

The first detection of the blazar S4 0954+65 at VHE with the MAGIC Telescopes during an exceptionally high optical state



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on behalf of the MAGIC and Fermi collaborations
and the MWL team

MAGIC
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OPTICAL and VLBA 43GHz
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28th Texas Symposium
15th December 2015

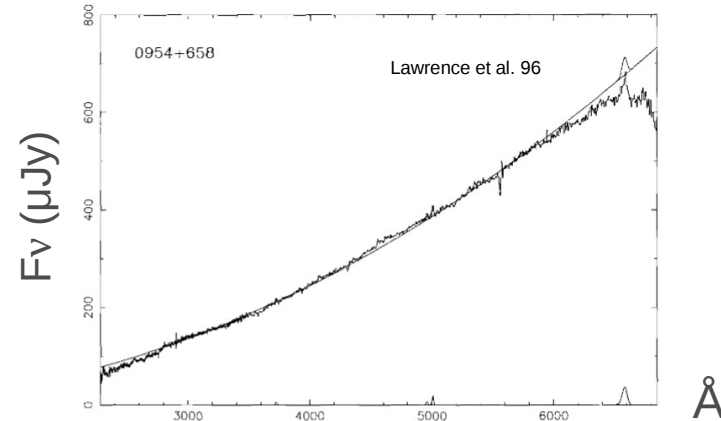
Outline

- > The blazar: Classification? Redshift?
- > The exceptional state of January/February 2015
- > MAGIC ToO observations
- > The MWL scenario: flaring activity in the lightcurve



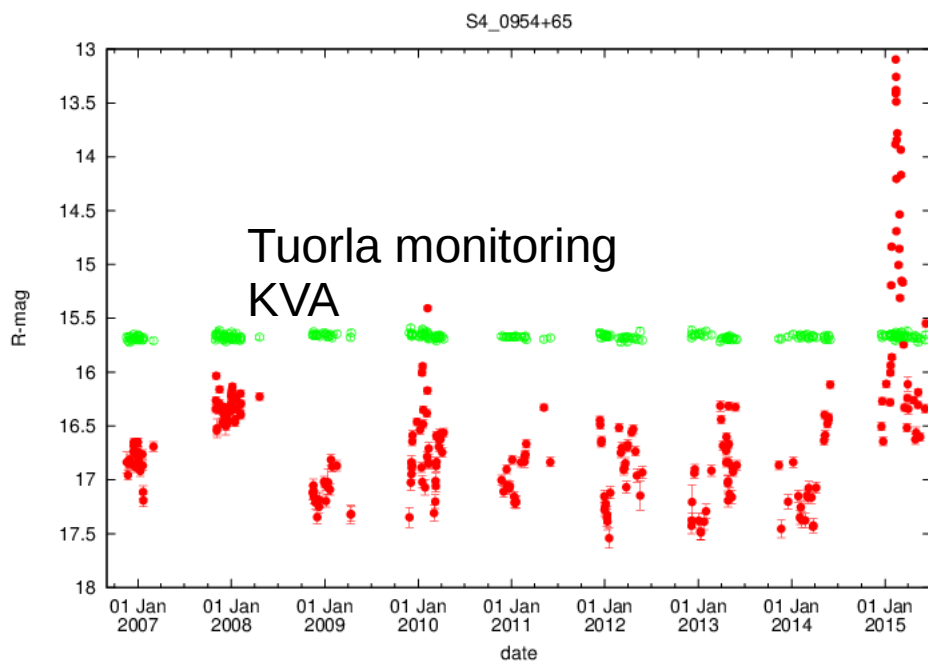
S4 0954+65 ID card

- > FSRQ(?) at $z=0.367(?)$.
- > Sometimes classified as FSRQ (ATELs in February 2015, Sambruna et al. 1996)
- > Small equivalent width of the lines in its spectrum
- > Ghisellini et al. (2011) classified this object as a LBL based on the SED.
- > It presents a flatter energy distribution than most BLLac objects (CRATES catalog) and can be seen as a **transitional object between FSRQ and classical BLLac**.
- > Redshift was determined by Lawrence et al. 1996 ($z=0.367$). Landoni 2015 did not detect any of the lines used for redshift ($z>0.45$), but data were taken at a high brightness ($R=15.5$)
- > Intra-night and long term optical variability well known (Wagner 1993, Morozova 2014)
- > Detected in HE already by EGRET and by Fermi already in 1FGL catalog

