A tricky statistical search for Fast Optical Bursts

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INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

OAR

Carlo Campa

Filippo Ambrosino
Piergiorgio Casella
Riccardo La Placa
Roberta Amato
and many others

Search for sub-second transients

Common in gamma-ray, X-ray, radio bands

Image credit: modified from NASA's Goddard Space Flight Center/S. Wiessinger

Search for sub-second transients

Common in gamma-ray, X-ray, radio bands

Optical astronomy focused on longer timescales

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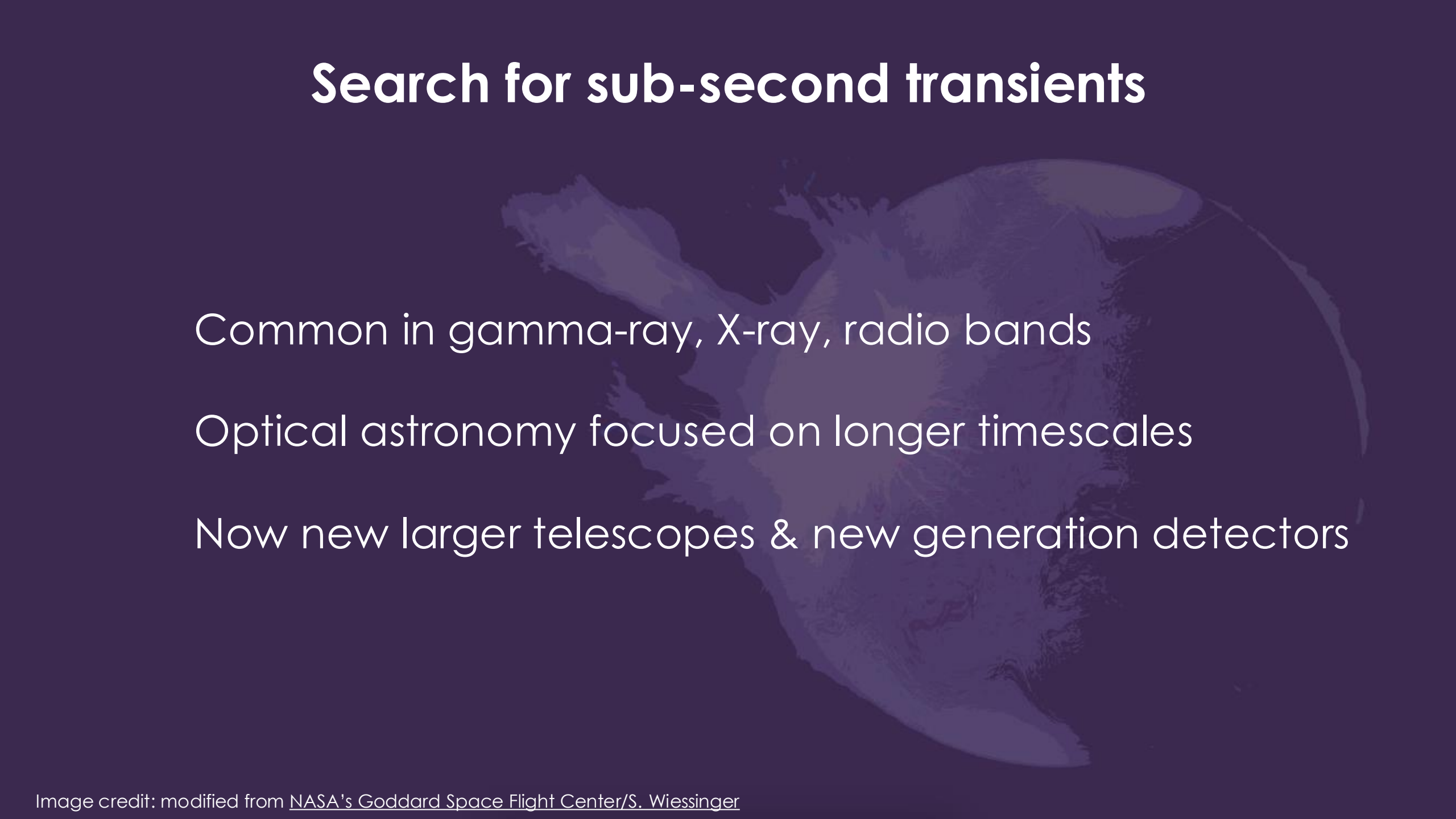
Search for sub-second transients



Common in gamma-ray, X-ray, radio bands

Optical astronomy focused on longer timescales

Now new larger telescopes & new generation detectors

Image credit: modified from NASA's Goddard Space Flight Center/S. Wiessinger

SiFAP2 – Telescopio Nazionale Galileo

Mounted on TNG: the largest italian telescope

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SiFAP2 – Telescopio Nazionale Galileo

Mounted on TNG: the largest italian telescope

Time resolution of 80 ps (previously 8 ns)

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SiFAP2 – Telescopio Nazionale Galileo

Mounted on TNG: the largest italian telescope

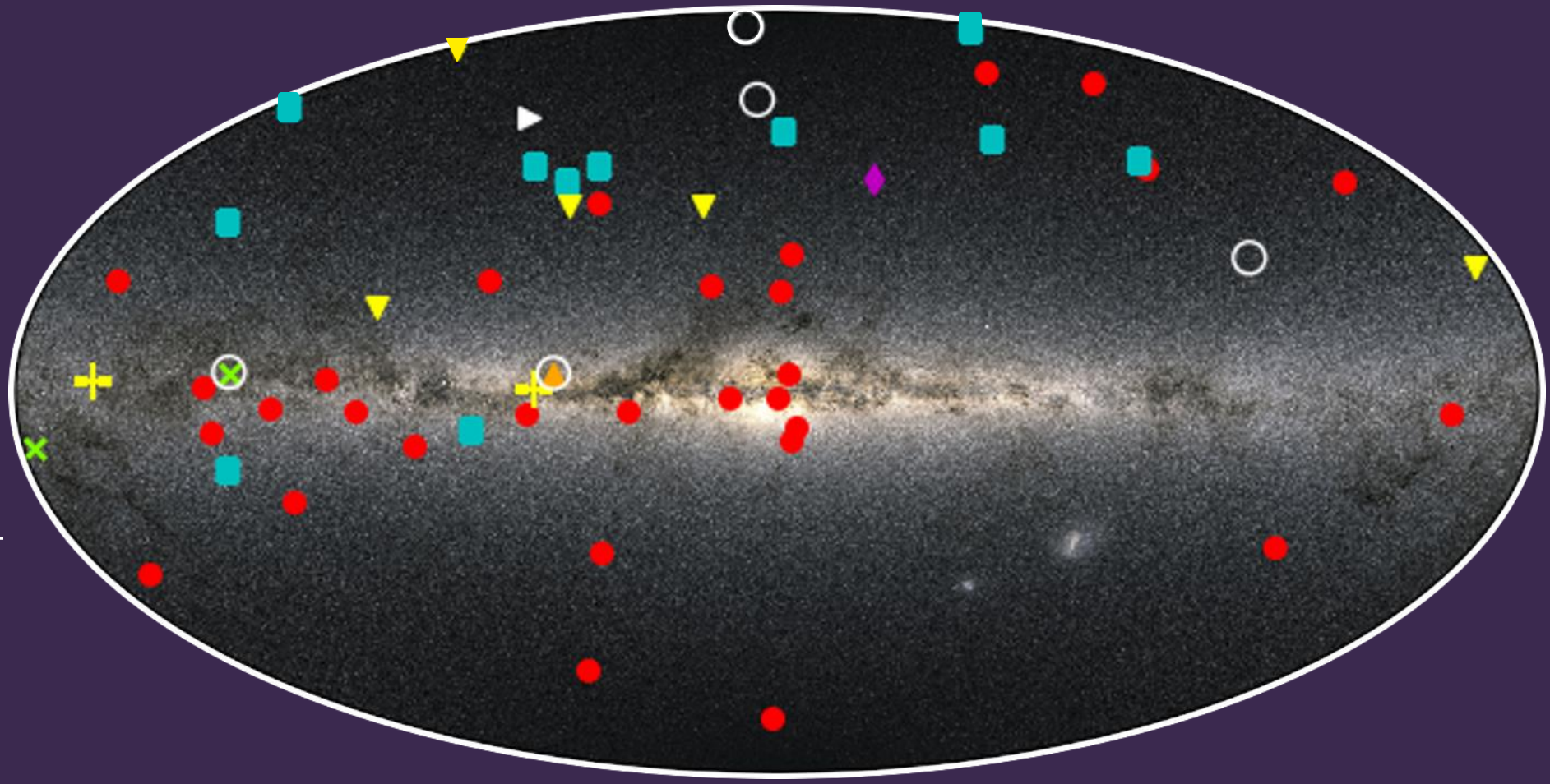
Time resolution of 80 ps (previously 8 ns)

Field of view of 7’’

Image credit: modified from Giovanni Tessicini, public domain via Wikimedia Commons

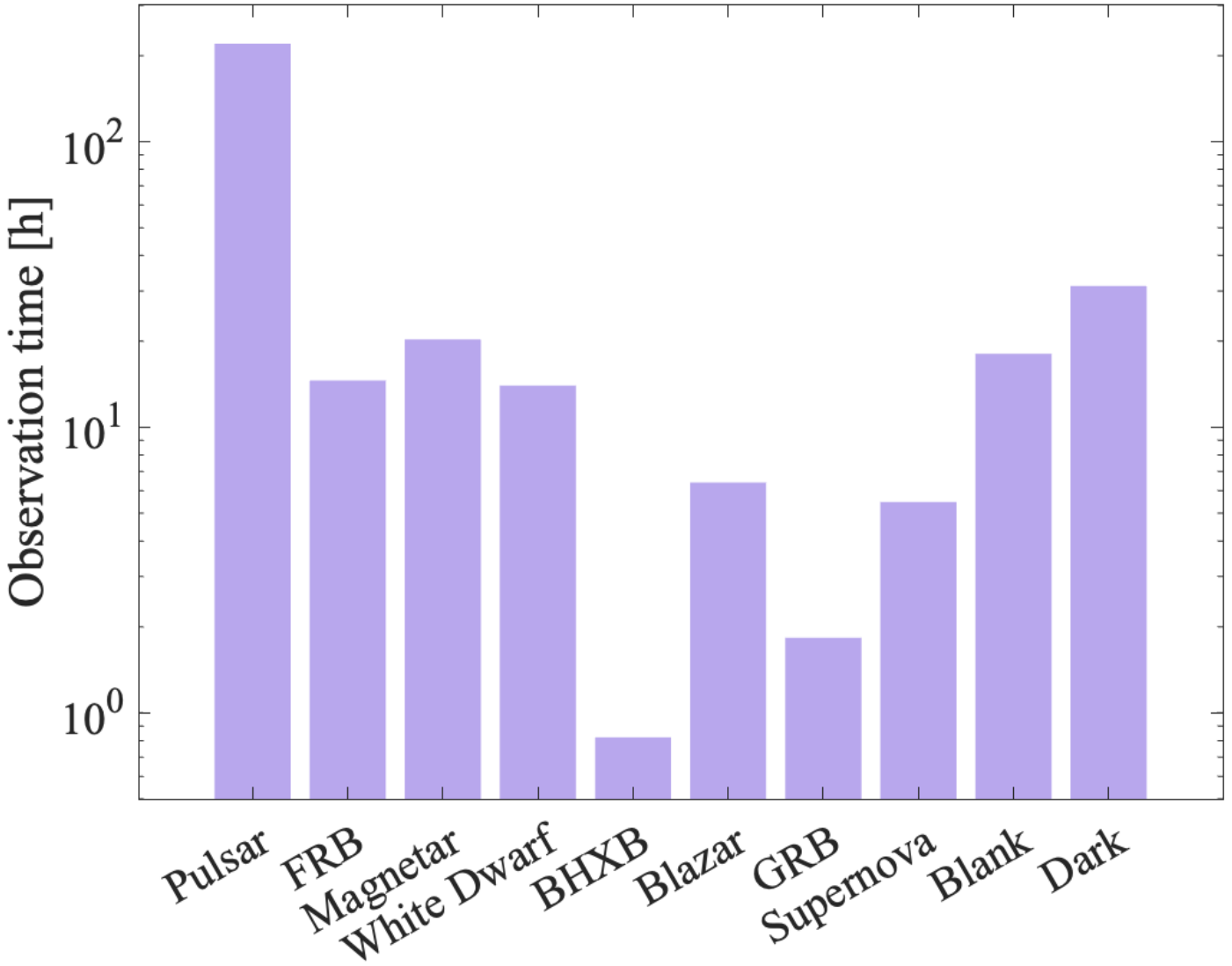
Astronomical observations

- Pulsar
- Fast Radio Burst
- Magnetar
- White Dwarf
- Black Hole Binary
- Blazar
- Gamma-ray burst
- Supernova
- Blank field

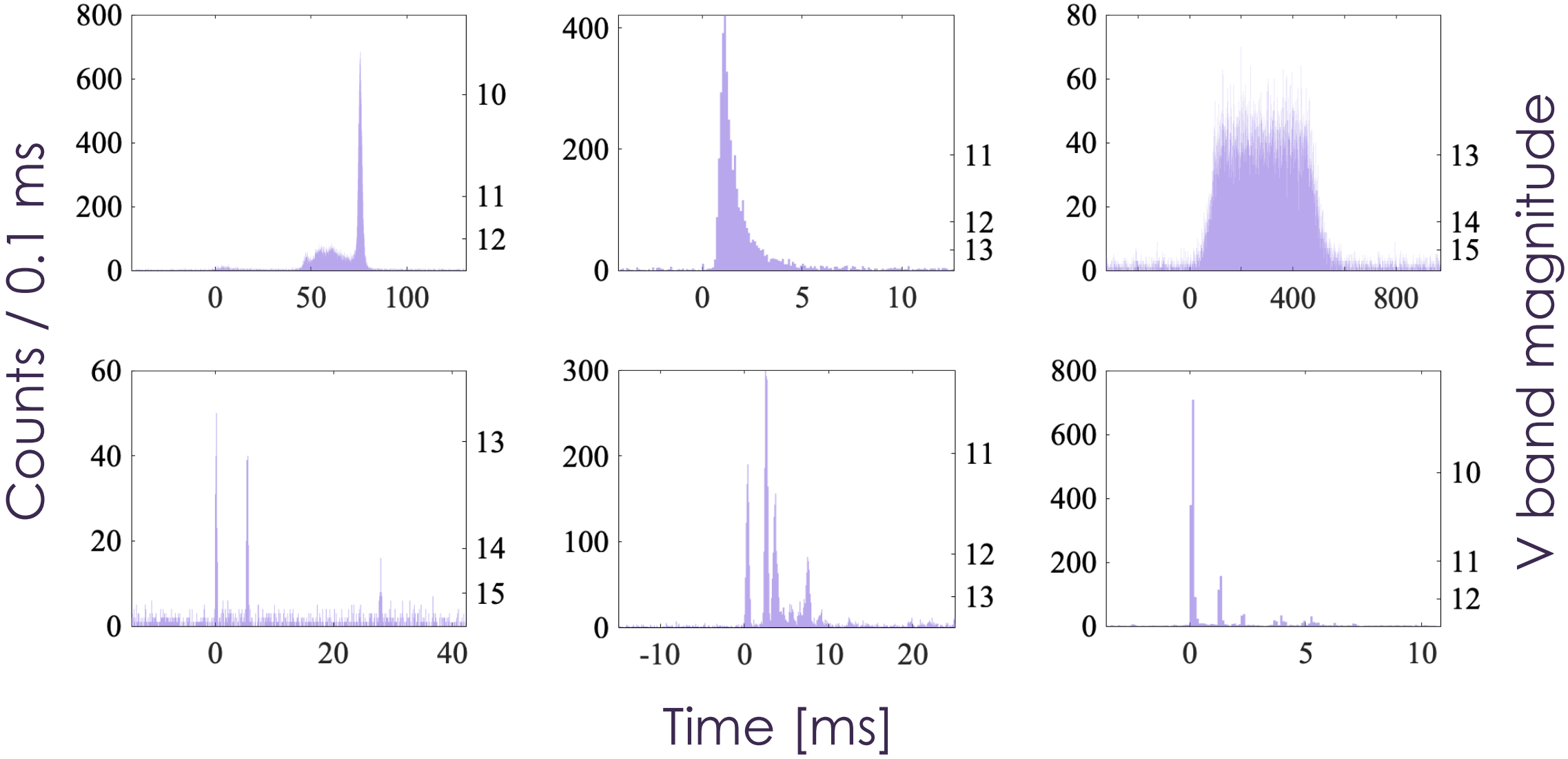


Astronomical observations

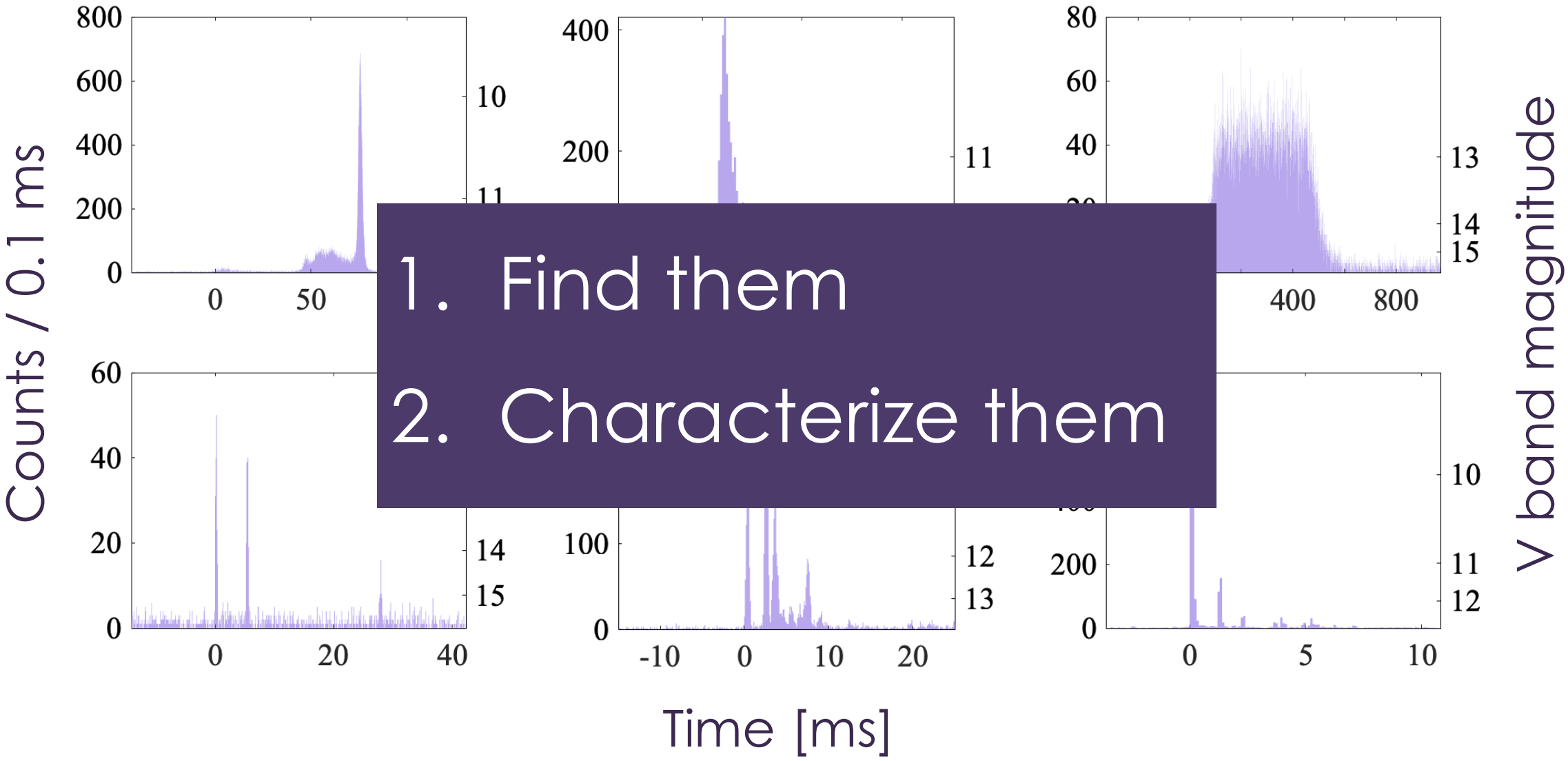
- 200 observations
- ~333 hours
- 63 targets



