Title: Microphysics to macrophysics: Astrophysics and gravitational wave science opportunities in the advanced detector era and beyond

Date: Jun 23, 2011 11:20 AM

URL: http://pirsa.org/11060034

Abstract:

Why use GW?

Gravitational Waves

Source:

~ any accelerating matter
no screening

Weak coupling:

Imaging impractical:
(strong sources)
<~ wavelength

- **Hard** to make & detect
- Hard to obscure

EM Waves

Source:

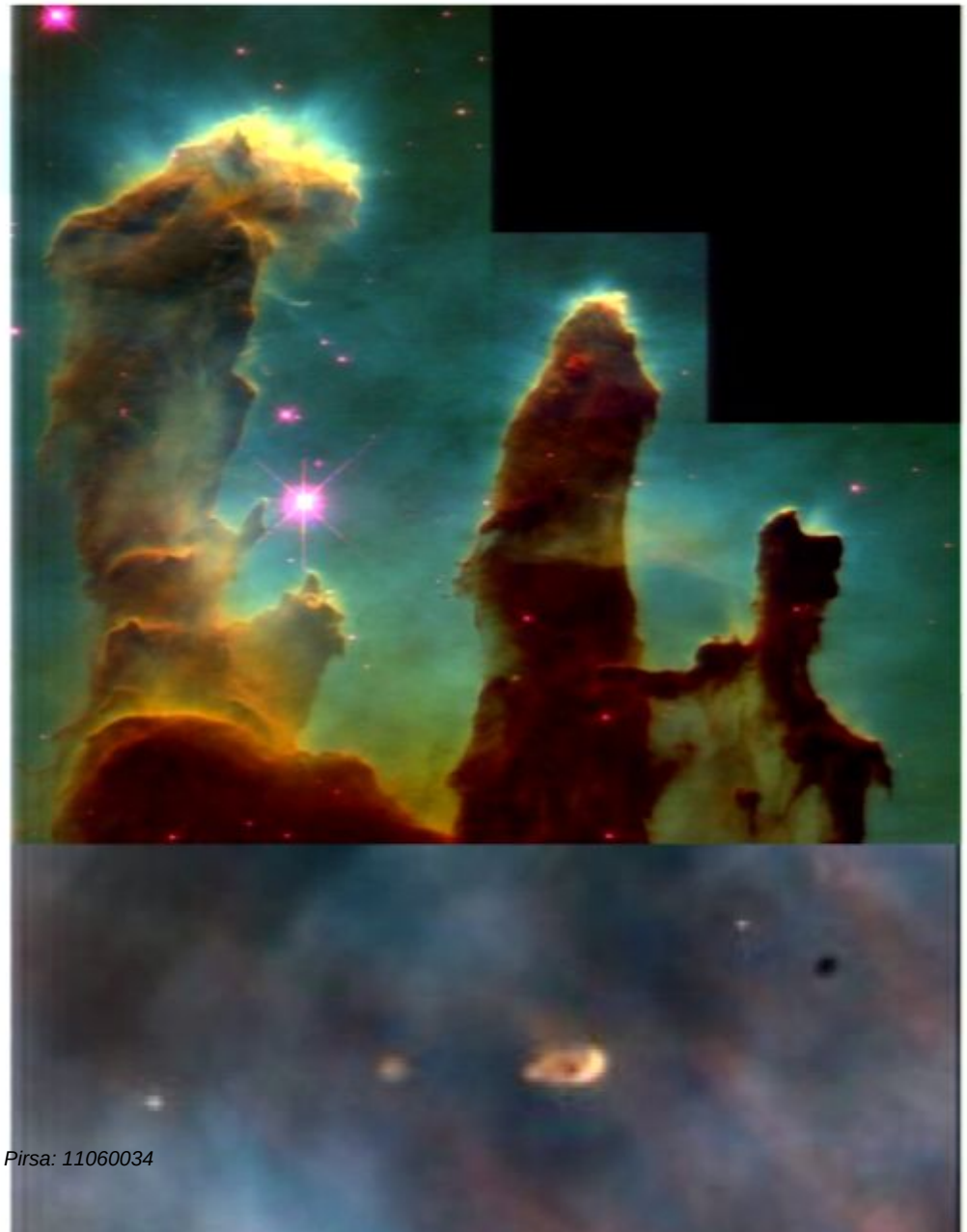
~any accelerating charge
screening limits size…

Strong coupling:

Imaging often practical:
(common sources)
>> wavelength

- Easy to make & detect
- Easy to obscure

Why use GW?



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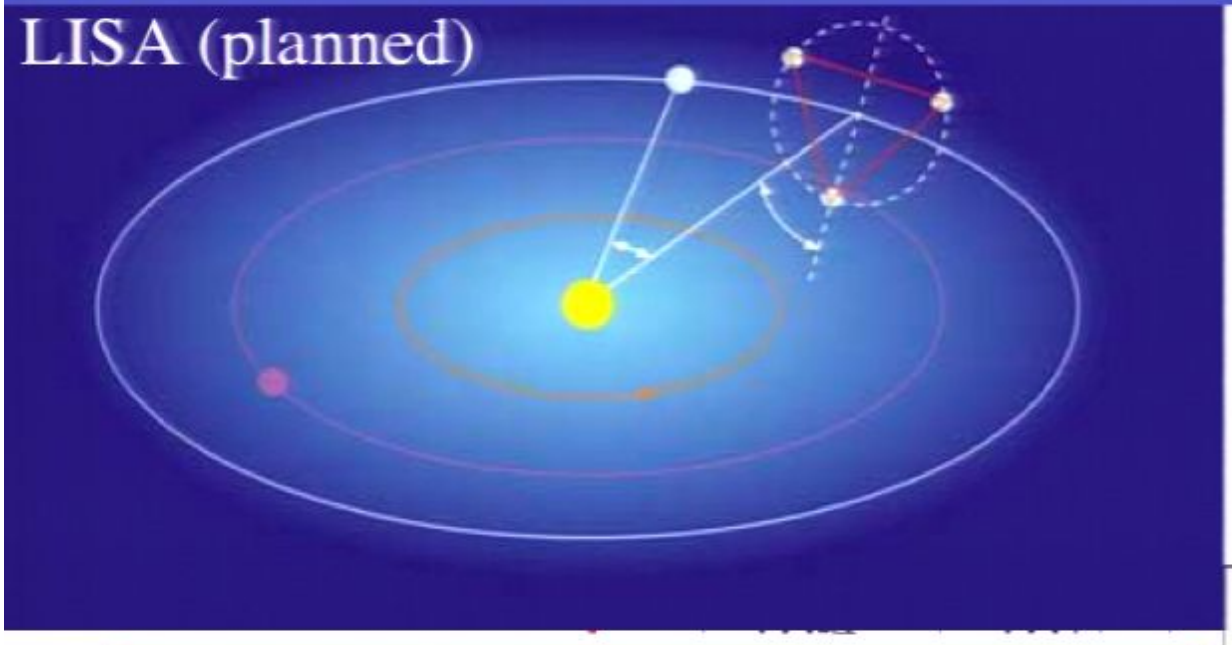
Detectors and scales



Detectors

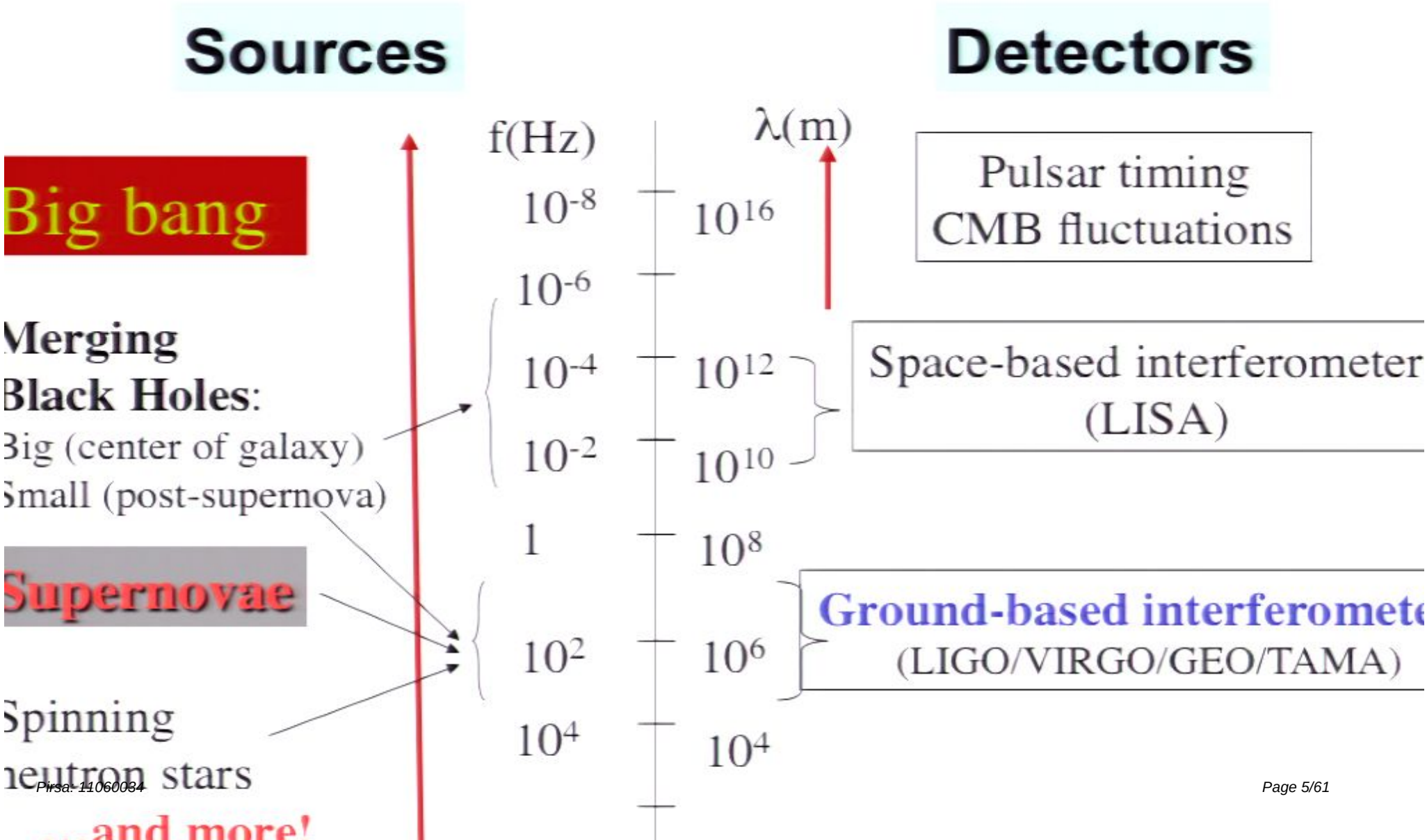
Pulsar timing
CMB fluctuations

Space-based interferometer
(LISA)

km

Ground-based interferomete
(LIGO/VIRGO/GEO/TAMA)

Detectors and scales



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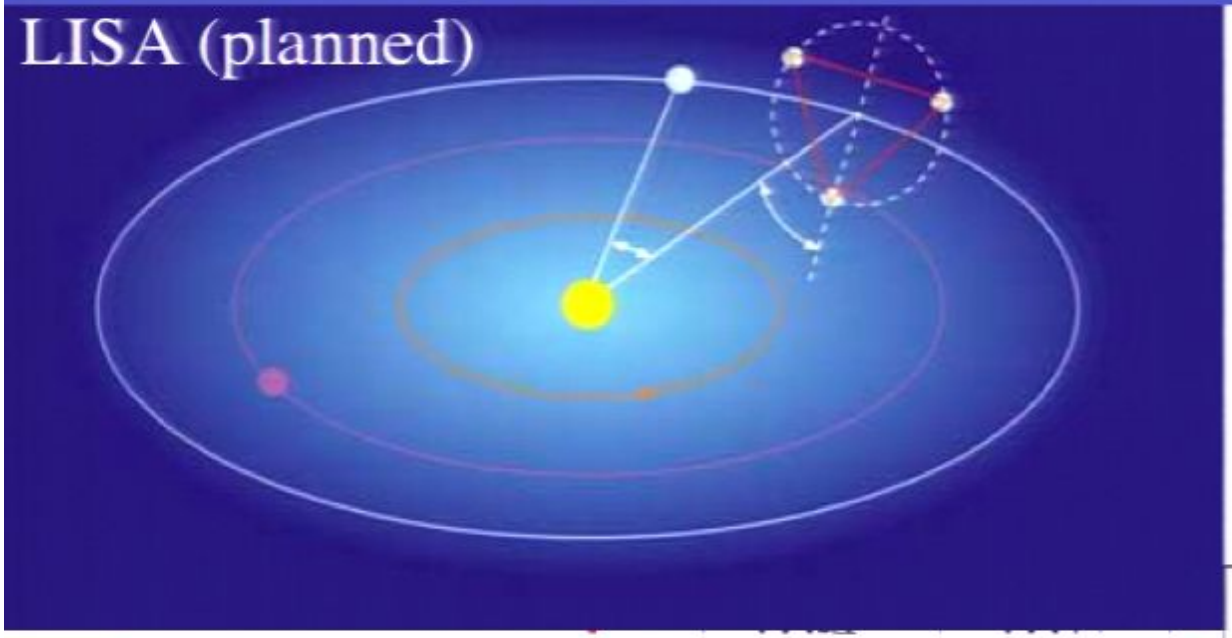

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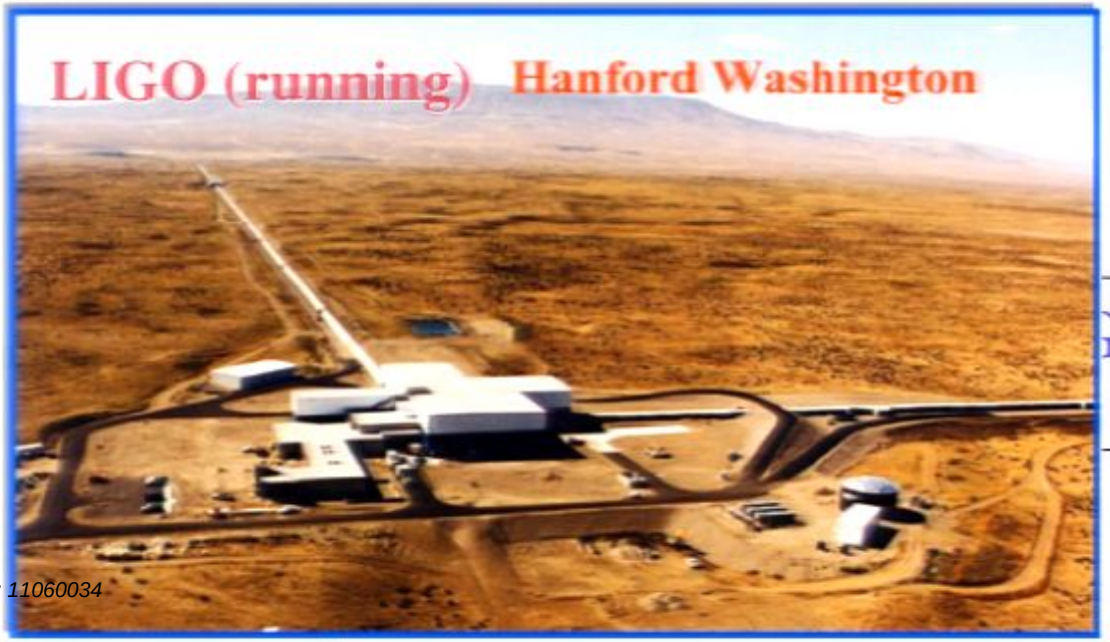

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Ground-based interferomete
(LIGO/VIRGO/GEO/TAMA)

Binaries: Collider analogy

- Mergers: nature's collider of nuclear matter
- GW : carry imprint of all bulk motion

  Talks : Duez, Read

  EM : outflow, accretion, nucleosynth, cracking

  Talks: Metzger, Tsang, Palenzuela
- Statistics: $>10^5$/yr accessible (3^{rd} gen)

  > few/yr (soon/already [GRBs])
- "Not monochromatic" : NS, BH mass,spins

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What can we **eventually** measure?

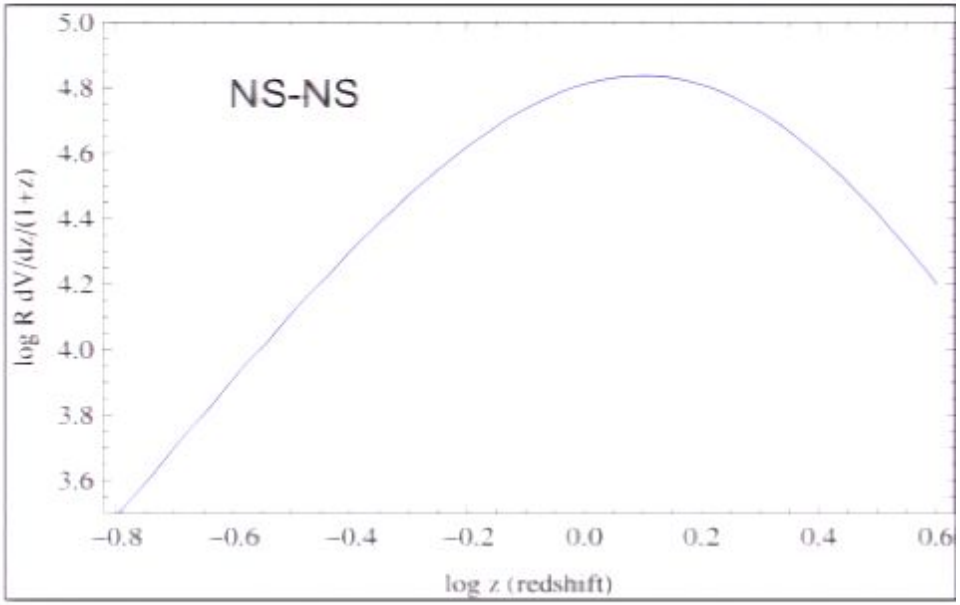
Third-generation: tomography

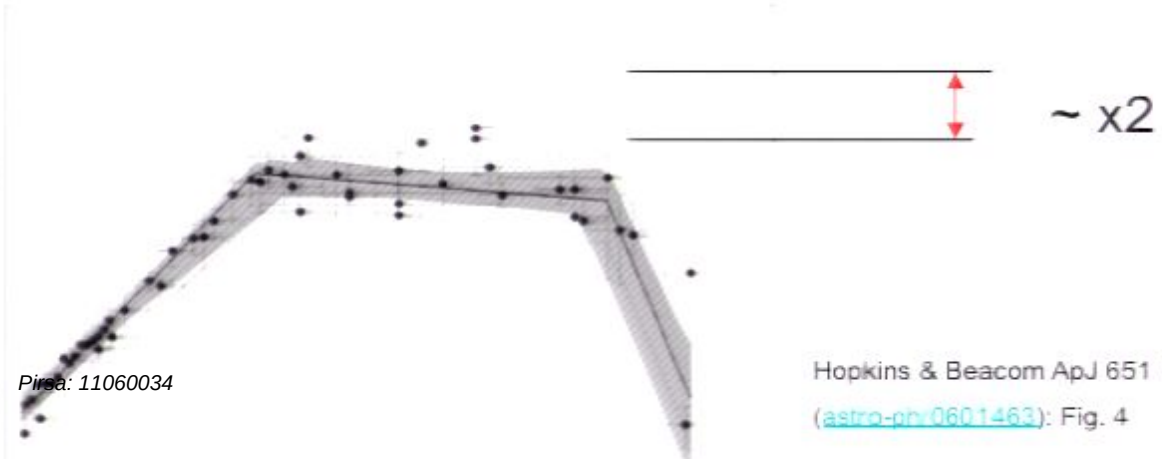
Example: NS-NS:

- dVolume(z)* rate(z)/(1+z)
  = "rate per redshift bin"

- O(10^5-10^6) detections
  - **Rate** vs distance
  - **Mass distribution** vs distance

- Reach ~ peak SFR





~ x2

Eventually

Distributions

Distributions vs z (& Z)

Few sources **really** brig

Hopkins & Beacom ApJ 651 142 2006 (astro-ph/0601463): Fig. 4

Binaries: Collider analogy

- Mergers: nature's collider of nuclear matter
- GW : carry **imprint** of all bulk motion

  Some modulations easier: collision **inputs** easy, nuclear signatures hard

  EM : outflow, accretion, nucleosynth

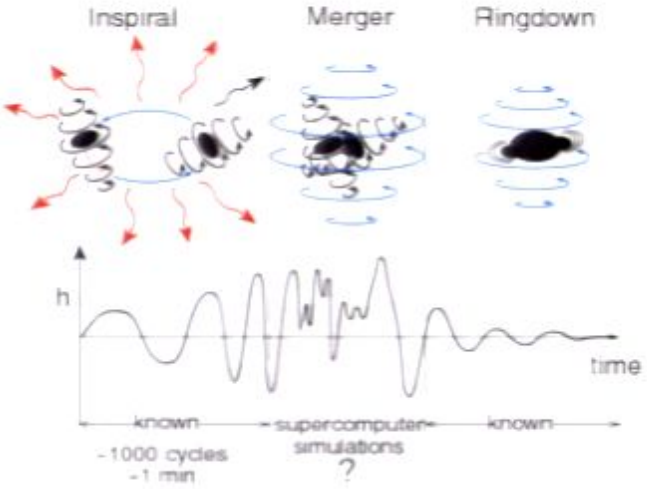
  Short GRBs
- **Statistics**: $>10^5$/yr accessible (3rd gen)

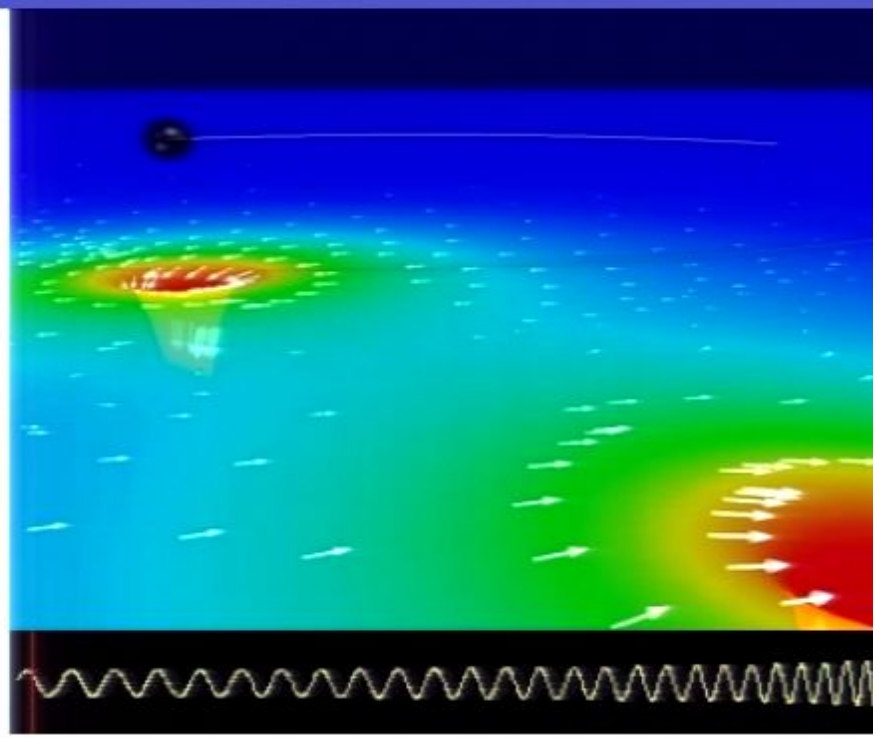
  > few/yr (soon/already [GRBs])
- "Not monochromatic" : **distributions**

Imprint of GW

Example: Two black holes (no spin)

Waveform: 3 epochs





Inspiral:

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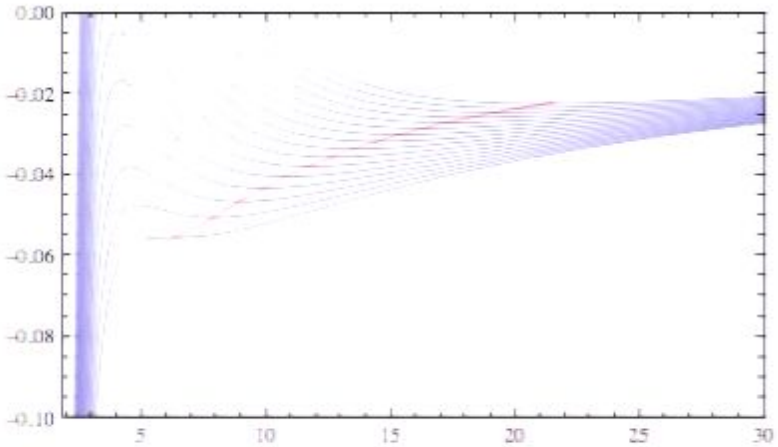

Merger, ringdown

Imprint of GW

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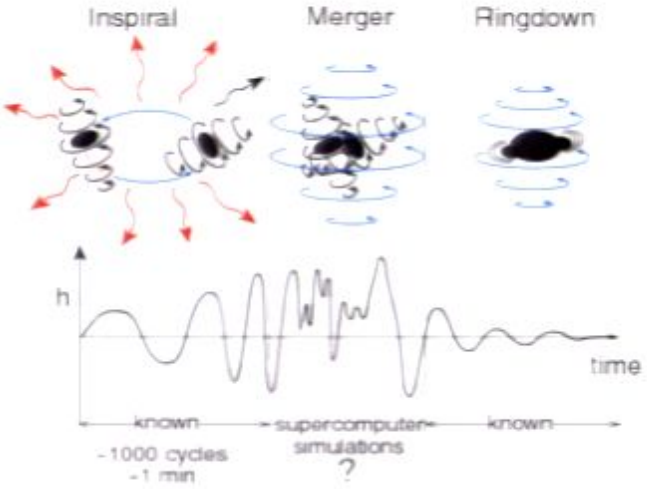

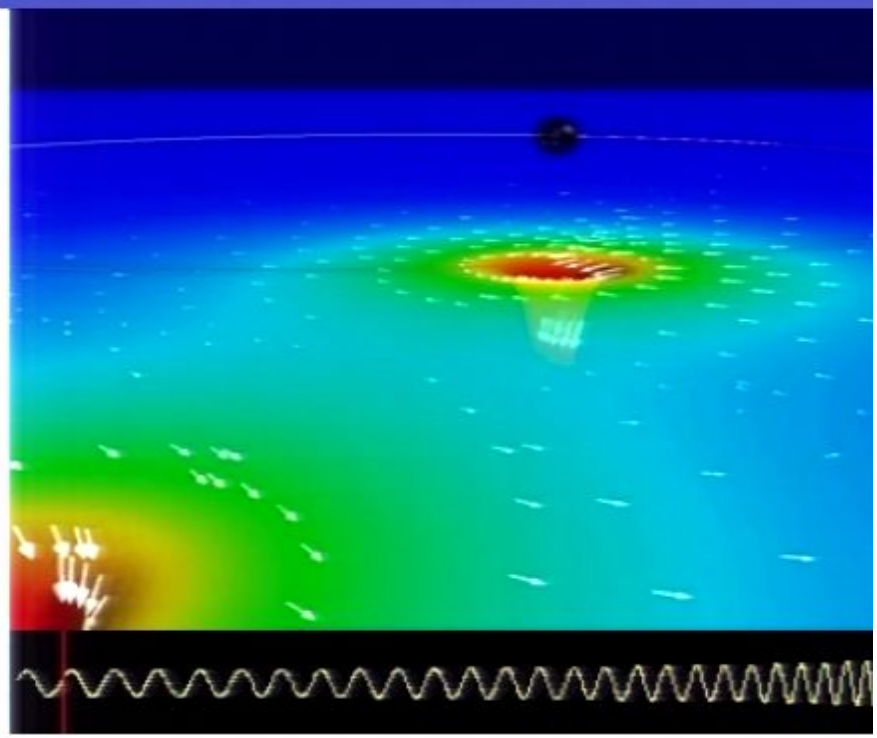

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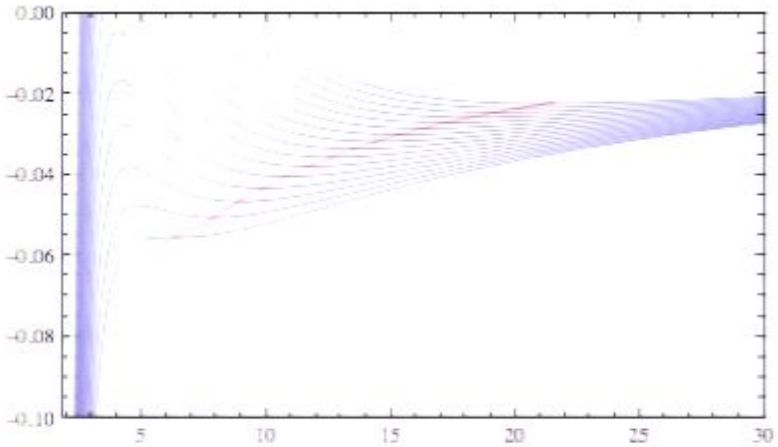

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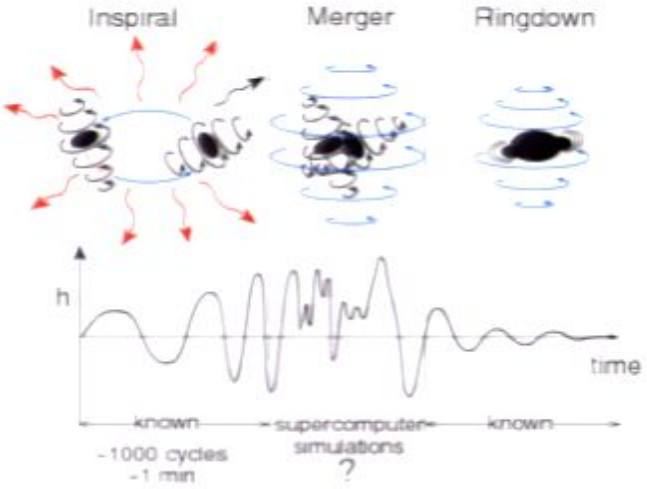

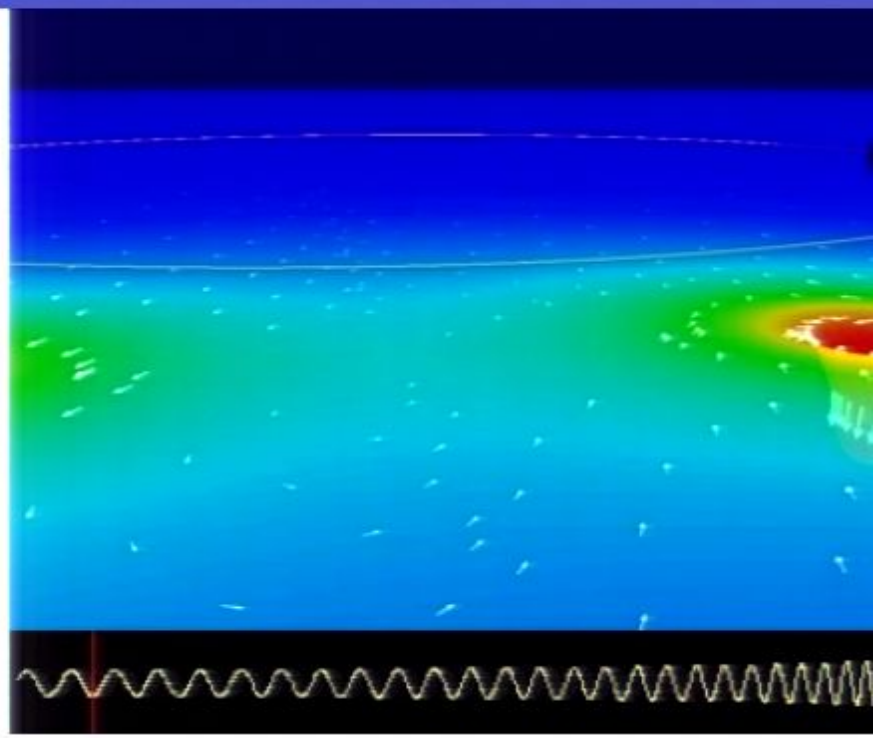

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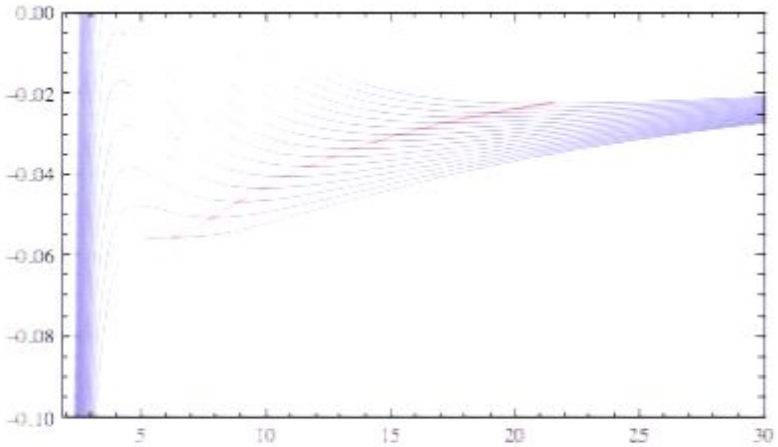

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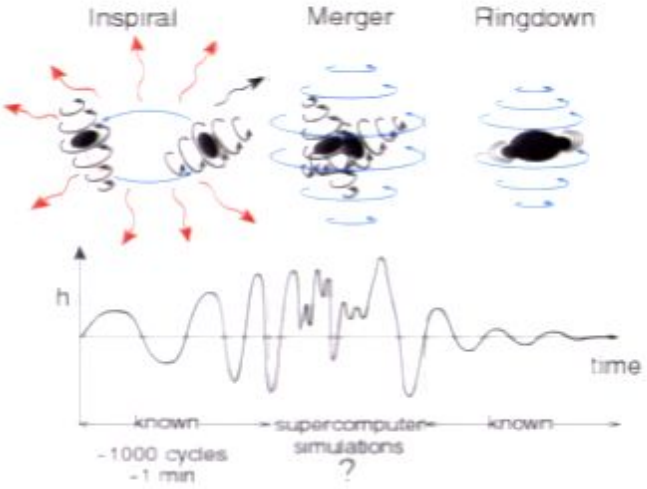

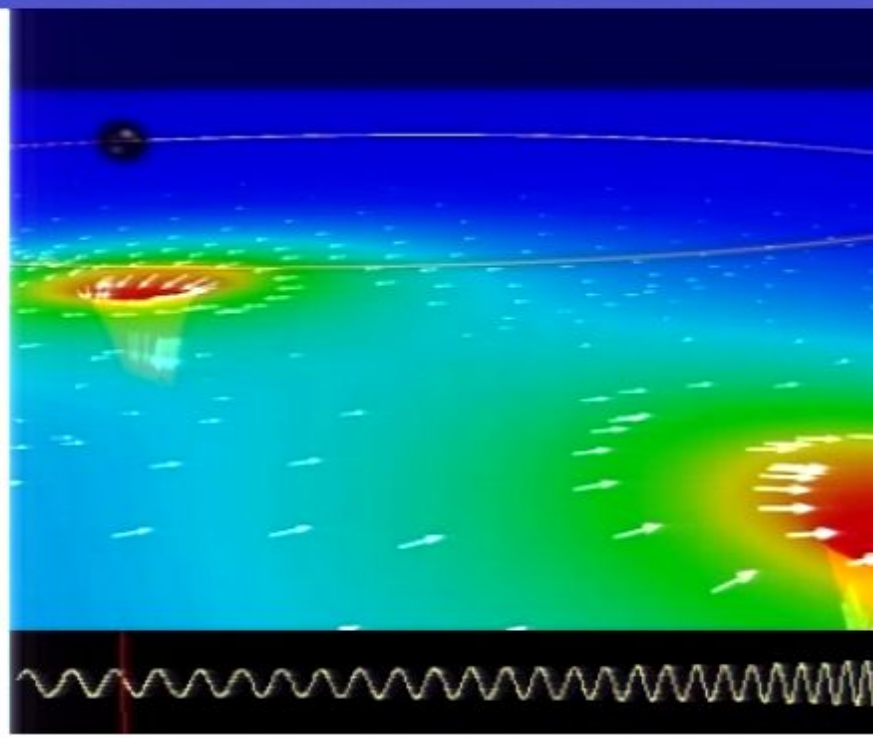

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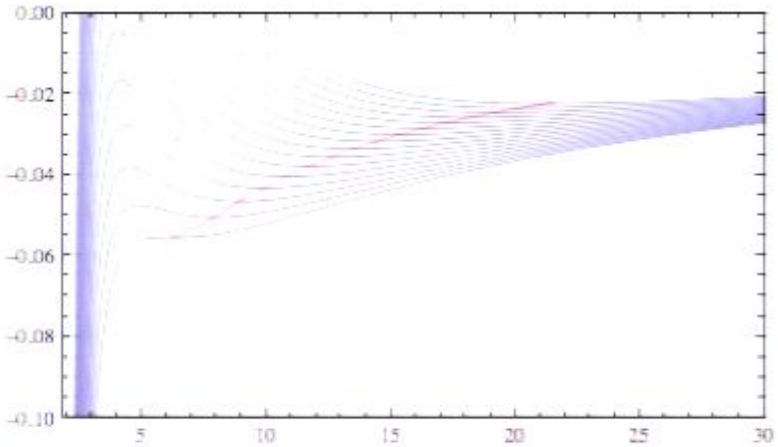

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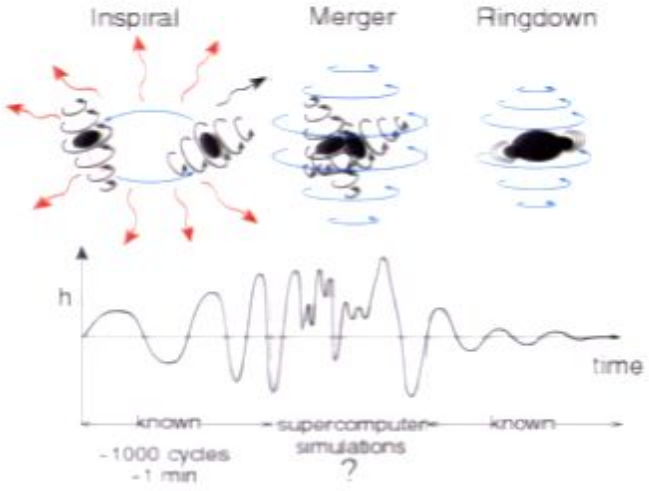

