Correlation Between Pulses and Phase Bins

Jiguang Lu, FAST, NAOC

20210714

中国科学院国家天文台
NATIONAL ASTRONOMICAL OBSERVATORIES , CAS

Manifestation of Correlation

- **Correlation between pulses**
  - the profile comparison in timing process
  - sub-pulse drift
- **Correlation between phases**
  - mode change
  - nulling pulse
  - micro-structure
  - the time scale of pulse profile
  - the longitude-longitude cross-correlation

Correlation Mechanism

Correlation is common.

- The evolution of an isolated system can be well-determined by the initial value and the differential equations.
- The perturbance in the magnetosphere has non-locality, and it would influence the entire magnetosphere via the a variety of waves, e.g., electromagnetic wave, Alfvén wave, etc.
- the “Butterfly Effect”
- The received radiation on the Earth reflects part information of the magnetosphere condition.
- Correlation exists inevitably.

Pulse Sequence Characteristics

Single pulse

- Single pulse studies aim to obtain the variation information of the pulsar radiation in a short time scale.
- Various of diagnosis statistic reflect the correlation in the pulsar data.

Pulse sequence is a stationary process?

- Pulse profile is stable.
- Drifting features are stable.
- The longitude-longitude cross-correlation is stable.
- kernel function of pulse sequence

Correlation and Predictability

Is single pulse predictable?

- $I(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} A(f)\exp(-2\pi \mathrm{i} f t)\,\mathrm{d}f$
- $A(f) = \int_{-\infty}^{\infty} I(t)\exp(2\pi \mathrm{i} f t)\,\mathrm{d}t = 2\int_{-\infty}^{\mathbf{0}} I(t)\exp(2\pi \mathrm{i} f t)\,\mathrm{d}t$ **(?)**
- **The next single pulse can be predicted.**
- $I(t) = H\left[\int_{-\infty}^{t} \mathcal{G}[I(t_0)]\mathrm{d}t_0\right]$
- **Can the single pulse be predicted with only the last one pulse? Is a N-bin single pulse sequence a Markov process? (the continuity of $I(\mathrm{t})$)**

Correlation Calculation

- **Linear correlation**
  - linearly dependent coefficient between different data bins
  - linear transformation to predict the next pulse
  - some variants: linear transformation only near diagonal, linear transformation with non-zero intercept, etc
  - features in Fourier domain
- **Nonlinear Correlation**
  - high-order transformation
  - cross terms in the transformation