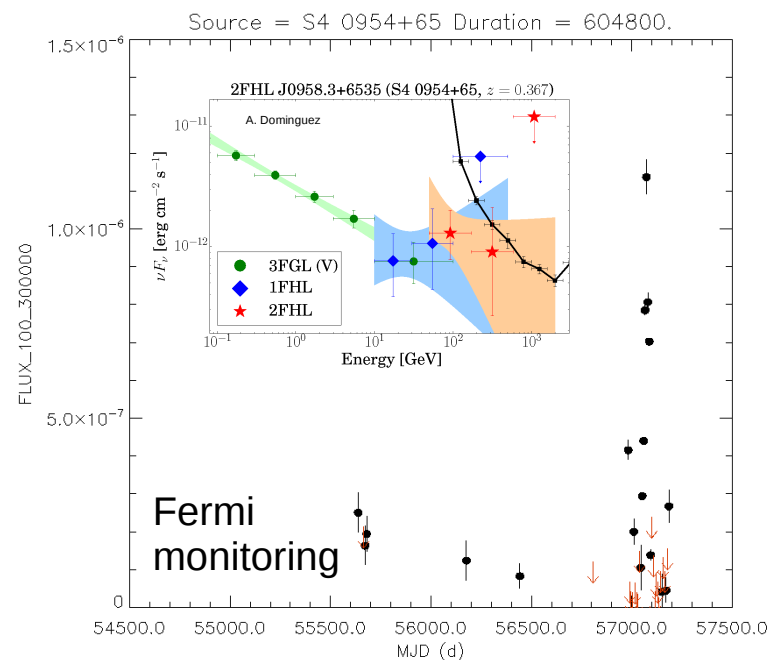


S4 0954+65: the Feb 2015 flare and the trigger

- This source is part of the MAGIC ToO program and Tuorla blazar monitoring
- Trigger by high optical state (highest state since 2006, KVA)
- Concurrent to a high Fermi/LAT state



http://users.utu.fi/kani/1m/S4_0954+65.html



MWL scenario in words

- > **Fermi LAT sees an increase in Nov 14**
→ ATEL #6709
28 times its average flux in the 2FGL catalog
- > **NIR and optical brightening on 27 January 2015**
ATEL # 6996, 7001 and others
→ start MAGIC observations, no detection
- > **Tuorla monitoring sees **extreme** state on ~12 February**
ATEL #7057, #7083 and others
→ MAGIC **detection** on the night of 13-14 February!!
<http://www.astronomerstelegam.org/?read=7080>
- > **LAT communicates an increase too**
ATEL(#7093)
Hard photon index ($E > 100 \text{ MeV}$, $\Gamma < \sim 2$) and high flux (15-30 times than in 3FGL catalog)
- > **Another reprise at middle/end of June in optical and NIR (not observable by MAGIC)**
ATEL #7684, #7750

Discovery of Very High Energy Gamma-Ray Emission from the FSRQ S4 0954+65 with the MAGIC telescopes

ATel #7080; **Razmik Mirzoyan (Max-Planck-Institute for Physics) on behalf of the MAGIC collaboration**
on 15 Feb 2015; 19:44 UT

Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Radio, Optical, Ultra-Violet, X-ray, Gamma Ray, >GeV, TeV, VHE, UHE, AGN, Black Hole, Blazar, Cosmic Rays

