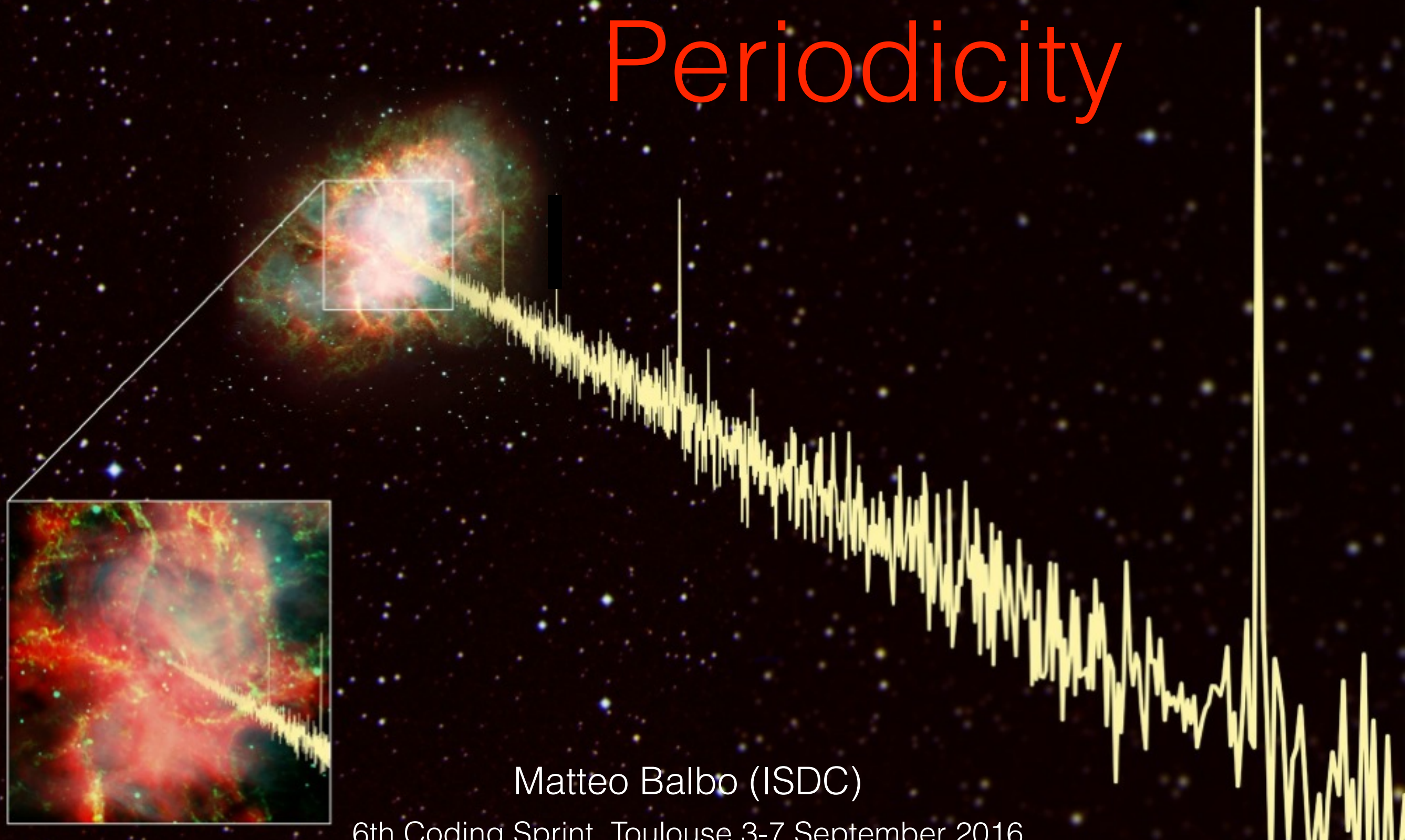


# Searching for

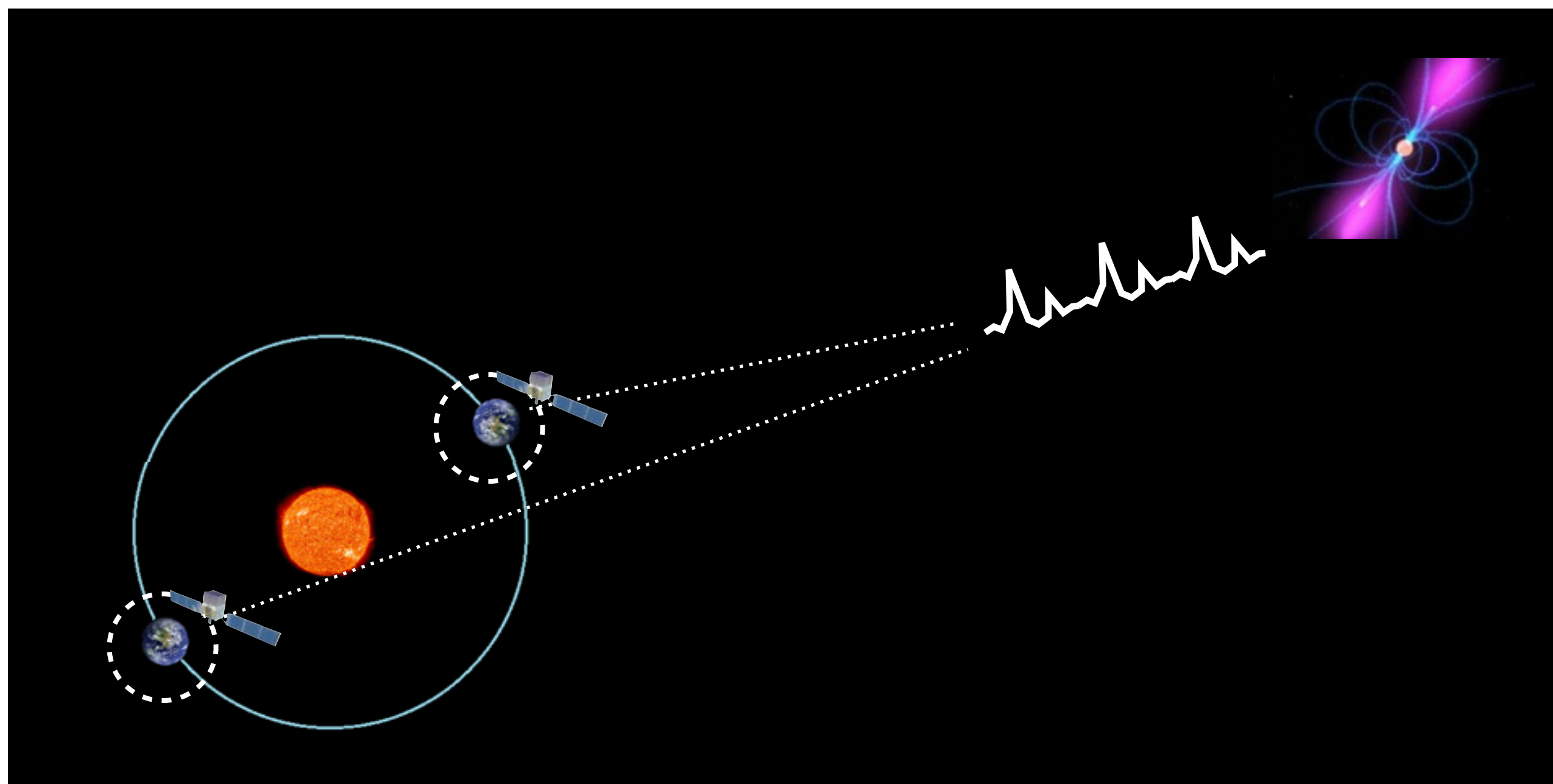


