



Recent VERITAS Results on Extragalactic Sources



Nepomuk Otte for the VERITAS Collaboration





VERITAS

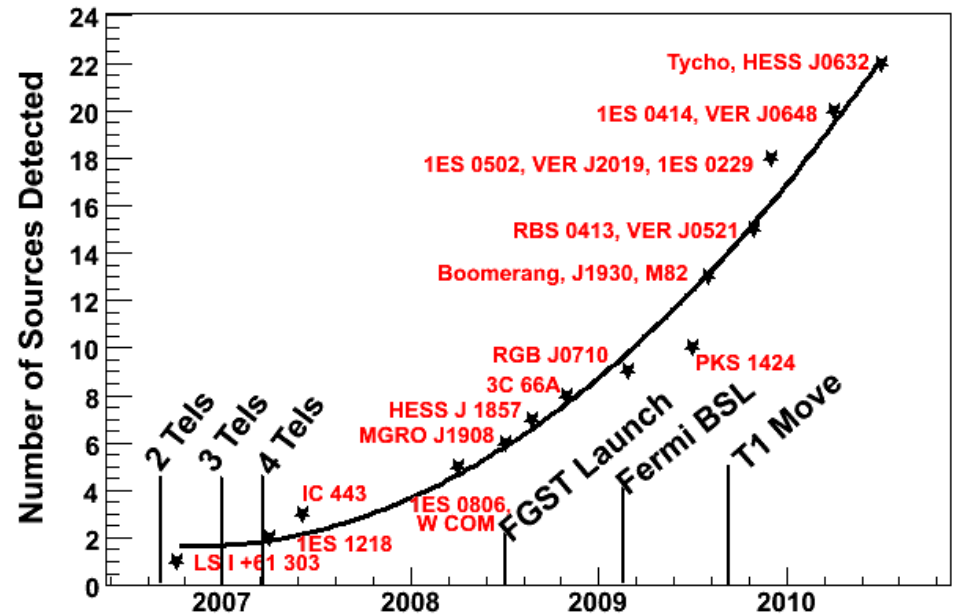
- **Energy range:** ~ 100 GeV to several 10 TeV
- **Angular resolution:** $\sim 0.1^\circ$
- **Energy resolution:** 15%
- **Systematic uncertainties:** Energy $\sim 20\%$; Spectral index ~ 0.2
- **Sensitivity:** **1% Crab Nebula flux in <30 hours**





Status of VERITAS

- 32 Detections (15 discoveries)
 - ➔ 18 Extragalactic
 - ➔ 7 Galactic
 - ➔ 7 Unidentified



Not including our “old friends”:
Crab, Mrk421, Mrk501,

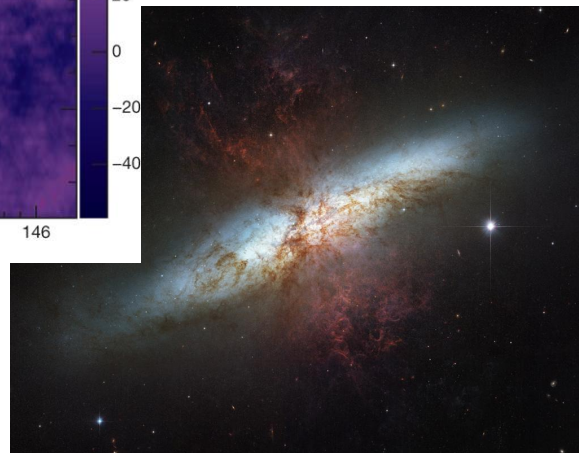
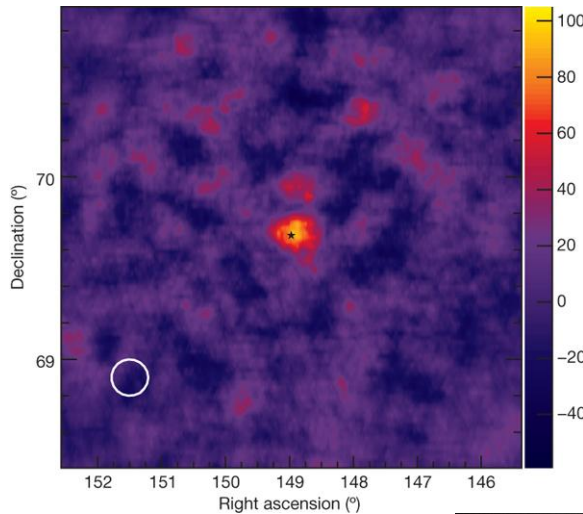


