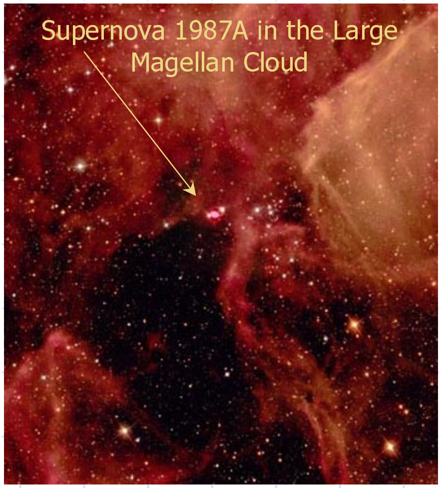
Entry of LIGO into SuperNova Early Warning System (SNEWS)

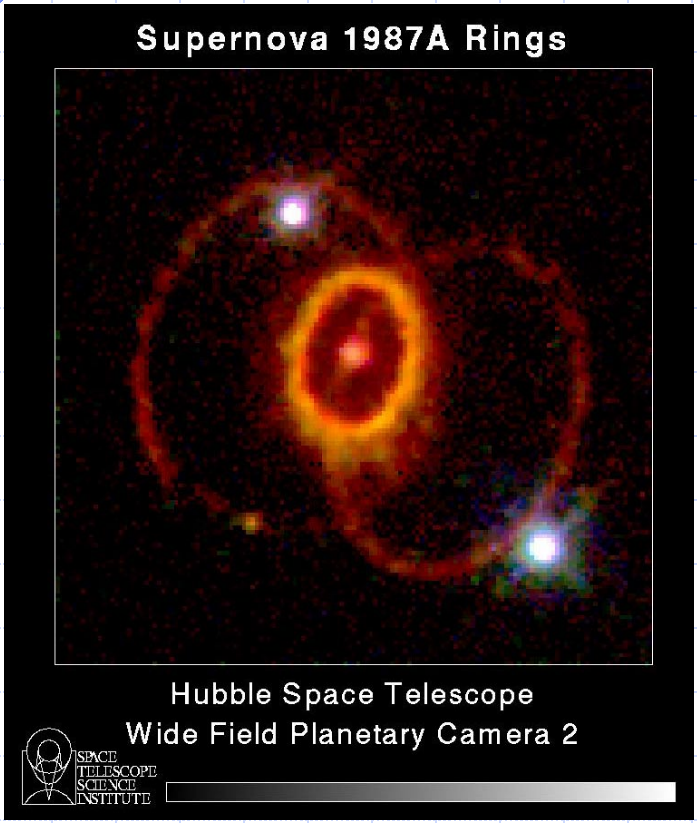


Szabolcs Márka (Caltech),
Kenneth Ganezer (UCSDH)

LIGO-SNEWS Project Goals

- Send and receive real time SN alarms
  - Prompt, automatic analysis upon alarm
  - Continuous, hierarchical search for SN
- Distribute supernova (SN) alarms to LSC
- Point of contact (SNEWS, Astronomers…)
- Measure GW, SN and ν properties
  - Analyze capabilities
  - Develop strategies to extract information