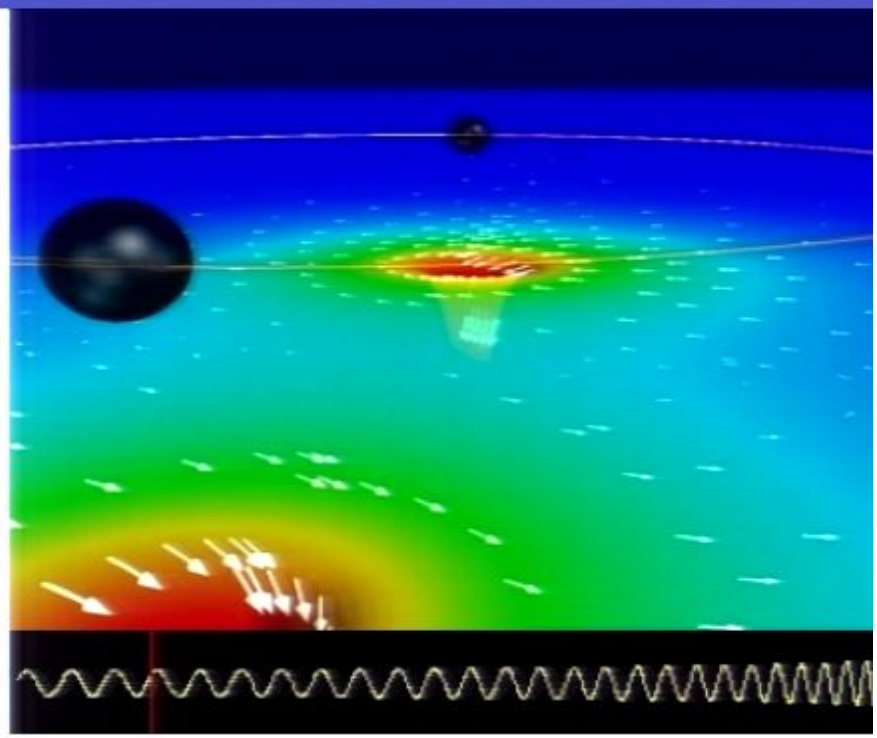

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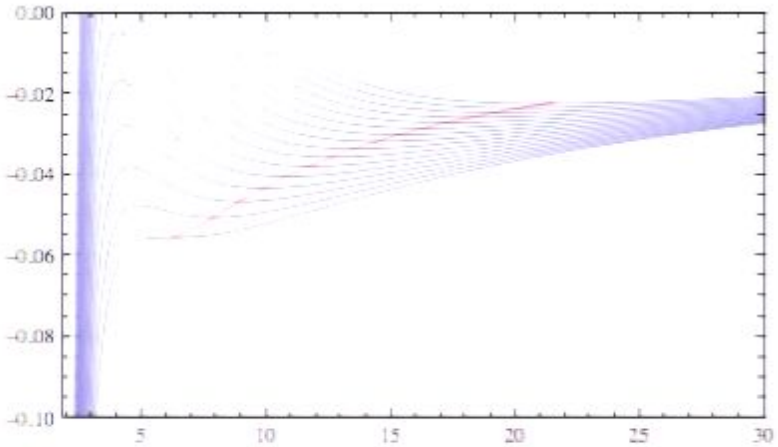

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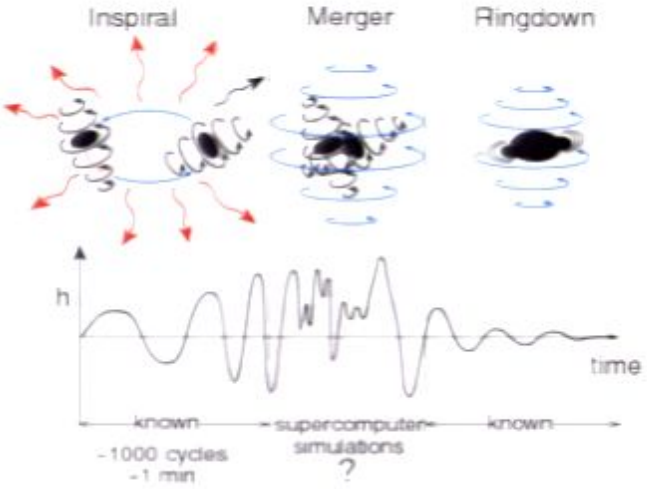

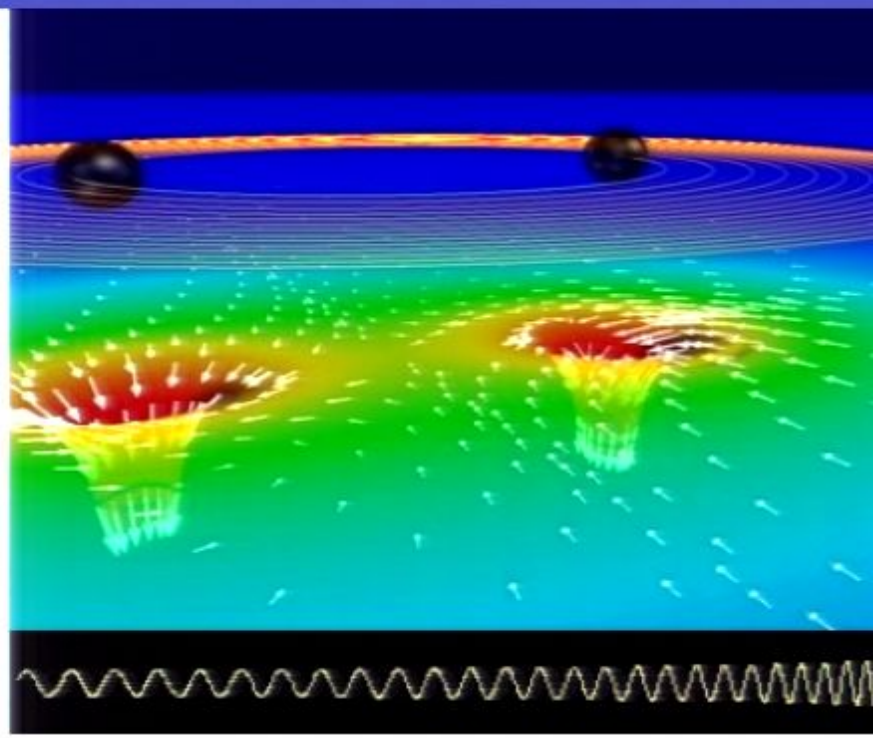

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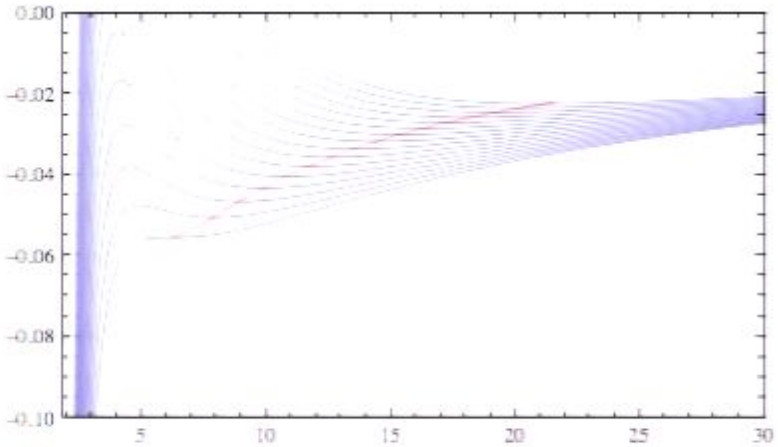

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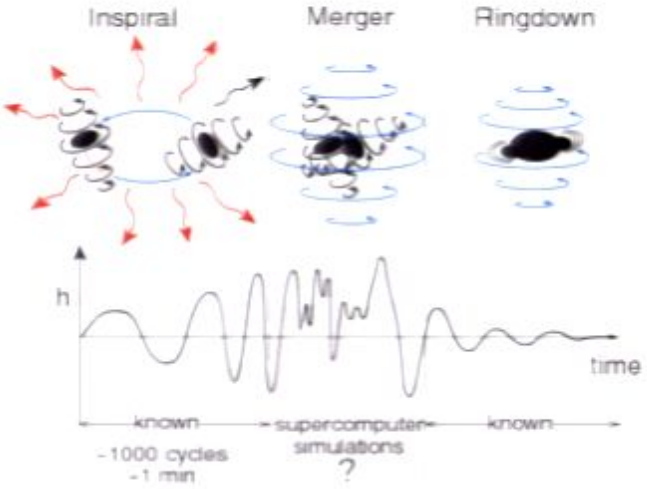

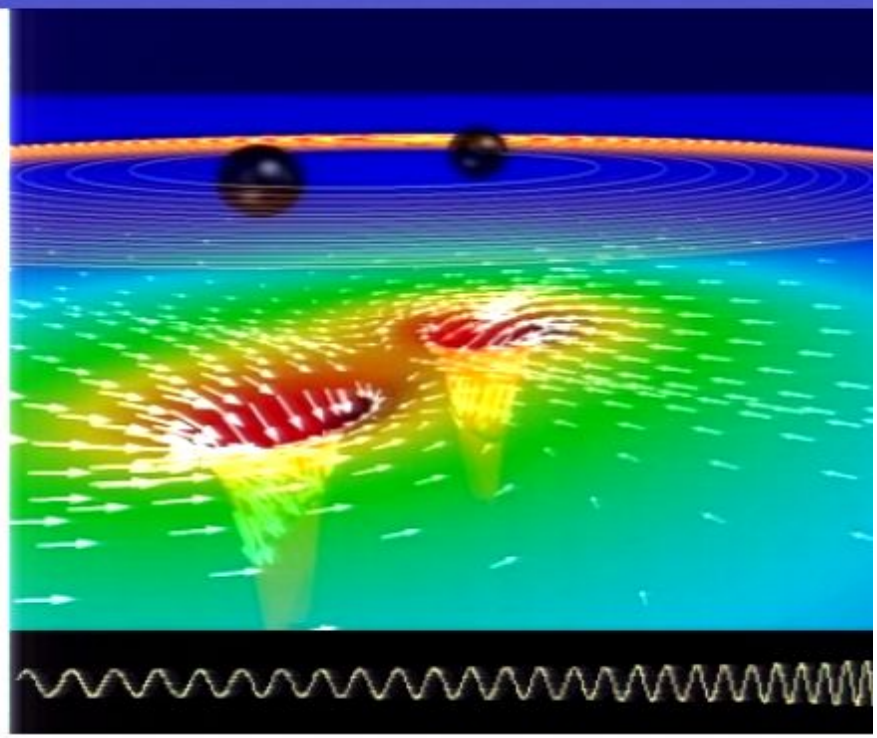

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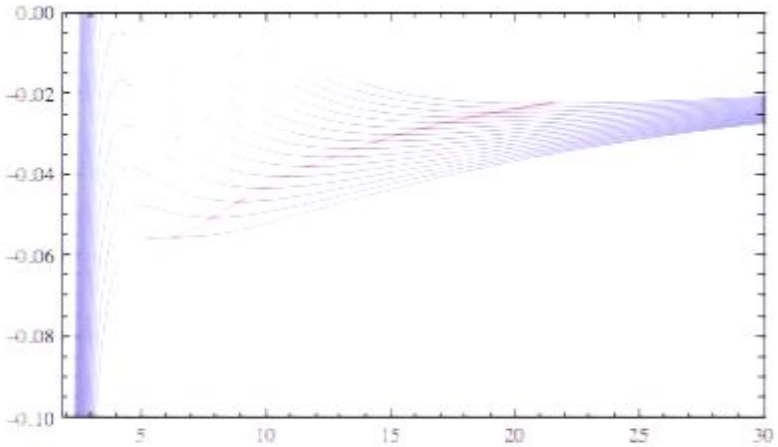

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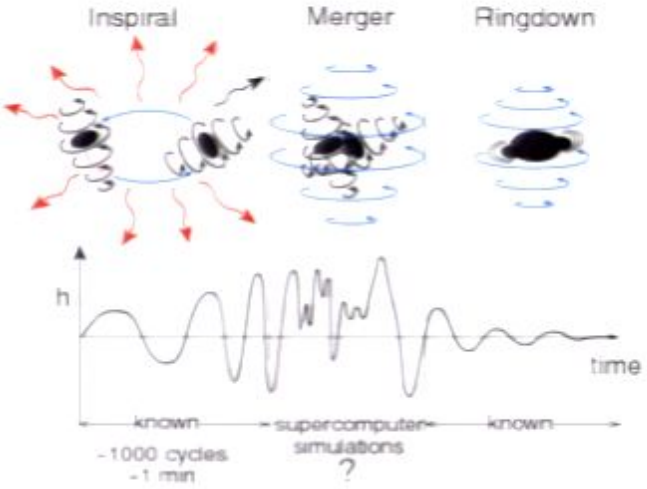

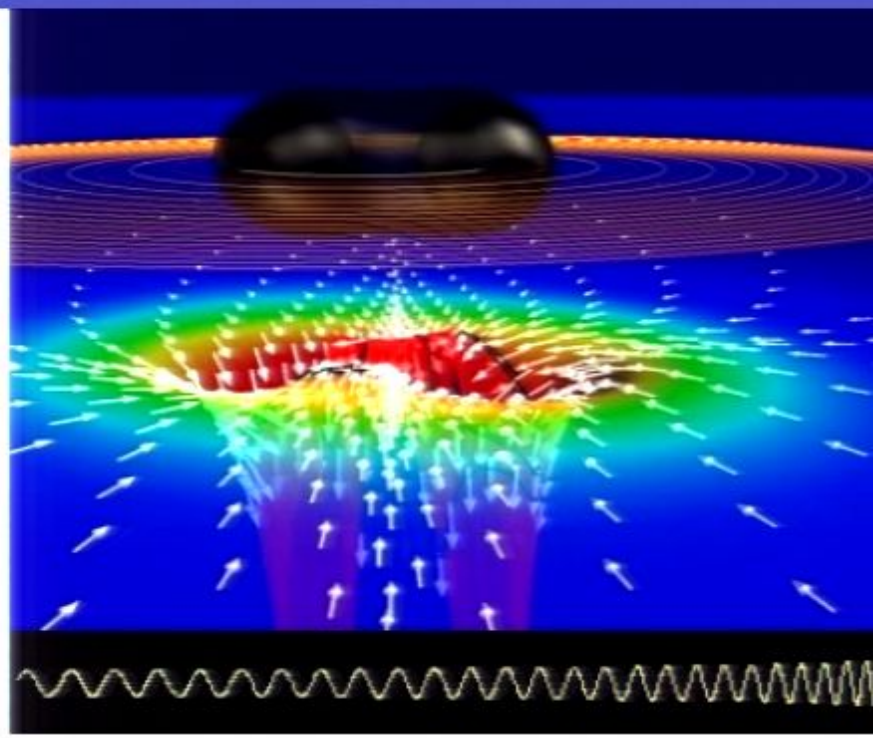

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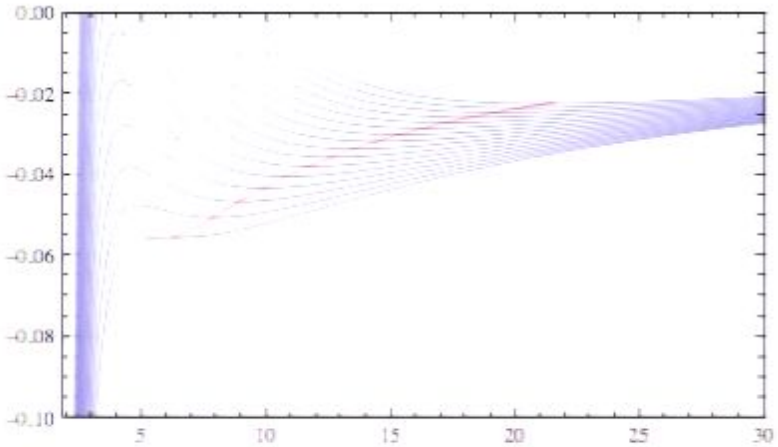

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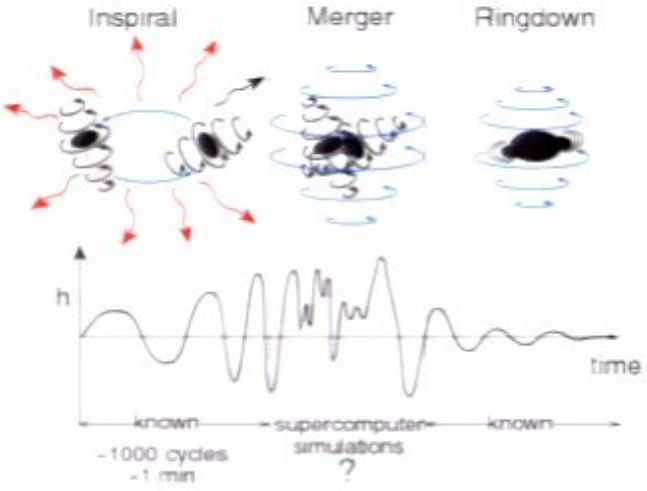

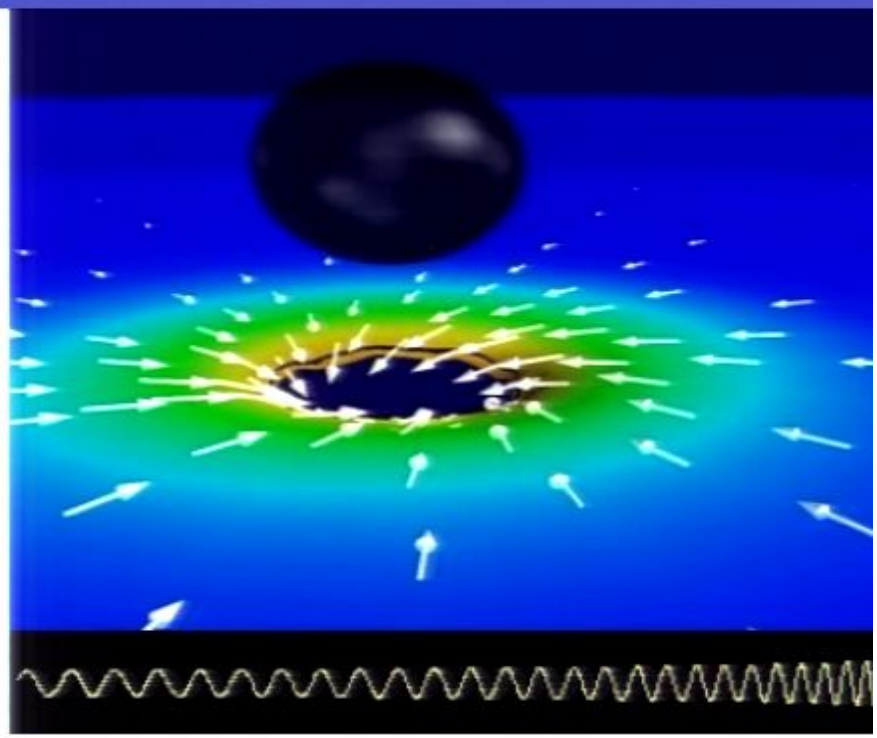

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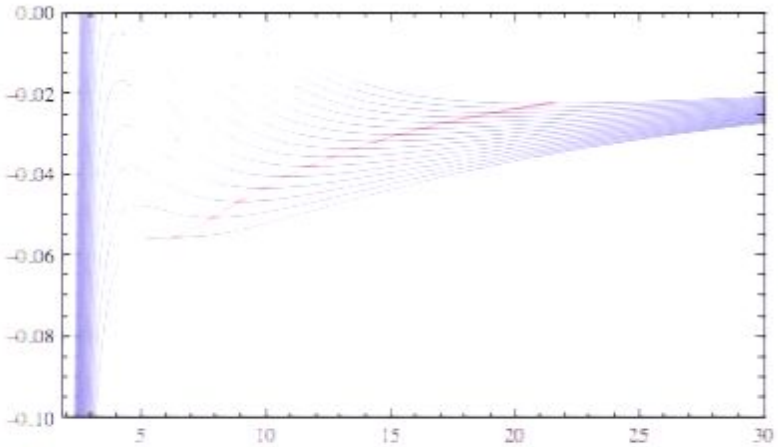

