Multi-Wavelength Monitoring of Two Gamma-ray Binaries: **1FGLJ1018.6-5856** And **LMC P3**

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NRF National Research Foundation

Gamma-ray Binaries

- High mass binaries of a **O-/B- type star** and a compact stellar remnant (**neutron star or black hole**)
- They emit across the EM spectrum, with most of their emission observed in the Gamma-rays band
  - ❖All gamma-ray binaries have characteristic SED that peaks above 1MeV

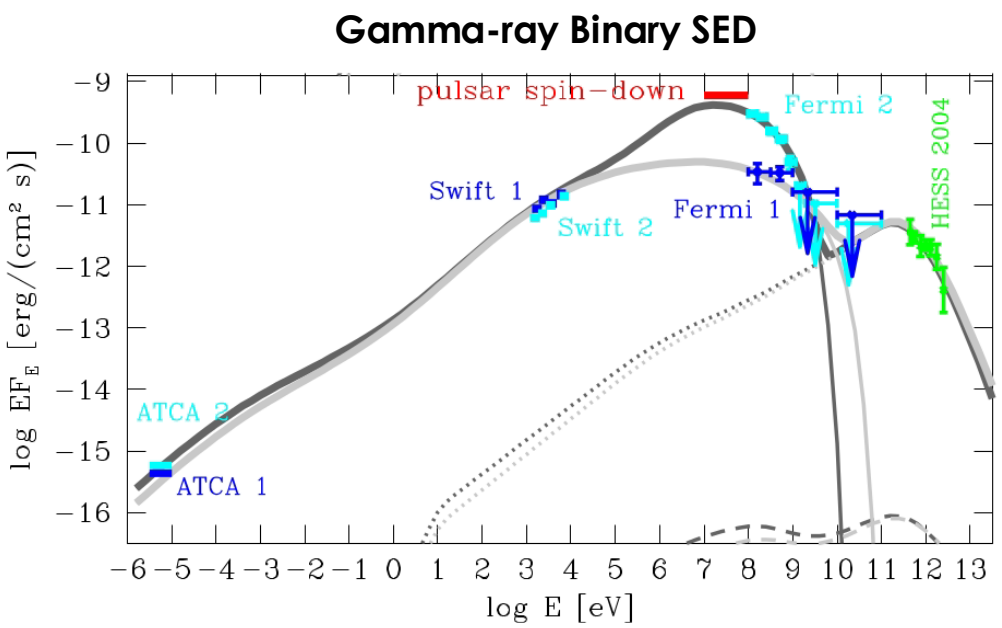


Fig 1:An SED of the Gamma-ray binary PSR B1259-63 (Dubus, 2013).

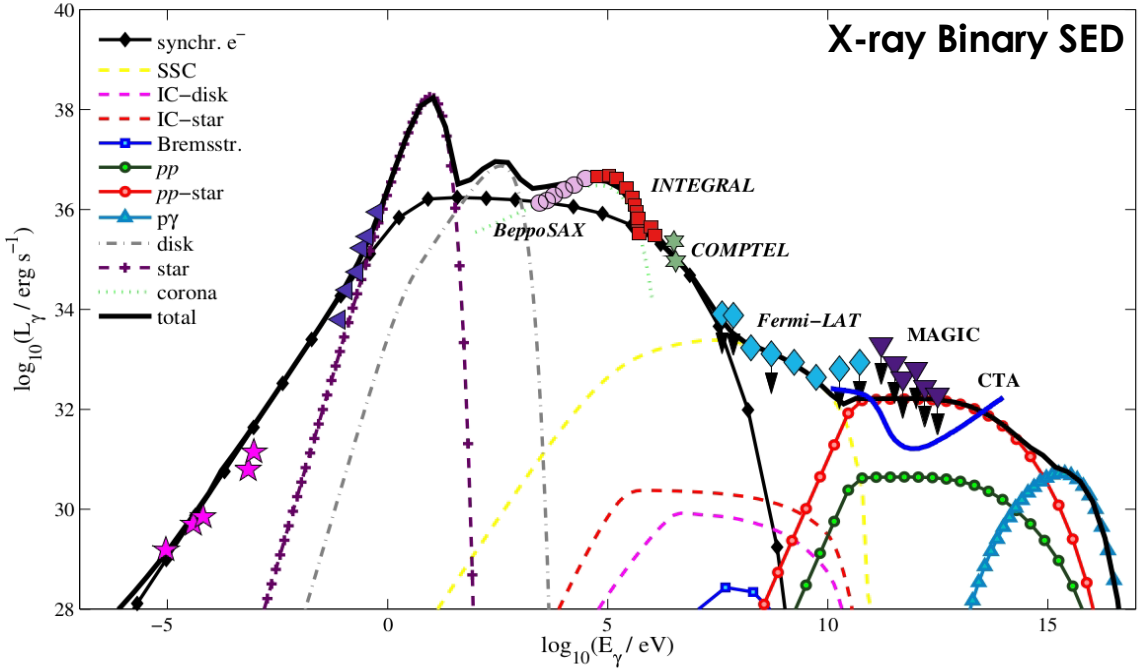


Fig 2: An SED of the X-ray Binary Cyg X-1(Pepe et al, 2015)

Gamma-ray Binaries

- These sources are very rare:

  Only **Ten** confirmed Gamma-ray binaries to date

  Compared to the **100s** of observed X-ray binaries

- Of the **Ten**, the nature of the compact companion is known in two of the sources:

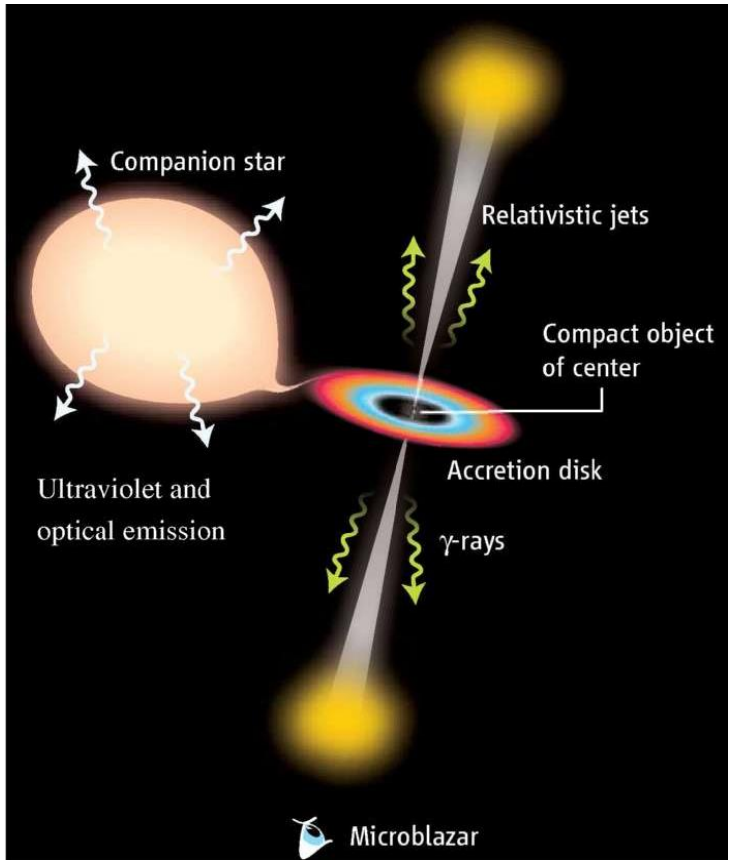
  PSRB1259-63 and **PSR J2032+4127**

- In both cases, the compact object is a neutron star:

  Confirmed from observed radio pulsations

multi-wavelength emission

Microquasar



Binary Pulsar

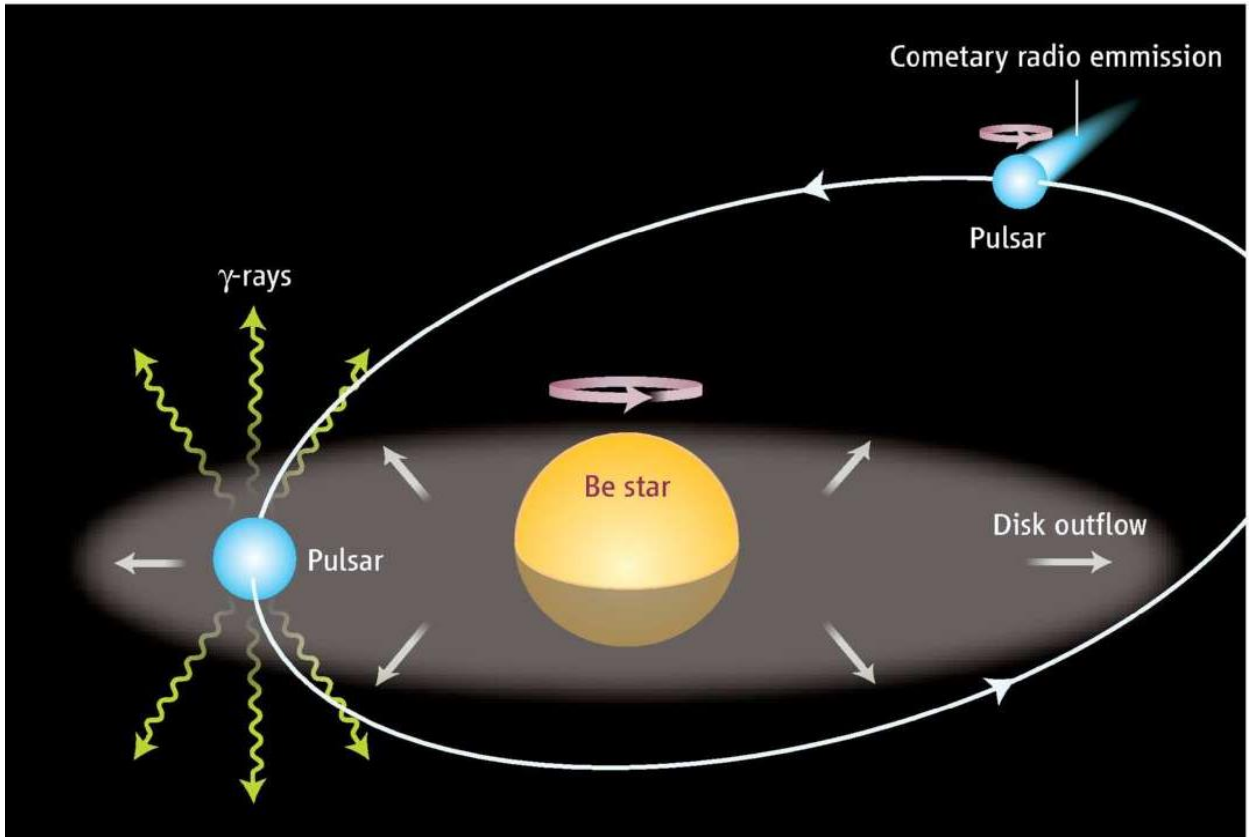


Fig 3: The Microquasar (left) and binary pulsar (right) models for gamma-ray binaries (Mirabel, 2012)

- PSRB1259-63 and PSR J2032+4127 are well explained by the binary pulsar model

Study Targets

	1FGLJ1018.6-5856 (Fermi LAT Collaboration et al. 2011)		LMC P3 (Corbet et al. 2016)	
Stellar companion	**O6V(f)**		**O5III(f)**	
Compact object	Probably a neutron star : radial velocity (van Soelen et al, 2019; 2022; Monageng et al, 2017)			
Orbital Parameters	P = 16.5507 ± 0.0004 days	e = 0.531 ± 0.033	P = 10.301 ± 0.002 days	e = 0.40 ±0.07
	van Soelen .et al(2022)		Corbet .et al (2016)	

Tab 1: The orbital parameters of 1FGLJ1018.6-5856 and LMC P3

Objectives

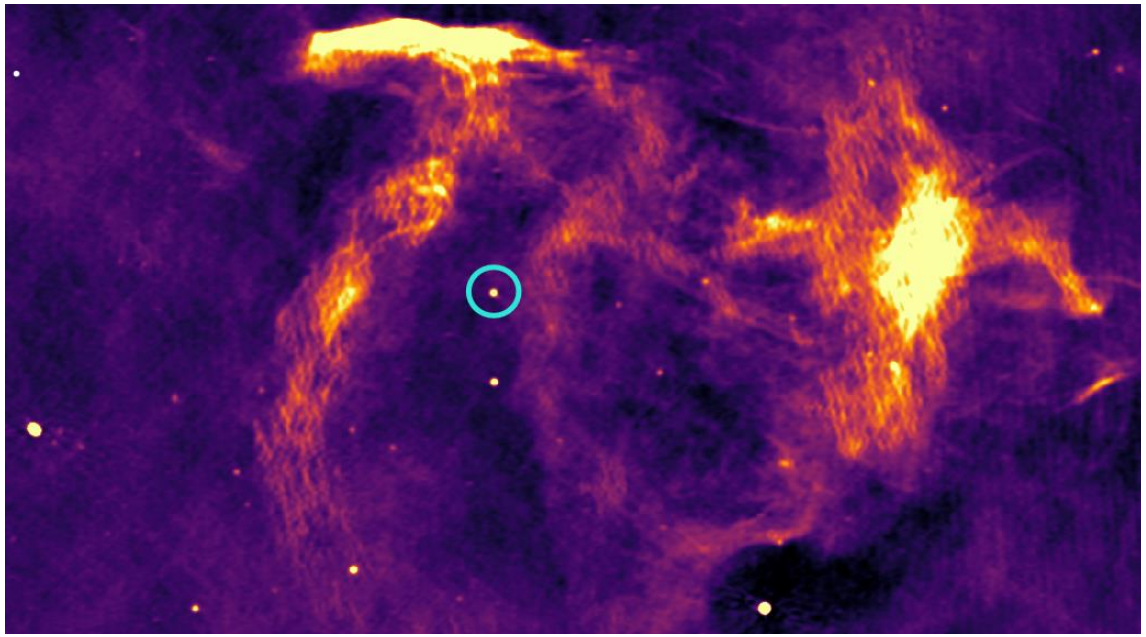
- The main project aim is to study the particle population producing non-thermal emission in the **1FGLJ1018.6-5856** and **LMC P3**, this is done by:

1. Reducing and analyzing the *MeerKAT* phase-resolved observations taken in 2019.

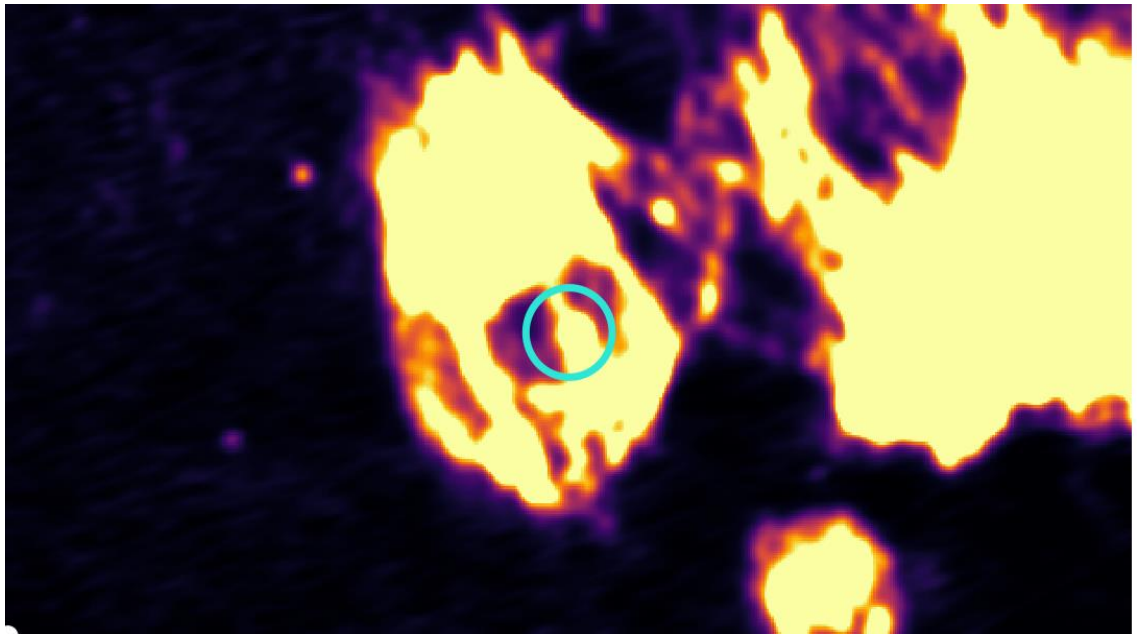
2. Performing a multi-wavelength cross-correlation analysis for these systems.
   - ❖ For the cross-correlation study, we use radio data from ***MeerKAT*** with archival X-ray and gamma-ray data from ***Swift-XRT*** and ***Fermi-LAT***.