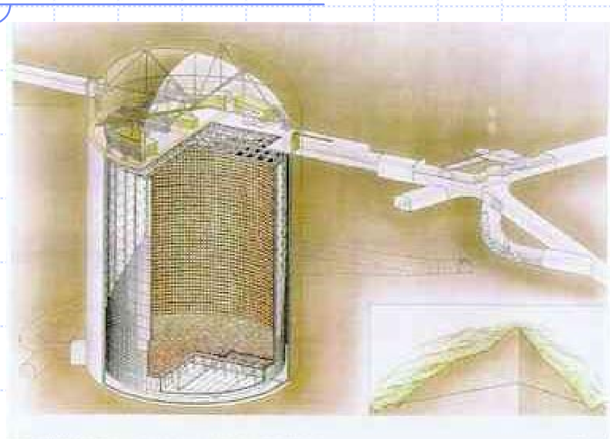
Supernova signals



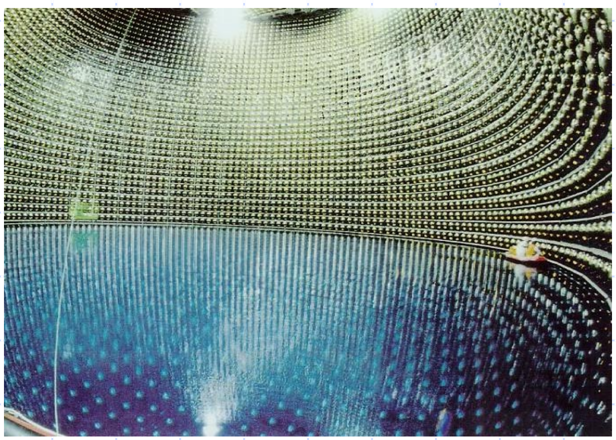
- Near immediate emission of
  - Neutrinos
  - Gravity waves
  - Probably GRBs
- Delayed emission of
  - Light (visible, UV, etc.)
  - Radio waves

Advanced warning is necessary!

What is SNEWS ?