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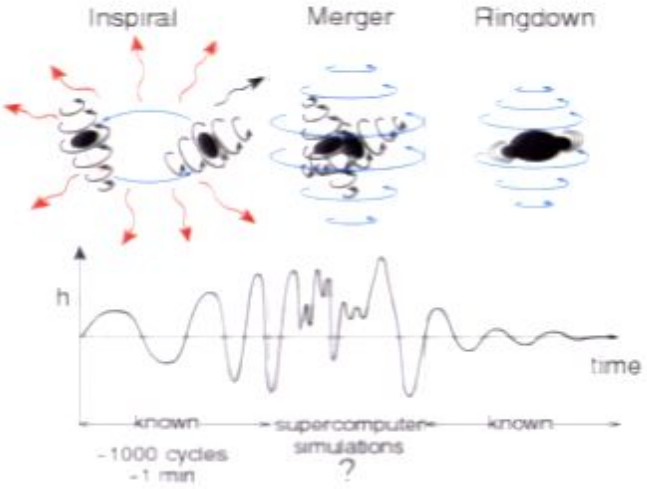

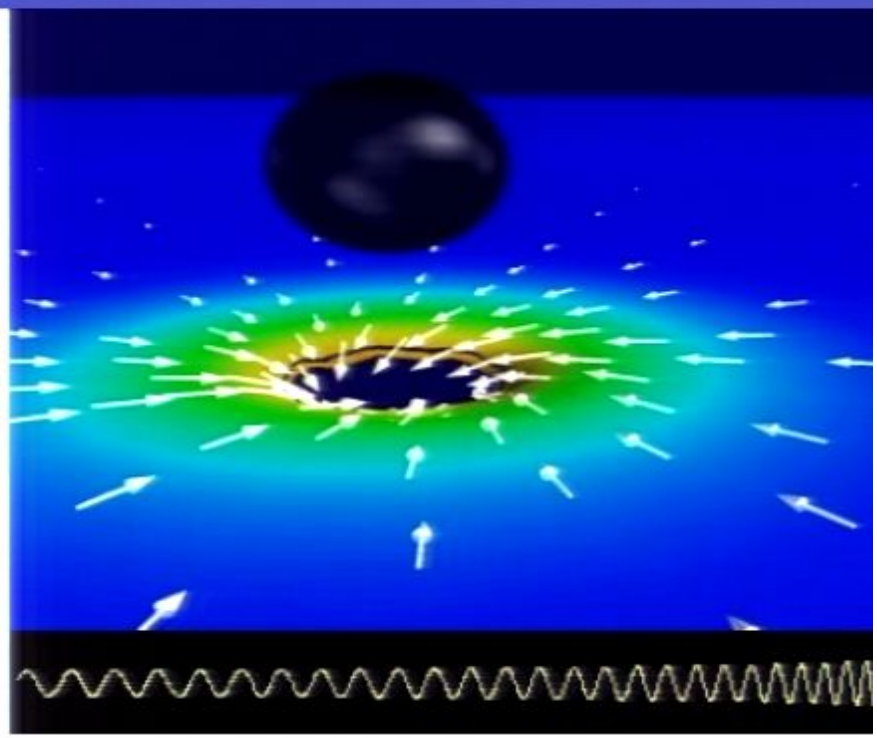

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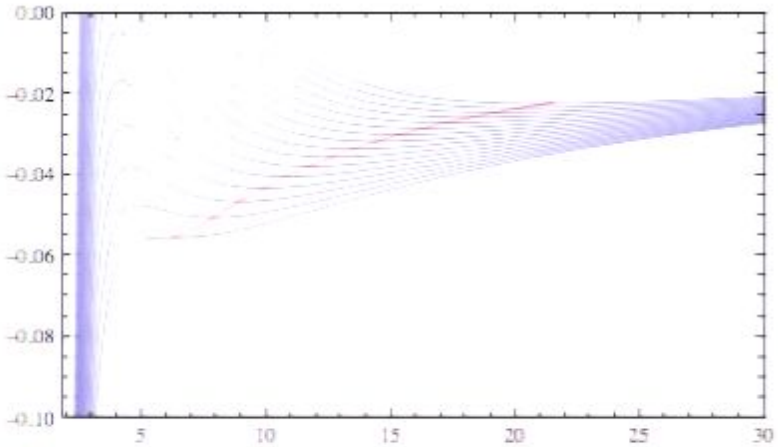

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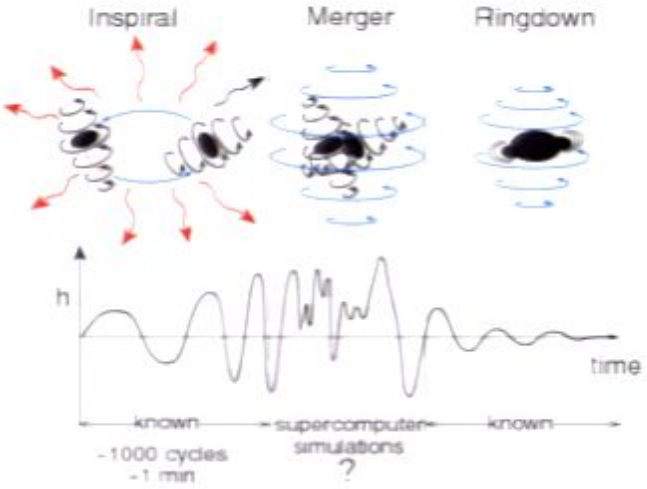

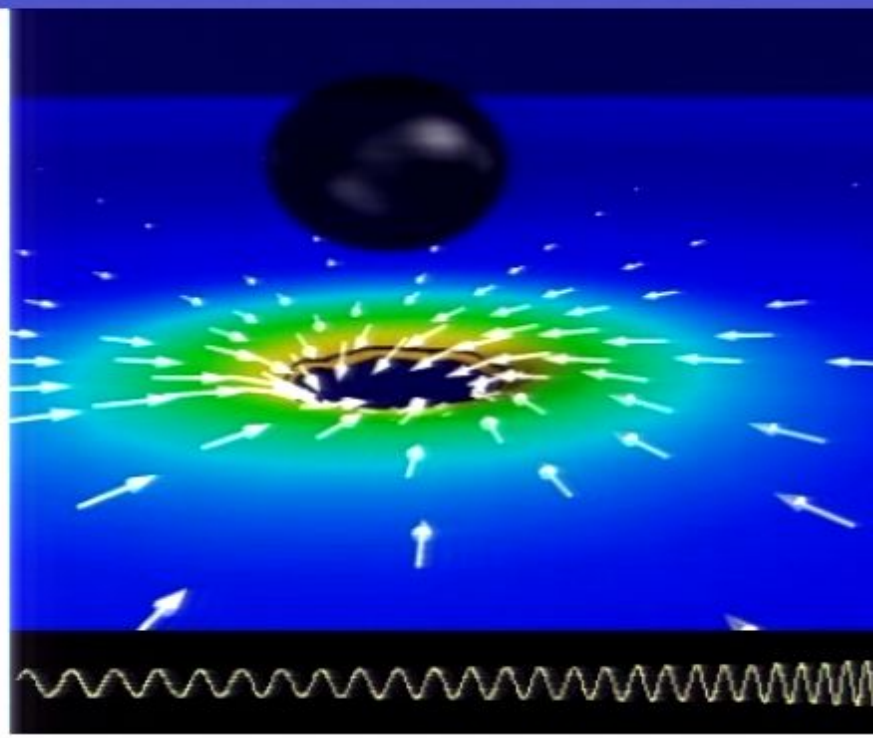

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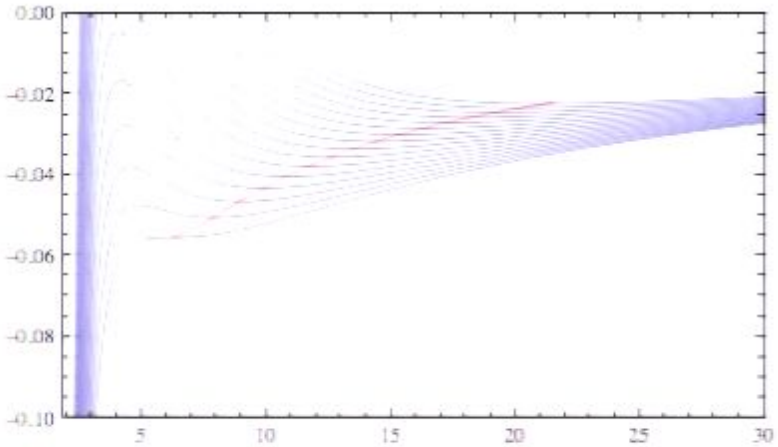

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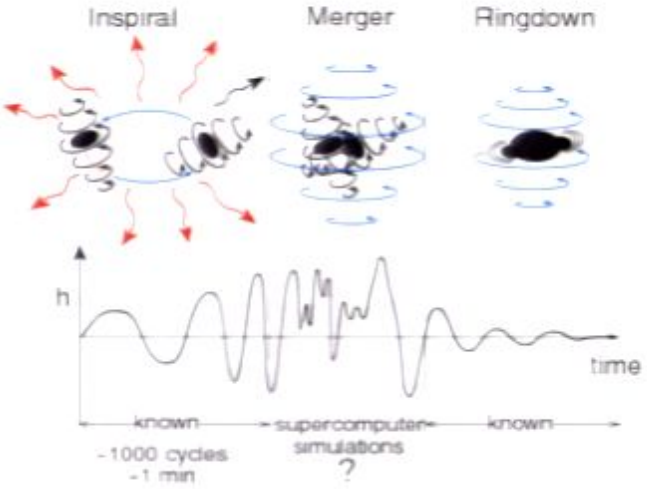

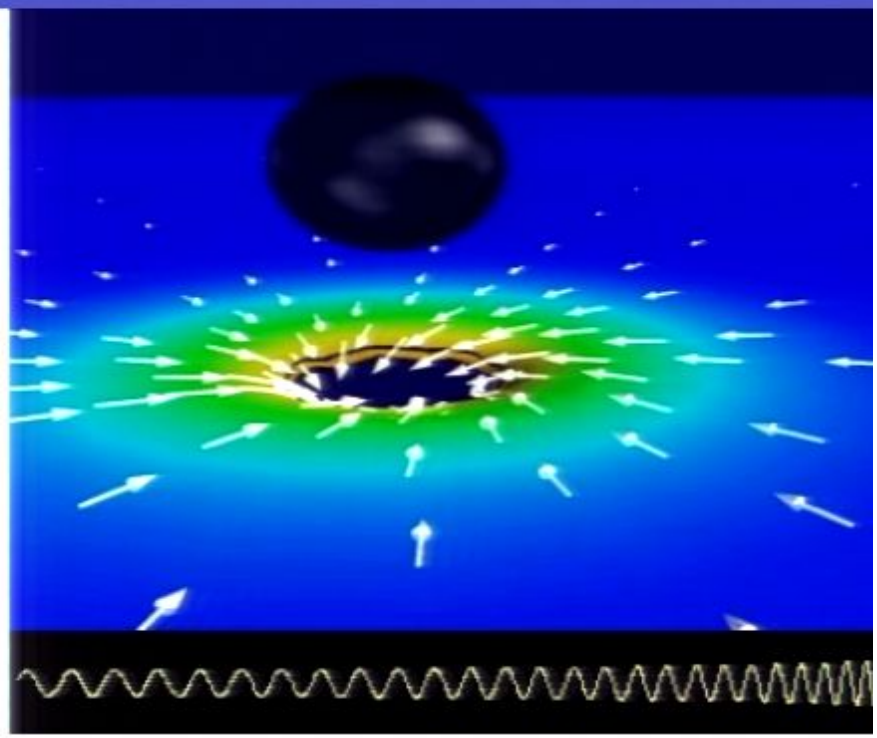

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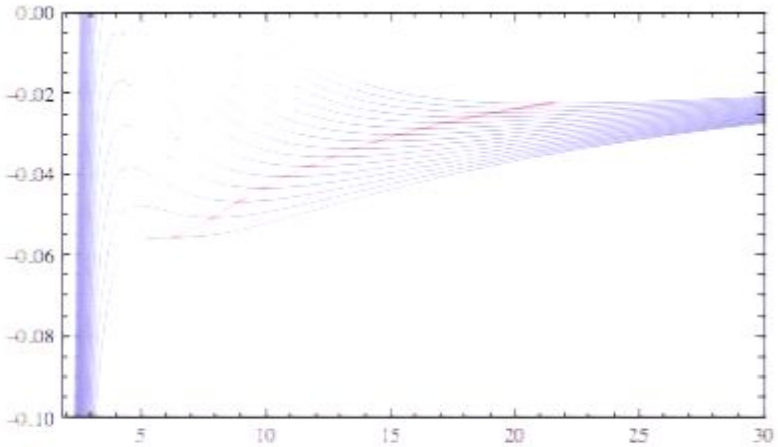

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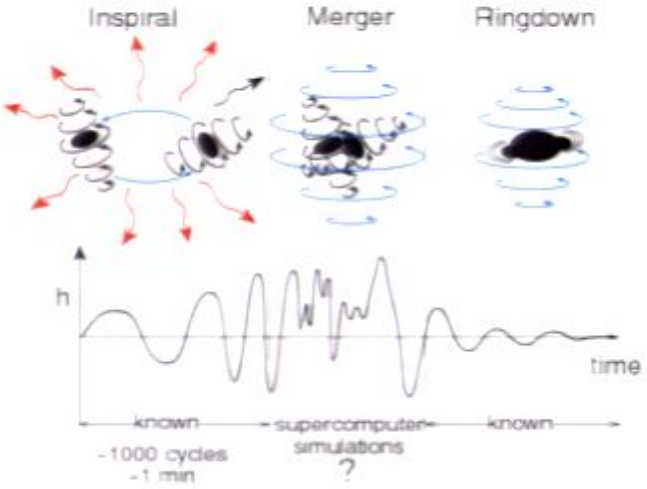

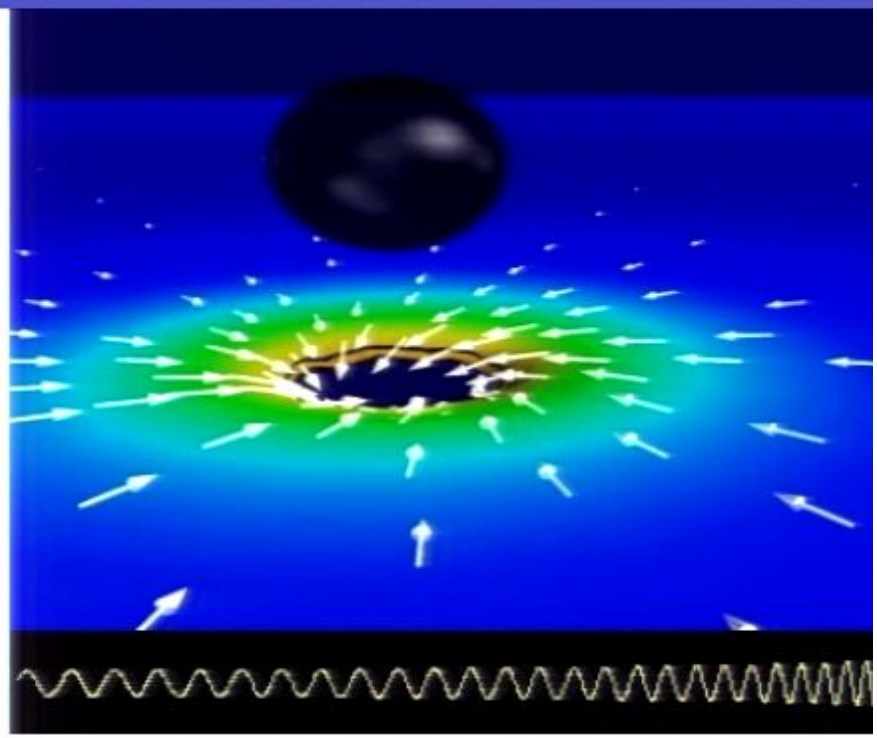

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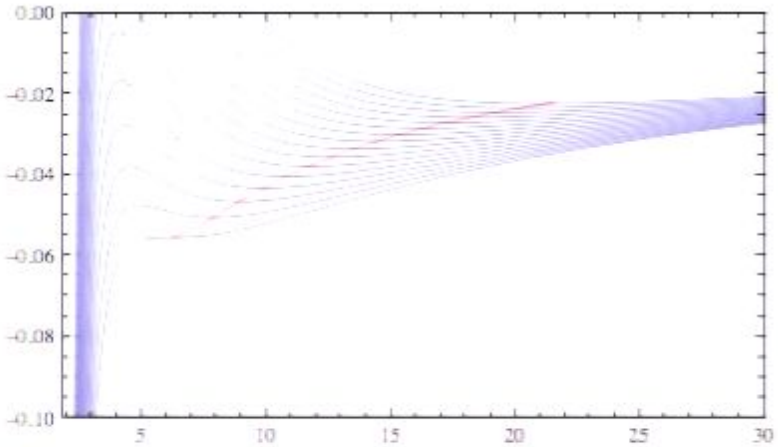

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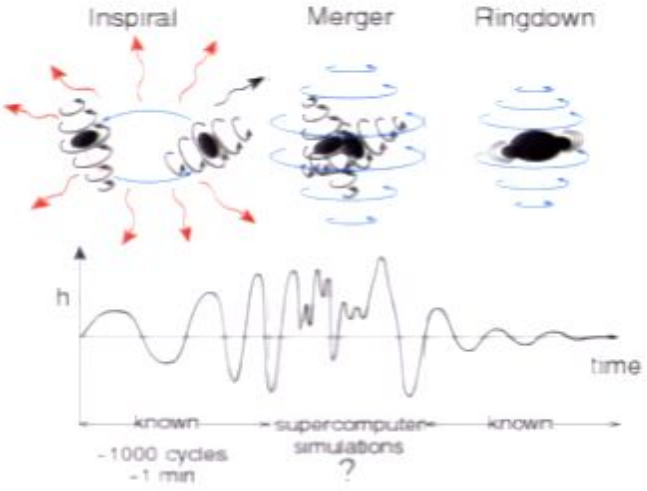

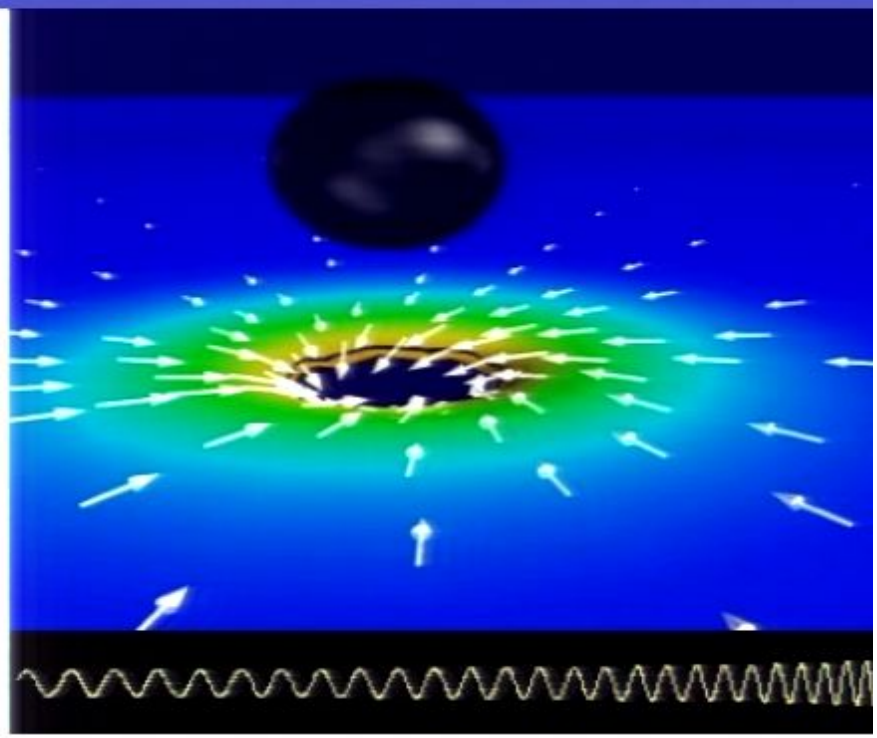

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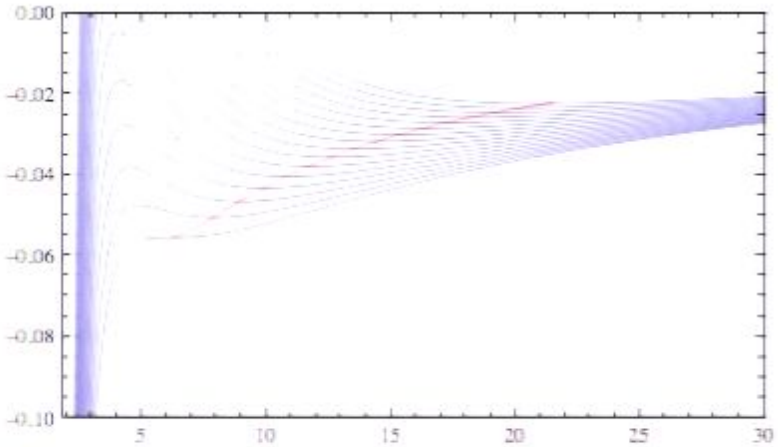

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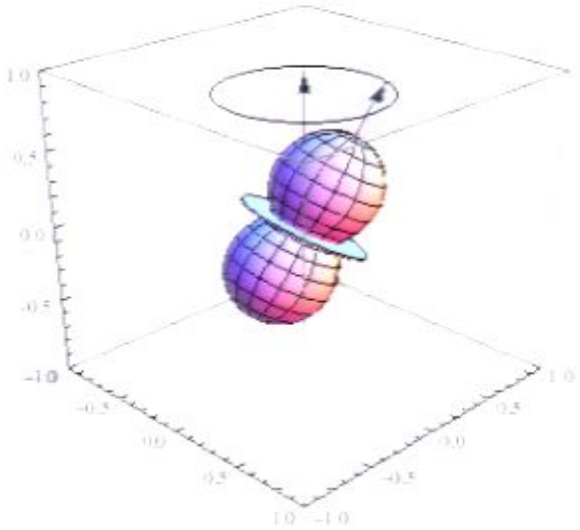
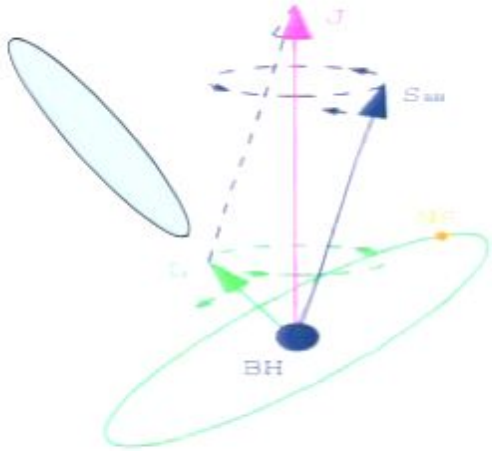
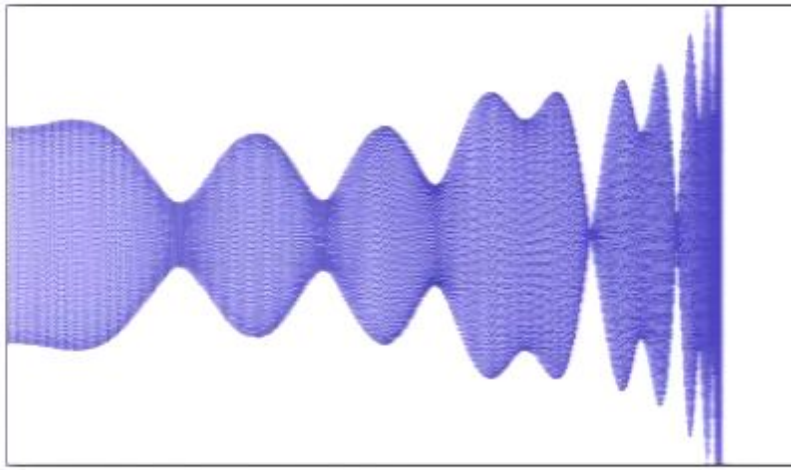
Imprint of GW

Early precession, modulation:







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Imprint of GW

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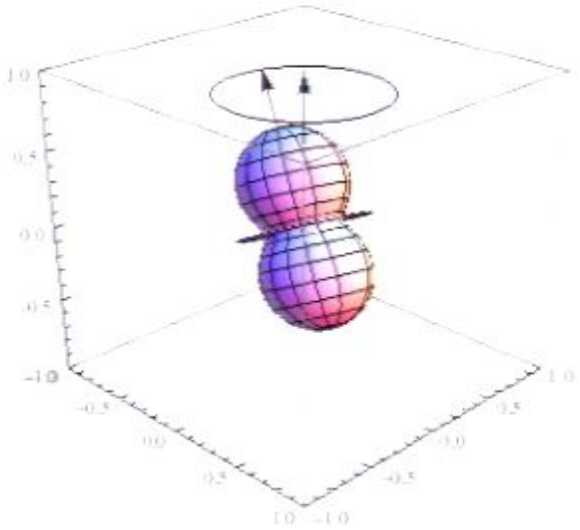

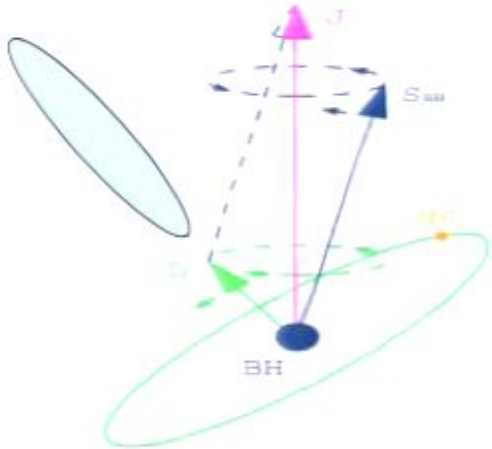

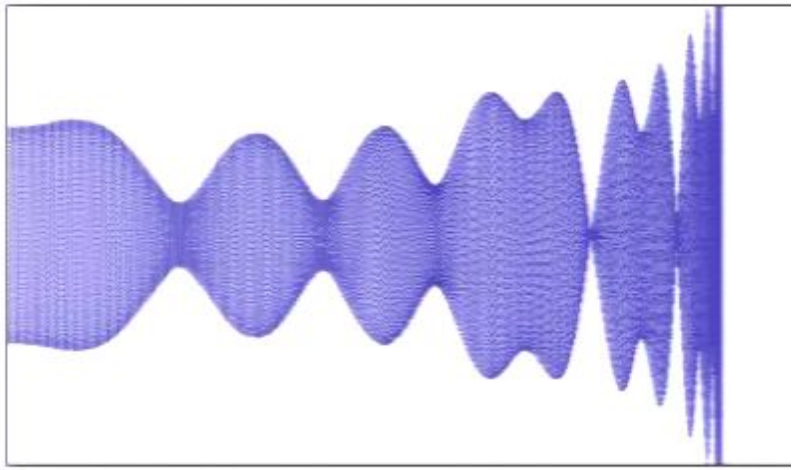

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Imprint of GW

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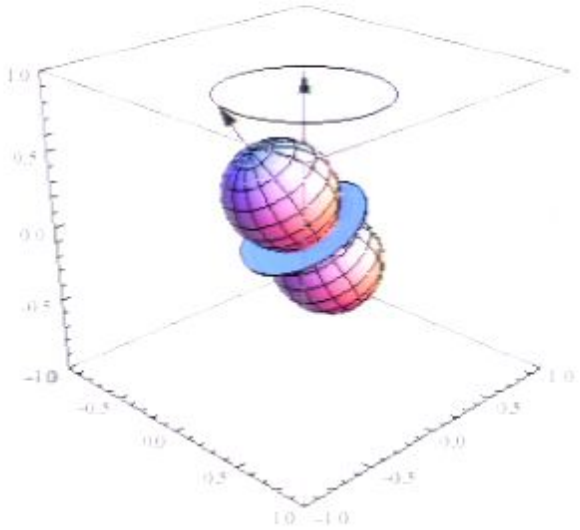

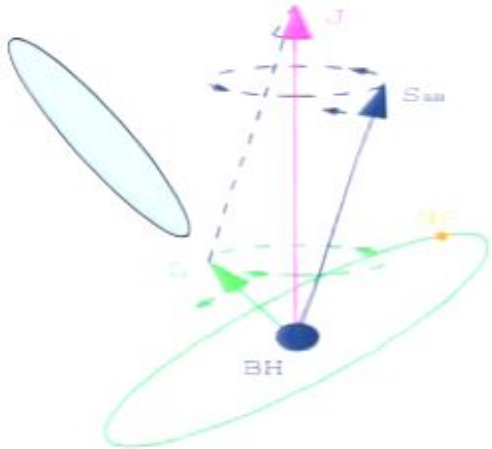

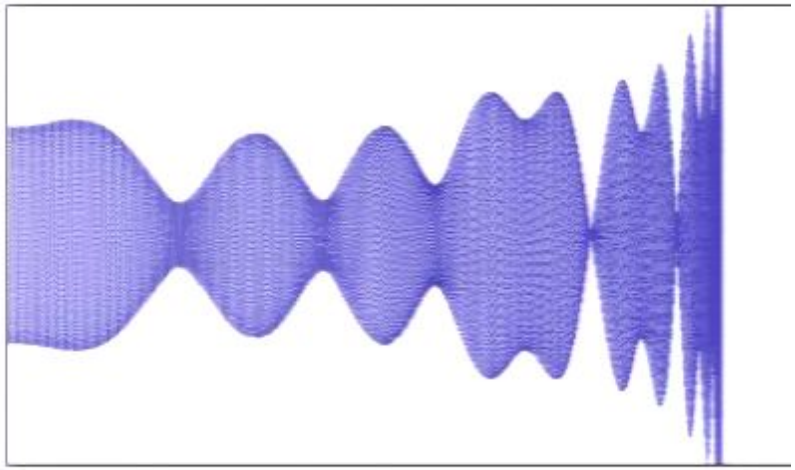

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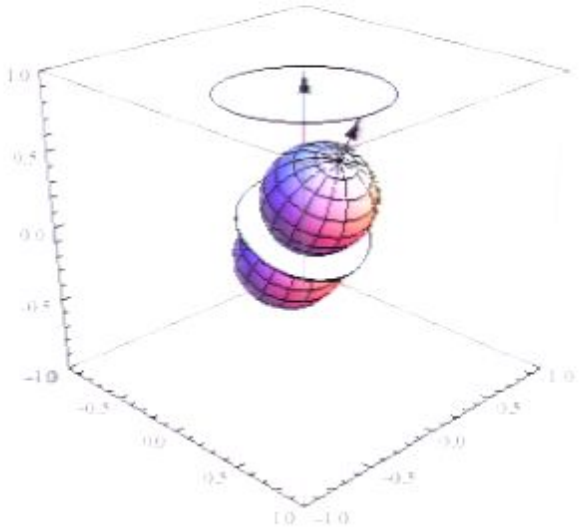

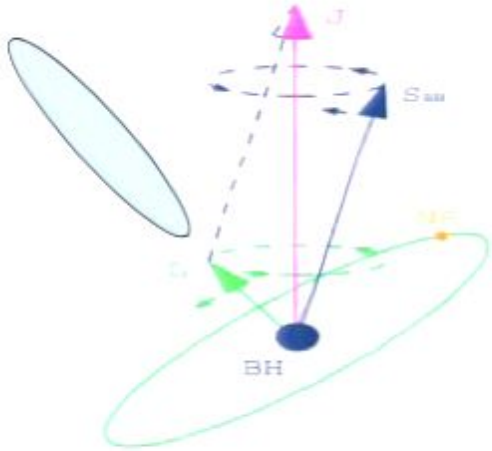

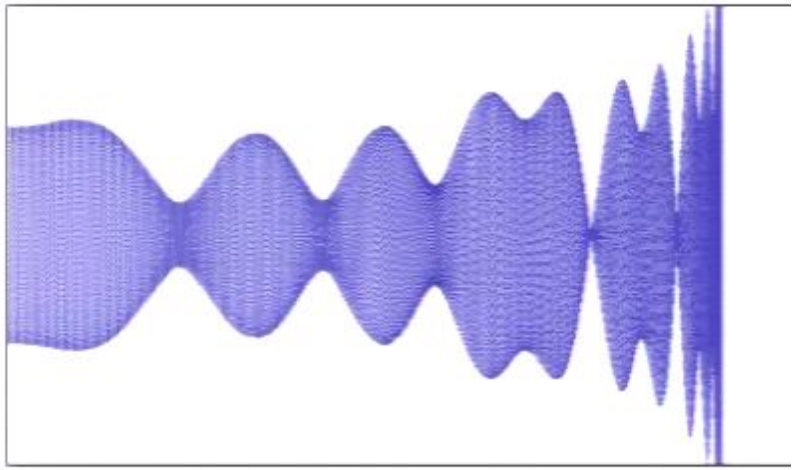

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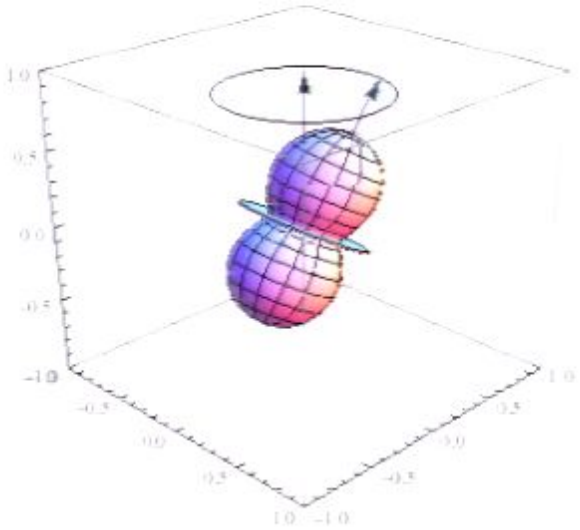

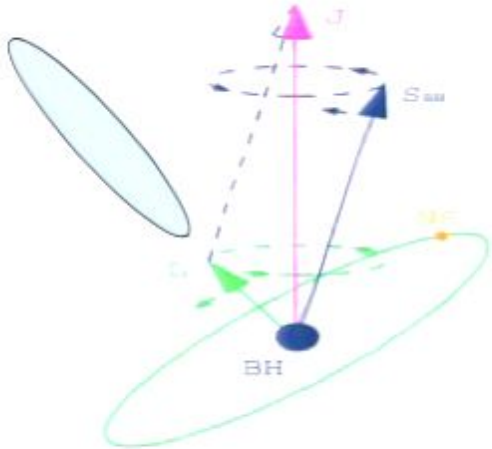

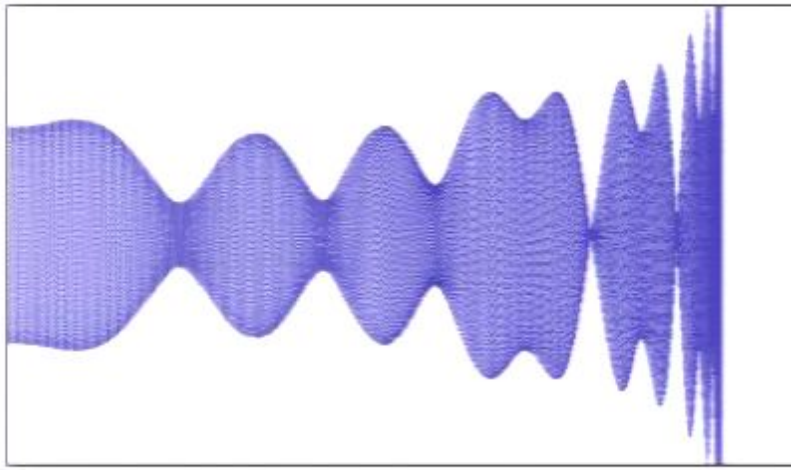

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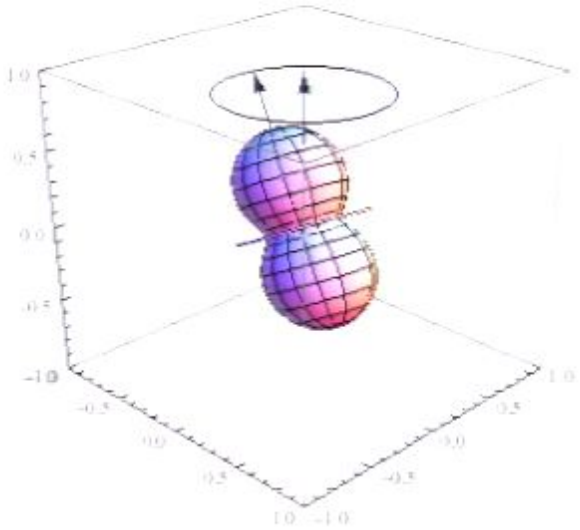

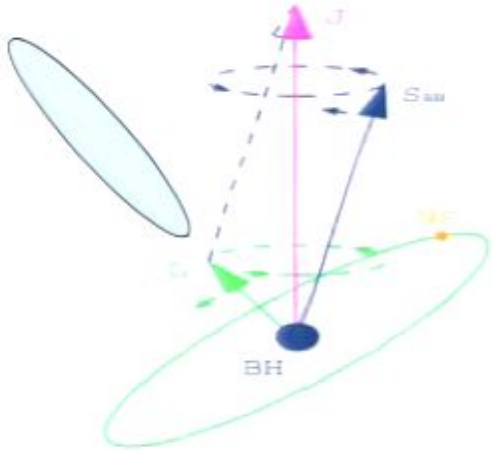

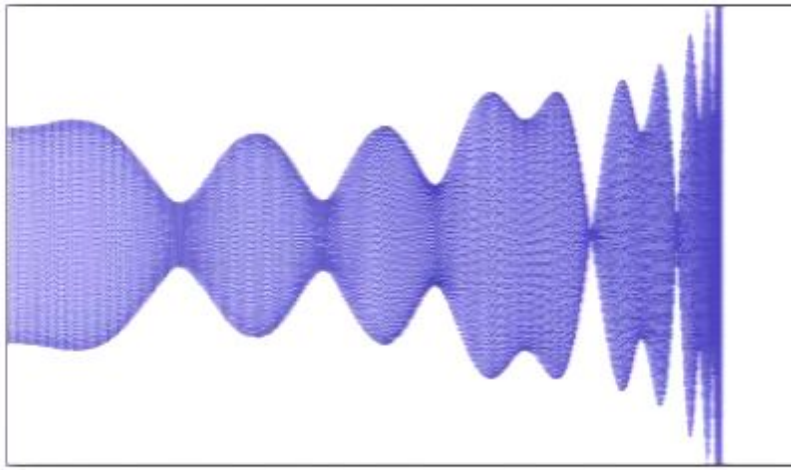

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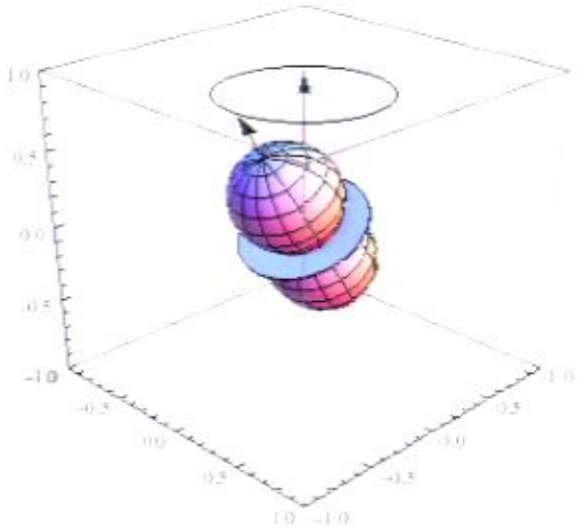

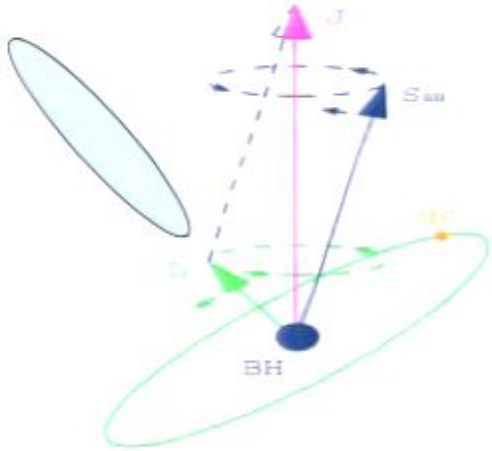

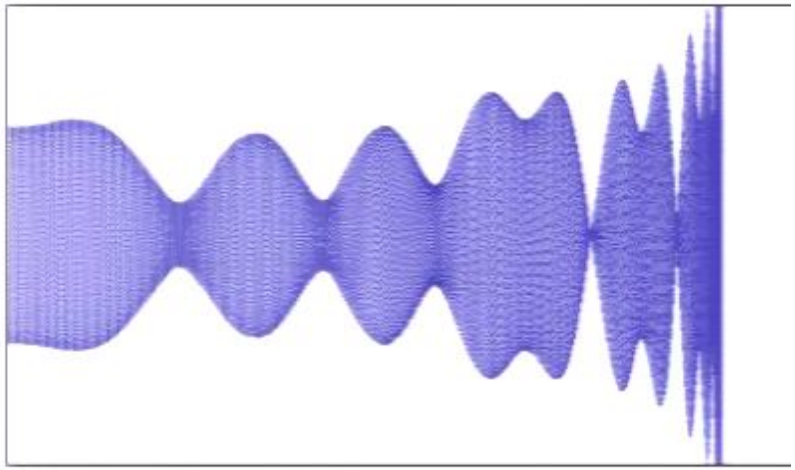

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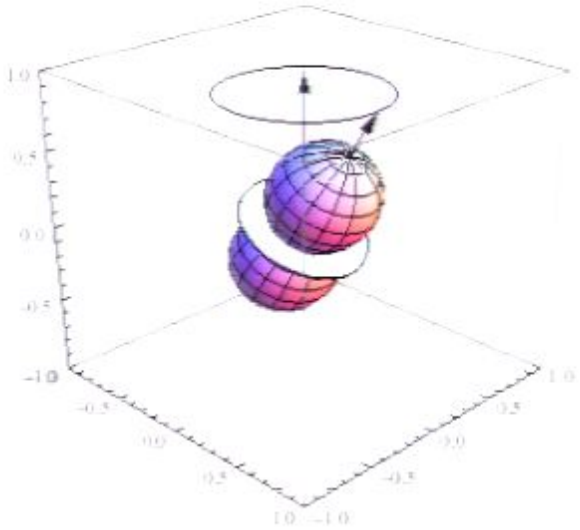

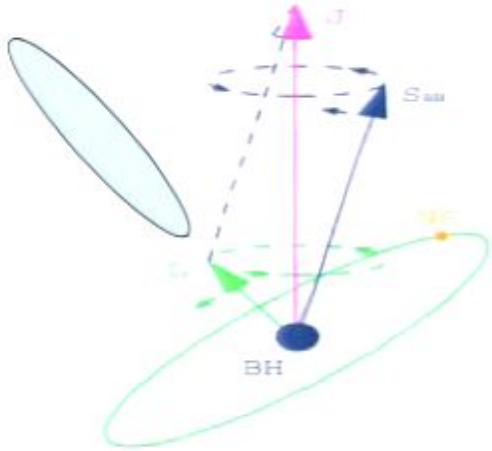

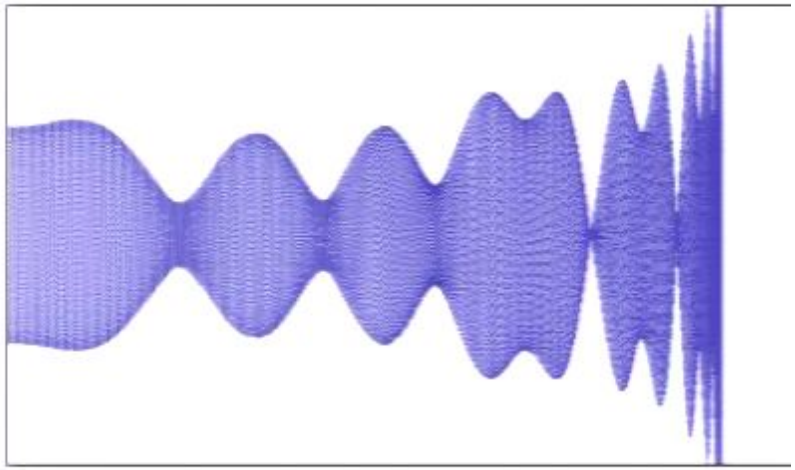

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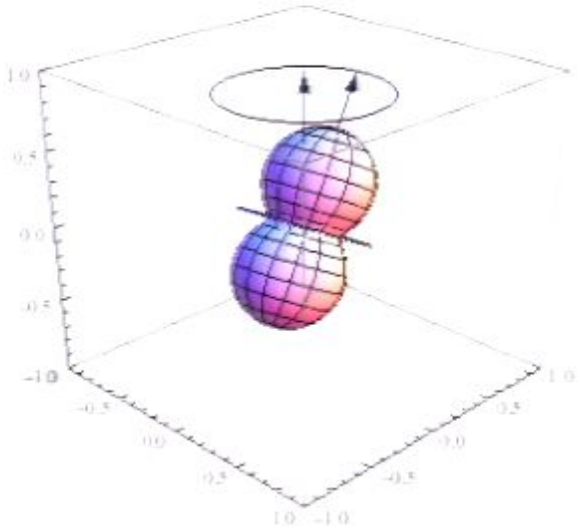

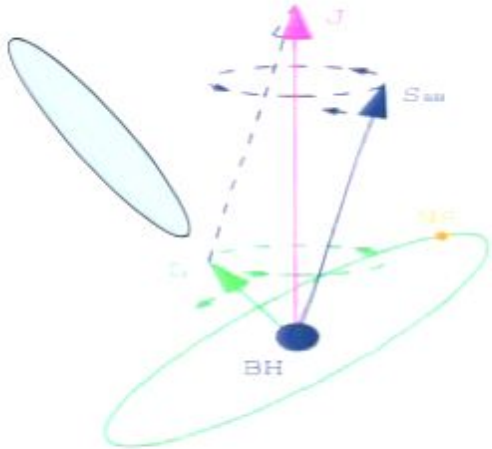

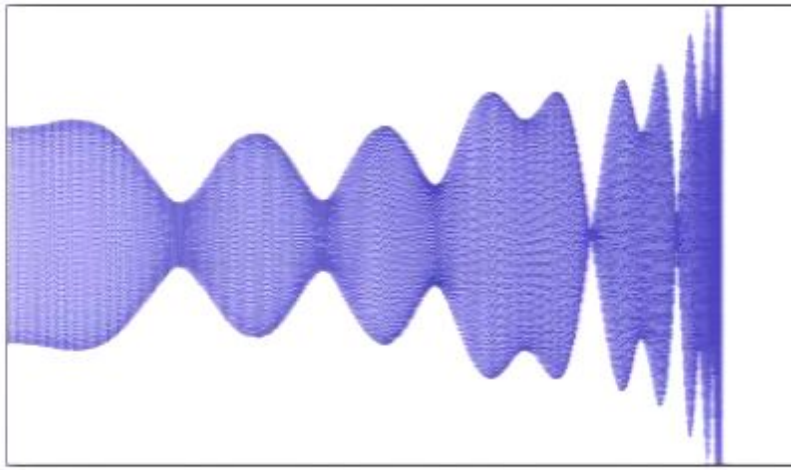

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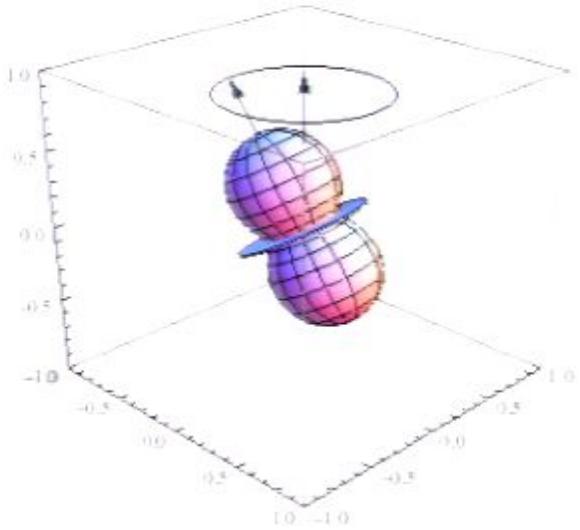

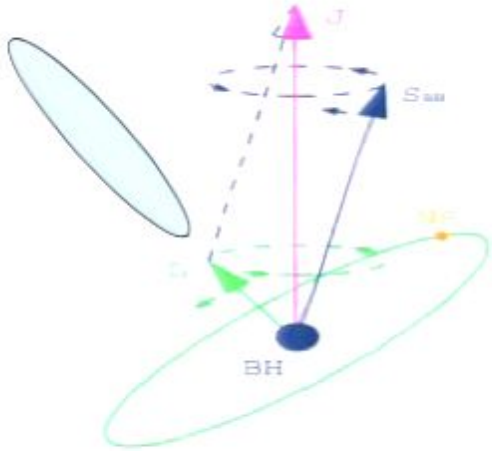

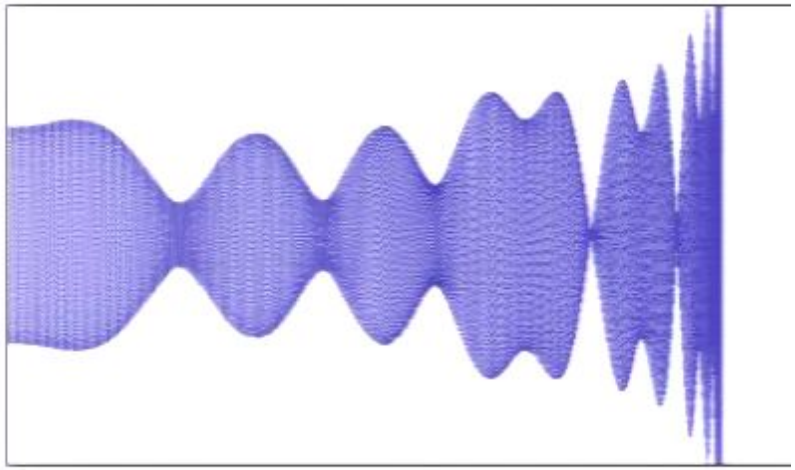

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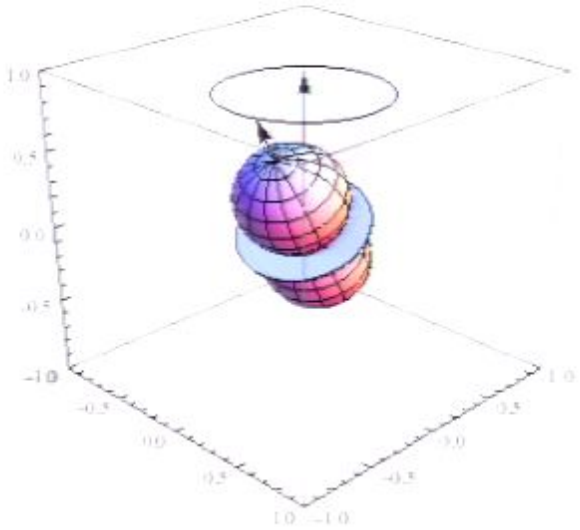

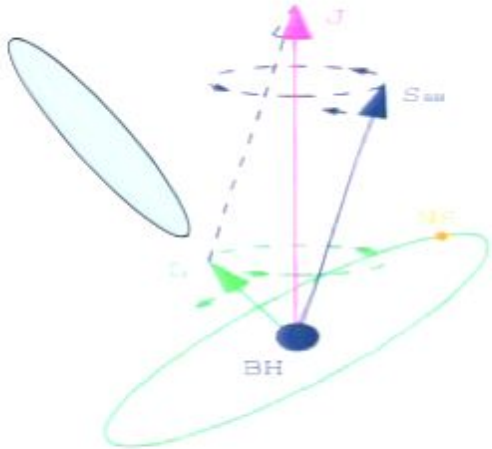

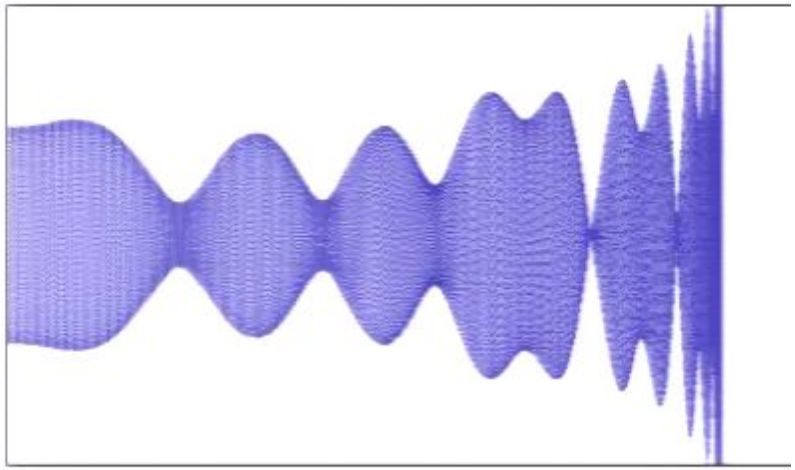

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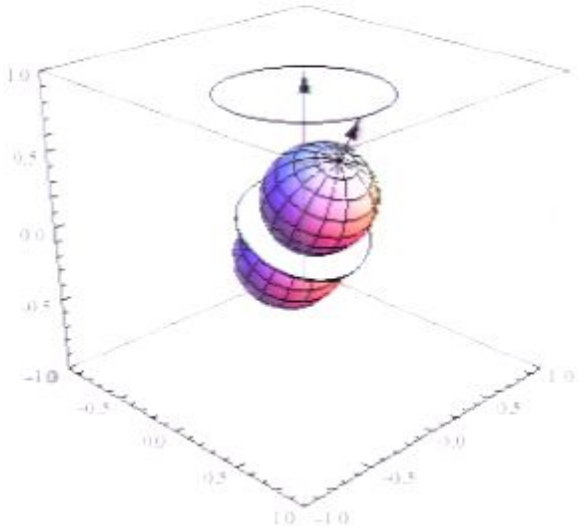

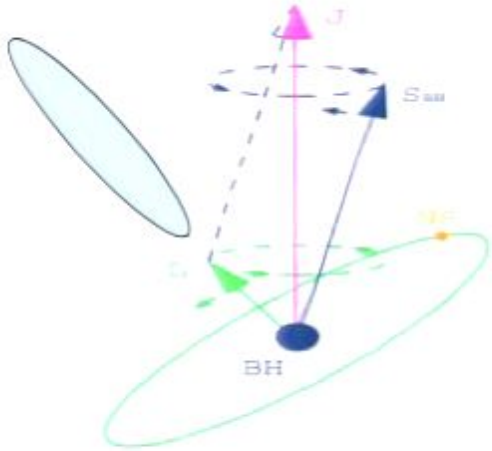

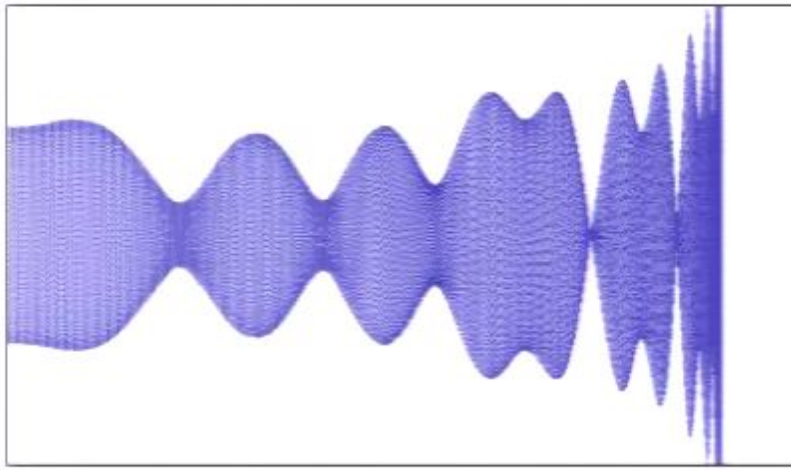

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What happens: Dynamics

Tidal disruption:

- BH tides disrupt
- Orbit along BH equator:
  - Disruption radius, ejected mass depend on BH spin
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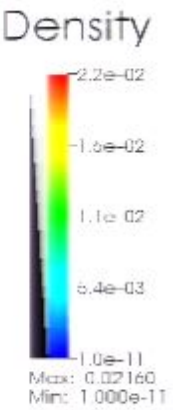

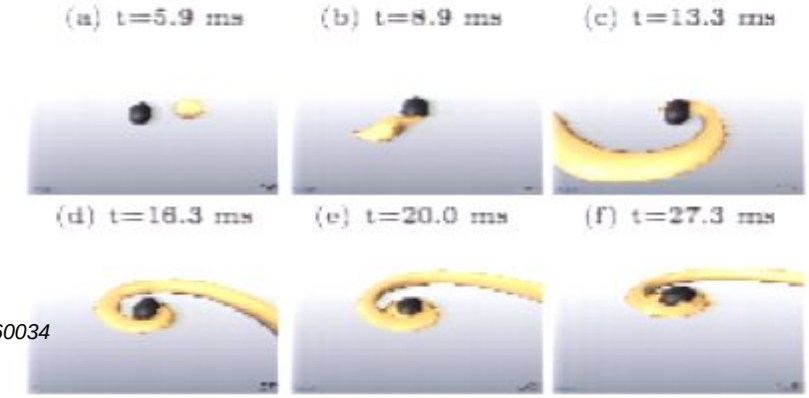

Time=104

Talk: Matt D.