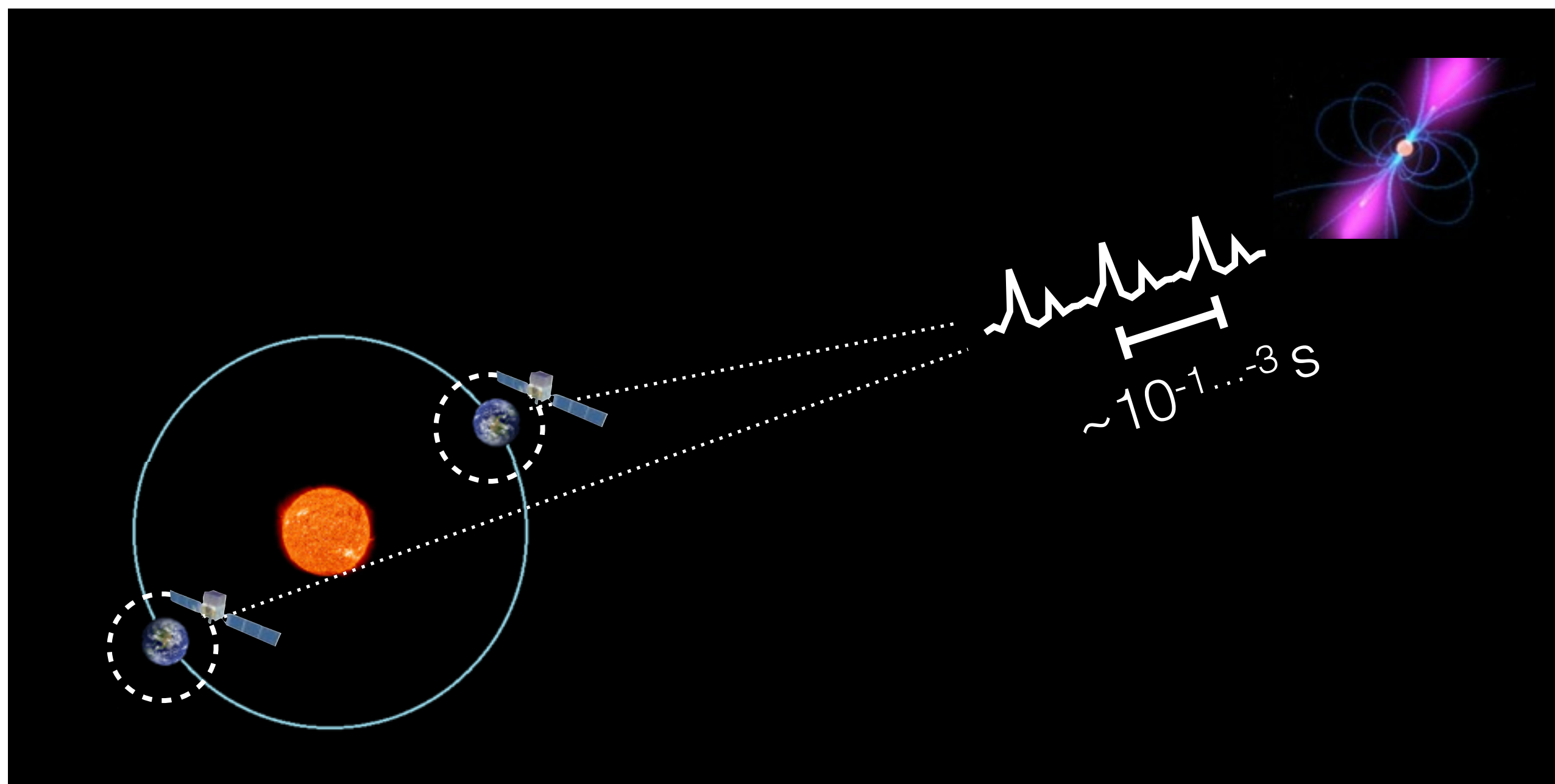
# Periodicity



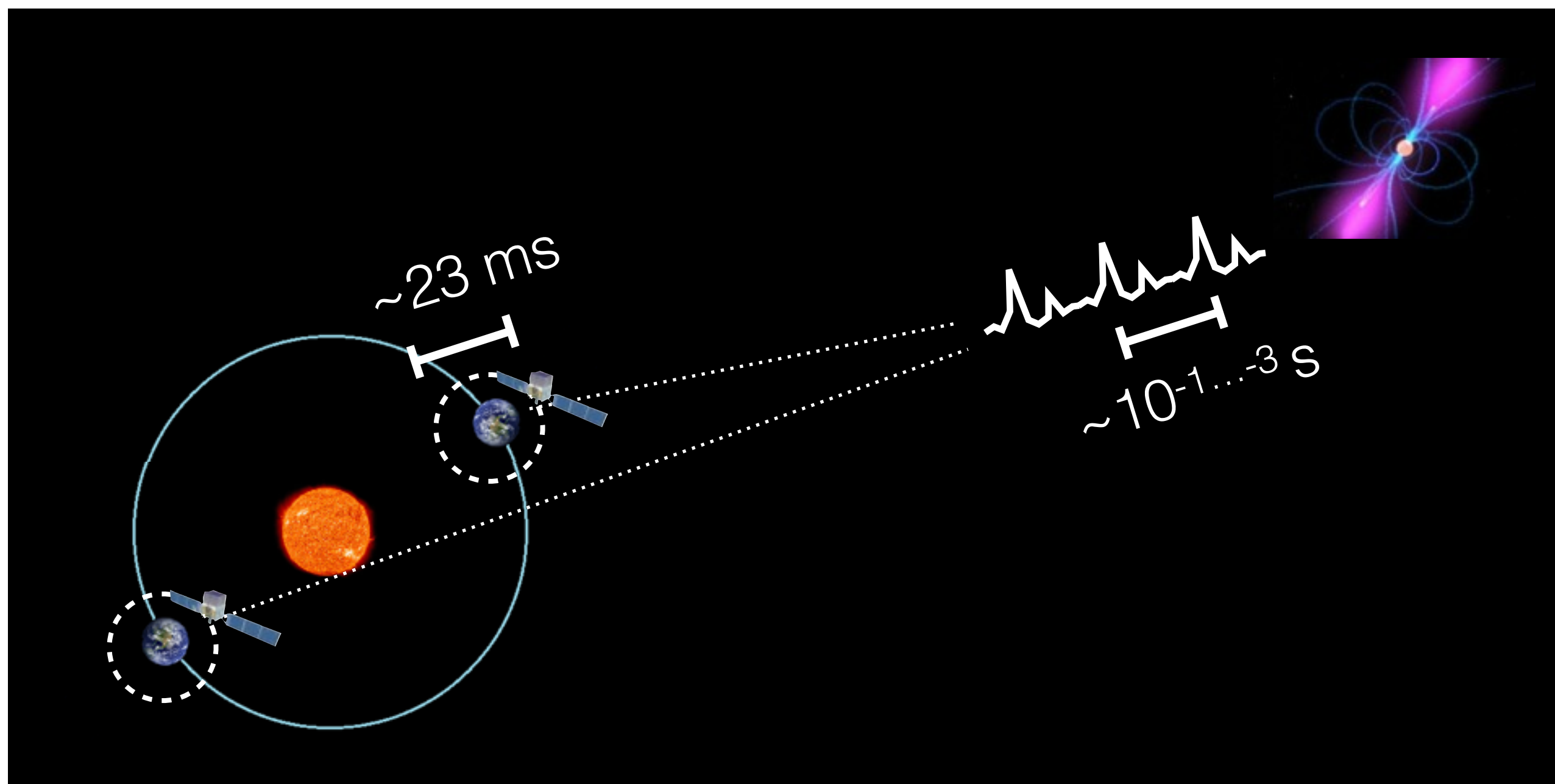
Matteo Balbo (ISDC)