MeerKAT Observations

1FGLJ1018.6-5856



LMC P3



- *MeerKAT* observations were conducted between **21 Aug** and **18 Sep 2019** in the L-band
- Observations taken every **~2 days** (**1FGLJ1018.6-5856: 14**- and **LMCP3: 12**- observations)
- Data reduction with the ***OxKAT*** pipeline (github.com/IanHeywood/oxkat)

1FGLJ1018.6-5856 Results

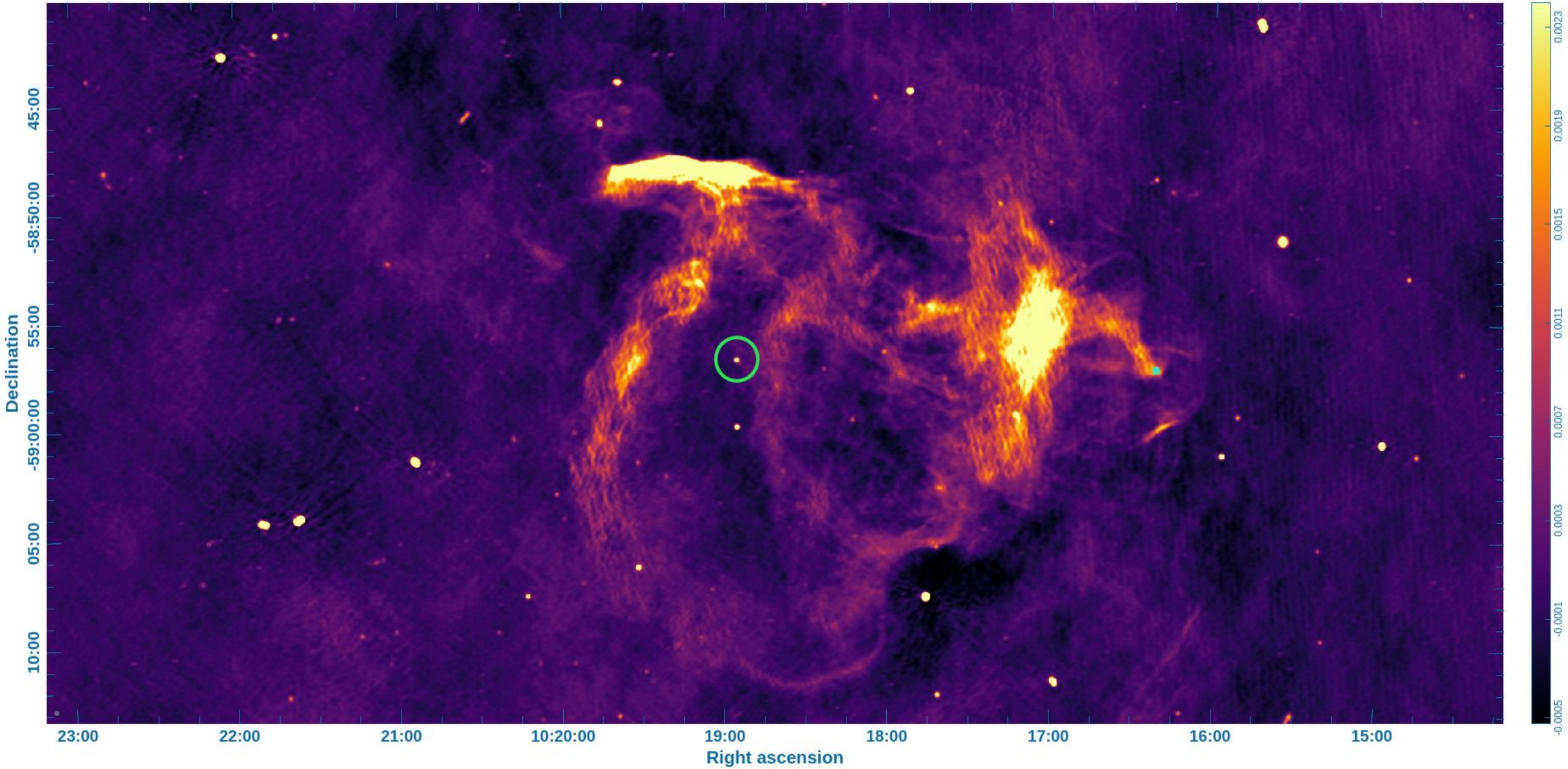


Fig 4: 1FGL J1018.6-5856 , PSR J1016−5857 , SNR G284.3−1.8

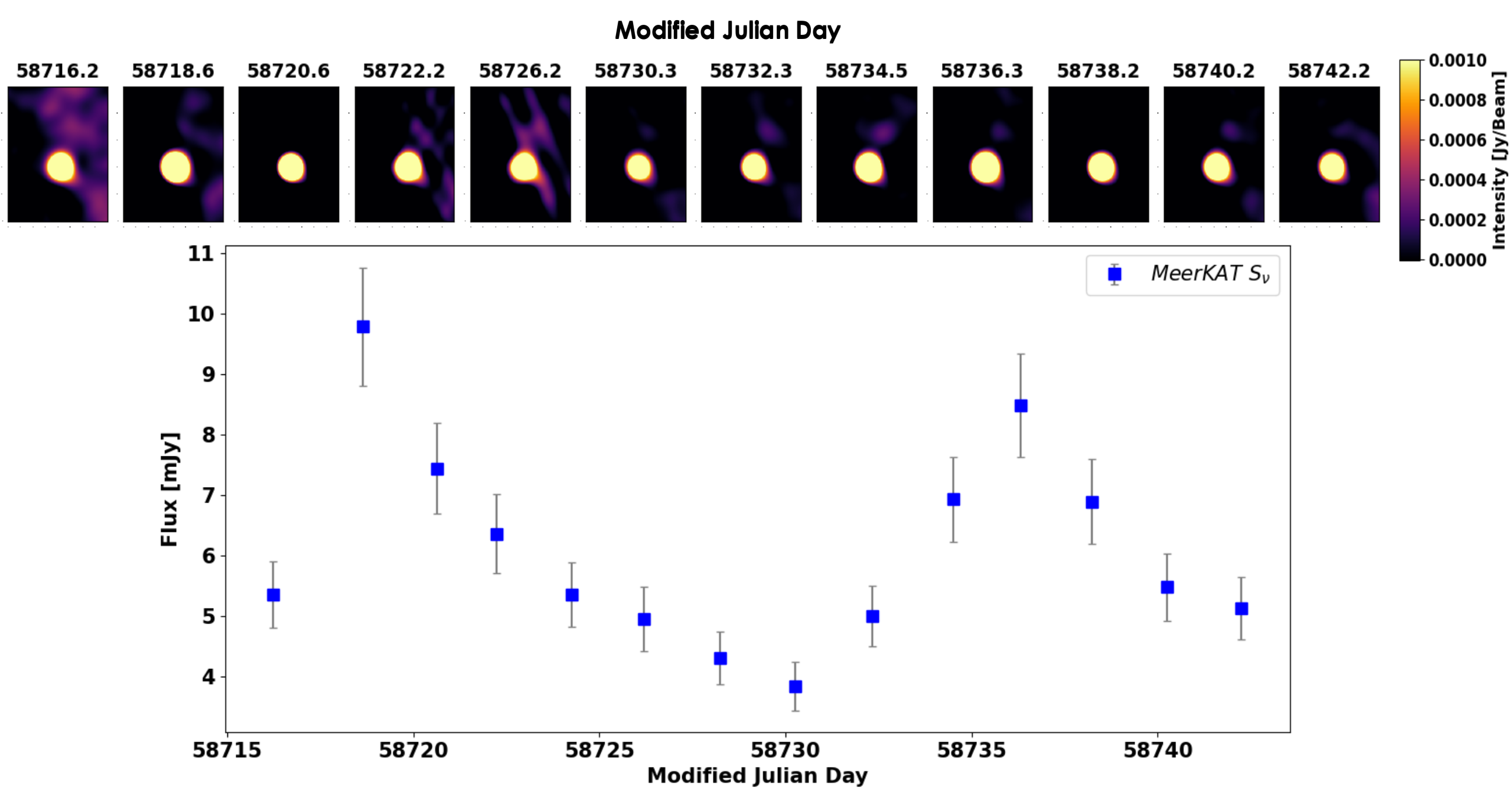


Fig 5: 1FGLJ1018.6-5856 **image cutouts** (above) and **light curve** (below)

