• Problem: Binary MSPs are sometimes undetectable in radio due to eclipses or the radio beam not pointing towards Earth. But blind searches for their gamma-ray pulsations have been infeasible until recently.

• Solution:
  • New methods (Slide 2):
    • Efficient multistage search, optimised search grids using parameter space metric, orbital constraints from optical counterpart
  • Search design (Slide 3):
    • Very sensitive for fixed amount of computing resources
    • Use of ATLAS Cluster in Hannover and Einstein@Home
  • Applications (Slide 4):
    • Blind searches exploiting orbital constraints
    • Targeted searches (for recently detected radio pulsars)
    • Long-term timing (of eclipsing binary pulsars)
Search Methods

- Semicohherent first stage
- Coherent follow-up
- Final stage with H-test

Credits: Nieder, L., Pletsch, H. J., Clark, C. J. in prep

Credits: Fehrmann, H., & Pletsch, H. J. 2014, PhRvD, 90, 124049


Search Design with Limited Computing Resources

Mismatch: fractional loss in signal-to-noise ratio due to offsets from pulsar parameters or approximated phase model

Metric: analytical approximation to the expected mismatch as function of the distance to the nearest grid point

Orbital constraints: from optical observations of companion and crucial to reduce the relevant parameter space

Search design: optimized sensitivity (minimized average mismatch and long coherence time) for limited computing resources

Einstein@Home: an distributed volunteer computing system used in searches for pulsars and for continuous gravitational waves

Number of grid points:

\[ N \propto m_{\text{max}}^{-7/2} \int_{\Lambda} \sqrt{\det g(\vec{\lambda})} \, d\vec{\lambda} \]

\[ \vec{\lambda} = \{ f, \dot{f}, \Omega_{\text{orb}}, x, T_{\text{asc}}, \eta, \kappa \} \]

and

\[ \sqrt{\det g(\vec{\lambda})} = T_{\text{obs}}^2 T_{\text{coh}}^2 f^5 \Omega_{\text{orb}} x^4 \]

Search parameters:
• Observation time \( \equiv T_{\text{obs}} \)
• Coherence time \( \equiv T_{\text{coh}} \)
• Maximum mismatch in grid \( \equiv m_{\text{max}} \)

Pulsar parameters:
• Spin frequency \( \equiv f \)
• Spin-down rate \( \equiv \dot{f} \)

Orbital parameters:
• Orbital frequency \( \equiv \Omega_{\text{orb}} \)
• Projected semi-major axis \( \equiv x \)
• Epoch of ascending node \( \equiv T_{\text{asc}} \)
• Eccentricity of orbit \( \equiv e \)
• Longitude of periastron \( \equiv \omega \)
• \( \epsilon_1 = e \sin \omega \)
• \( \epsilon_2 = e \cos \omega \)

Recovered signal-to-noise ratio:

\[ S/N \propto (1 - m) \sqrt{T_{\text{coh}} T_{\text{obs}}} \]
Applications of Methods

Blind Searches:

Targeted Searches:

• Precise timing solutions require frequent observations of a radio pulsar over several years

• The measurement uncertainty of some pulsar parameters (e.g. spin frequency, orbital period) is inversely related to the total observation time

• In the case of detected gamma-ray pulsations Fermi LAT’s on-going all-sky survey allows us to extend the solution of a radio detection over 9 years of gamma-ray data

• The distance metric can assist here with the building of an efficient search grid while the phase model can be used even for eccentric pulsars

Long-term Timing:
