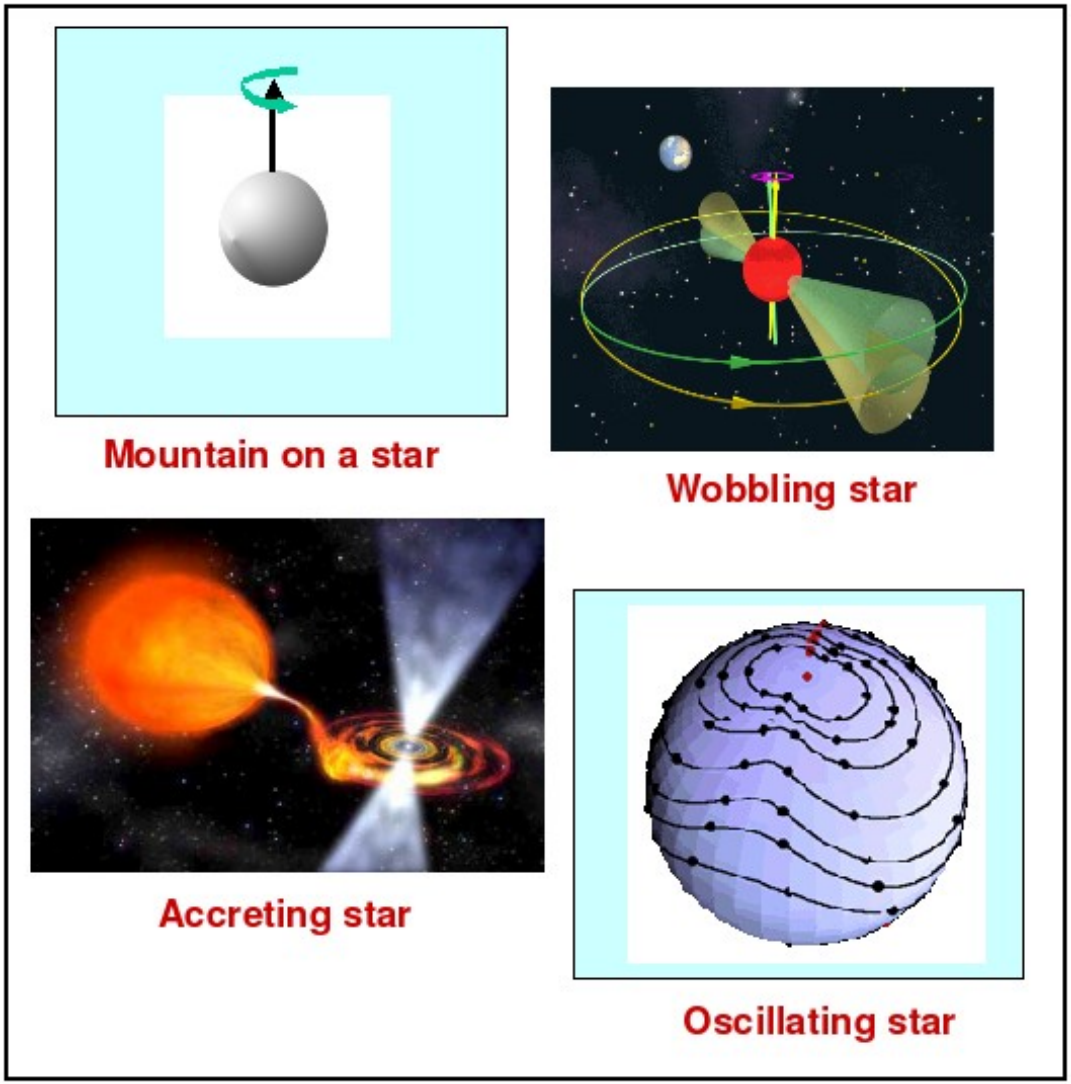
Searches for CW signals



M.Alessandra Papa for the CW group
LSC meeting, 23-26 July 2007, MIT

The CW group

* ~ 20 active members
* “teams” work on specific searches or software
* not single integrated software
* every type of search has been cross-checked with 2 independent codes
* overlap yes, but a lot of complementarity and fine tuning for different scopes
* lots of communication and exchange between “teams”
* most mature software not only utilized by developers
* Virgo efforts fit right in
* history of exchange of ideas well before MOU (SFTs first proposed by Frasca and Astone at GWDAW0 at MIT)
* designated an official liason between the group and the community of astronomers, B. Owen

The CW efforts

* Analysis development:
  - to extend depth of deep wide parameters space searches
  - to enhance sensitivity of the fast scans of data
  - to extend capabilities beyond isolated objects

* Perform searches:
  - utilize existing software to search in interesting parameter space regions (optimization problem to determine parameter of search and then set up search, i.e. grid, thresholds, coincidence windows)

Searches *now* underway

Searches for signals from known pulsars, isolated and in binary systems (S3/S4 paper accepted for publ. In PRD, Crab paper in prep, with also f-fdot search, all S5 for all pulsars at end of S5 underway)

Blind searches for signals from isolated pulsars (final draft of semi-coherent methods S4 paper, final results E@H S4, S5 hierarchical search running, S5a fast scan underway)

Targeted searches for signals from known (or suspected) non-pulsating isolated objects (S5 CasA search underway)

Upper limits: on what ?