In-band spectral Index

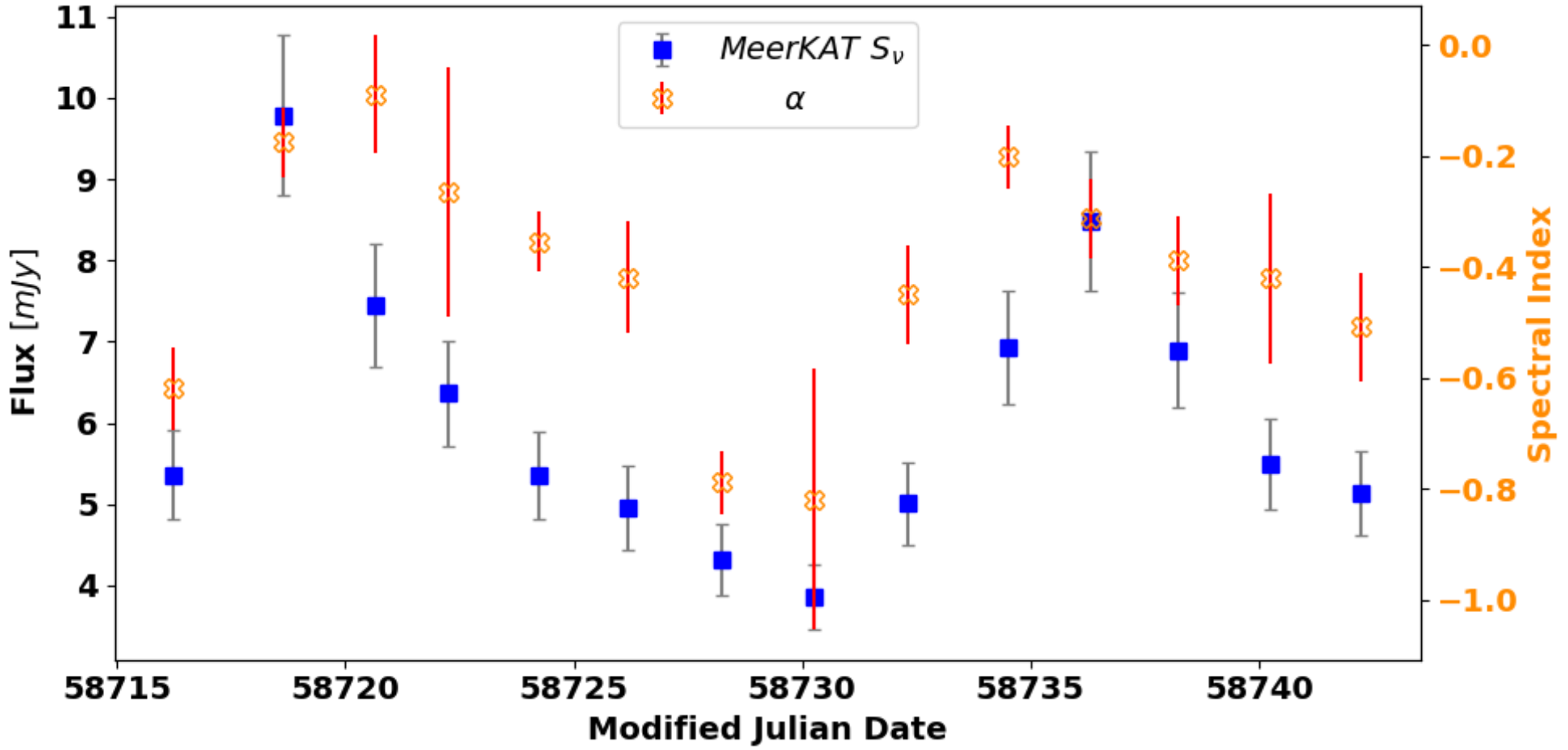


Fig 6: 1FGLJ1018.6-5856 **light curve** and **spectral indices**

- The spectral index varies from **~-0.8** to **~-0.1**
- Suggests a **non-thermal synchrotron** origin

