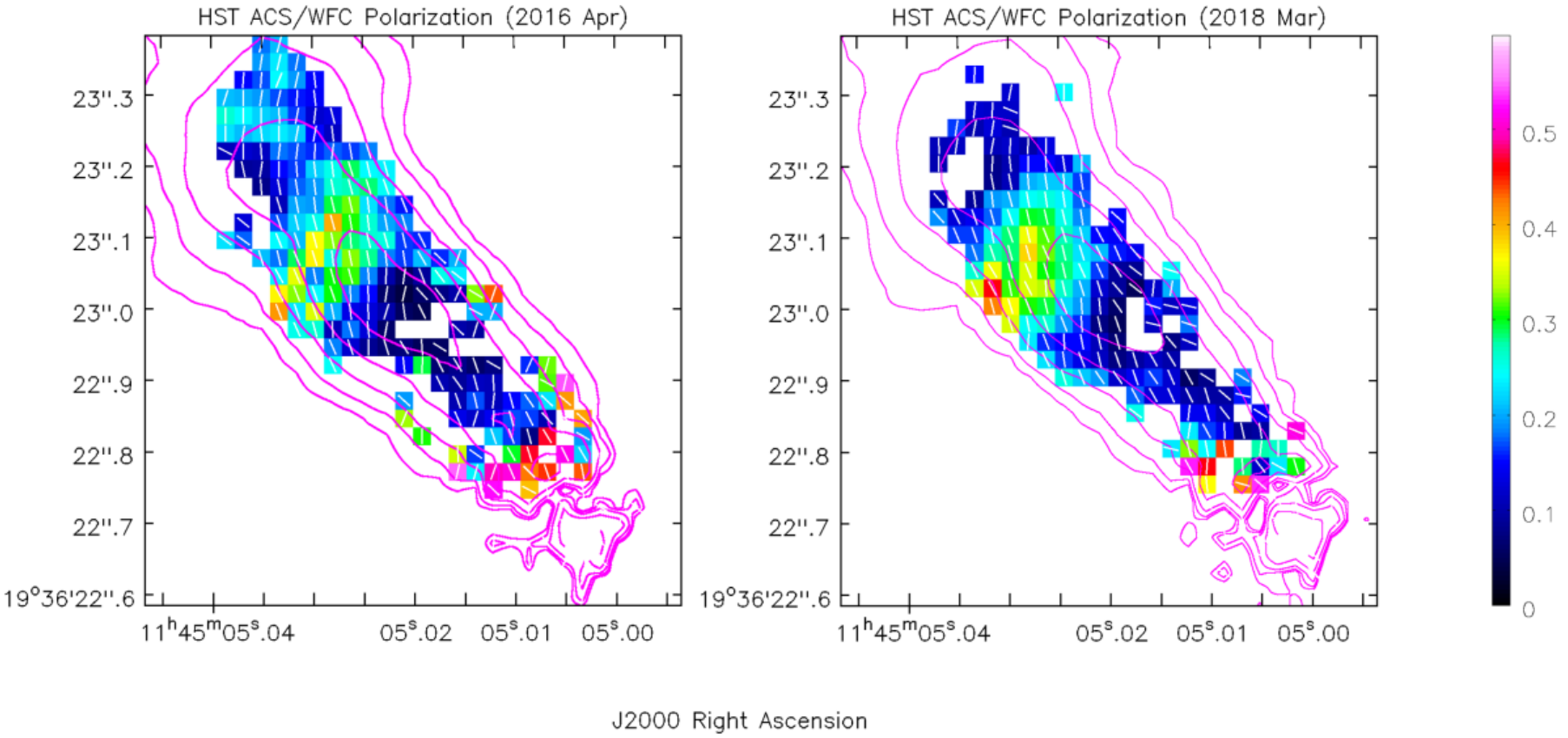
AP Librae is a blazar (knots are much weaker than the core, as shown, due to differential in Doppler Boosting). However also shows a broad GeV-TeV component.