Fast Optical Bursts



Fast Optical Bursts

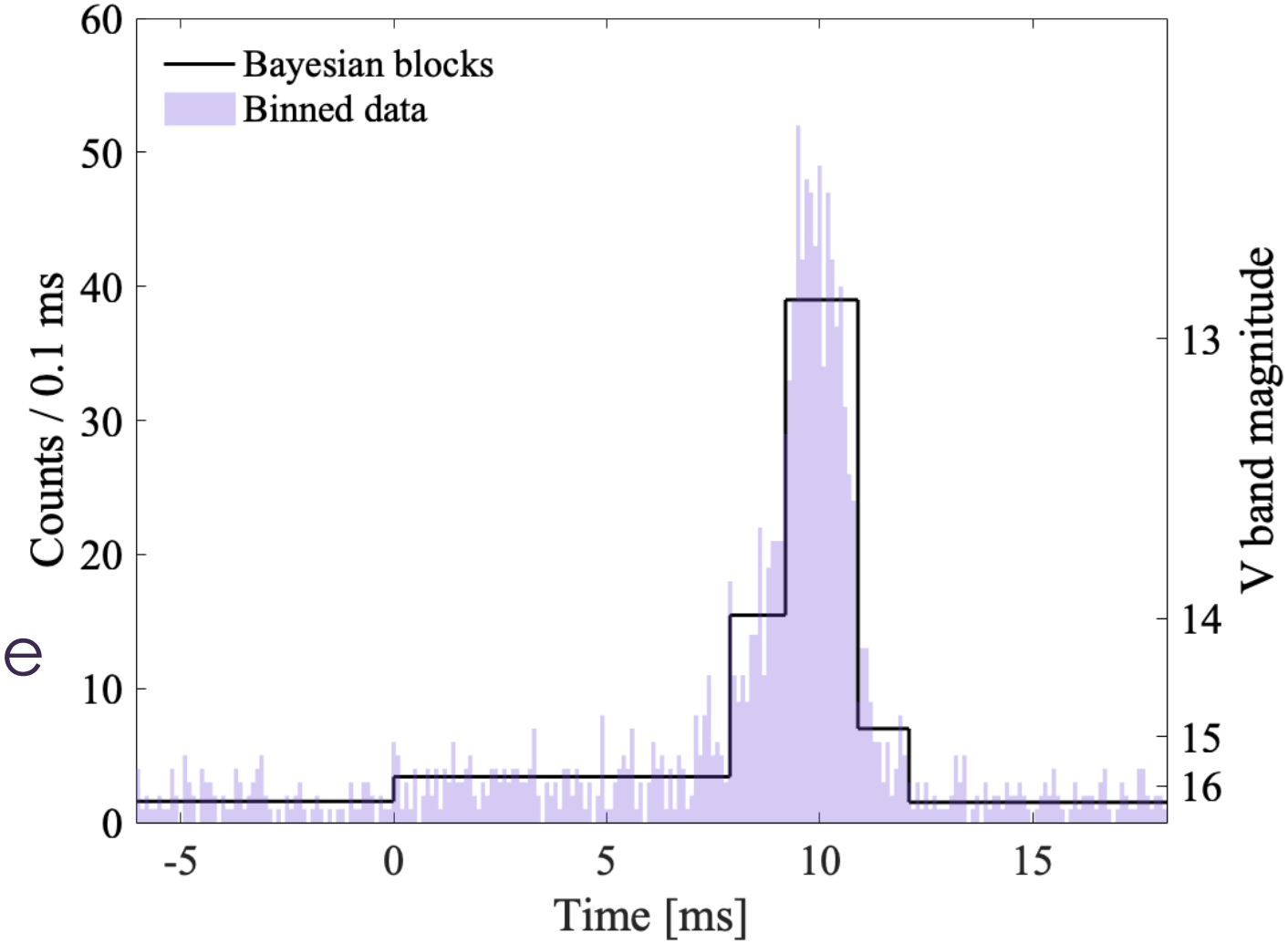


Classic Bayesian blocks

Adaptive binning algorithm

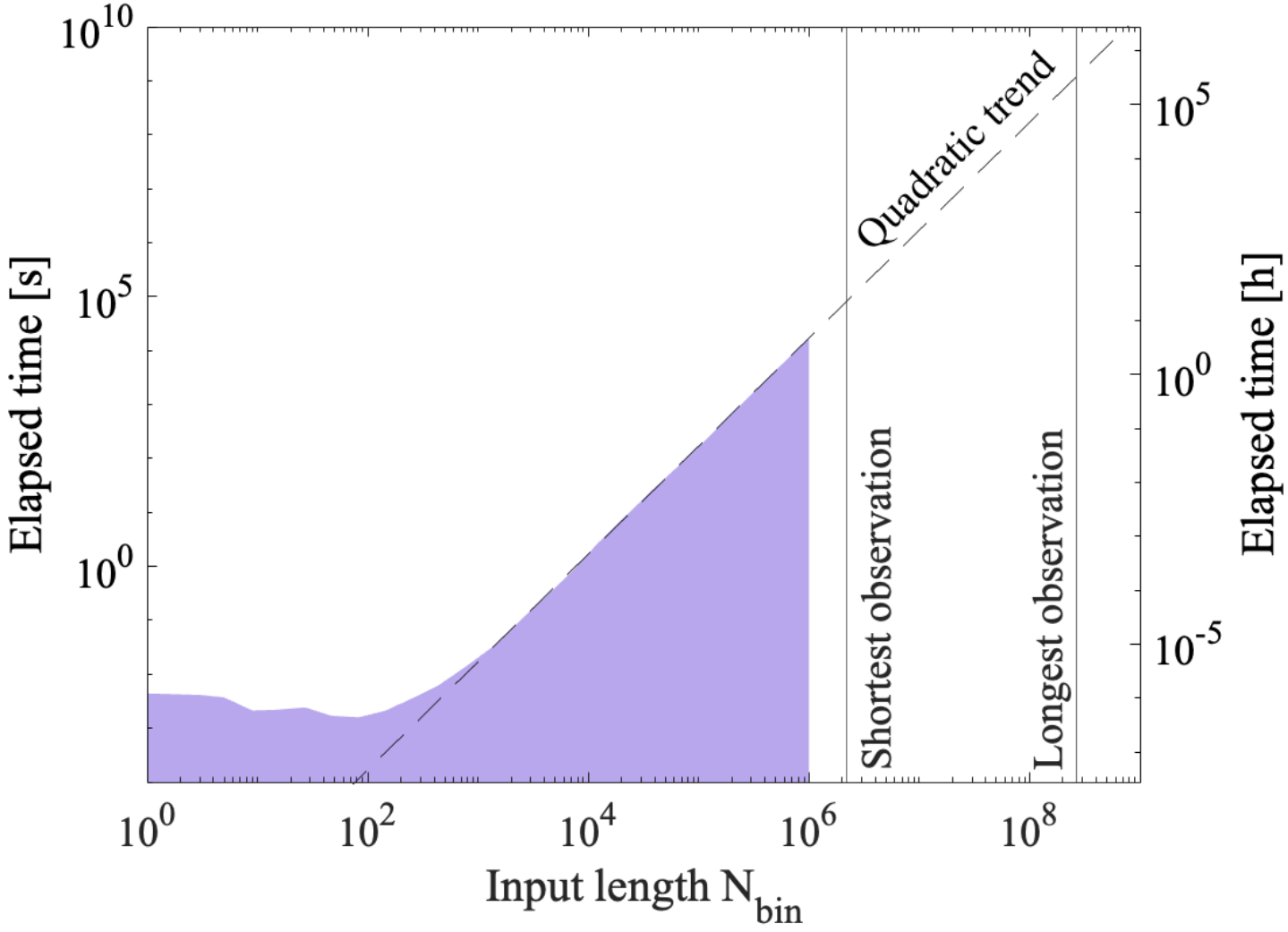
Identifies statistically significant local variation

Aims to eliminate Poisson noise

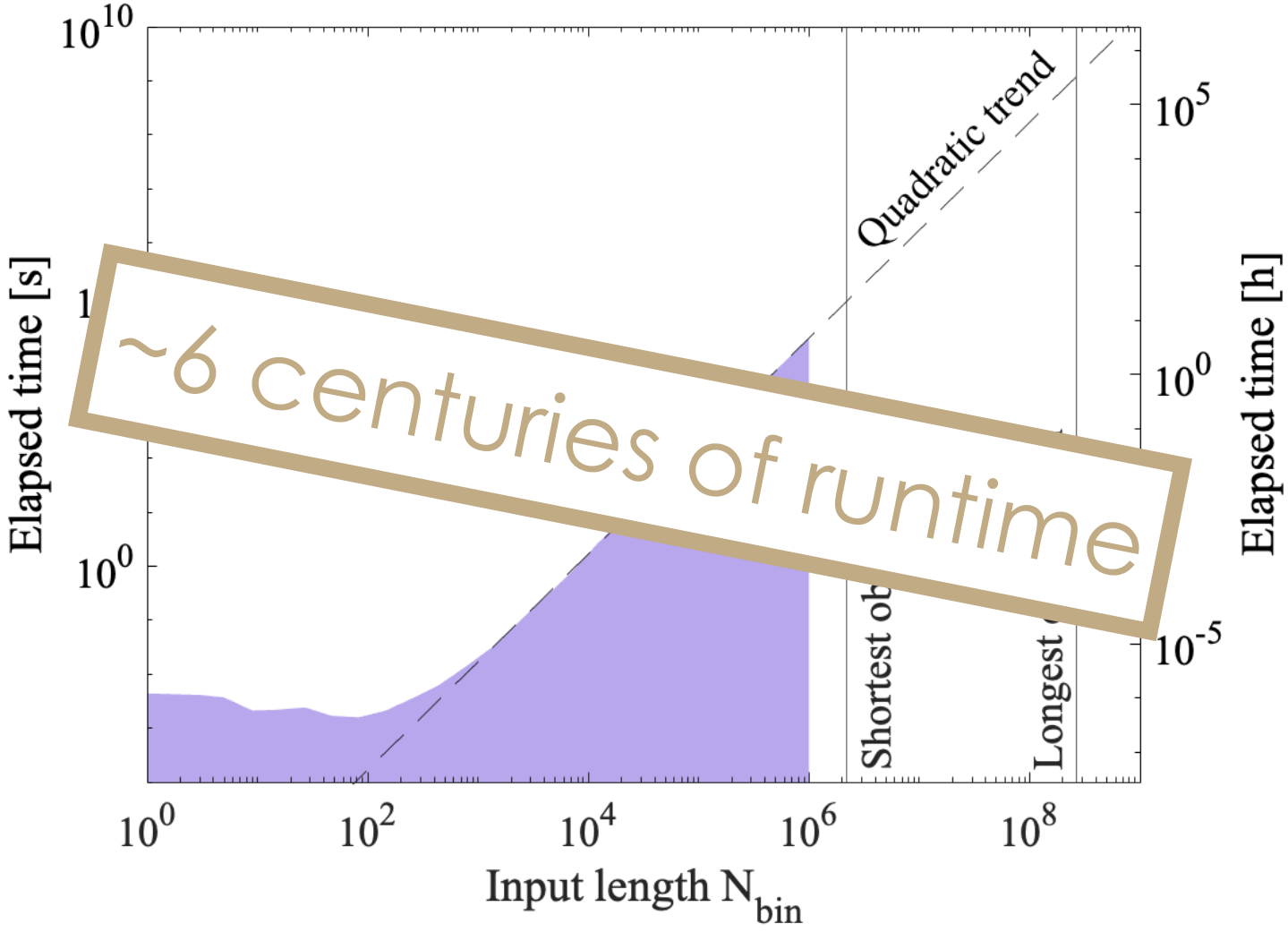


Link to the paper by Scargle and collaborators (2013)

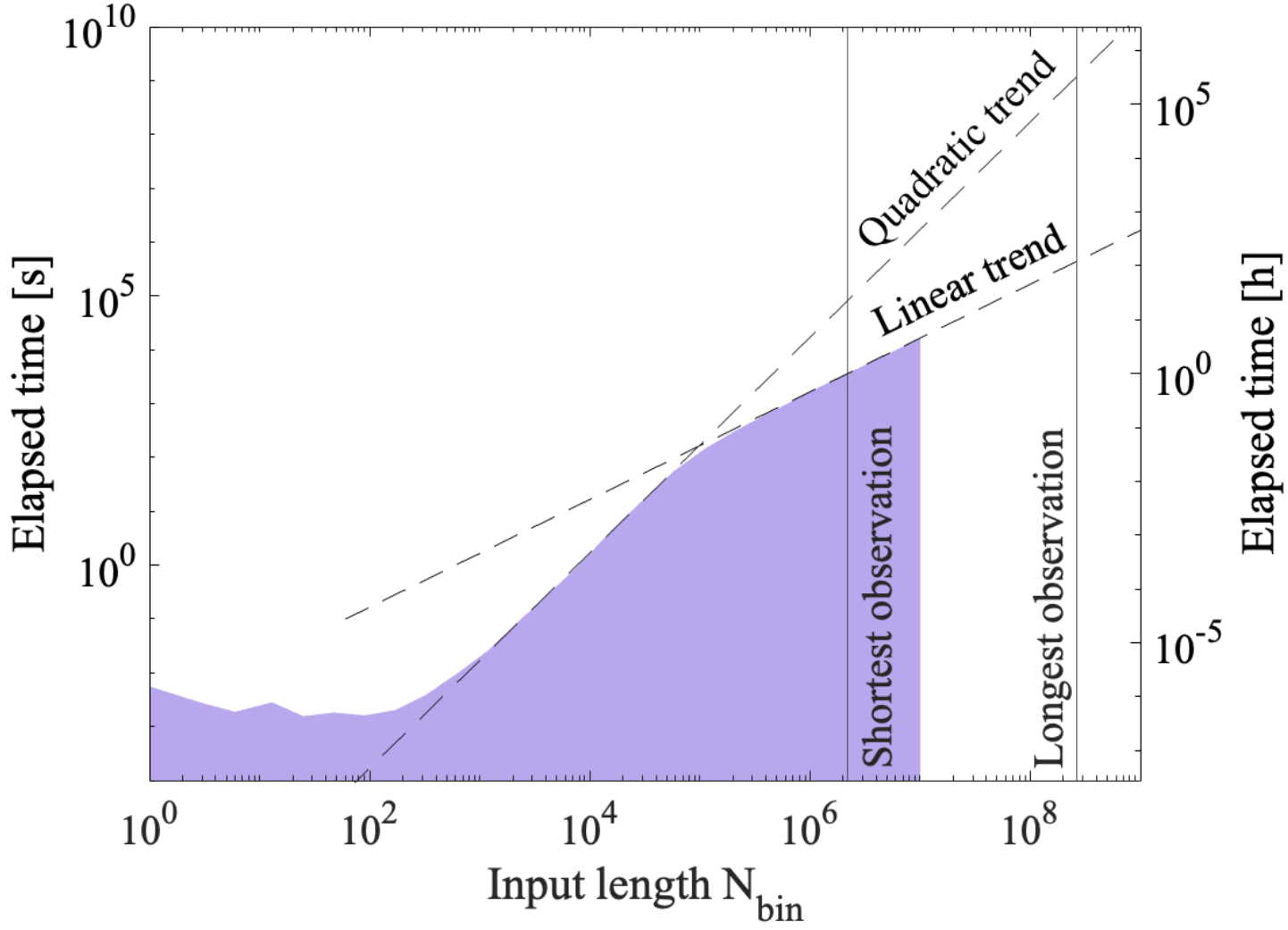
Classic Bayesian blocks



Classic Bayesian blocks



1st change: *Linearized* Bayesian blocks



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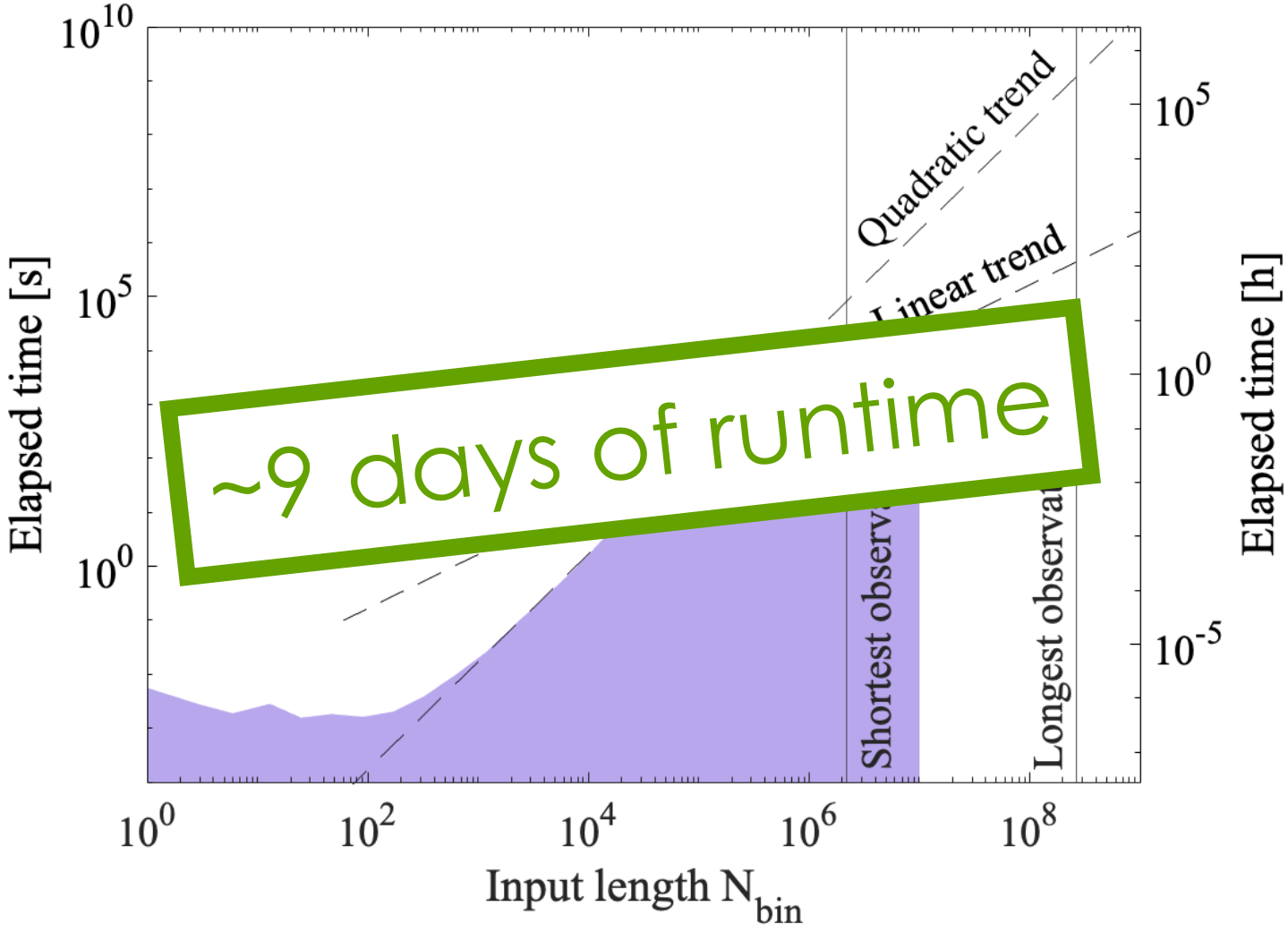
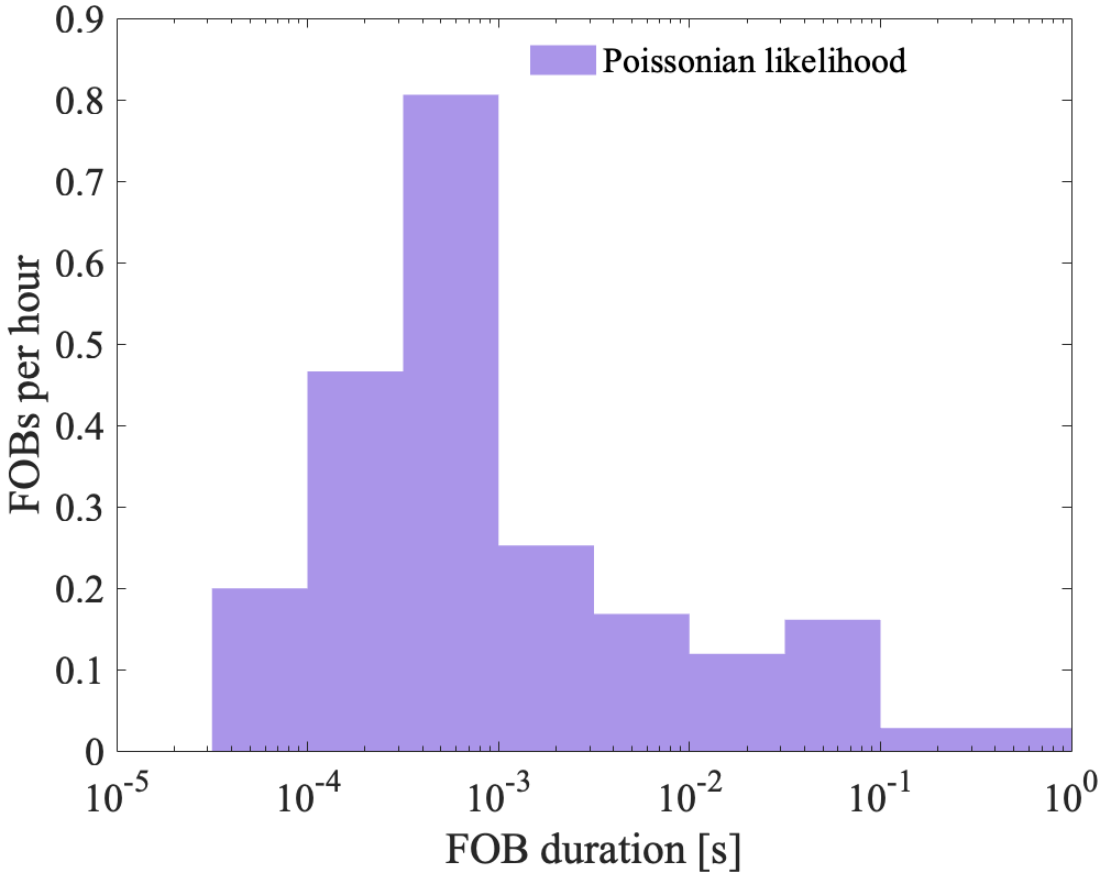
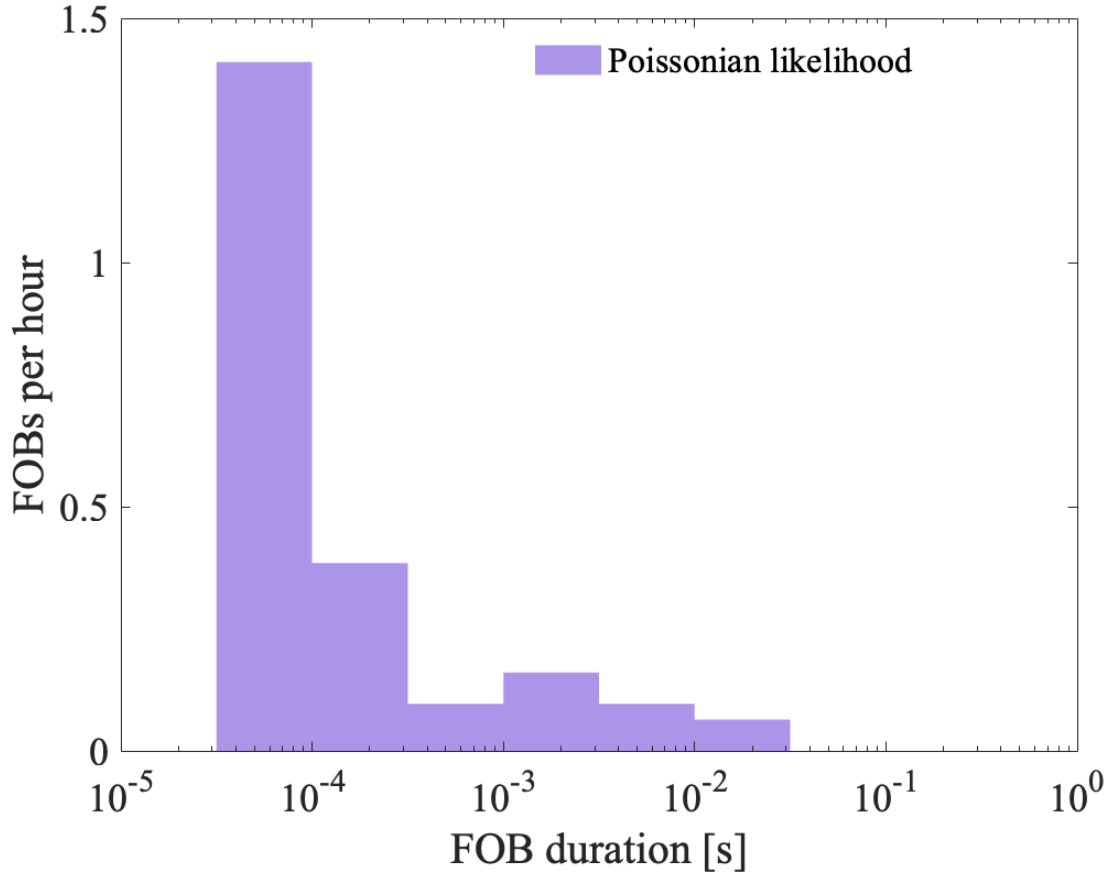