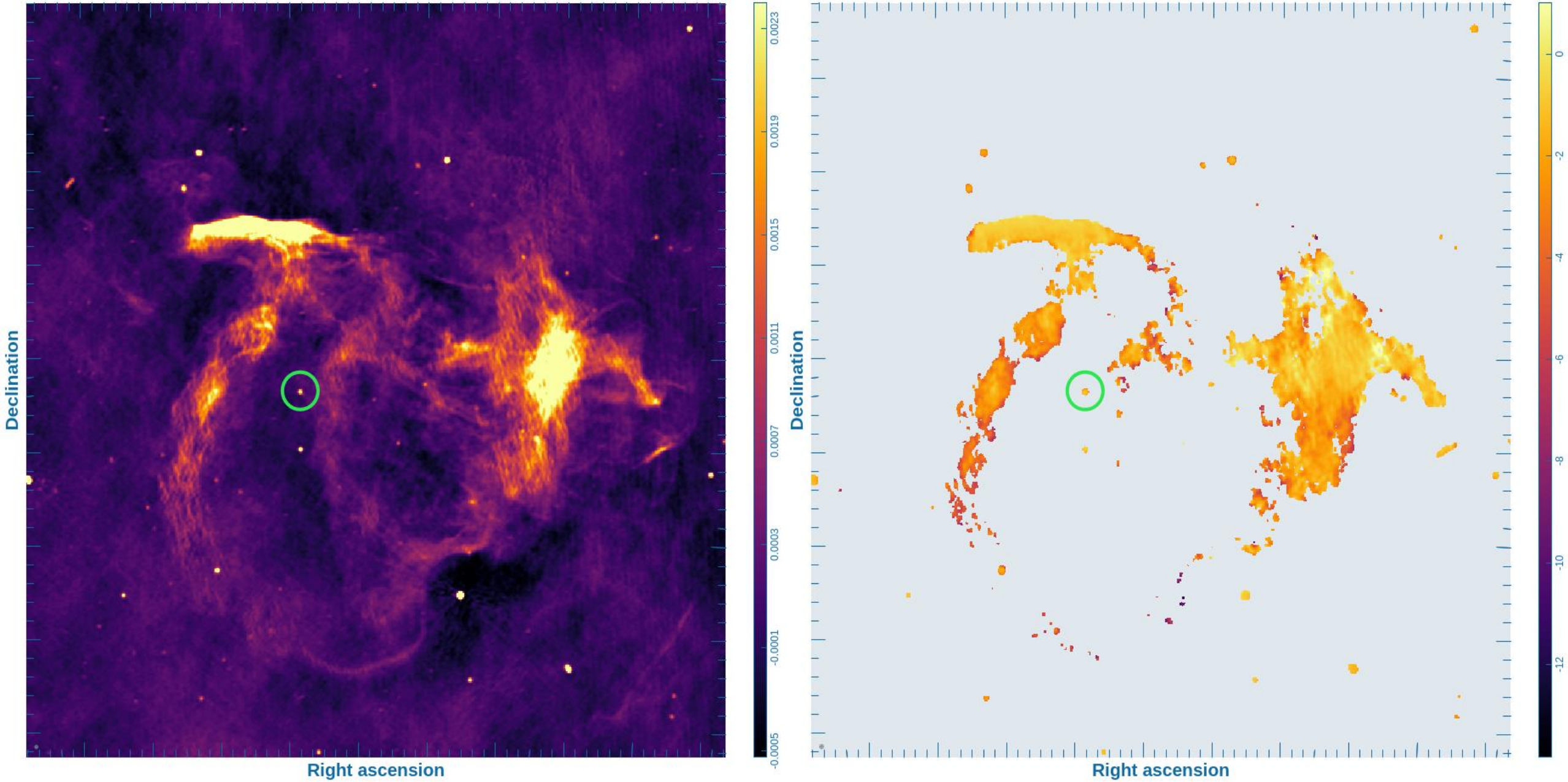
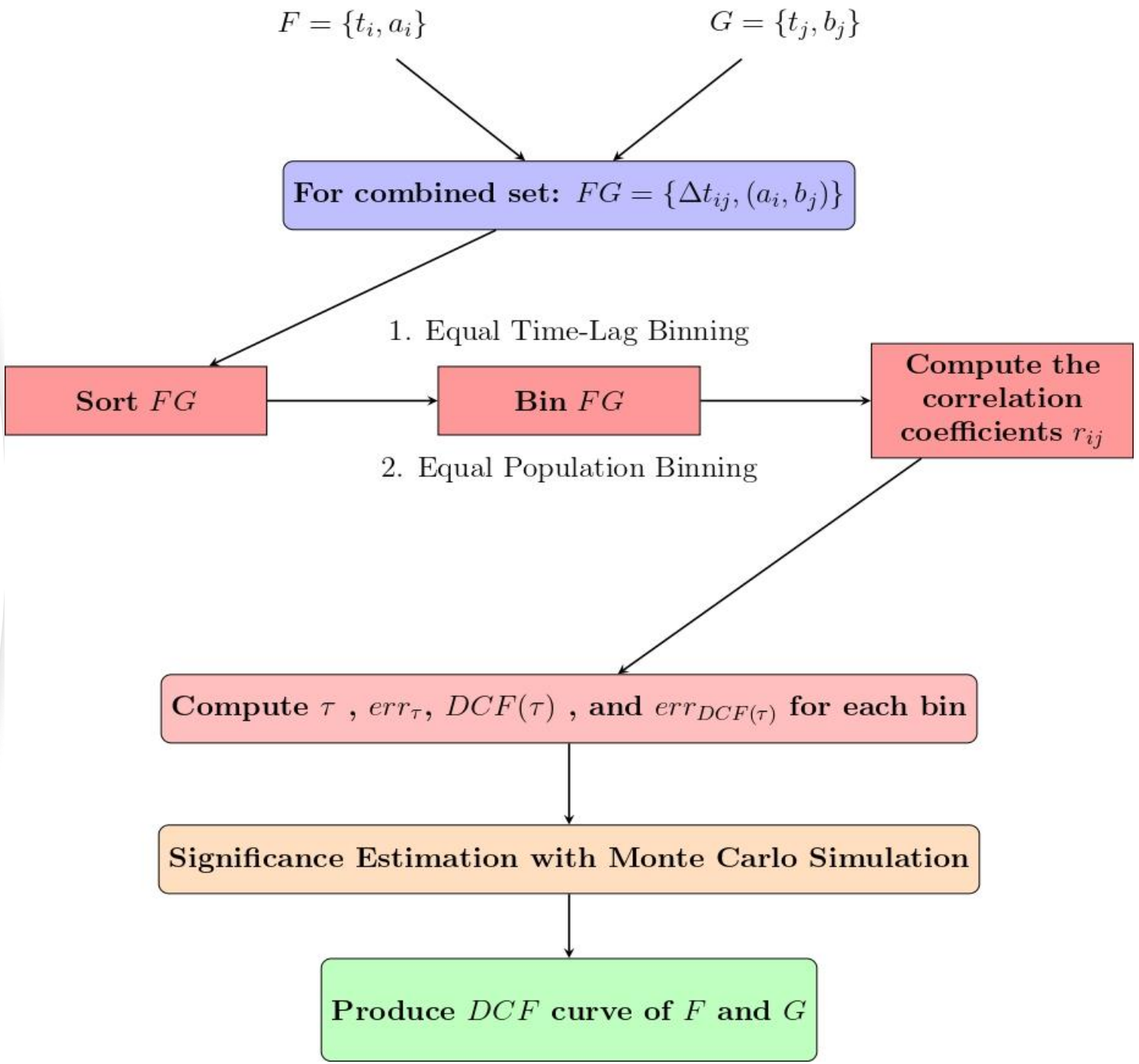
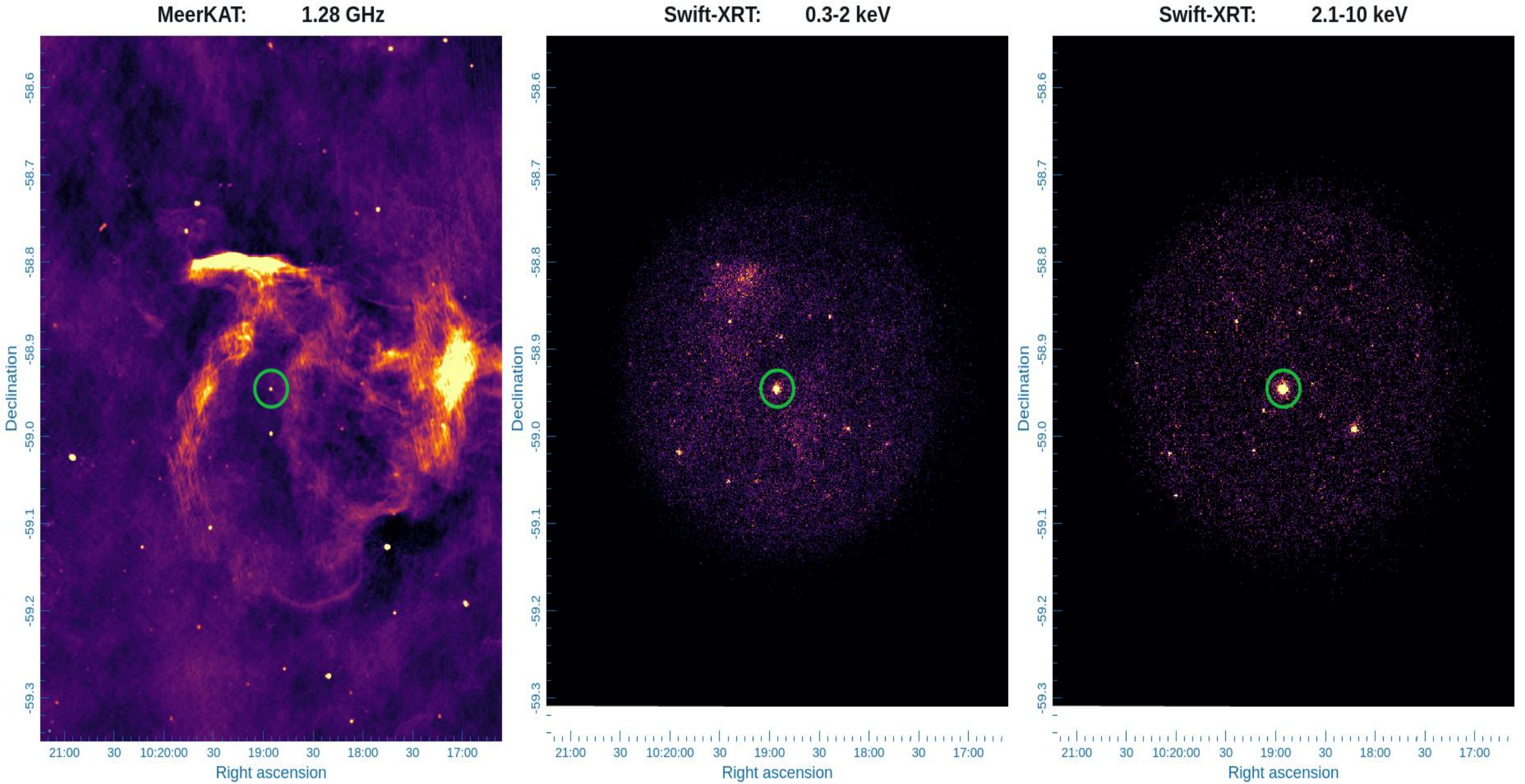


Fig 7: Image and Spectral index map of the 21 August 2019

Cross-Correlation Analysis



Swift-XRT observations of 1FGLJ1018.6-5856



Swift-XRT 2019 Observations

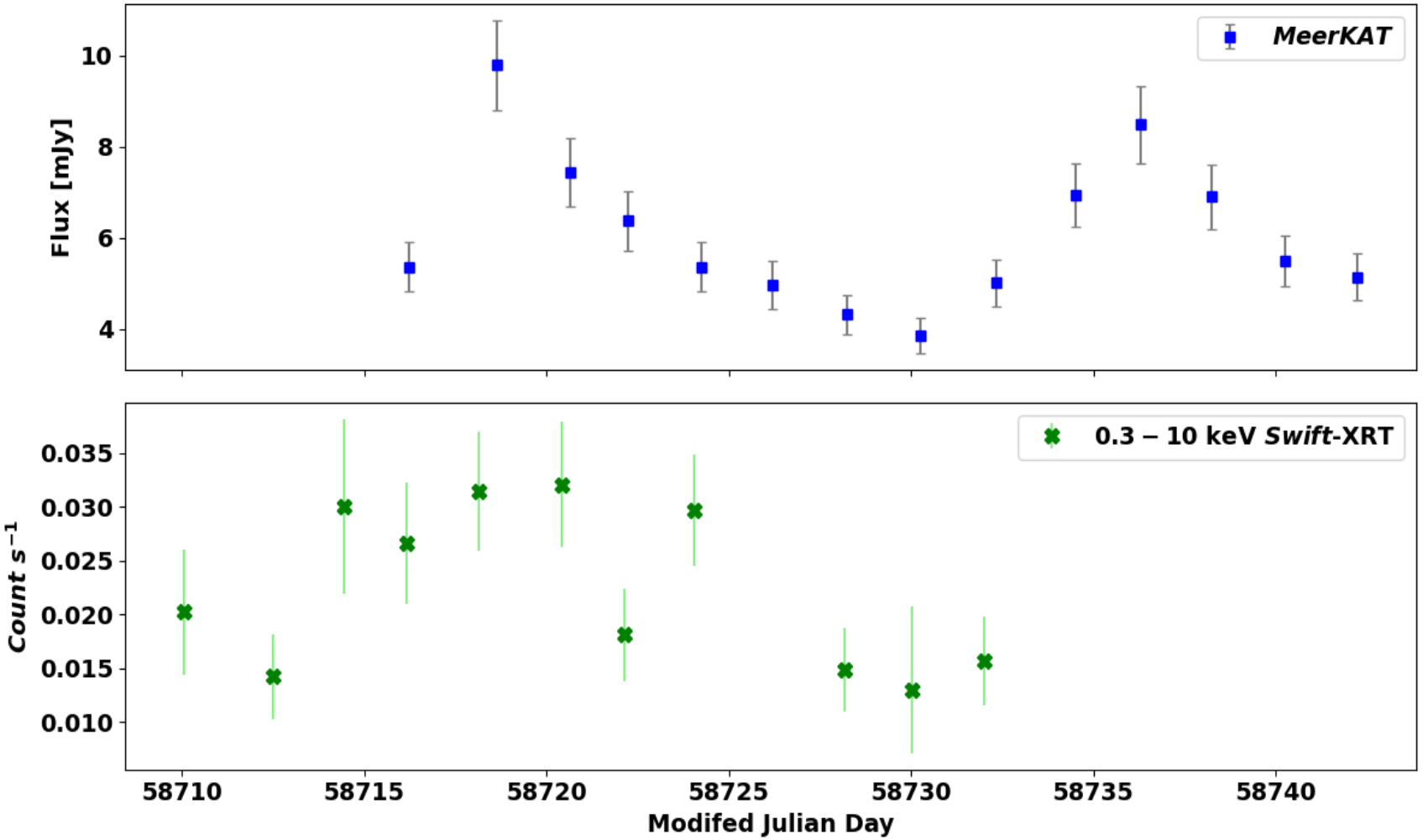


Fig 8: 1FGLJ1018.6-5856 ***MeerKAT*** and ***Swift-XRT*** *light curves from 2019 observations*

- Swift-XRT Observed from **15 Aug** to **06 Sep 2019** (~17 days of simultaneous Radio and X-ray data)
- Archival XRT data from **2011** to **2019** was obtained from **UKSSDC** (UK Swift Science Data Centre)

2019 MeerKAT v.s *Swift-XRT* Cross-correlation

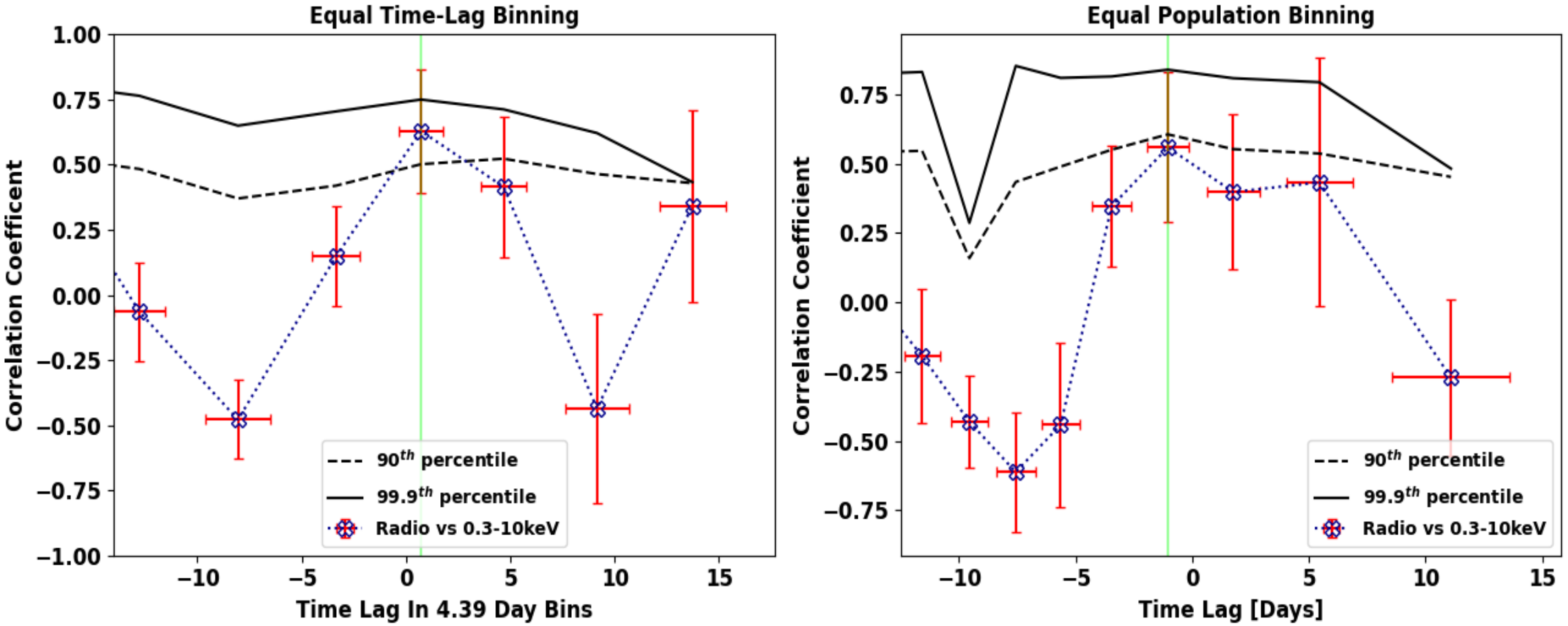


Fig 9: 2019 Radio and X-ray cross-correlation. The lime vertical line shows the time-lag between the light curves of the highest correlation

