EXPLORING PULSAR PROFILES AT POPULATION SCALE FROM A GRAPH THEORY PERSPECTIVE

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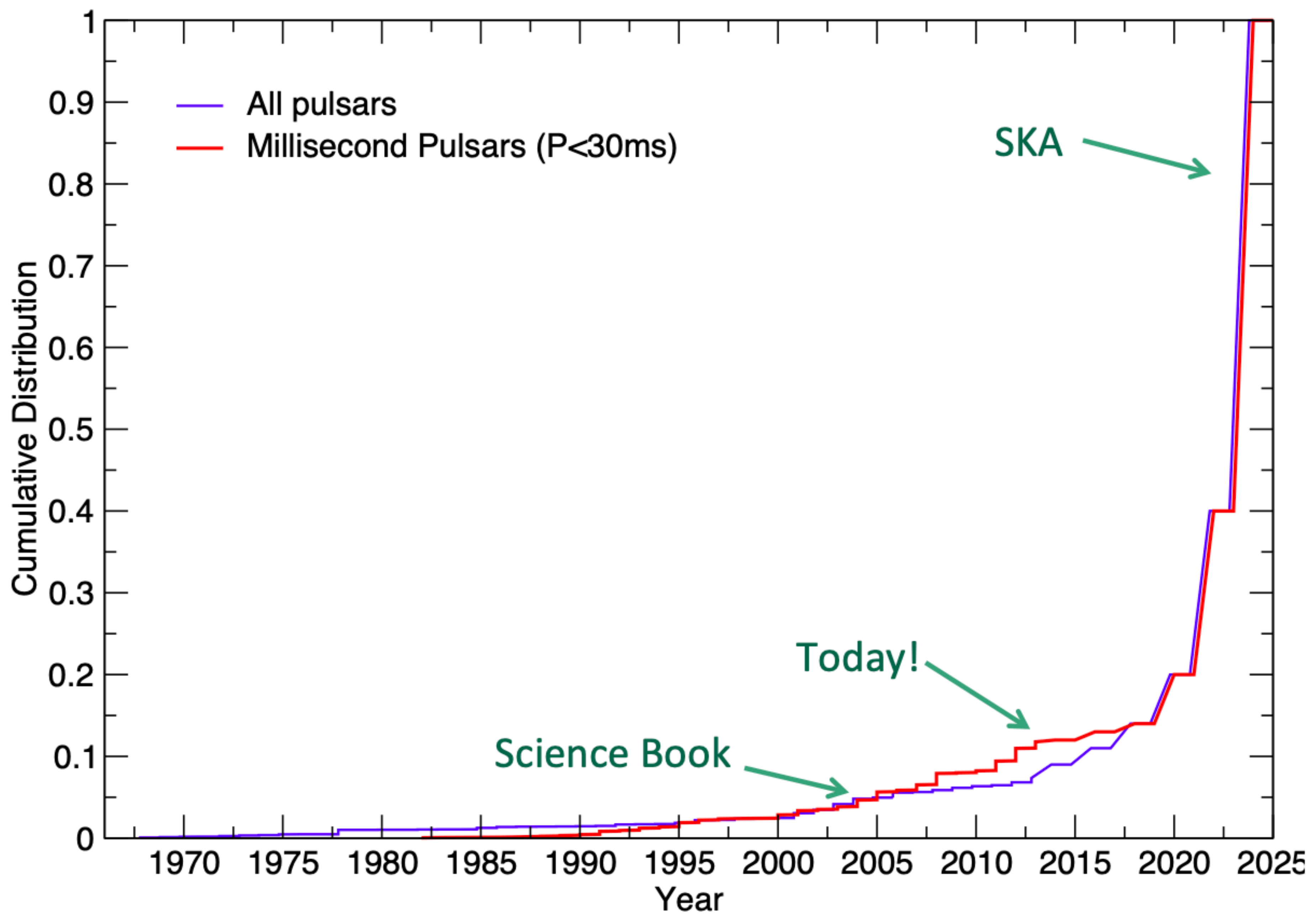
SKA 2021 · 18 MARCH 2021

ASTRON

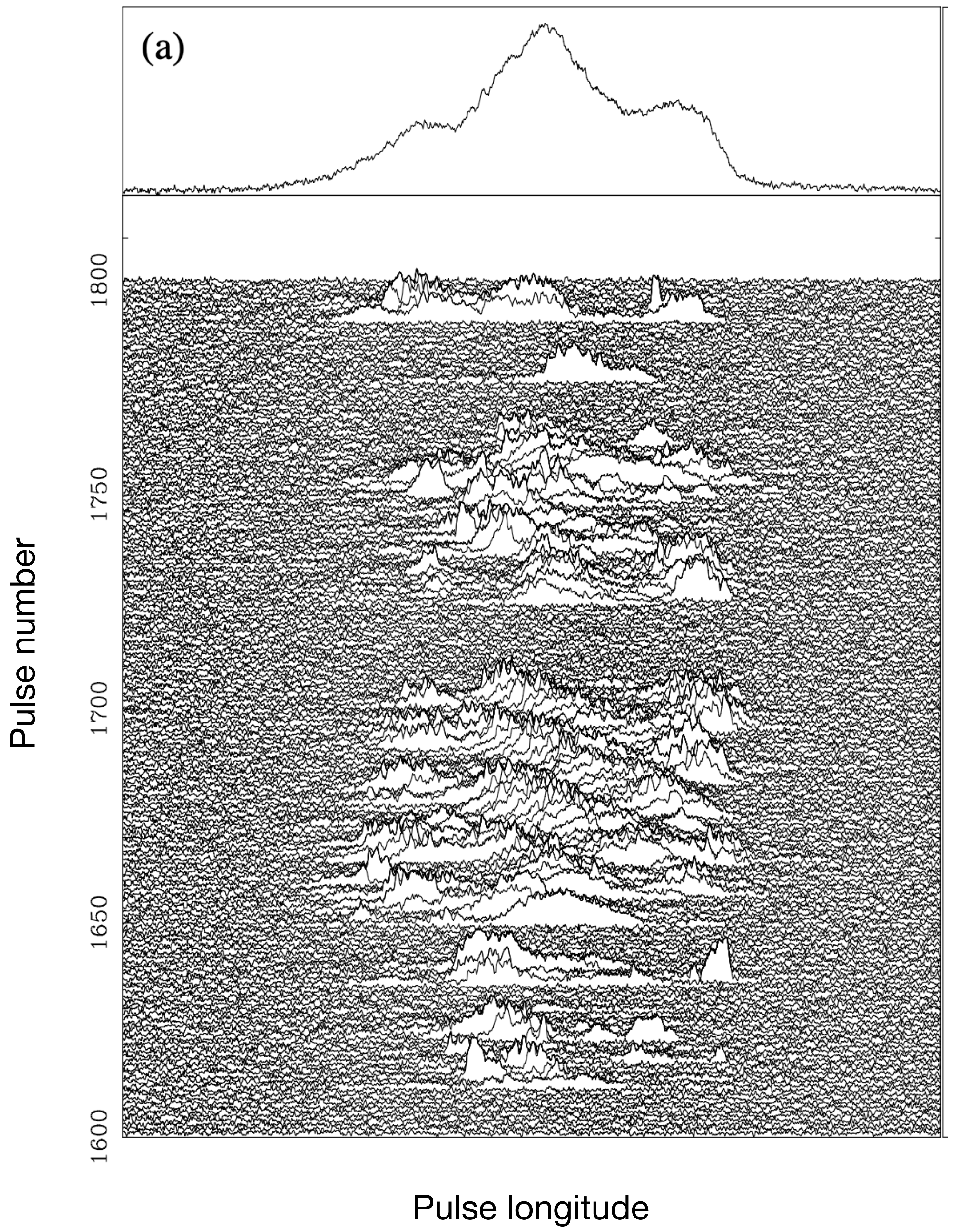
Pulsar science with the SKA

- Known population (~2,900) expected to increase with full SKA by more than 10-fold (good fraction expected during phase I)
- Broadband coverage SKA-Mid & -Low, polarization
- Evaluate/develop automated methods requiring little to no human intervention
- Here, status of an on-going project to explore the task of automatically sequencing profiles



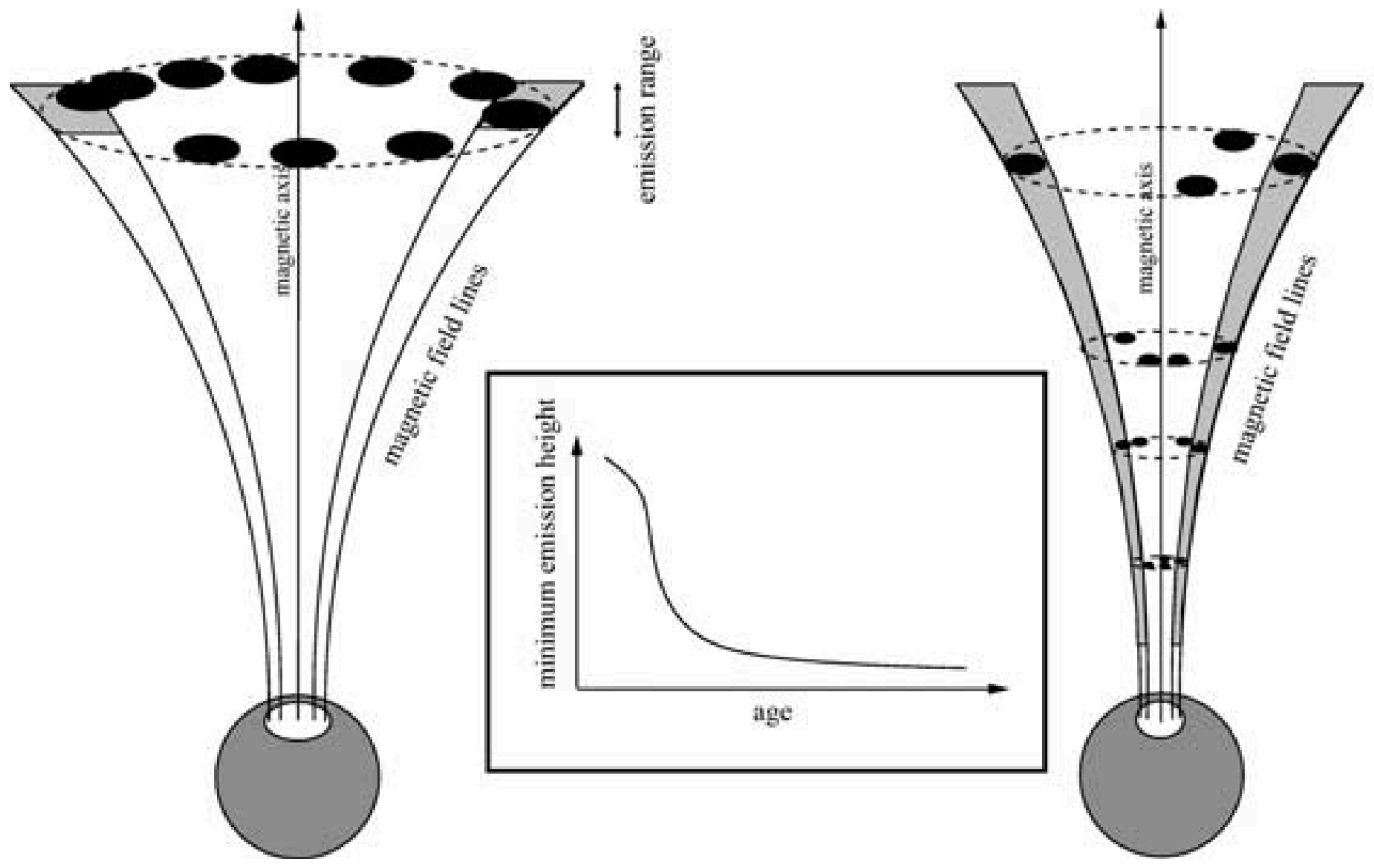
Kramer & Stappers (2015)