2nd change: *Modified-Poisson* Bayesian blocks

From **real** observations



From **dark** observations



2nd change: *Modified-Poisson* Bayesian blocks

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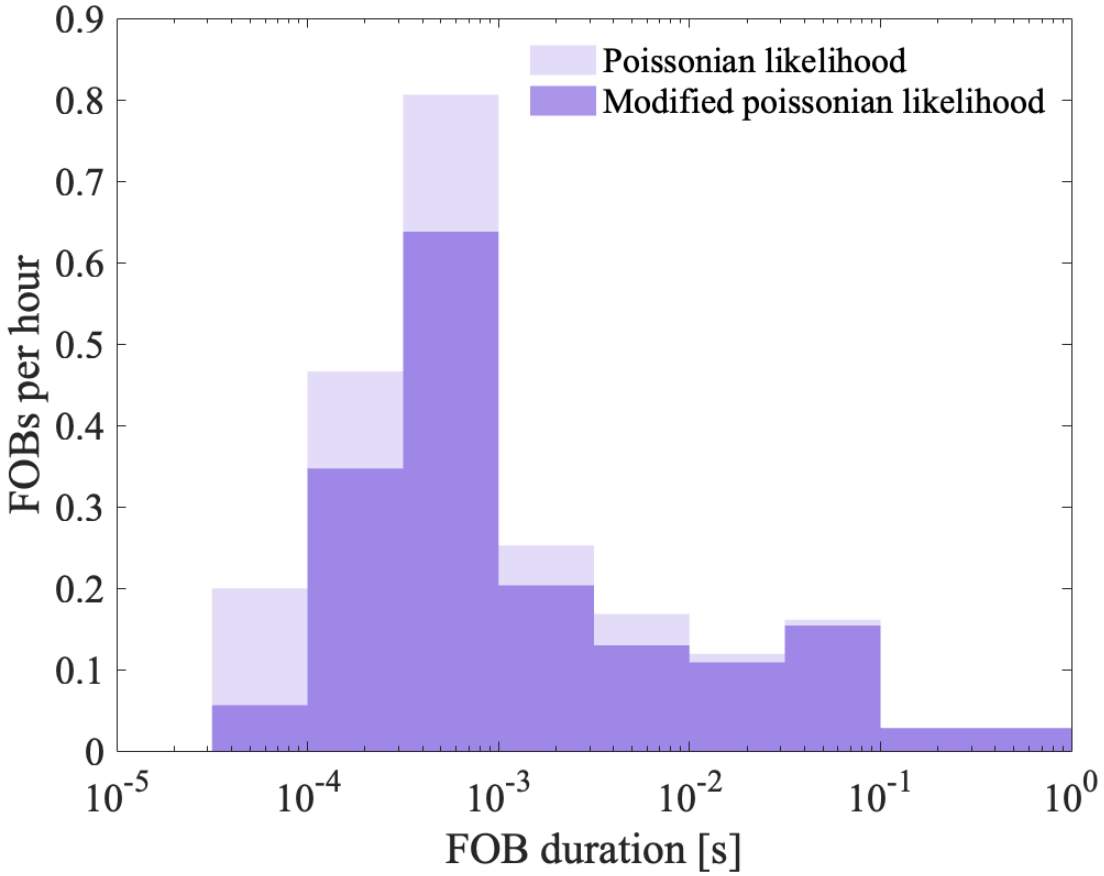
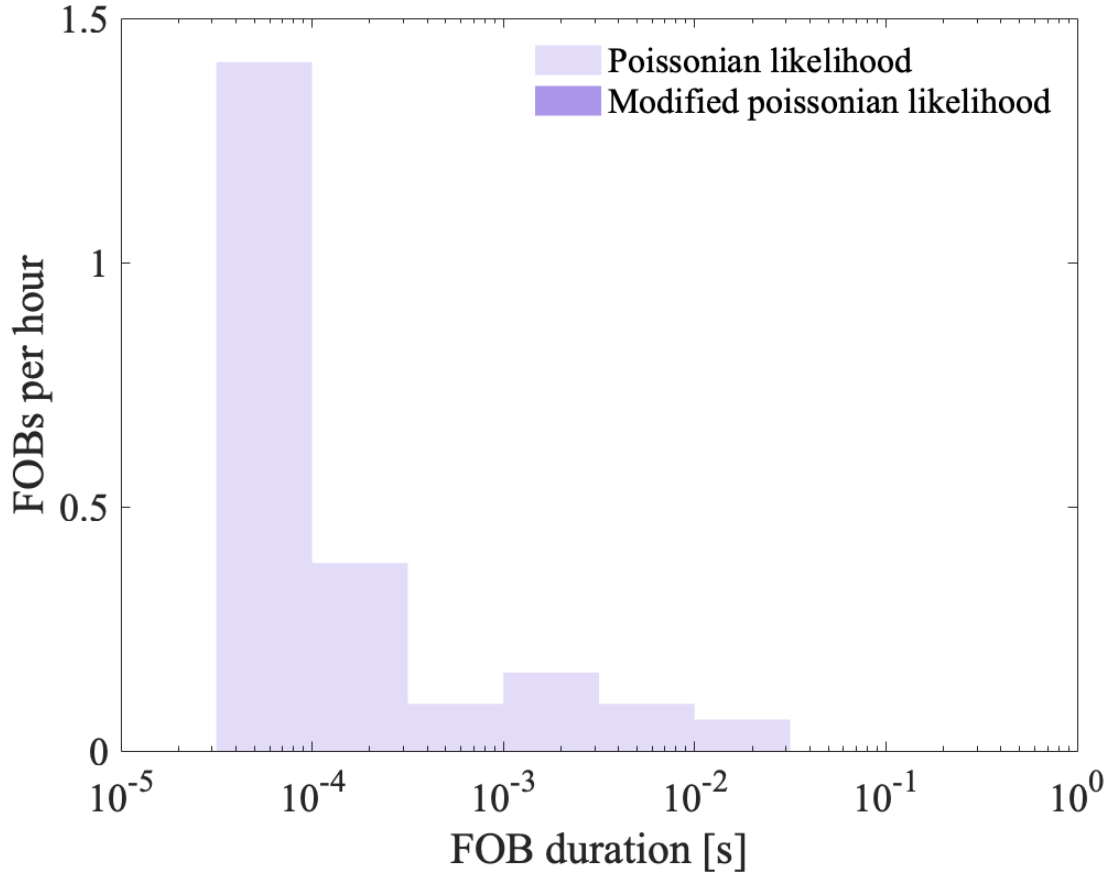
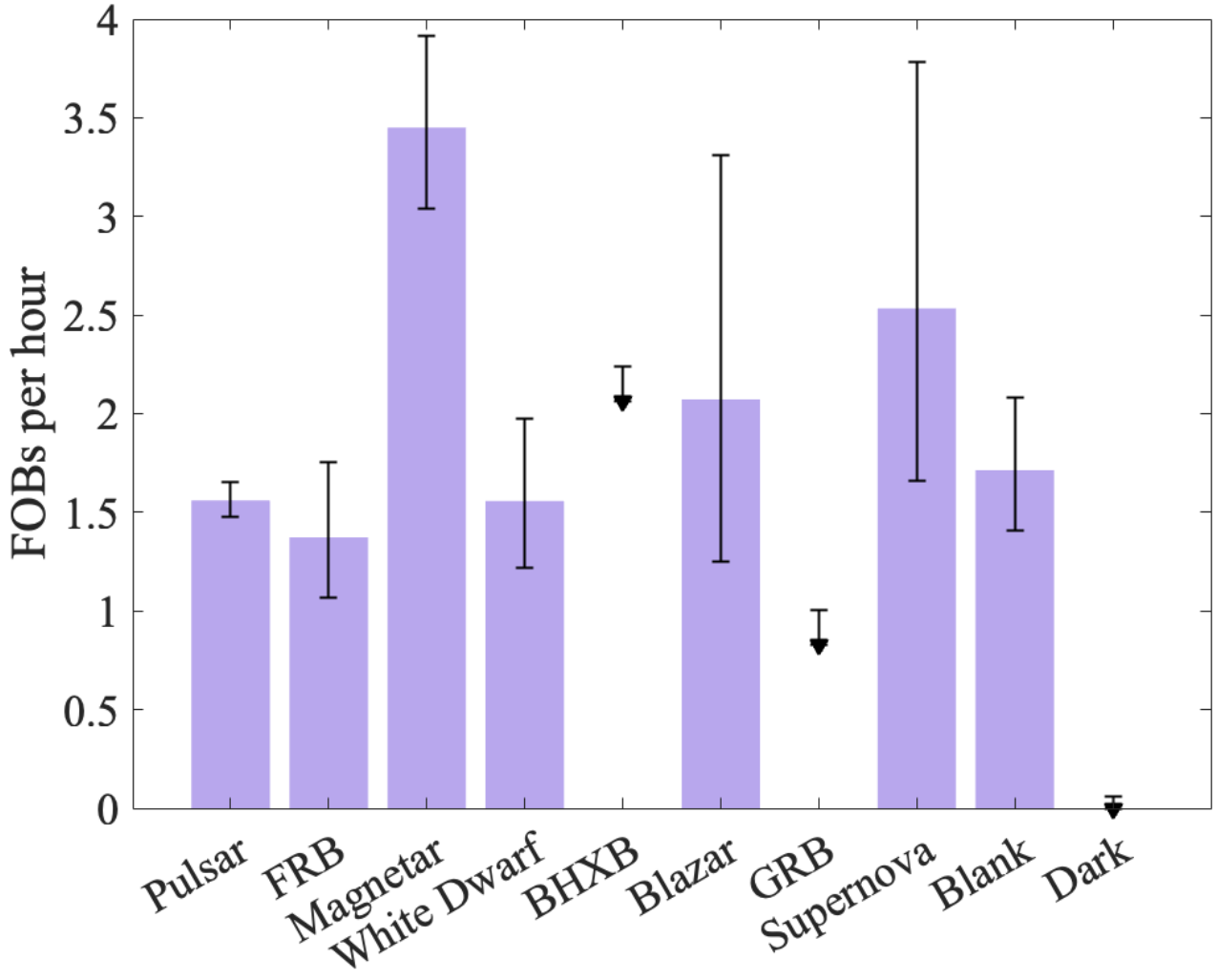


From **dark** observations



FOBs per observed source class



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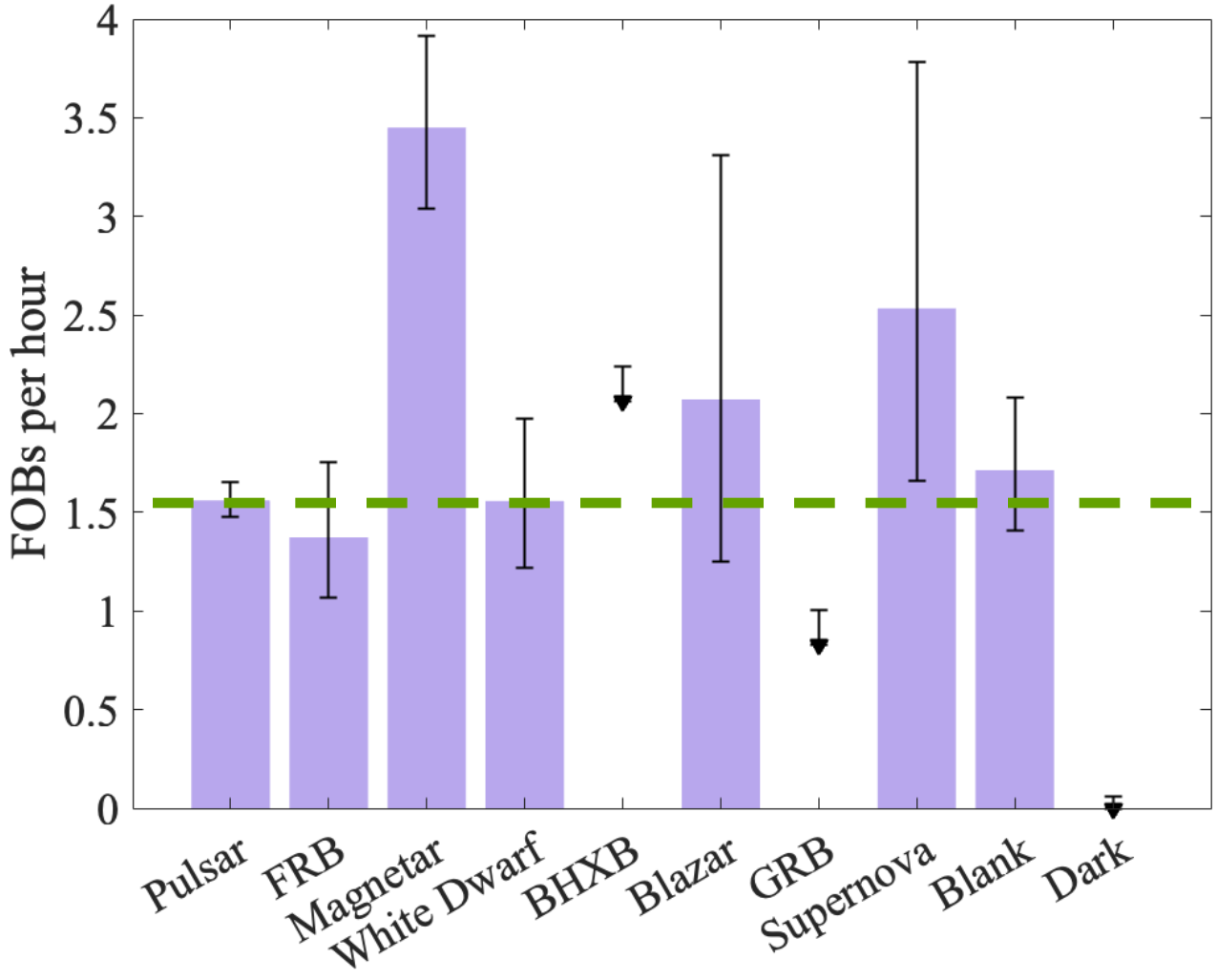
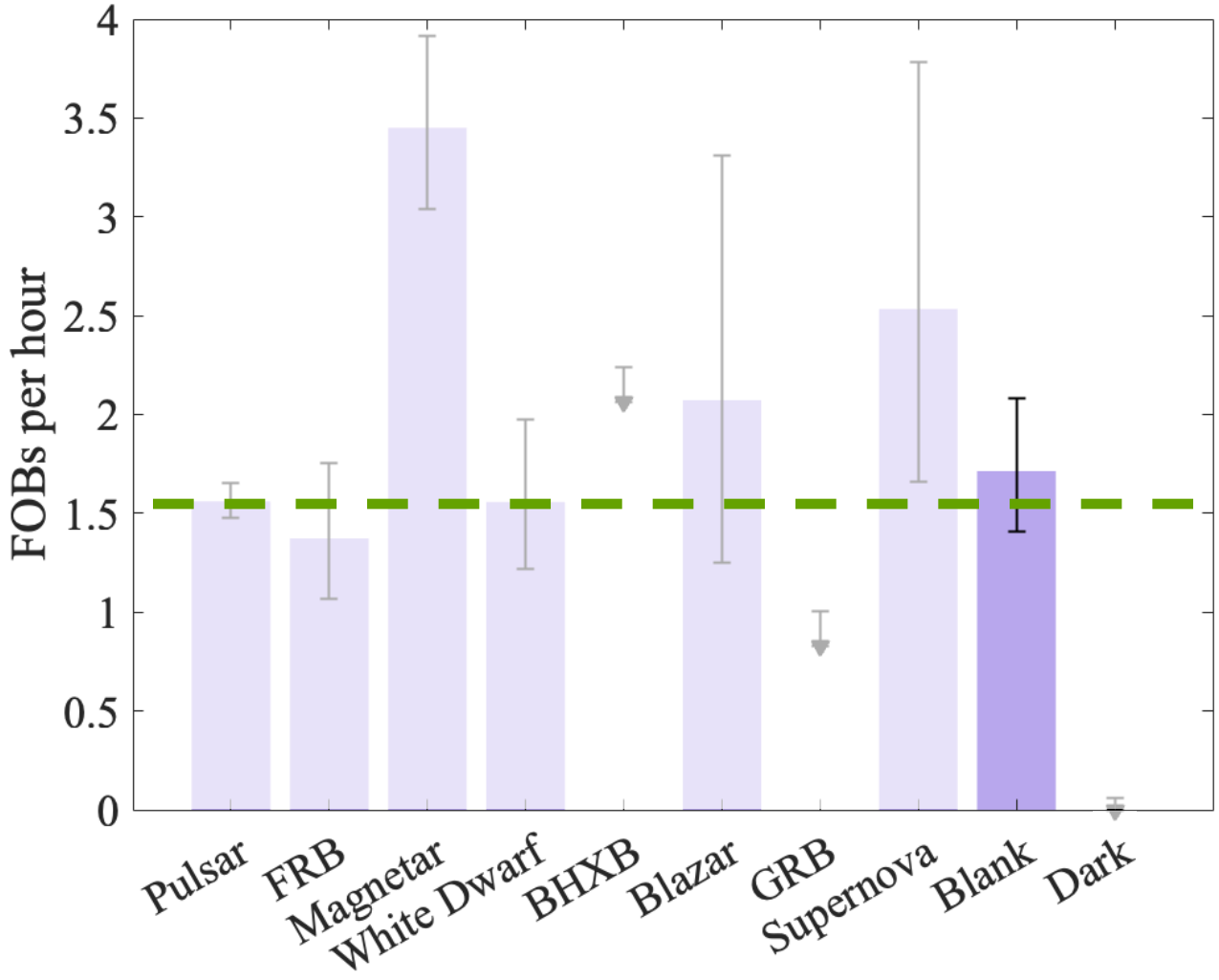


$4x10^{11}$ FOBs/day/sky

FOBs per observed source class



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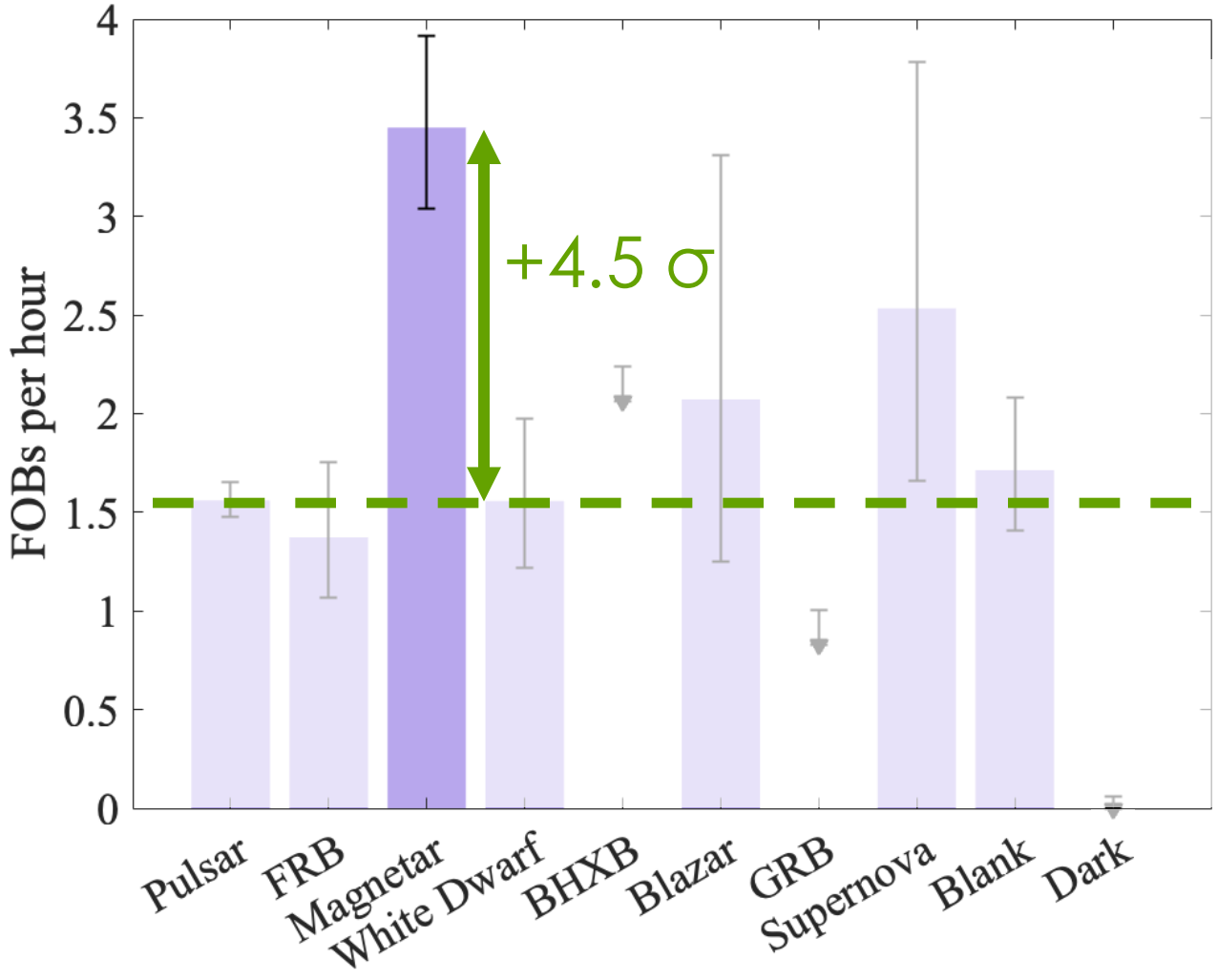

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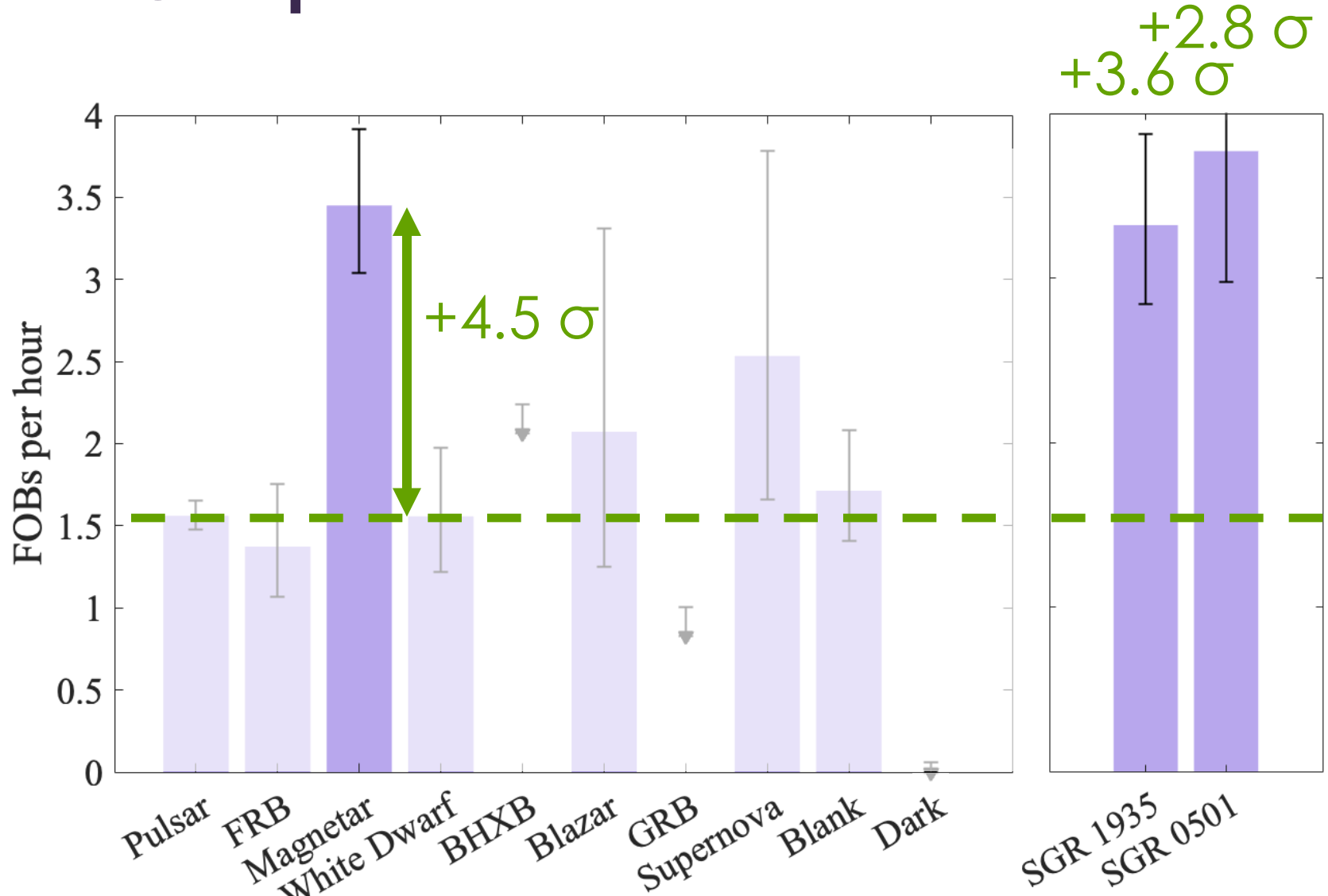

