The New Spectral and Temporal Variability Phase of OJ 287: A Multi-wavelength View

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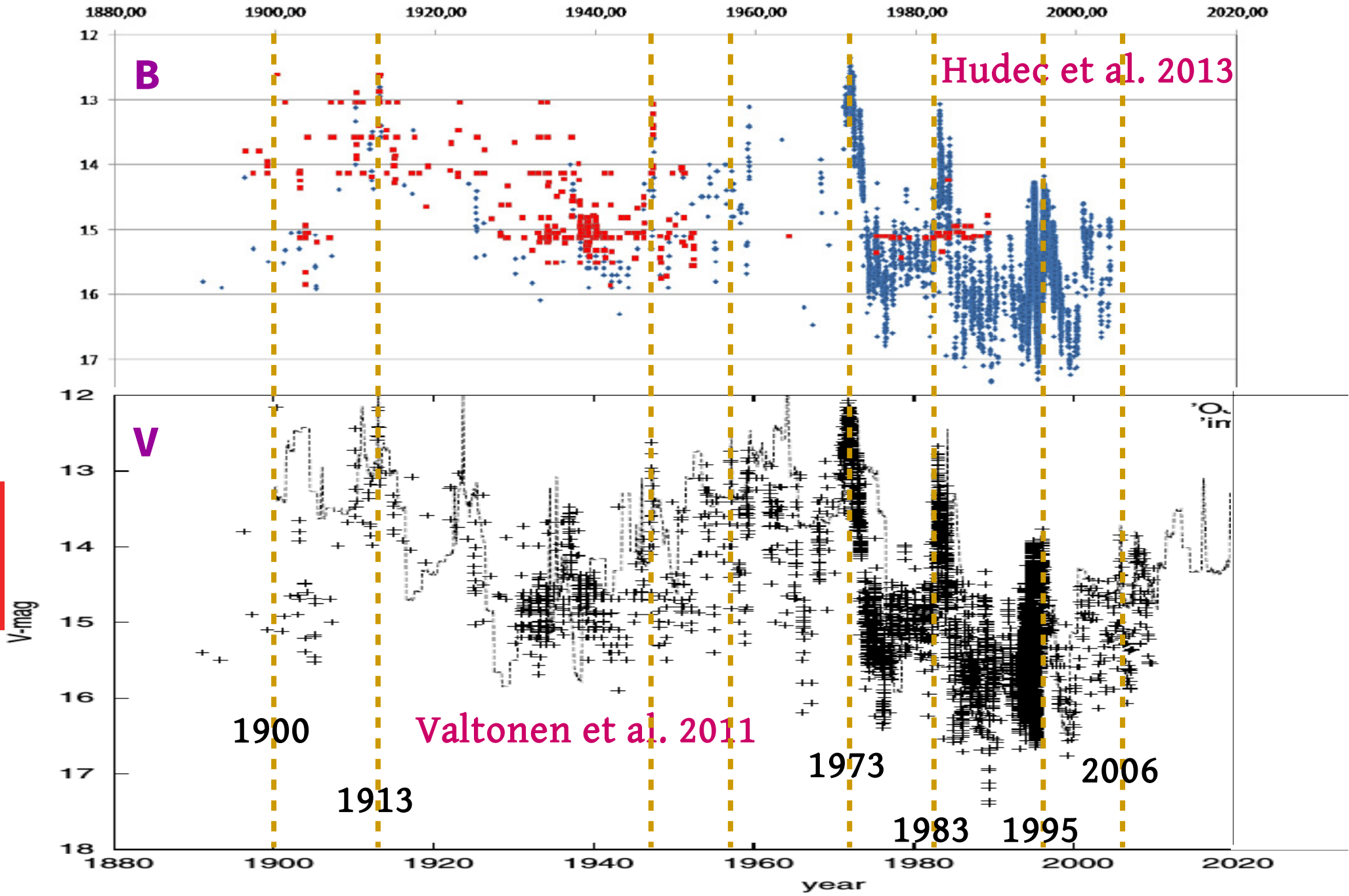
OJ 287

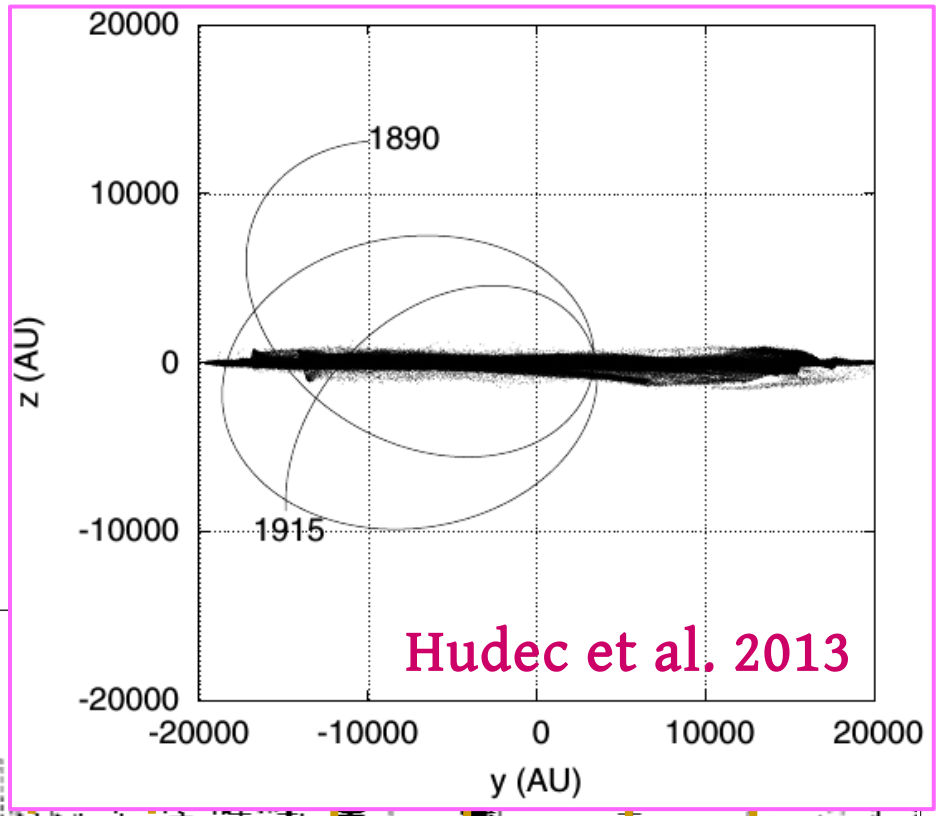
- BL Lacertae (very weak or no emission lines in optical spectrum) object at z = 0.306
- One of the brightest source at radio and optical energies
- Though identified in 1967, optical data available since 1890
- Most famous for its regular ~12 periodic optical outbursts
- Claimed to be a precessing SMBH system with optical outbursts resulting from the impact of secondary (1.8×10^8 M_o) on the accretion disk of primary secondary (1.3×10^{10} M_o, Sillanpaa et al 1988; Valtonen et al 1996, 2016)

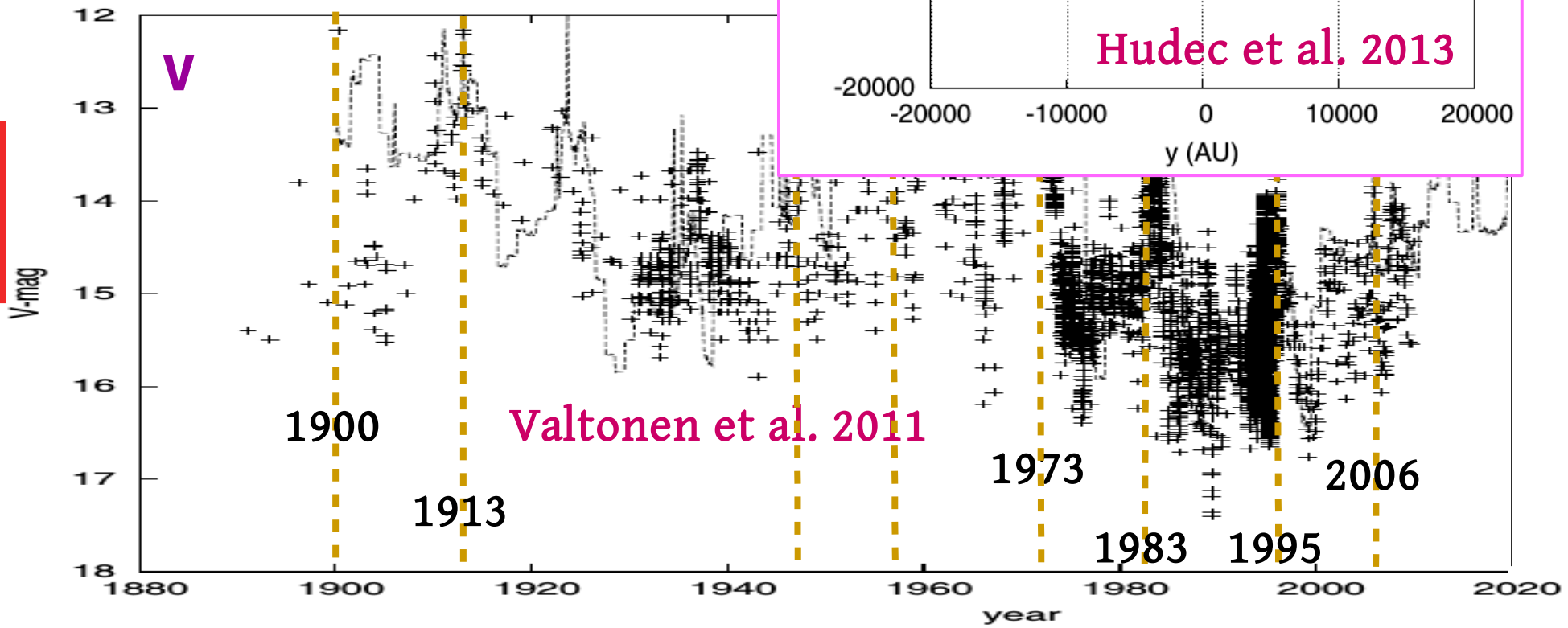
OJ 287: Optical Light curves Vs Model



OJ 287: Binary-SMBH Model

- Precess ~39.1°/cycle
- Spin: 0.31, e ~ 0.7
- Impact outbursts have relatively low polarization