- A significant radio and X-ray correlation at around 0-day Time delay

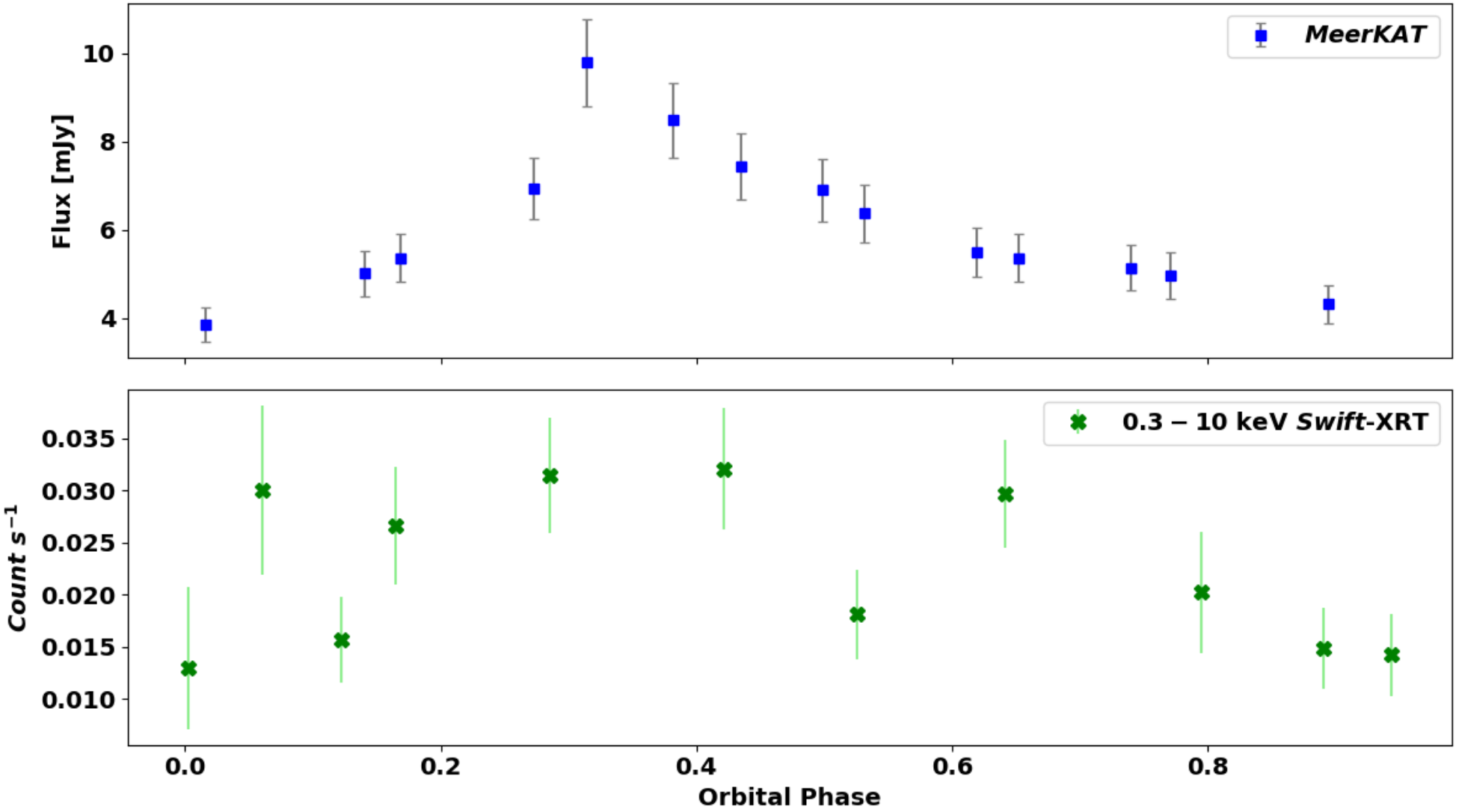


Fig 10: 1FGLJ1018.6-5856 ***MeerKAT*** and ***Swift-XRT*** folded light *curves from the 2019 observational compaign*. The light curves are folded on a period of ***16.5507 days*** and T_0 **= *55403.3 MJD*** (van Soelen .et al, 2022).

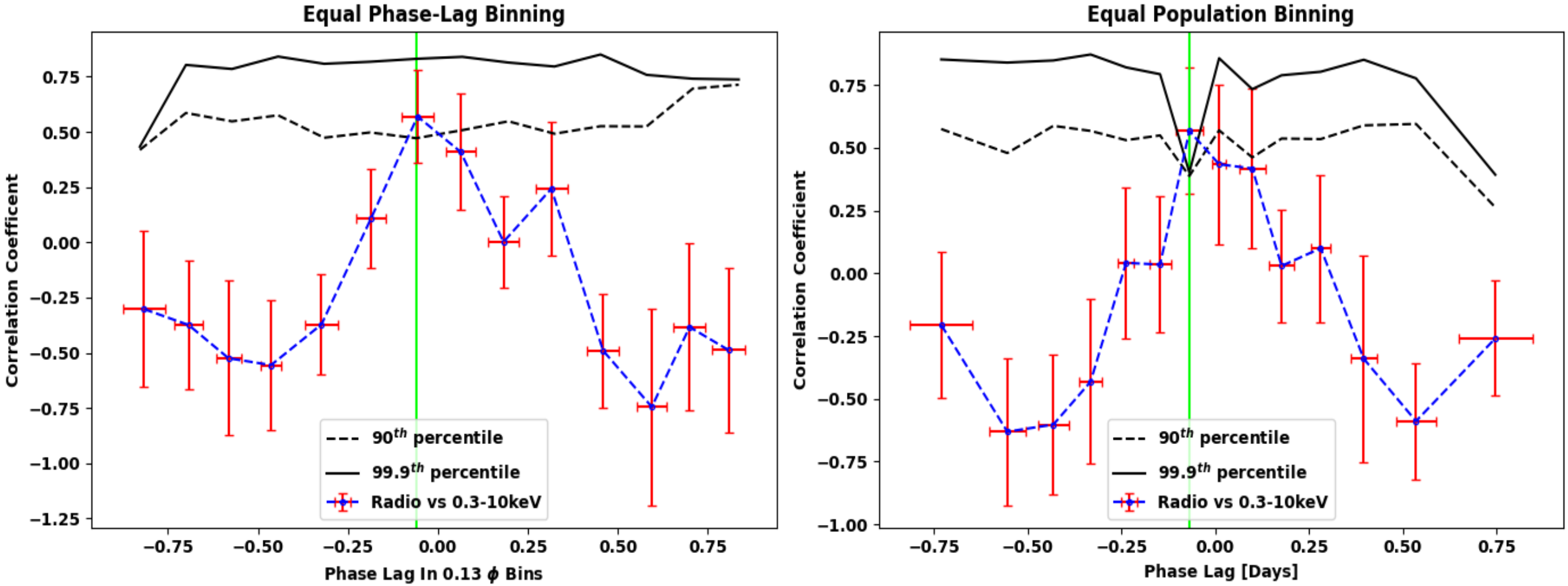


Fig 11: Folded 2019 Radio and X-ray cross-correlation. The lime vertical line shows the phase-delay between the light curves of the highest correlation

- A significant correlation with X-ray emission **leading**
- Phase-lag **~ -0.064**, translates to a Time-delay of **–0.064 x 16.5507 ~ -1.07 days** between the X-ray and Radio emissions

Summary

- The varying spectral indices of 1FGLJ1018.6-5856 indicate the radio emission is of non-thermal synchrotron dominance
- The X-ray and Radio cross-correlation results shows a significant correlation with X-ray radiation leading the radio radiation.
  - ❖ This correlation with X-ray leading is also seen in long-term data, which supports Synchrotron dominance

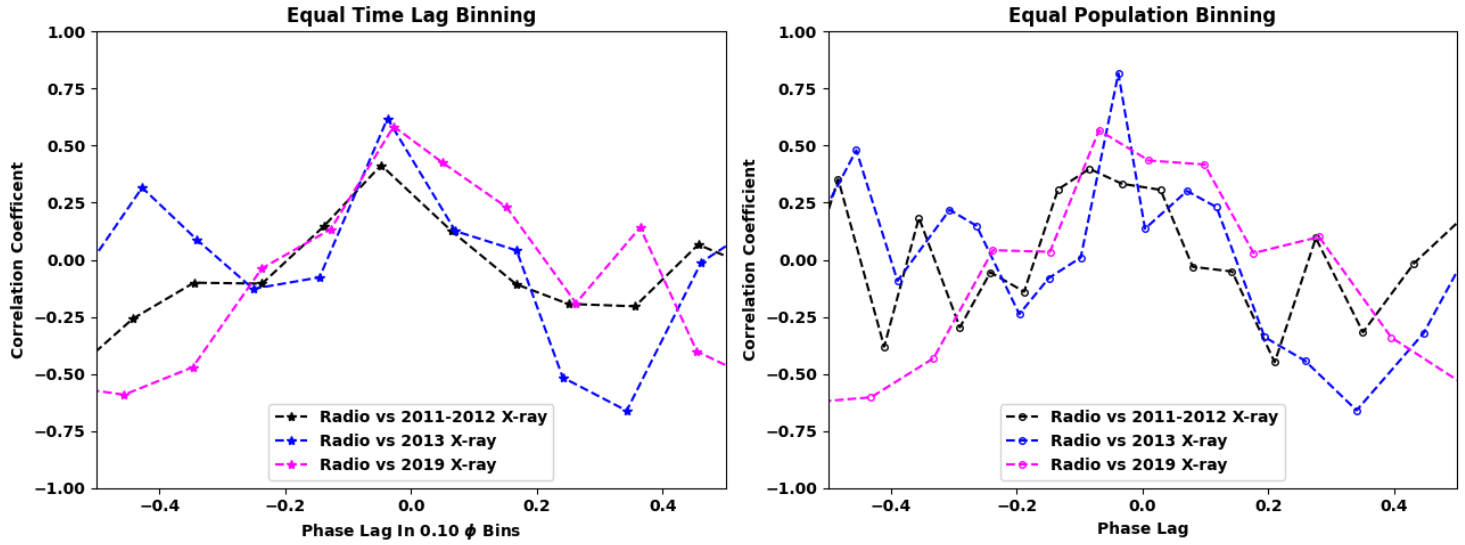


Fig 12: Folded Radio and (**2011-2012** , **2013** and **2019**)X-ray cross-correlation