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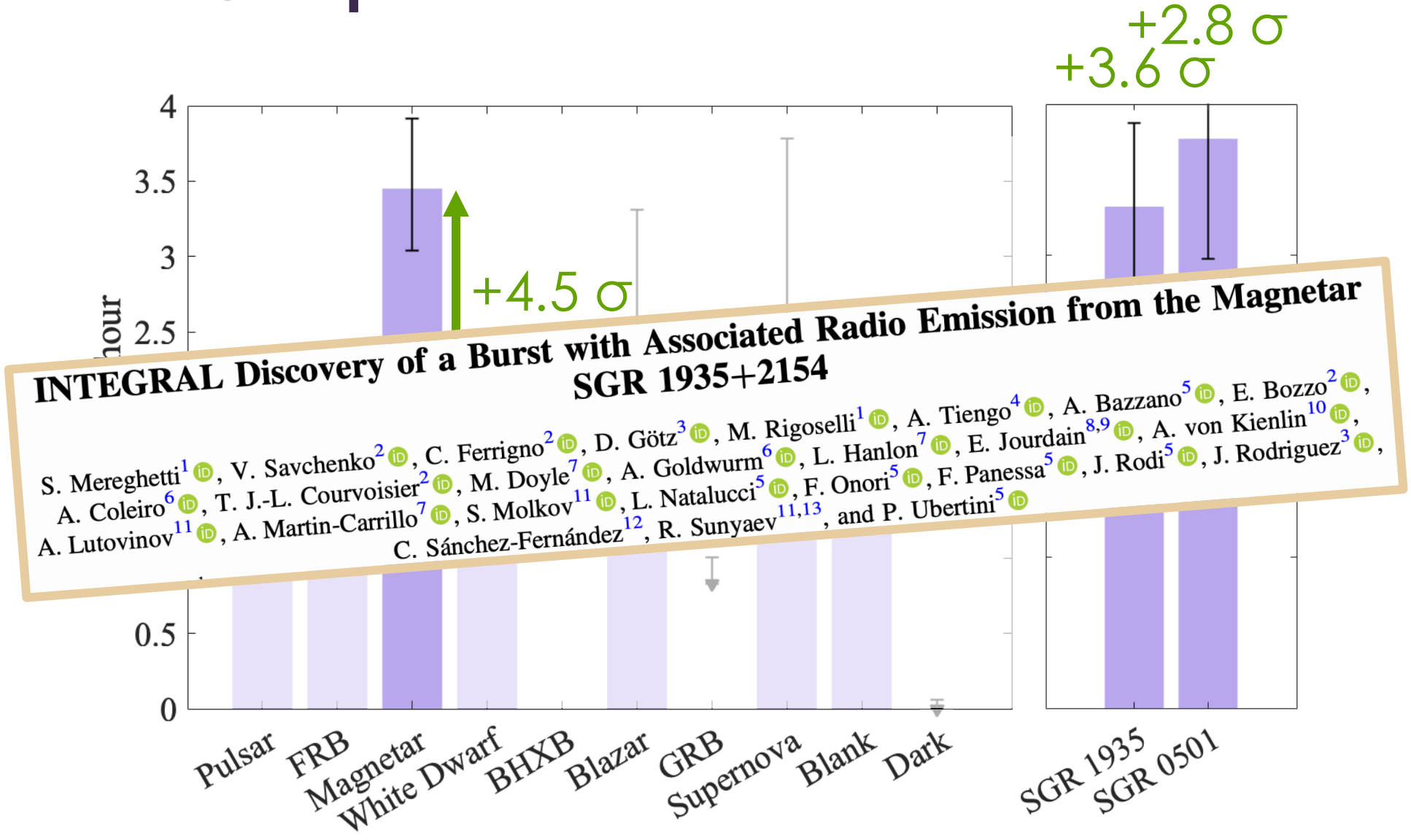
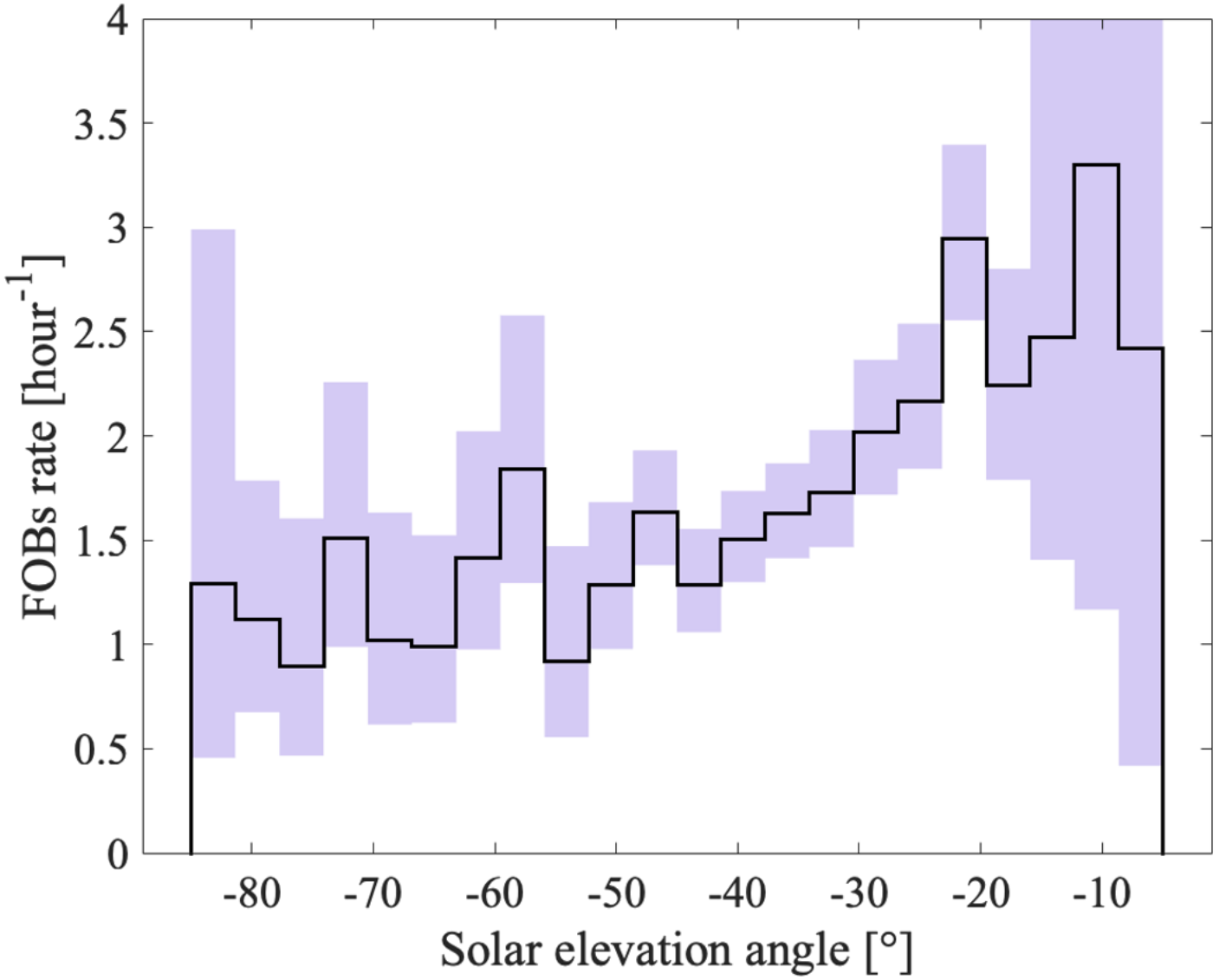


INTEGRAL Discovery of a Burst with Associated Radio Emission from the Magnetar SGR 1935+2154

S. Mereghetti[1], V. Savchenko[2], C. Ferrigno[2], D. Götz[3], M. Rigoselli[1], A. Tiengo[4], A. Bazzano[5], E. Bozzo[2], A. Coleiro[6], T. J.-L. Courvoisier[2], M. Doyle[7], A. Goldwurm[6], L. Hanlon[7], E. Jourdain[8,9], A. von Kienlin[10], A. Lutovinov[11], A. Martin-Carrillo[7], S. Molkov[11], L. Natalucci[5], F. Onori[5], F. Panessa[5], J. Rodi[5], J. Rodriguez[3], C. Sánchez-Fernández[12], R. Sunyaev[11,13], and P. Ubertini[5]

FOBs with solar elevation angle



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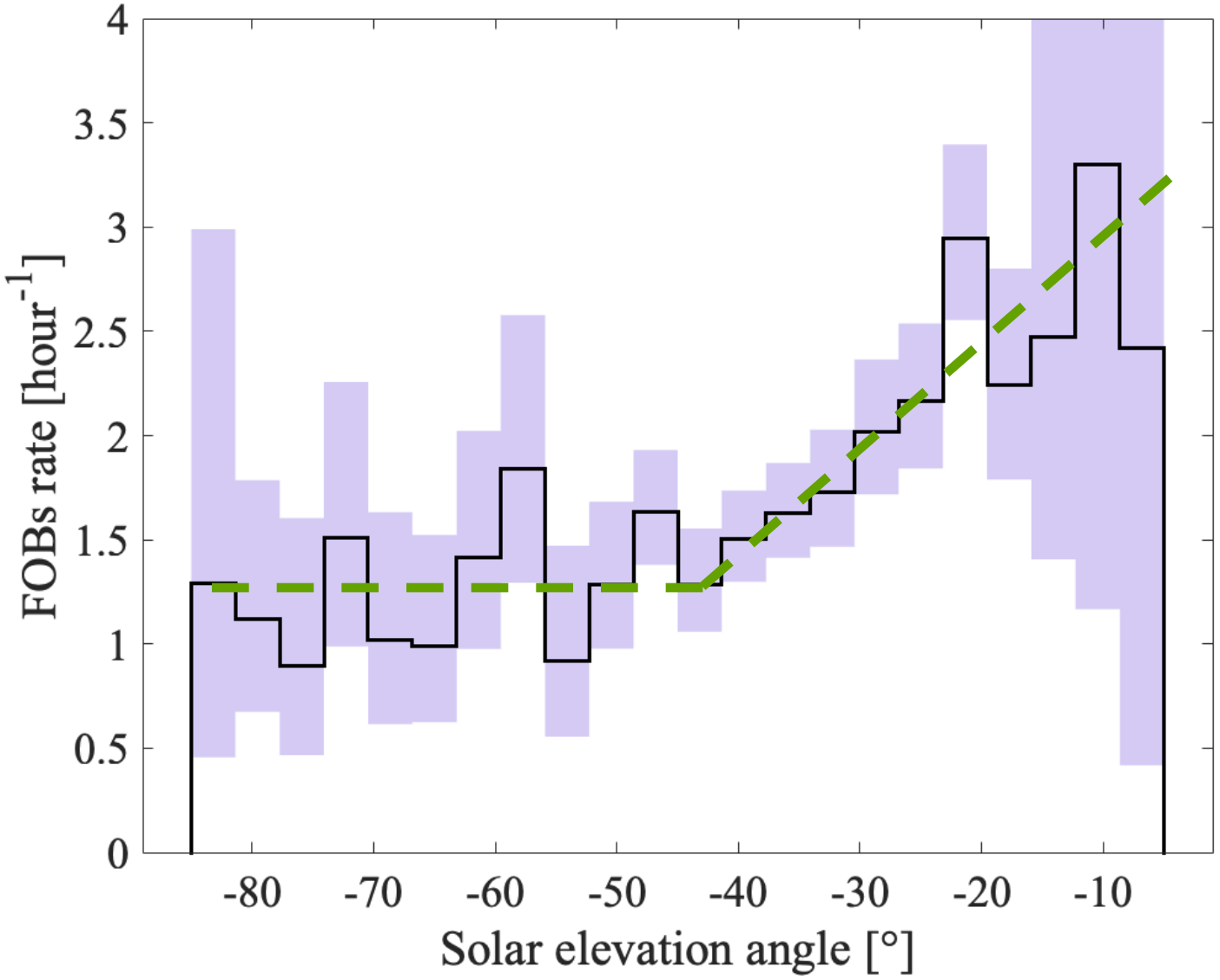

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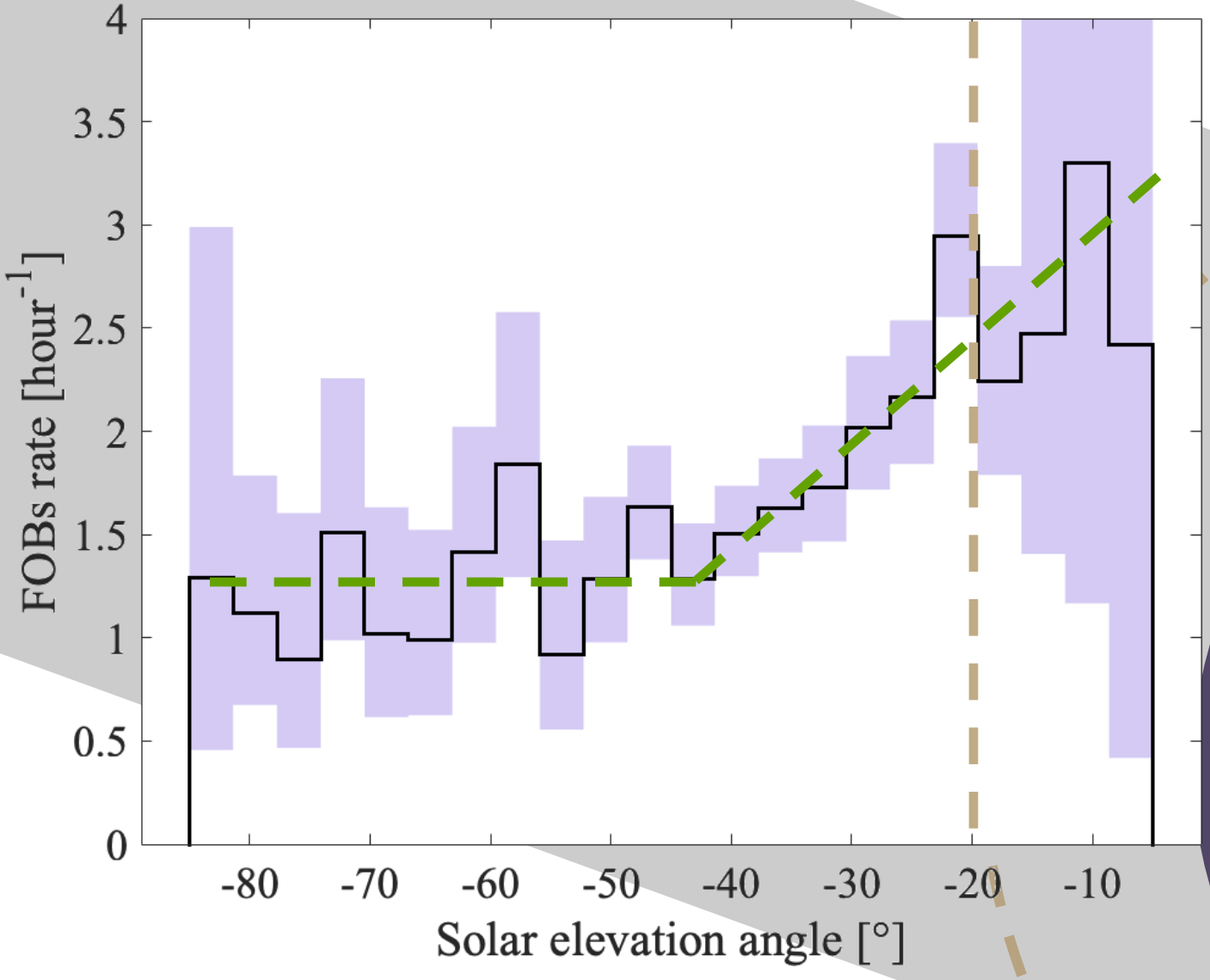

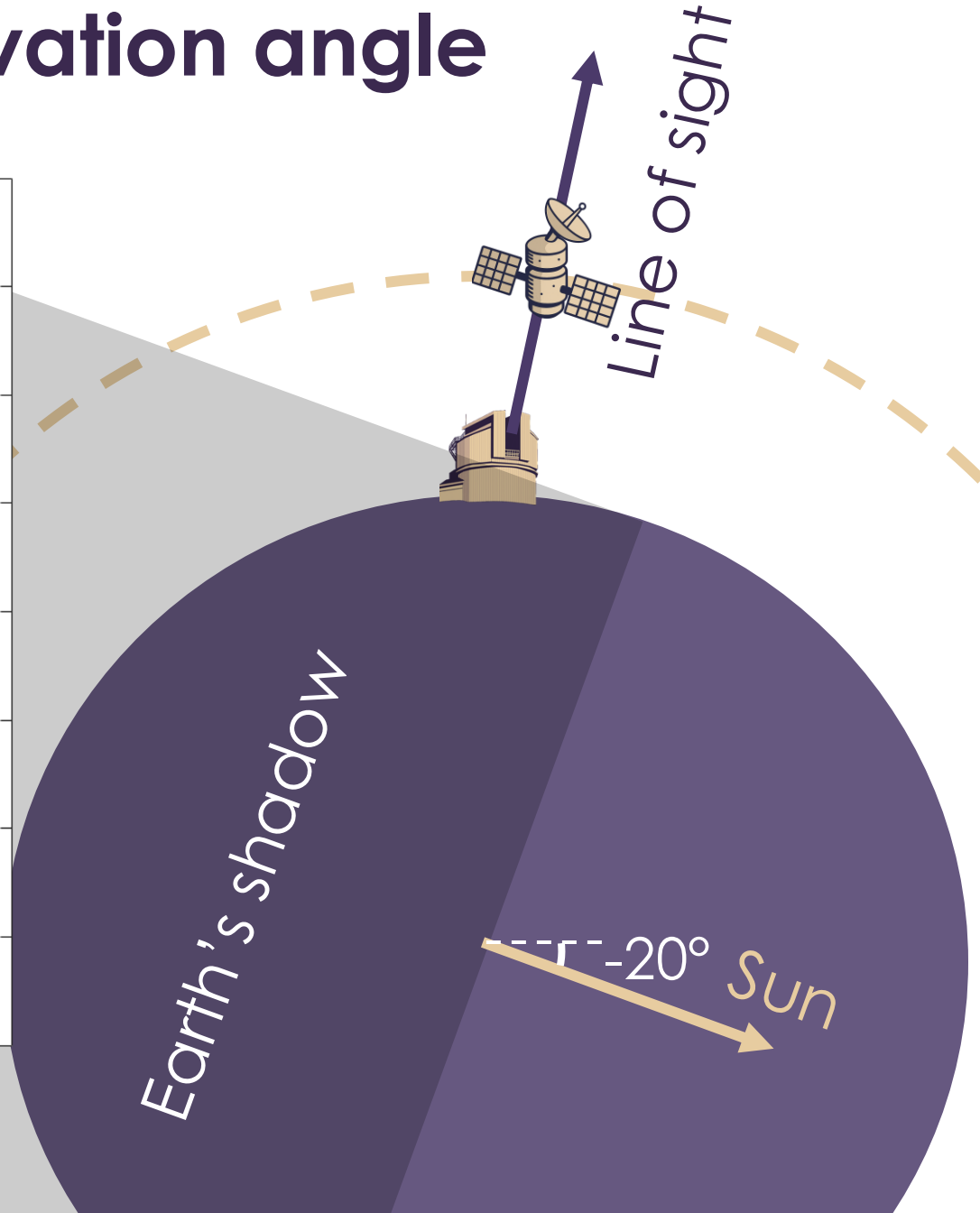

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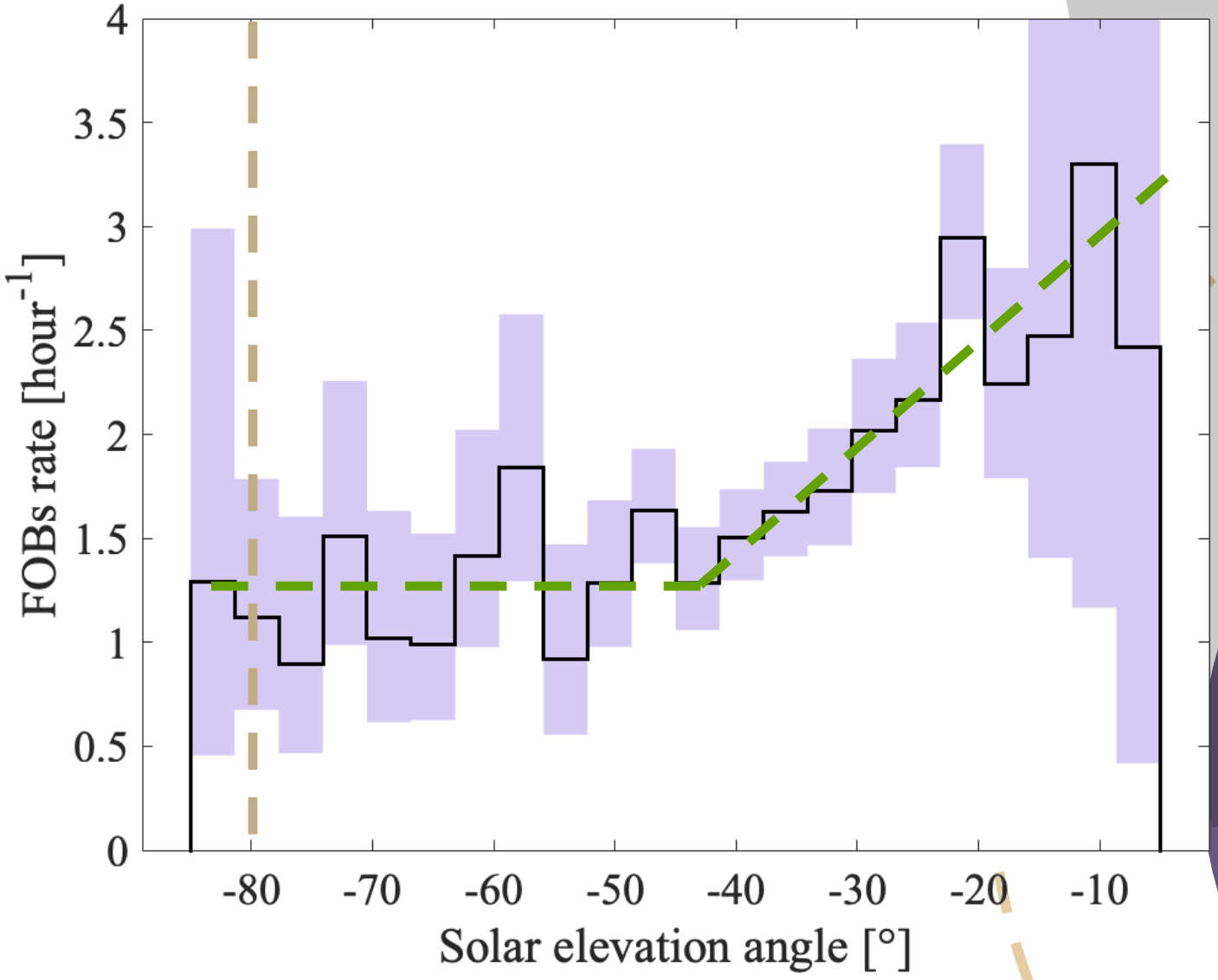