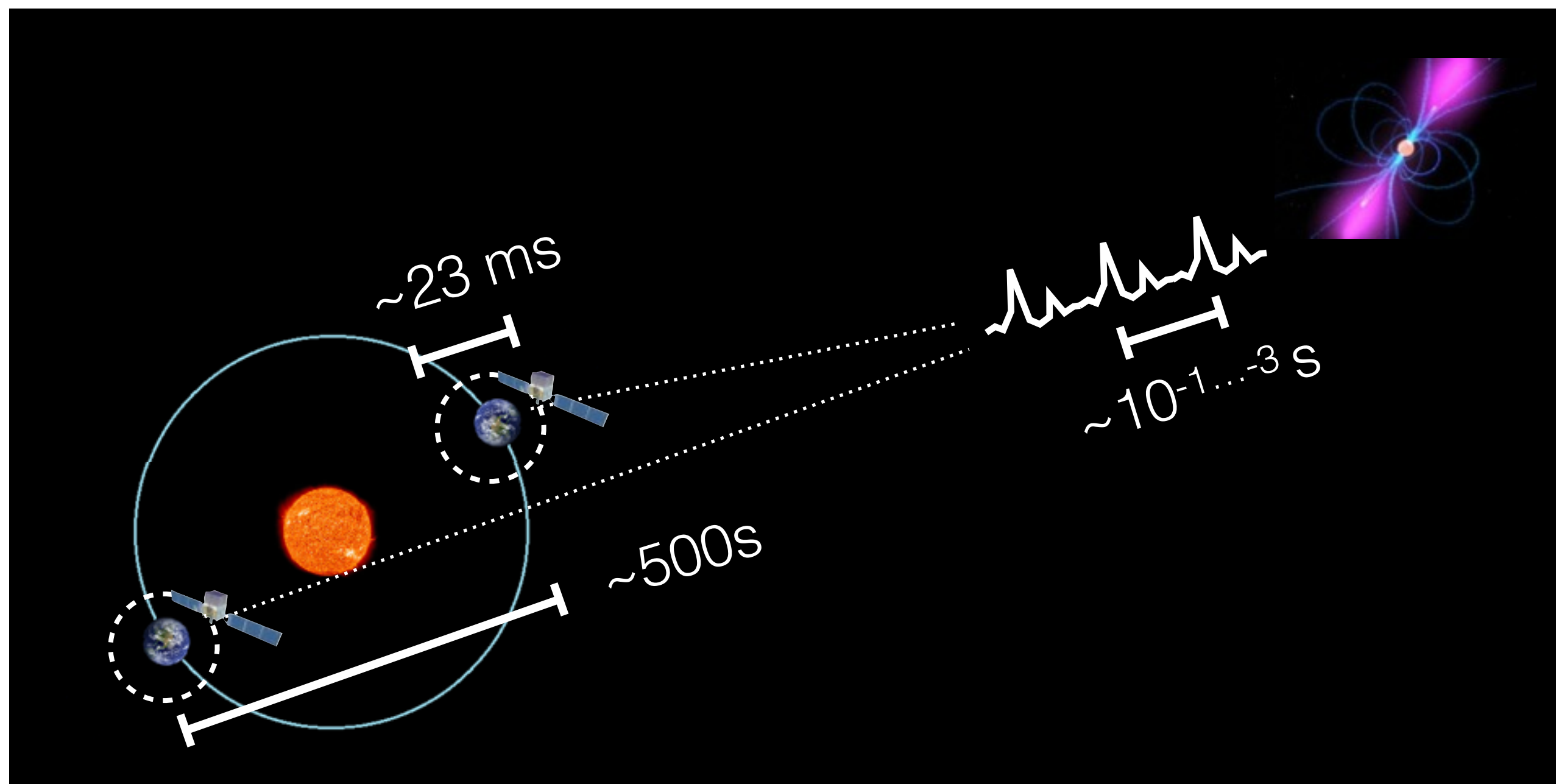
6th Coding Sprint, Toulouse 3-7 September 2016





