CW Discrimination

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LIGO Scientific Collaboration Meeting

LIGO Livingston Observatory

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Outline:

- Amplitude Modulation Discrimination
  - Goals & Milestones
  - Progress to Date & Plans
- Instrumental Artifact Discrimination (Wandering Oscillators)
  - Goals & Milestones

Amplitude Modulation Discrimination

People:

David Chin, Keith Riles (D.C. doing the real work)

Ultimate Goal:

Determine whether putative astrophysical CW source displays expected amplitude modulation due to rotating antenna (IFO)

Short-term Goal:

Write LAL procedure to provide expected h_+, $h_\times$ sensitivity for given source/IFO parameters

Procedure inputs:

Source direction / orientation (RA, δ, Ω)

IFO name (LHO, LLO, VIRGO, GEO, TAMA, 40M)

GPS starting time

Time step size, number of steps

Procedure output:

Vector of F_+, $F_\times$ beam pattern scale factors

Amplitude Modulation Discrimination

Milestones

(Taken from September 1999 Document)

By December 31, 1999:

- Finish in-house algorithm for producing a vector of h_+ and h_- scale factors for a given IFO, source direction on sky, GPS starting time, time step size, and number of times.

By March 31, 2000:

- First version of LLAL-based, LDAS-ready software
- Make available for trial by others.

By June 30, 2000:

- "Final" version of LDAS-integrated program.

Amplitude Modulation Discrimination

Progress to Date

- Have written in-house C code to convert GPS time to local sidereal time:
  - GPS $\Rightarrow$ UTC (trivial)
  - UTC $\Rightarrow$ Greenwich Mean Sidereal Time (GMST) (cubic expansion in Julian centuries from 1/1/2000)
  - GMST $\Rightarrow$ local sidereal time (trivial)
- Have written in-house C code to compute F_+, $F_\times$ in low-frequency limit for given:
  - Source RA, δ, Ω
  - GMST, Detector longitude λ, latitude ϕ
  - Detector orientation angle ψ
- Negligible effects not included in present code: (using UTC, not UT and using GMST, not GAST)
  - Variable earth rotation
  - Precession / nutation of earth
  - Time dependence of RA, δ for fixed source
  - Orbital motion of earth (aberration, grav. potential)
  - Earth's oblateness