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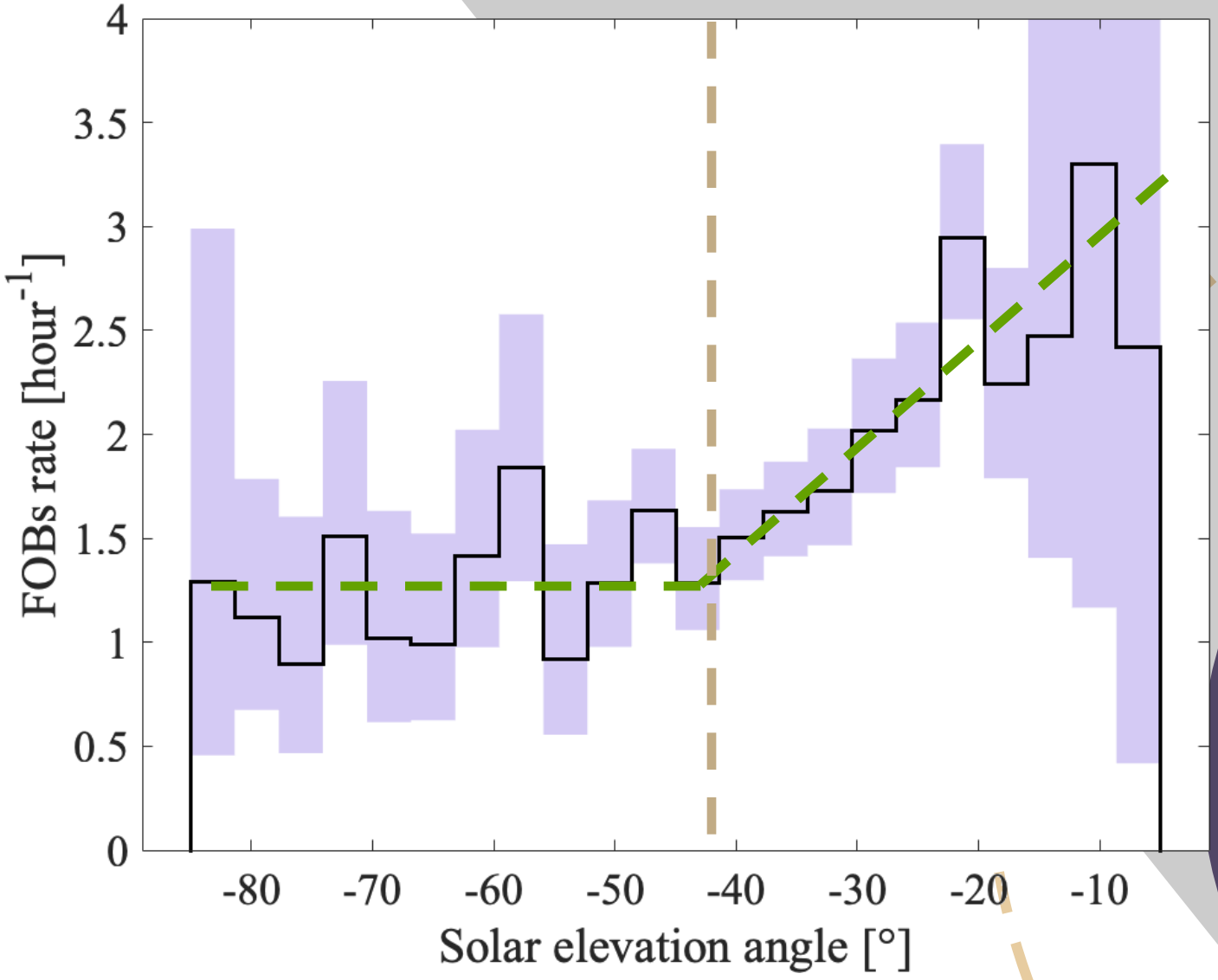

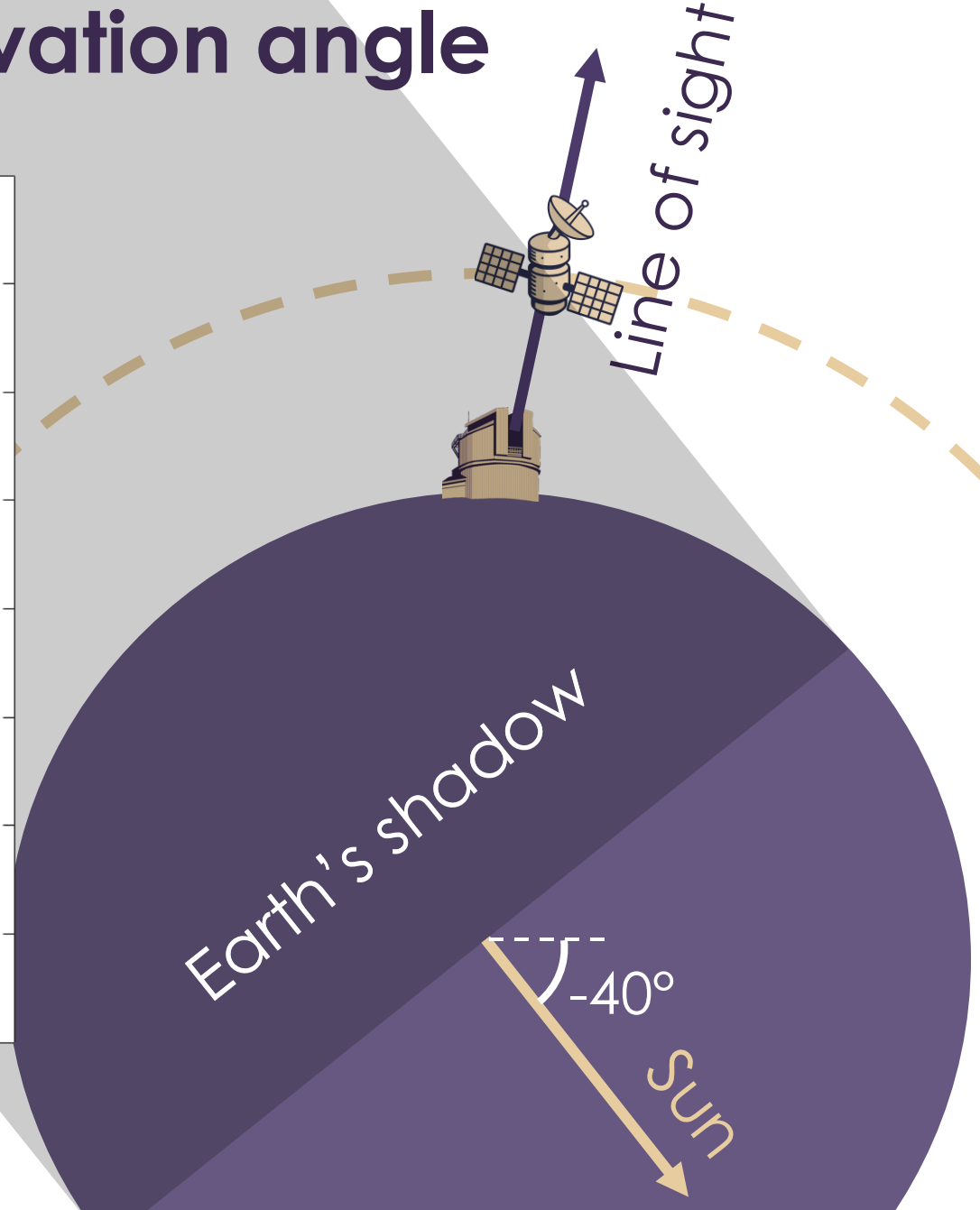

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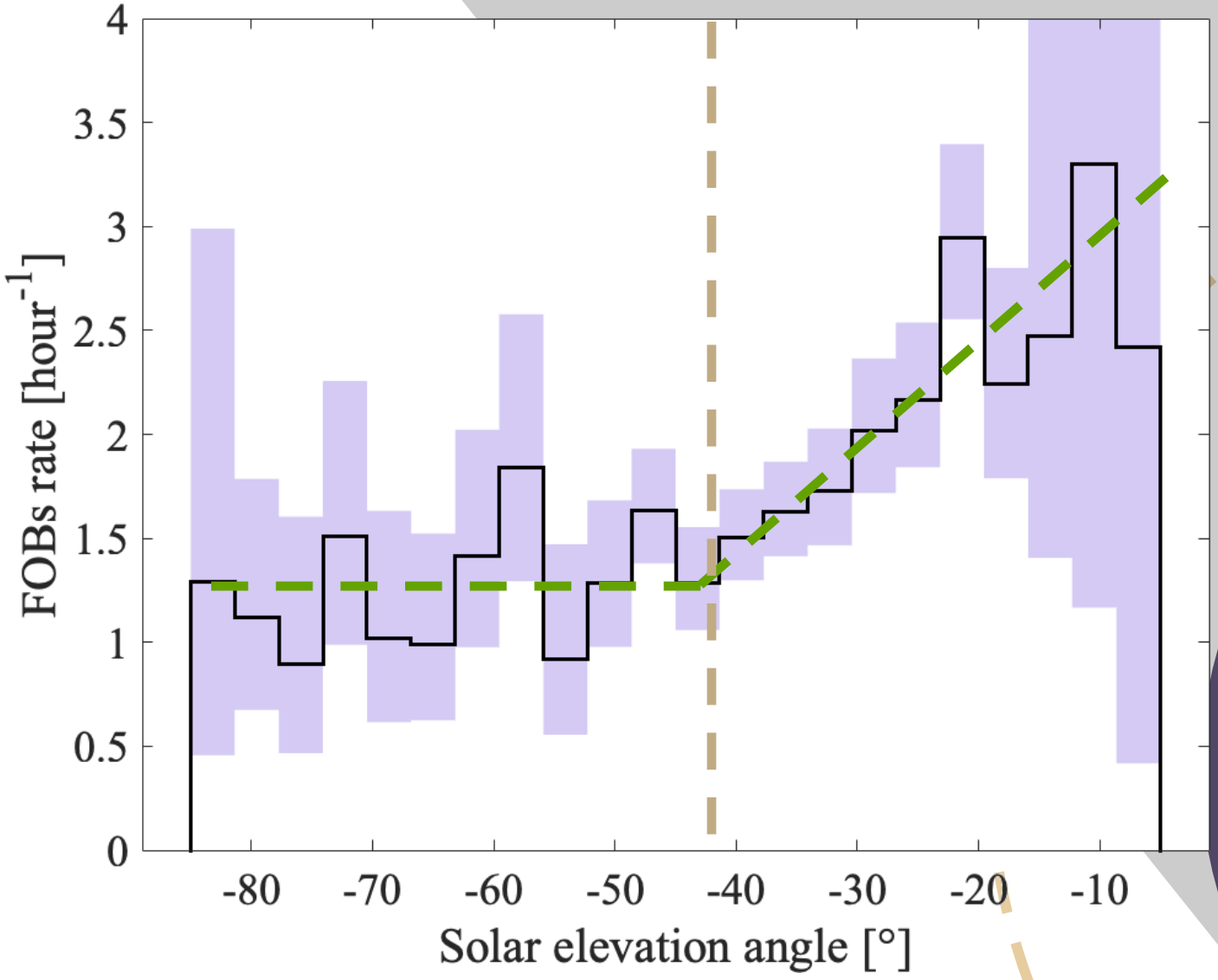

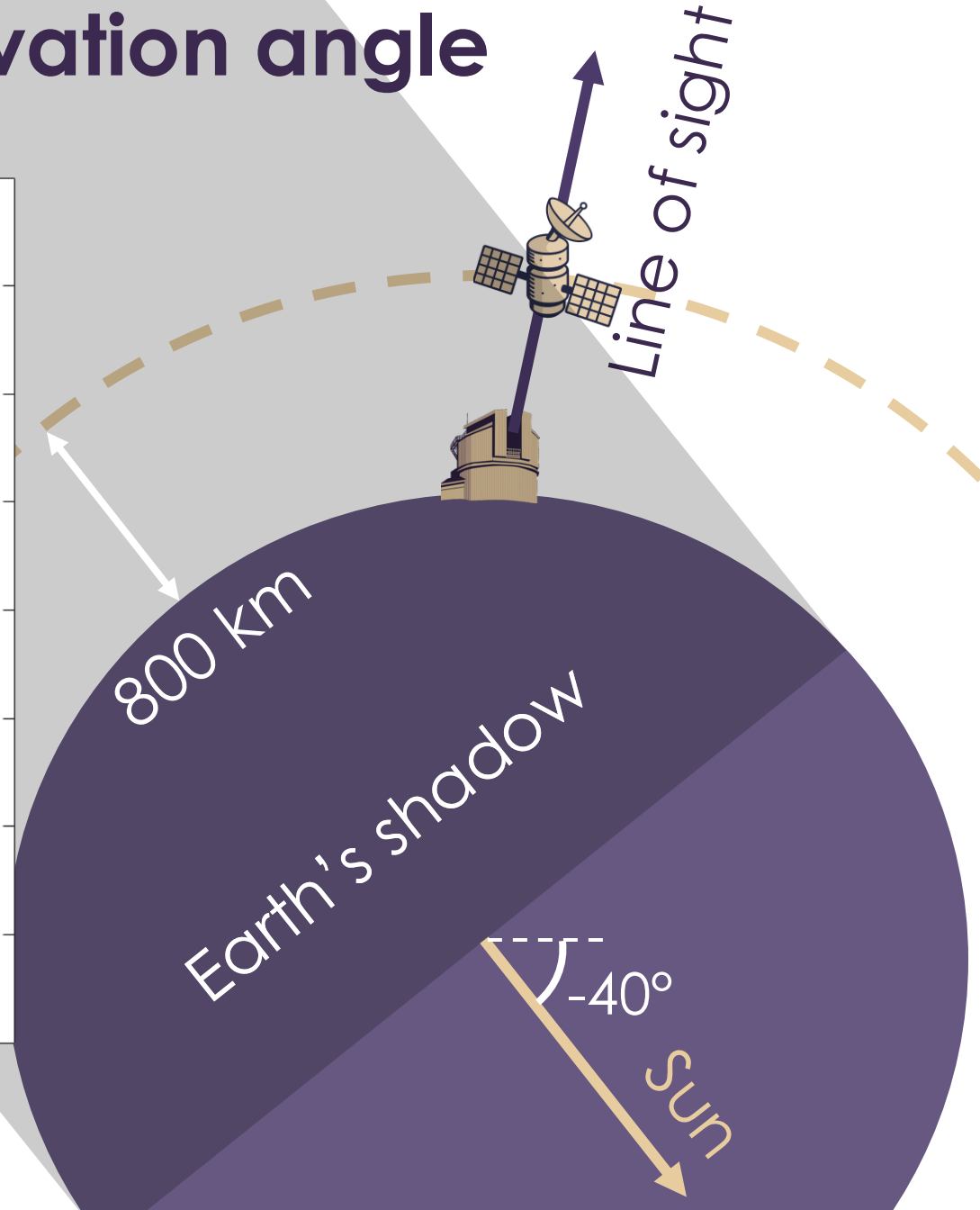

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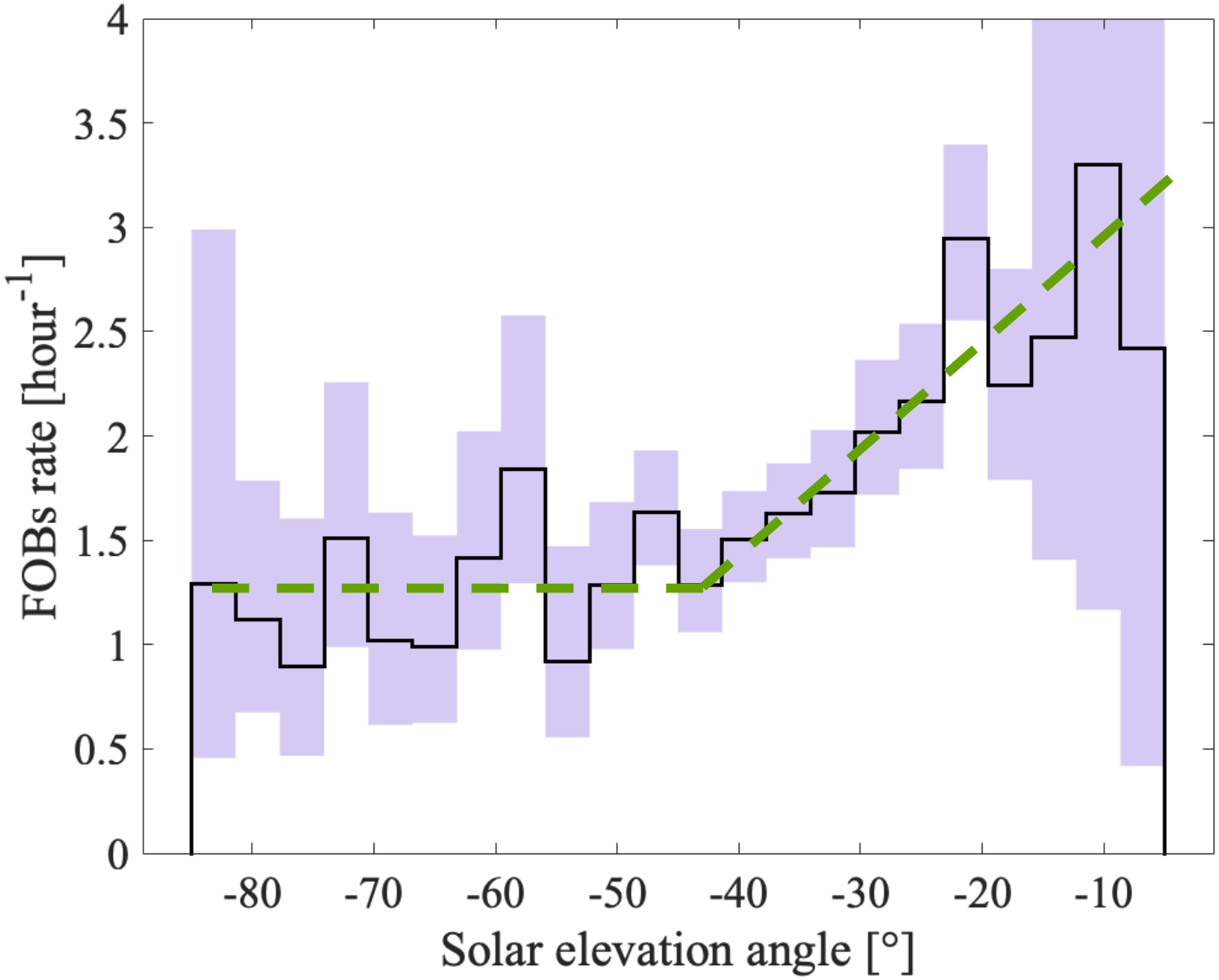
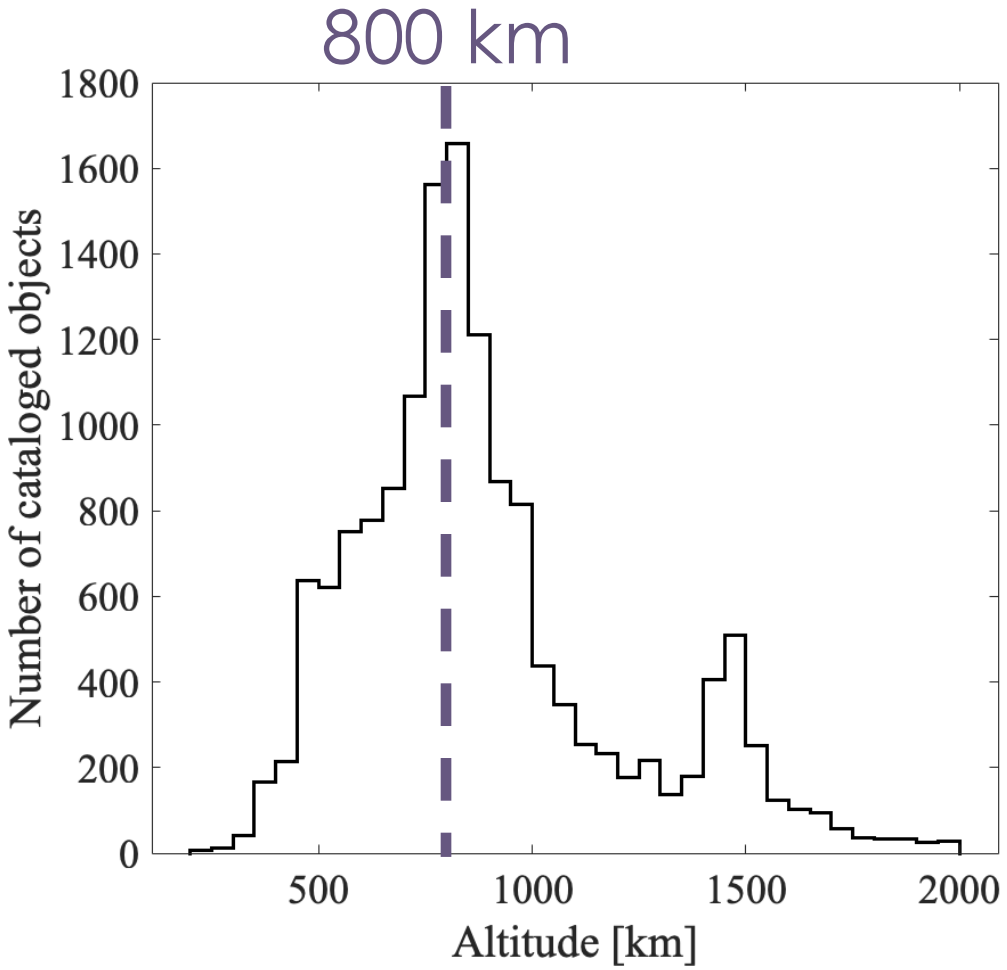
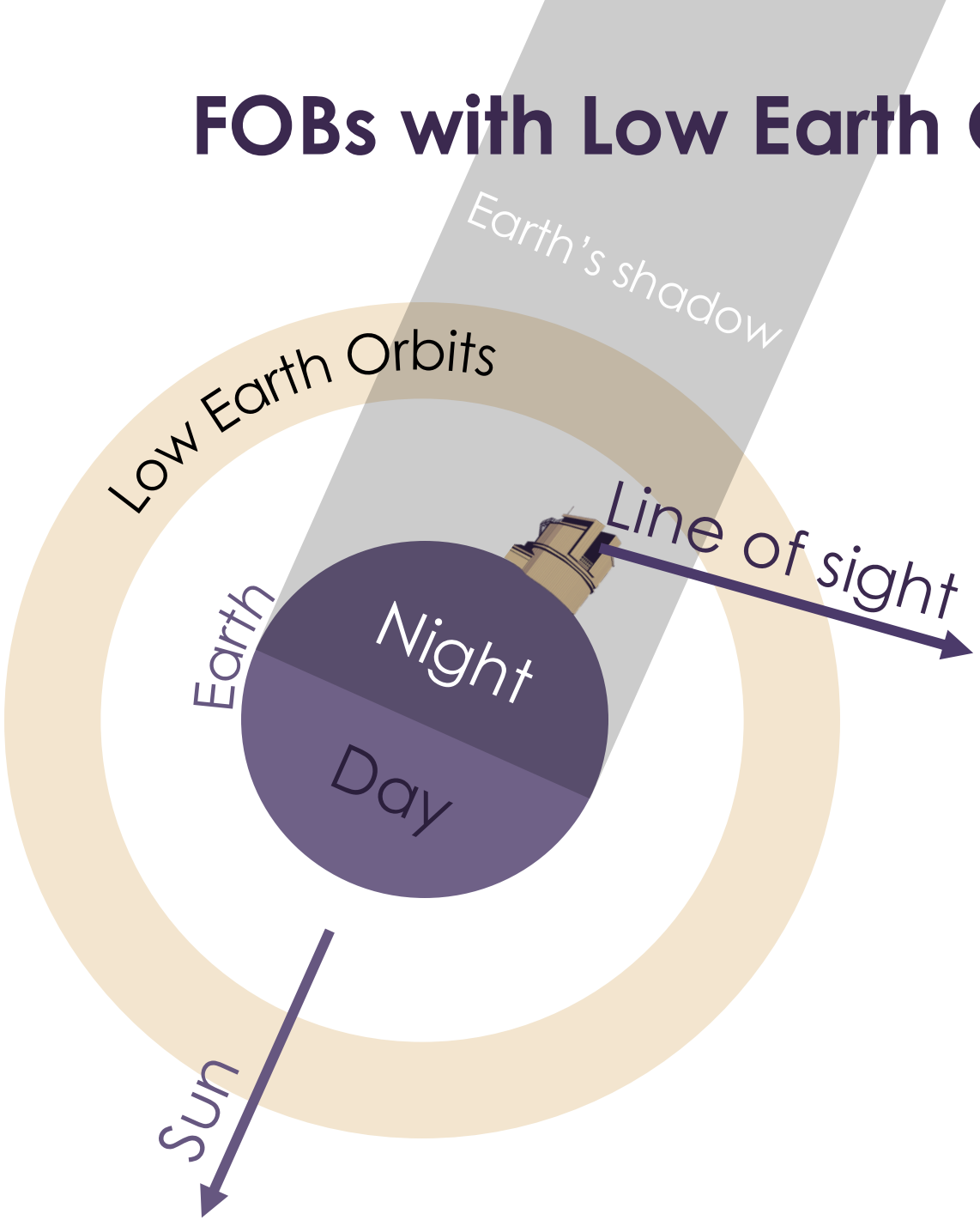
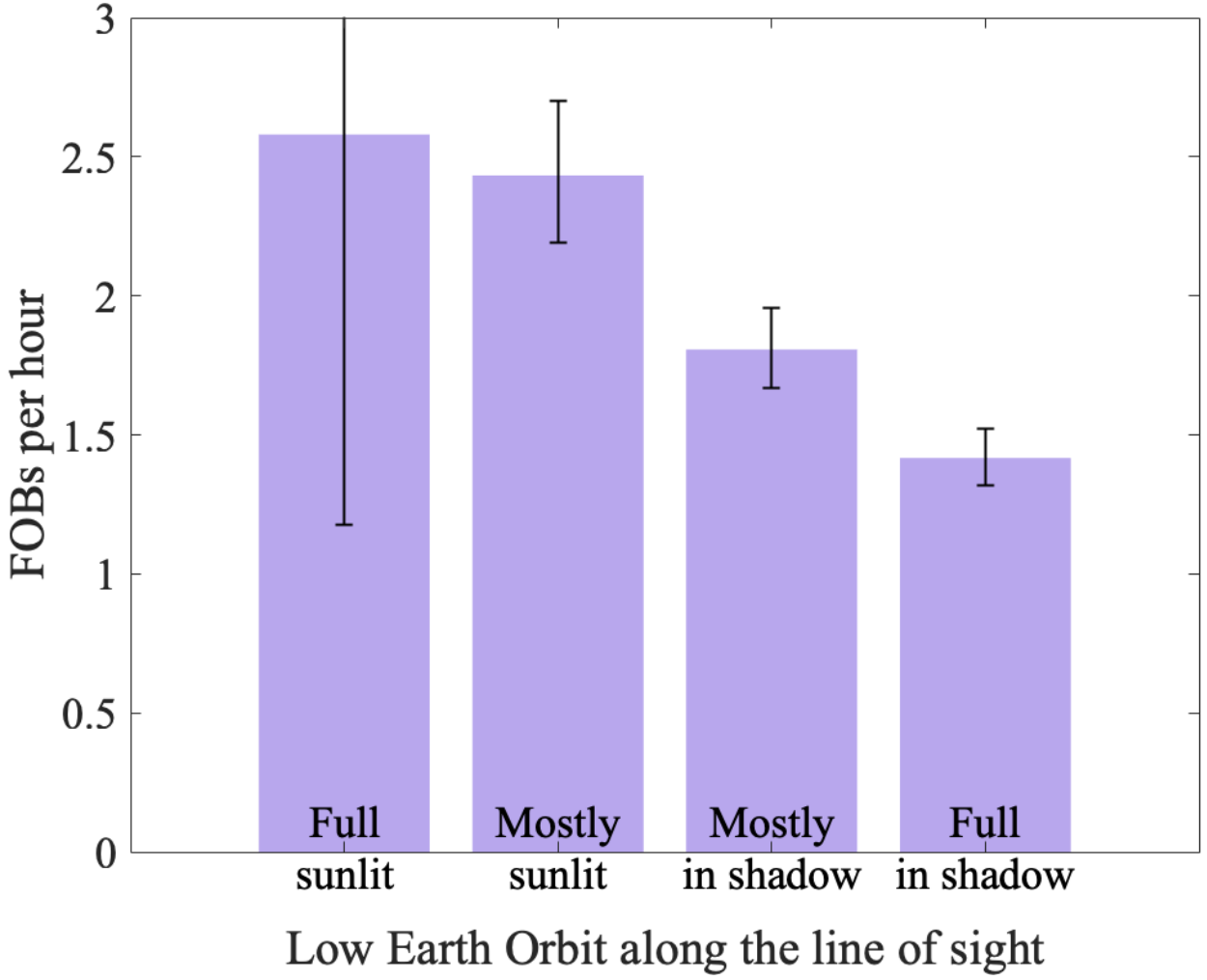