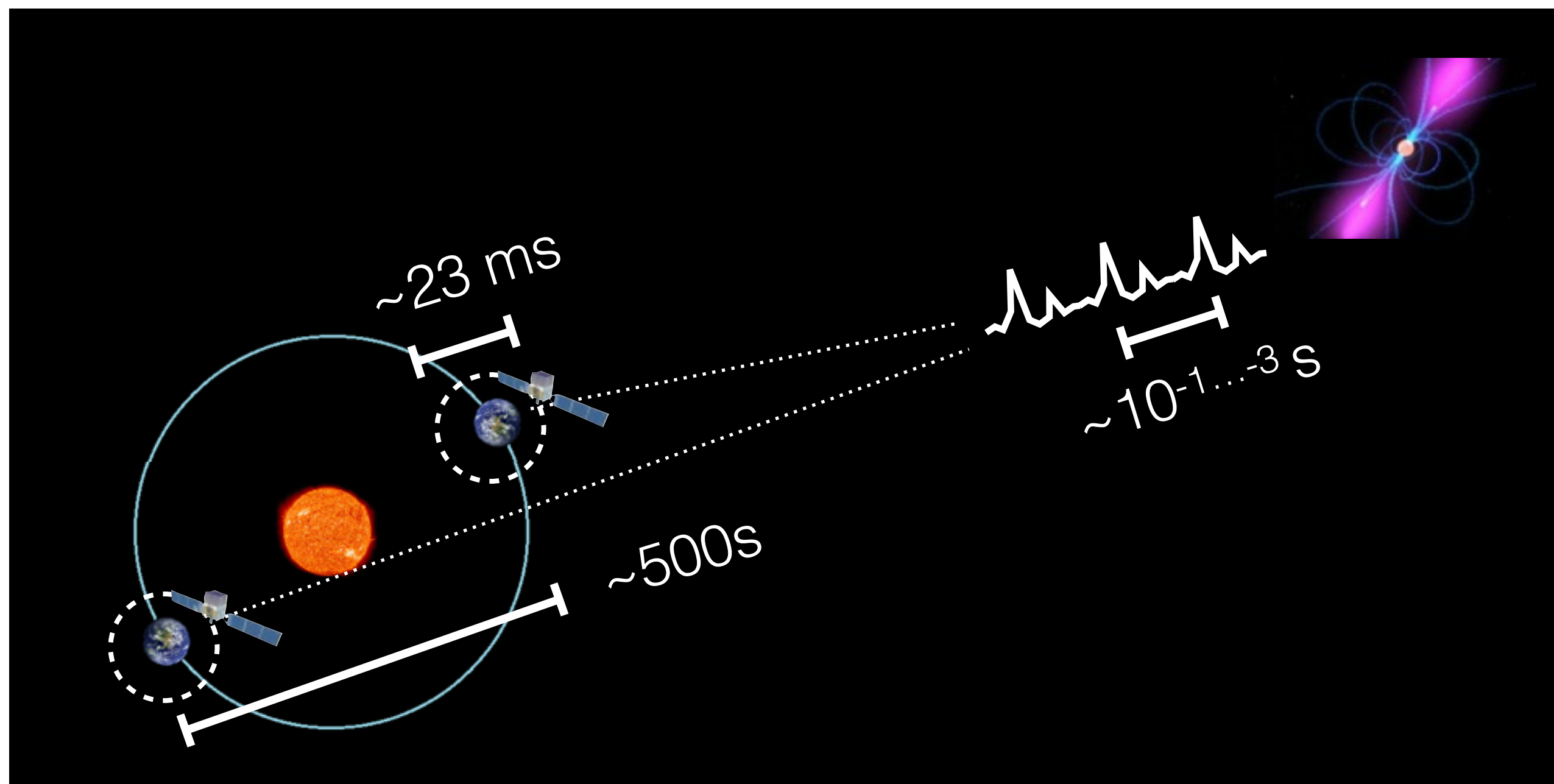


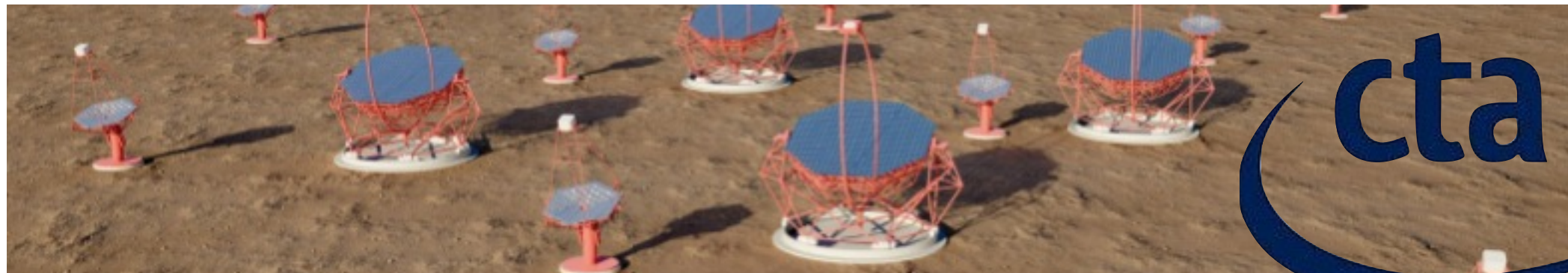




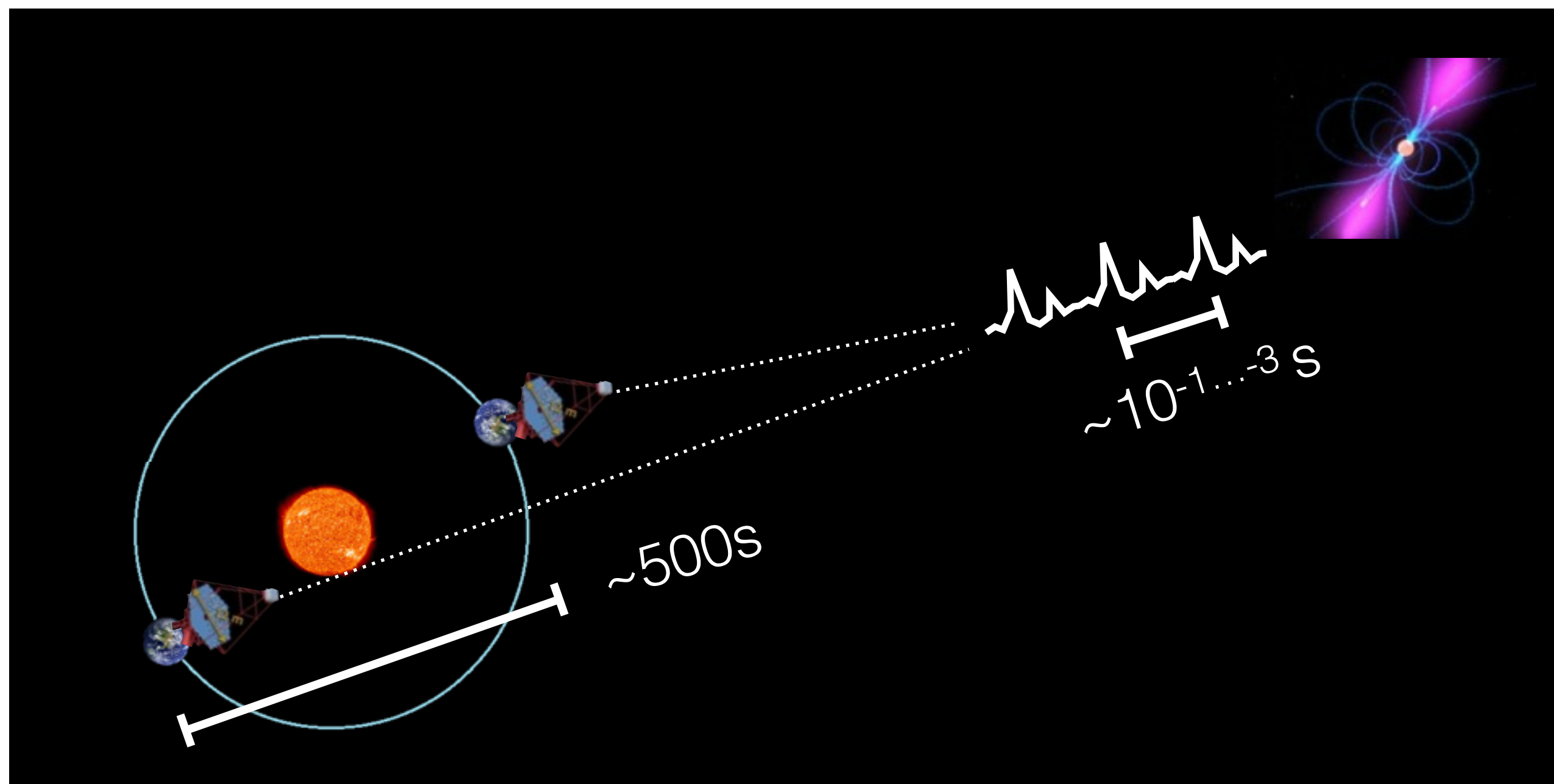


gtbary >>>> ctbary

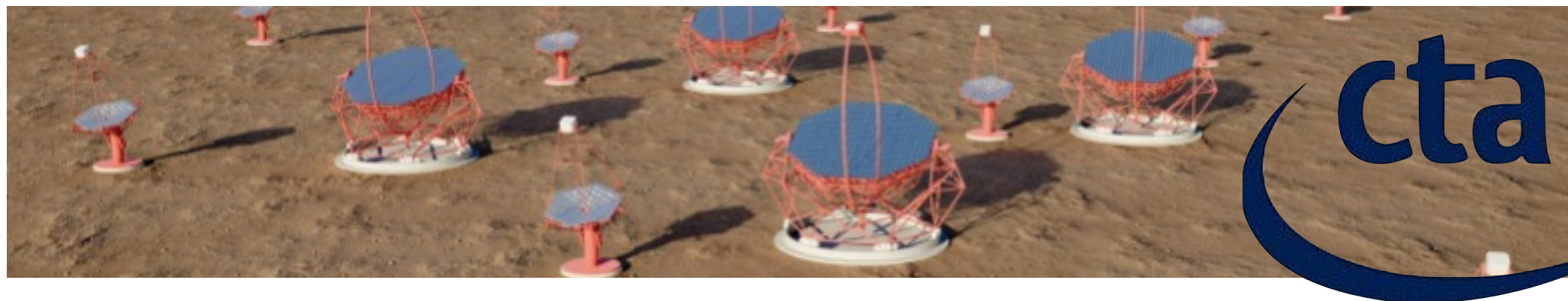




gtbary >>>> ctbary







gtbary >>>> ctbary

## Algorithms

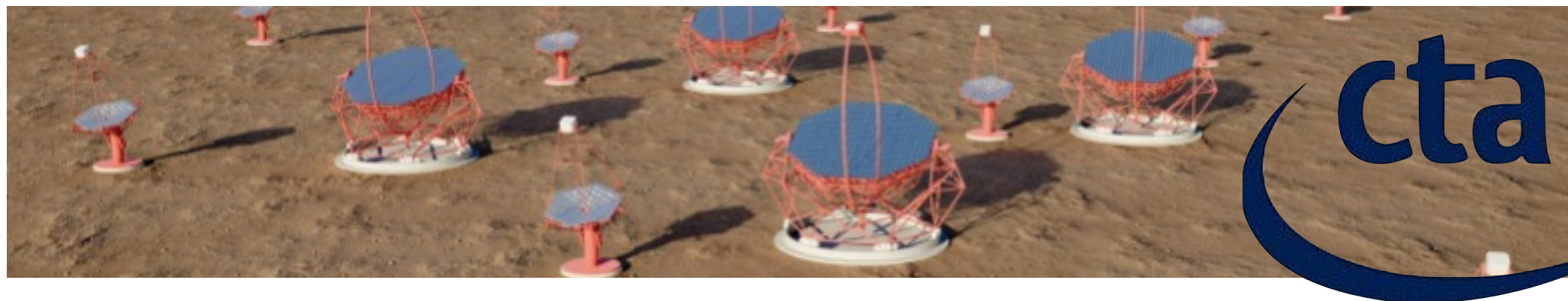
Photon arrival times are usually converted in the order shown in the table below, one step at a time. Note that each step of conversion also has a common name, and that additional information about arrival time conversion is included.