The Extragalactic Sky seen by VERITAS

- 17 AGN +2 likely associations with AGN
- 1 Starburst Galaxy: M82



VERITAS Nature: 462, p 770 (2009)



AGN	Type	z
M87	FR I	0.004
Mkn 421	HBL	0.030
Mkn 501	HBL	0.034
1ES 2344+514	HBL	0.044
1ES 1959+650	HBL	0.047
W Comae	IBL	0.102
RGB J0710+591	HBL	0.125
H 1426+428	HB	0.129
1ES 0229+200	HBL	0.139
1ES 0806+524	HBL	0.138
1ES 1218+304	HBL	0.182
RBS 0413	HBL	0.190
1ES 0414+009	HBL	0.287
PG 1553+113	HBL	0.43<z<0.47
1ES 0502+675	HBL	0.34±?
3C 66A	IBL	0.444±?
PKS 1424+240	IBL	?
VER J0521+211	Blazar	?
RX J0648.7+1516	Blazar	?

Legend:

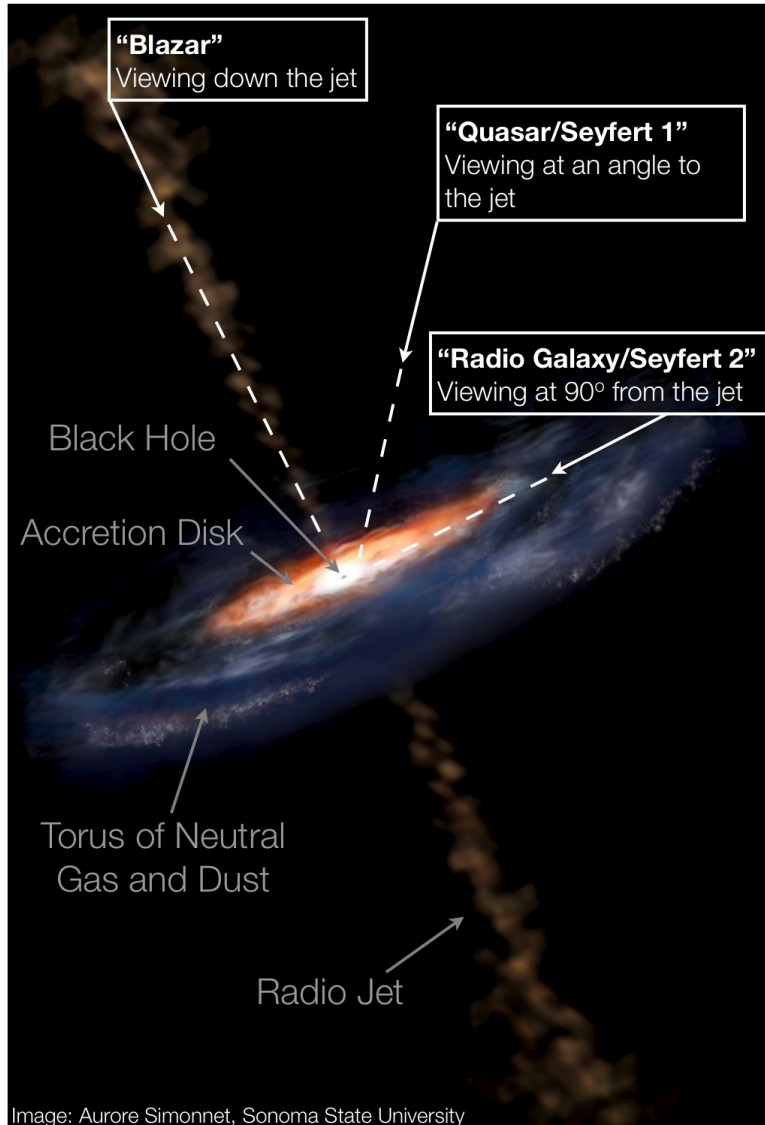
VERITAS discoveries

Previously known

Hard spectrum blazars for EBL studies



AGN Science with VERITAS

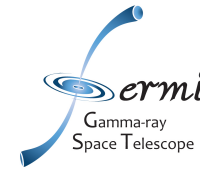


- What is the AGN population, is there a sequence?
- Model the AGN mechanisms & locate **emission region**
- Origin of different AGN states
- Constrain optical/IR **EBL**
- **Fundamental physics:** quantum gravity, intergalactic magnetic field