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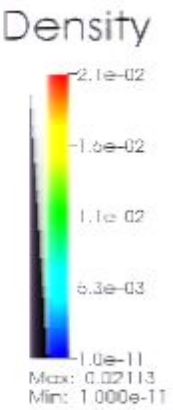

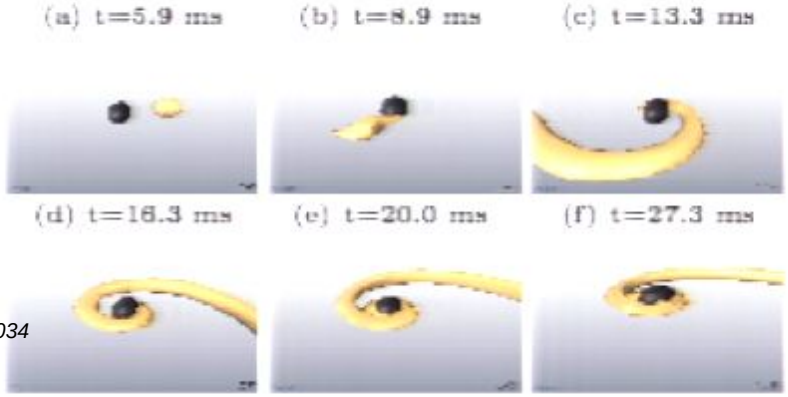

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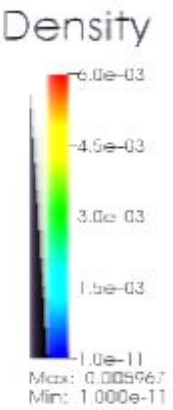

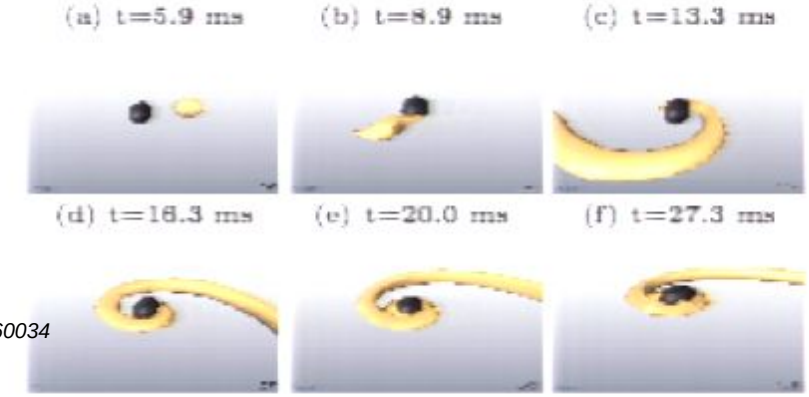

Time=374

Talk: Matt D.

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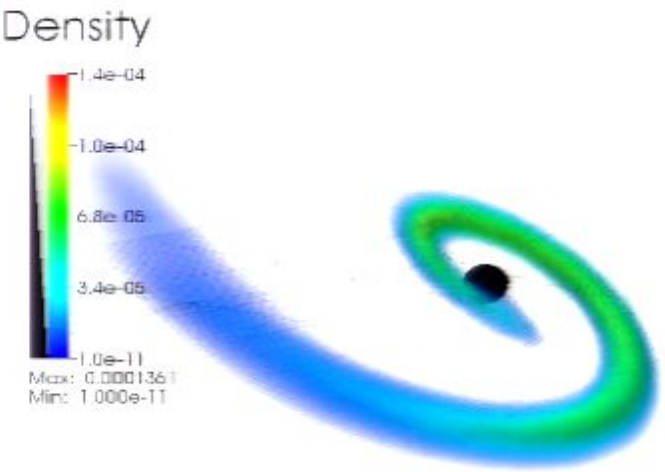

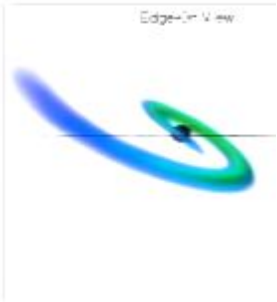

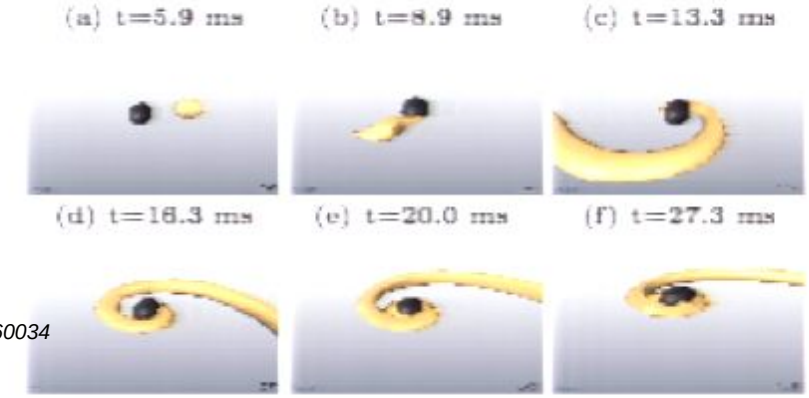

Time=494

Talk: Matt D.

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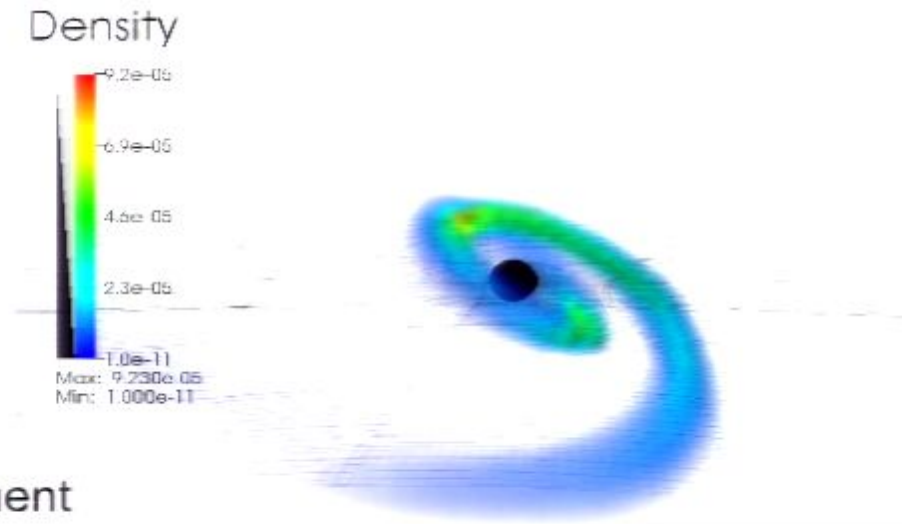

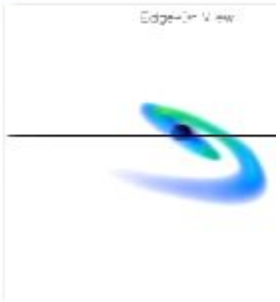

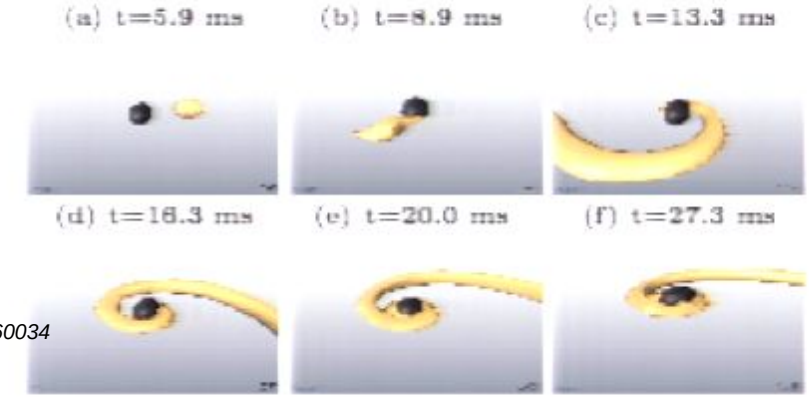

Time=624

Talk: Matt D.

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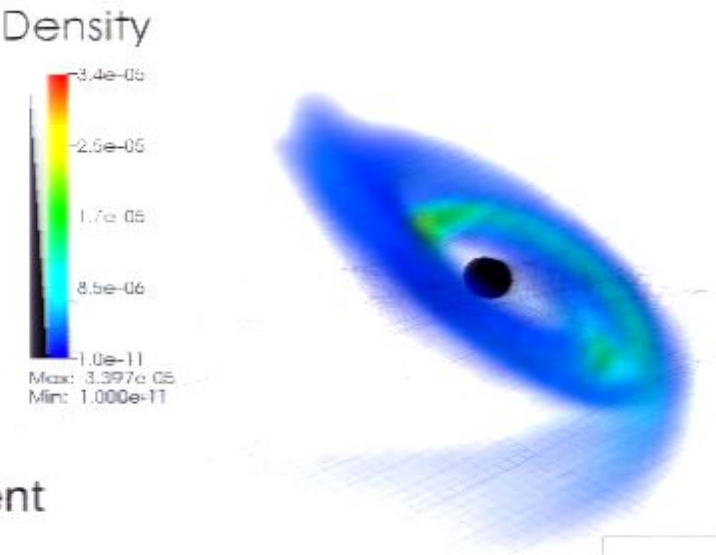
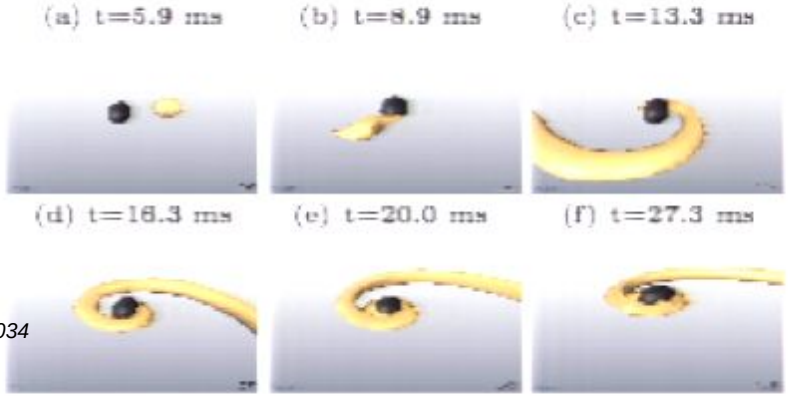
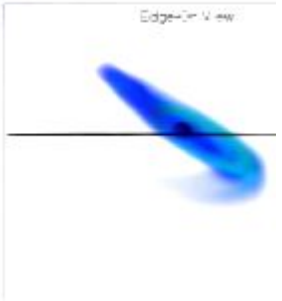
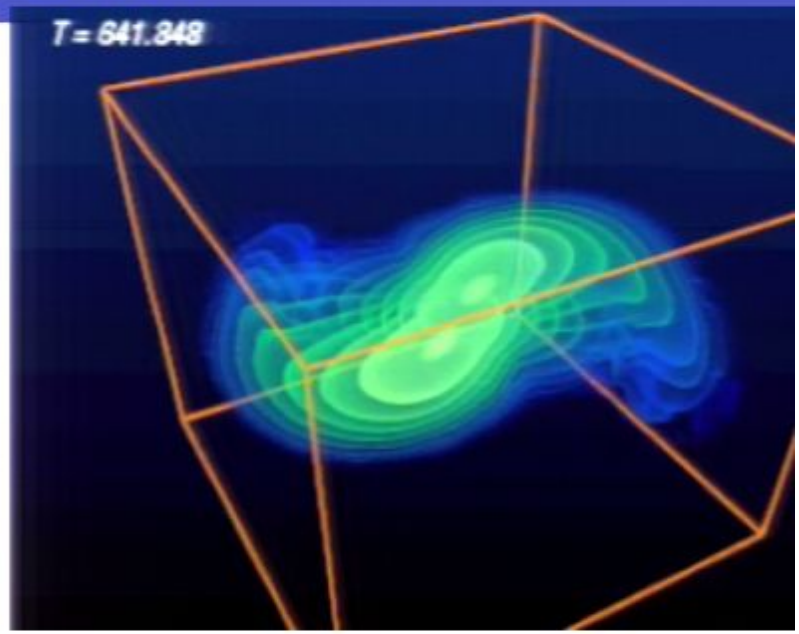






Talk: Matt D.

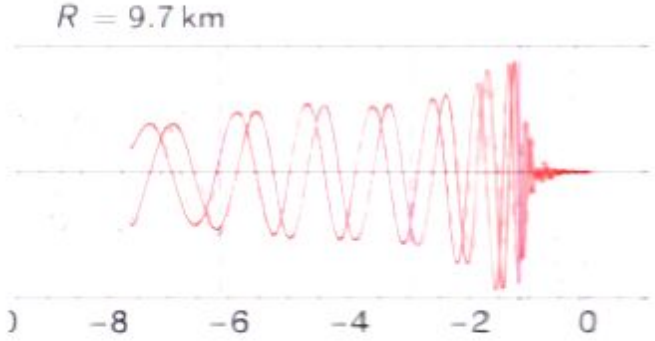
Imprint of GW

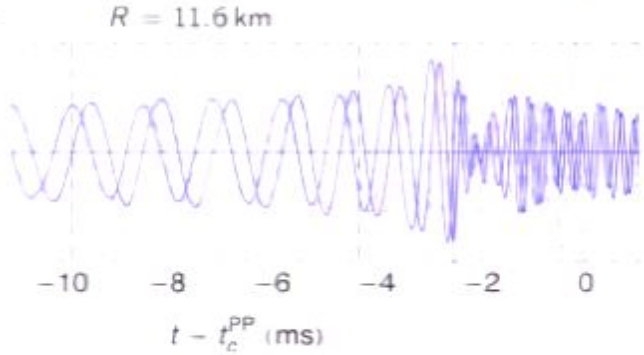


Tidal termination [example: NS-NS]

~ Terminates at tidal radius

Radius depends on nuclear matter EOS





J. Read, (next talk)

Problem: high frequenc

BH, fluid ringdown modified vs BH-BH, NS-NS:

- less excited by smooth merger
- Modes

Stergoulias et al 1105.0368; Bauswein and Janka 1106.1616

Weakly (!) driven by accretion

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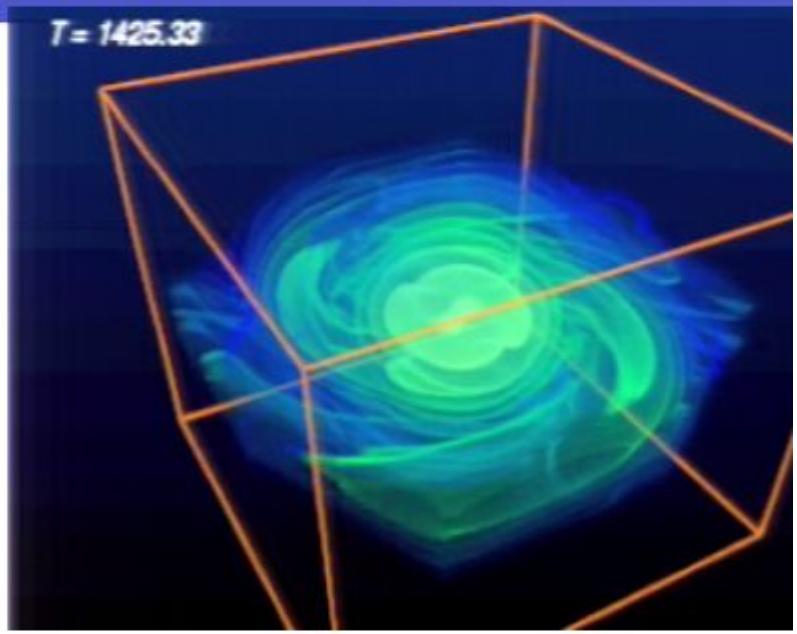

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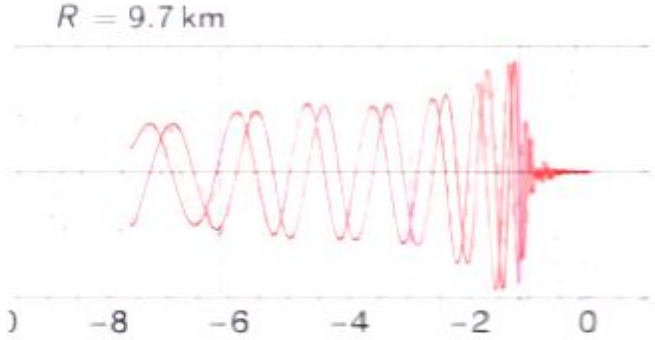

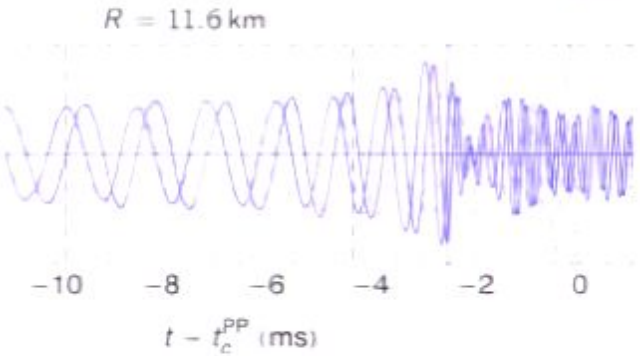

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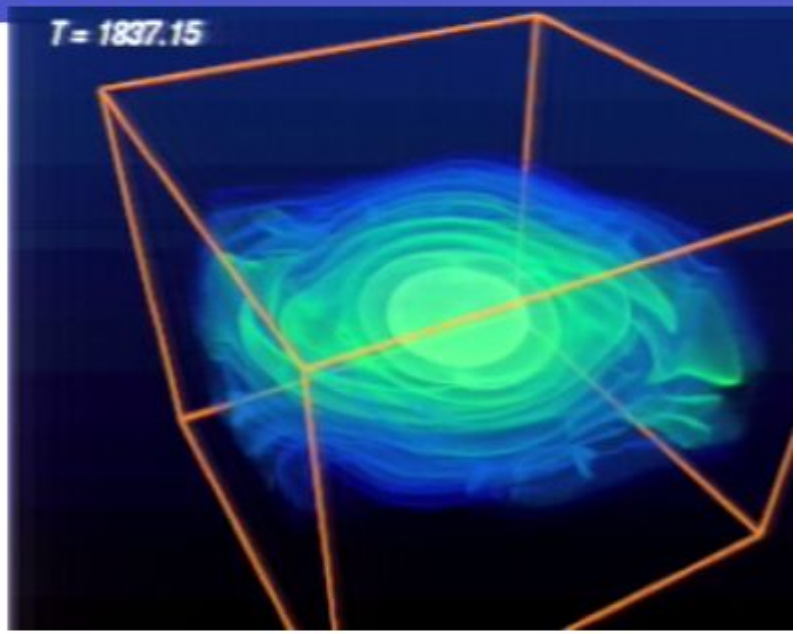

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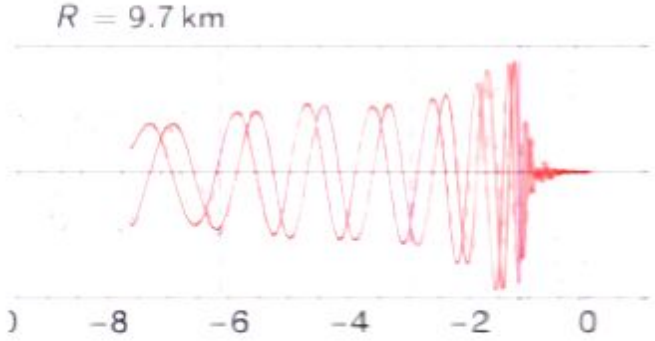

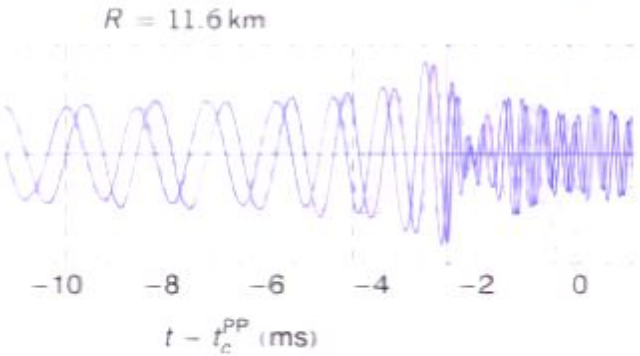

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Weakly (!) driven by accretion