Conversion	Convert from	Convert to	Light travel time	Time system conversion
Geocentric correction	Mission Elapsed Time	Geocentric time	$\pm 23$ ms at maximum	From mission-dependent time system to TT
Barycentric correction	Geocentric time	Barycentric time	$\pm 500$ s at maximum	From TT to TDB
Binary demodulation	Barycentric time	Binary-demodulated time	Depends on binary parameters	None

**Note:** Since the pulsar location is needed to calculate photon travel time between the spacecraft and the geocenter, in principle **everything after a geocentric conversion depends on the pulsar location.**

- $TT = TAI$  (International Atomic Time) + 32.184 s
- $TAI = UTC + 32$  s at January 1.0, 2001, UTC
- Approximately,  $TDB = TT + 1.658 \text{ ms} \times \sin g + 0.014 \text{ ms} \times \sin 2g$ , where  $g$  is a mean anomaly of the center of gravity of the Earth-Moon system around the Sun. More precise estimate is necessary to meet the requirement on absolute time accuracy for Fermi (formerly GLAST).
- The solar system barycenter is located near the surface of the Sun, which is 2.3 light-second away from the center of the Sun.
- For micro-second precision timing, relativistic effects are not negligible. Such effects include: the Shapiro delay in the solar system, aberration due to the motion of the spacecraft around the Earth and the motion of the Earth around the Sun, and relativistic delay at the source (for binary pulsars only).
- Also see Goddard Space Flight Center's ["A Time Tutorial"](#) in ["The ABC of XTE"](#) for basic information about temporal analyses.





gtbary



ctbary

## Algorithms

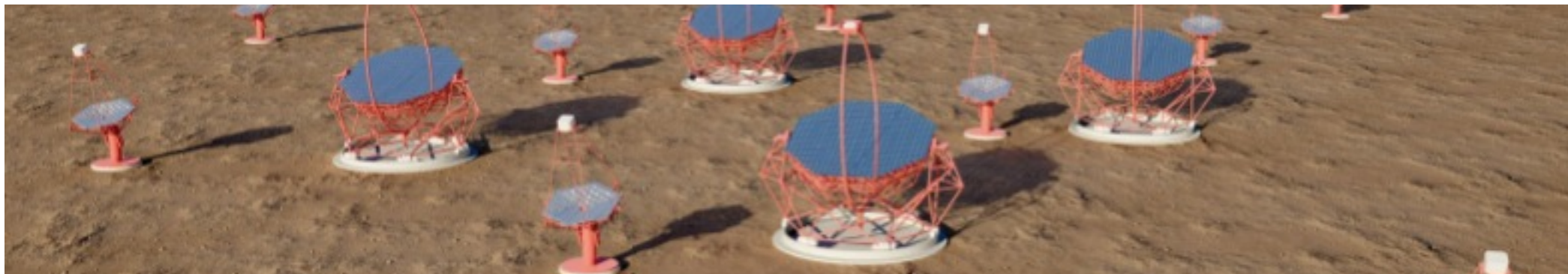
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# gtpsearch



# ctpsearch

## Period Search (gtpsearch) Tutorial

The *gtpsearch* tool searches for pulsations in data which is known or suspected to have a pulsation of a known approximate period or frequency.

**Note:** It is not useful for a so-called **blind period search**, in which data are examined for pulsations at any frequency.

**Known Issues:** When running *gtpsearch* multiple times using the GUI, plot windows from previous runs reappear after they are closed manually. Thus, there is no way to permanently close plot windows without exiting the GUI.

### Prerequisites

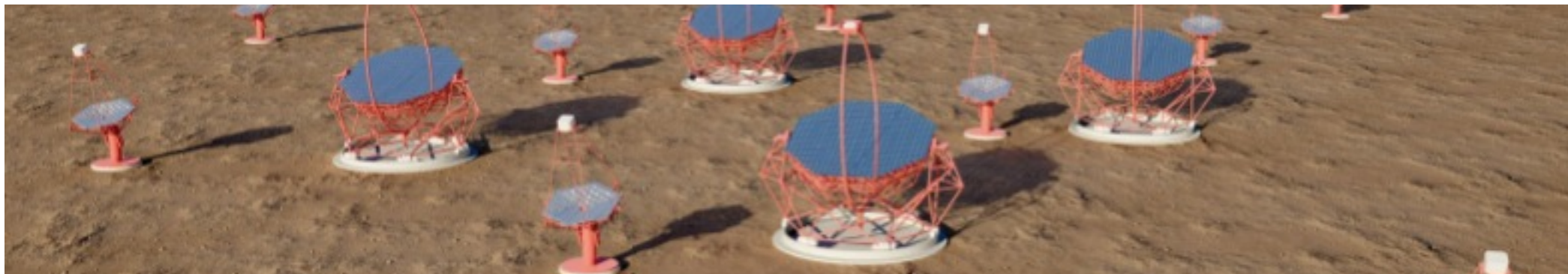
- Event data file in FT1 format, also known as a photon data file. (See [Extract LAT Data.](#))
- Orbit file to use for the barycentric correction
- Ephemeris information of suspected pulsation provided in one of the following forms:
  - Manually input the source (pulsar) location (for the barycentric correction), pulse frequency or period, and related information
  - Automatically extracted from a pulsar ephemerides database, available online.

**Sample Files.** To try the examples in this section, you can download the following simulated data files. The simulated data is for demonstration purposes and the simulated pulsar is slightly brighter than the Vela pulsar. For more information, see [the parameters used for the simulation.](#)

- [fakepulsar\\_event.fits](#) (372 kB) ([Parameters Used](#))
- [simscdata\\_1week.fits](#) (2.5 MB)
- [bogus\\_pulsar.db](#) (256 kB)

**Note:** The output of *gtpsearch* consists of text describing the result of the periodicity search and an optional plot. This tool also creates an output file when requested. The output file contains the result of computation, i.e., the search result in the text output and the data array to plot, for future reference.





**gtpsearch**



**ctpsearch**

## Period Search (gtpsearch) Tutorial

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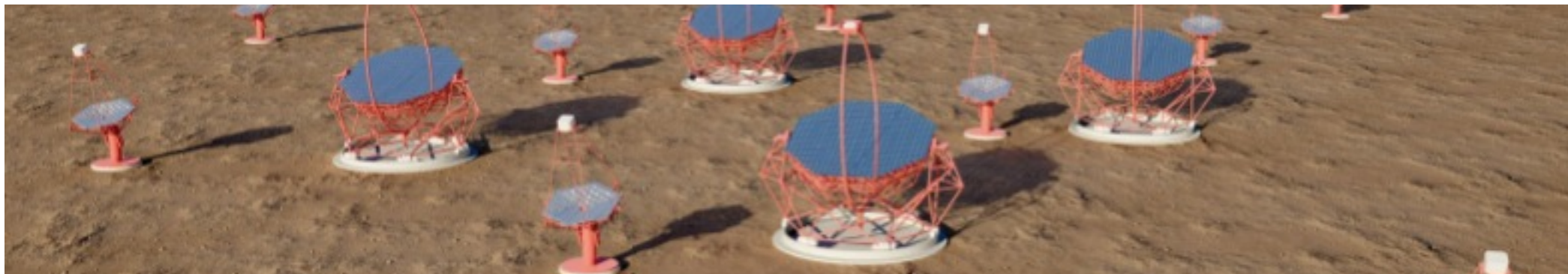
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♦ **events.fits**

♦ **ft2.fits**

♦ **Ephemeris**





**gtpsearch**



**ctpsearch**

## Period Search (gtpsearch) Tutorial

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- Ephemeris information of suspected pulsation provided in one of the following forms:
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  - Automatically extracted from a pulsar ephemerides database, available online.

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♦ **events.fits**

♦ ~~**n2.fits**~~

♦ **Ephemeris**

The **ctpsearch** tool searches for pulsations in data which is suspected to have a pulsation of a known approximate period

**(not meant for a BLIND search)**

2 possible methods for the ephemeris:

- ✦ **DATABASE**
- ✦ **Manual input**

```
$ ctpsearch
$ This is ctpsearch version 1.0.0
$ Event data file name[] event.fits
$ Pulsar ephemerides database file name[] pulsar.db.fits
$ Pulsar name[] Crab
$ Output FITS file name[] ctpsearch_example_1.fits
$ Type of statistical test to perform (CHI2|RAYLEIGH|Z2N|H) [] Chi2
$ Number of phase bins for Chi2 test[] 10
$ Size of steps for trials, in units of the Fourier resolution (0.:) [] 0.5
$ Number of trials[] 1600
$ How will the time origin of the periodicity test be specified? (START|STOP|MIDDLE|USER) [] MIDDLE
$ How will spin ephemeris be specified? (DB|FREQ|PER) [] FREQ
```


```
—> Search Type: Folding Analysis
Fourier Resolution: 1.65352e-06 Hz
Sampling Frequency: 8.26762e-07 Hz
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of freedom
Search Range (Hz): [12.3443081844528, 12.3456301768625]
Number of Trial Frequencies: 1600
Number of Independent Trials: 800
Maximum Statistic: 457.721899224806 at 12.3449695940386 Hz
Chance Probability Range: (5.12306683181322e-90, 5.12357914272081e-90)
```

