Plan for On-the-Fly Matched Filtering Analysis using Fast Chirp Transforms (FCTs)

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History of Effort

- 1998-1999: worked together with Walid Majid on use of Stationary Phase Formalism for on-the-fly generation of templates
- Summer 1999: requested to be part of ASIS task list on binary inspiral detection
- September 1999: proposed to NSF
- November 1999: presentation of proposal at LIGO PAC meeting
- November 1999: first formulation of fast chirp transform
- December 1999: first implementation of fast chirp transform
- Jan/Feb 2000: submission of paper to Phys Rev D (LSC review)
- March 2000: 1st draft of LSC proposal circulated
- May 2000: NSF proposal accepted
- June/July 2000: 1st implementation of N-parameter FCT
- August 2000: proposal to LSC for FCT development

Proposal to NSF

- Background and Expertise
- Scientific Motivation
  - – BH-BH coalescence: the most promising LIGO I source
- Technical Approach
  - – Robust/adaptable methods for binary inspiral detection
  - – Stationary Phase Formalism (SPF)
    - On-the-fly computation of templates
    - "Control group" templates for measuring false event rates
    - Binary inspiral detection
- Proposed Effort

Development of a Fast Chirp Transform (FCT)

What is an FCT?

Problem	Detection of Periodic Sources	Detection of Chirp Signals
Matched Filter "templates"	$\sin(\omega_j t), \cos(\omega_j t)$	Chirp Waveforms $W_j(t)$
Detection	$\Sigma s(t) s(\omega_j t)$	$\Sigma s(t) W_j(t)$
Transform Approach	FT DFT FFT	CT DCT FCT

The Fast Chirp Transform

- What is an FCT?
  - Directly analogous to the Fast Fourier Transform (FFT), but works for non-linear phase evolution
  - In the FFT, we do not explicitly generate sine and cosine functions and cross-correlate them with the data. In the same way, the FCT removes the need to cross-correlate with individual templates.
  - Computations are done as a combination of short variable-length FFTs, or alternatively using a set of on-the-fly phase factors from look-up tables (similar to recursion and storage in an FFT)
  - Computational speed as good as, or better than matched filtering (but more general and flexible)
  - The FCT is a way to efficiently evaluate the matched filter equations => detection sensitivity is the same as conventional methods