On h_0: the intrinsic amplitude at the detector.

Signal at the detector:

$$h(t) = h_+(t) F_+(t, pos, pol) + h_x(t) F_x(t, pos, pol)$$

$$h_+ = 0.5\, h_0 (1 + \cos^2 i) \cos\Phi(T) \quad h_x = h_0 \cos i \sin\Phi(T)$$

We do not directly measure h_0 we infer it from detection efficiency studies.
But it is nicely connected to interesting properties of the source.

$$h_0 = \frac{16\pi^2 G}{c^4} \frac{\epsilon I f^2}{d}$$

Searches for signals from known pulsars

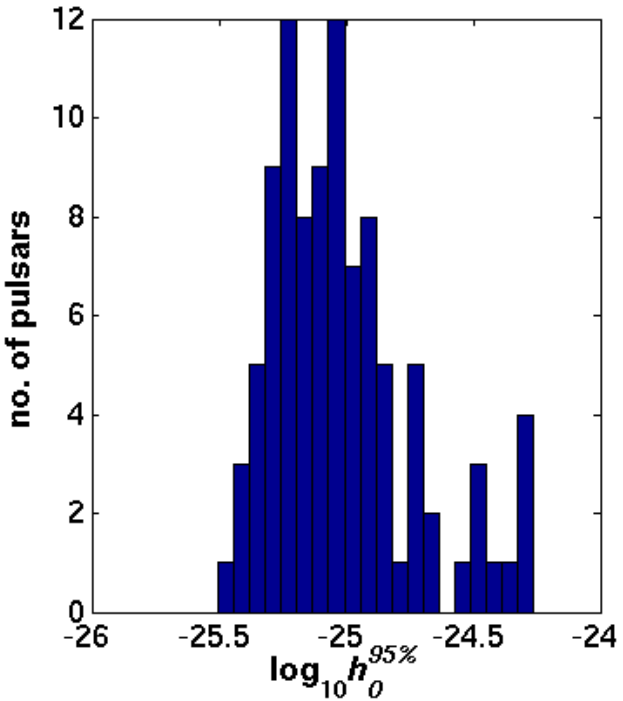
* timing data from astronomers, assuming:
    * EM and GW phases locked
    * $f_{GW}=2f_{em}$
* spin-down inferred upper limits exist but...
    * for objects in globular clusters these should be taken with grain of salt
    * moment of inertia is not known precisely
* so:
    * first direct limits
    * starting to probe new grounds
* Plan to increase targets X 2

Known pulsars, preliminary S5

Joint 95% upper limits from first ~13 months of S5 using H1, H2 and L1 (97 pulsars)

Lowest h_0 upper limit:

PSR J1623-2631 (ν_{gw} = 180.6 Hz, r = 2.2 kpc) $h_{0\_min} = 3.4 \times 10^{-26}$



Known pulsars, preliminary S5

$$h_0 = \frac{16\pi^2 G}{c^4}\frac{\epsilon I f^2}{d}$$

known

fiducial value

Lowest h_0 upper limit:

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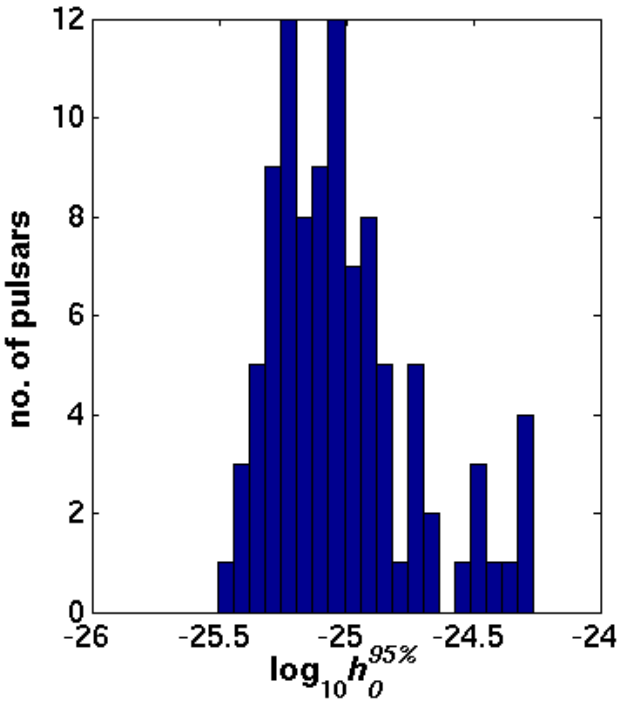
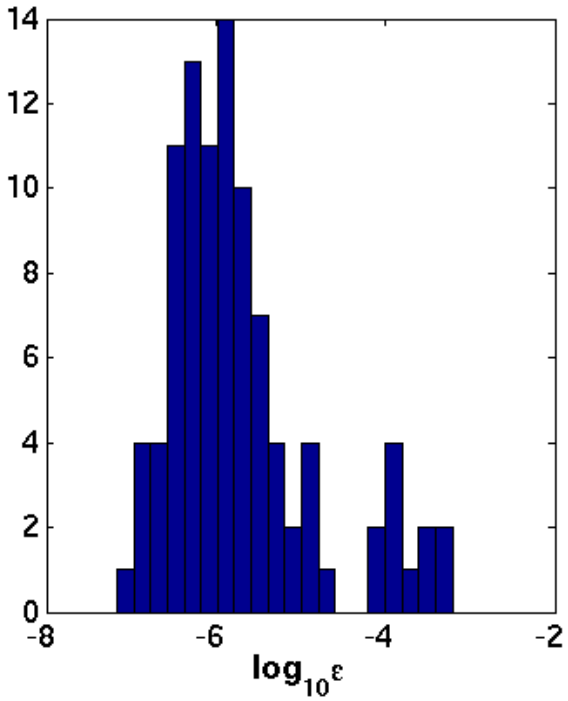
Lowest ellipticity upper limit:

PSR J2124-3358 (ν_{gw} = 405.6Hz, r = 0.25 kpc) $\varepsilon = 7.3\times10^{-8}$





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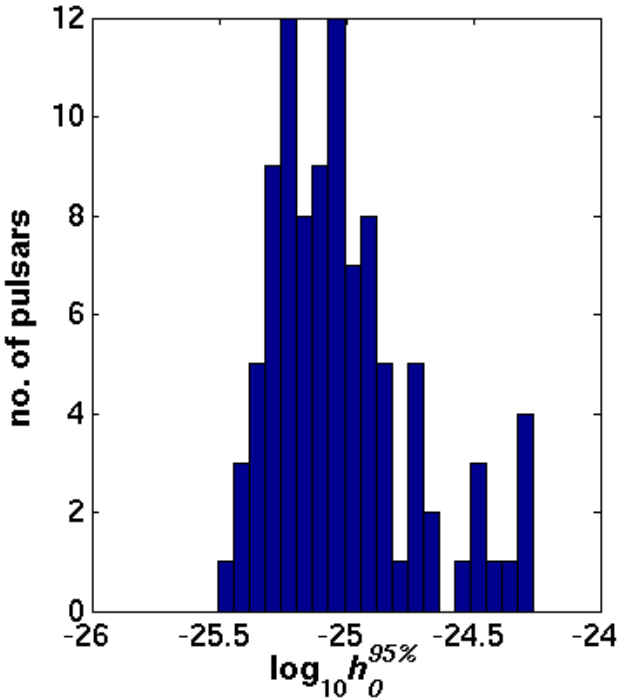
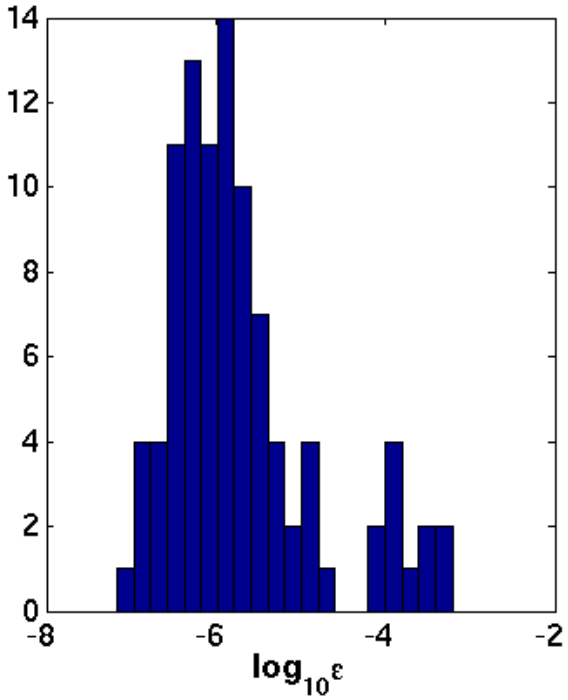
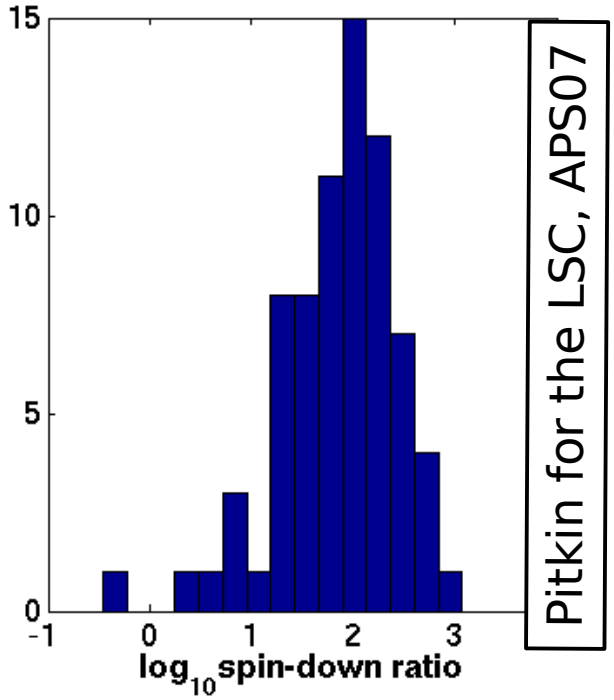
If all rotational kinetic energy were carried away by Gws, their