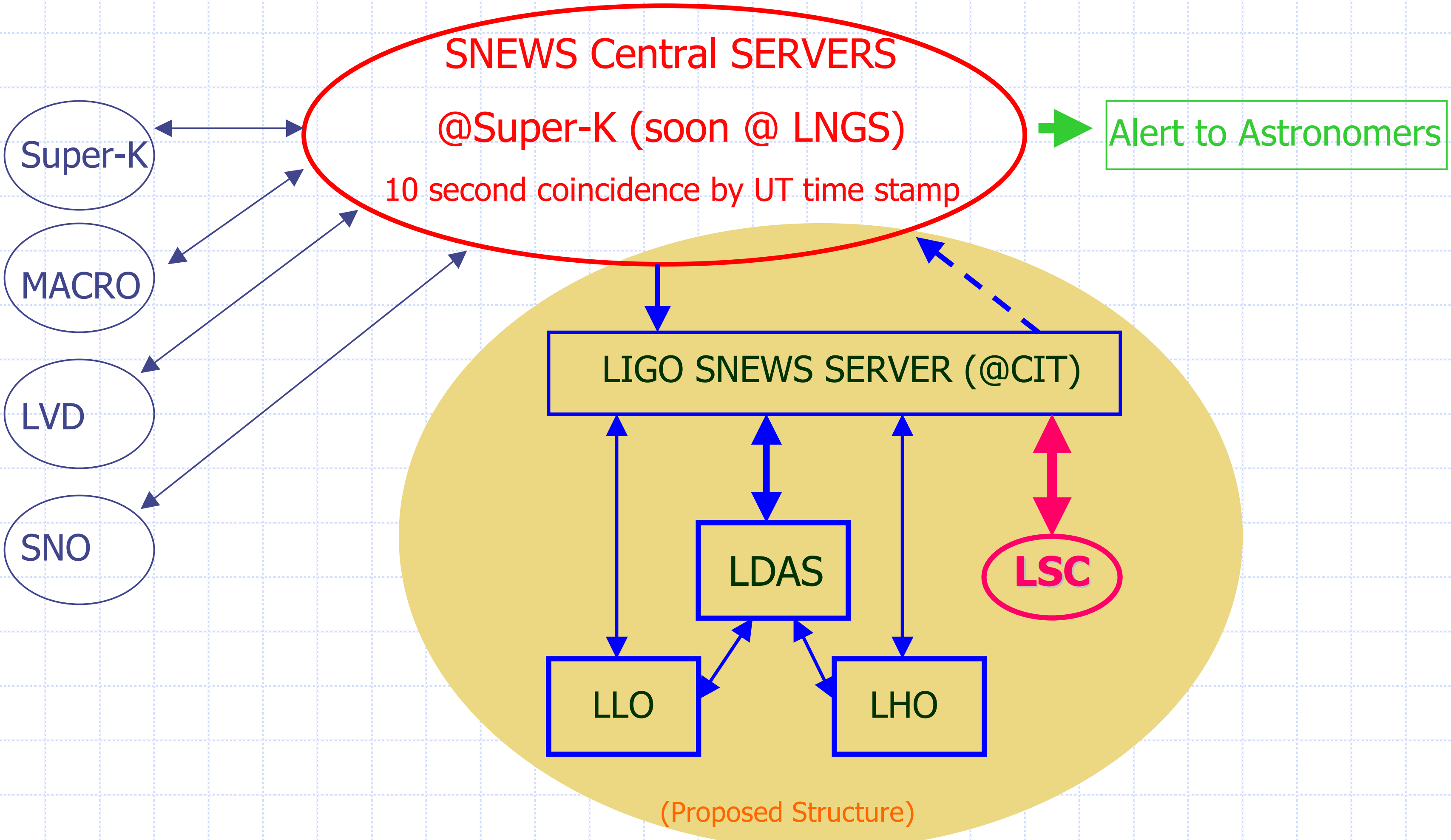


The Super-Kamiokande Detector



- International collaboration of SN sensitive neutrino detectors
- Provides near-real time SN alarm
- Based on inter-experiment coincidence
  - Timing and pointing information
  - Very high confidence
    - Less than 1 false alarm/100y !
- Coordinates detector downtime
- Centralized timing verification
- Privacy is ensured
  - Input data is strictly secured

SNEWS Project Organization with LIGO



SNEWS Benefits and Requirements

- Top Benefits
  - High confidence alarm
    - Less than 1 false alarm per century
  - Real time cooperation among fields
    - Absolutely the best science!
  - Motivates early work on SN at LIGO
    - ν + GW <u>together</u> promise top physics
    - Accelerates LIGO SN learning curve
- Major requirements
  - MUST have < 1 false alarm/week !
  - We must understand our noise !

SNEWS Collaboration Members

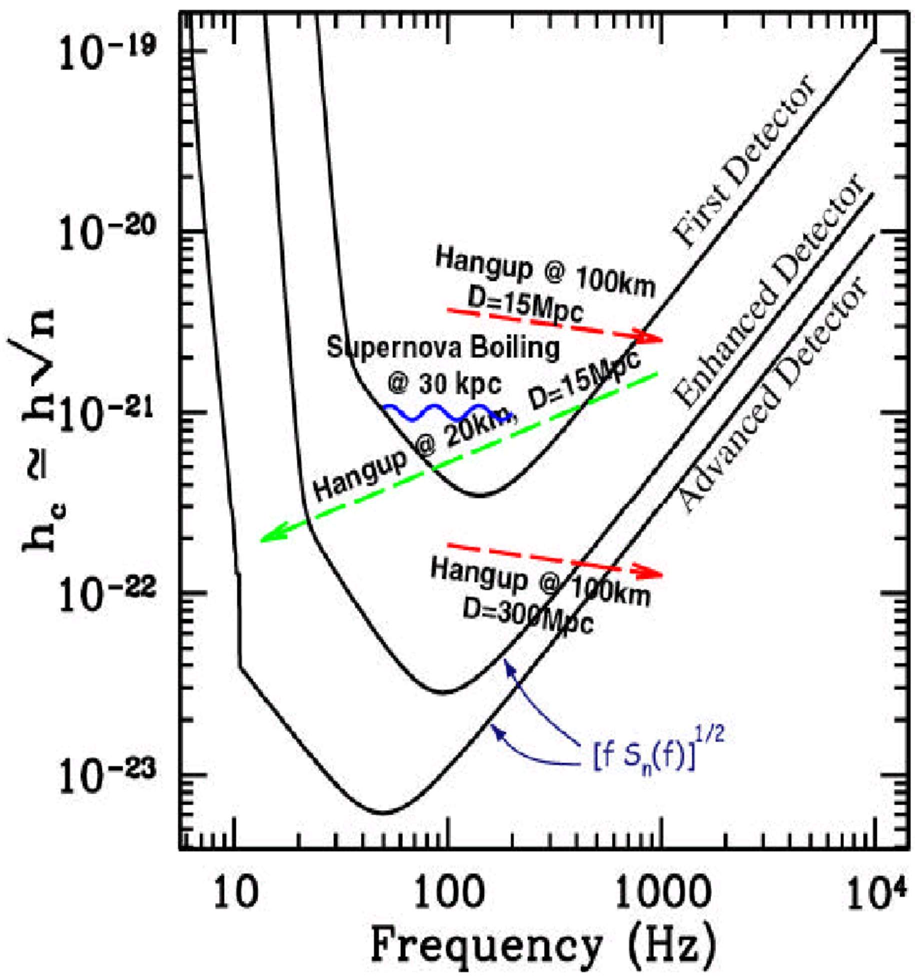
Pietro Antonioli [1], Hans-Gerd Berns [2], Adam Bouchta [3], Peter Doe [2], R. J. Douglas [4] , Walter Fulgione [5], Yoshiyuki Fukuda [6], AlecHabig[7], J. Heise [8], Edward T. Kearns [7], Lutz Koepke [9], Art McDonald [10], Alexander Murphy [11], Hakki Ogelman [12], Leif J. Robinson [13], **Kate Scholberg** [7], Michael H. Schwendener [14], Yoichiro Suzuki [6], R. Svoboda [15], Reda Tarout [14], Mark R. Vagins [16], Carlo Vigorito [5], Clarence J. Virtue [14], Ralf Wischnewski [3]