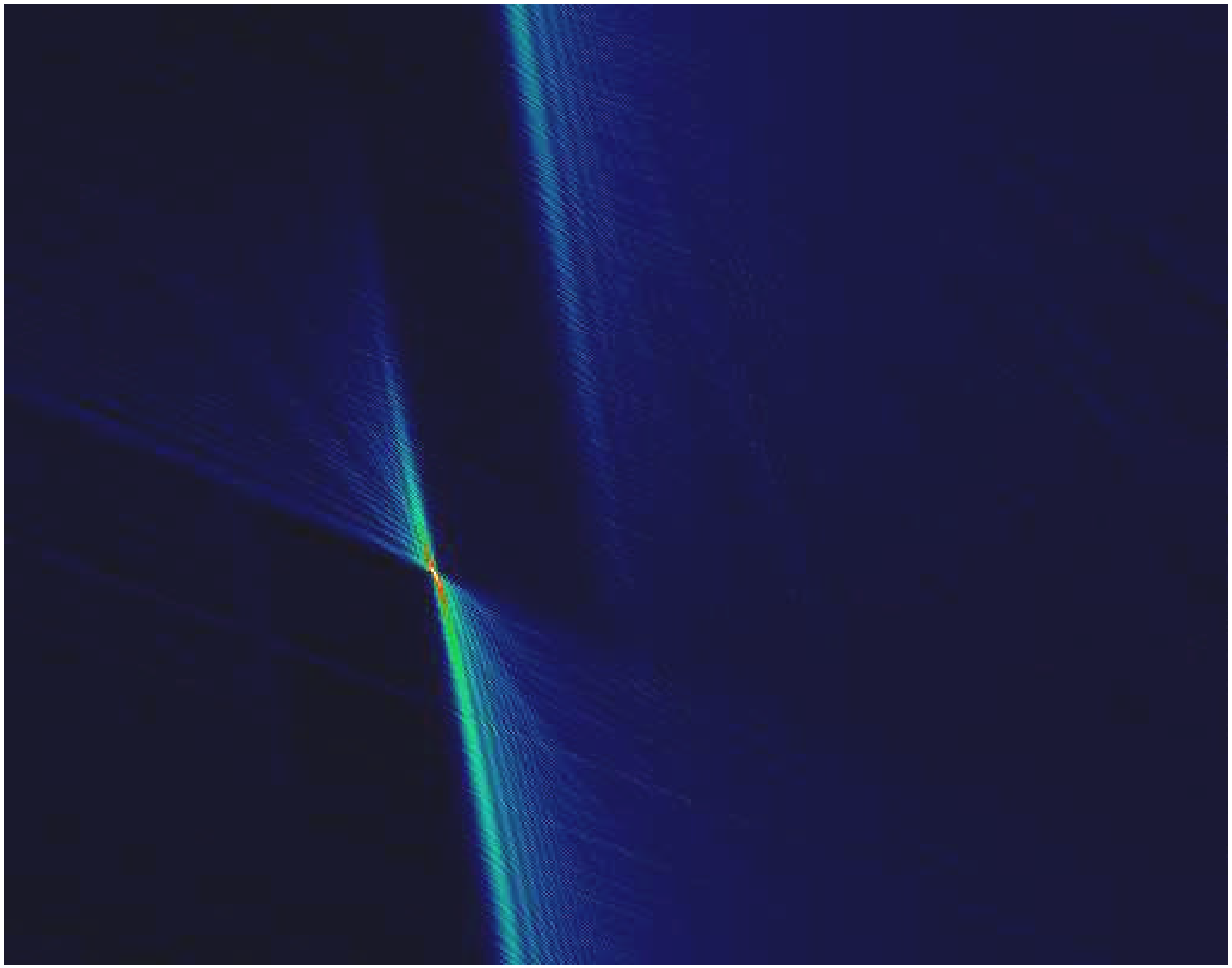
The Fast Chirp Transform

- Application of the FCT
  - Not just gravitational waves
  - Many potential applications: we are applying it to radio and x-ray astronomy data (searches for pulsars in binary systems)
  - Other potential applications in signal processing, communications, etc.

The Fast Chirp Transform

- Why an FCT?
  - The FCT provides a parametrized search technique. Searches can be made over mass parameters ("chirp times") in the same way that the FFT searches over frequency.
  - The FCT allows considerable flexibility in the way the search region can be chosen
  - The FCT allows searches for binaries with spin.
  - The FCT allows searches of regions outside the physically accessible template regions

FCT for a Newtonian Chirp



Implementation Plan

Recently Submitted LSC Proposal

Proposal to the LSC
for a
Prototype Implementation
of a
Binary Inspiral Search
Based on the Fast Chirp Transform

Kent Blackburn, Patrick Brady, Phil Charlton, Jolien Creighton,
Teviet Creighton, Jeff Edlund, Sam Finn, Rick Jenet,
Scott Hughes, Albert Lazzarini, Tom Prince (Project Coordinator),
B. Sathyaprakash, Linquing Wen