Pulse profile

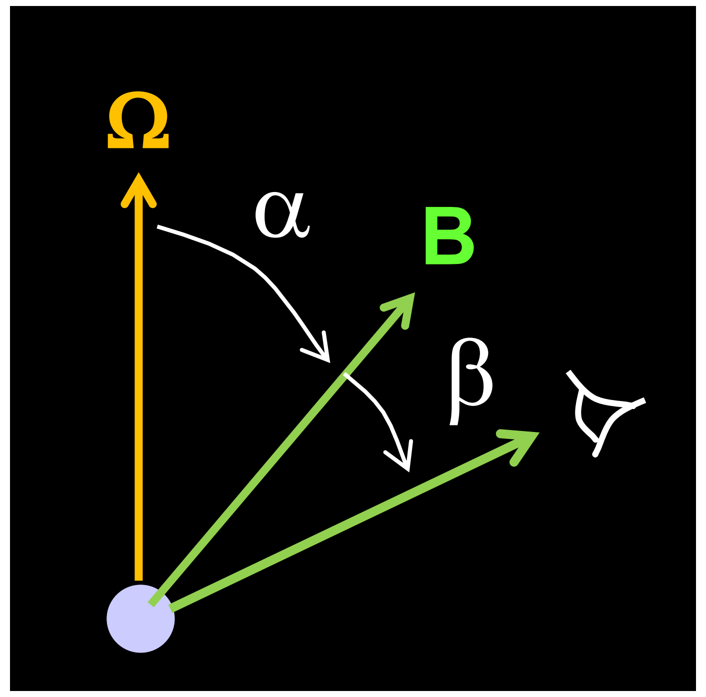


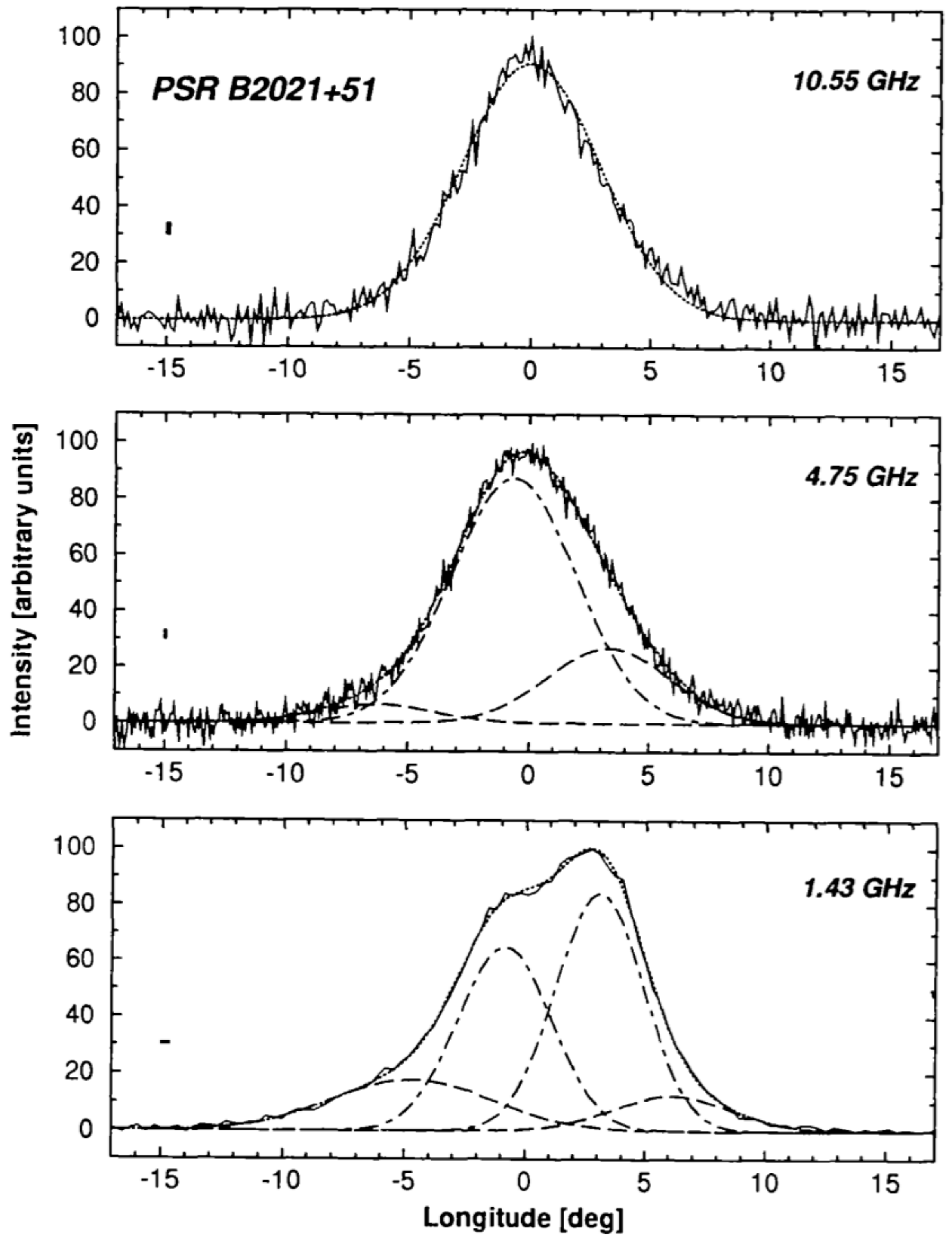
Lorimer & Kramer (2005)

Magnetosphere and geometry

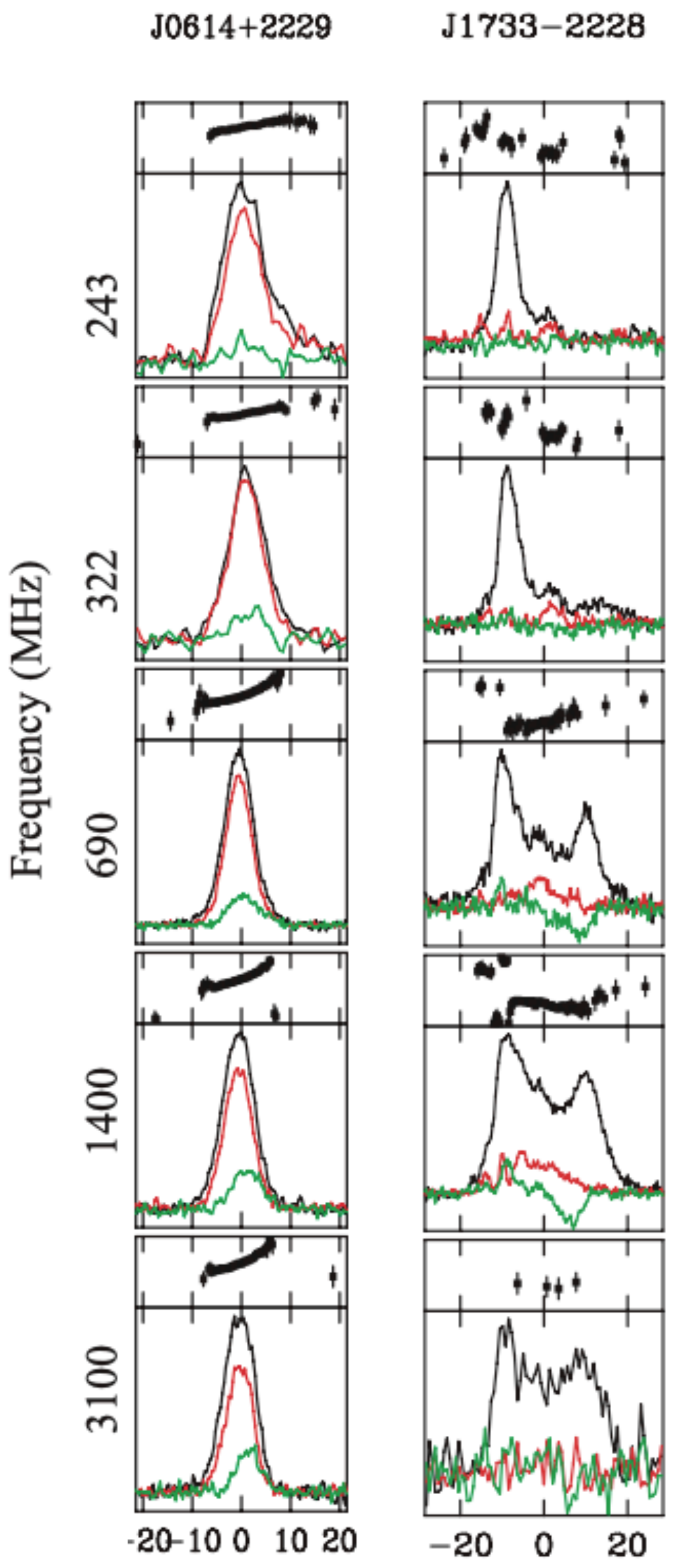


Karastergiou & Johnston (2007)





