Search for continuous gravitational waves from the Low Mass X-ray Binary Scorpius X-1

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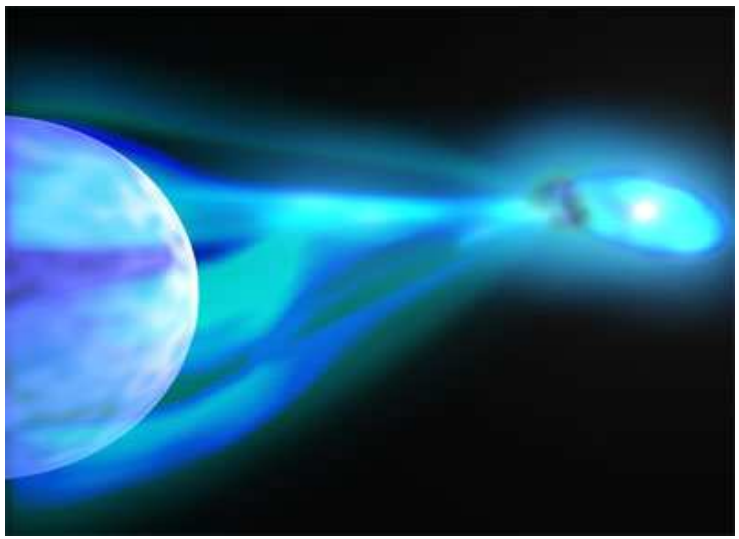
AEI Hannover-Golm Group Meeting

December 1, 2009

Motivation

- continuous GW searches
  - $\Rightarrow$ long coherent observation
  - $\Rightarrow$ many templates in parameter space
  - $\Rightarrow$ large computing costs
- targeted semi-coherent search
  - $\Rightarrow$ requires less templates
  - $\Rightarrow$ not computationally limited
  - $\Rightarrow$ longer observation times achievable



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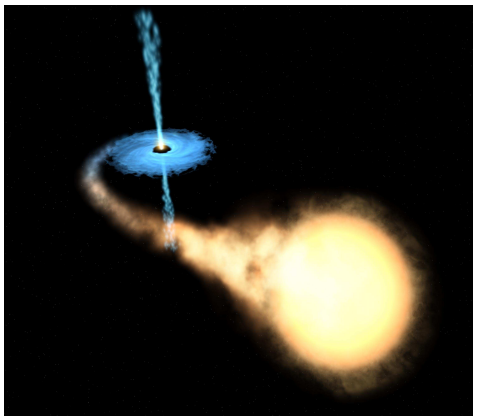
Introduction and Background

Low Mass X-ray Binaries (LMXBs)

- compact object (NS) in orbit with lower mass companion
- companion accreting at very high rate leading to X-ray emission
- EM observation of LMXBs:
  - accurate measurement of sky position and orbital period (P_{orb})
  - reasonable measurement of semi-major axis ($a \sin \iota$)
- **rotational spin frequency (ν_{s}) not directly measurable without a pulse**

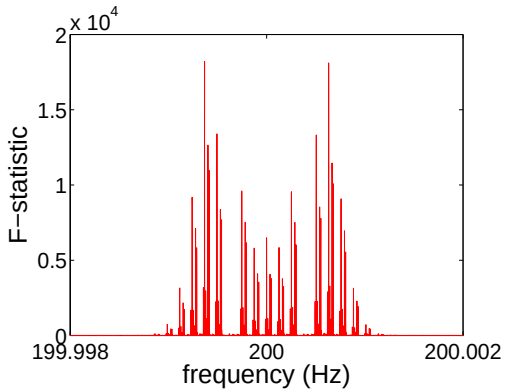


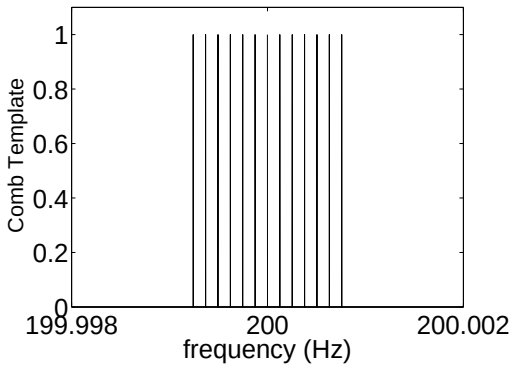
GWs from LMXBs

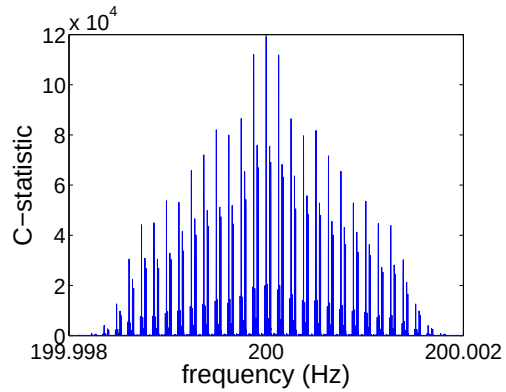
- emitted due to non-axisymmetric deformations in the NS (possibly caused by accretion)
- one of the leading explanations of observed accretion rates maxing out at a limit which is lower than expected ($\sim$ 650 Hz)
- if GWs balance accretion torque, then x-ray flux (F_X) can be used to estimate GW strain amplitude (h_0) taking GW frequency $f_0 = 2\nu_{\text{s}}$

$$h_0 \approx 4 \times 10^{-27} \left(\frac{F_X}{10^{-8} \text{erg cm}^{-2} \text{s}^{-1}} \right)^{1/2} \left(\frac{600 \text{Hz}}{f_0} \right)^{1/2}$$

The Search







$\mathcal{F}$-statistic

- continuous wave search matched filter
- most likely candidates in phase parameter space (α, δ, f, $\dot{f}$)
- targeted LMXB - know α, δ, choose T_{obs} to ignore $\dot{f}$, left with f

Signal

- Source in binary system

$\Rightarrow$ Doppler modulated signal

$\Rightarrow$ frequency modulated (FM) sidebands in $\mathcal{F}$-statistic

$\Rightarrow$ characterised by orbital parameters (P_{orb} and $a_0 = a \sin \iota$) and GW frequency f

Template

- LMXB source

$\Rightarrow$ known P_{orb} and a_{P}

$\therefore$ can construct template of unit amplitude spikes for each guess GW frequency f

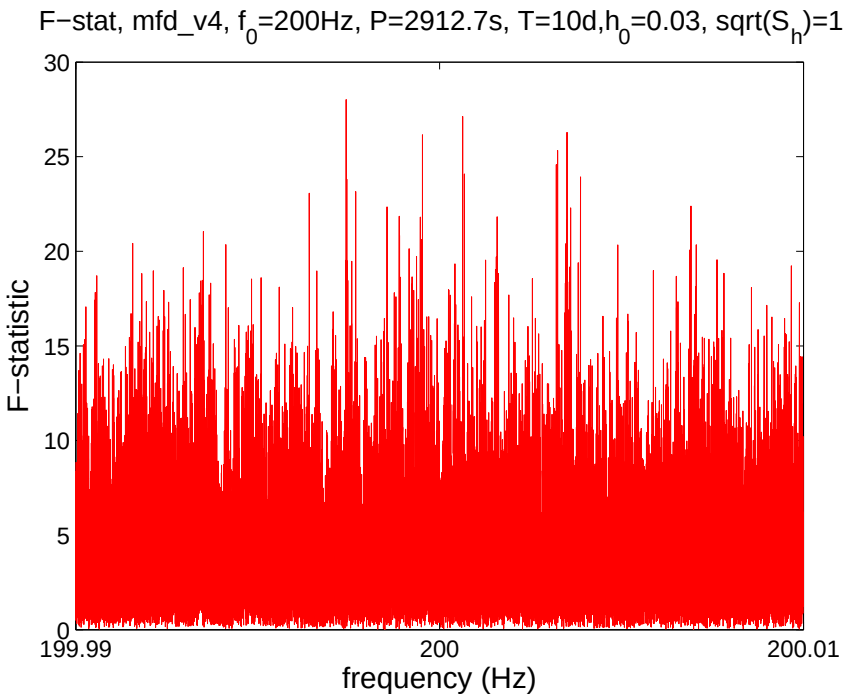
  - $2\pi f a_0$ spikes on either side of central peak at $f = f_0$
  - $1/P_{\text{orb}}$ peak separation

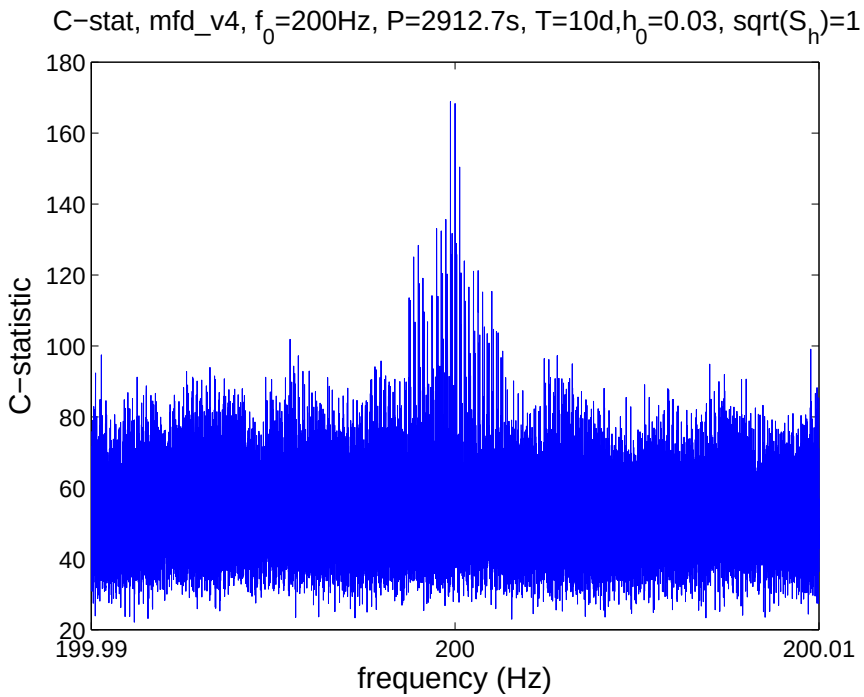
$\mathcal{C}$-statistic

- stronger detection statistic for frequency modulated GW signals
- sum of $\mathcal{F}$-statistic sidebands at each guess frequency f

$\Rightarrow$ convolution of $\mathcal{F}$-statistic with template
i.e. $\mathcal{C} = 2\mathcal{F} \otimes$ "Template"

Example on injected signal





Sensitivity

Target source: Sco X-1

- brightest extra solar X-ray source in the sky ($F_X = 2 \times 10^{-6}$ erg cm^{-2} s^{-1})