August 12, 2000

LIGO

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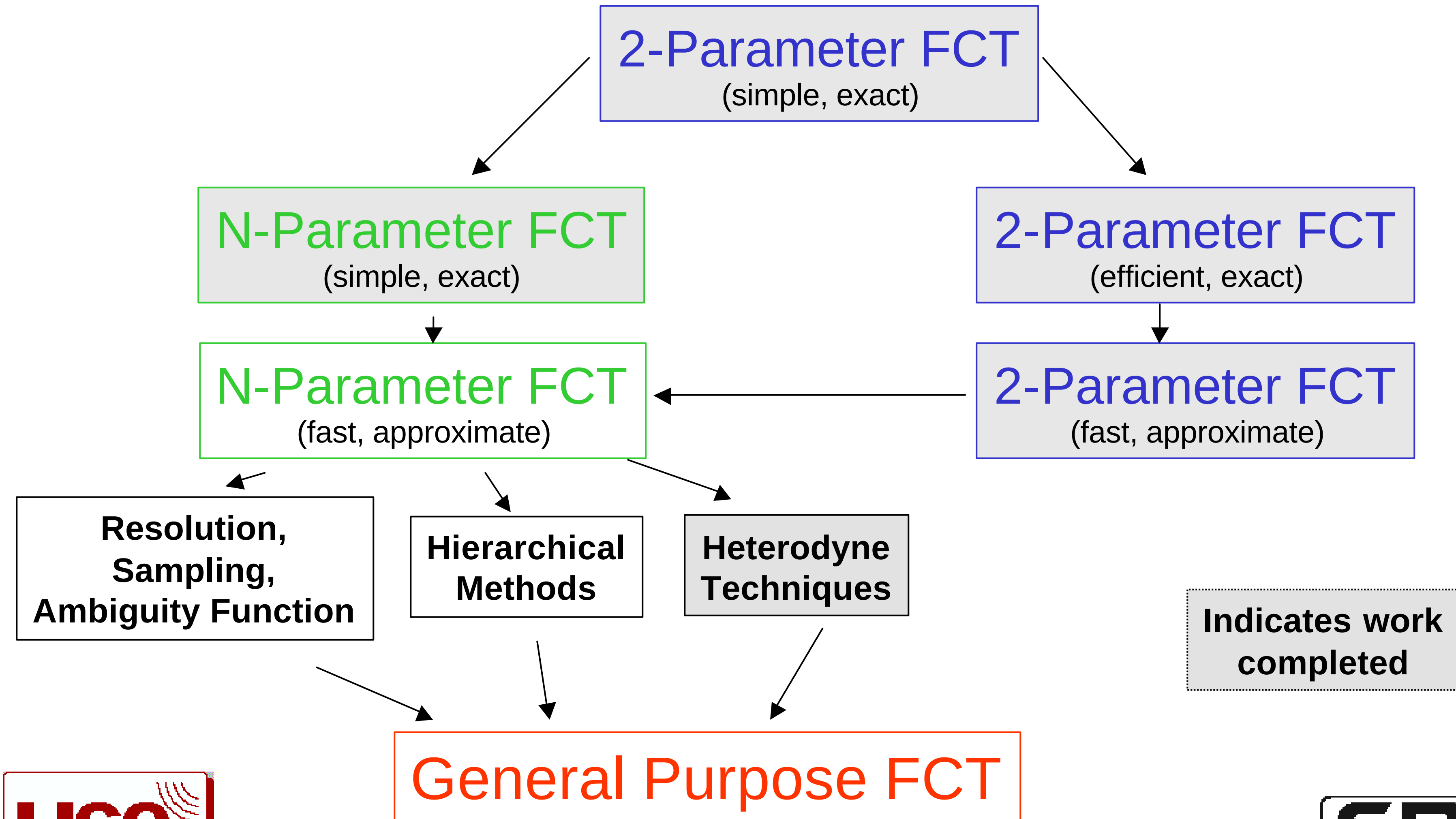
Components

1 Implementation of the generalized FCT

2 Application of the FCT to the Binary Inspiral search

3 Testing/validation of the technique on LIGO data

FCT Development



Implementation - General FCT

- Design and Coding: 2-Parameter/N-Parameter FCT
  - Phil Charlton, Jeff Edlund, Rick Jenet, Albert Lazzarini,Tom Prince
- FCT Website (http://www.srl.caltech.edu/fct)
  - Rick Jenet, Jeff Edlund
- Milestones
  - ✓ Simple 2-Parameter: 3/00
  - ✓ Fast-approximate 2-Parameter: 5/00
  - ✓ Simple N-Parameter: 7/00
  - ✓ Heterodyne Methods (8/00)
  - Efficient, exact N-Parameter: 9/00
  - Efficient, approximate N-Parameter: 11/00
  - Optimal sampling (10/00); Hierarchical Methods(11/00)

Implementation: Application to Binary Inspiral

- Test of 2-Parameter Algorithm for Newtonian Chirps
  - Jenet, Prince (4/00)
- N-Parameter Algorithm for 2PN chirps
  - Charlton, Edlund, Lazzarini (9/00)
- Use of FCT for alternate Waveforms
  - Sathyaprakash + others (9/00)
- Resolution, Sampling, Ambiguity Function Issues
  - T. Creighton, Jenet, Hughes, Sathyaprakash, Prince + others (10/00)
- Hierarchical Methods
  - Blackburn, Finn, Jenet, Lazzarini + others (10/00)
- General FCT GW Code (Single Processor)
  - J. Creighton, Edlund, Wen (1/01)

Implementation: LIGO Data

- Generalized GW FCT
  - Single Processor: ready by 1/01
  - MPI version: ready by 3/01
- Test on LIGO IF data
  - Charlton, Wen, others from LSC

Key Areas for Additional LSC Involvement

- Resolution, ambiguity function issues
- Hierarchical searches
- Alternate expansions
- Use of FCT as instrument diagnostic
- Testing
  - Simulated chirps/noise
  - 40m data
  - LIGO data

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