$$h_0 = \sqrt{\frac{5G}{2c^3}\frac{I\dot{f}}{d^2 f}}$$







Crab pulsar preliminary result

$h_{0\ spin\text{-}down} = 1.4\text{x}10^{-24}$ — $\varepsilon_{spin\text{-}down} = 7.3\text{x}10^{-4}$

$h_{0\ S5\ first\ year} = 5\ \text{x}10^{-25}$ at fiducial $I = 10^{38}$kg m^2 — $\varepsilon_{S5\ first\ year} = 2.6\ \text{x}10^{-4}$

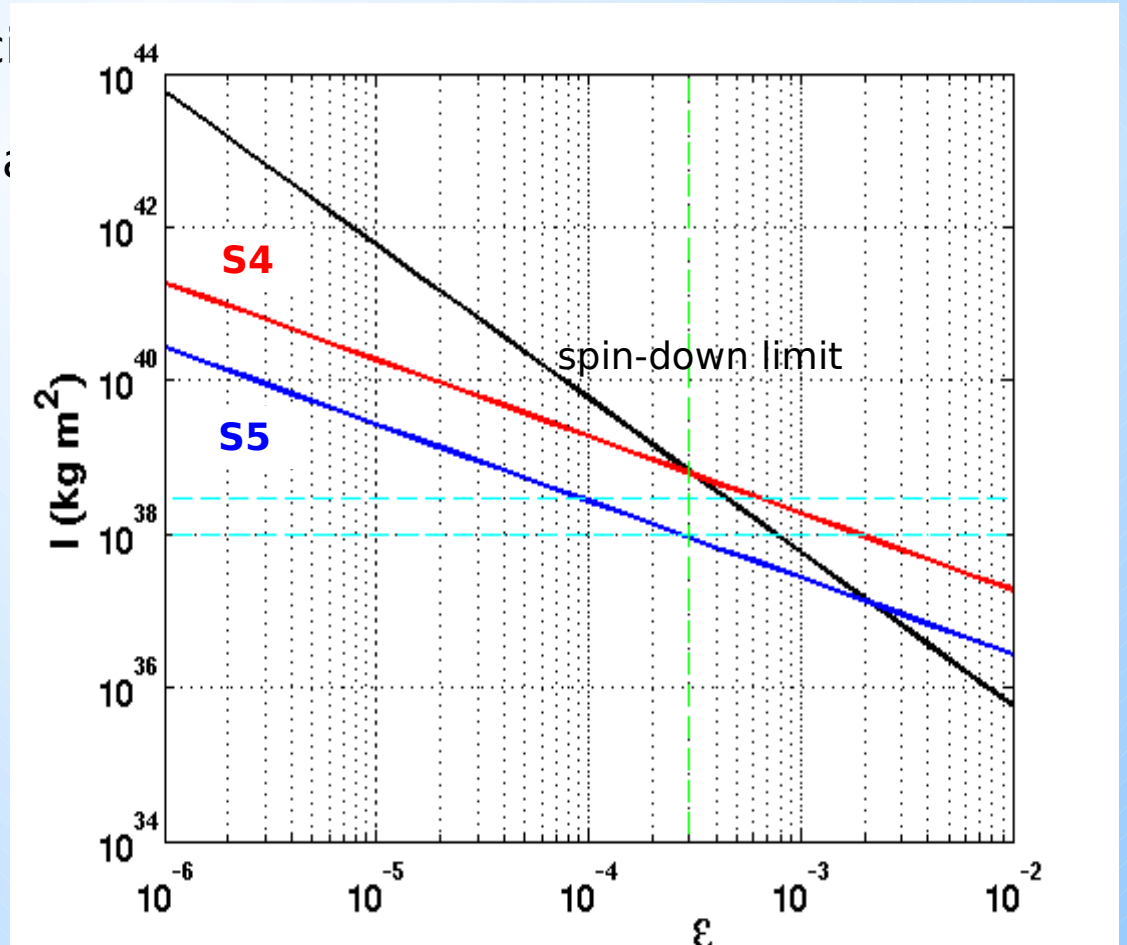
However, we know that not all energy goes into GWs: [1] estimates