FOBs with Low Earth Orbits sunlight exposure





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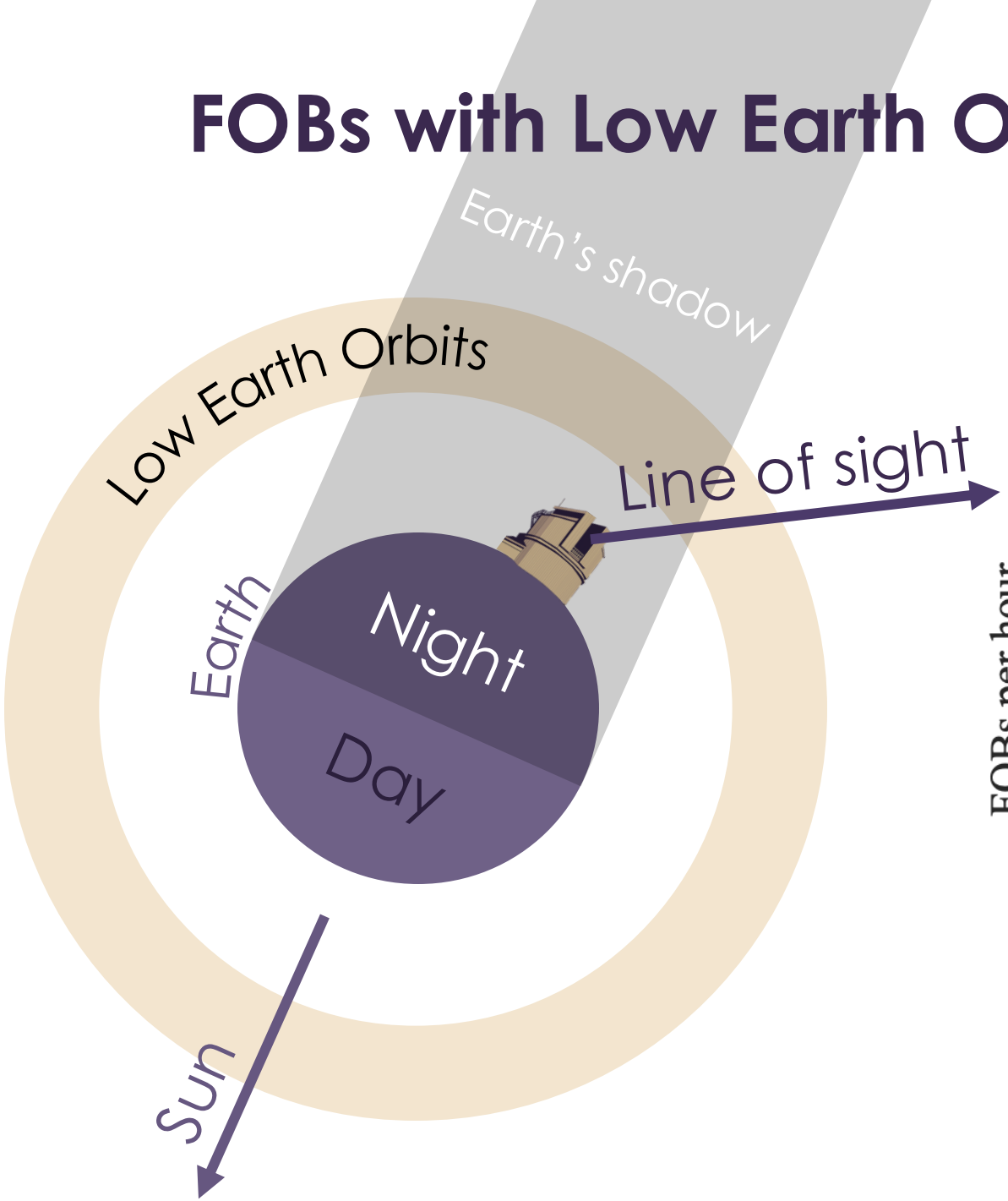

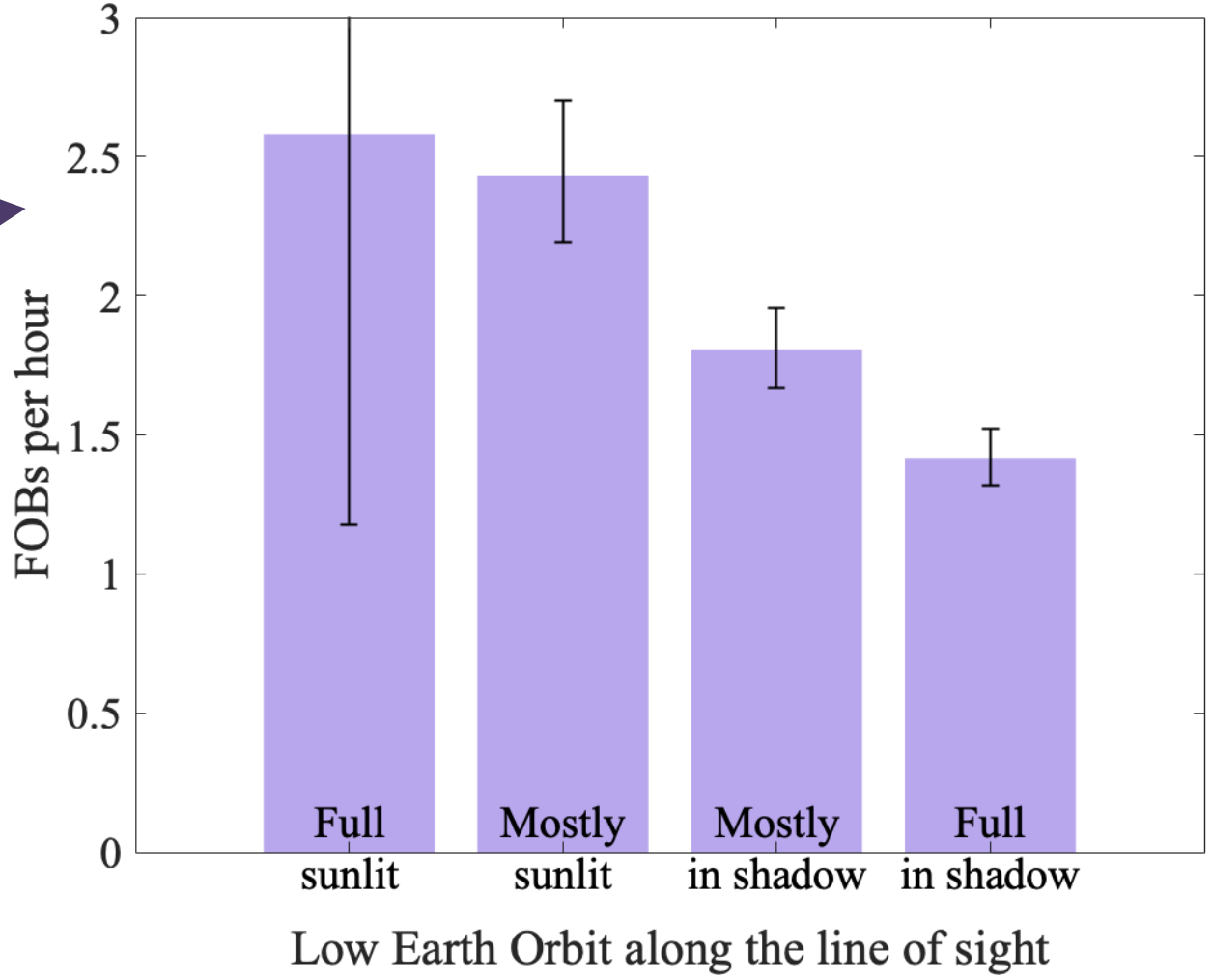

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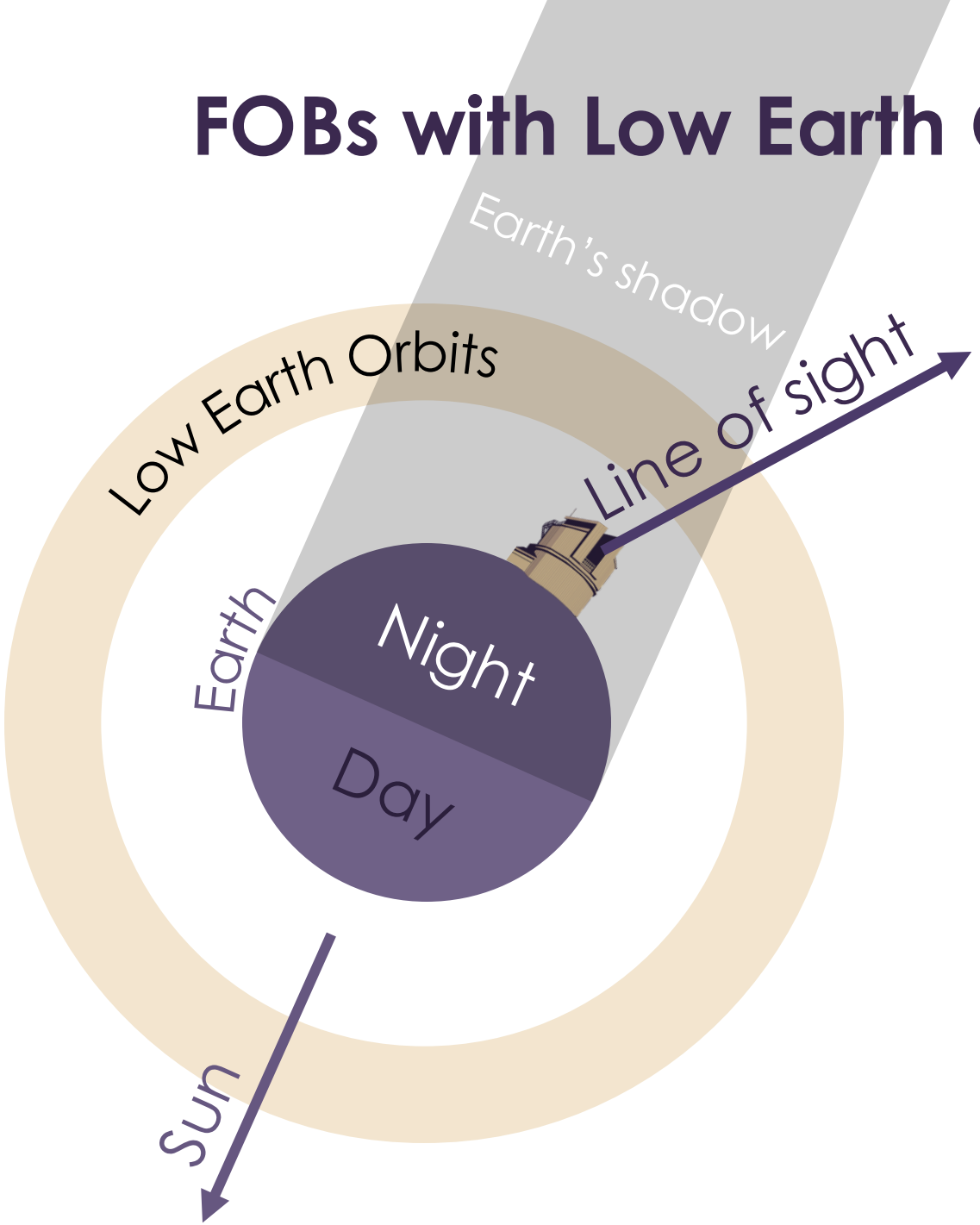