Correlation Characteristics

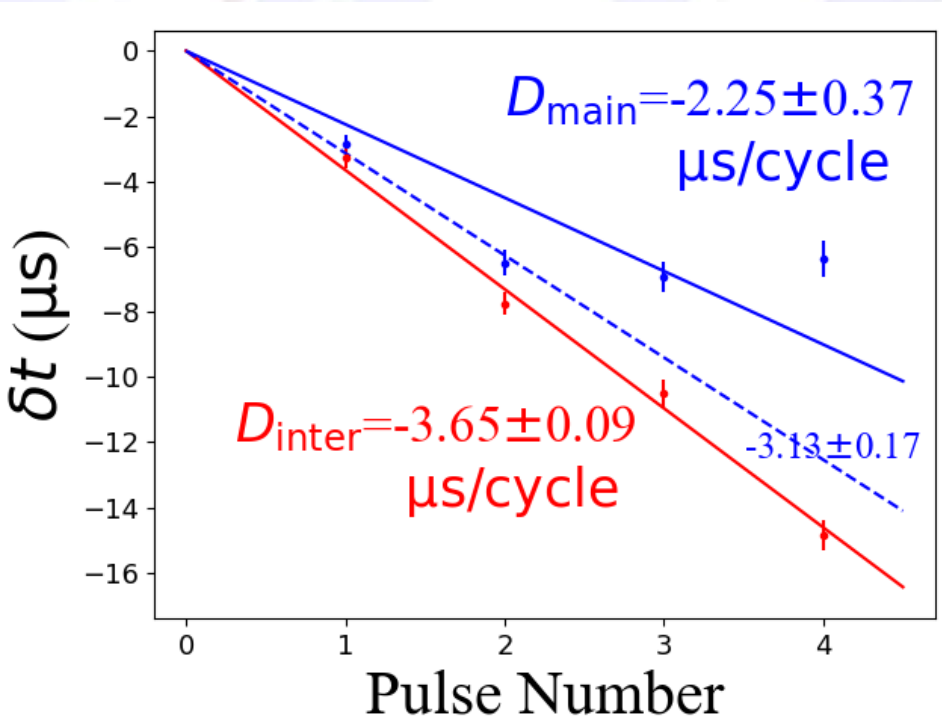
N-bin single pulse sequence

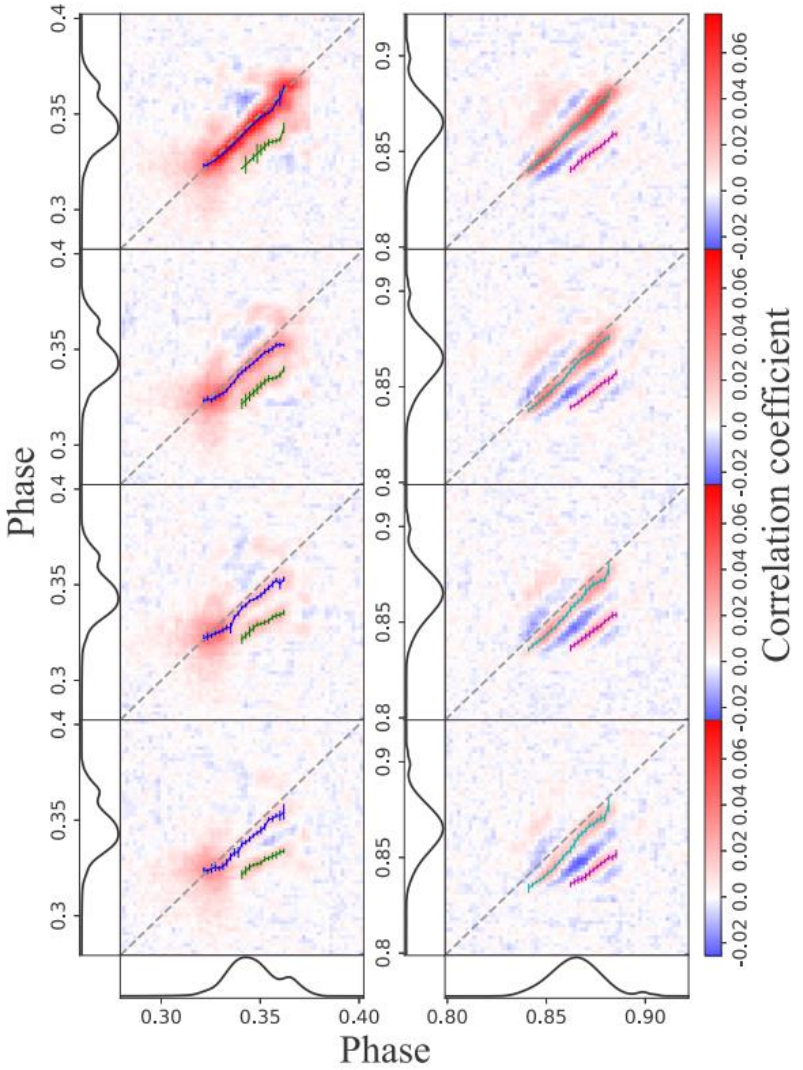
- (Random) Walk in N-dimensional space.
- fixed-point of a transformation and pulse profile
- rotation of the N-dimensional vector and the radiation region evolution (spark point drift?)
- invariant of the transformation (stationary process) and the magnetosphere stability
- completely random component(?)