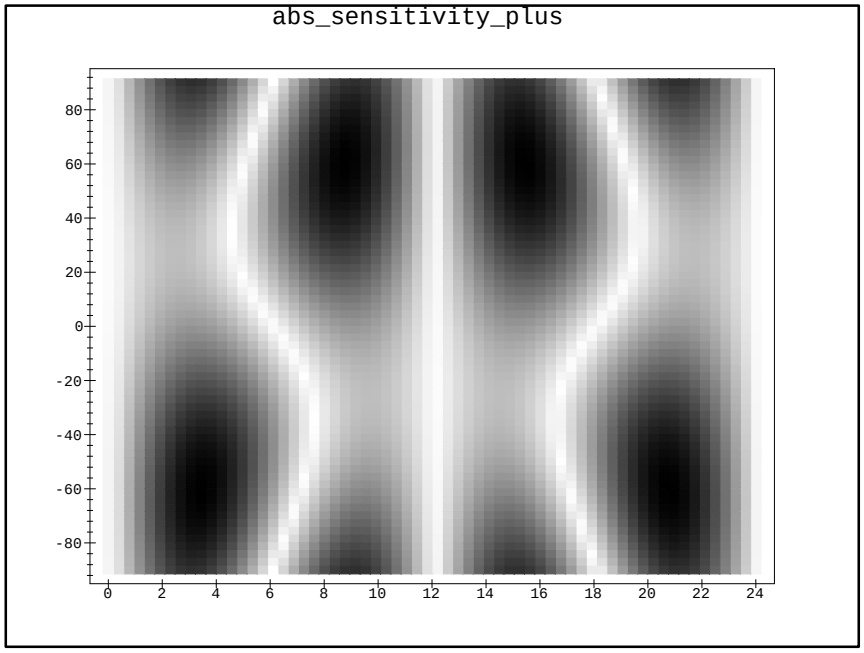
Amplitude Modulation Discrimination

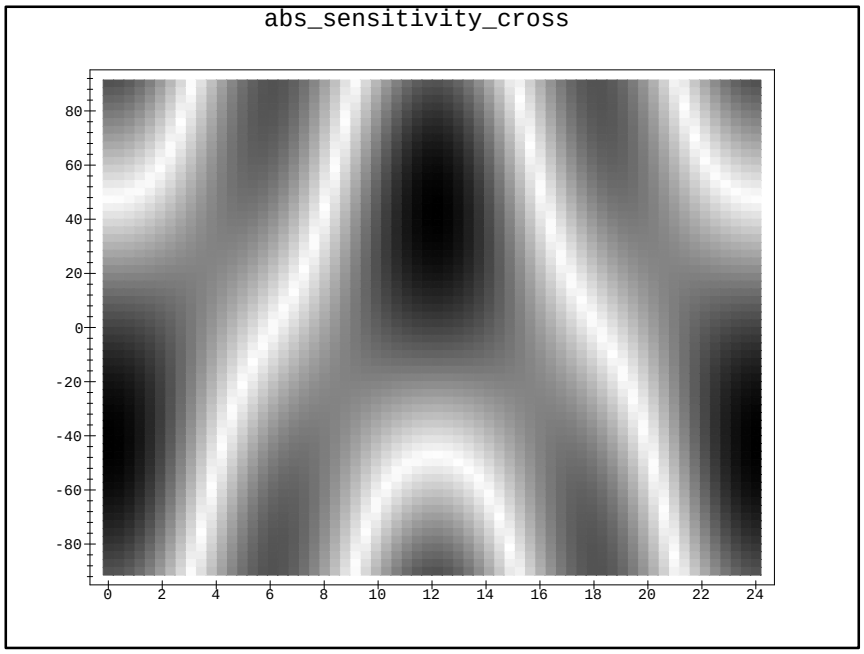
Checks to Date

- Verified that UTC $\Rightarrow$ GMST gives better than 0.1 second agreement with Astronomical Almanac tables
  (but UT/UTC difference can be as large as 0.9 seconds)
- Comparison with Jeffrey Livas Ph.D. dissertation
  (1987 search for CW sources with MIT detector)
  - Slight disagreement with printed transformation matrix
  - Agreement with derived $(\frac{\Delta\ell}{\ell})_+$
  - Disagreement with derived $(\frac{\Delta\ell}{\ell})_\times$
  - Disagreement with antenna sensitivity map
    (Certain day/time at MIT in 1985, 45° rotation of IFO)
    $\Longrightarrow$ See figures
- Agreement with beam pattern factors quoted in Thorne for detector at north pole
  ("300 Years of Gravitation" article)

Amplitude Modulation Discrimination

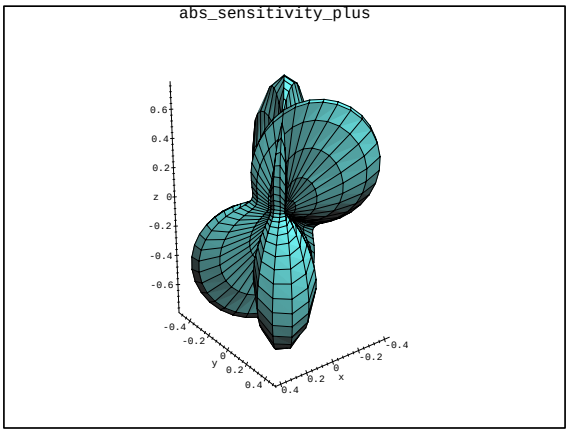
Predicted antenna sensitivity to h_+, $h_\times$ for MIT IFO (45° orientation) at 8:00 p.m. EDT June 3, 1985