$\varepsilon_{corrected\ spin\text{-}down} = 3\text{x}10^{-4}$

But I could be higher than the fiduc value. No definitive observational evidence but a number of theoretic investigations* suggest:

$I = 1\text{-}3 \times 10^{38}$ (kg m^2)

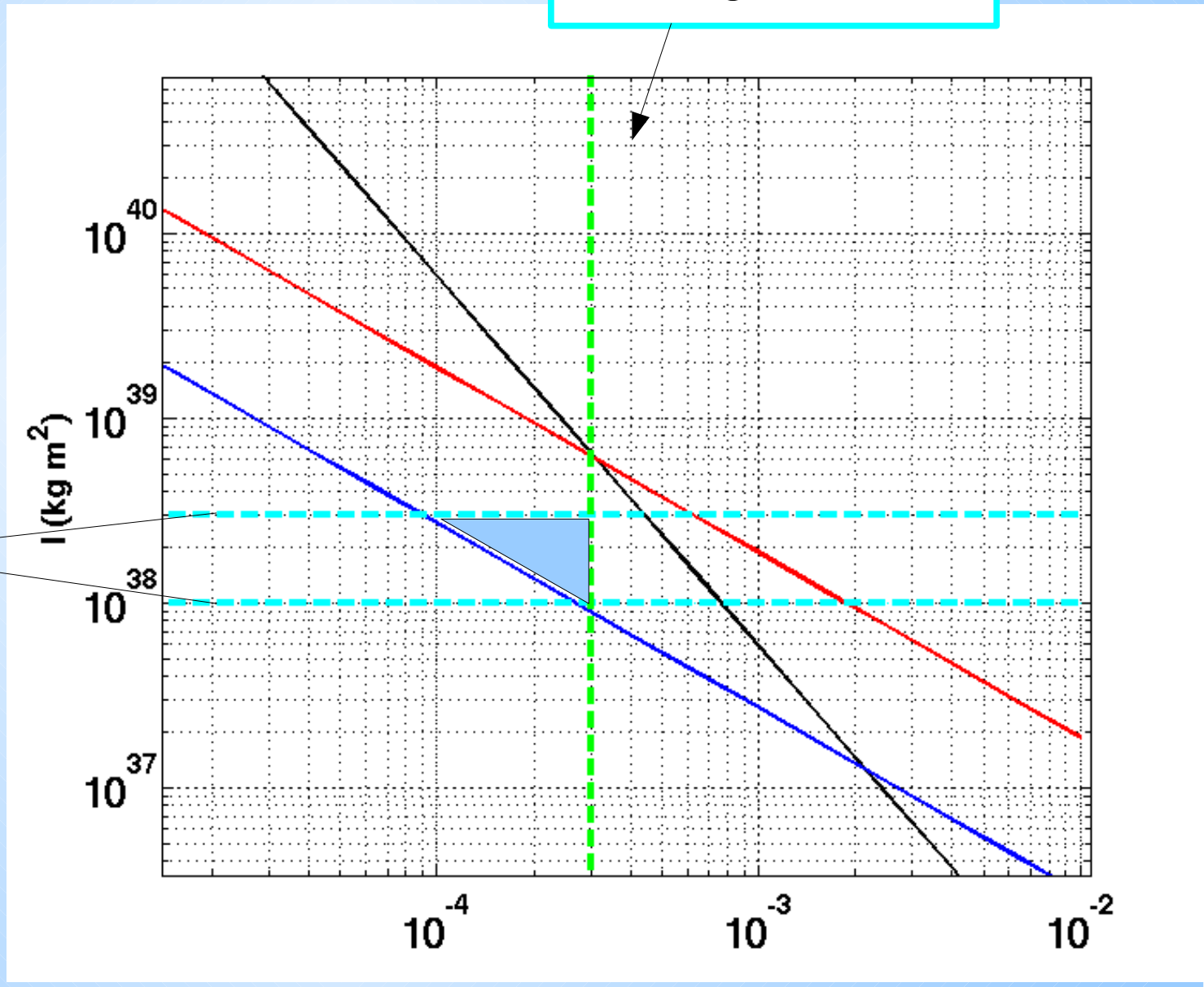
Upper limit on h_0 can be recast as exclusion area on $I\varepsilon$ plane:



[1]: Palomba, AA, (354) (2000)

Crab

Exclusion region goes as low as $\varepsilon = 9 \times 10^{-5}$ for $I = 3 \times 10^{38}$ (kg m^2)



Isolated interesting objects

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for which we do not have complete information

Targeted searches towards non-pulsating objects

Assuming spin-down due to GW emission:

$$h_{IUL} = 2.3\,X\,10^{-24}\,\frac{1\,kpc}{D}\sqrt{\frac{I}{10^{38}\,kg\,m^2}}\sqrt{\frac{1\mathrm{kyr}}{\tau}}$$

τ: age, D distance, I moment of inertia

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f-fdot searches for point-sources (from Chandra observations):

CasA : $h_{IUL} = 1.2 \times 10^{-24}$ (τ = 325 yr, D=3.4 kpc)

VelaJn: $h_{IUL} = 5.7 \times 10^{-24}$ (τ = 680 yr, D=480 pc)

SN1987A : 3.2×10^{-25} (τ = 20 yr, D=50 kpc)

K. Wette

Actively planned:

Semi-targeted searches, towards:

* Galactic Center (8kpc) : could ``see'' objects formed in last 100 yrs
* Globular clusters (2 kpc): could ``see'' objects formed in last 1000 yrs . Less likely.