[1]INFN-Bologna, Italy; [2]University of Washington, Seattle, WA; [3]DESY, Zeuthen, Germany; [4]Frequency and Time Standards, Institute for National Measurement Standards,National Research Council, Ottawa, Ontario, Canada; [5]Institute of Cosmo-Geophysics, CNR, INFN-Torino, Italy; [6]Kamioka Observatory, ICRR, University of Tokyo, Japan; [7]Boston University, Boston, MA; [8]University of British Columbia, Vancouver, Canada; [9]Mainz University, Mainz, Germany; [10]Queen's University, Kingston, Ontario, Canada; [11]Ohio State University, Columbus, OH; [12]University of Wisconsin, Madison, WI; [13]Sky & Telescope magazine, Cambridge, MA; [14]Laurentian University, Sudbury, Ontario, Canada; [15]Louisiana State University, Baton Rouge, LA; [16]University of California, Irvine, CA

Large Volume Detector (LVD), Super-Kamiokande (Super-K), Antarctic Muon and Neutrino Detector Array (AMANDA), Sudbury Neutrino Observatory (SNO), Monopole, Astrophysics and Cosmic-Ray Observatory (MACRO), Observatory for Multi flavor Neutrinos from Supernovae (OMNIS), Kamioka Liquid Scintillator Anti-Neutrino Detector (KamLAND)

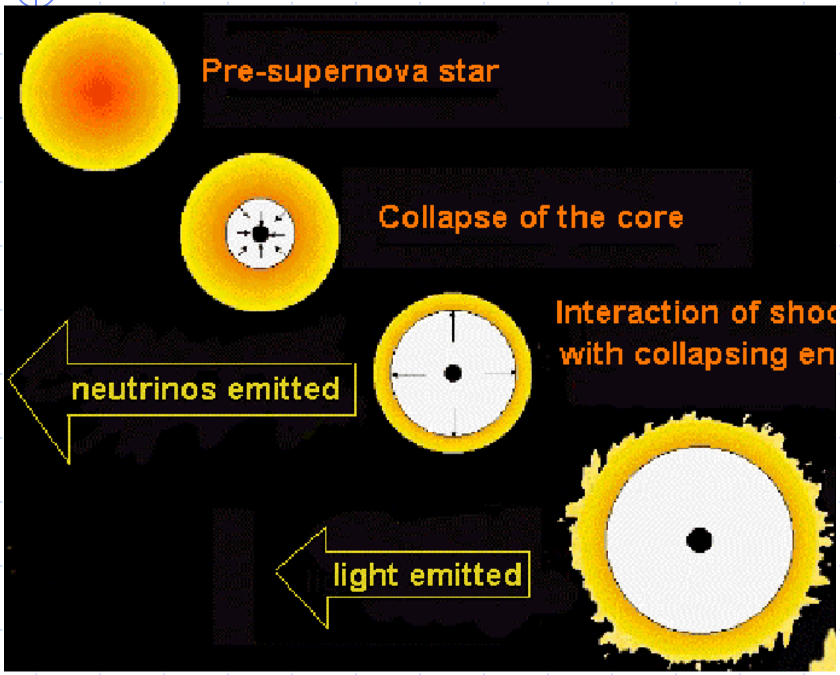
SNEWS advisory board: B. Barish (MACRO), S. Barwick (AMANDA), W. Fulgione (LVD),A. McDonald (SNO), Y. Suzuki (Super-K)

