Time evolution of luminosity and spin period of X-ray pulsars in the Small Magellanic Cloud

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Introduction to the library of pulsars in the Magellanic Clouds

event lists, light curves, periodograms & spectra

• Why study pulsars in Magellanic Clouds:

NSs hold unsolved problems; population-statistical study.

low absorption, minimum foreground contamination, known distance (-> categorize luminosity of the Pulsars). The process of accretion and X-ray emission in HMXB

• Known pulsars with combination of 3 satellites, physical parameters

e.g. SXP 348, SXP 1323

• Pulse profile modeling

e.g. SXP 504

In sum

Outline
Library of pulsars in the Magellanic Clouds

**Pulsars In SMC & Model**

**Intro Library**

**Pulsars spin up/down**

**Pulse profile model**

**In sum**

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Chandra
155+30 Obs: 2000-2014

XMM-Newton
116+42 Obs: 2000-2014

RXTE
Weekly Obs: 1997-2012
Luminosity of X-ray pulsars in the Small Magellanic Cloud

Spin Period (s)

Luminosity Range: \(10^{31}-10^{38} \text{ erg/s}\)

Observation overview

Luminosity:

- \(10^{31}-10^{38} \text{ erg/s}\)

Classify:

- pulsating
- non-pulsating

Intro Library

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In summary

Fast pulsars rarely detected

Faint source

Short exposure
Luminosity of X-ray pulsars in the Small Magellanic Cloud

Observation overview

Luminosity Range:
$10^{31} - 10^{38}$ erg/s

Spin Period (s)

Fast pulsars rarely detected
Faint source
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Pulsars in SMC & Model

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Classify: pulsating & non-pulsating
Pulsars in SMC & Model Intro Library

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In sum

Time evolution of Source properties with 3 satellite combination
e.g. SXP 348

Luminosity (erg/s)

Pulse fraction

Amplitude (Counts/s)

Spin Period(s)

Significance (%)

Modified Julian Date

XMM-Newton

Chandra

RXTE does not have Pulse Frac info

Spin up: Mass and angular momentum to NS

RXTE does not have Pulse Frac info

In sum

Modified Julian Date

Spin up: Mass and angular momentum to NS

RXTE does not have Pulse Frac info

In sum
SMC Pulsar library products

- **Spin up**: 0.016932 s/day
- **Pulse profile model**
- **Orbital modulation, accretion torque**
- **In sum**: 26 spin up, 17 spin down
- **43 out of 65 pulsars have measured orbit period**
Model: Off-center magnetic axis with GR effect

Best fitting angle: $\theta = 28^\circ$ and $\beta = 52^\circ$

$\theta$: angle between spinning axis and B
$\beta$: angle between spinning axis and light of sight

SXP 504 2003-12-14 Observation

Class 1

Class 2

Class 3

Class 4

Phase

Period (s)

The reduced $\chi^2$

Pulsars In SMC & Mode I

Intro Library

Pulsar spin up/down

Pulse profile model

In sum
Summary & Outlook

- Library of 3 satellites combination: Chandra, XMM-Newton, RXTE
  Known pulsars in SMC & LMC: event lists, pulse profiles, spectra

- Time evolution of their luminosities and spin period
  26 spin up and 17 spin down

- Modeling
  More phenomenon into current model: e.g., flow column geometry including physics of accretion shock, accretion rate and photon energy

- Astrosat & HXMT (Hard X-ray Modulation Telescope)
  Investigate the hard X-ray sources; bright galactic pulsars, expand the period range of the pulsars
In sum, Pulsars spin up/down. Pulse profile model.

In SMC & Mode

Thank you!
Library of pulsars in the Magellanic Clouds

Pulsars in SMC & Model

Intro Library

Pulsars in SMC

Pin up/down

Pulse profile model

In sum
Library of pulsars in the Magellanic Clouds

Pulsars in SMC & Model

Into Library

Pulsars spin up/down

Pulse profile model

In sum
Library of pulsars in the Magellanic Clouds

Observation overview

Amplitude

# of observations

Log (pulse amplitude (cnt/s)) with Chandra Observations

Log (pulse amplitude (cnt/s)) with XMM-Newton Observations
SMC Pulsar library products

Pulsars
In SMC Mode

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Intro Library

Pulsar spin up/down
Pulse profile model

In sum

XMM-Newton EPIC PN photon counts
Cumulative # of pulsation detected

Spin Period (s)

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| XMM-newton Obs | Chandra Obs | RXTE Obs |

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Pulsars
In SMC Mode

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Library of pulsars in the Magellanic Clouds

Observation overview

Propeller line (P-line) in Magellanic high mass X-ray binaries;

Did not find the pulsations below the P-line

\[ L_{X,\text{min}} = L_0 \left( \frac{\mu}{10^{20} \text{ Gcm}^2} \right)^2 \cdot P^{-7/3} \]

\[ L_{X,\text{gap}} = \frac{L_{X,\text{min}}}{167 \cdot 870562 \cdot P^{5/3}} \]

SXP 348
Pulsars in SMC & Model

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Into Library

Pulsars spin up/down

Pulse profile model

In sum

Make up

**Graph**

**Axes:**
- **X-axis:** Spin Period (s)
- **Y-axis:** $dP/P$ and $\delta P/P$

**Data Points:**
- XMM-newton Obs
- Chandra Obs
- RXTE Obs

**Legend:**
- Green dots: XMM-newton Obs
- Blue dots: Chandra Obs
- Yellow dots: RXTE Obs

**Graph Features:**
- The graph displays a scatter plot with data points representing the spin period and its variations.
- The $dP/P$ and $\delta P/P$ are plotted against the spin period.
- The data points are color-coded to distinguish between different observational datasets.
Pulsars In SMC & Model

Jun Yang

Into Library

Pulsars spin up/down

Pulse profile model

In sum

Make up

Makeup
Pulsars in SMC & Model

Jun Yang

Into Library

Pulsars: spin up/down

Pulse profile model

In sum

Make up

SXP 1323  Spin up: 0.0209 s/day
Pulsars In SMC & Model

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Into Library

Pulsars spin up/down

Pulse profile model

In sum

Make up

Luminosity (erg/s) vs. Spin Period (s)

\[ L_{X,\text{min}} = L_0 (=2.0 \times 10^{37} \text{ erg/s}) \times \left( \frac{I}{10^{43} \text{ G cm}^2} \right)^2 \times P^{-7/3} \]
Astrosat

• Broadband Spectroscopic studies of X-ray sources