The **ctpsearch** tool searches for pulsations in data which is suspected to have a pulsation of a known approximate period

**(not meant for a BLIND search)**

2 possible methods for the ephemeris:

- ✦ **DATABASE**
- ✦ **Manual input**



```
$ ctpsearch
$ This is ctpsearch version 1.0.0
$ Event data file name[] event.fits
$ Pulsar ephemerides database file name[] pulsar.db.fits
$ Pulsar name[] Crab
$ Output FITS file name[] gtpsearch_example_1.fits
$ Type of statistical test to perform (CHI2|RAYLEIGH|Z2N|H) [] Chi2
$ Number of phase bins for Chi2 test[] 10
$ Size of steps for trials, in units of the Fourier resolution (0.:) [] 0.5
$ Number of trials[] 1600
$ How will the time origin of the periodicity test be specified? (START|STOP|MIDDLE|USER) [] MIDDLE
$ How will spin ephemeris be specified? (DB|FREQ|PER) [] FREQ

—> Search Type: Folding Analysis
Fourier Resolution: 1.65352e-06 Hz
Sampling Frequency: 8.26762e-07 Hz
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of freedom
Search Range (Hz): [12.3443081844528, 12.3456301768625]
Number of Trial Frequencies: 1600
Number of Independent Trials: 800
Maximum Statistic: 457.721899224806 at 12.3449695940386 Hz
Chance Probability Range: (5.12306683181322e-90, 5.12357914272081e-90)
```



The **ctpsearch** tool searches for pulsations in data which is suspected to have a pulsation of a known approximate period

**(not meant for a BLIND search)**

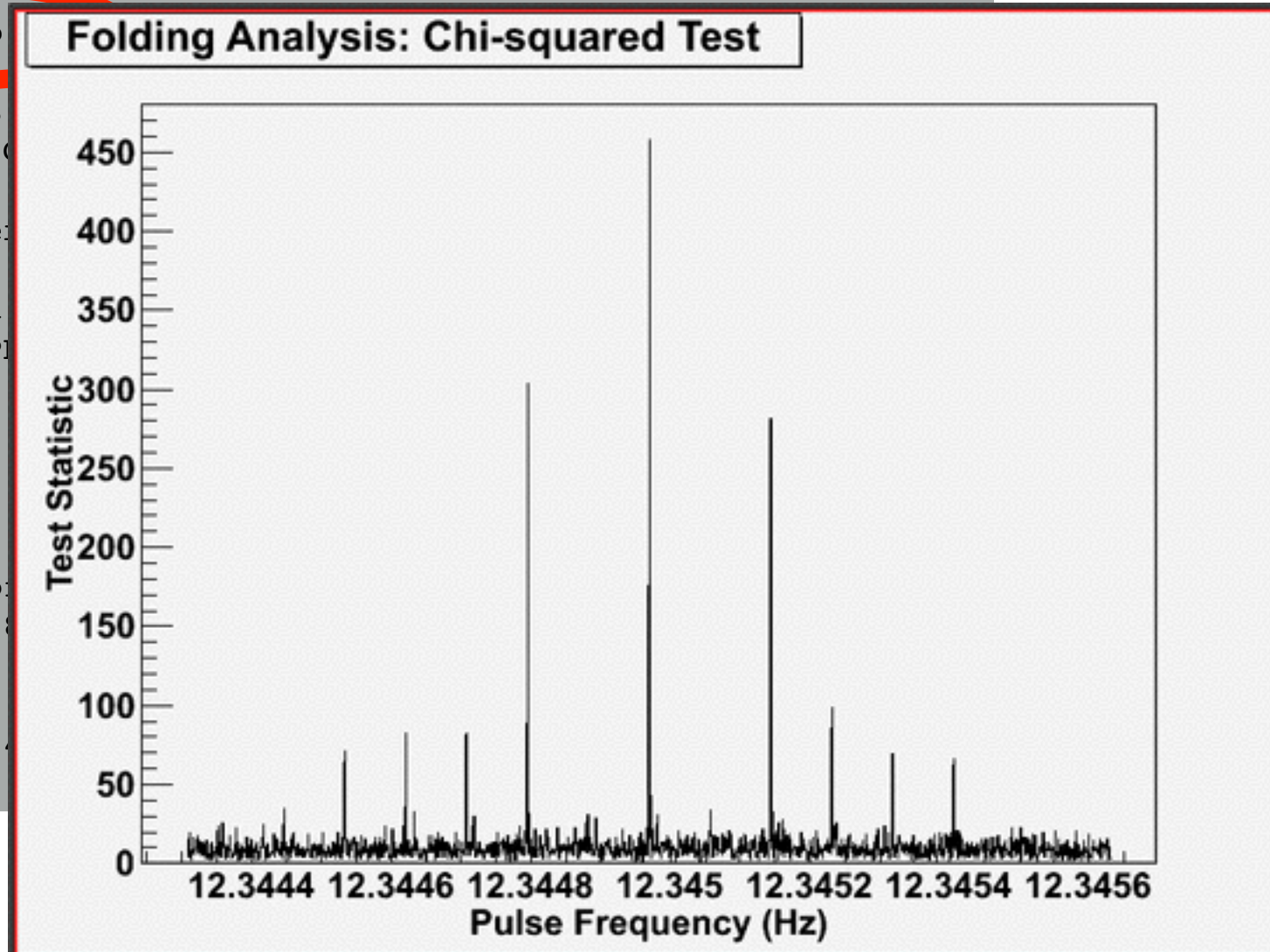
2 possible methods for the ephemeris:

✦ **DATABASE**

✦ **Manual input**

```
$ ctpsearch
$ This is ctpsearch version 1.0.0
$ Event data file name[] event.fits
$ Pulsar ephemerides database file name[] pulsardb
$ Pulsar name[] Crab
$ Output FITS file name[] gtpsearch_example_1.fits
$ Type of statistical test to perform (CHI2|RAYLEIGH)
$ Number of phase bins for Chi2 test[] 10
$ Size of steps for trials, in units of the Fourier
$ Number of trials[] 1600
$ How will the time origin of the periodicity test
$ How will spin ephemeris be specified? (DB|FREQ|P)
```

```
—> Search Type: Folding Analysis
Fourier Resolution: 1.65352e-06 Hz
Sampling Frequency: 8.26762e-07 Hz
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of freedom
Search Range (Hz): [12.3443081844528, 12.3456301768]
Number of Trial Frequencies: 1600
Number of Independent Trials: 800
Maximum Statistic: 457.721899224806 at 12.344969594
Chance Probability Range: (5.12306683181322e-90, 5.12306683181322e-90)
```



The **ctpsearch** tool searches for pulsations in data which is suspected to have a pulsation of a known approximate period

**(not meant for a BLIND search)**

2 possible methods for the ephemeris:

- ✦ **DATABASE**
- ✦ **Manual input**

```
$ ctpsearch
$ This is ctpsearch version 1.0.0
$ Event data file name[] event.fits
$ Pulsar ephemerides database file name[] NONE
$ Pulsar name[] Crab
$ Output FITS file name[] gtpsearch_example_2.fits
$ Type of statistical test to perform (CHI2|RAYLEIGH|Z2N|H) [] Chi2
$ Number of phase bins for Chi2 test[] 10
$ Size of steps for trials, in units of the Fourier resolution (0.:) [] 0.5
$ Number of trials[] 1600
$ How will the time origin of the periodicity test be specified? (START|STOP|MIDDLE|USER) [] MIDDLE
$ How will spin ephemeris be specified? (DB|FREQ|PER) [] FREQ
$ Epoch for the spin ephemeris[0.] 54870.0
$ Time format for spin ephemeris epoch (FILE|MJD|ISO|FERMI|GLAST) [FILE] MJD
$ Time system for spin ephemeris epoch (FILE|TAI|TDB|TT|UTC) [FILE] TDB
$ Right Ascension to be used for barycenter corrections (degrees)[0.] 111.11
$ Declination to be used for barycenter corrections (degrees)[0.] 22.22
$ Pulse frequency at the epoch of the spin ephemeris (Hz) (0.:) [1.] 12.3448
$ First time derivative of the pulse frequency at the epoch of the spin ephemeris (Hz/s)[0.] -2.3e-10
$ Second time derivative of the pulse frequency at the epoch of the spin ephemeris (Hz/s/s)[0.] 0.0

—> Search Type: Folding Analysis
Fourier Resolution: 1.65352e-06 Hz
Sampling Frequency: 8.26762e-07 Hz
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of freedom
.. .. ..
```