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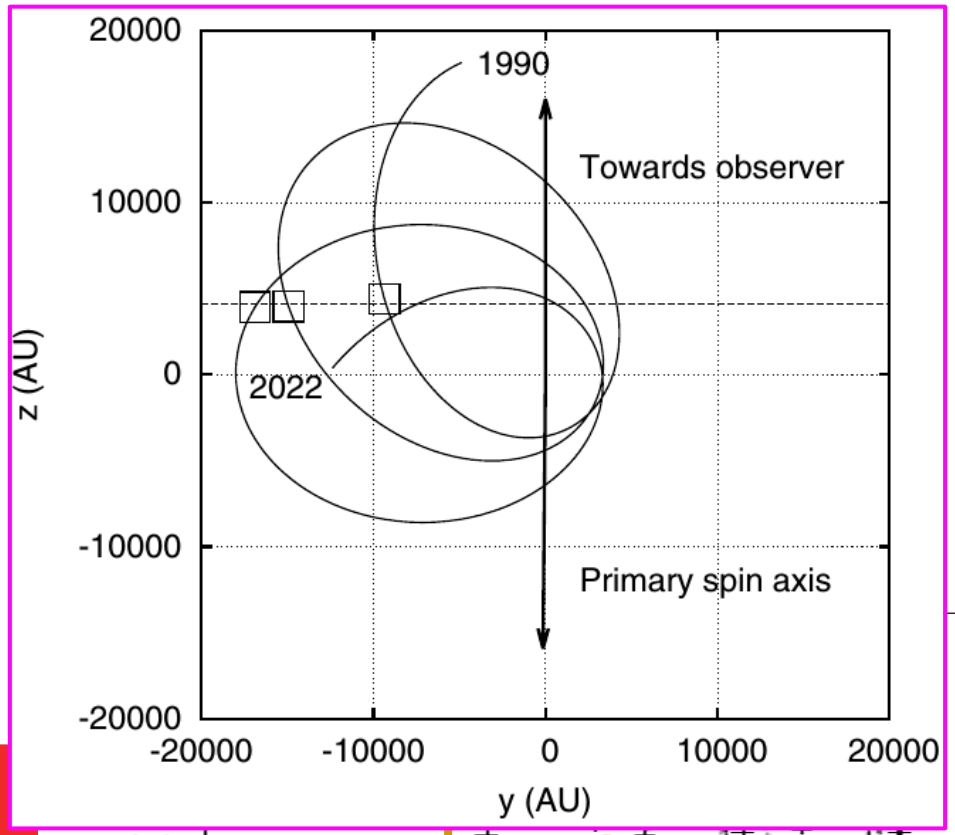

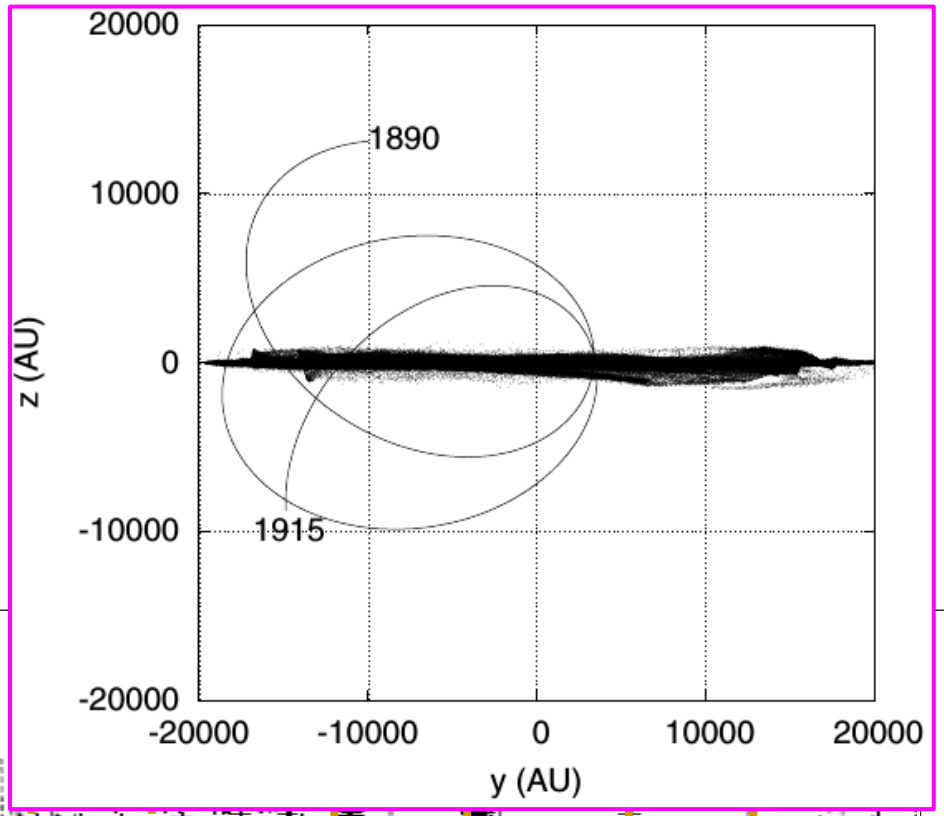

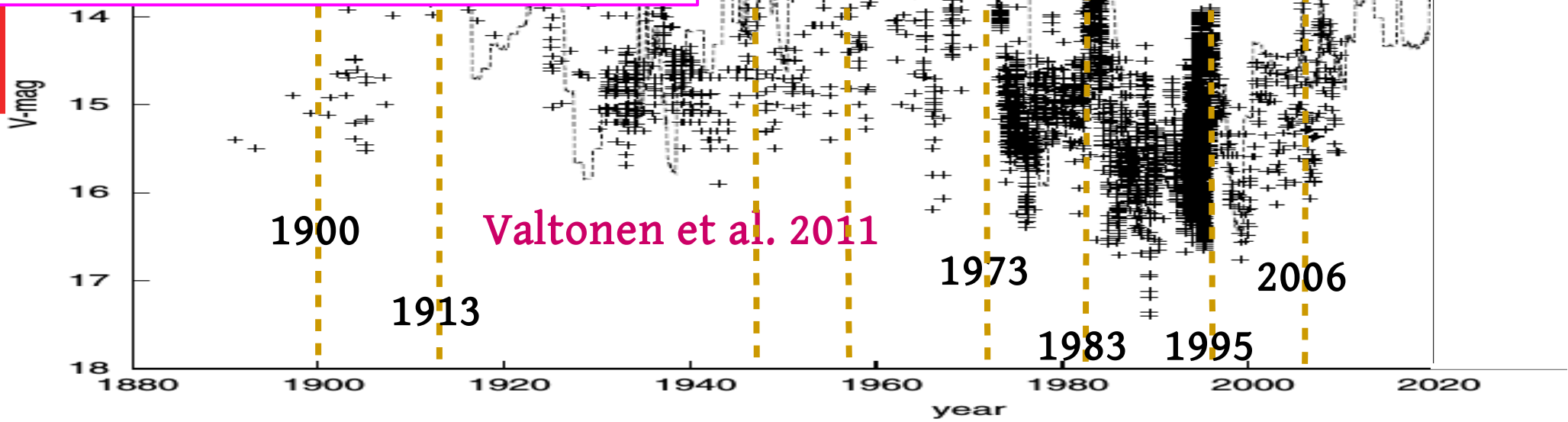

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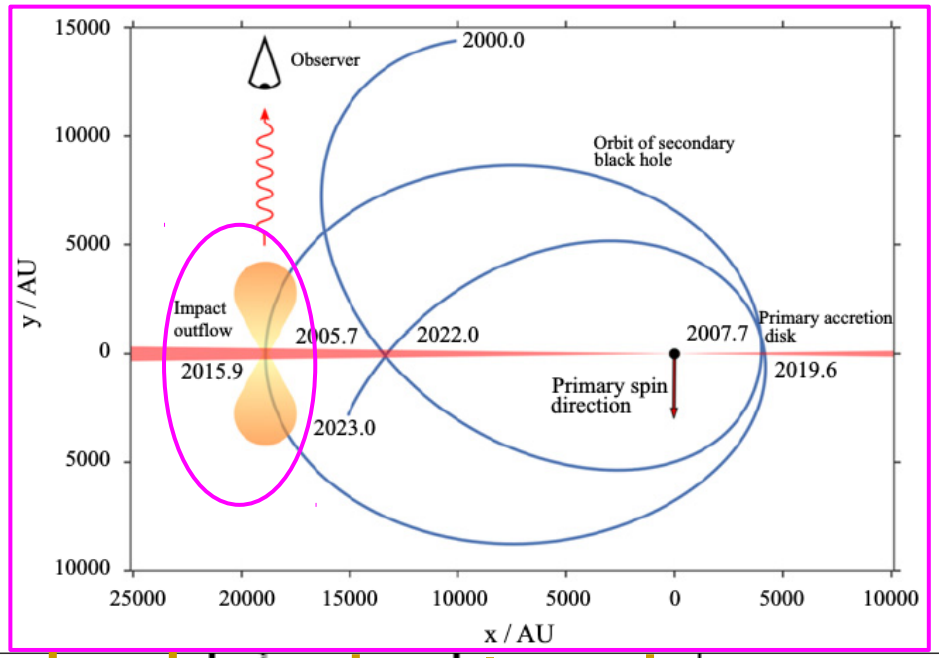
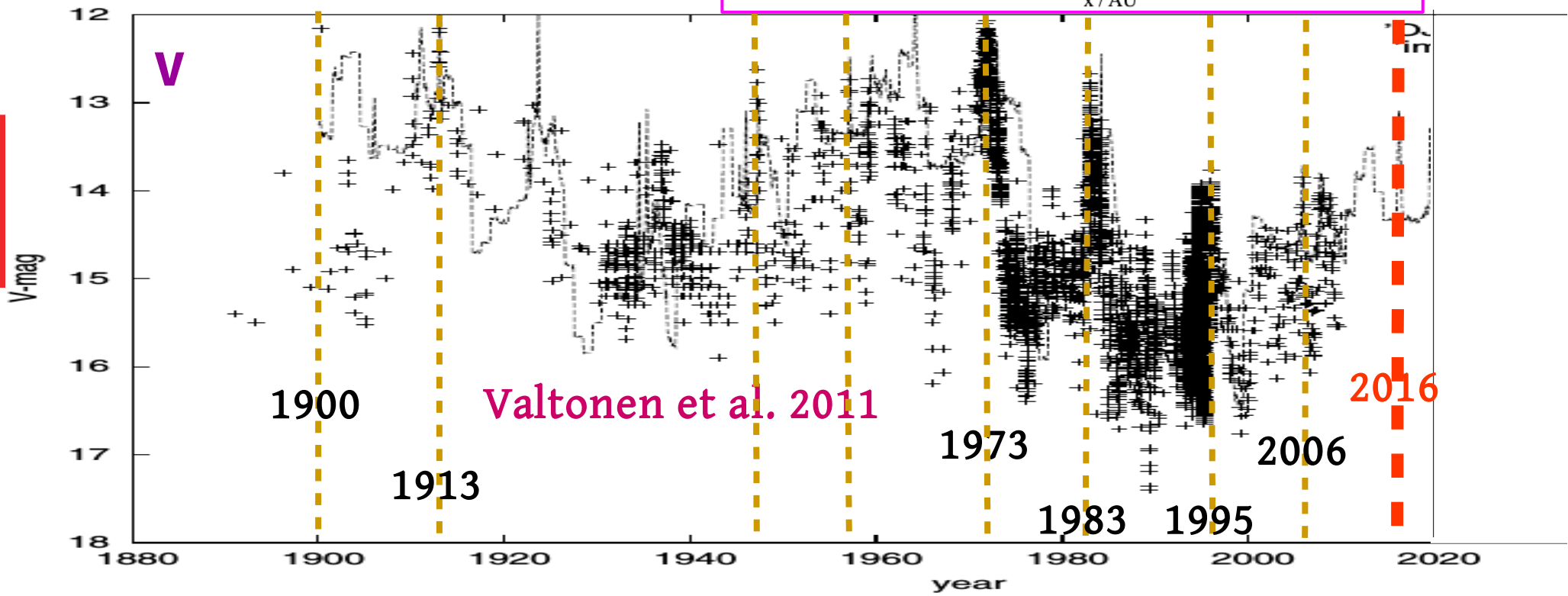
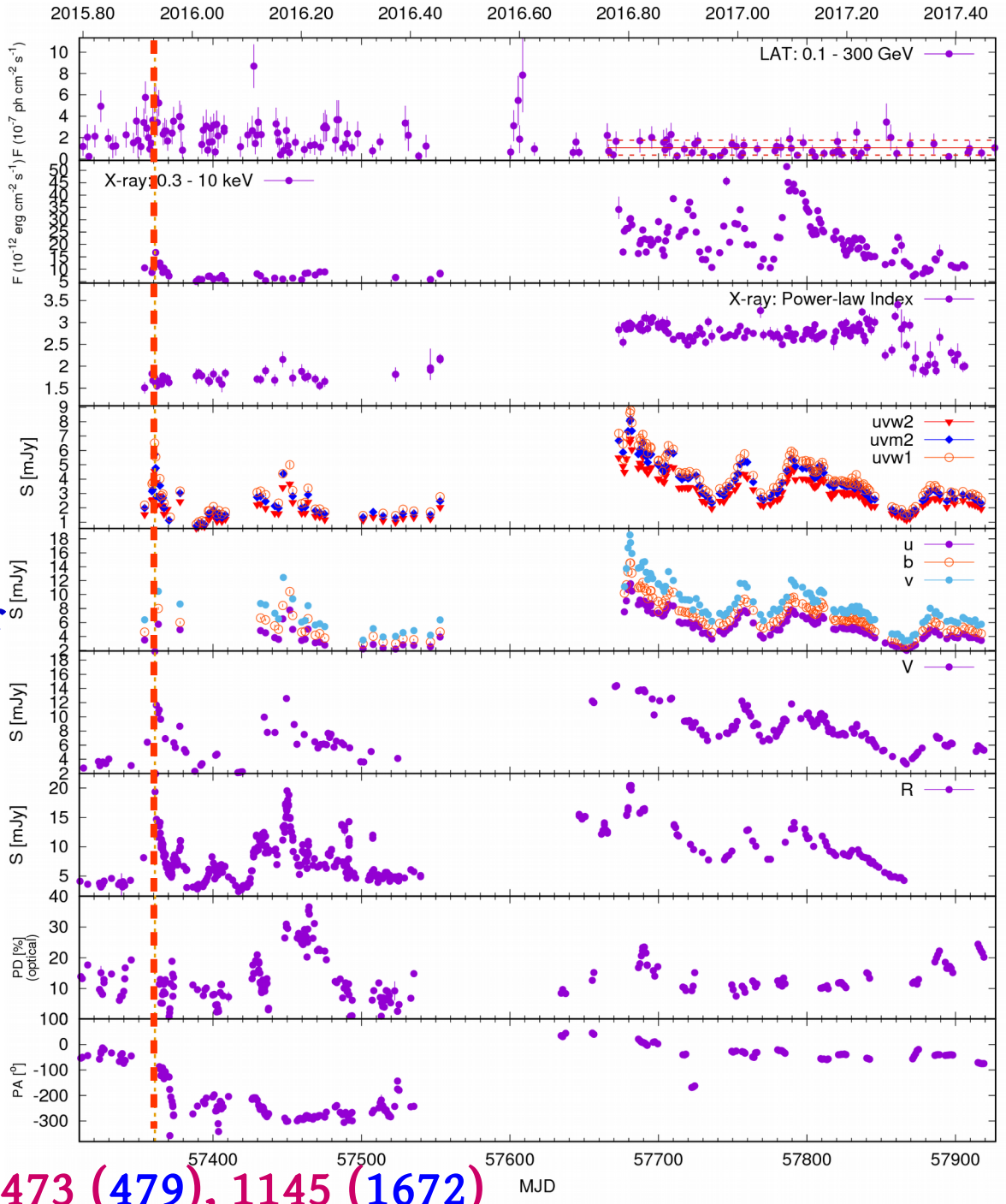