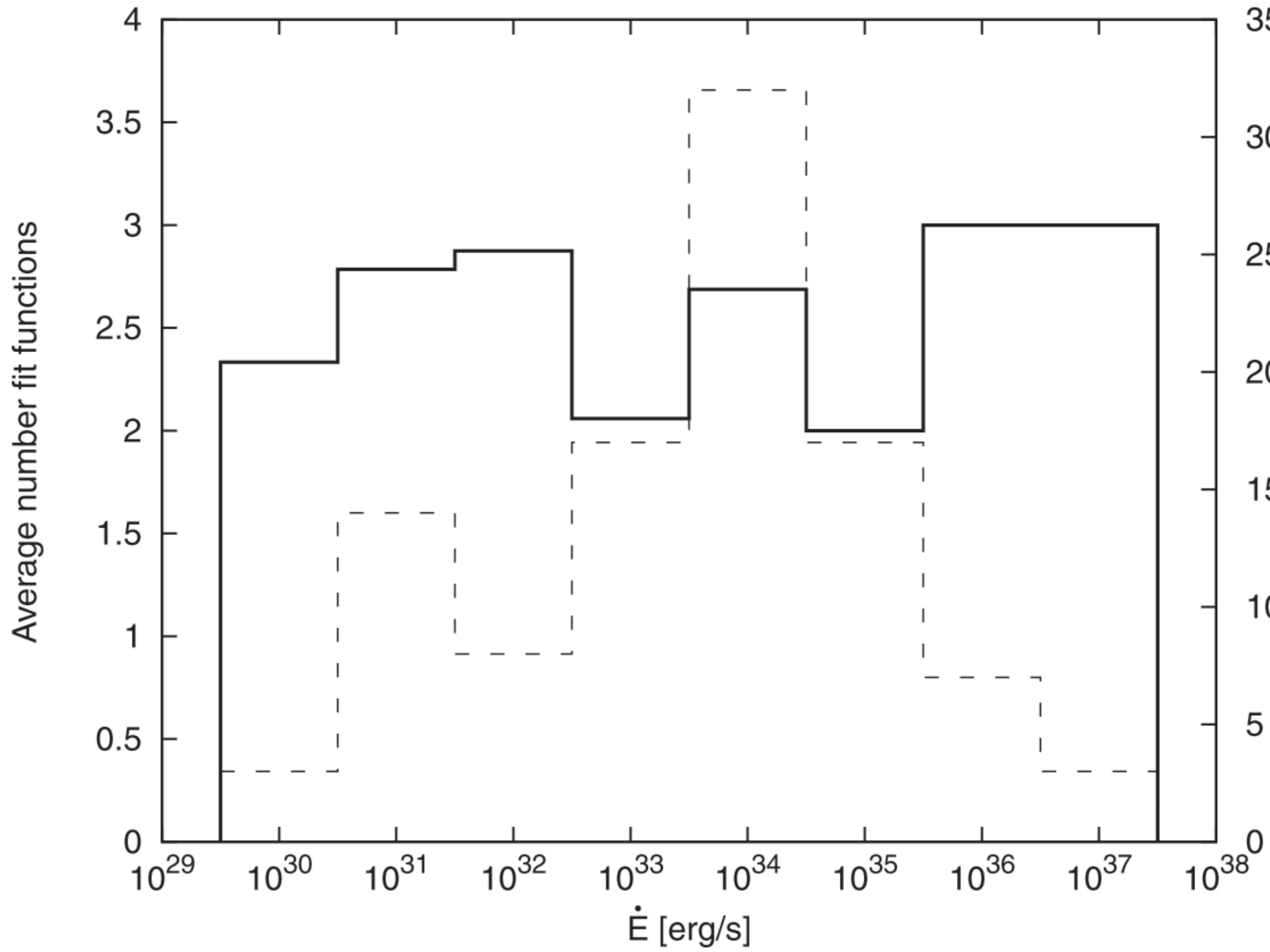
Kramer (1994)



Johnston *et al.* (2008)

Linking geometry to pulsar identity

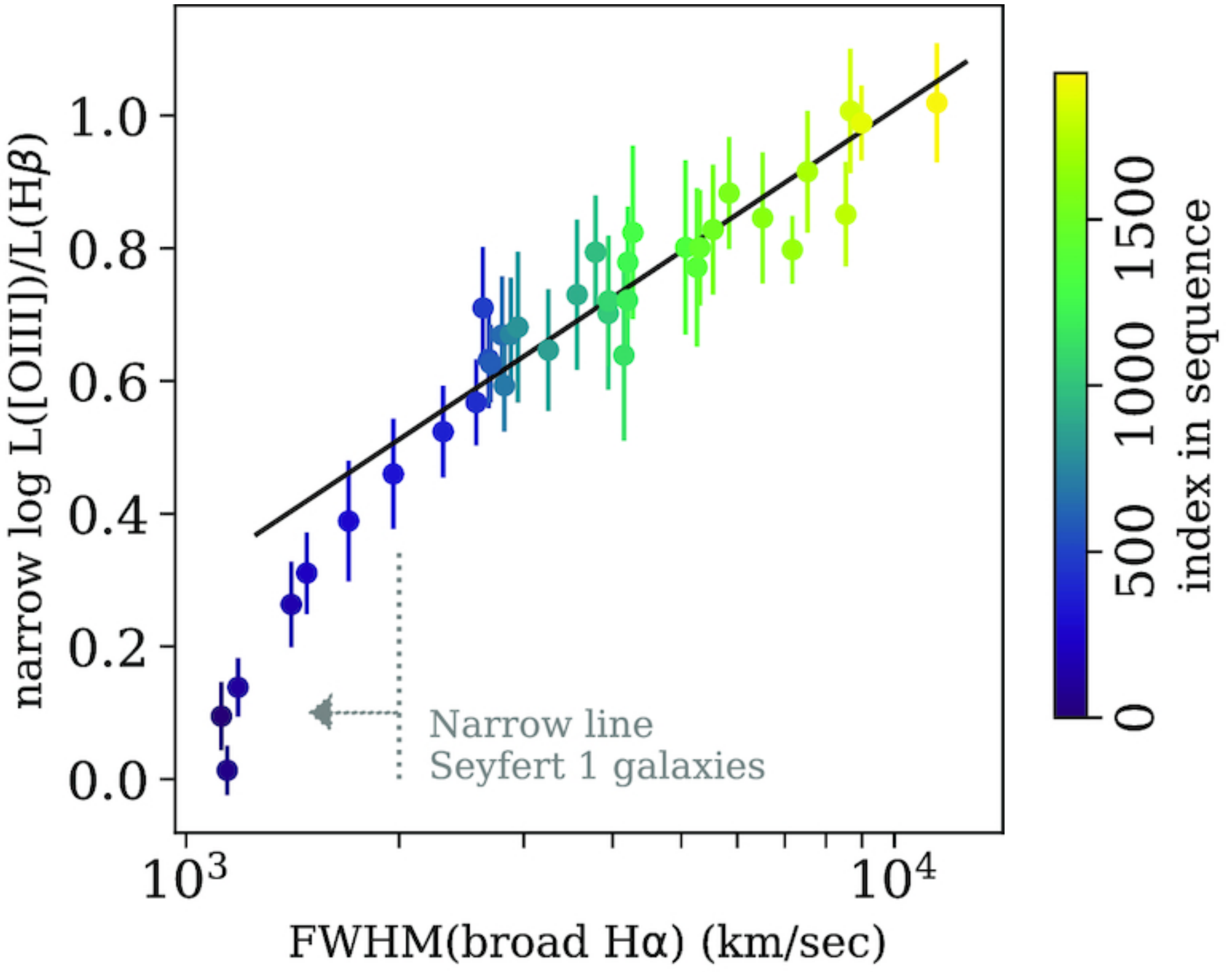
- How are the radio emission properties related to the identity ($P, \dot{P}, \dot{E}, B$, age) and geometry of each pulsar?
- With SKA's large N, can we simply let the data speak for itself?

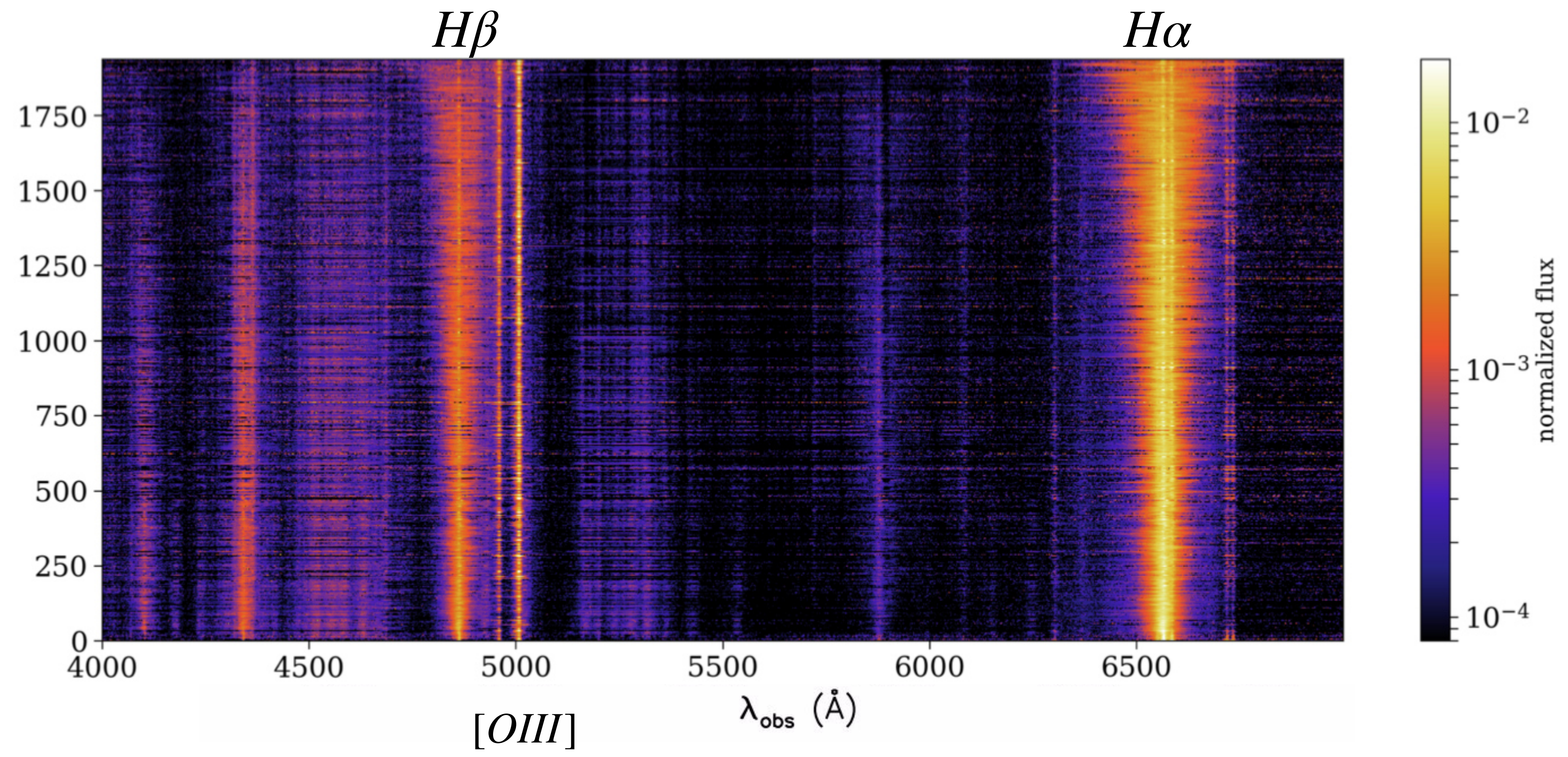


Weltevrede & Johnston (2008)