Referred to by ATEL #: 7093

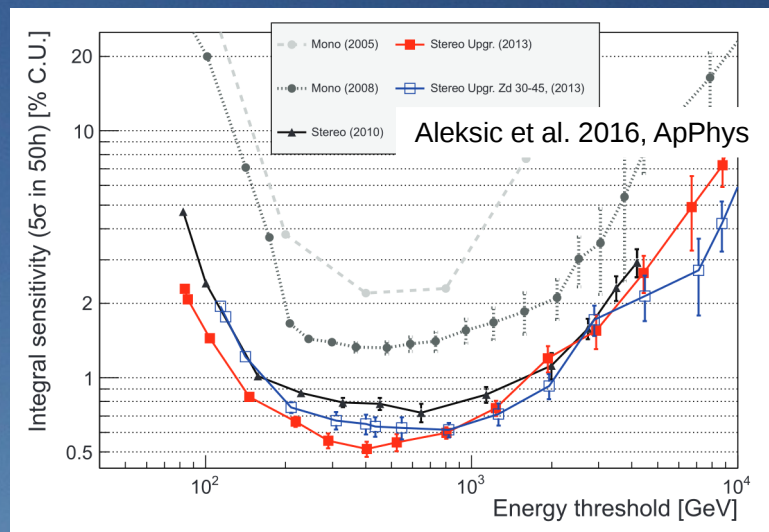
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The MAGIC collaboration reports the discovery of very high energy (VHE; $E > 100 \text{ GeV}$) gamma-ray emission from the FSRQ S4 0954+65 ($RA = +9:58:47.00$, $DEC = +65:33:55.00$, $J2000.0$), located at redshift $z = 0.368$. The object was observed with the MAGIC telescopes for ~2 hours during the night 2015 February 13/14 (MJD 57067). A preliminary analysis of the data yields detection with a statistical significance of more than 5 standard deviations. This is the first time a significant signal at VHE gamma rays has been seen from S4 0954+65. The flux above 150 GeV is estimated to be about $2e-11 \text{ cm}^{-2} \text{ s}^{-1}$. S4 0954+65 is entered an exceptionally high state at optical and near infrared frequencies (ATels #7057; #7055; #7046, #7001; #6996), which triggered the MAGIC observations. Optical observations performed with the KVA telescope suggests that this is the brightest state ever observed from this source since November 2006 (beginning of KVA observations). The preliminary lightcurve is available at: http://users.utu.fi/kani/1m/S4_0954+65.html. During the preparation of this ATEL, we were informed by Fermi-LAT collaboration that the gamma-ray flux above 100 MeV from S4 0954+65 also increased substantially during the last few days. MAGIC observations on S4 0954+65 will continue during the following nights, and multiwavelength observations are encouraged. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) and E. Lindfors (ellin@utu.fi). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Canary island of La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.