$\Rightarrow$ strong GW candidate

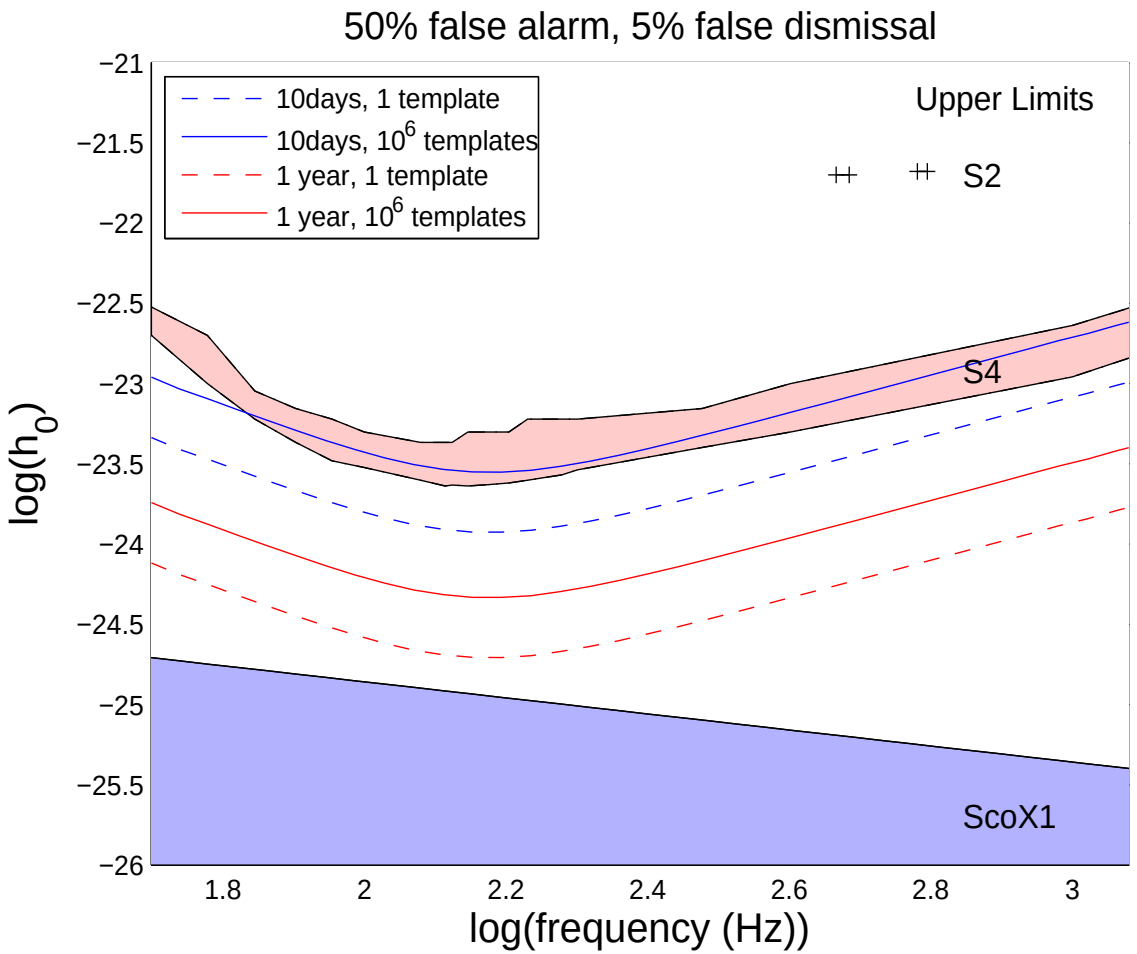
- also very close ($D = 2.8 \pm 0.3$ kpc)
- GW strain amplitude $h_0 \approx 6 \times 10^{-26}$ at 600 Hz could be detectable with advanced LIGO

Source Parameters

P_{orb}	=	68023.84 $\pm$ 0.08 s
$a \sin \iota$	=	1.44 $\pm$ 0.18 s

Search Parameters

T_{obs}	$\geq$	10 days
f range		all possible
detectors		all possible



Summary

- comb search computes $\mathcal{C}$-statistic
  - for binary systems with known sky position and orbital period
  - determines likely candidates in frequency
- sensitivity estimates can beat previous upper limits
- working version of code analysing S5 data

Further work

- instrumental noise line vetoes
- upper limit calculations
- method for confident detection and non-detection
- method to implement spin wandering