VERITAS: AGN Observing Program

- **Discovery Program** physics through population studies
- **Multiwavelength Campaigns** deep exposure of individual sources
- **ToO** the unpredictable

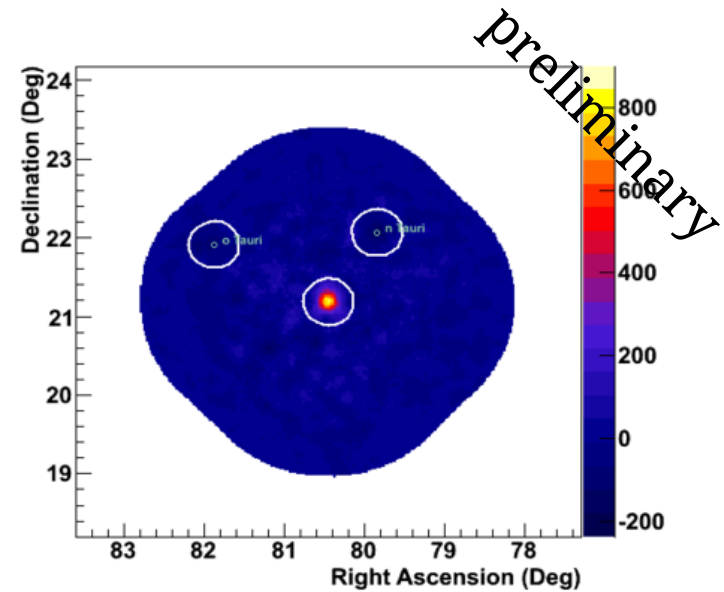




VERITAS latest Discoveries I

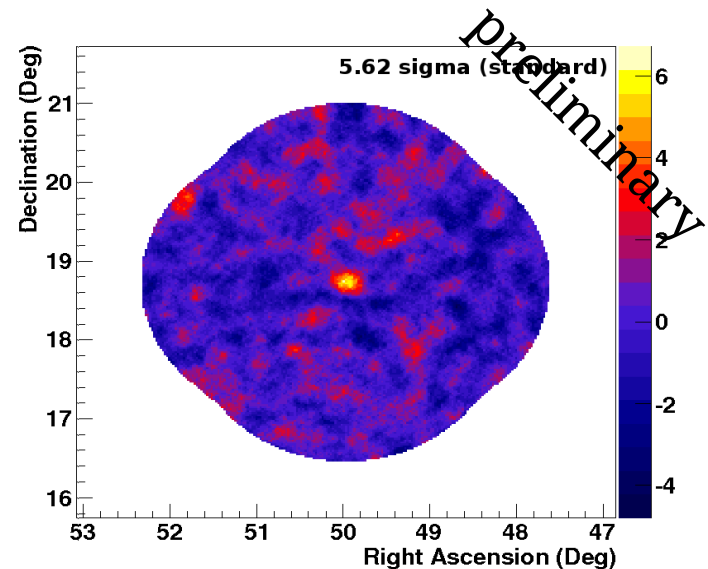
VER J0521+211

- Hot spot in Fermi data > 30 GeV
- Radio loud AGN RGB J0522+2112 ?
- 5.5σ in 4 hr (5% Crab)
 - ➔ Atel #2260 (Oct 2009)
- Variable source (\rightarrow 20% Crab)
 - ➔ Atel #2309 (Nov 2009)



RBS 0413

- HBL $z=0.19$
- 5.6σ in 26 hr (\sim 2% Crab)
 - ➔ Atel #2272 (Oct 2009)

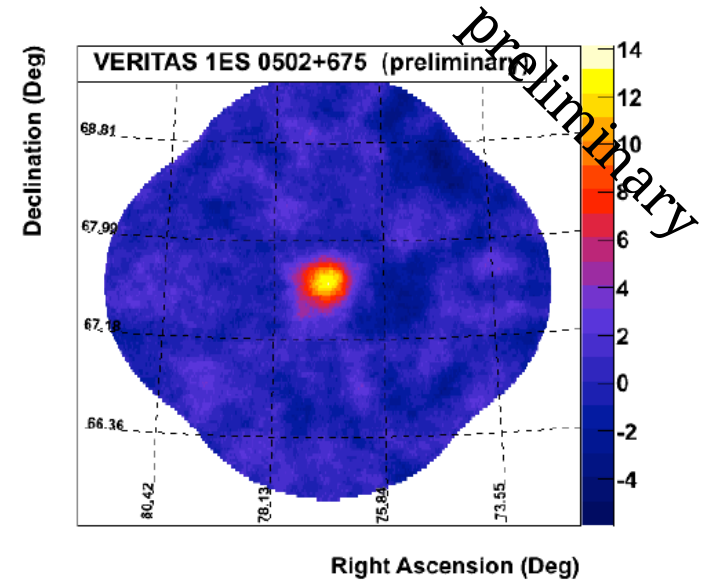




VERITAS latest Discoveries II

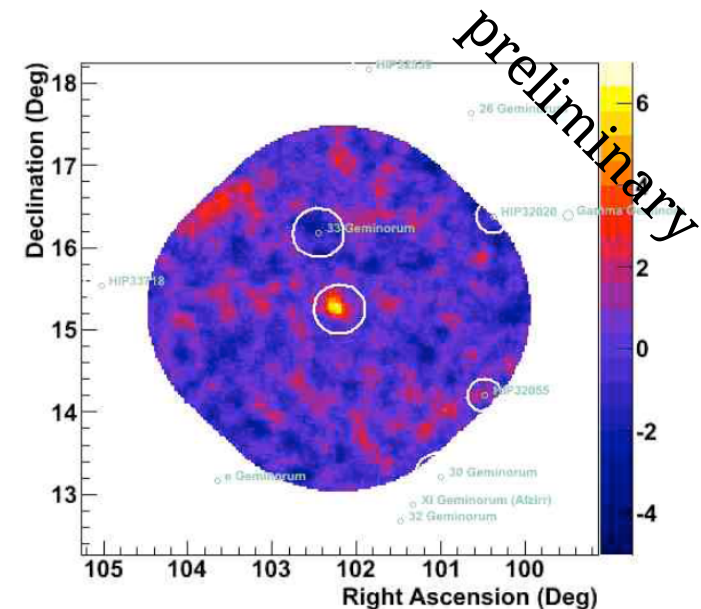
1ES 0502+675

- HBL $z=0.34$?
- 12σ in 30 hr ($\sim 5\%$ Crab)
 - ➔ Atel #2301 (Nov 2009)



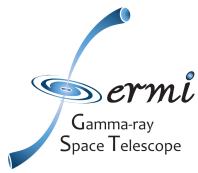
VER J0648+152

- RXJ 0648+152 ?
- 5σ in 6 hr ($\sim 5\%$ Crab)
 - ➔ Atel #2486 (Mar 2010)





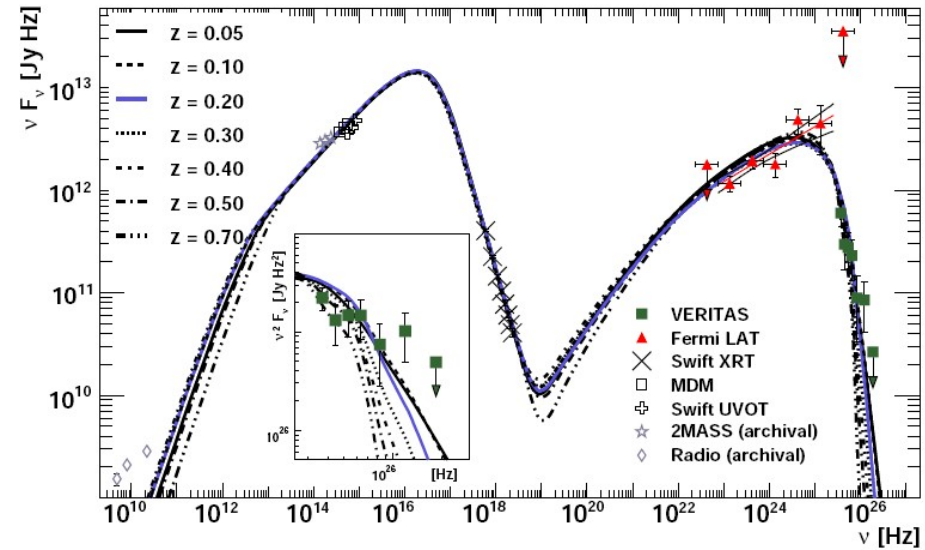
+



PKS 1424+240

VERITAS ApJL, 708, 100 (2010)

- **First AGN detected > 100 GeV as a result of a follow up of Fermi data.**
- **Intermediate / High frequency peaked BL Lac**
- **Simultaneous VERITAS, Fermi, Swift and MDM data**
 - ➔ well described by a one zone SSC model (leptonic).