GW from supernova core collapse



- Candidates: Type II, Ib(?)
- Three major mechanisms
  - Asymmetric core collapse
    - Models, simulations exist
    - Level of asymmetry is not clear
    - Some related observations exist
  - Boiling of neutron star
    - Probably visible if close by
  - Hang-up processes
    - Rapidly rotating "bar-like" cores
    - Fraction of SN is unknown

Asymmetric Core Collapse

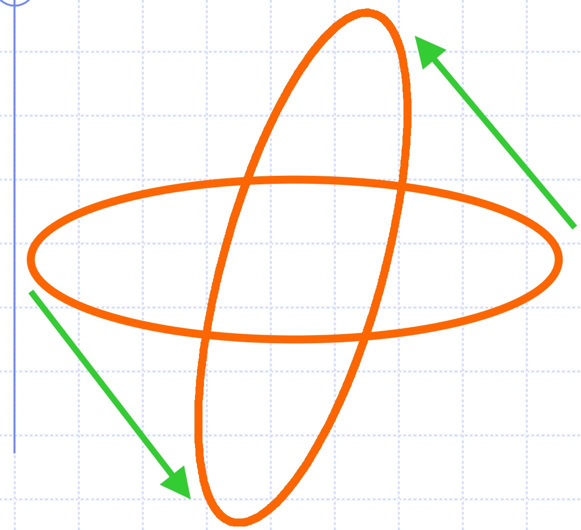


- Significant results exist
  - Some GW is expected
  - Models, simulations exist
  - Observed high NS recoil speeds
- Sensitive LIGO range
  - Weak radiation expected
  - LIGO I reach somewhere between:
    - ~50kpc (galactic) (Arnaud)
      - Based on simulation
    - ~3-4Mpc (M81) (Nagin)
      - Based on observed recoils
- The rate is very low
  - We need luck but have a chance
  - Observation = Significant science

Non-spherical Boiling of Neutron Star

- Newborn NS is convectively unstable
  - Almost certainly asymmetric process
  - Models exist (Burrows)
- Weak waves are predicted
  - LIGO I will only have galactic reach
  - Comparable to the range of Neutrino detectors
- Probably very common NS behavior
  - Rate might be relatively high
  - Low but finite chance!
  - Expected high scientific payoff!

Rotation-Induced Hang-up Processes



- Rotation strongly flattens core
  - "Bar-like" core spins rapidly
  - Might even break up
  - Very strong GW radiation is expected
  - Similar to NS-NS coalescence signal
    - Substantial LSC knowledge base
  - Unknown fraction of SN displays this behavior
- Possible huge reach = Finite rate!
  - LIGO I might reach the Virgo Cluster
  - We have significant chance for detection

Possible Scientific Benefits of SN Detection and Collaboration between LIGO and Neutrino Observatories

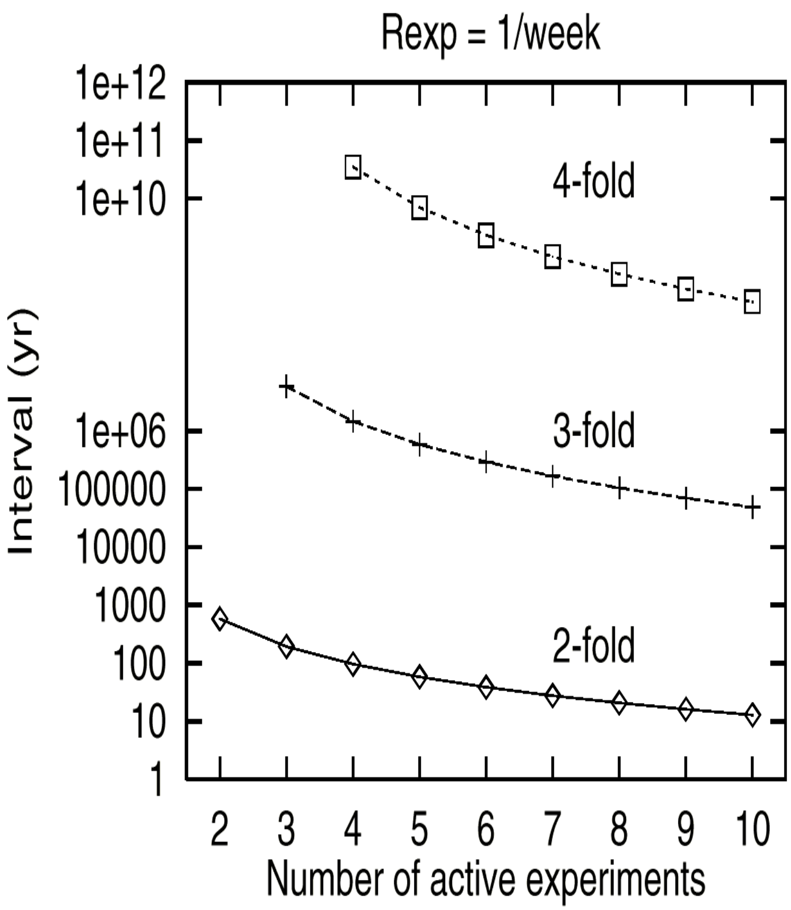
- Upper limit or measurement of neutrino mass
- Improved understanding of SN core collapse
- Limits or measurements of GW properties
- SN direction
- Extended SN range for neutrino detectors
- Upper limit on the total energy emitted in the GW channel during SN core collapse
- The far reach of LIGO II will dramatically increase early SN warning frequency for astronomers
- Increased confidence in SN alarms