Valtonen et al. 2016



Nov 2015 – June 2017 MW Data: 2015 Outburst

- Impact outburst on MJD 57361 (2015.93) occurred, as predicted by the Binary SMBH model (2015.96 ± 0.12)
- Relatively low optical polarization < 10% but with a huge swing of ~200° in PA
- Simultaneous outburst from γ-rays to optical seen



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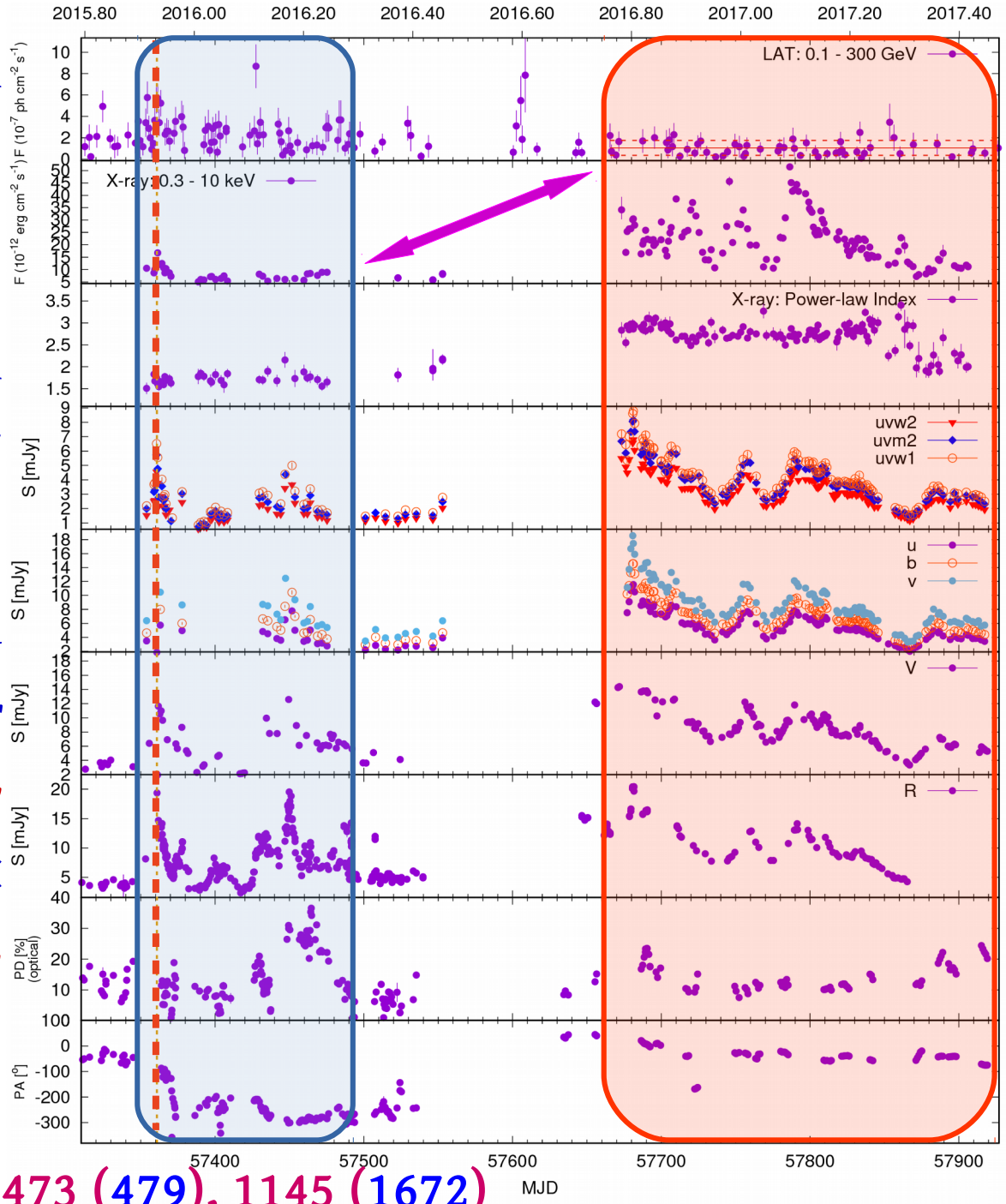
Nov 2015 – June 2017: Temporal Variations

- Two activity phases in temporal variation: **57300 – 57450 & 57650 - 57930**
- 57300 – 57450: Variation from NIR to Fermi-LAT γ-ray
- **57650 – 57930:** Intense NIR to X-ray variability but not in Fermi-LAT band, highest ever reported X-ray flux, first ever detection of VHE emission