- Future: complete Radio, X-ray, and Gamma-ray analysis

Thank You

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Extra Slides

Long-term MeerKAT v.s *Swift-XRT* Cross-correlation

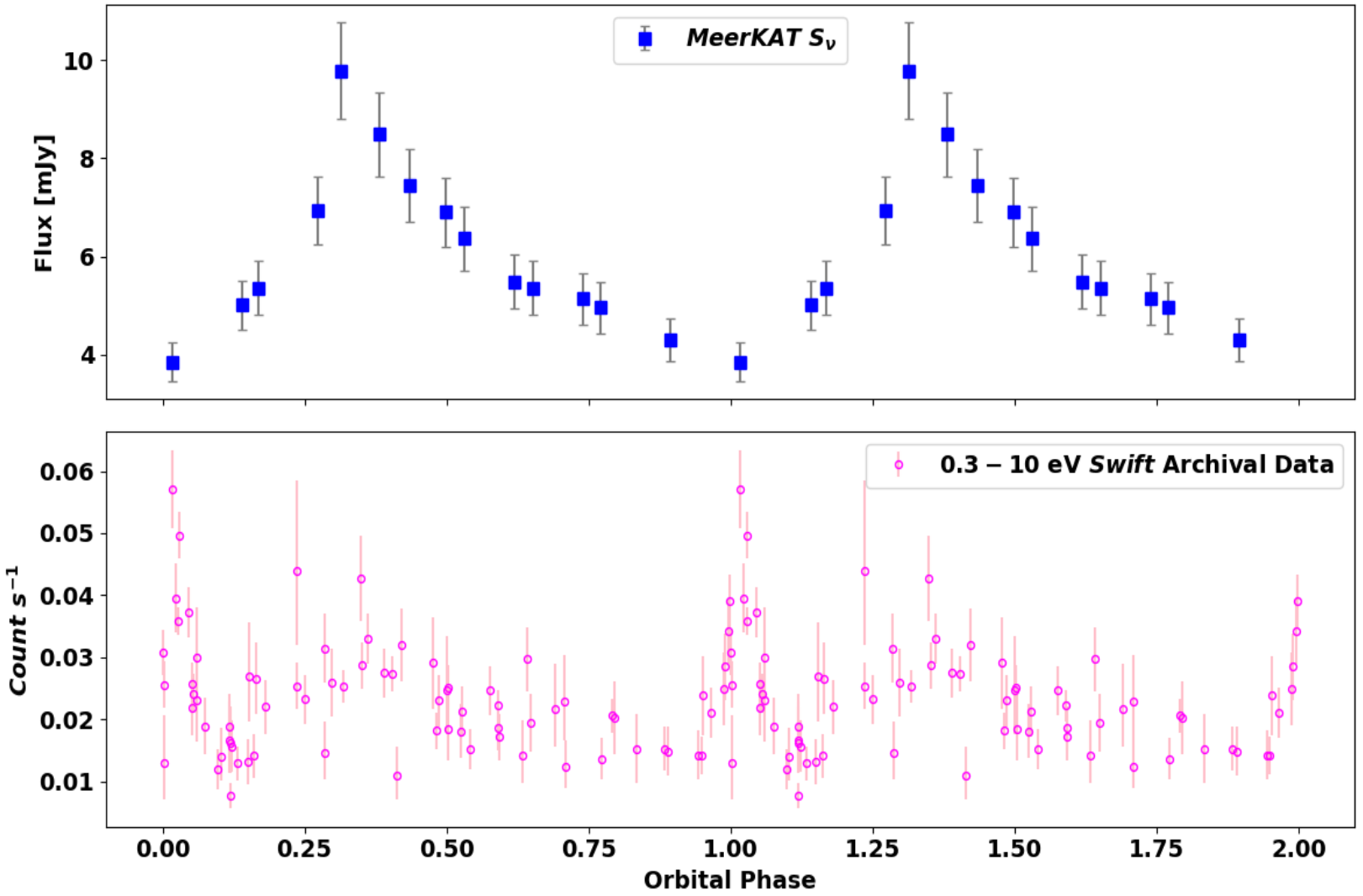

Fig 11: **Radio** light curve from the 2019 MeerKAT observations of 1FGLJ1018.6-5856 and long-term **X-ray** Swift-XRT count rates (between 2011 and 2019). The light curves are folded on a period of ***16.5507 days*** and T_0 ***= 55403.3 MJD*** (van Soelen .et al, 2022).

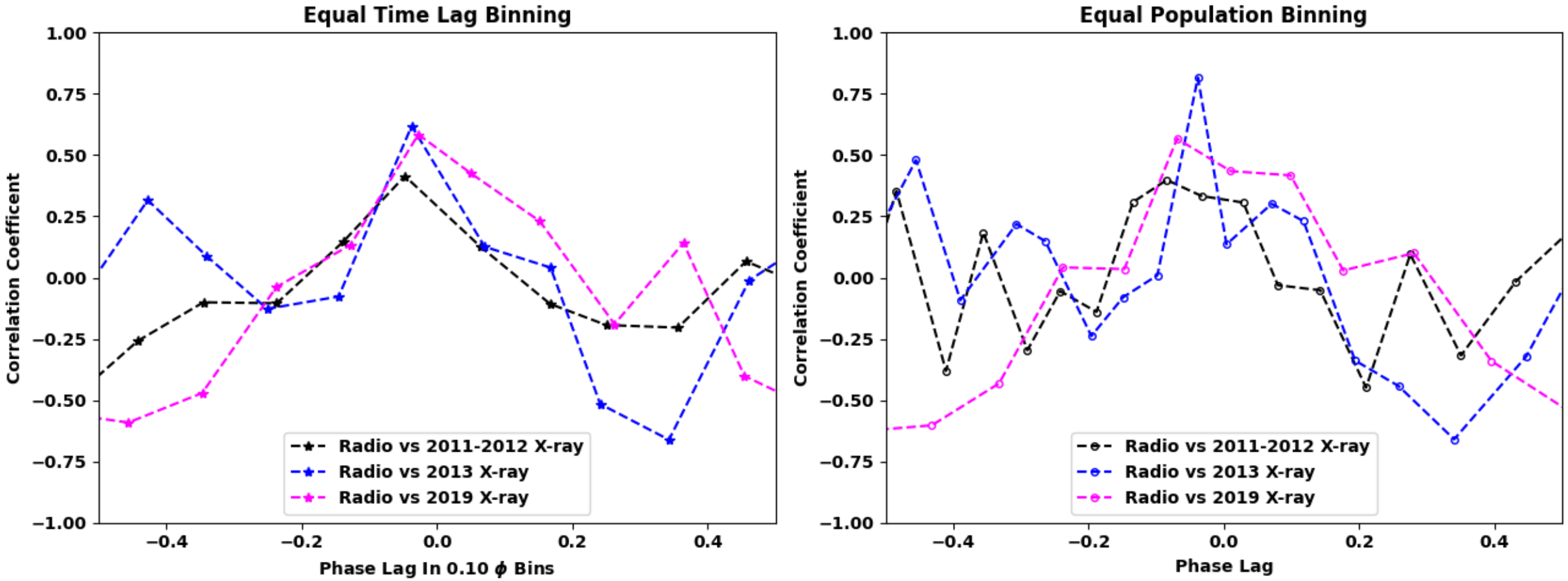

Fig 12: Folded Radio and (**2011-2012** , **2013** and 2019)X-ray cross-correlation

- A significant radio and X-ray correlation with X-ray **leading** Radio radiation