- **Redshift unknown**

- ➔ VERITAS and Fermi spectrum + EBL models.
 - ◆ $z < 0.66$
- ➔ Preferred redshift from MWL modeling < 0.1 .
- ➔ Lower limits from optical measurements range from $z = 0.06$ to $z = 0.67$.



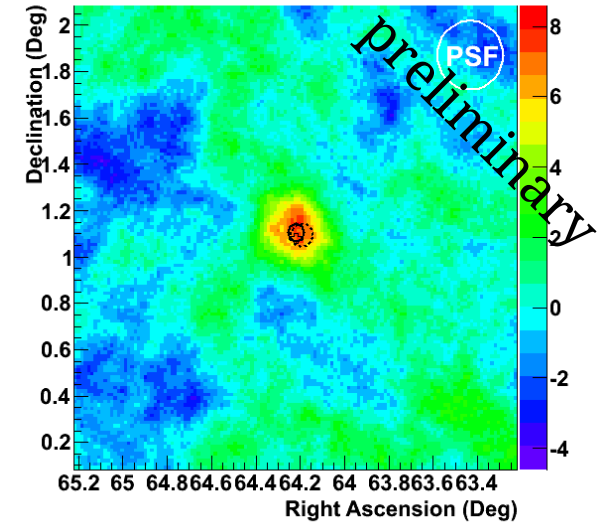
Hard Spectrum Blazars: 1ES 0414+009 & PG 1553

1ES 0414+009

- HBL @ $z=0.287$
- High z analog to Mrk421, PKS2155 ?
- H.E.S.S. Discovery (Nov 2009)

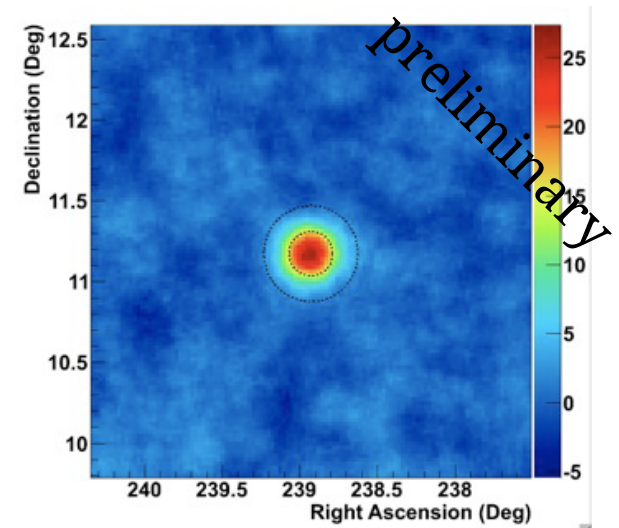
VERITAS observations

- 6.9σ in 45 hr ($\sim 2\%$ Crab)
- Steady flux (2008-2010)



PG1553

- New redshift info $z=0.43 - 0.47$
- 25σ in 25 hr ($\sim 6\%$ Crab)
- Flux/Spectrum compatible with previous VHE measurements