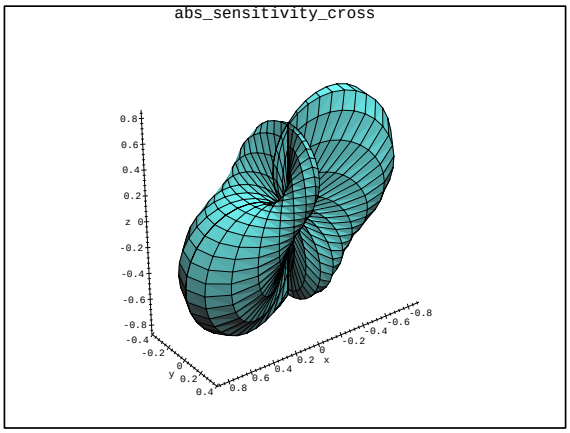


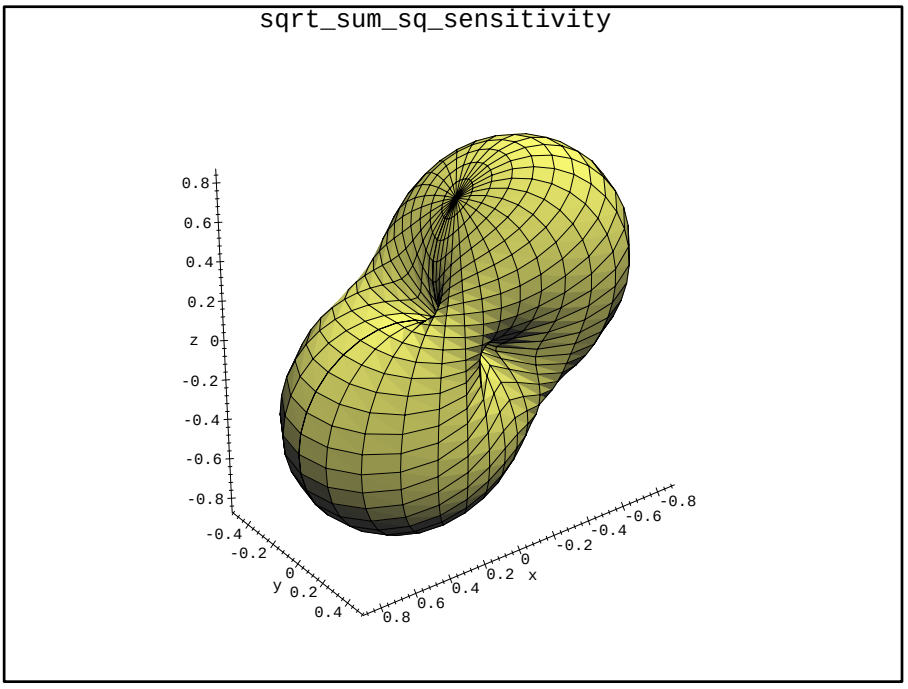


Amplitude Modulation Discrimination

Perspective view of sensitivities and combined norm
(h_+ and $h_\times$ defined w.r.t. *equatorial* coordinates)







Amplitude Modulation Discrimination

Near-term plans:

- Resolve discrepancies with Livas results –
  Other checks to be made:
  - Numerical comparison with GRASP algorithm
  - Compare with Estabrook (1985), Schutz & Tinto (1987)
- Put all the pieces together
- Convert to LAL code
- Make available to collaboration

Far-term plans: (no milestones defined yet)

- Examine importance of frequency dependence
  $\Longrightarrow$ Use simple parametrization?
- Investigate much more accurate timekeeping:
  (okay now for F_+, $F_\times$ but not for 6-month pulsar timing)
  - Adapt Princeton group's TEMPO code?
  - Incorporate Naval Observatory's NOVAS code?
  - Is anyone else working on this?
- Work with LSC colleagues to incorporate F_+, $F_\times$ parameters into complete analysis to quantify statistical consistency of candidate signal with expected amplitude modulation

Instrumental Artifact Discrimination

People:

David Chin, Dick Gustafson, Joseph Marsano, Keith Riles

Goals:

Catalog "lines" in data due to known instrumental artifacts

- 60 Hz & harmonics & sidebands
- Violin modes
- Other mechanical resonances & sidebands

Quantify drift / modulation of lines

Main Worry:

Wandering oscillators with daily modulation
(seismic, thermal, electrical, thermoelectrical)

Solar day $\neq$ sidereal day, in principle
but not so different for short integration times

Increases effective noise in all-sky CW search
(excess of false alarms)

Instrumental Artifact Discrimination

Plans:

- Catalog obvious, "a priori" line sources in GW channel
- Catalog associated sidebands (due to non-linearity)
- Quantify daily modulation strengths
- Look for other modulations (heterodyne)
- Similar searches in other channels (longitudinal/orientational servos, environmental)
- Quantify long-term time dependence of line strengths and modulations / drifts
- Pursue and identify every persistent line that pops up as time integrations lengthen

Note:

- Data Monitor Tool (e.g. Ottewill/Allen line tracker) will provide info for 1st iteration of catalog, but tracking of daily modulation better suited to LDAS code running on data archive.

Instrumental Artifact Discrimination

Milestones

(Taken from September 1999 Document)

By June 30, 2000:

- First version of LDAS-ready software including:
  - Catalog entry / retrieval routines
  - Definition of catalog records
  - Solar-day heterodyne-based search routine
  - Interface to line-tracker for flagging drifting lines
  - "Toy" entries in catalog from Hanford 2-km commissioning data

By September 30, 2000:

- More mature (but probably not final) version of the above.
- "Real" entries in catalog from Hanford 2-km with ongoing effort to augment

More realistic:

June 30 $\Longrightarrow$ August 31

September 30 $\Longrightarrow$ November 30