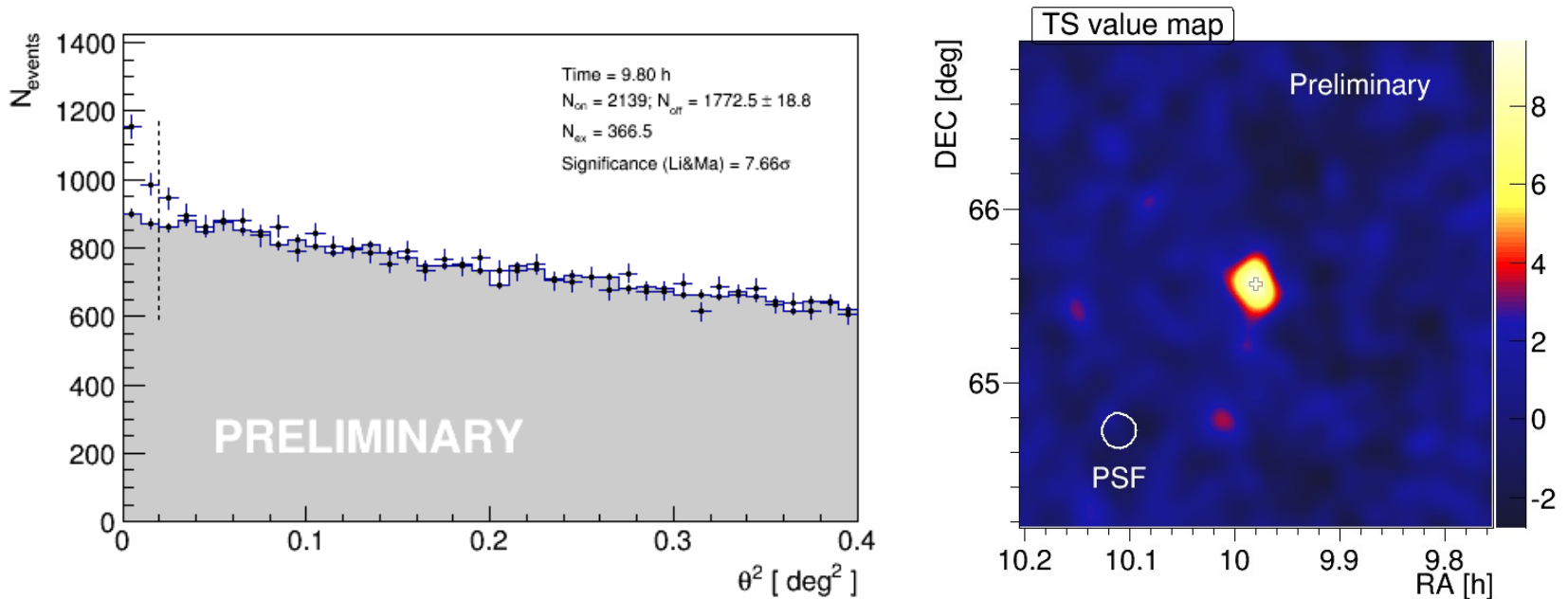
The MAGIC telescopes

- > Sensitive down to energy ~ 50 GeV
- > Angular resolution $\sim 0.15^\circ$ at 150 GeV [zd>30°]
- > Energy resolution $\sim 20\%$ at 150 GeV [zd>30°]
- > Observations possible also in partial moonlight



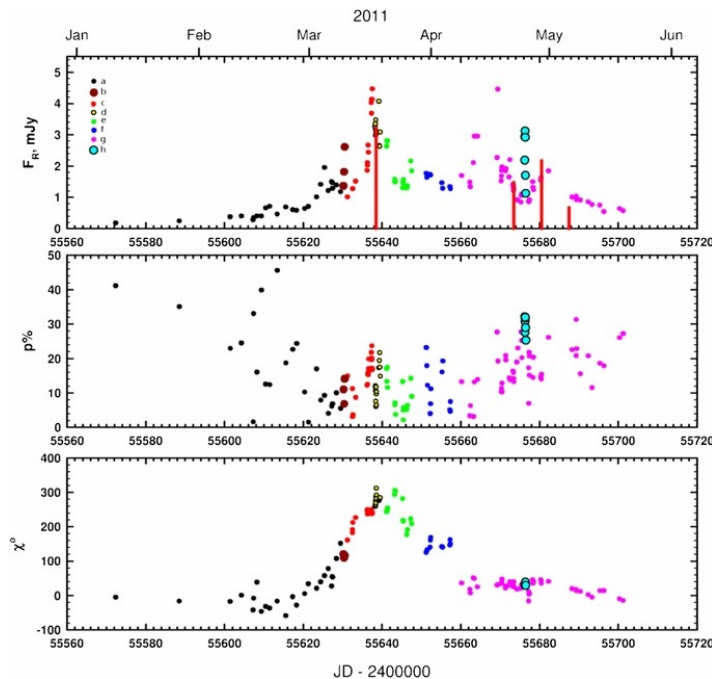
S4 0954+65: MAGIC detection

- > Data from end of January to beginning of March. Total of ~13 hours of observation (including bad weather and strong moon, not shown here)
- > Zenith range from 35deg to 50deg (→ increased energy threshold)



- > Detection from full sample, but mostly concentrated on 14th Feb (MAGIC ATEL night)

- Large flare in 2011 connected with smooth rotation of polarization angle of 300 degrees and a simultaneous knot ejection



R band vs. time in 2011 January–May; Red vertical bars in the upper panel mark positive Fermi-LAT detection; the height of a bar is proportional to the γ -ray flux.