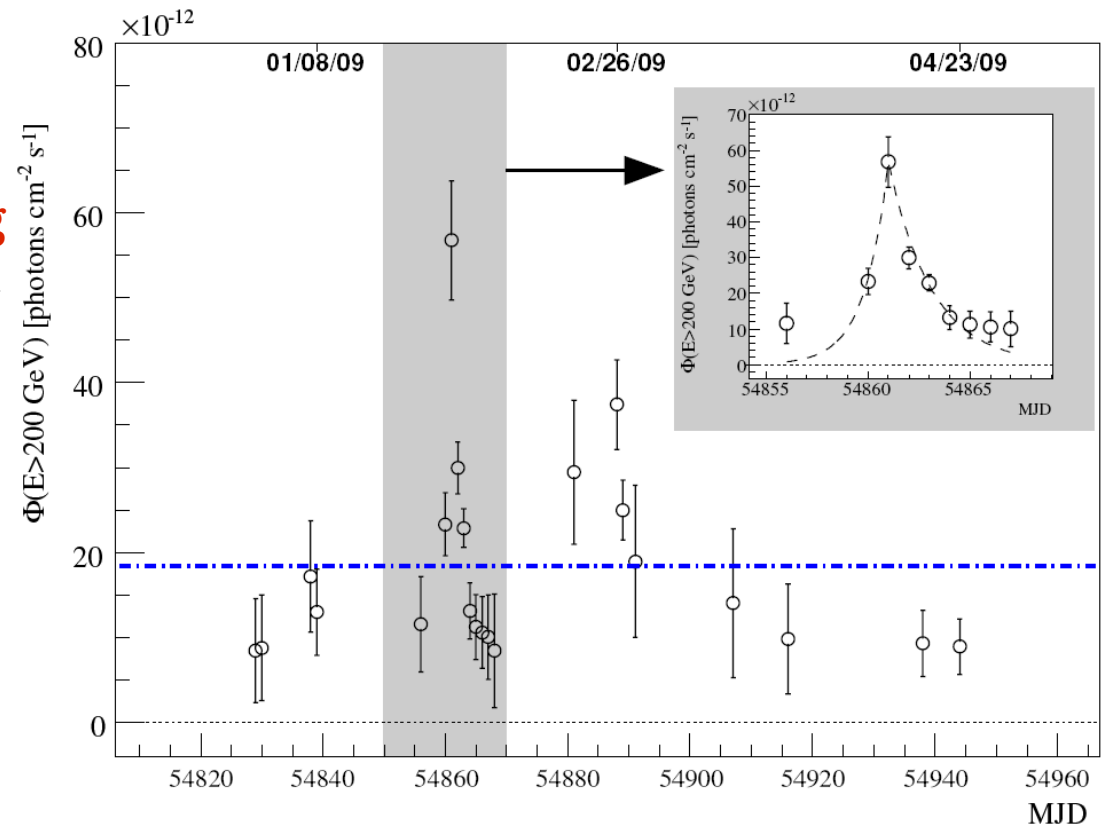
Optical / near IR EBL implications under analysis



1ES 1218+304 $z=0.182$

VERITAS ApJL, 709, 163 (2010)

- Part of VERITAS program to study the mid IR EBL.
- **First time detection of VHE flaring activity** 6% \rightarrow 20% Crab Nebula flux above 200 GeV.
 - Compact emission region $<0.01\text{pc}$
 - Flare challenges CMB-inverse-Compton interpretation:
 - pc-scale emission regions
 - Emission in kpc scale jet



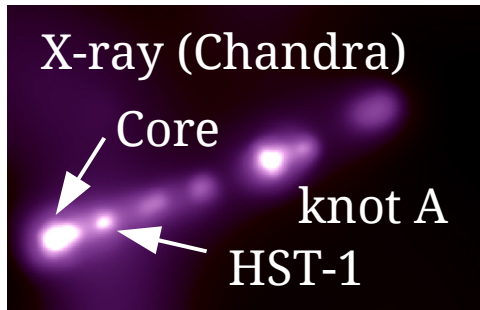


M87: 2008 Campaign

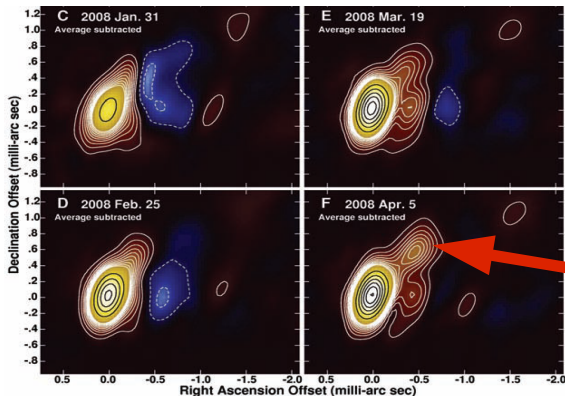
Science, 325, 444, 2009

- Close Collaboration between: VLBA, H.E.S.S., MAGIC and VERITAS
- TeV flare correlated with increased radio and x-ray activity at the nucleus.