MW Follow-up: VLA



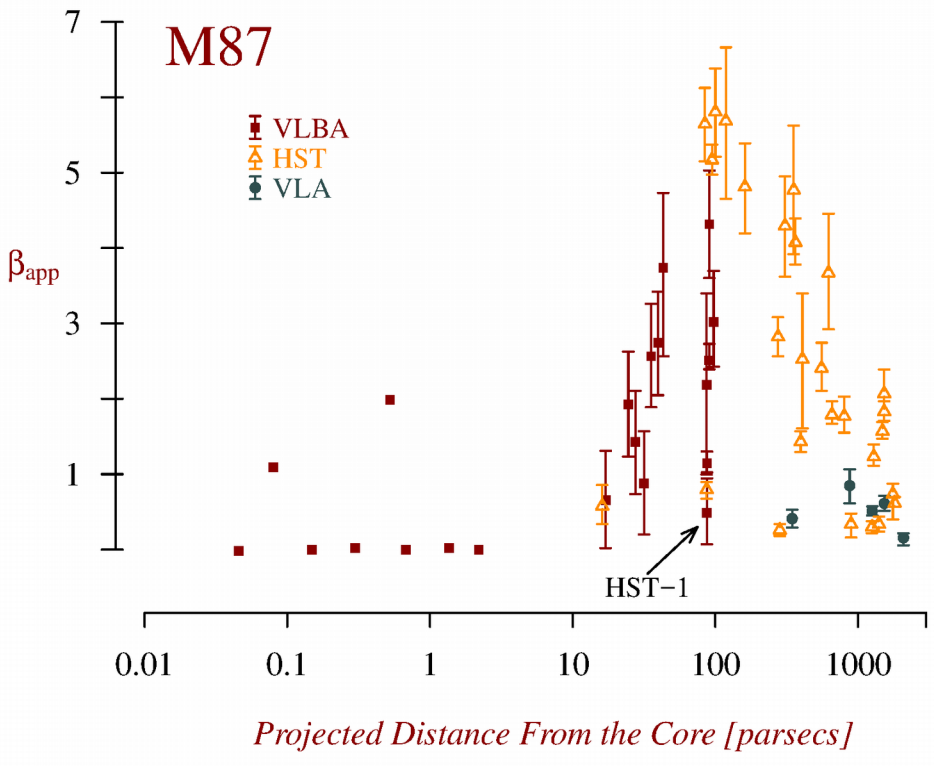
Polarization Structure Consistent between 2015 and 2018
High polarization ~ 22% at the outer edge of the colliding knot region
Little Evidence for strong shocks (i.e., transverse B-field)

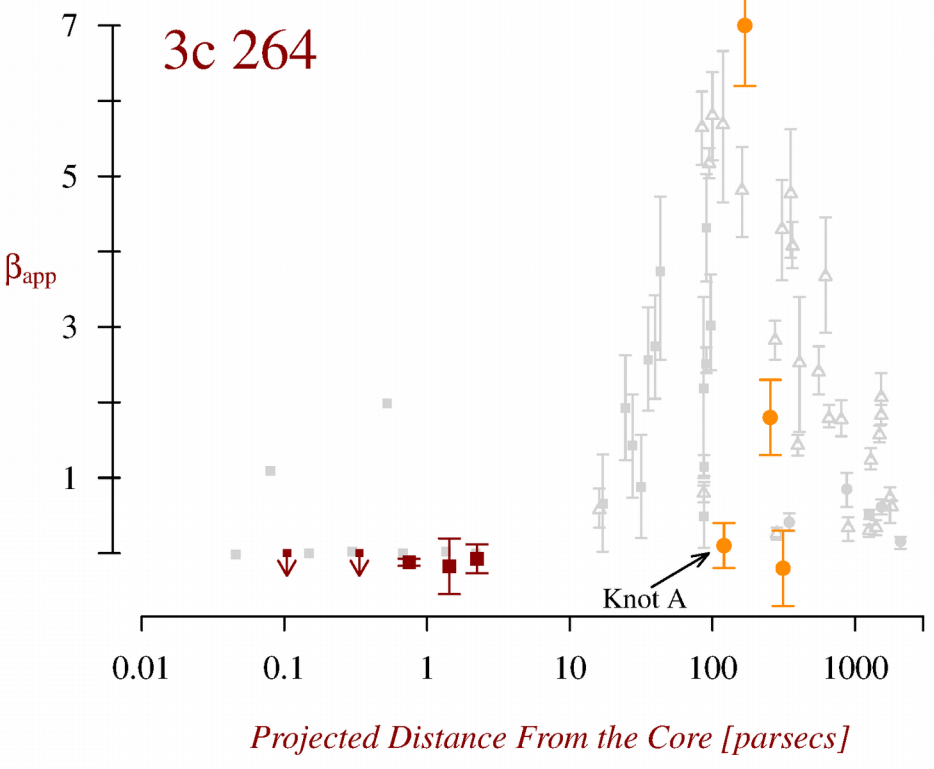
MW Follow-up: HST



Polarization Structure Consistent between 2016 and 2018
High polarization ~ 35% at the outer edge of the colliding knot region
B-field shows more disorder; some oblique components in the central collision region.