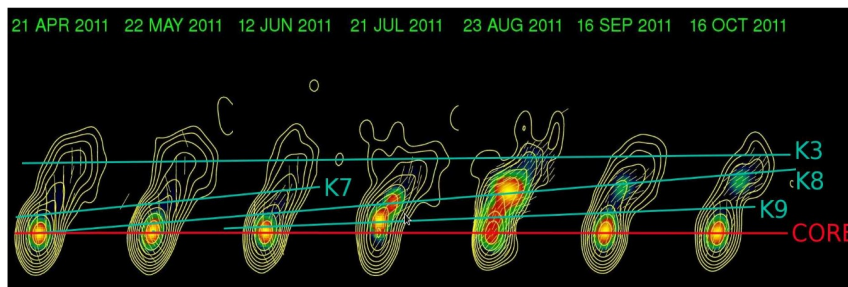
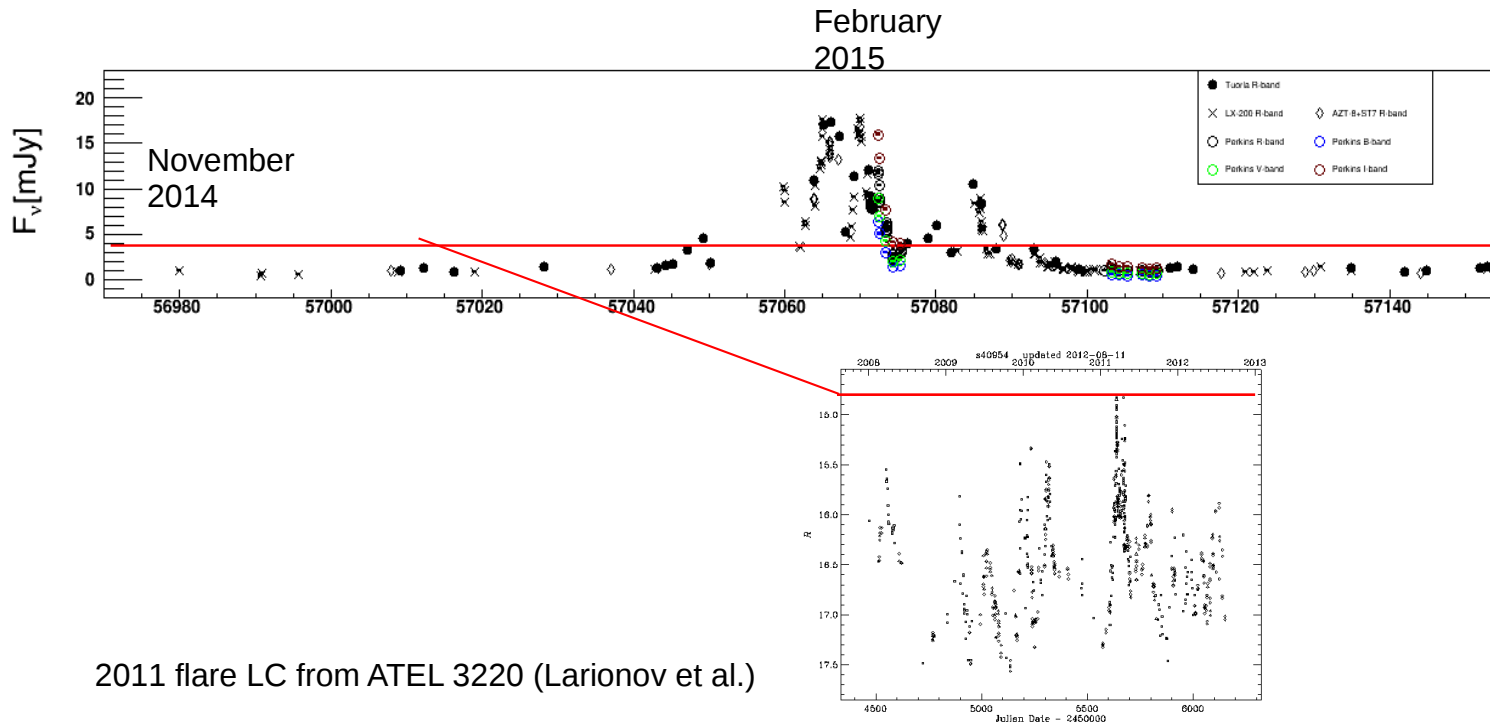