Blind searches for signals from isolated objects

What about pulsars that we do not see ?

Blind searches for signals from isolated objects

* @SSB monochromatic signal with spin-down
* search method works well if phase coherence is maintained over coherent search time baseline

* 2 types of searches, both hierarchical:
  - long time-baseline initial coherent search (≈day) **Deep, comput. Intensive**
  - short time-baseline initial coherent search (≈hour) **Robust, wide param space, fast scans**

Blind searches for signals from isolated objects

* various types of building blocks:
  - Fstat coherent search
  - Virgo coherent search
  - Powerflux semi-coherent
  - Stack-slide semi-coherent
  - Hough semi-coherent (2 flavours)

* specifically, the 2 hierarchical searches use:
  - Multi-IFO Fstat + Hough/Stack-slide (E@h)
  - Powerflux/Hough, for Virgo + coincidences + coherent follow-ups

S5 Powerflux fast scan: H1 (best sky) upper limit [worst case orientation]

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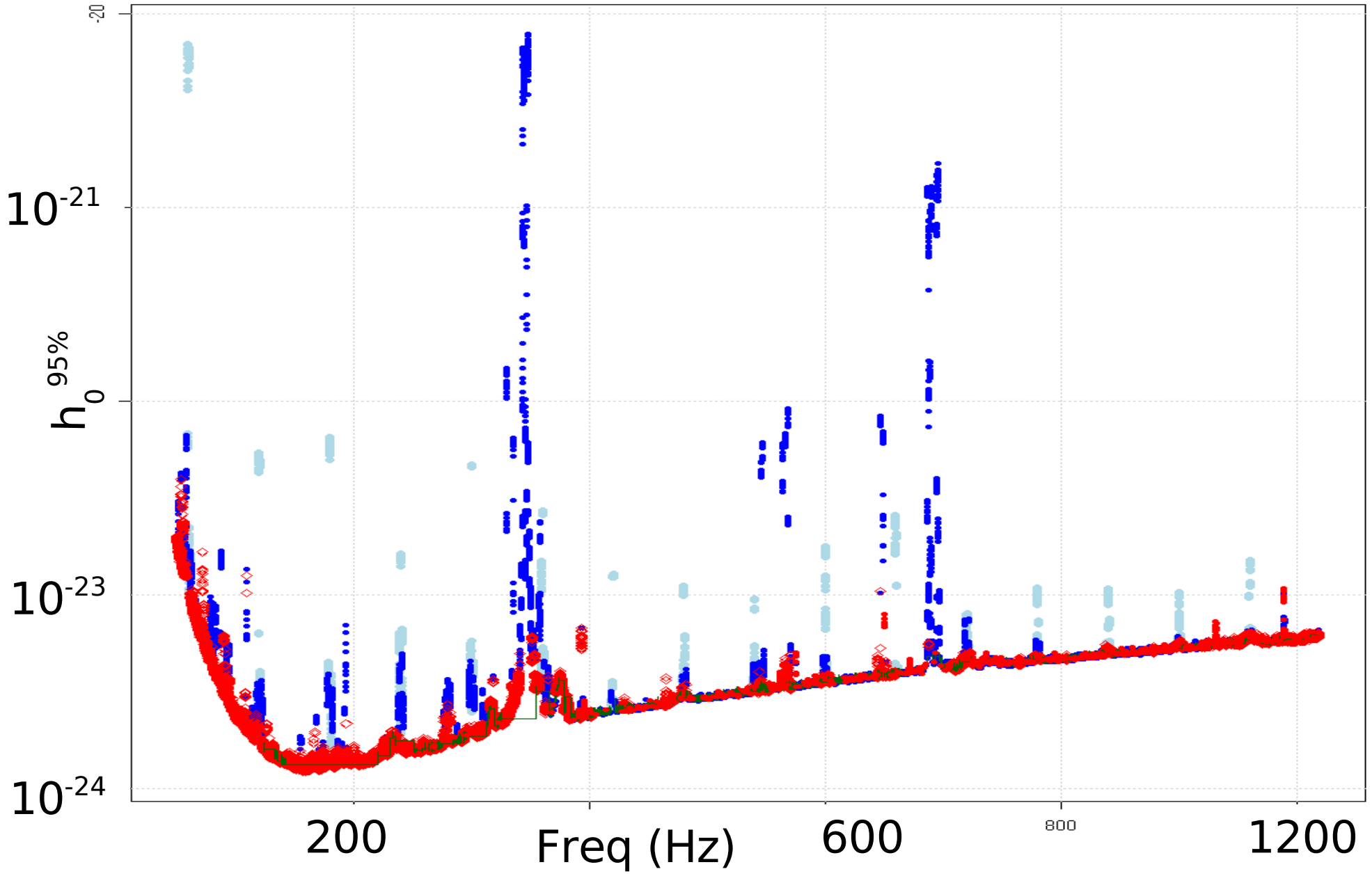

The Big Picture (!)