Data-driven approach via Graph Theory

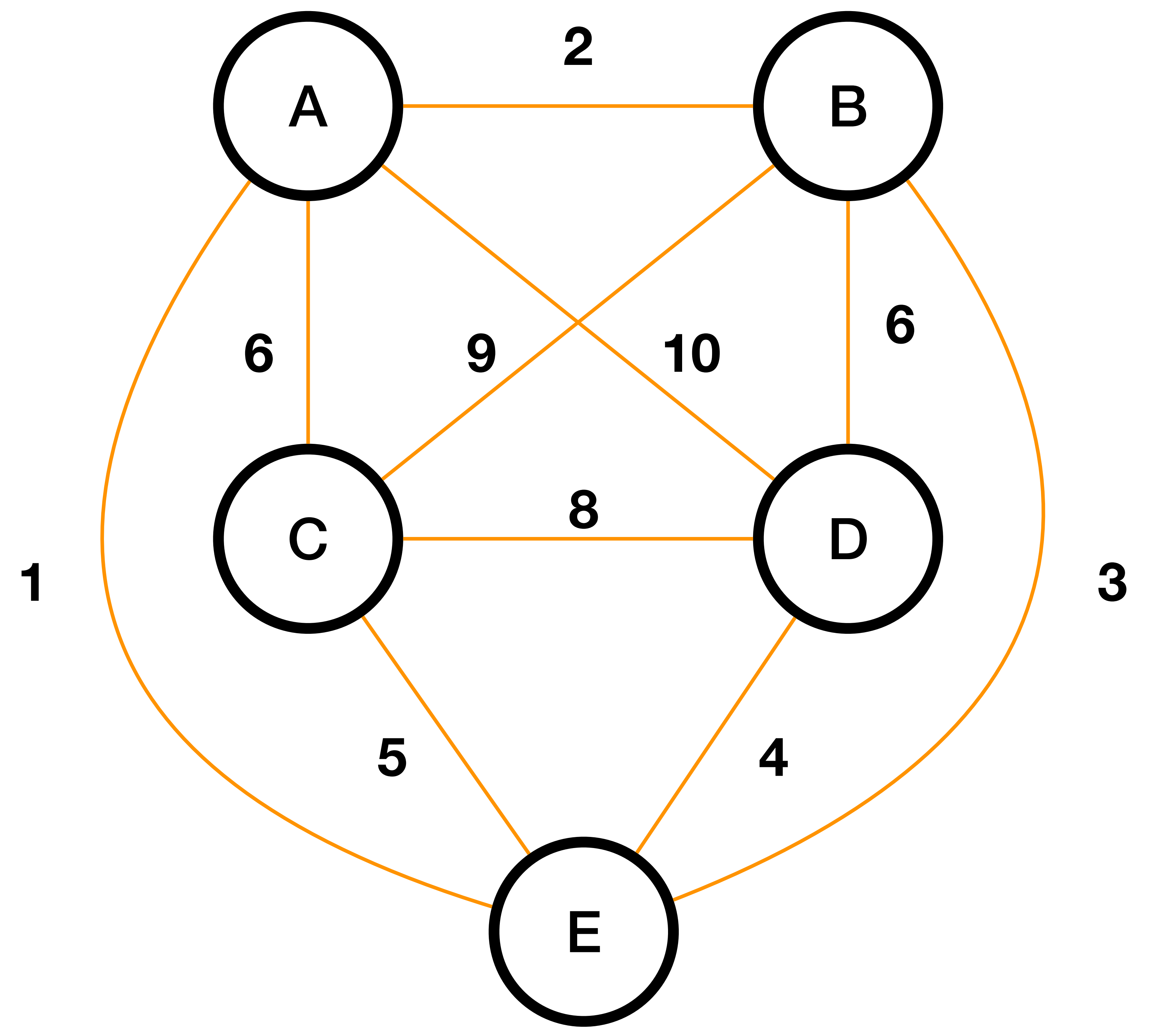
- Baron & Ménard (2019)
  - Sequencing 2000 type I AGN revealed unknown scaling relation between ionized gas and black hole mass
  - Scaling relation can be used to estimate black hole masses for Type II from narrow emission only





Data-driven approach via Graph Theory

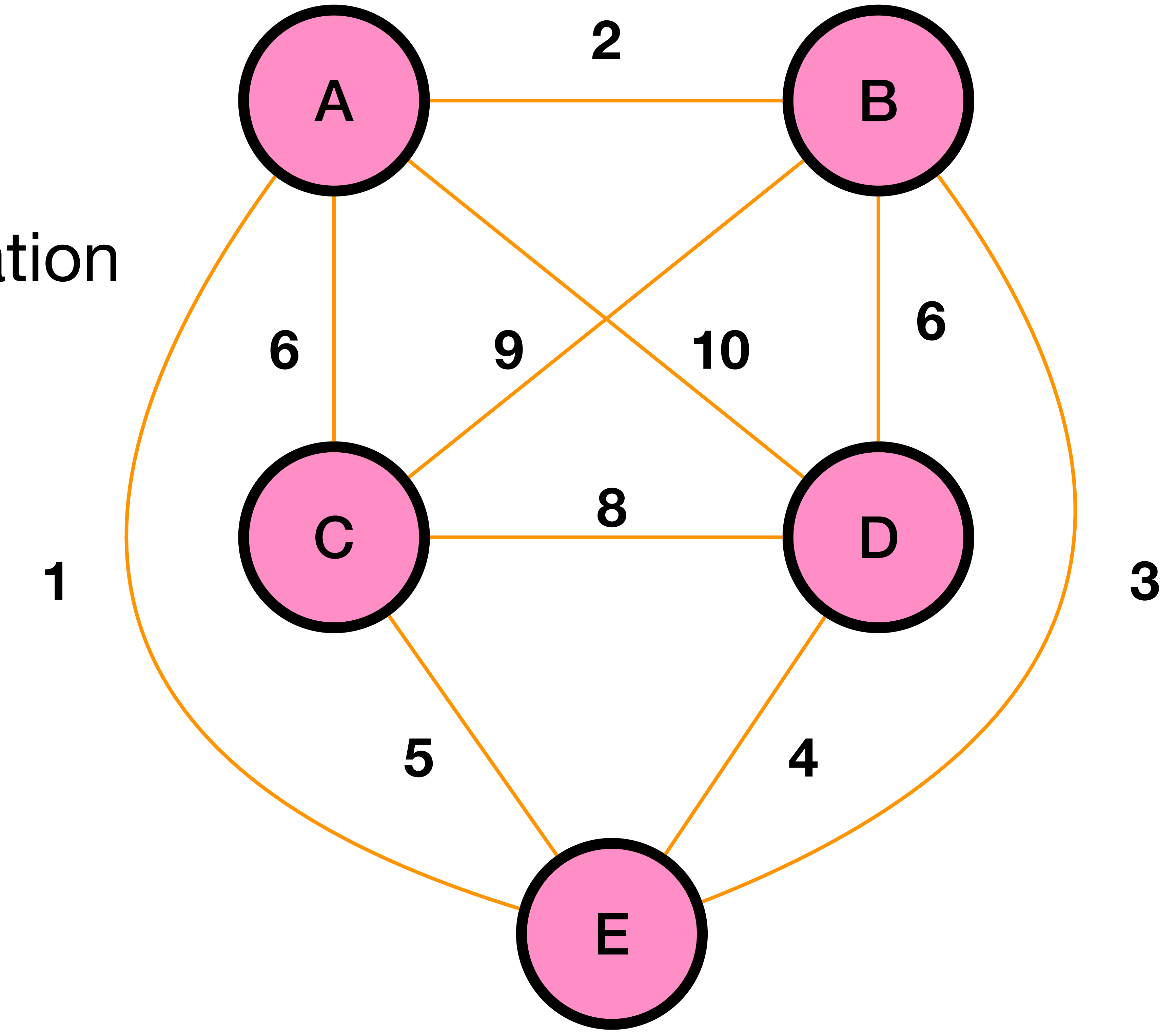
Complete (undirected) weighted graph



Data-driven approach via Graph Theory

Complete (undirected) weighted graph

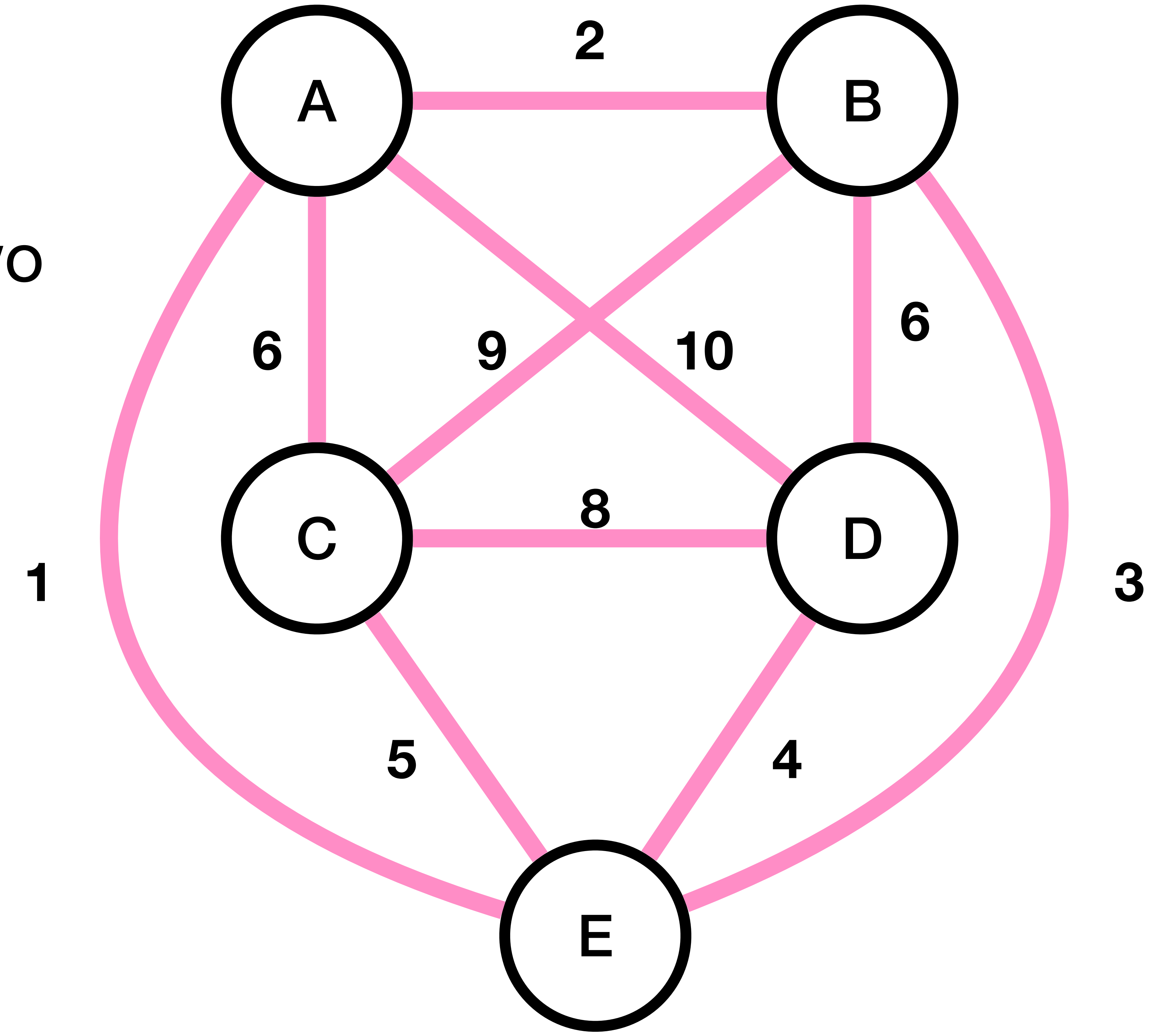
- **Vertices**
  - Represent pulsars
  - Set of vertices = Population