MW Follow-up: VLBI Kinematics

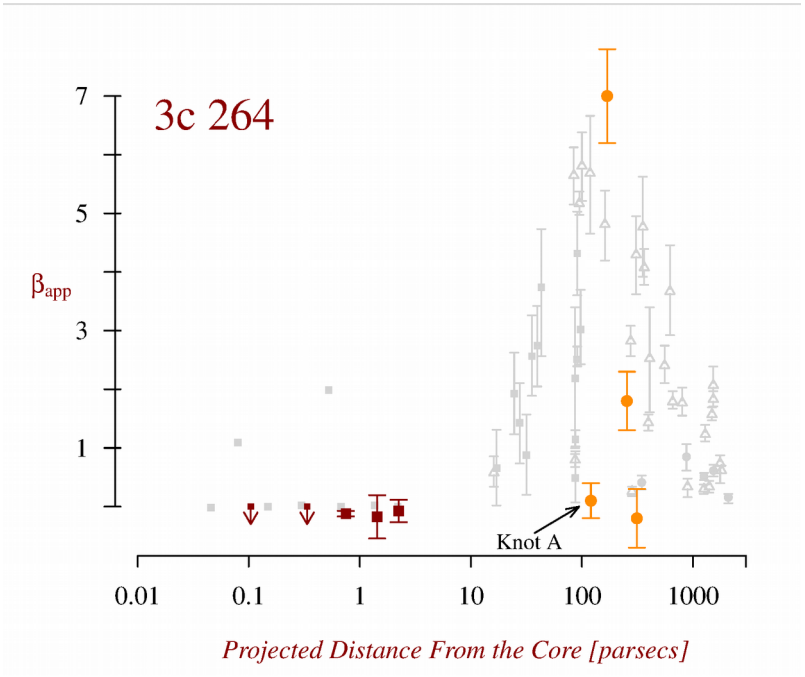


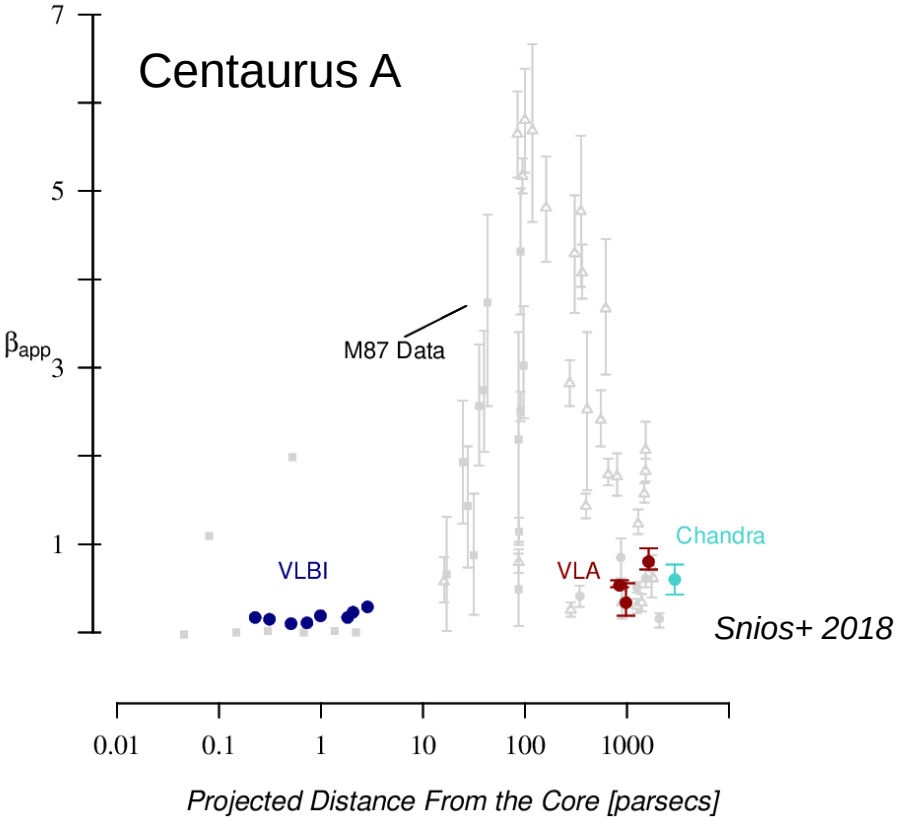


Very, very few jets have a “full kinematic profile” from sub-pc to kpc scales
3c264 looks very similar to M87. Fast speeds are not seen until VLA/HST scales. Both have stationary knot at about 100 pc (projected) from the core.

(No major change in VLBI image during March 2018 observation)

MW Follow-up: VLBI Kinematics





-3C 264 and M87 arelow-power FR Is ($10^{43.8}$ and $10^{43.7}$ erg/s respectively; Meyer+2011)
-Cen A has a jet power which is even lower ($10^{43.4}$ erg/s).

Based on the observed maximum speeds, the jets in M87 and 3C264 must be oriented at no more than 16 or 17 degrees. In Cen A, it is thought that the jet angle may be as large as 45 degrees (Muller 2014).

Conclusions

- VERITAS detection is significant in 2018 but lack statistics to declare it definitively a “flare”
- Most distant radio galaxy discovered at VHE, clearly a misaligned source
- Both synchrotron and VHE peak freq relatively high compared to other RG

- No major changes in any MW observations (radio, optical, or X-ray) despite good time coverage – mostly like VHE comes from core

- No major change in parsec-scale jet or core flux as seen by VLBI
  - Possible VLBI core polarization EVPA direction between 2018-03-30 and 2018-04-22 (preliminary analysis)

- Continued monitoring of knot collision shows only linear brightening, no major polarization changes yet (however timescale is decades)