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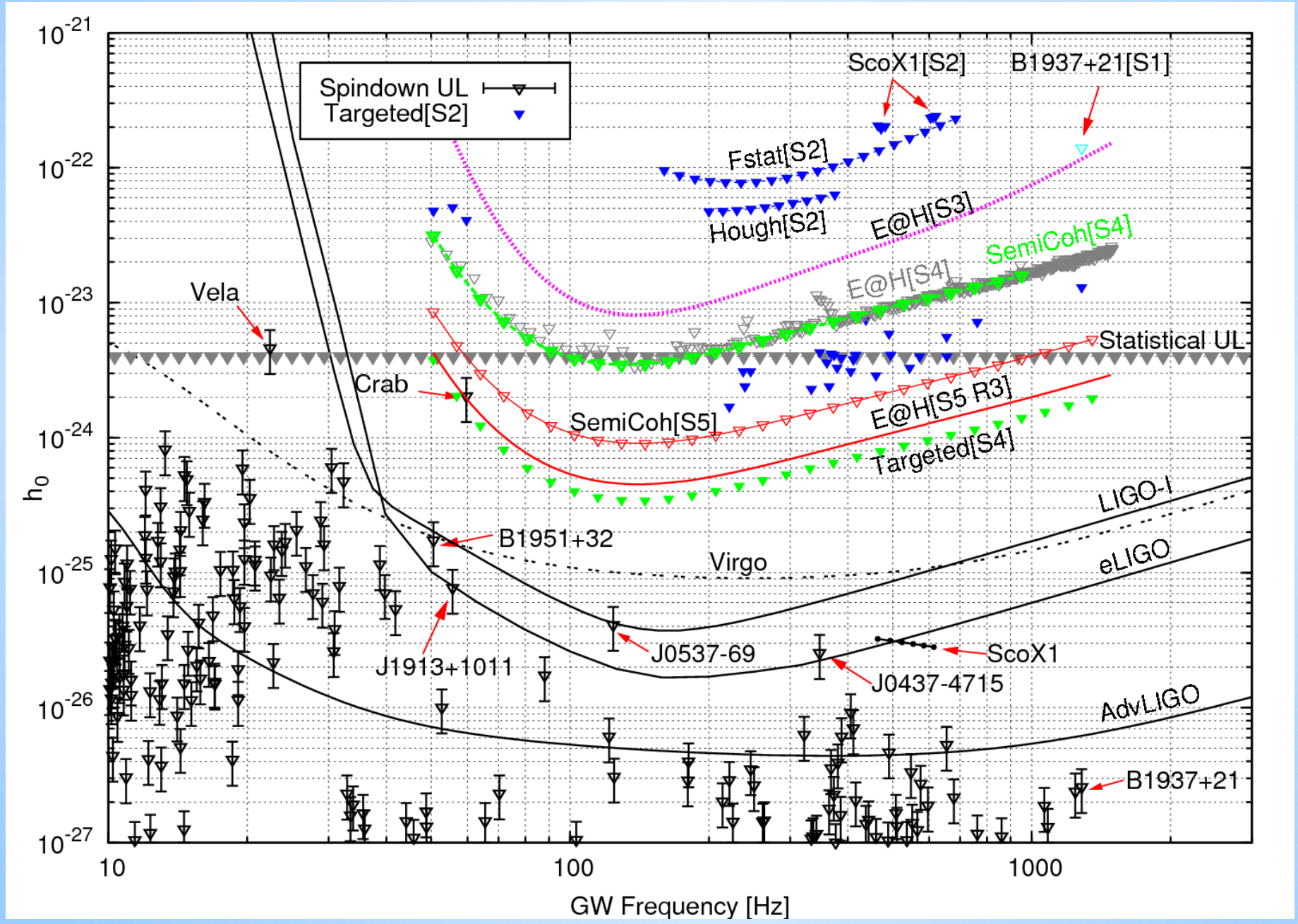
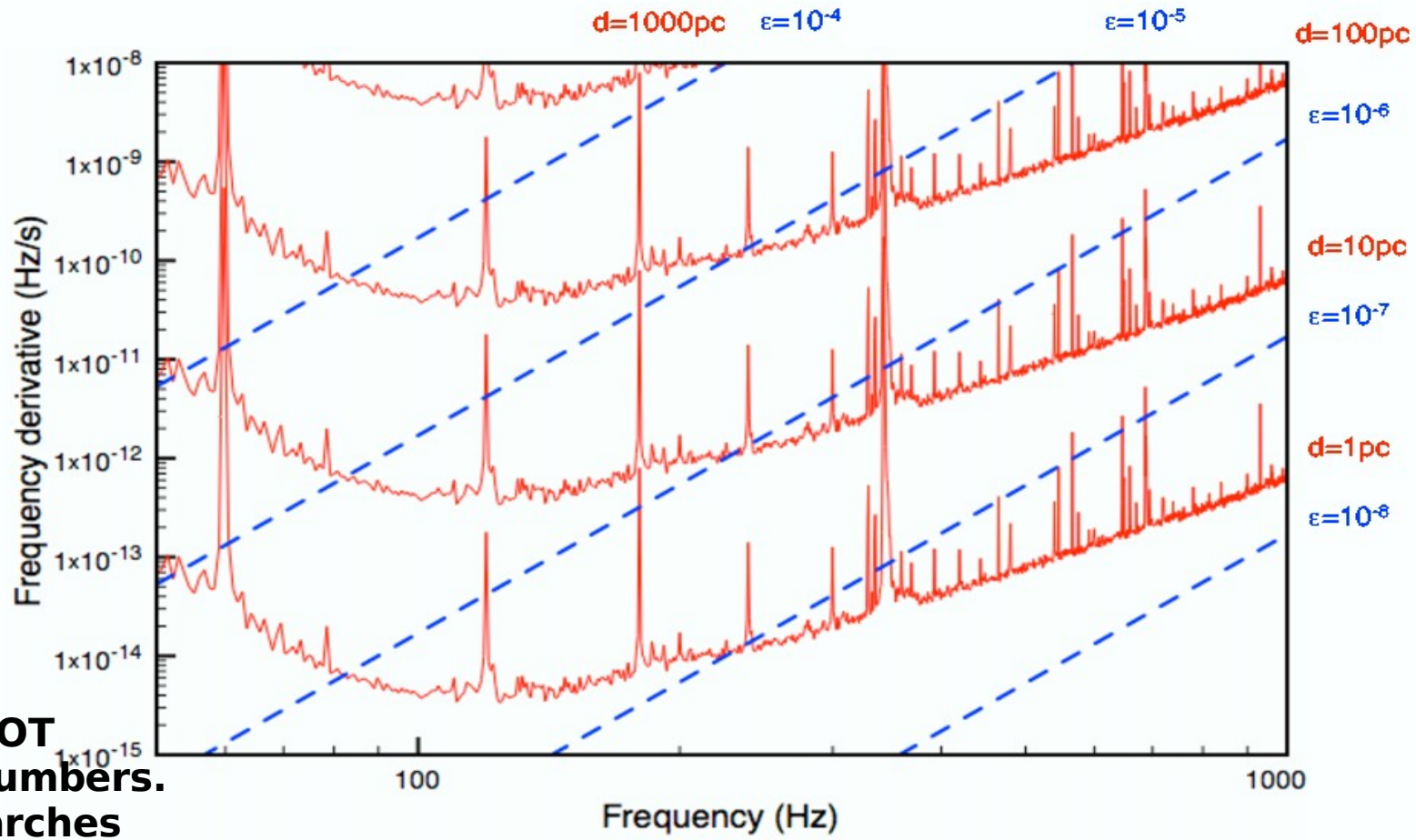