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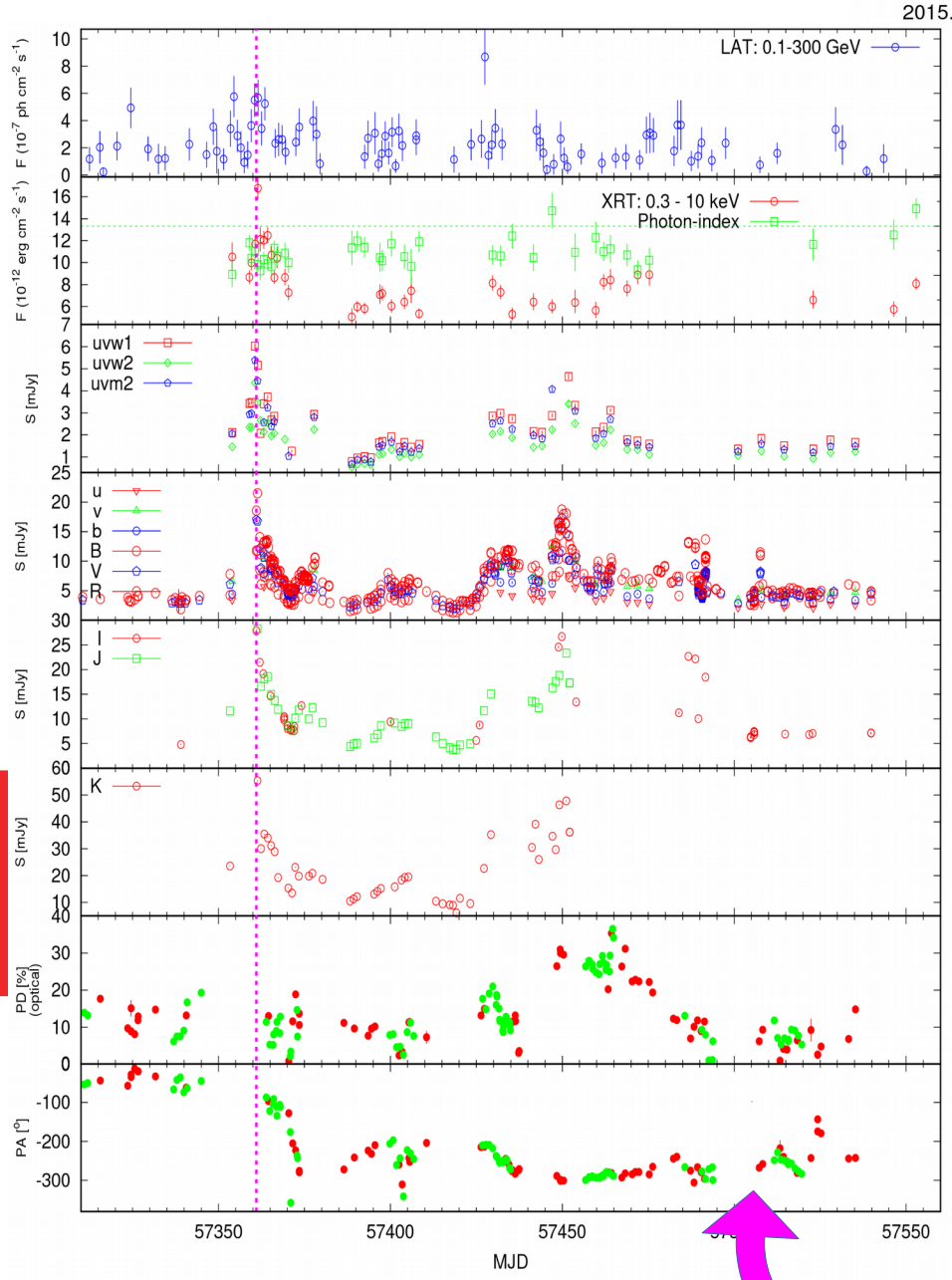
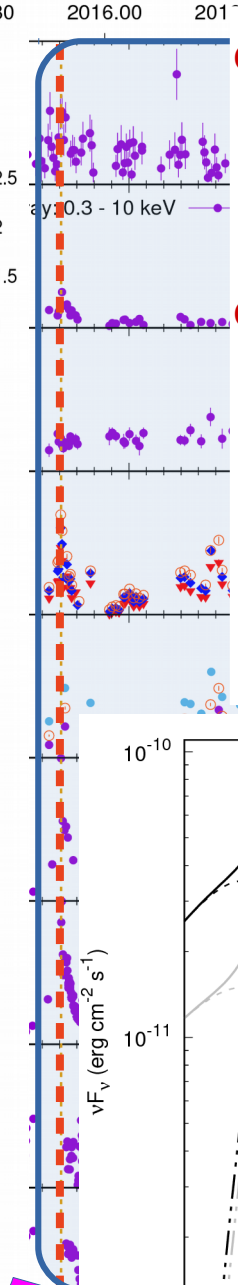
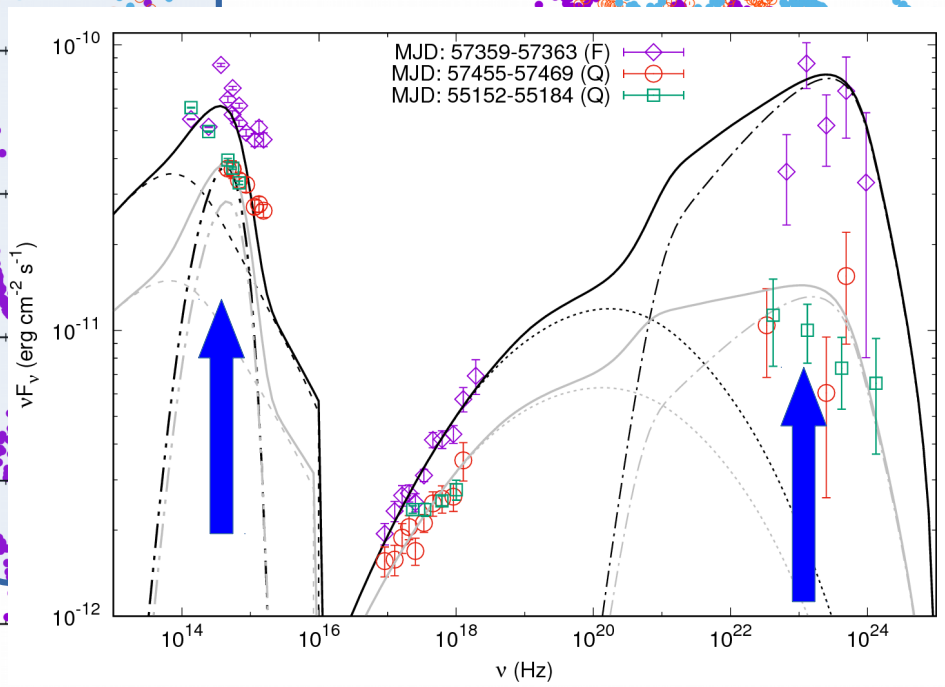
Nov 2015 – April 2016: Spectral & Temporal Variations





- Simultaneous variation in all bands
- Claimed impact flare show relatively low polarization % but accompanied by huge change (~ 200°) in PA



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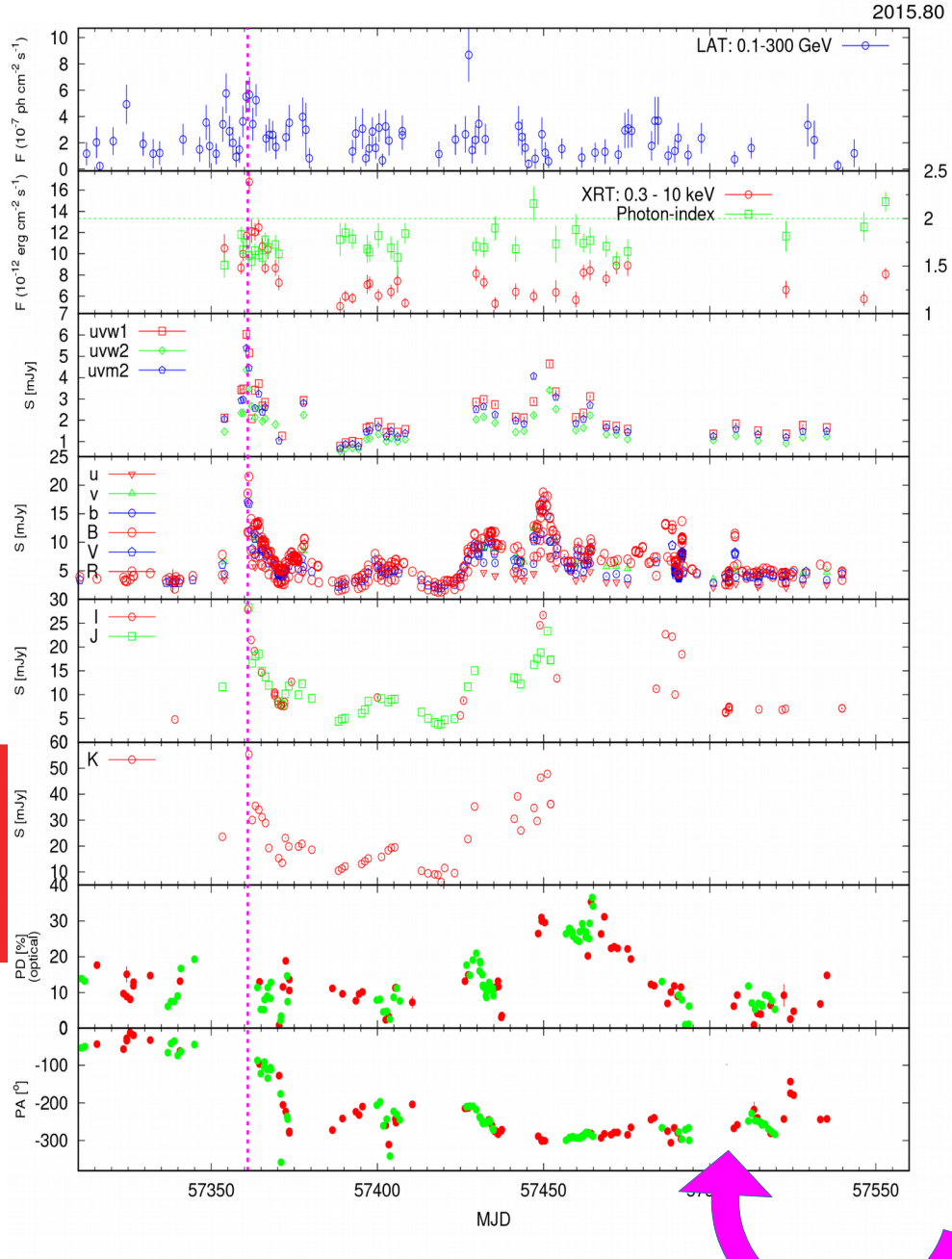
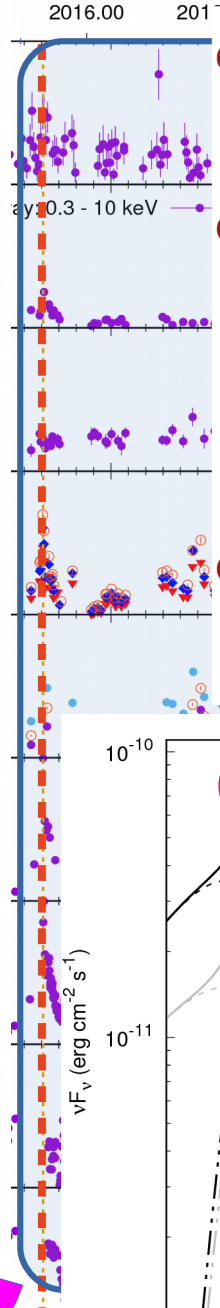
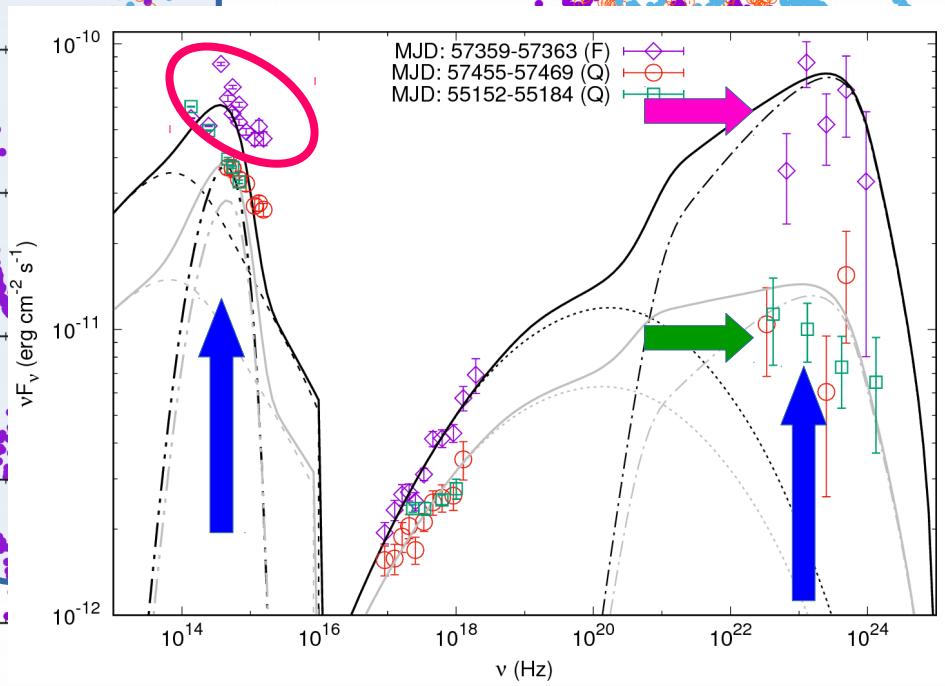
Nov 2015 – April 2016: Spectral & Temporal Variations