Data-driven approach via Graph Theory

Complete (undirected) weighted graph

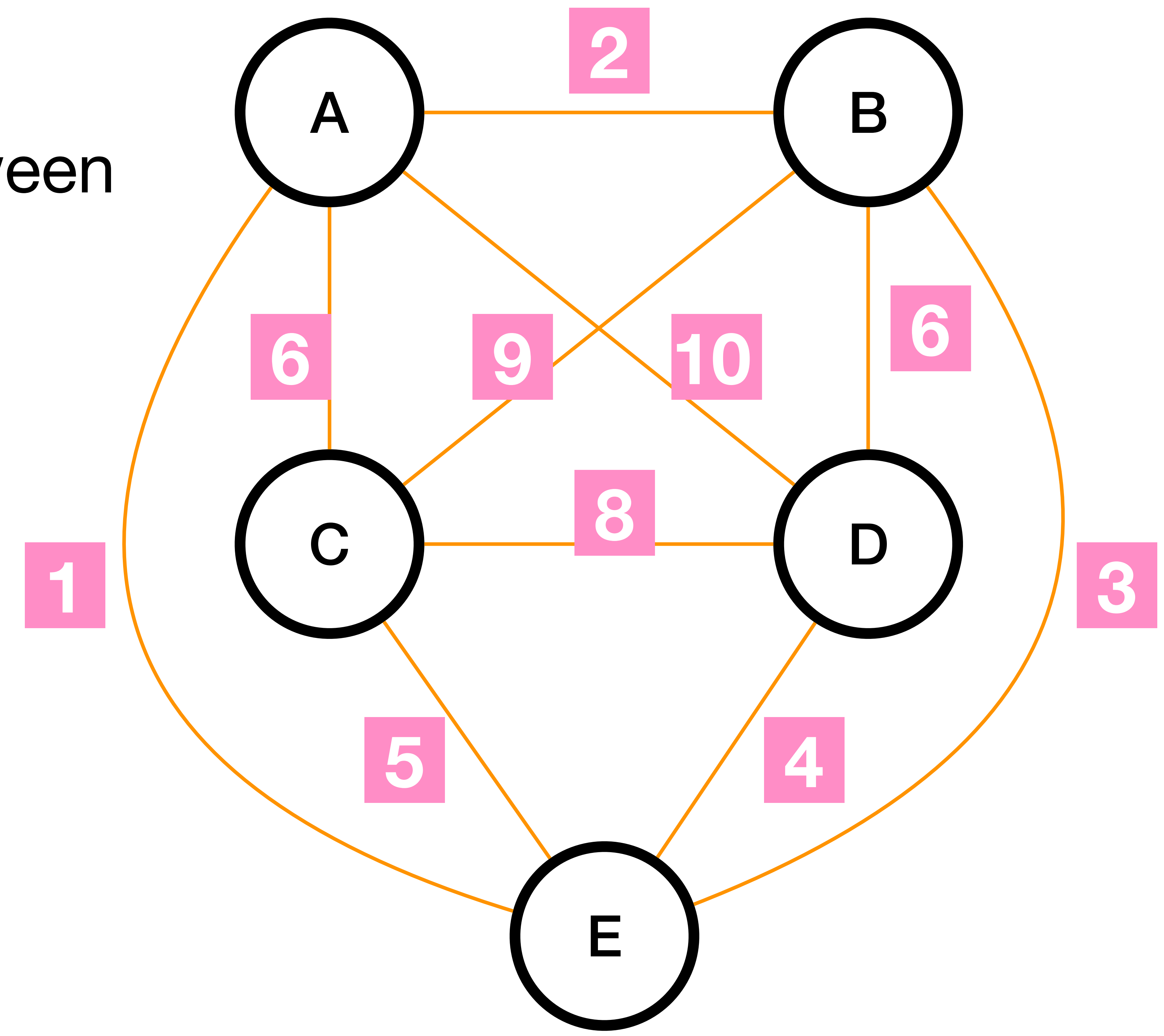
- **Edges**
  - Represent connection
  - Comparison between two pulsars