Expressing the reach of search from UL values.

Contour plots of distance at which one of the fast-scan **S4 searches** could detect a source with a given f and fdot.



These are NOT typical S5 numbers. Deepest searches are expected to reach at 1kpc for $\varepsilon=10^{-5}$ at ~ 220Hz.

What about objects in binaries?

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* Known pulsars we target already and will expand the number of targets.

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* Known pulsars we target already and will expand the number of targets.

* There are ones we know about but miss information:
- LMXBs (85 known), unknown spin freq, higher accretion rates
- AMXPs (7 known), known spin freq

First hierarchical search under construction using a method similar to what used in radio-astronomy (C. Messenger)

* Blind (or targeted) searches ? **First steps towards search (E. Goetz and Nikhef group)**

What to work on

* Streamline fast scans and follow-ups
* Expand known targets
* Explore interesting regions, find right search tool for every region
* Expand searches to unknown binary systems
* Keep talking to astronomers

That's it for today

What about pulsars in binaries?

Assuming GWs balance torque from accretion:

$$h_{IUL} = 5\,X\,10^{-27}\sqrt{300\frac{Hz}{\nu}}\sqrt{\frac{F_x}{10^{-8}\,erg\,cm^{-2}\,s^{-1}}}$$

* The ones we now about:
- LMXBs (85 known), unknown spin freq, higher accretion rates
- AMXPs (7 known), known spin freq

Hierarchical search under construction using a method similar to what used in radio-astronomy (C. Messenger)

* Blind (or targeted) searches ? **First steps towards search (E. Goetz and Nikhef group)**