- Simultaneous variation in all bands
- Appearance of thermal like bump at NIR-optical, consistent with standard accretion disk
- Change in location of peak of γ-ray SED



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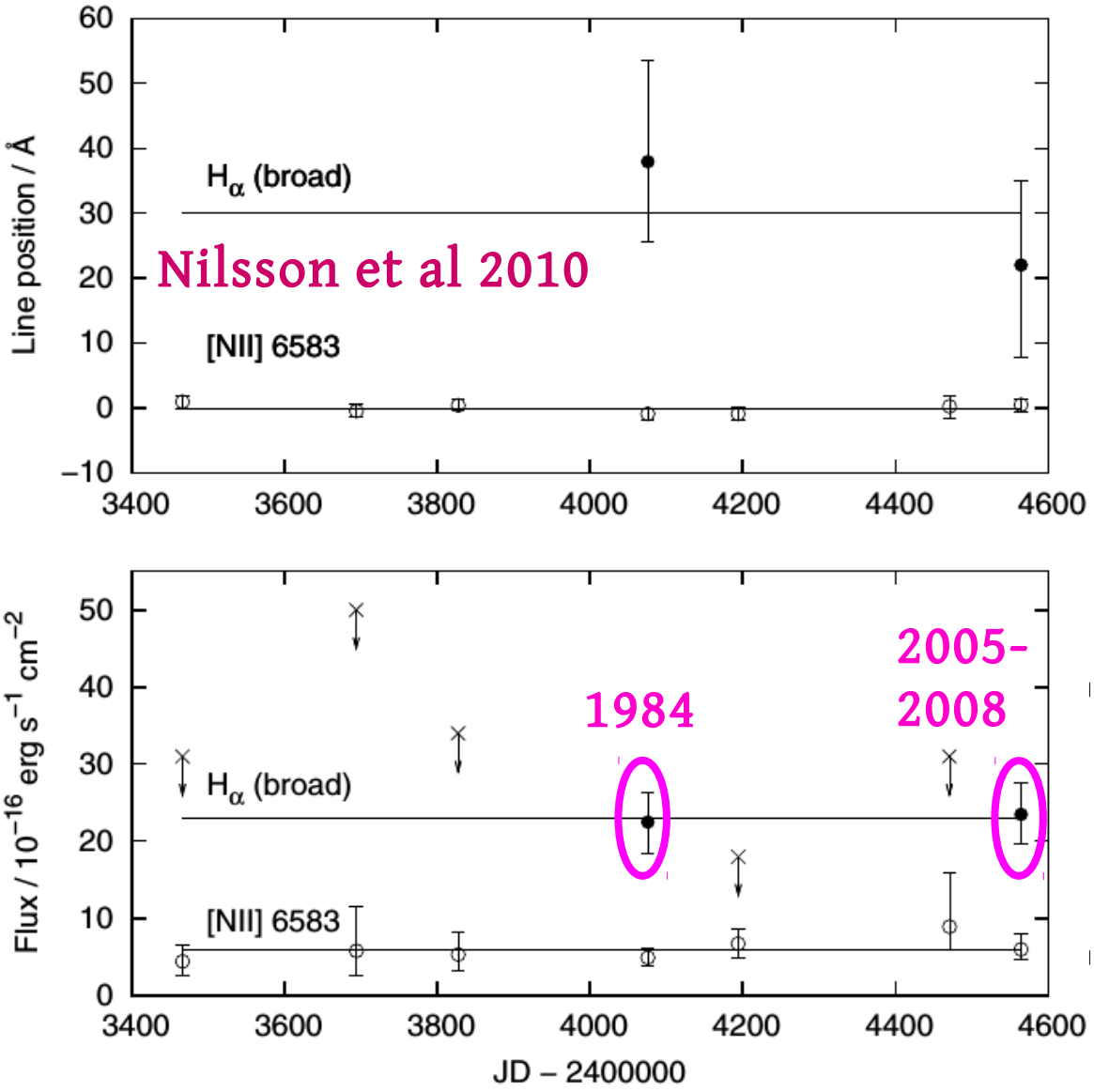
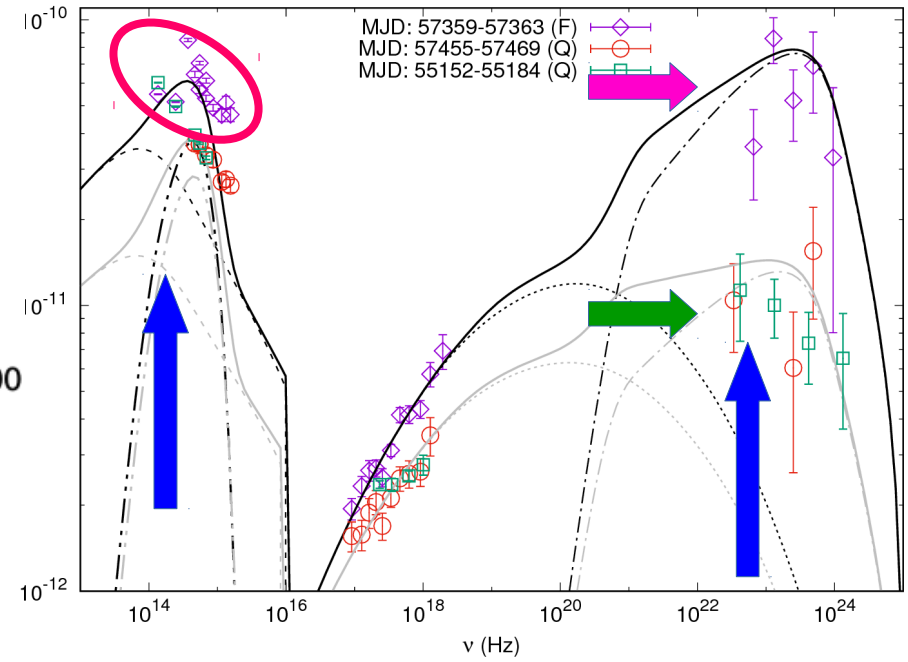
Nov 2015 – April 2016: SED Explanation



- Emission lines seen during previous impact periods (Nilsson et al 2010)
- No apparent change in the location of synchrotron peak wrt 2009 SEDs (NIR-optical)



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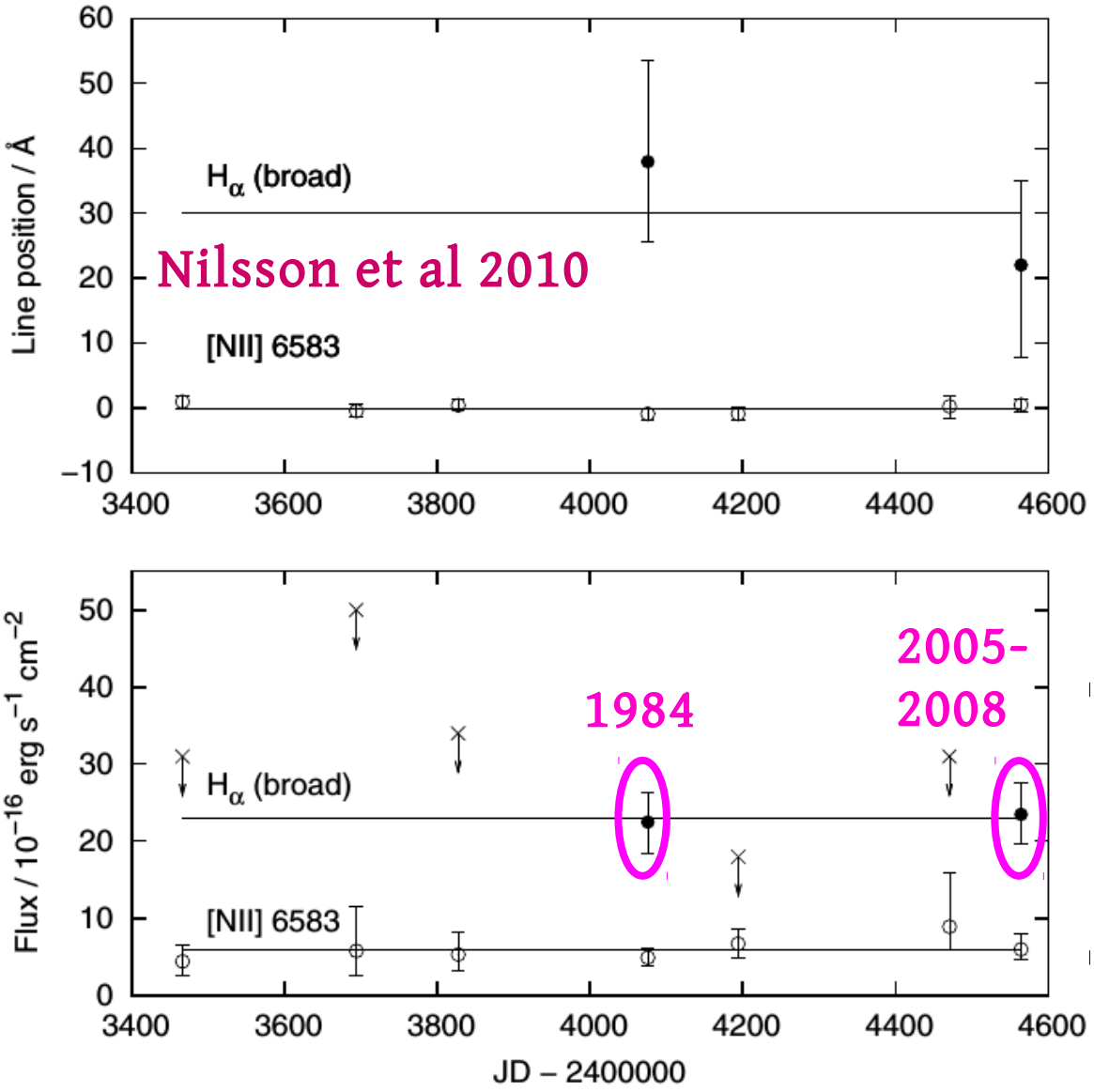
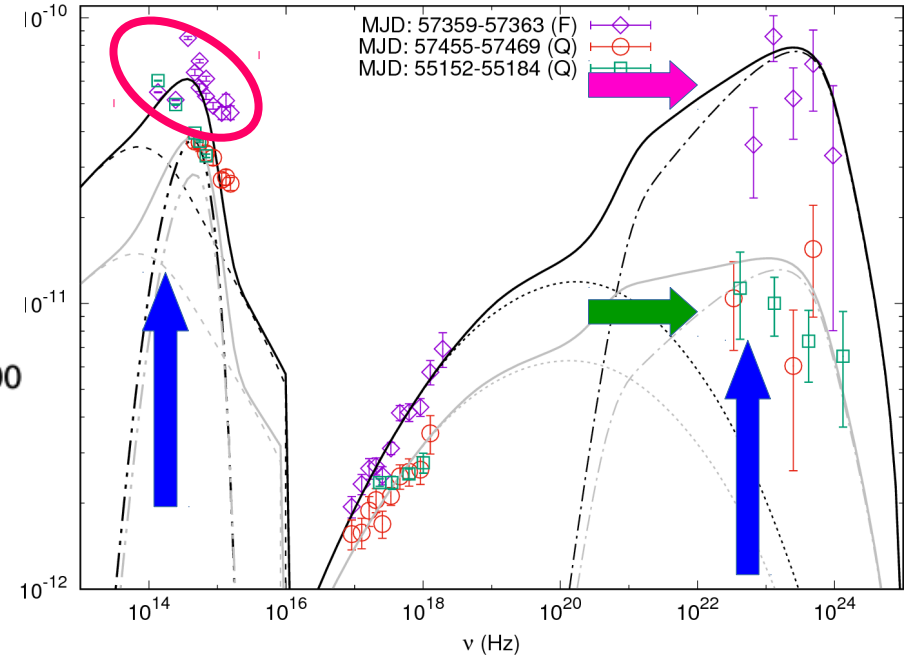