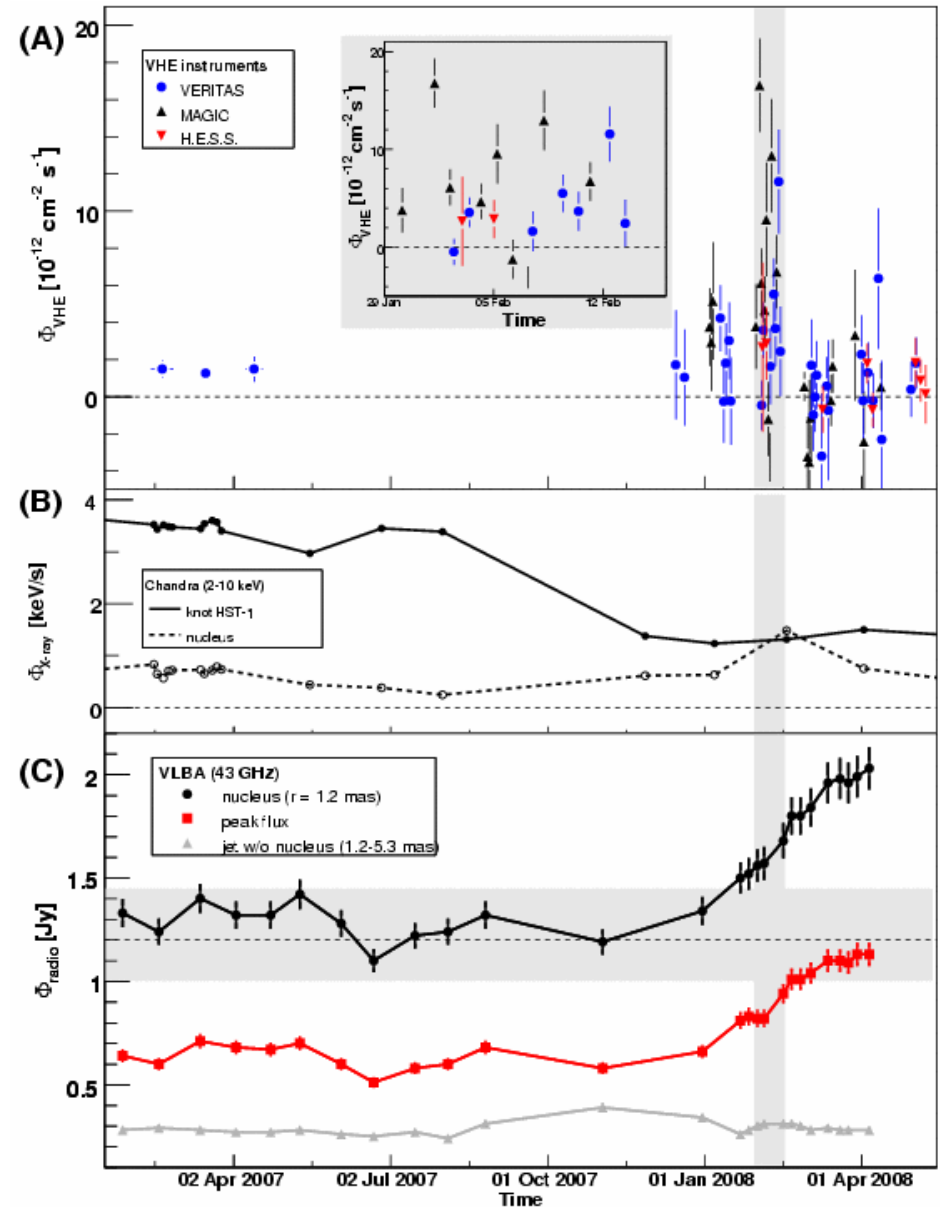
➔ Establishes core as emission region.