Data-driven approach via Graph Theory

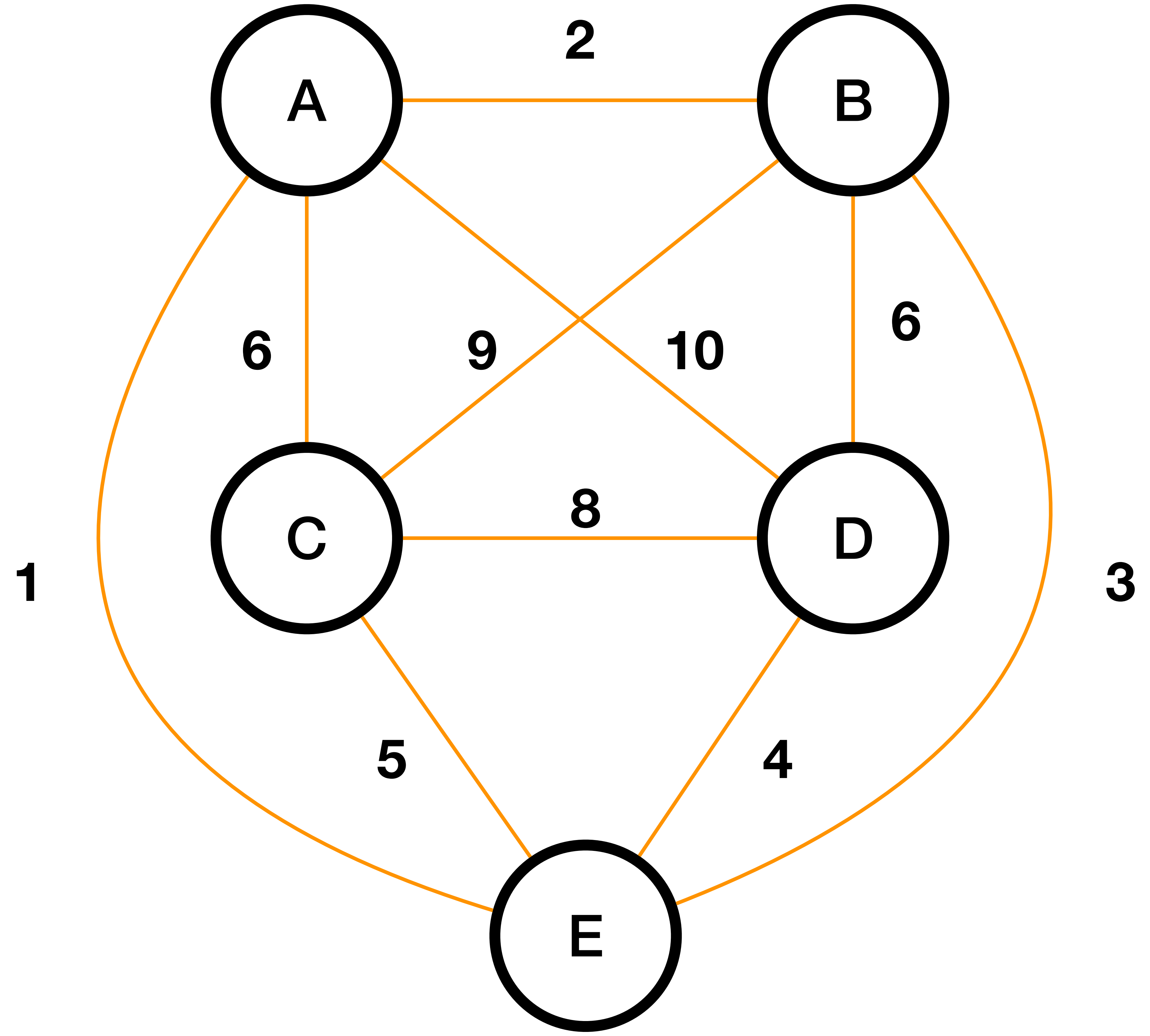
Complete (undirected) weighted graph

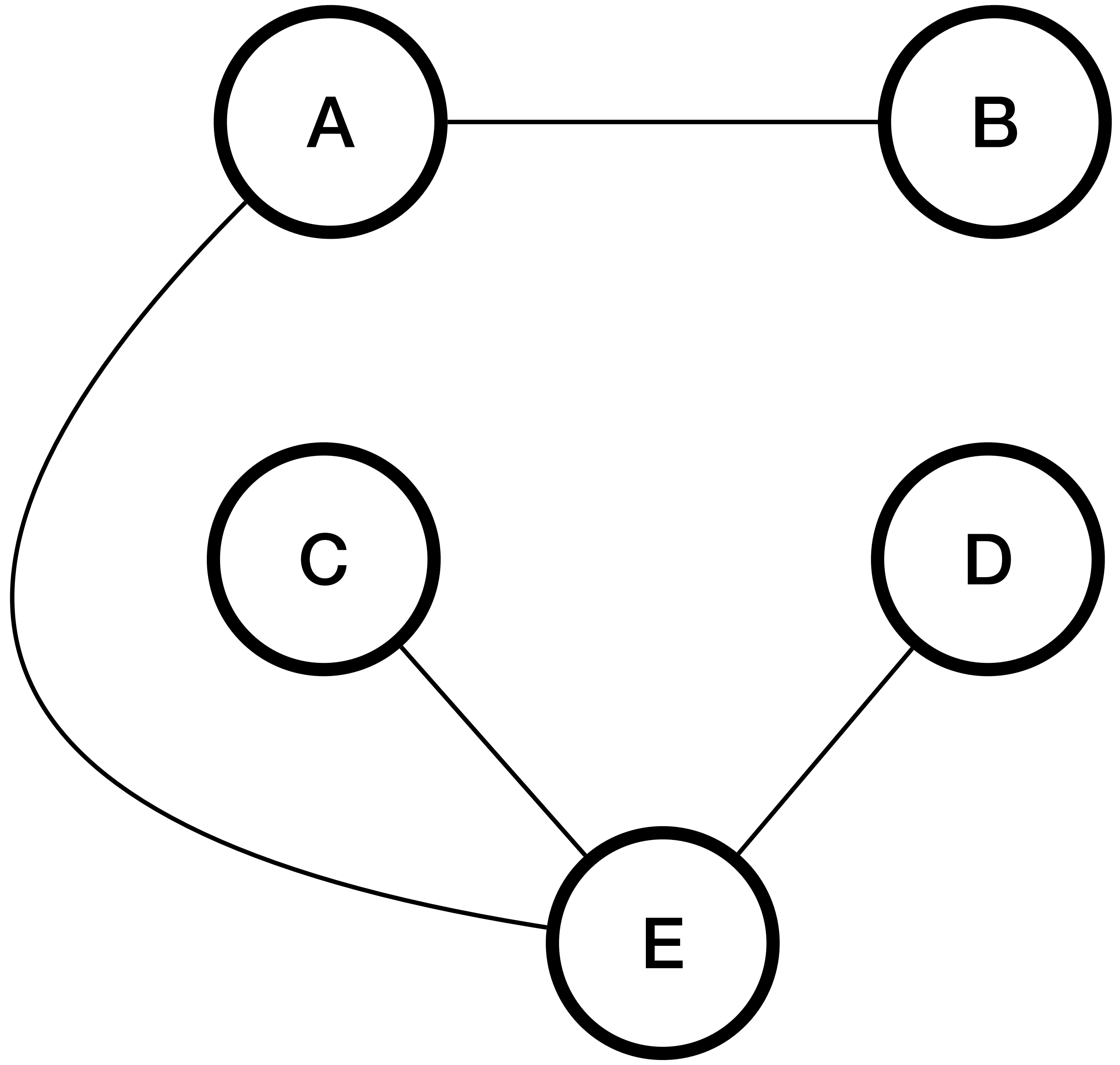
- **Weights**
  - Similarity/distance between pulsar pairs
  - Need to define what to measure as distance



Data-driven approach via Graph Theory

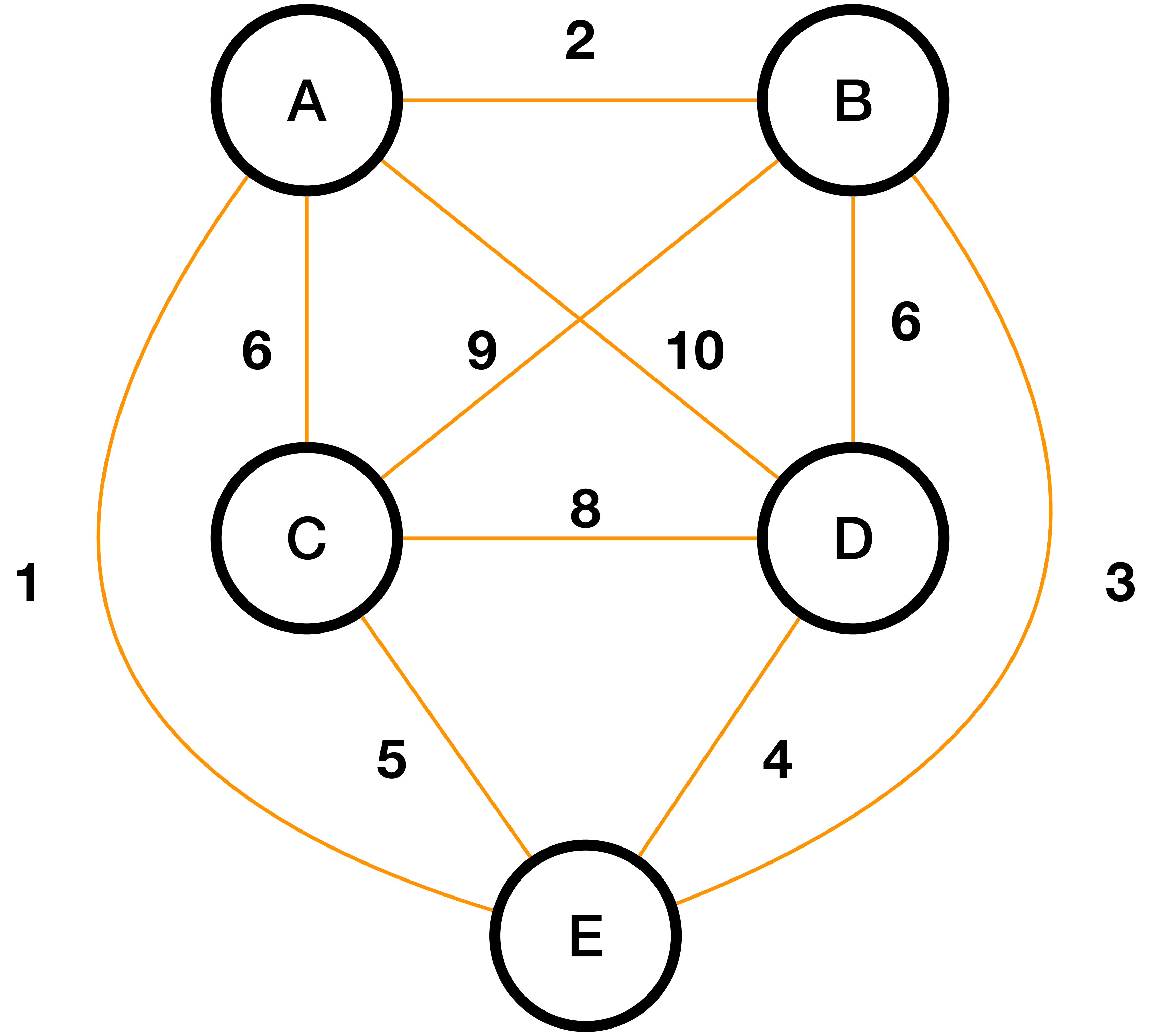
Solution space minimization: Minimum Spanning Tree