- Emission lines seen during previous impact periods (Nilsson et al 2010)
- The γ-ray SED shift can be naturally reproduced by IC of BLR photons & thermal bump by Shakura-Sunyaev disk



Suggest emission region at sub-parsec scales

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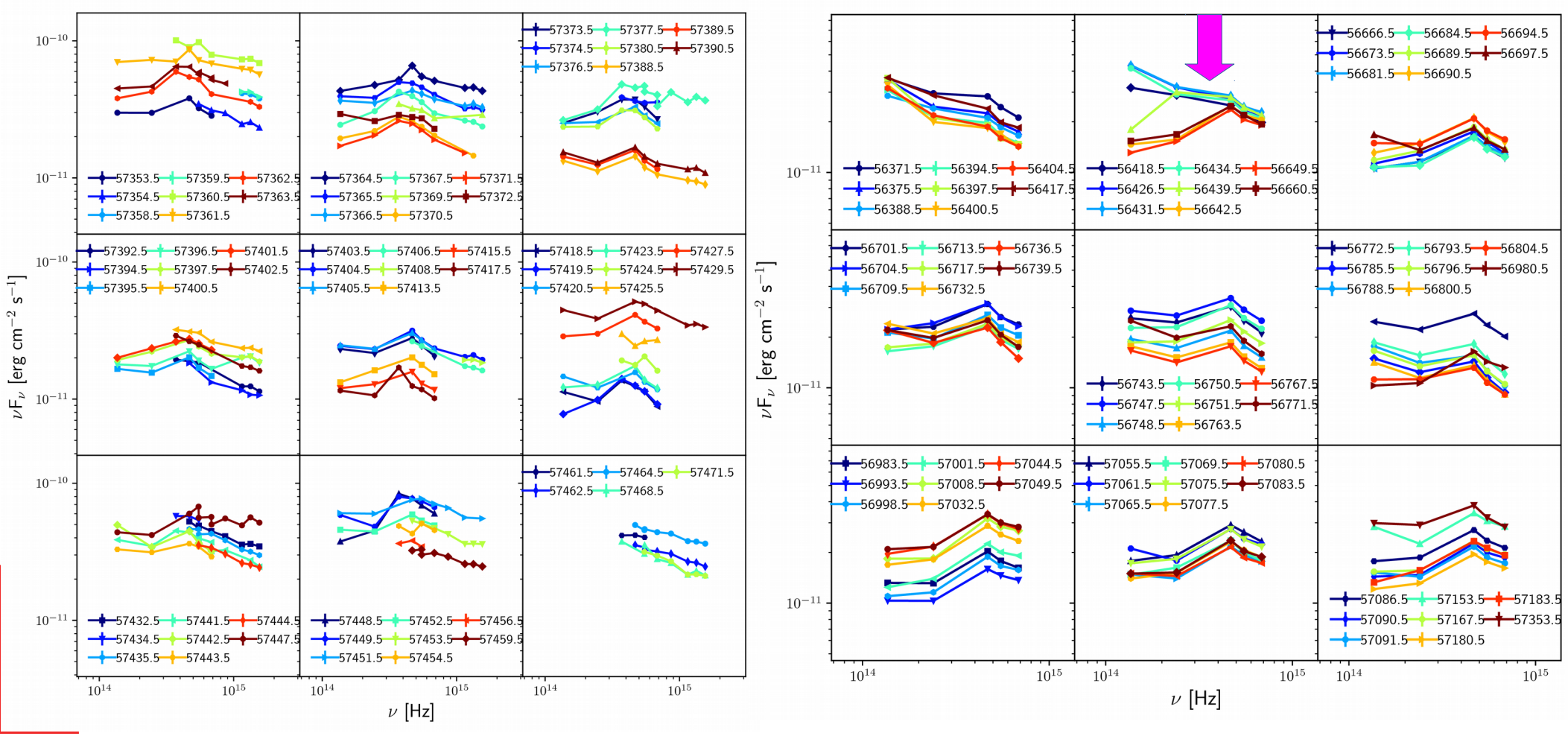
Sept 2016 – June 2017: NIR-Optical Spectral Evolution



- Thermal bump first appeared on MJD 56439 (May 2013), around the time of impact in the BH frame per the Binary SMBH model and is present since then

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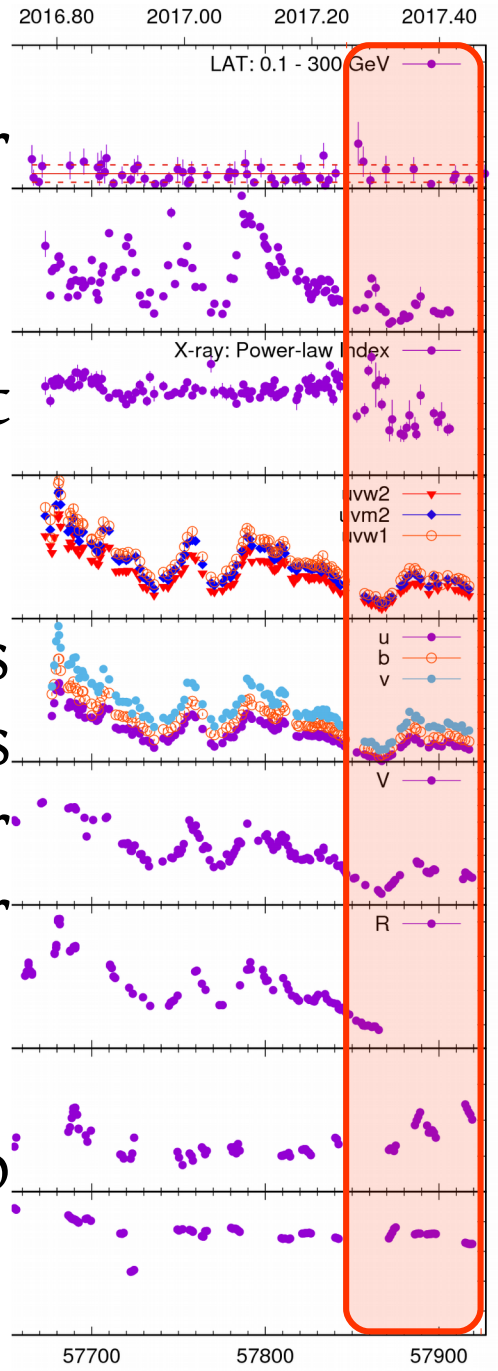
Sept 2016 – June 2017: Temporal Variations

- Intense NIR-optical variations, X-ray ~an order of magnitude higher than previous duration
- Daily Fermi-LAT -ray statistically consistent with no variability
- Simultaneous variation throughout in all bands except for one duration: 57850-57930, shows systematic trend with emission at higher energies appearing first followed by the lower energies ones
- The broad trend in NIR to X-ray is similar to the change in polarization angle



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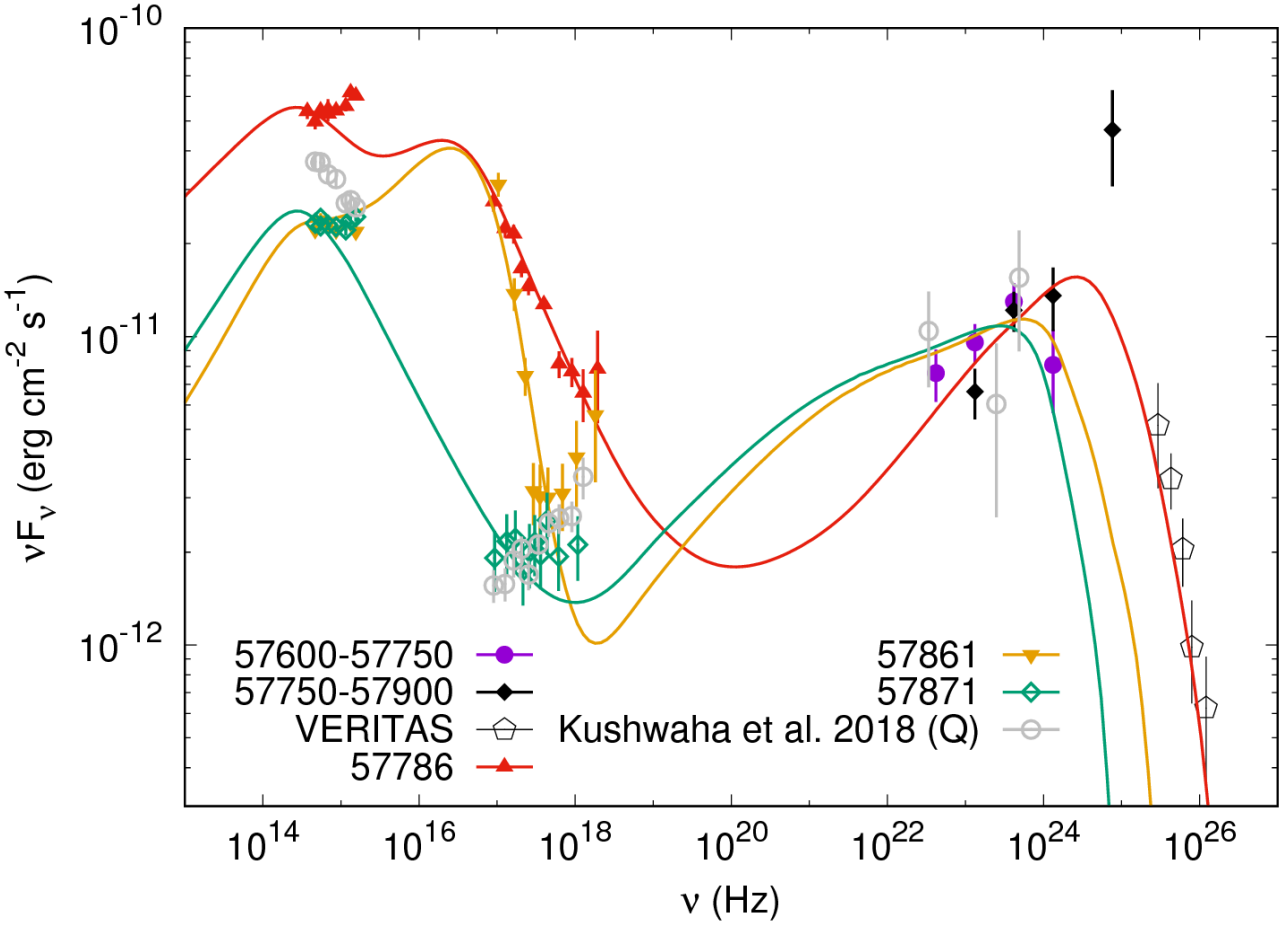
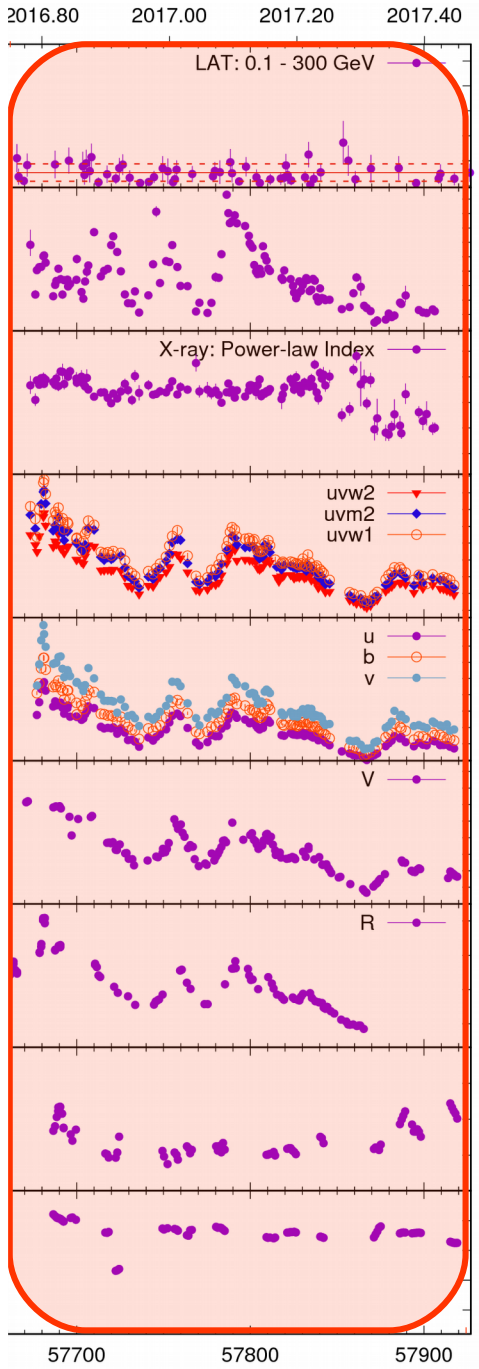
Sept 2016 – June 2017: Broadband SEDs