VLBA image of the core



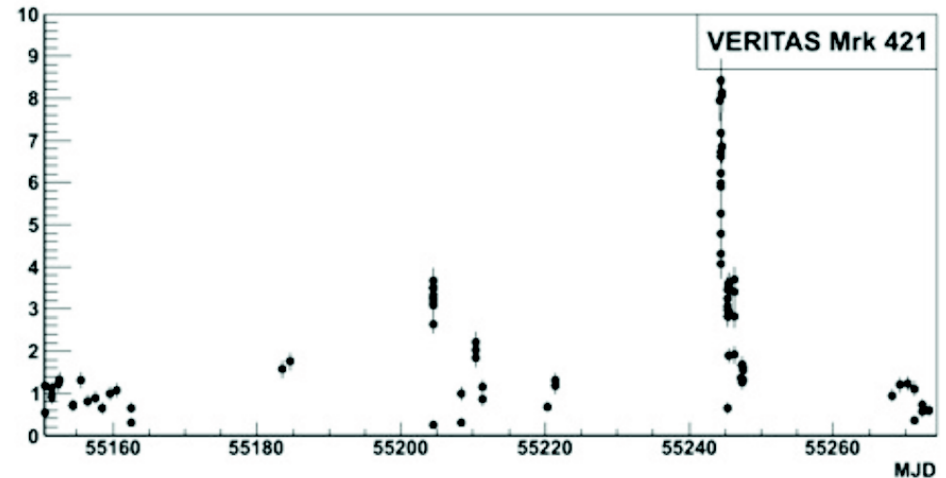
Birth of "radio" knot





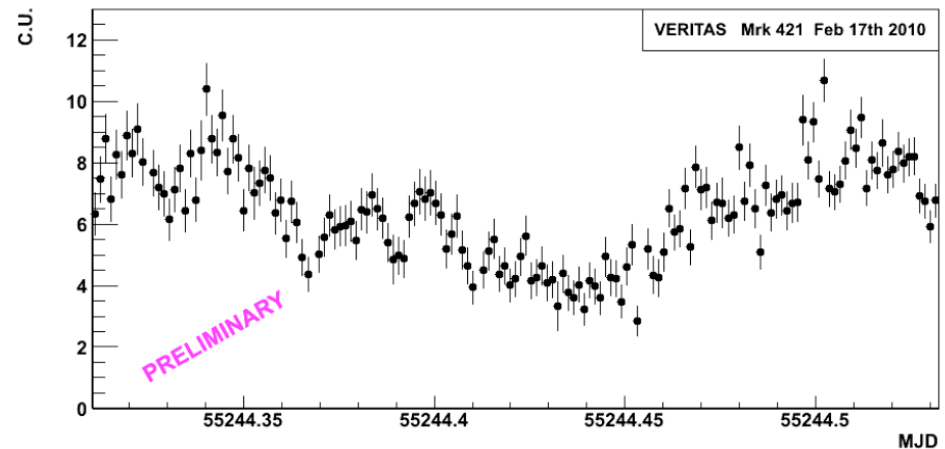
Mrk 421 2010 Flare

- Hot in VHE and X-Ray since November
- Season long monitoring, MWL
- Huge flare on Feb 17



Feb 17

- 6 hr observation
- $> 10 \sigma$ detection every 2 minutes!
- X- γ correlation and spectral evolution study in progress





Summary and Outlook

- It's great times for VERITAS!
 - ➔ Most sensitive measurements of ~ 20 AGN
 - ➔ All blazars studies with simultaneous MWL coverage
 - ◆ HBL \rightarrow SSC works independent of state
 - ◆ IBL \rightarrow hints that EC is needed
 - ➔ Deep exposure of hard spectrum blazars \rightarrow EBL constraints
 - ➔ Several strong flares recorded for M87 and Mrk 421
- Plans for the coming seasons:
 - ➔ Improve low energy sensitivity \rightarrow higher redshifts
 - ◆ VERITAS Upgrade Program (s. G. Maier E110 15:20)
 - ➔ Optimize use of Fermi data \rightarrow Shorter response times
 - ➔ Deep exposure of hard spectrum blazars \rightarrow EBL in the mid IR
 - ➔ **Waiting for those lucky catches: short time flaring, flaring at high redshift,...**



VERITAS: Factsheet

- **Location:** Basecamp of the Whipple observatory in south Arizona
- 1.3 km a.s.l.
- Array of 4 Cherenkov telescopes
 - Davies-Cotton Optics; $f/D = 1$
 - 12m diameter
 - Tessellated reflector 350 hexagonal mirrors
 - **Camera:**
 - ◆ 499 PMTs
 - ◆ 3.5° FoV
 - Trigger rate $\sim 250\text{Hz}$
 - 500 MSamples/s FADC readout



The VERITAS array after relocation of T1 in Summer 2009

Fully operational since 2007