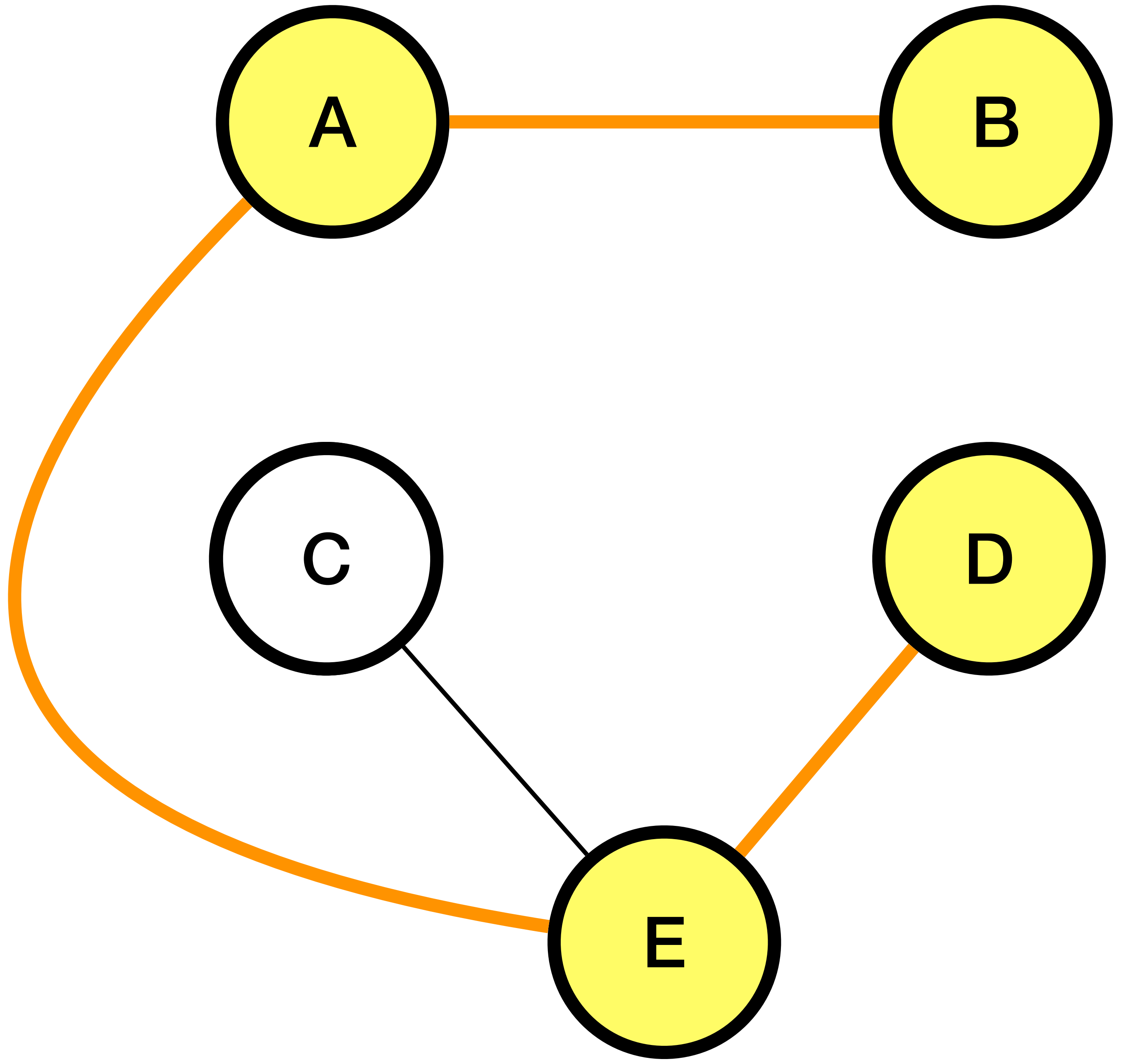




Data-driven approach via Graph Theory

Trends: longest manifold





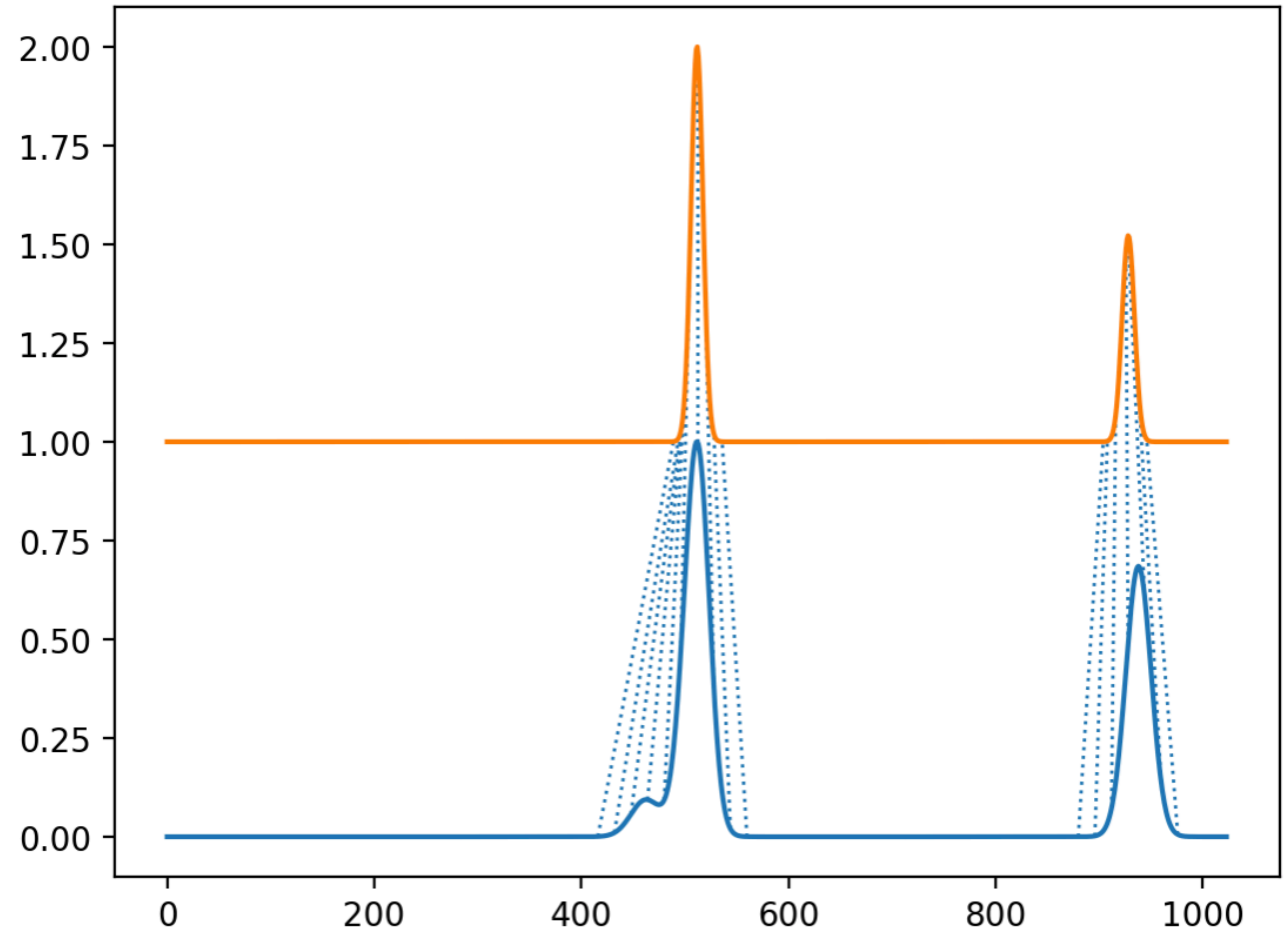
Experiment

- **EPN database**
    - 840 pulsars, 2458 profiles, 77 references
  - Heterogeneous (sampling, S/N, …)
- **Set of 85 pulsars (minus 6 showing scattering tails)**
  - S/N > 20
  - IQUV
  - 4 Frequency bins (MHz)
    - [400,700)
    - [700,1000)
    - [1000,1500)
    - [1500, 2000)

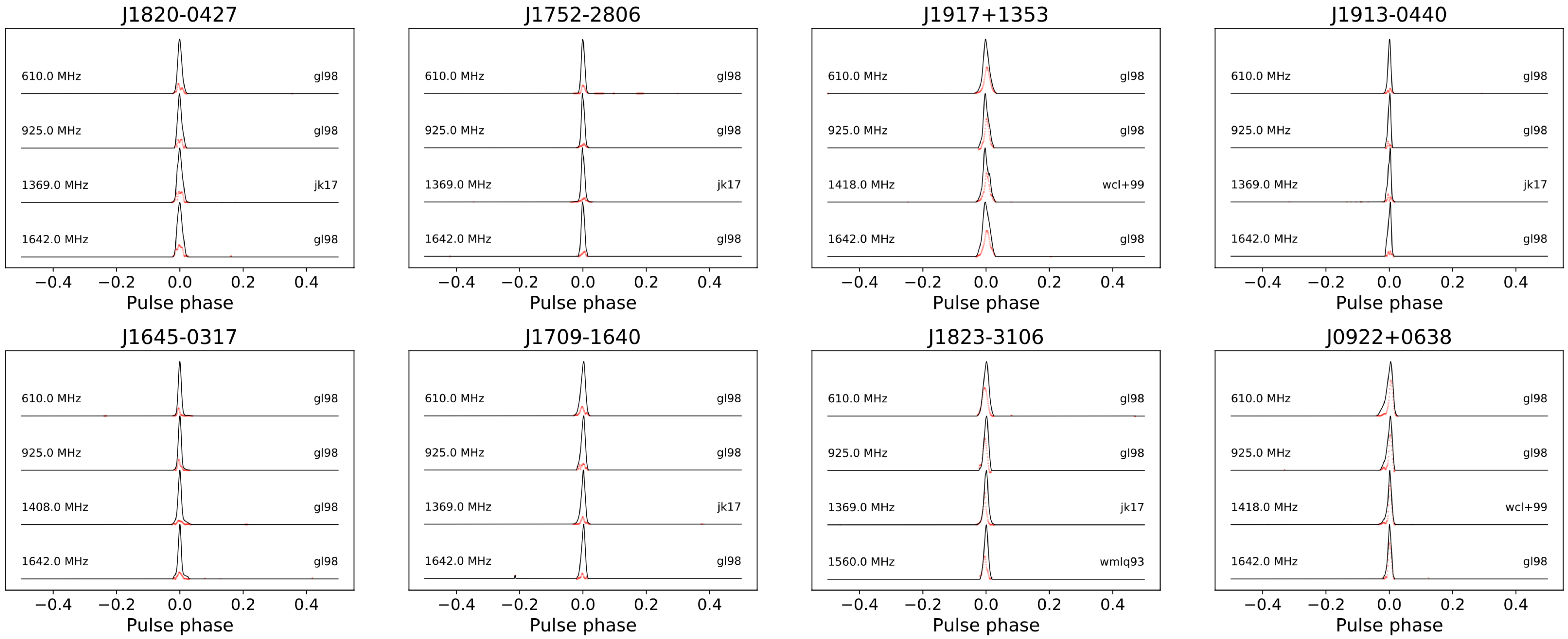
Special thanks to Michael Keith for help with accessing EPN database

Distance metric

- Dynamic Time Warp
- Evaluate Stokes I and Stokes L evolution over frequency



Preliminary results



Vohl et al. 2021 (in prep.)

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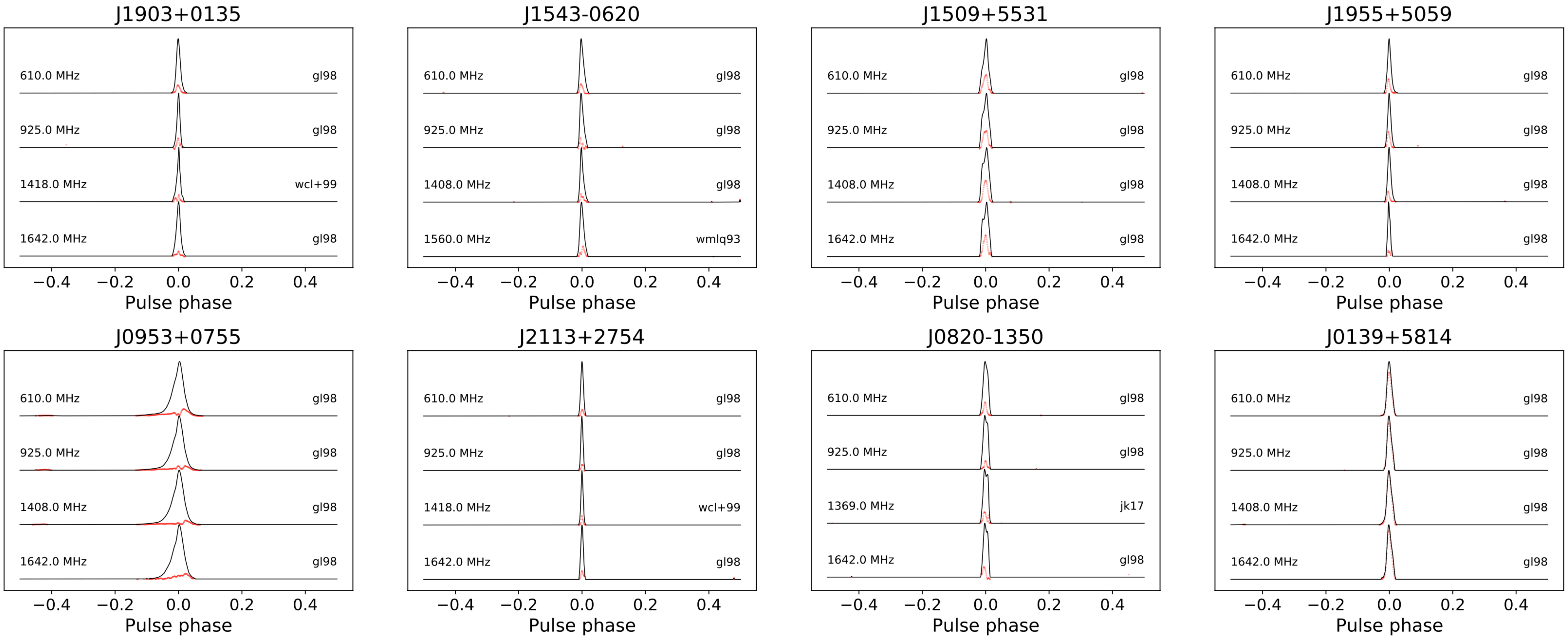