The **ctpsearch** tool searches for pulsations in data which is suspected to have a pulsation of a known approximate period

**(not meant for a BLIND search)**

2 possible methods for the ephemeris:

✦ **DATABASE**

✦ **Manual input**

```
$ ctpsearch
$ This is ctpsearch version 1.0.0
$ Event data file name[] event.fits
$ Pulsar ephemerides database file name[] NONE
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$ Output FITS file name[] gtpsearch_example_2.fits
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$ Number of phase bins for Chi2 test[] 10
$ Size of steps for trials, in units of the Fourier resolution (0.:) [] 0.5
$ Number of trials[] 1600
$ How will the time origin of the periodicity test be specified? (START|STOP|MIDDLE|USER) [] MIDDLE
$ How will spin ephemeris be specified? (DB|FREQ|PER) [] FREQ
$ Epoch for the spin ephemeris (FILE|MJD|ISO|FERMI|GLAST) [FILE] MJD
$ Time system for spin ephemeris epoch (FILE|TAI|TDB|TT|UTC) [FILE] TDB
$ Right Ascension to be used for barycenter corrections (degrees)[0.] 111.11
$ Declination to be used for barycenter corrections (degrees)[0.] 22.22
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$ Second time derivative of the pulse frequency at the epoch of the spin ephemeris (Hz/s/s)[0.] 0.0

—> Search Type: Folding Analysis
Fourier Resolution: 1.65352e-06 Hz
Sampling Frequency: 8.26762e-07 Hz
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of freedom
... ..
```



The **ctpsearch** tool searches for pulsations in data which is suspected to have a pulsation of a known approximate period

**(not meant for a BLIND search)**

2 possible methods for the ephemeris:

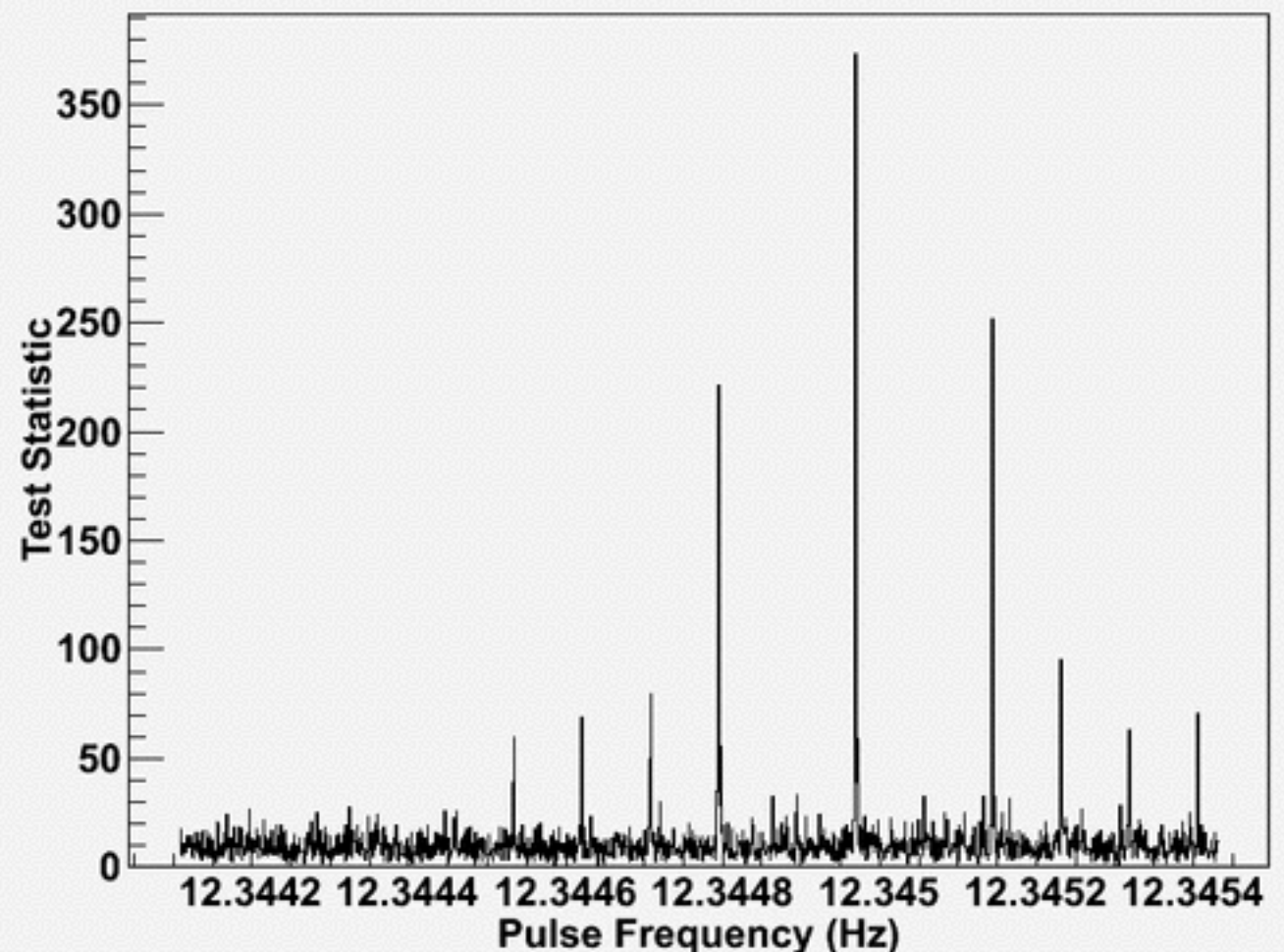
✦ **DATABASE**

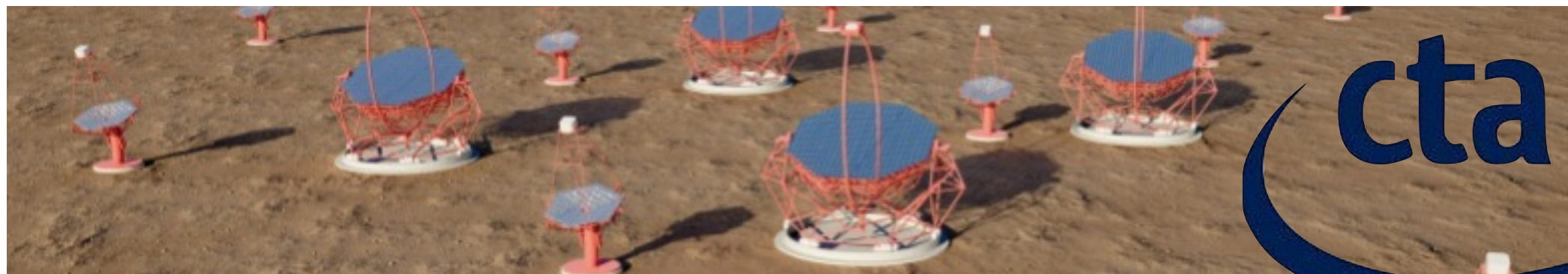
✦ **Manual input**

```
$ ctpsearch
$ This is ctpsearch version 1.0.0
$ Event data file name[] event.fits
$ Pulsar ephemerides database file name[] NONE
$ Pulsar name[] Crab
$ Output FITS file name[] gtpsearch_example_2.fits
$ Type of statistical test to perform (CHI2|RAYLEIGH)
$ Number of phase bins for Chi2 test[] 10
$ Size of steps for trials, in units of the Fourier
$ Number of trials[] 1600
$ How will the time origin of the periodicity test
$ How will spin ephemeris be specified? (DB|FREQ|P)
$ Epoch for the spin ephemeris
$ Time format for spin ephemeris epoch (FILE|MJD|ISO|F
$ Time system for spin ephemeris epoch (FILE|TAI|TDB|T
$ Right Ascension to be used for barycenter correction
$ Declination to be used for barycenter corrections (d
$ Pulse frequency at the epoch of the spin ephemeris (
$ First time derivative of the pulse frequency at the
$ Second time derivative of the pulse frequency at the

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Fourier Resolution: 1.65352e-06 Hz
Sampling Frequency: 8.26762e-07 Hz
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of fr
... ..
```