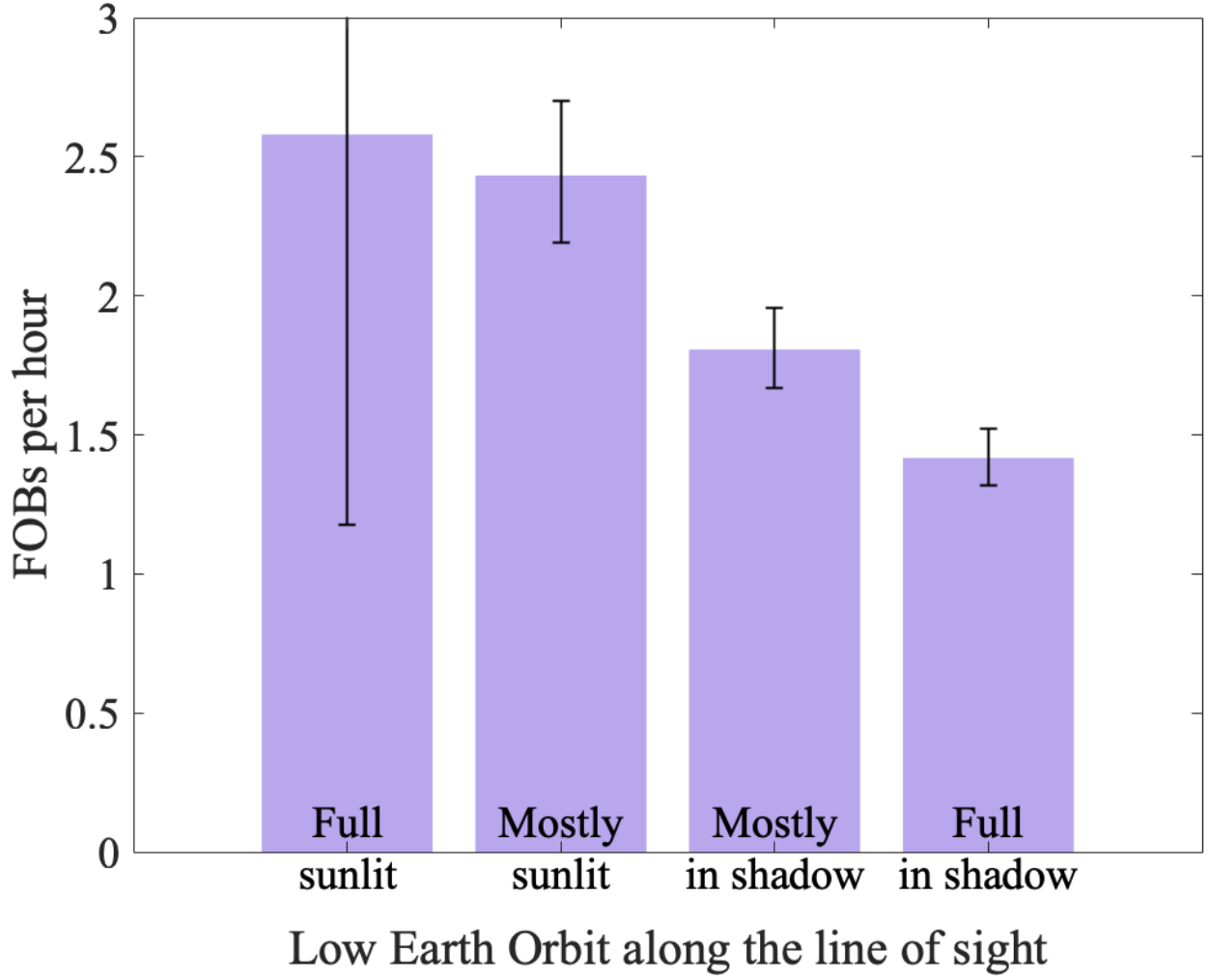

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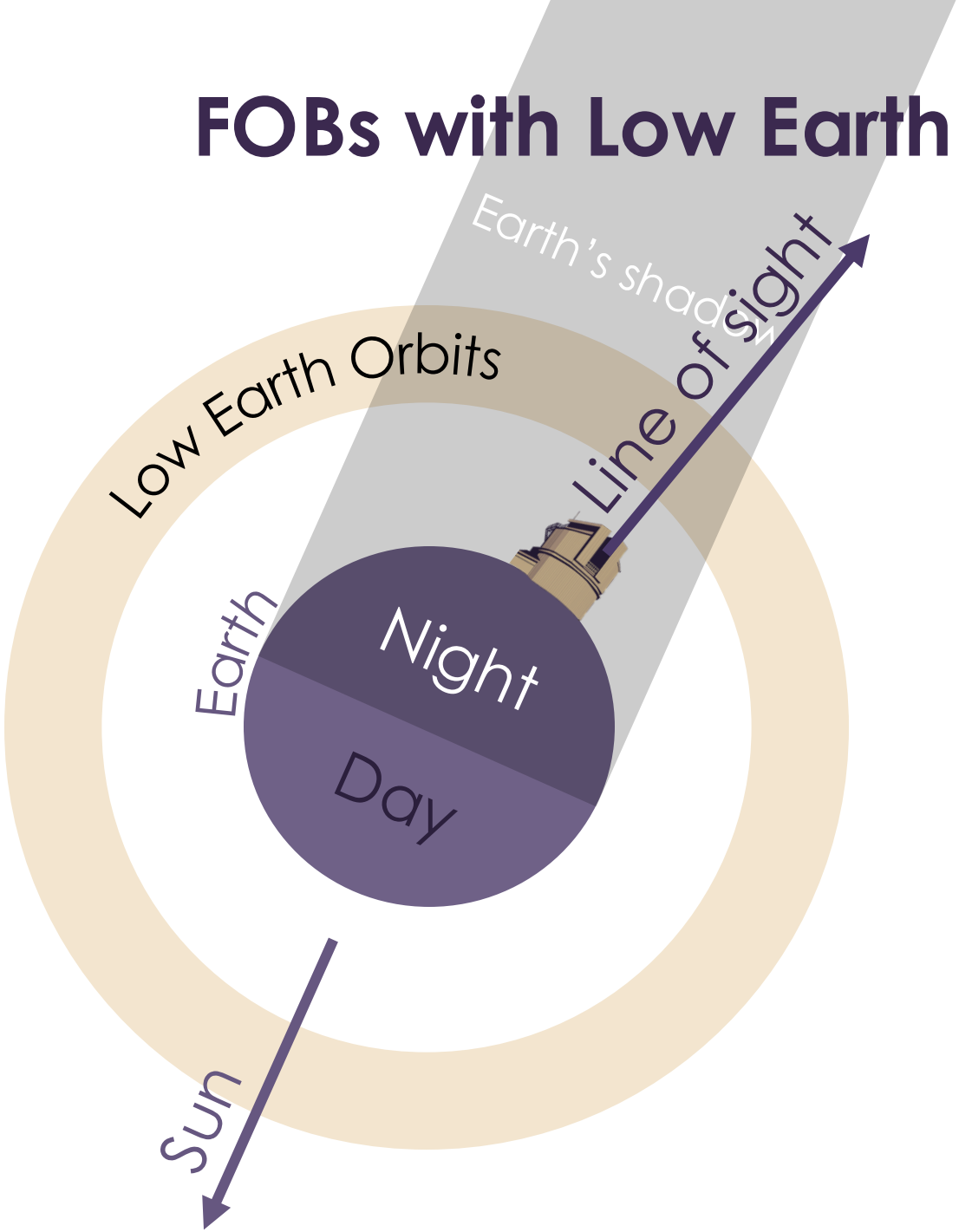
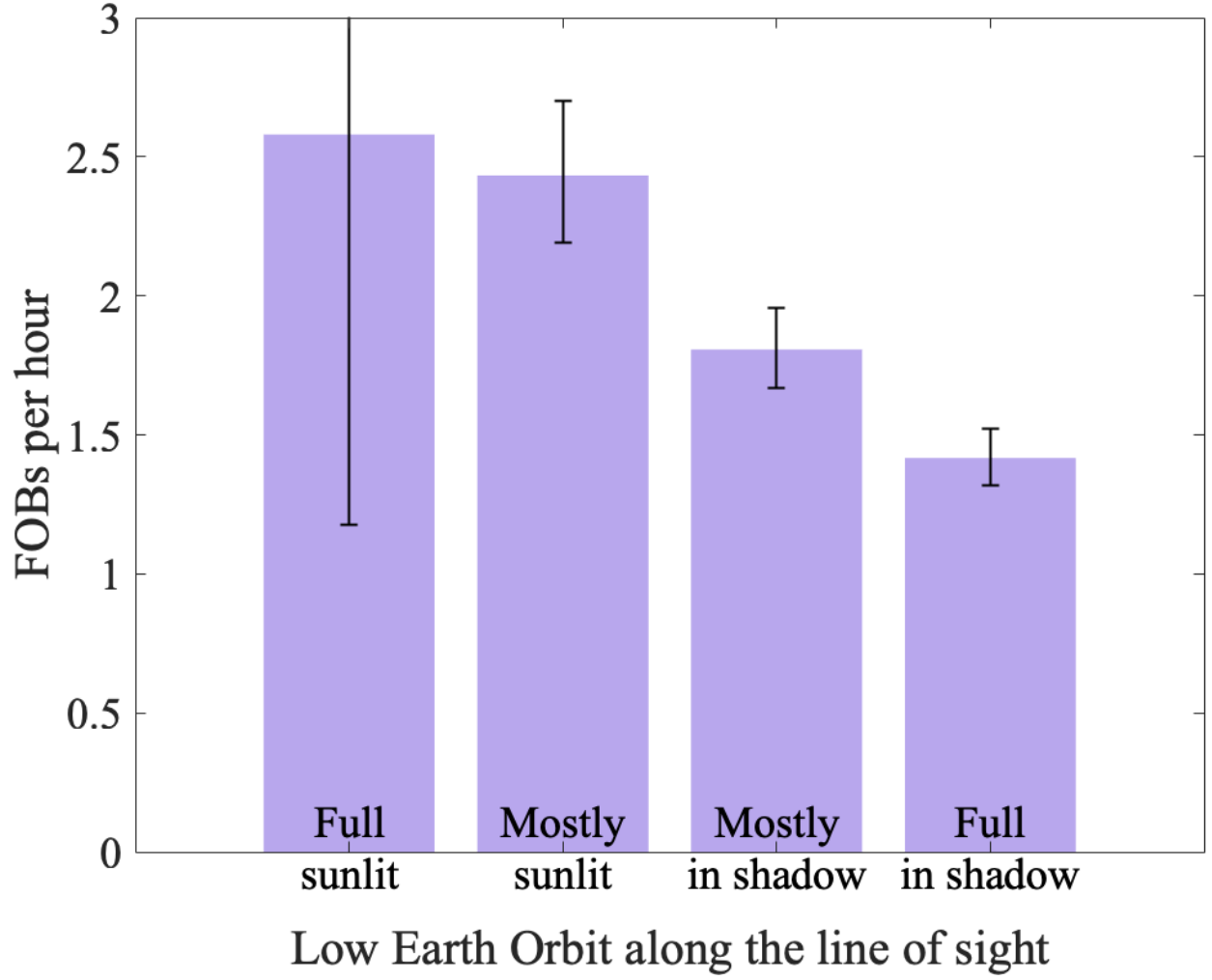
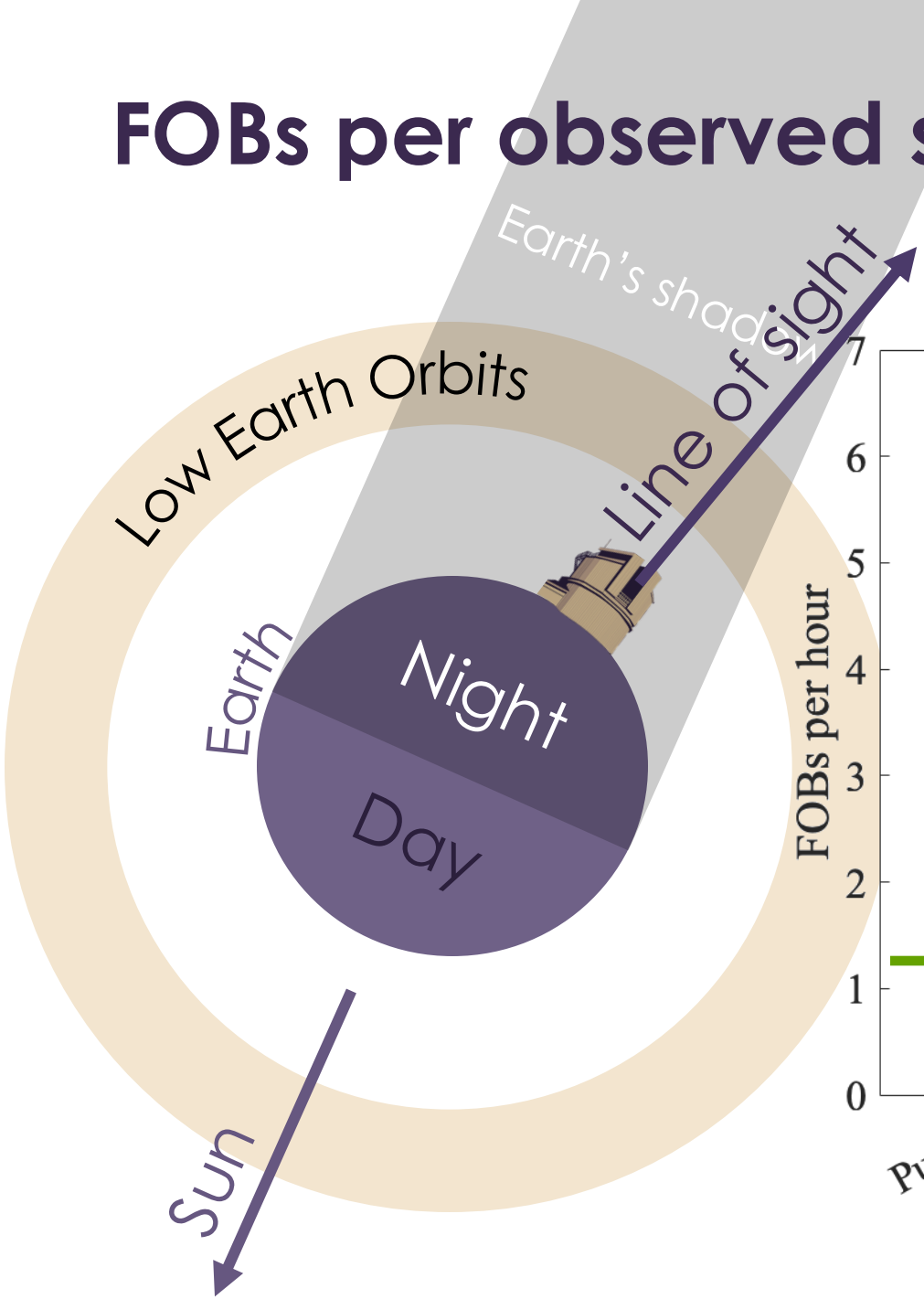
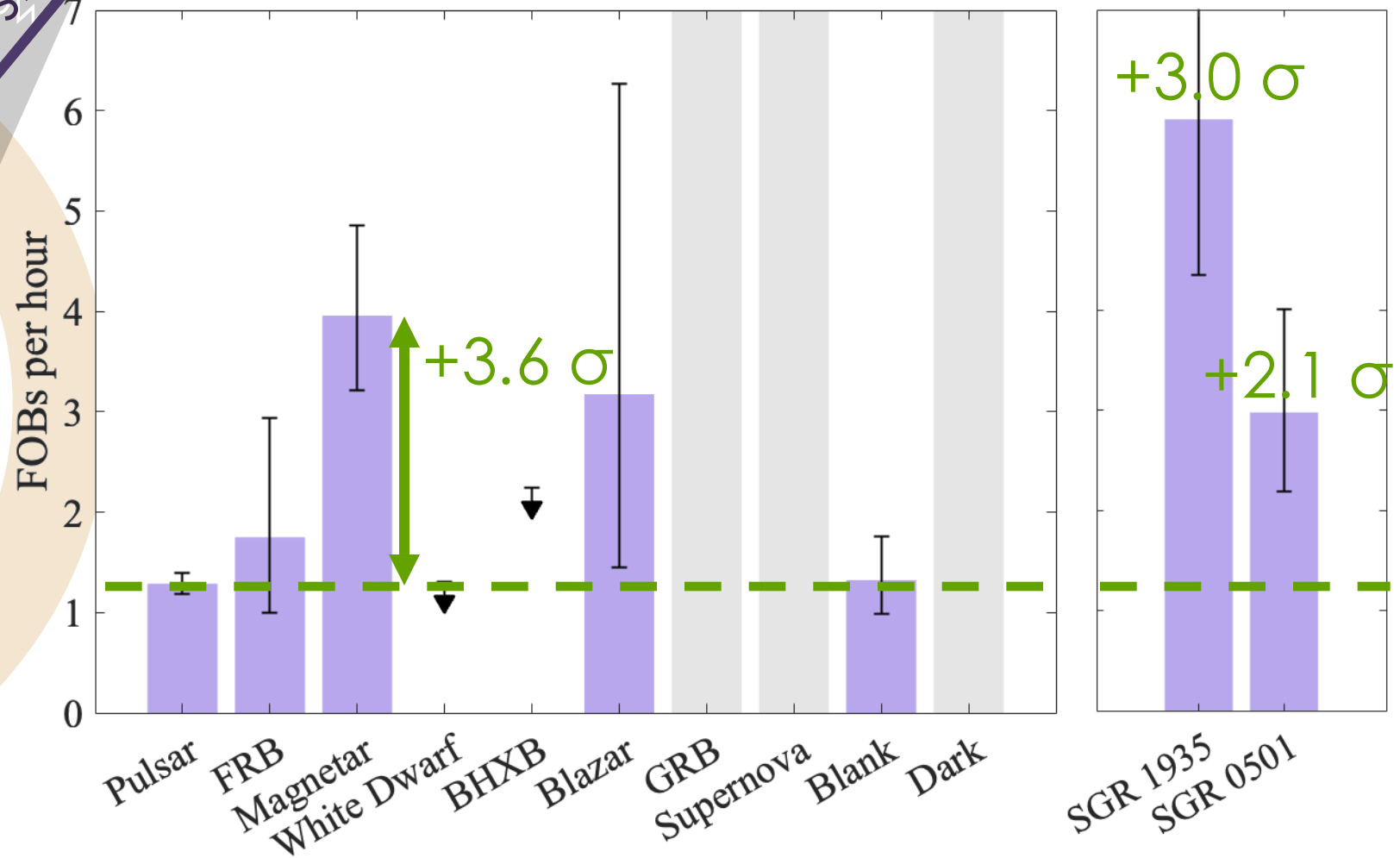




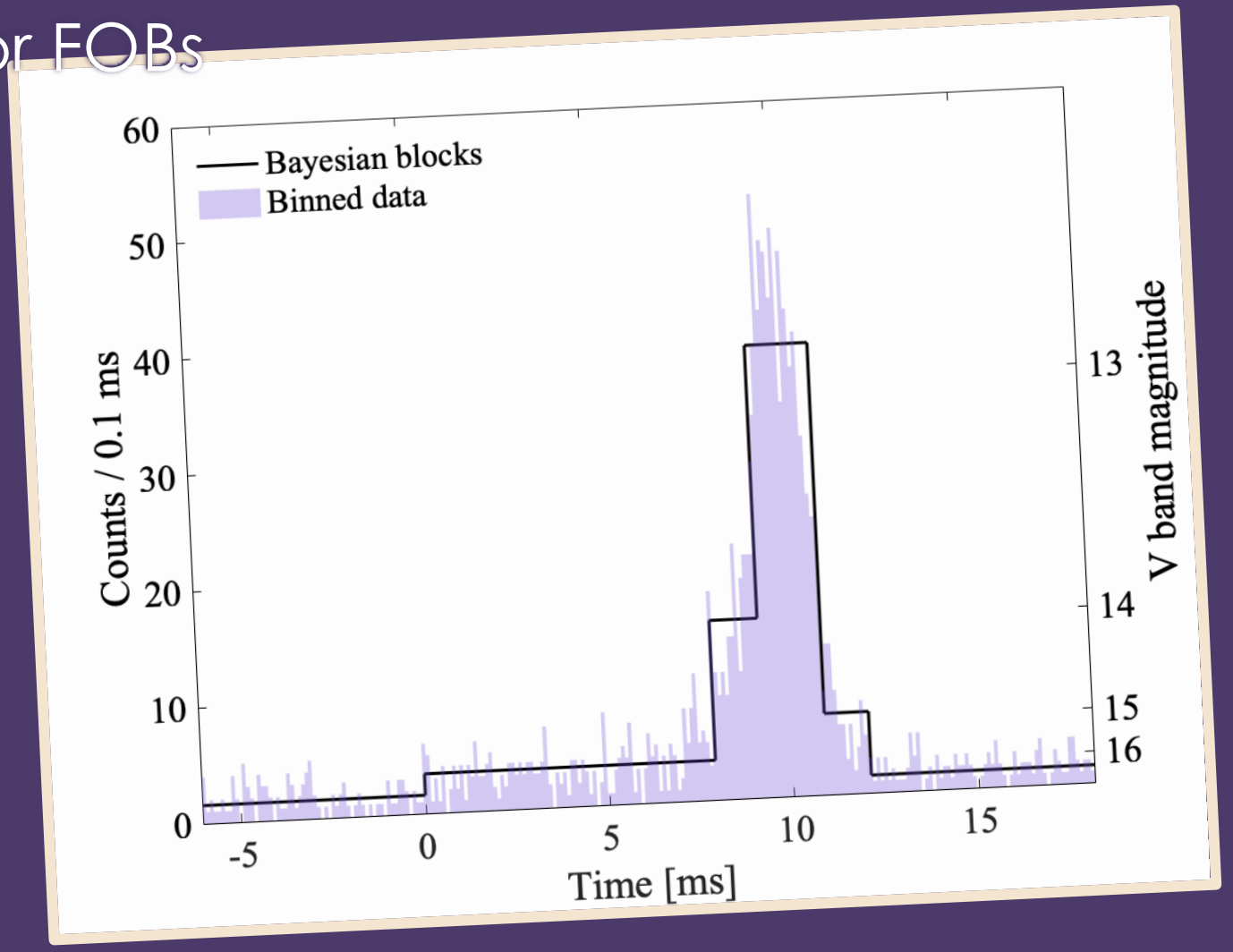
FOBs per observed source class (LEO in shadow)





Final recap

- Developed a modified Bayesian blocks algorithm to search for FOBs



Final recap

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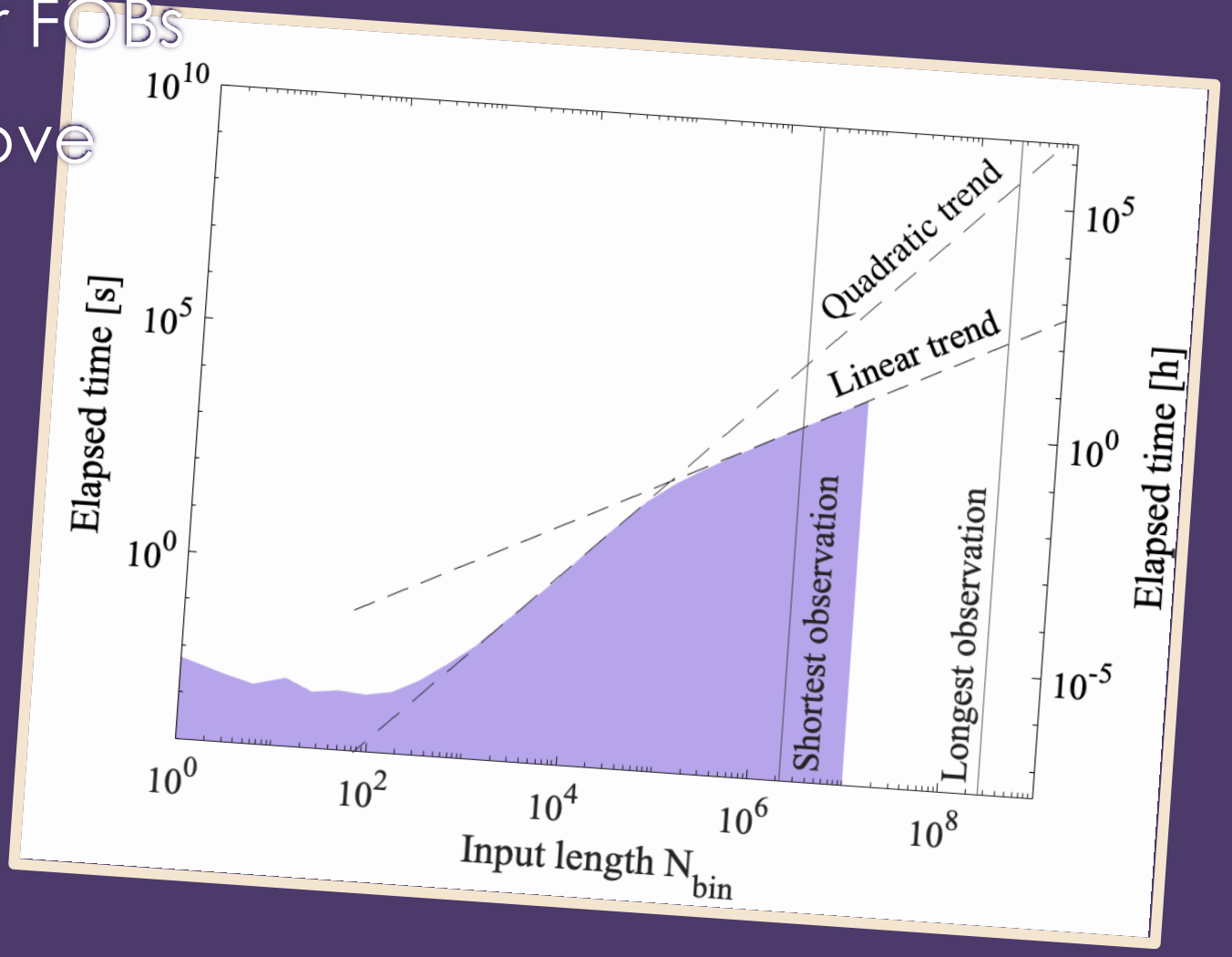
  - Linearized version to improve speed