Application of Correlation

Single pulse phenomena analysis

- drifting sub-pulse
- radiation geometry
- radiation mechanism

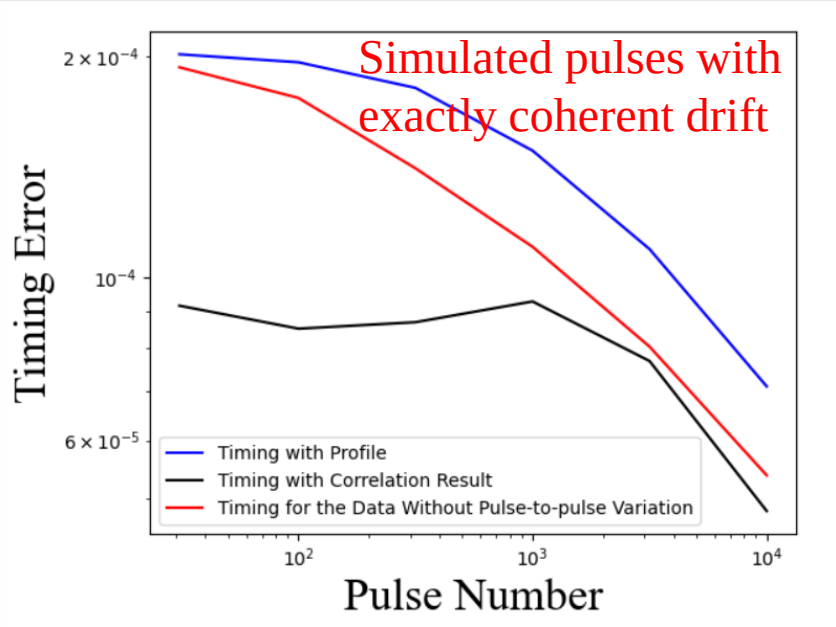


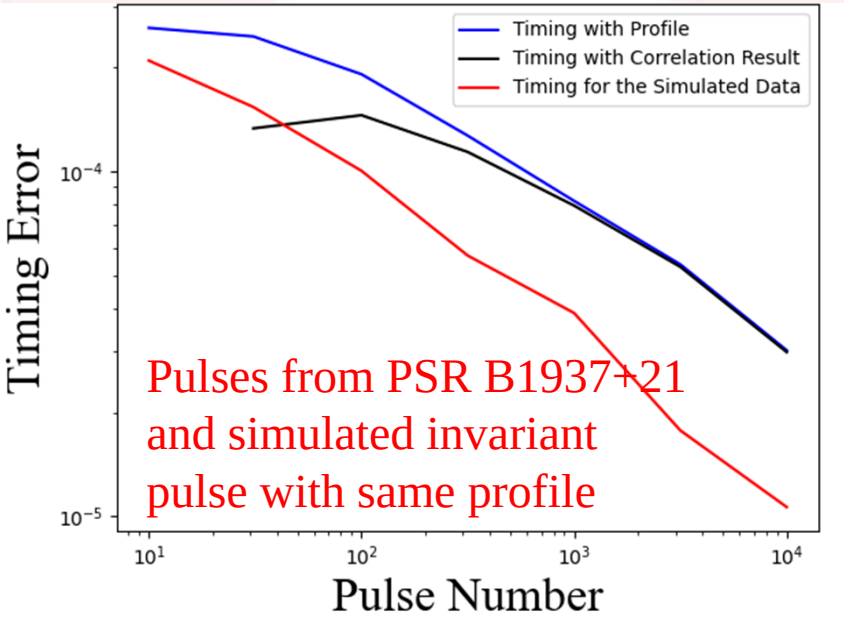


Application of Correlation

Pulsar timing: pulse correlation and jitter noise

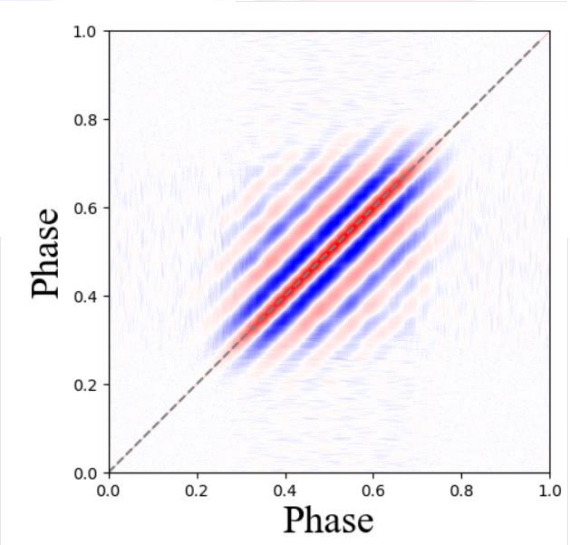
- Pulsar timing need stable statistic features versus pulse phase, such as pulse profile.
- The correlation features are stable, and can supply timing results independent of those determined with pulse profile.
- Can the influence of jitter noise be completely eliminated?