### Folding Analysis: Chi-squared Test





# gtpphase >>>>> ctpphase

## Pulse Phase Calculation (gtpphase) Tutorial

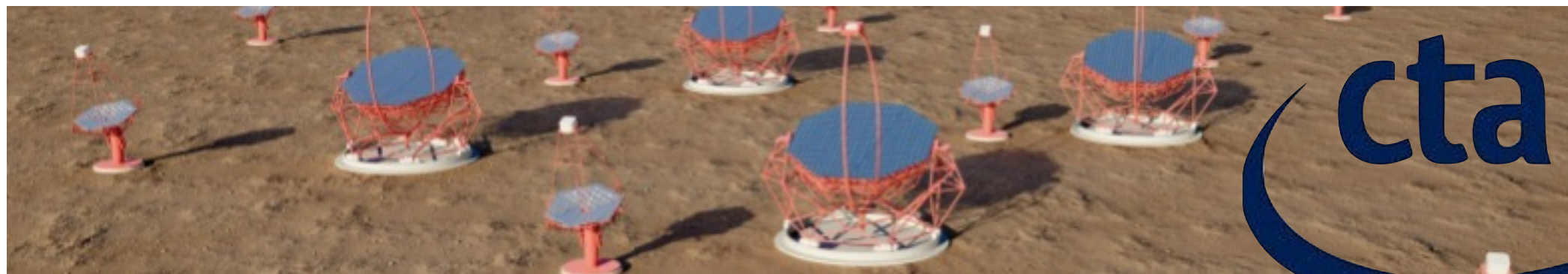
The *gtpphase* tool's purpose is to assign a pulse phase to each record in an event file, based on one or more known pulsar ephemerides.

### Prerequisites

- Event data file (See [Extract LAT Data](#)).
- Ephemeris information of suspected pulsation provided in one of the following forms:
  - Manually input the source (pulsar) location (for the barycentric correction), pulse frequency or period, and related information
  - Automatically extracted from a pulsar ephemerides database, available online.

Tutorial	SciTools References
<a href="#">Pulsar Analysis Tutorial: Calculate Pulse Phase for Each Photon</a>	<a href="#">gtpsearch</a>
<a href="#">Period Search Tutorial</a>	<a href="#">gtpphase</a>
<a href="#">Binary Orbital Phase Calculation</a>	<a href="#">gtophase</a>





**gtpphase** >>>> **ctpphase**

## Pulse Phase Calculation (gtpphase) Tutorial

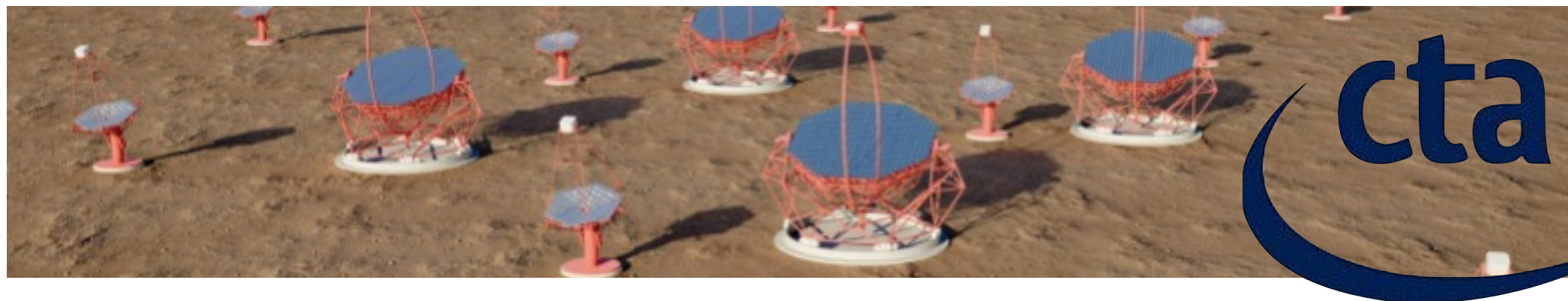
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<a href="#">Binary Orbital Phase Calculation</a>	<a href="#">gtophase</a>





**gtpphase**



**ctpphase**

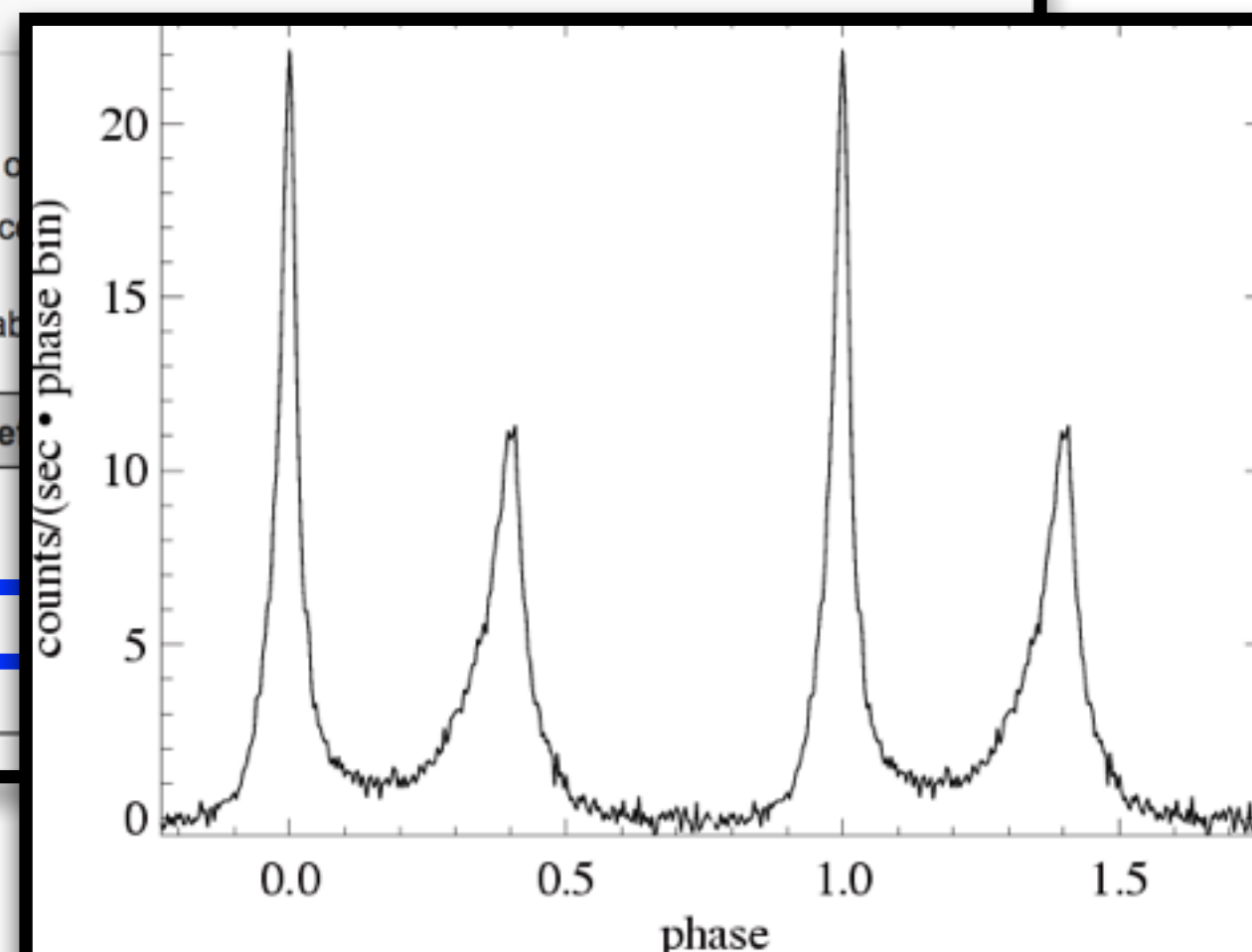
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# Searching for



# Periodicity