... and dozens of great things not thought of yet !

Interaction between LIGO & SNEWS

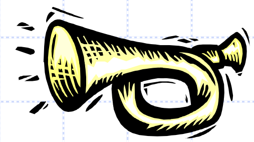
- What does LIGO get?
  - Initially we will get the same warning as any other field
  - Later we might get LIGO specific warning
  - Expertise in neutrino physics
  - Motivation and ways to share data
- What should LIGO provide?
  - Possibly participate in SNEWS code and infrastructure development
  - Ultimately provide real time automatic SN alarm towards SNEWS and the LSC community
    - NOTE: This warning is **automatic** and in **real time**; it will initiate the detailed SN search by LSC!

SNEWS Warning Requirements



- False alarm rate requirement
  - 1/week or less for contributors
    - Extremely low final false alarm rate
      - Less than 1/century!
    - Maintains high confidence in SNEWS
    - Ensures significant attention in case a SNEWS alarm is released
- Data quality
  - We MUST understand our noise
  - We have to provide significant and accurate information with confidence levels
- Privacy

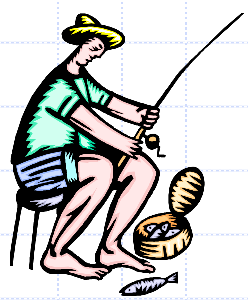
Project Organization (incoming warning)



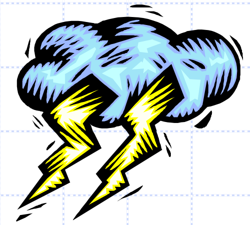
1. Promptly distribute warning to interested LSC members
2. Initiate the scan of recent data at the observatories
   - Strengthen the search by
     - use of timing (if available pointing, distance, etc.) information contained by the SNEWS datagram.
     - utilizing more sensitive (slower) algorithms, which require more computing power than available for the real time search
3. Depending on the result of this strong search, various preliminary measurements and upper limits will be computed, based on the assumption that the SNEWS warning is real.
   - It will require the immediate transfer of ~2 hours of data from the detectors to the CIT LDAS facility
   - The estimates will be secured and will not be communicated to outside of the LSC
   - The results will serve as preliminary information for LSC scientists, who will continue the high level very detailed analysis of the data off line
4. Accurate record of the warning and the results of automatic search will be archived in the LIGO database for future reference

Project Organization (outgoing alarm)

1. Loose (fast) filters on LDAS clusters at LHO and LLO will scan the incoming data real time looking for a SN signature
   - To strengthen the search different algorithm banks might be used at different observatories
2. The properties of a candidate event are passed to the SNEWS server at CIT if no environmental veto is issued by the GDS system
3. The server checks for loose coincidence between the detectors
4. In case of positive result a strong search is initiated by the server
   - Prompt transfer of ~30 minutes of data to CIT LDAS facilities
   - Detailed (slower than real time) search will be initiated
   - Coincidence and lack of environmental veto will be required
5. If all the requirements are satisfied a LIGO-SNEWS warning is issued
   - Three phase development:
     - Construction phase: Warning will be sent only to developers
     - Testing phase: Warning will be sent to interested LSC members
     - Release phase: Warning will be released to SNEWS
       - This phase will happen only after full LSC approval
6. Alarm parameters will be archived and referenced to the corresponding SNEWS coincidence record (if issued)