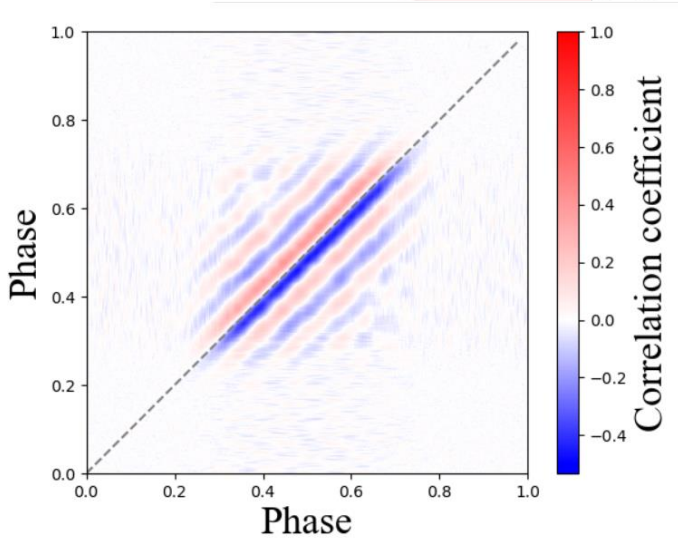


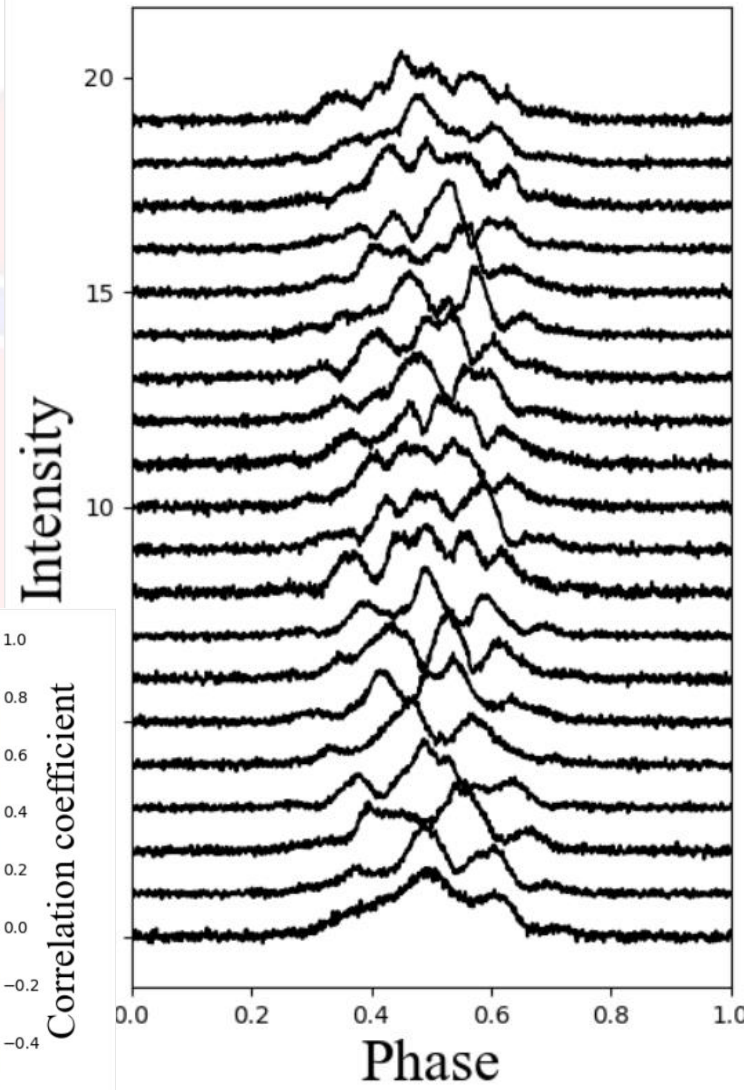


Application of Correlation

- **Single pulse simulation**
  - drifting sub-pulse simulation
  - Random pulses simulation
- **Other applications**
  - Candidates filtrating in pulsar searching







NAOC

Thanks!

中国科学院国家天文台
NATIONAL ASTRONOMICAL OBSERVATORIES , CAS