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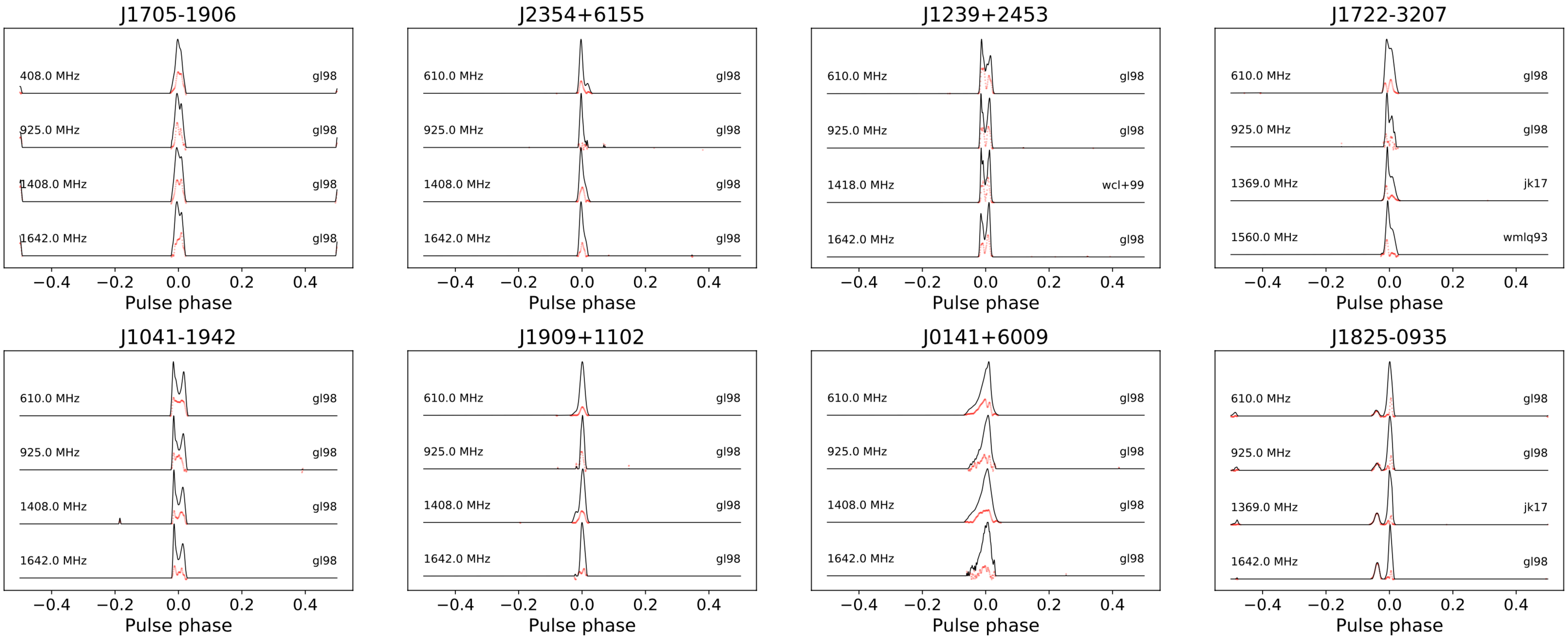

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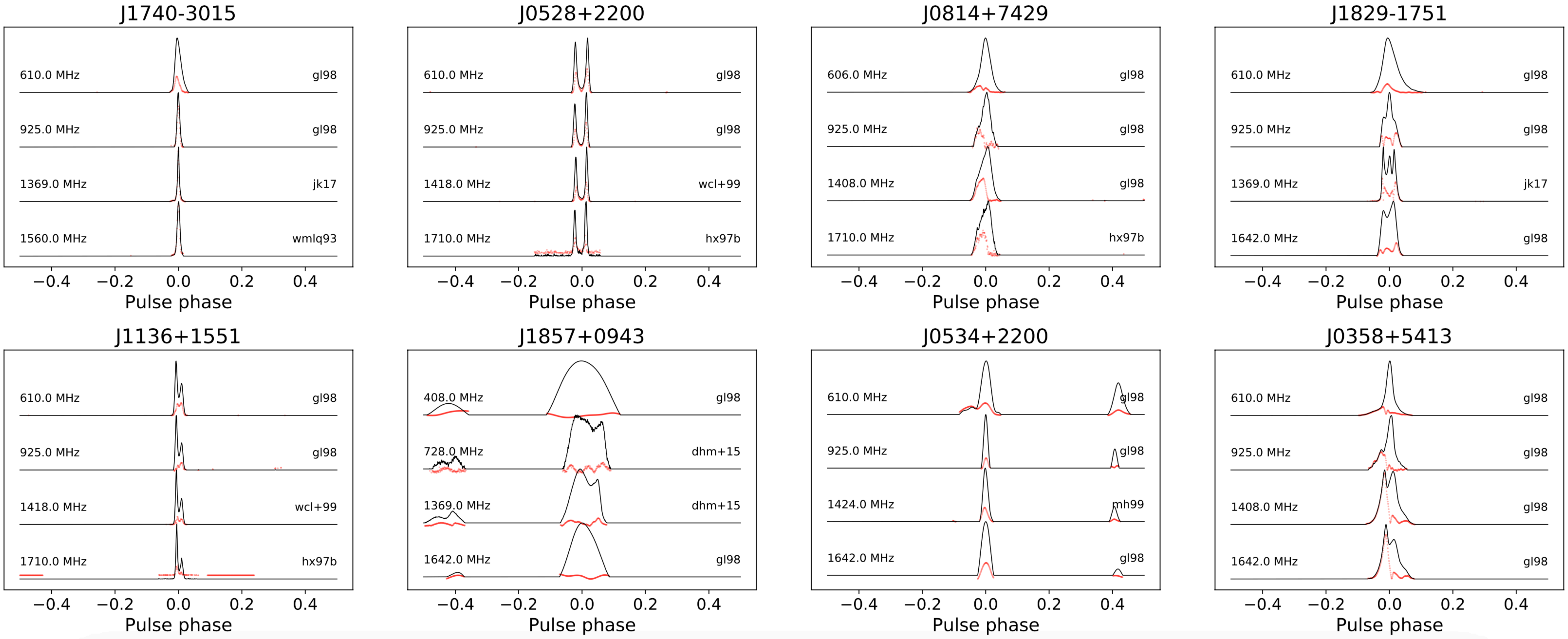

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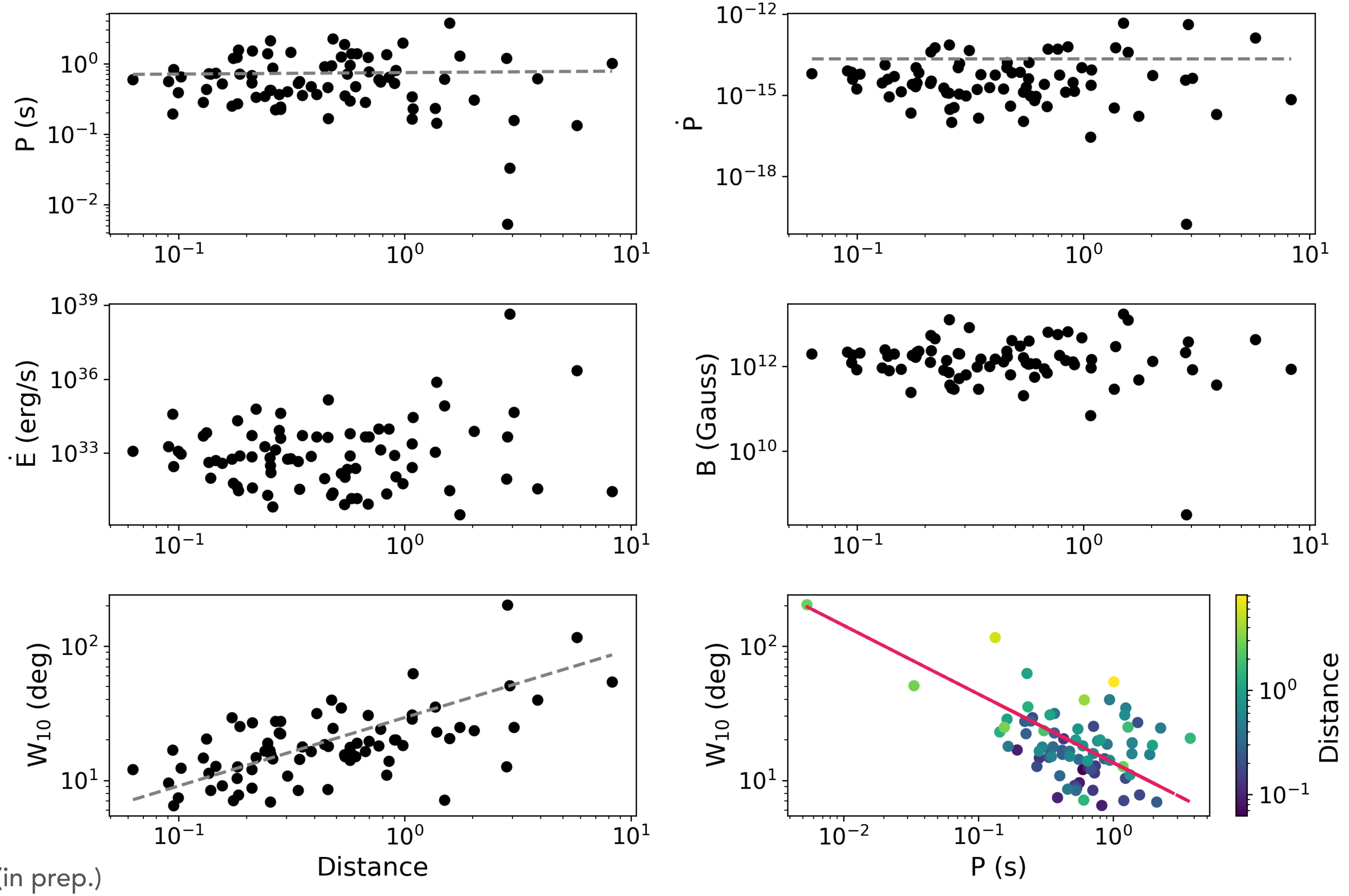

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Final thoughts

- SKA's **large N** will require automated methods
- Presented a method to investigate pulsar population through their profiles, to evaluate, e.g.
  - Period—width relation through a different angle: emission heights, viewing angle?
  - If core-cone emission is a distinction or a gradual scale
- SKA data and its higher S/N —> will permit stronger conclusions
- Method can be applied to (repeating) **FRBs** profiles too
- Other properties of the graph could be exploited: e.g. clustering
- Side product of this work:
  - Flexible python codebase to handle, process, and analyse pulse profile population
  - Questions/comments : **vohl@astron.nl**

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grant AA-ALERT (027.015.G09)