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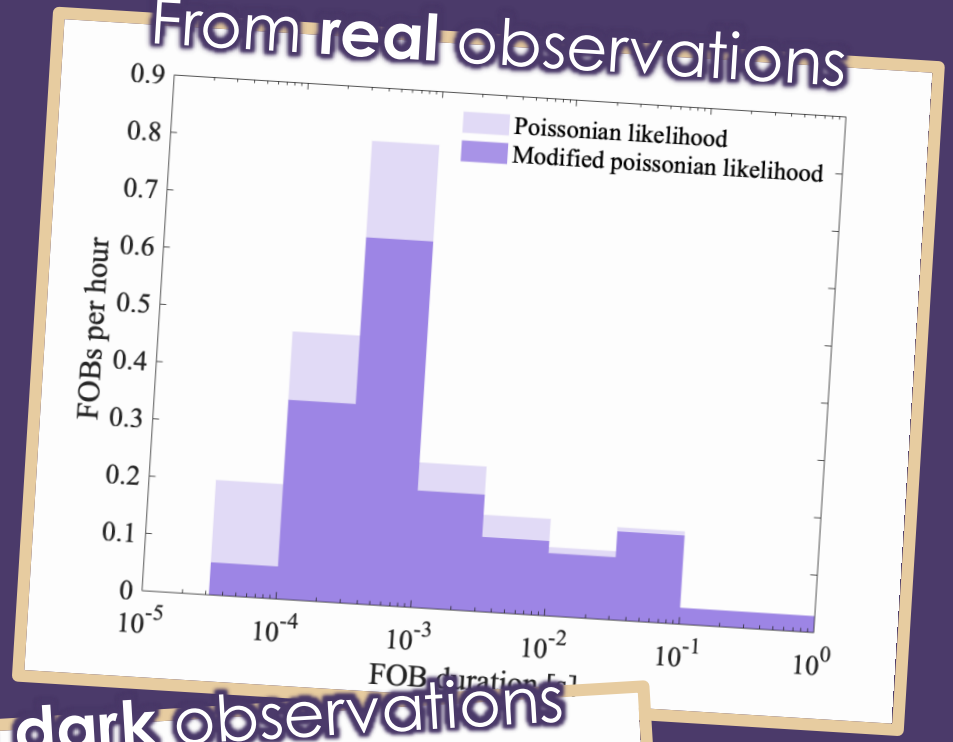
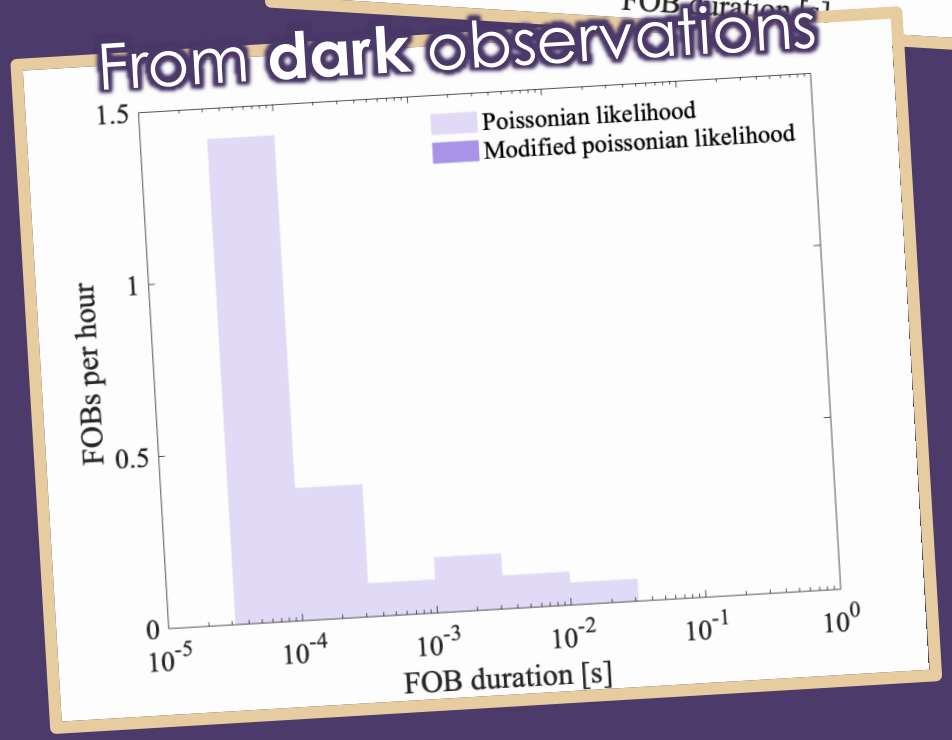
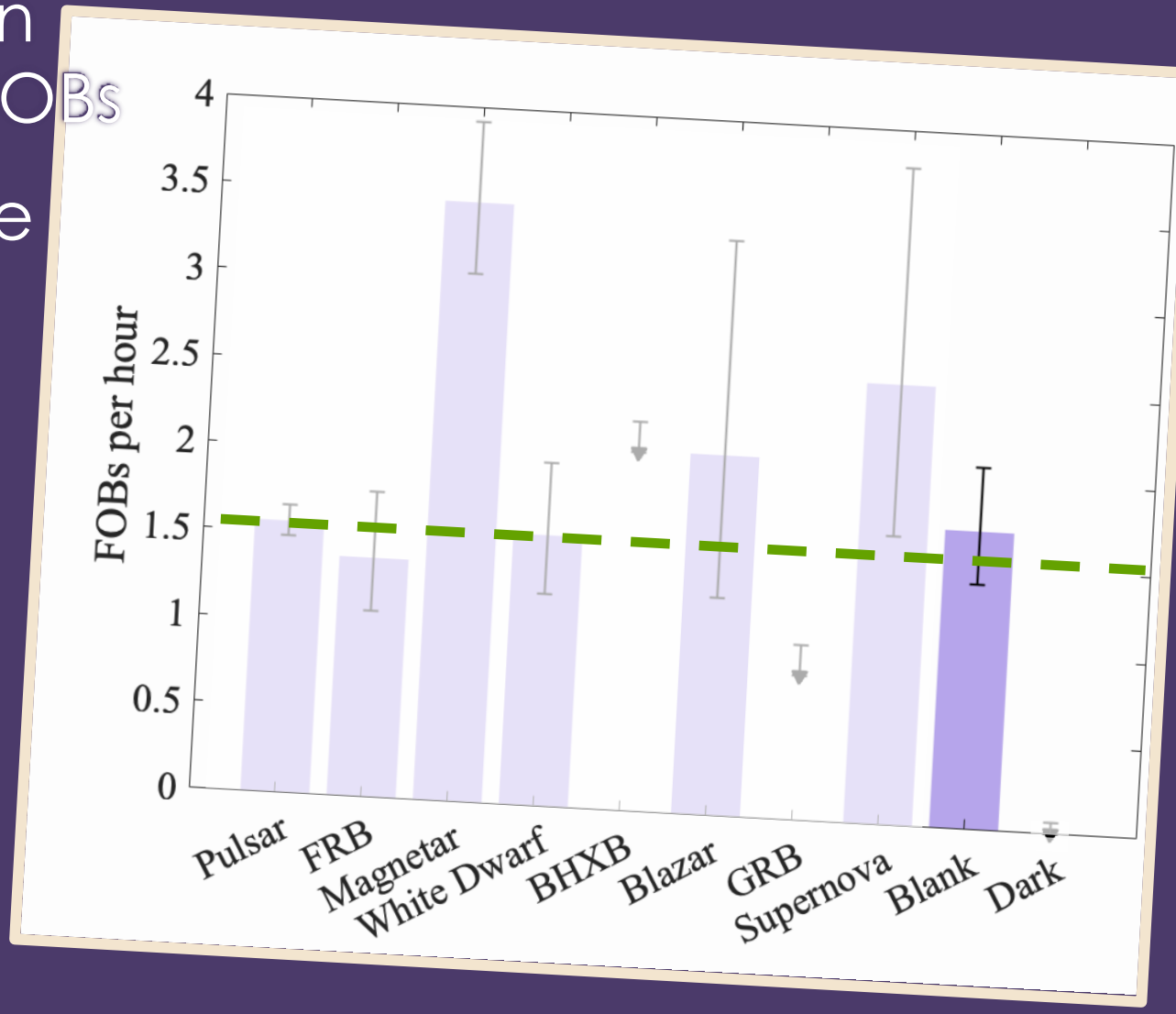
  - Poisson likelihood including Crosstalk correction





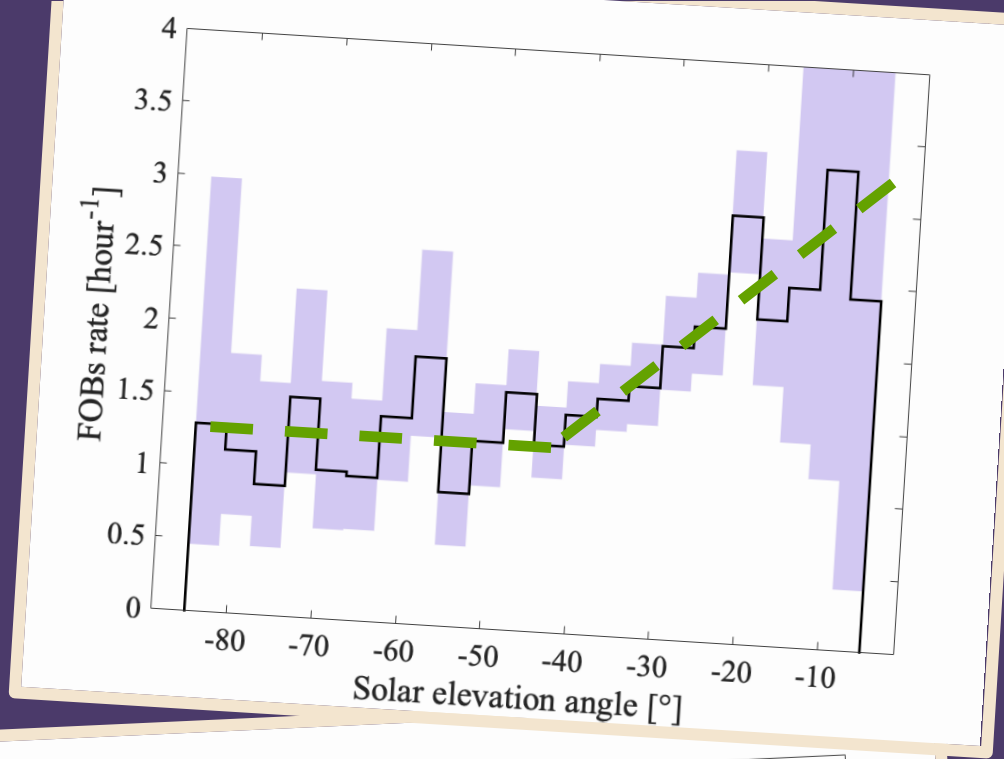
Final recap

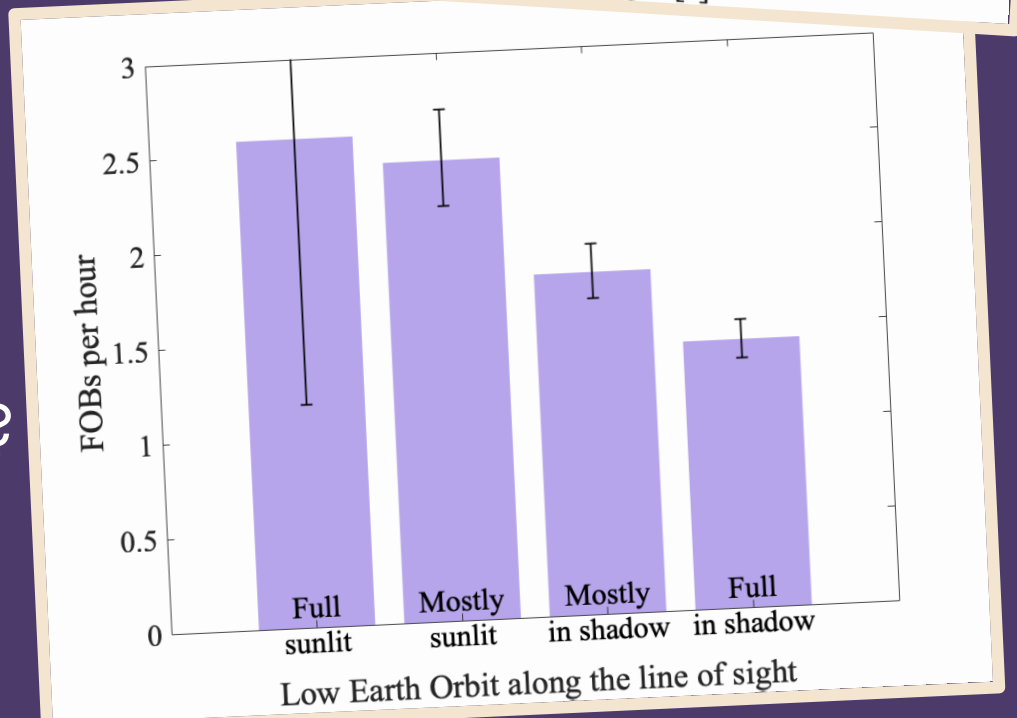
- Developed a modified Bayesian blocks algorithm to search for FOBs
  - Linearized version to improve speed
  - Poisson likelihood including Crosstalk correction
- Most FOBs does not originate from the targeted source



Final recap

- Developed a modified Bayesian blocks algorithm to search for FOBs
  - Linearized version to improve speed
  - Poisson likelihood including Crosstalk correction
- Most FOBs does not originate from the targeted source
  - Sunlight reflection of object in LEO?





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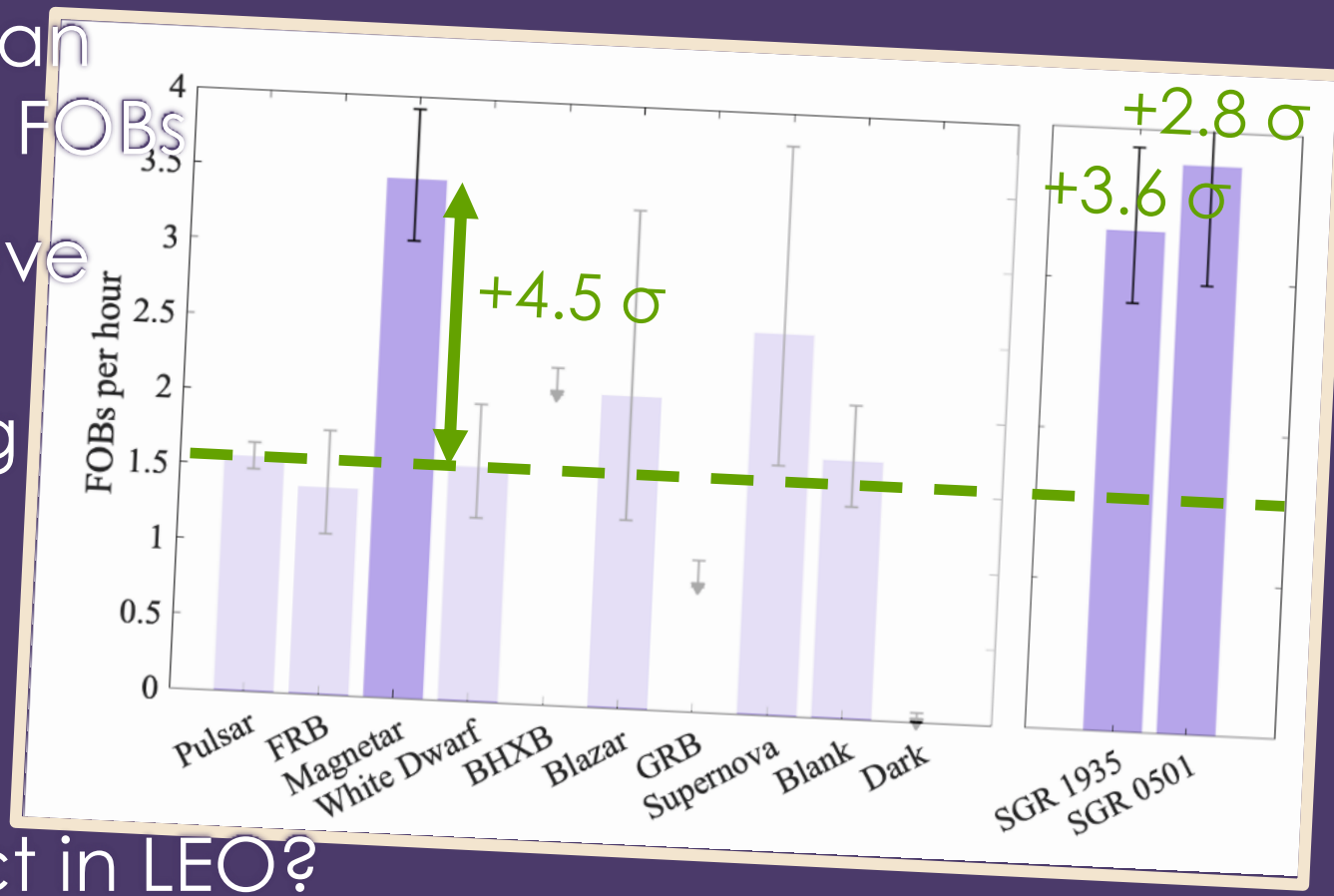
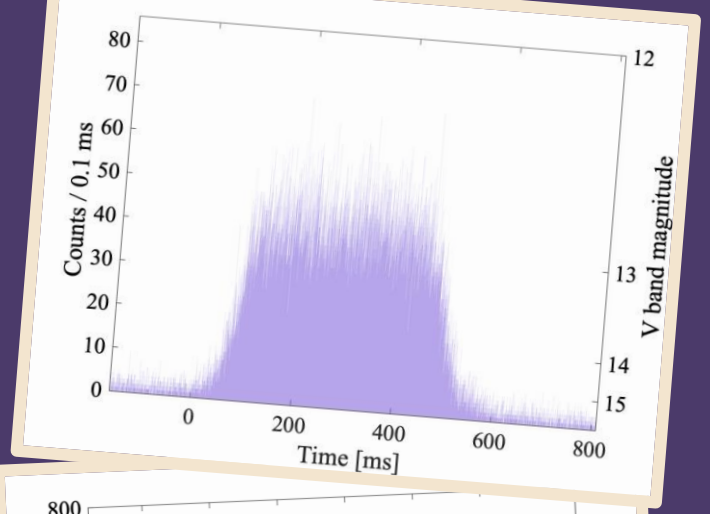
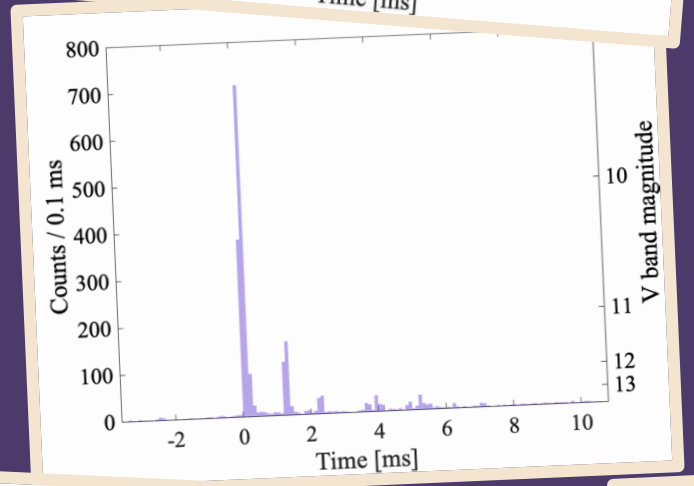
  - Linearized version to improve speed
  - Poisson likelihood including Crosstalk correction
- Most FOBs does not originate from the targeted source
  - Sunlight reflection of object in LEO?
- Excess from the directions of the magnetars

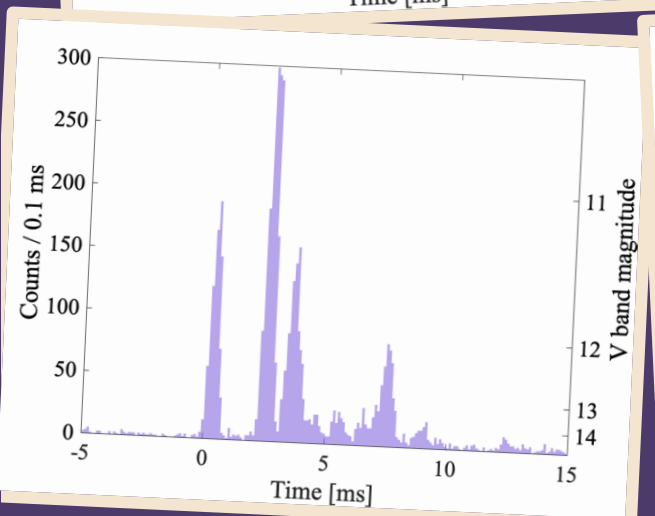


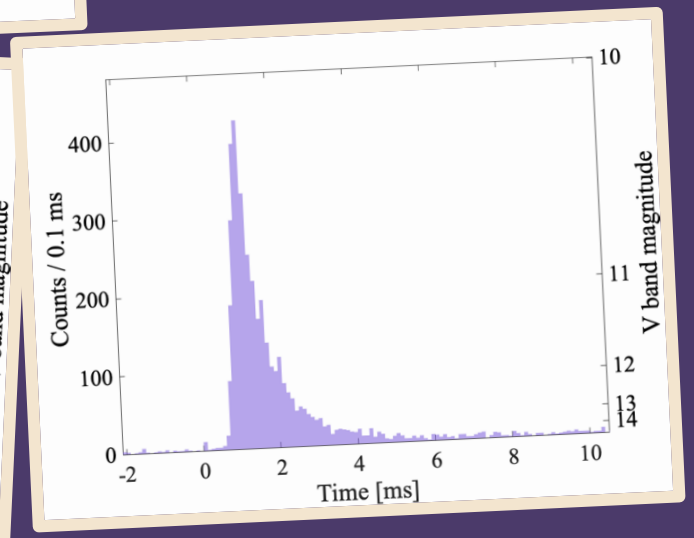
Future steps

- Morphology analysis of bursts, starting with simmetry

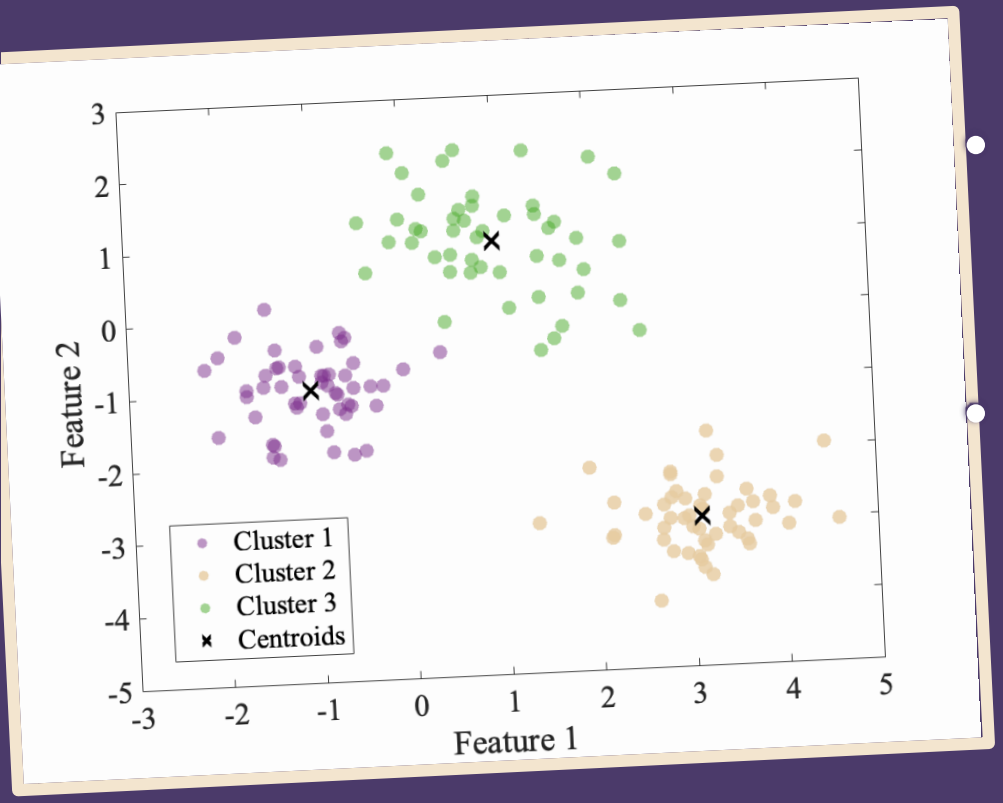




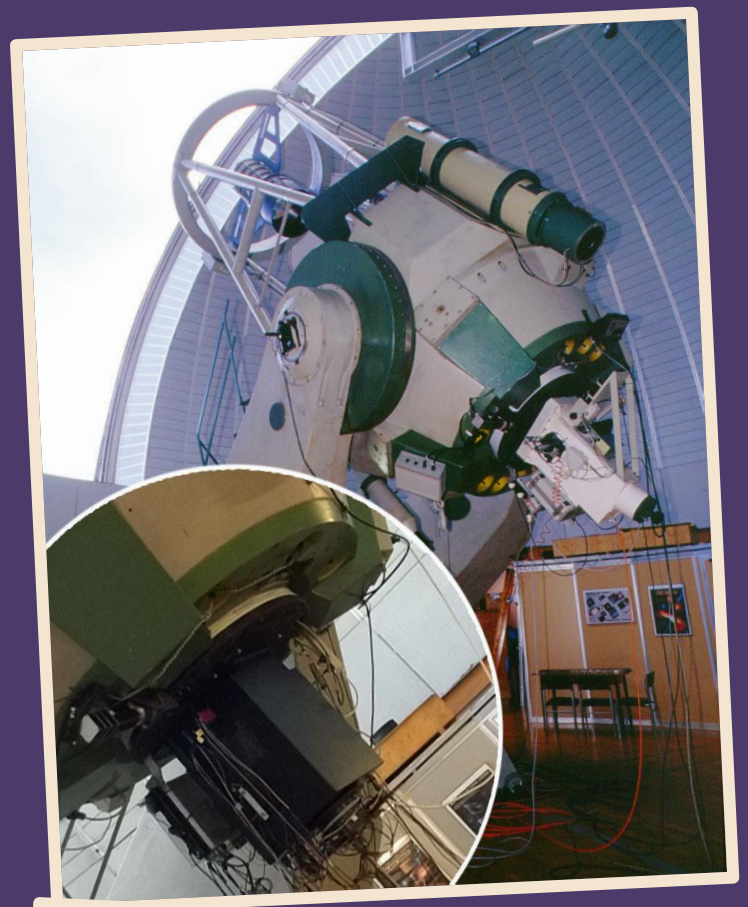




Future steps



- Morphology analysis of bursts, starting with simmetry
- Unsupervised machine learning for clustering



Future steps

- Morphology analysis of bursts, starting with simmetry
- Unsupervised machine learning for clustering
- Simultaneous observations with optical and multi-wavelength facilities