- Gamma-ray shift is present, VHE & Fermi-LAT spectra are consistent with each other
- New component in X-ray, HBL like, responsible for the intense variability

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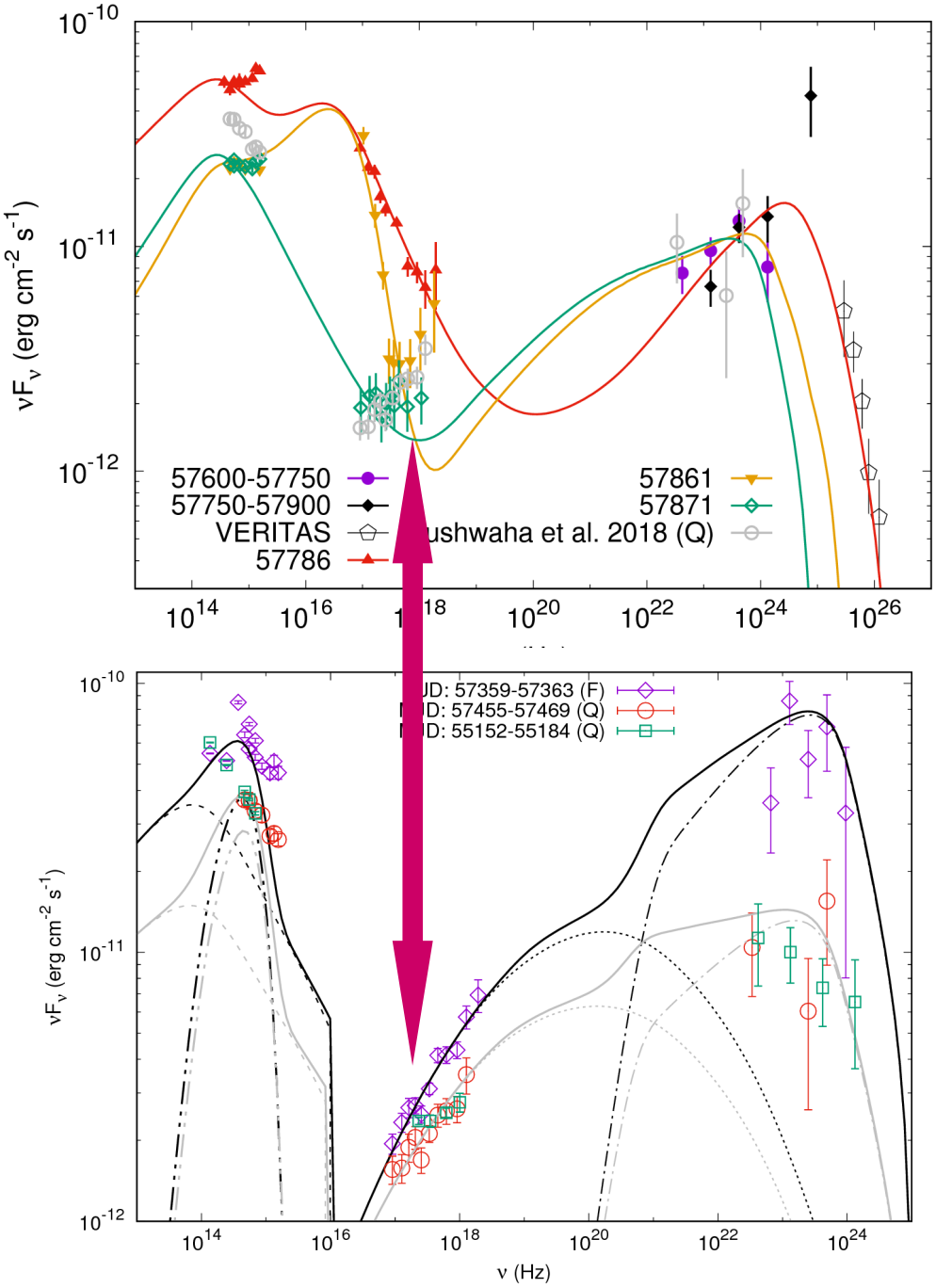
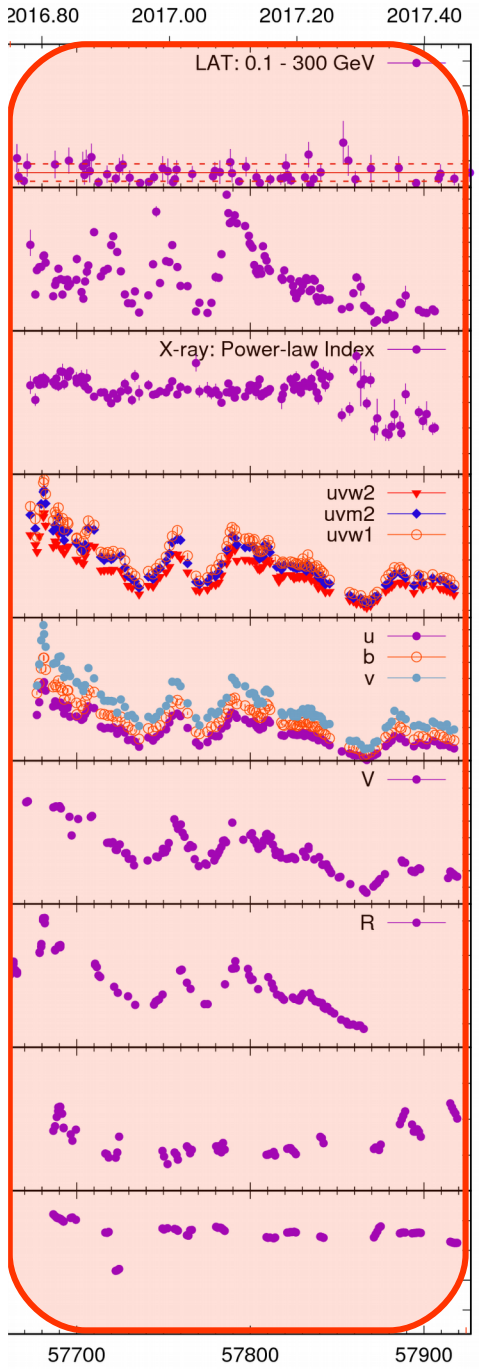
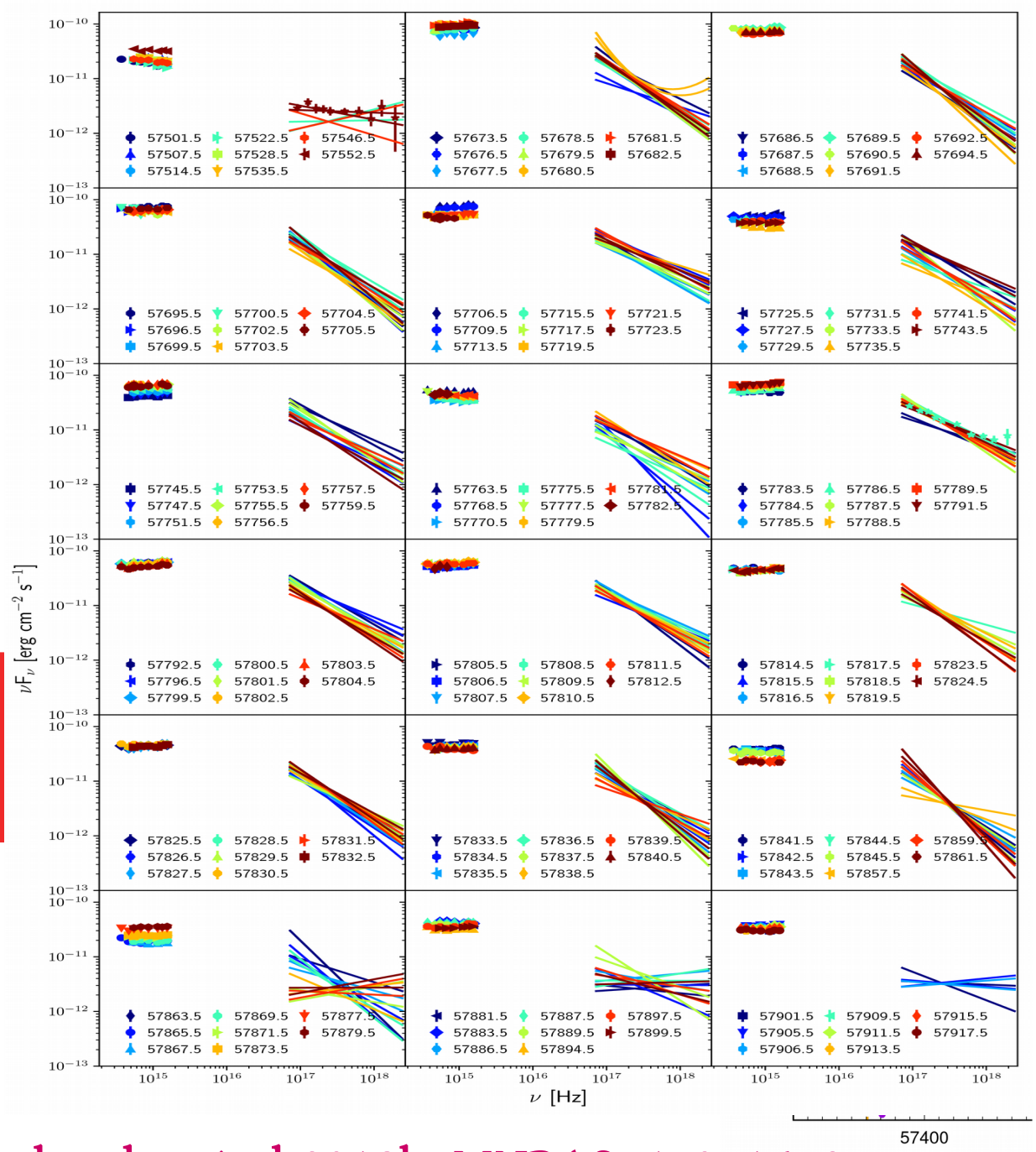
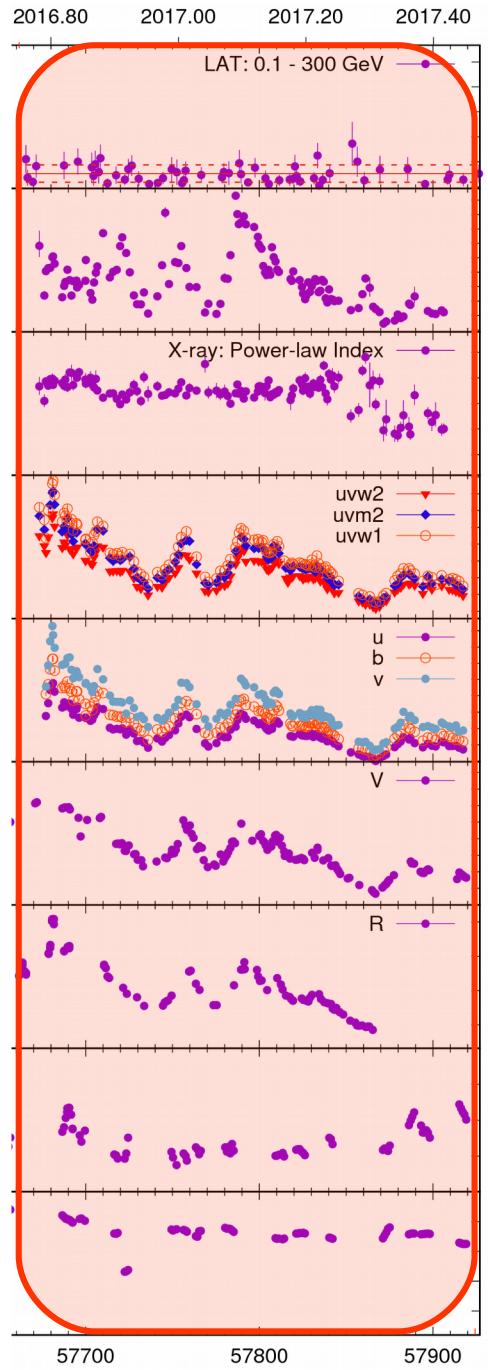
Sept 2016 – June 2017: Broadband SEDs Comparison