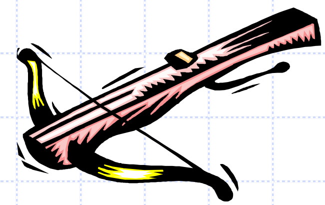


Coincidence Requirements



- SNEWS uses simple time-windowed coincidence
- LIGO will require triple internal coincidence before issuing an alarm
- Initially we will use the similar basic method, but
  - environmental veto will be considered from the beginning
  - coincidence window will be set according to event type
  - in case of incoming SNEWS warning we will use the SNEWS timing and pointing information
- Later we plan to use advanced coincidence requirements, which take event and detector characteristics into account

Resources



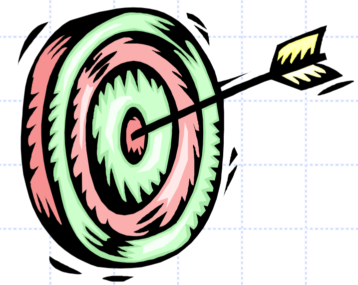
- Optimal use of existing LSC resources
  - Integrate into LDAS infrastructure
    - Utilization existing analysis systems
    - Full compatibility with standardized LIGO data structures
  - Complement ongoing LSC work on burst sources
    - Build on existing results, expertise and allocation
    - Use all appropriate existing search methods
    - Implement new/not yet used but promising algorithms
- Optimized load on computer systems
  - Hierarchical use of machines
  - Require high load only in case of high confidence
  - Off-line post-alarm analysis using reserves

Hardware and Human Resources

- A dedicated SUN workstation at CIT as
  - alarm distribution center and SNEW client
  - coincidence evaluation & post-alarm coordination hub
  - supernova online document library server

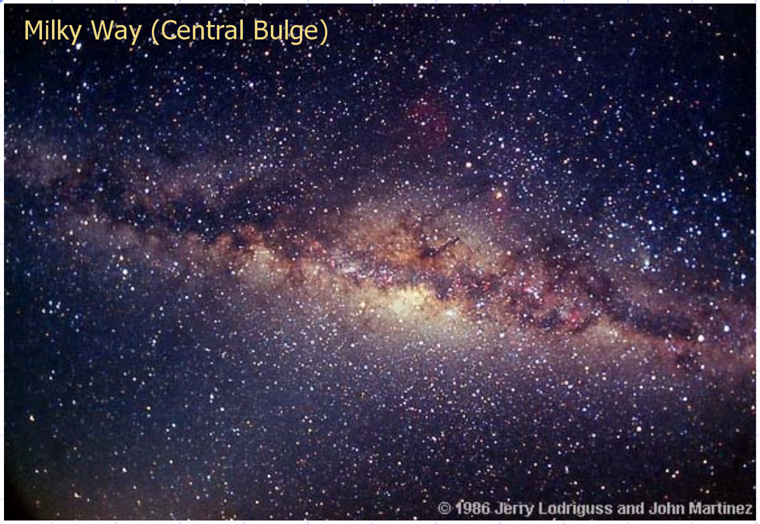
- Personnel
  - LSC, CIT personnel
  - UCSDH Graduate and Undergraduate students
  - Estimated effort: 2 years Full Time Equivalent
- LSC and LIGO-wide distributed analysis
- LDAS, GDS and theory support

Related Documents



- LIGO-SNEWS web-page
  - http://www.ligo.caltech.edu/~smarka/SN/snews-LIGO.htm
  - Comprehensive SN related reference list!
- General document (draft LIGO note)
  - http://www.ligo.caltech.edu/~smarka/SN/Document.pdf
- 4 page LSC proposal (draft)
  - http://www.ligo.caltech.edu/~smarka/SN/Prop.pdf
- E-mail questions:
  - smarka@ligo.caltech.edu

Conclusion



- It makes sense for LIGO to join SNEWS
- This is the right time
- Development of a real time, automatic LIGO SN warning is a challenge…, but
- it is possible to develop a useful warning!
- Takes luck to observe a SN with LIGO, but
- the possible scientific payoff is huge!
- It takes the LSC to do so…

Let’s do it!