FIG. 9.— Total (yellow contours) and polarized (color scale) intensity images at 43 GHz; yellow line segments over the color scale show the direction of the electric vector.

K8 knot is the one associated with the flare

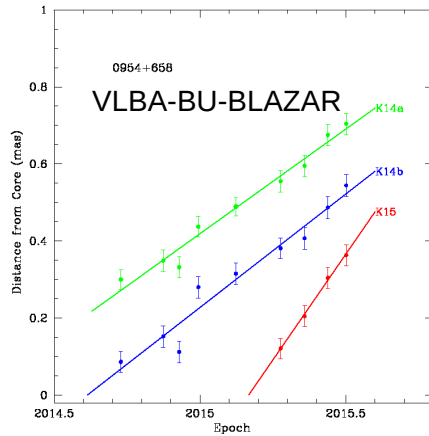
MWL scenario in LC – optical

- Collaborators provided additional optical photometry, polarization from Perkins, LX-200, AZT-8+ST7 telescopes and VLBA 43 GHz imaging
- Feb 2015 flare is quite exceptional in optical:
factor ~5 higher flux in R-band wrt 2011
factor ~30 higher flux in R-band wrt low states

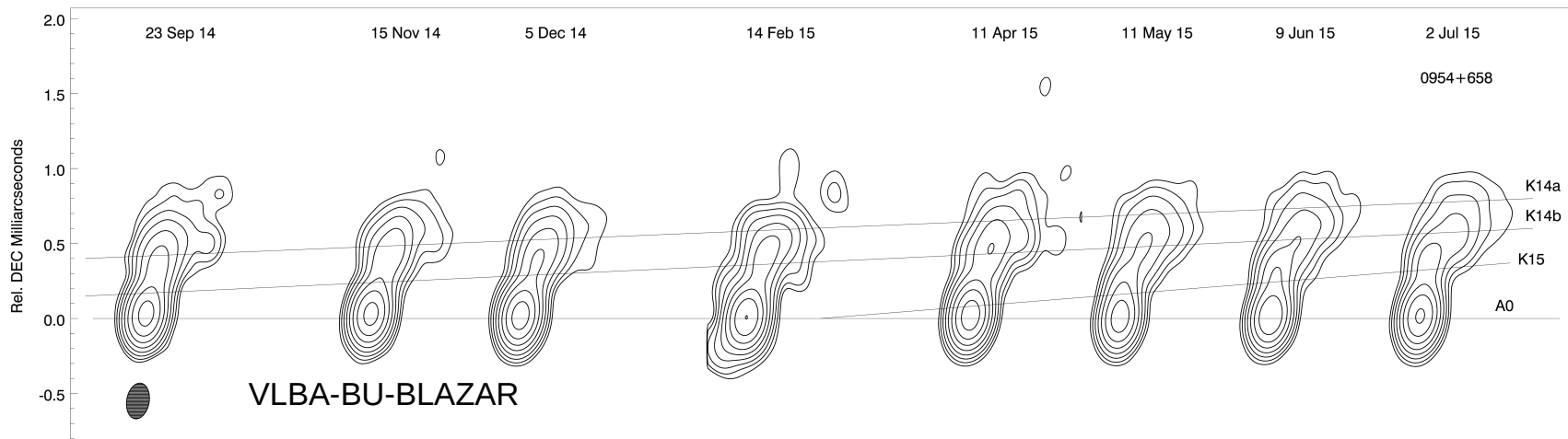


Knots emerging: VLBA 43 GHz imaging

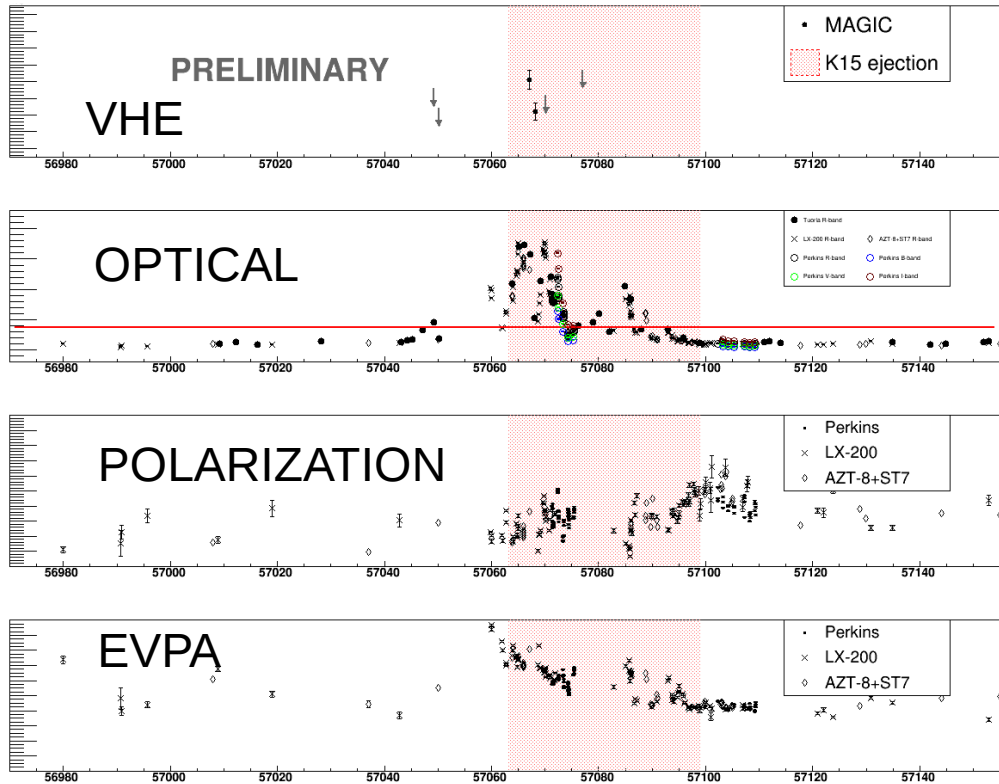
- K15 zero epoch separation is “simultaneous” with optical flare, VHE detection and change of polarization angle



- The simultaneity could still be chance coincidence, but the enhanced state in most wavelengths discourages this interpretation
- K15 is particularly fast