Sept 2016 – June 2017: Spectral Evolution





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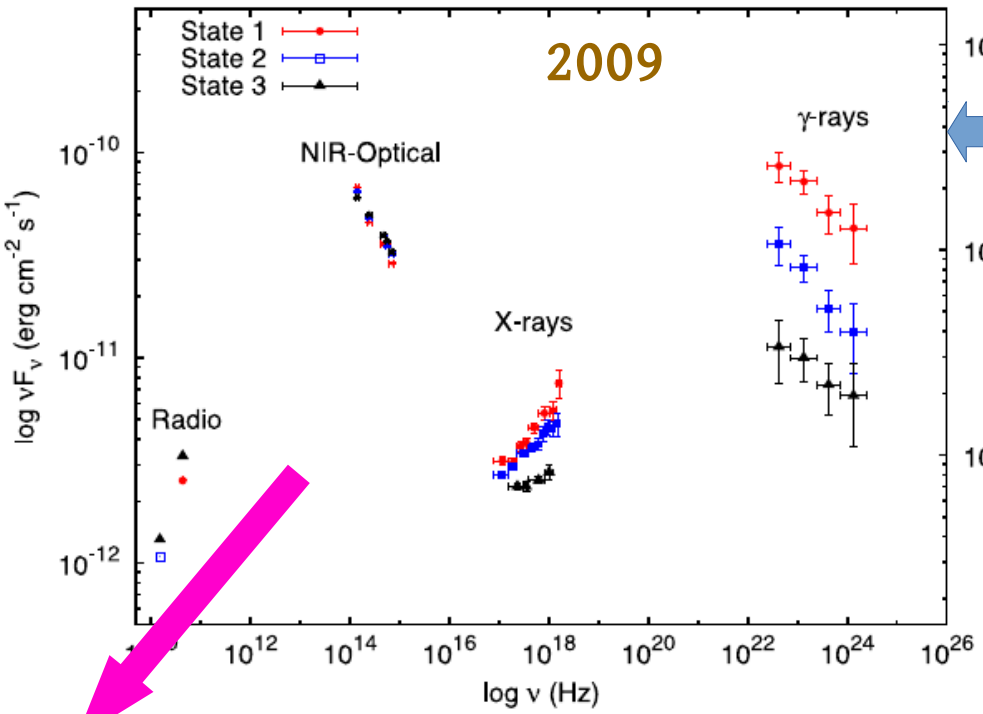
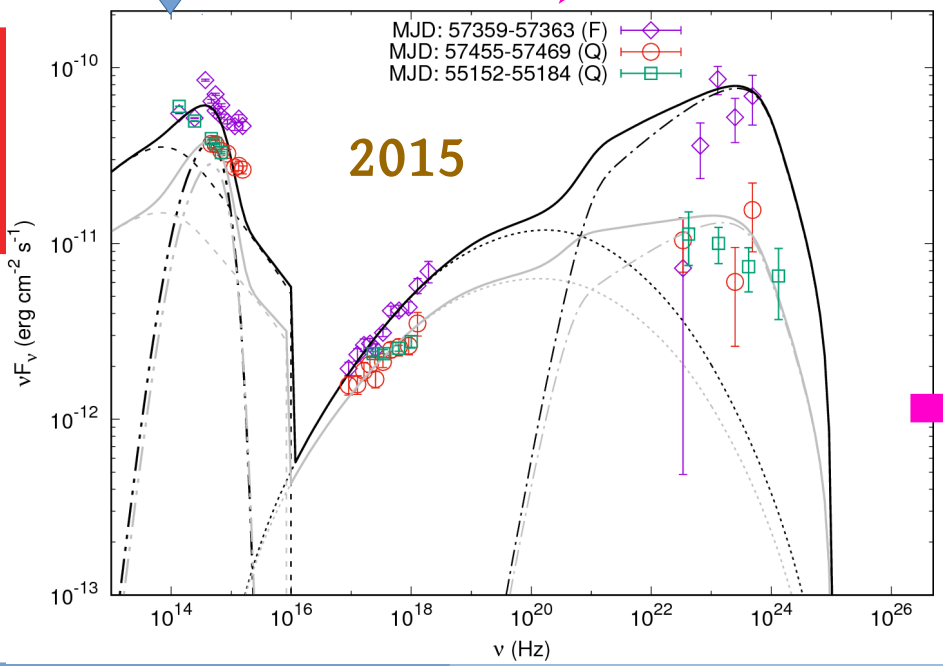
OJ 287: Implications on Location of Emission Region

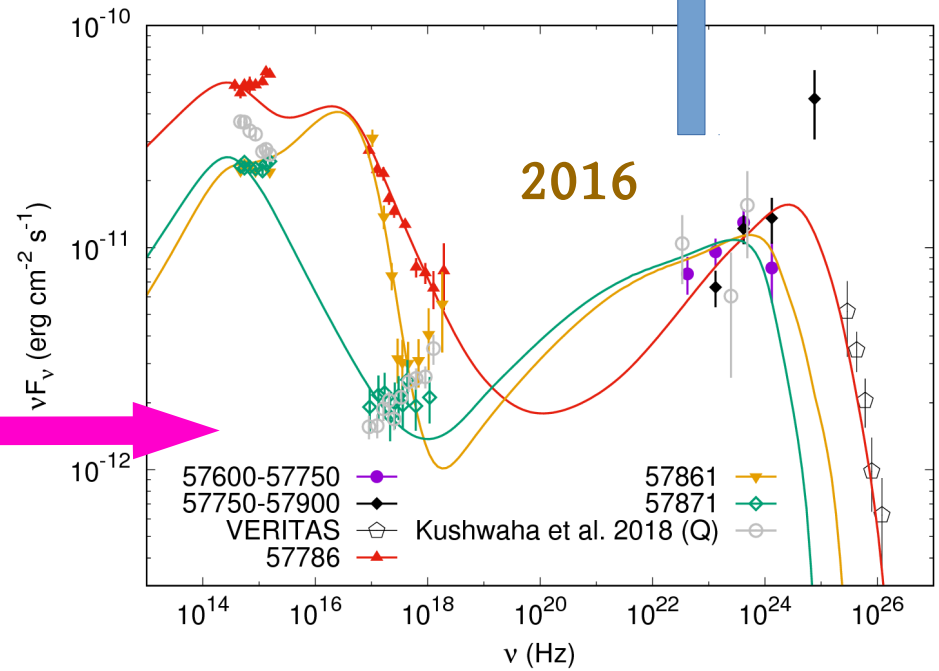
Emission region at parsec scales from mm γ-ray correlation

Emission region at sub-pc scales from shift in γ-ray peak (IC-BLR) but not in NIR-optical

VHE at pc scales to avoid γγ pair production with BLR photons







Summary

- Dec 2015 outburst study revealed a new activity phase of OJ 287 with many first time seen features spectrally and temporally
- Outburst has low polarization but accompanied by a huge swing in PA (~200°) similar to previously seen ones
- NIR-optical region show a thermal like feature and is consistent with standard accretion disk description
- Thermal bump appeared around the time of impact of SMBH as per the model
- Gamma-ray spectra show hardening and shift in the peak, can be naturally produced by IC of BLR photons, suggest location of emission region at sub-pc scales
- VHE activity and intense NIR to X-ray variability triggered by appearance of new HBL like component
- VHE spectrum consistent with Fermi-LAT, and $\gamma\gamma$ pair production on BLR suggests the VHE location at parsec scales

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Thanks