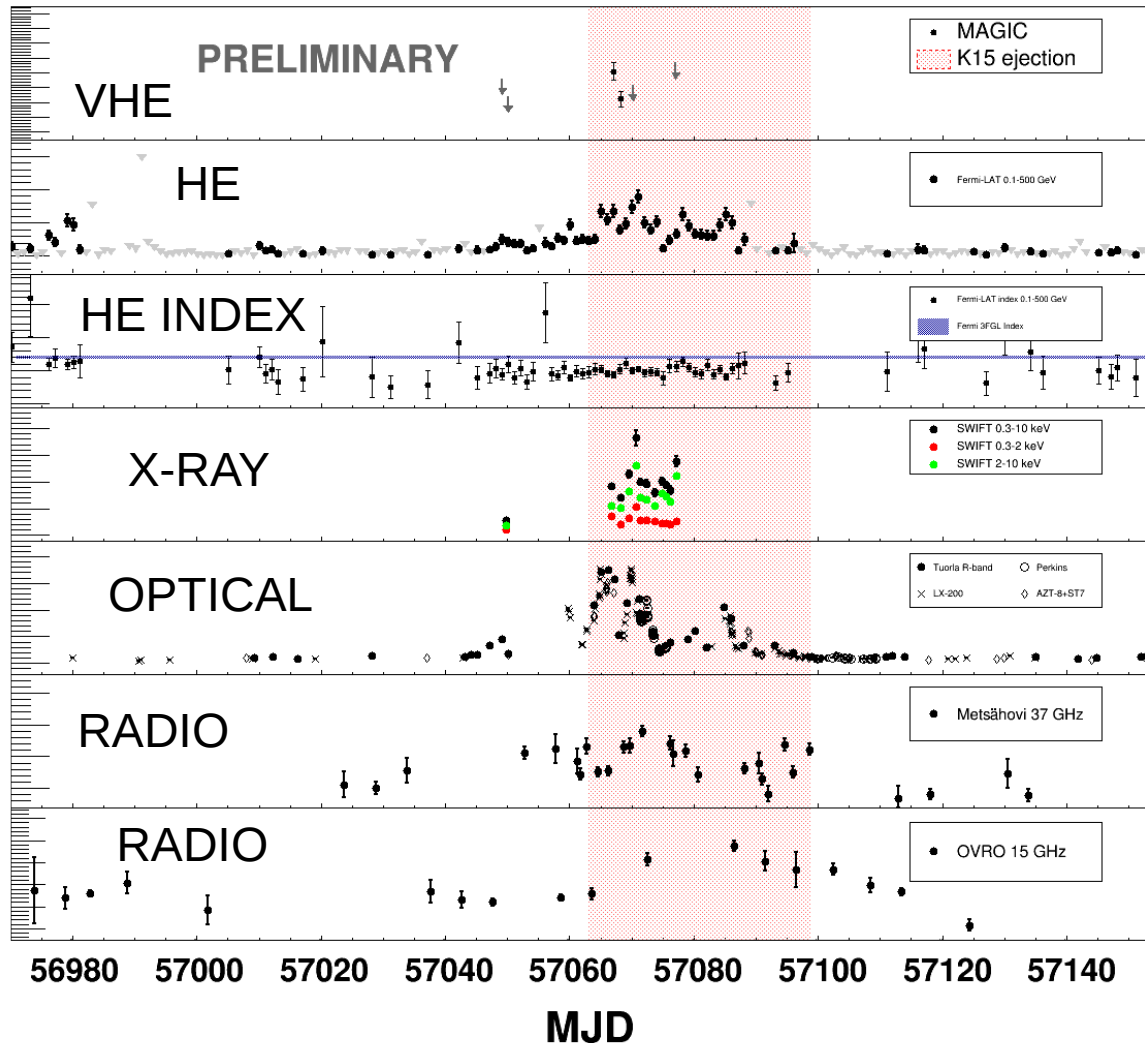


MWL scenario in LC – optical



- > K15 ejection coincident with MAGIC detection and high optical state
- > Small increase of fractional polarization (more pronounced after the flare)
- > Change of polarization angle (~100deg rotation)
- > Spiral motion in a helical magnetic field?

MWL scenario in LC



- > Enhanced flux state in all wavelengths
- > Hard HE spectrum during MAGIC detection
- > Delayed(?) peak emission at lower energies (X-ray, radio)



Conclusion

- > MAGIC ToO program very successful
- > S4 0954+65 was detected for the first time at VHE during an exceptional optical flare
- > Enhanced state in all wavelengths
- > Coincident with the zero epoch separation of knot K15 (identified in 43GHz images)
- > Delayed peak emission at lower energies (X-ray, radio)? TO BE STUDIED

Thanks for your attention!
Questions?