Binaries: Collider analogy

- Mergers: nature's collider of nuclear matter
- GW : carry imprint of all bulk motion

  Some modulations easier: collision **inputs** easy, nuclear signatures hard

  EM : outflow, accretion, nucleosynth

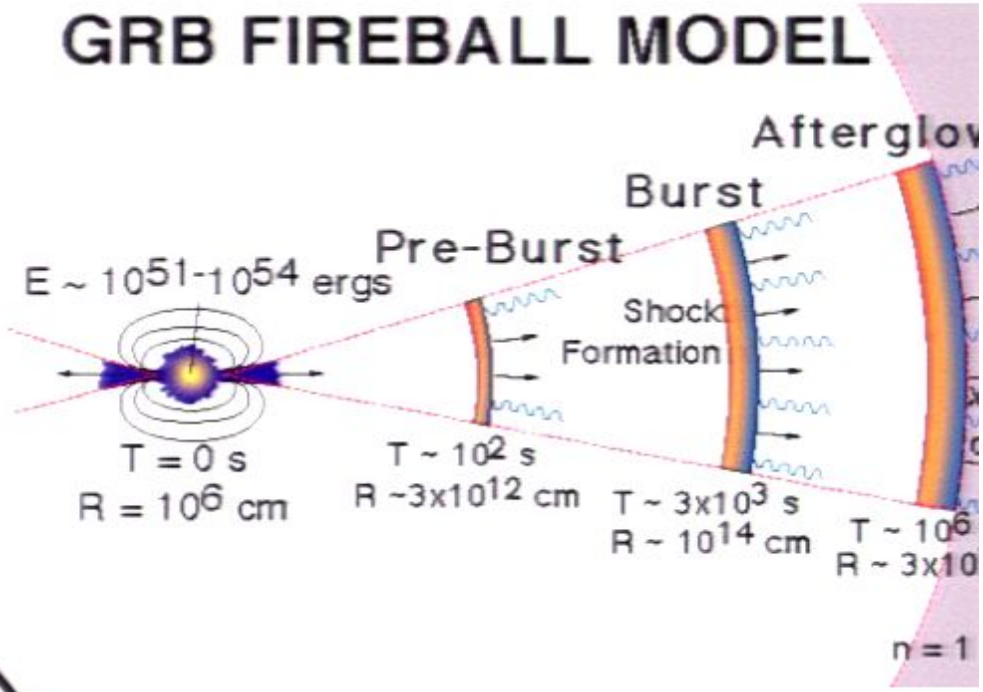
  Short GRBs
- Statistics: $>10^5$/yr accessible (3^{rd} gen)

  > few/yr (soon/already [GRBs])
- "Not monochromatic" : distributions

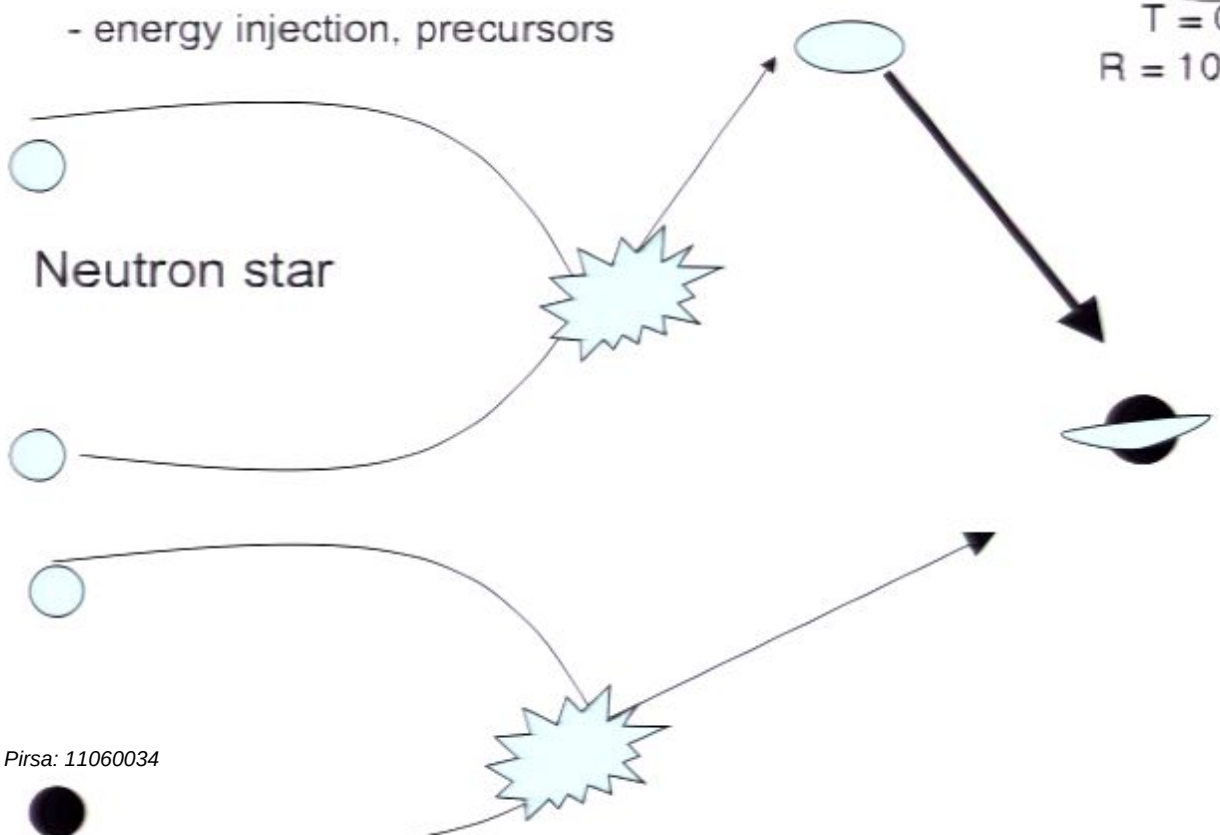
Short GRBs: Obscured merger?

GRBs generally

- "Fireball model": central engine hidden
  (unless post-blast wave signature: SN = long?)
- **Total power +**
- **Non-fireball** signal needed:
  - off-axis
  - energy injection, precursors



Swift website



Duez talk

What happens: Dynamics

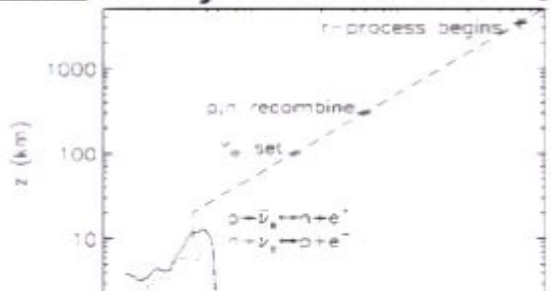
Accretion; fallback; winds

Prompt capture, disk: see movie

Fallback : $dM/dt \sim t^{-5/3}$ (Newtonian: Rosswog ; GR+MHD, a=0.7: Chawla et al 1006.2839)

Bursty (?) accretion ~ hours later

R-process in ejecta/winds: [Lattimer & Schramm 1974; Surman et al 2008; Metzger et al 2010]



Talk: B. Metzger

What can we measure?

NS specific (hard)

Tidal disruption point (degenerate: a, EOS) Ferrari 2010 PRD 81 4026

Each event with EM counterpart:

EM emission vs

spin-orbit misalignment (beaming)

Masses, spins (~ disk mass: "central engine")

Host galaxy

Metallicity & star formation: past and present

Optical counterpart, non-afterglow [Metzger 2010]

r-process in mergers or not?

Ejecta, disk mass vs BH mass, spin

GW not requi

(just trigger)

Population:

M,m2/m1, |S| distribution (BH masses & spins)

EM counterpart: m1 vs Z : BH mass vs metallicity

spin-orbit misalignment (SN kicks)

Conclusions

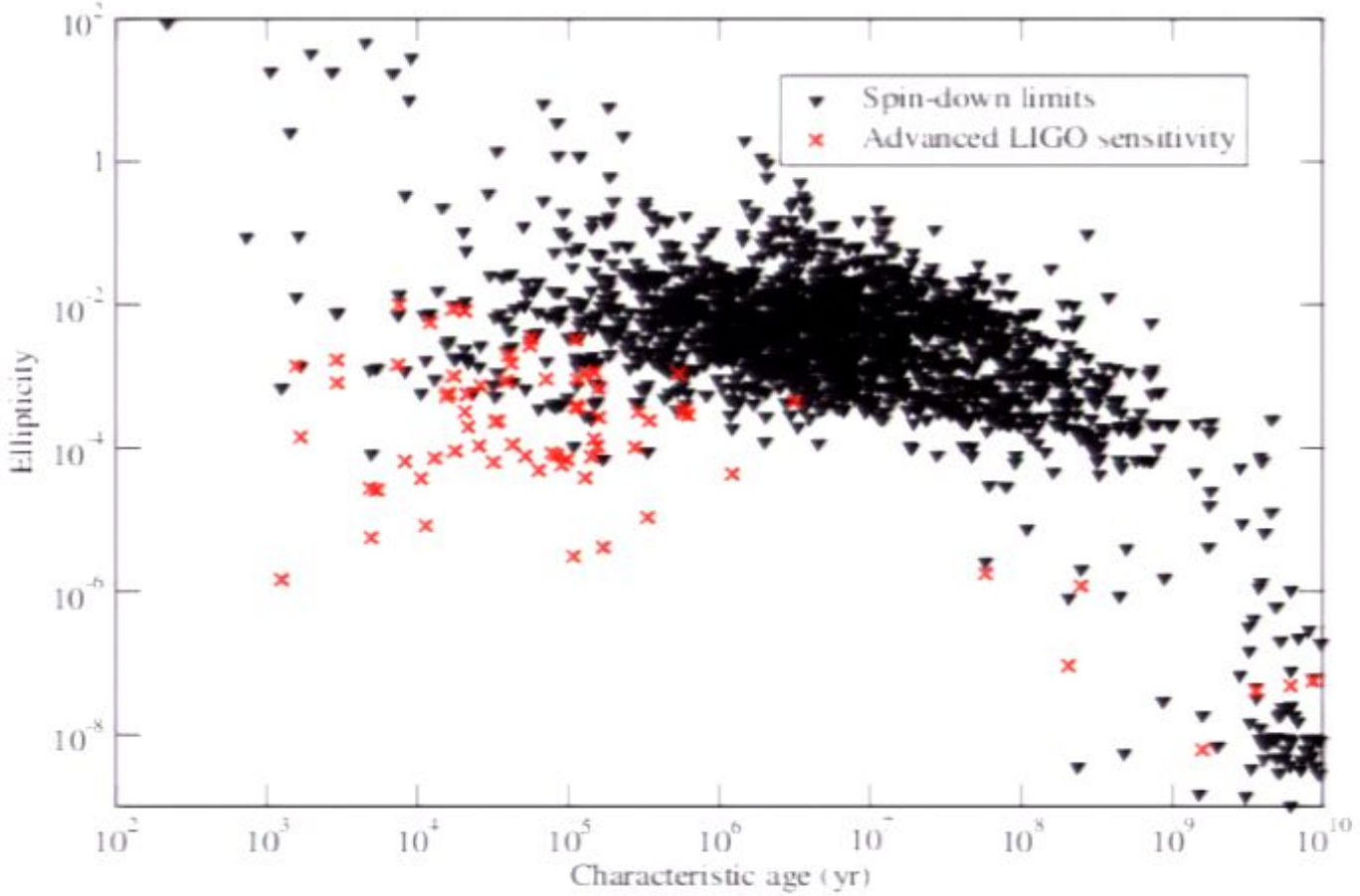
- Binaries:
  - GW : trace **inputs**, “deformability”, sloshing
  - EM : tracks accretion & crust breaking
    - EM+GW: Need
      - jet power vs mass, spin, EOS
      - Accretion rate : expansion (EOS), heating, and cooling

Talks: Metzger, Arcones

- Isolated
  - Need:
    mountain-building model
    detailed flare + GW calculations [Ioka; Corsi and Owen 2011]

- Pre-merger phases
  - Need:
    Metallicity (and rotation): change in evolution, SN?
    HCE
    SN (kicks, spins, BH masses, …)

Isolated NS



ROS and B. Owen

Conclusions

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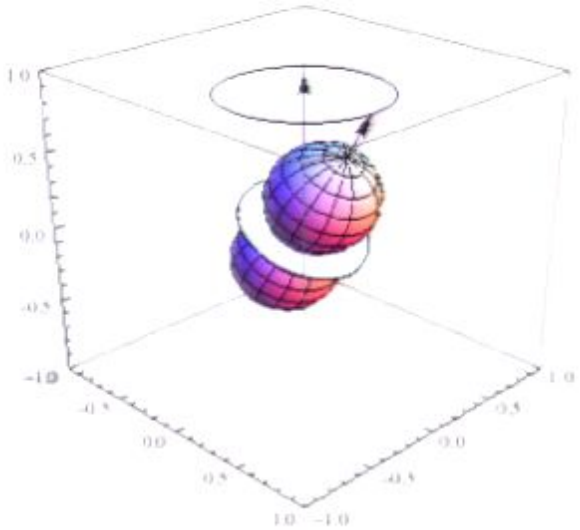
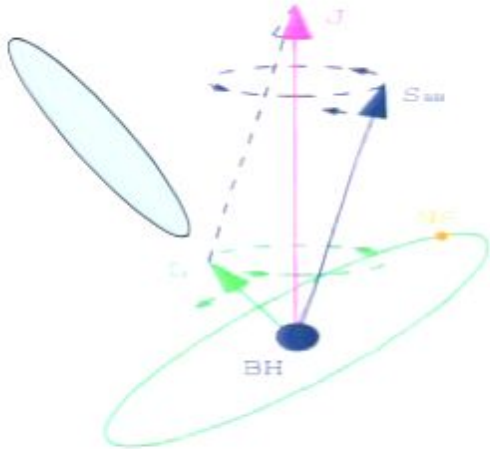
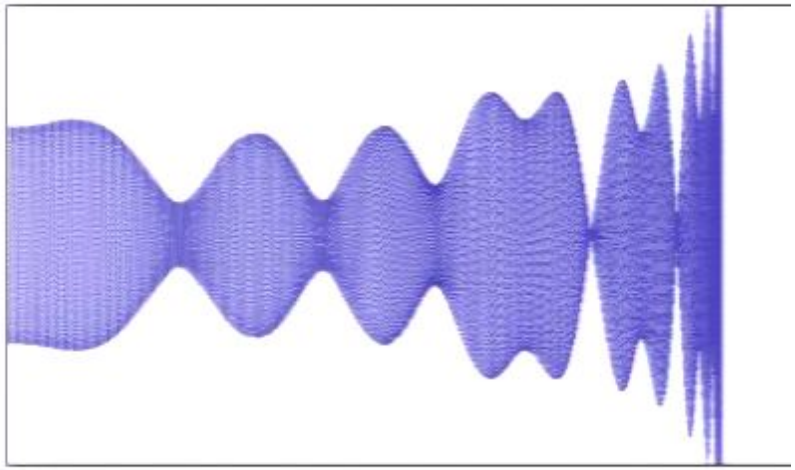
Imprint of GW

Early precession, modulation:







- occurs ~ at peak LIGO/Virgo sensitivity
- **identifies "inputs" to collision**

+ (statistically) : SN model info - NS kicks; BH,NS masses

Binaries: Collider analogy

- Mergers: nature's collider of nuclear matter

- GW : carry imprint of all bulk motion

  Talks : Duez, Read

  EM : outflow, accretion, nucleosynth, cracking

  Talks: Metzger, Tsang, Palenzuela

- Statistics: **$>10^5$/yr accessible** (3^{rd} gen)

  > few/yr (soon/already [GRBs])

- "Not monochromatic" : NS, BH mass,spins

What can we **eventually** measure?

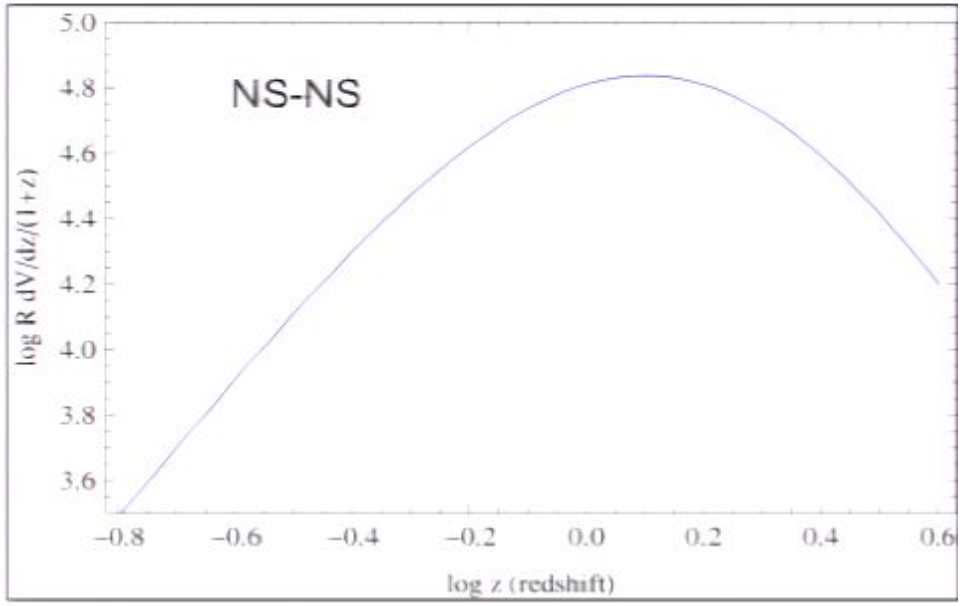
Third-generation: tomography

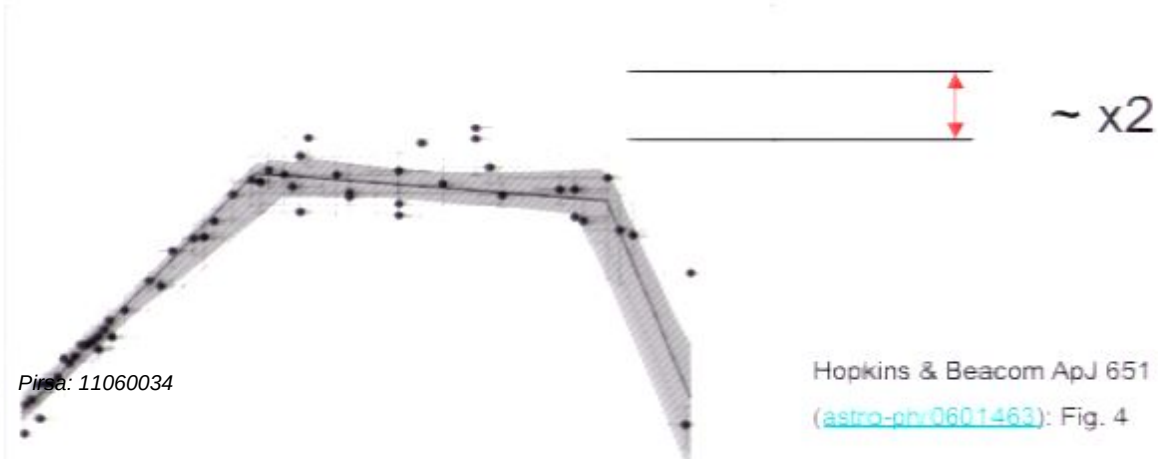
Example: NS-NS:

- dVolume(z)* rate(z)/(1+z)
  = "rate per redshift bin"

- O(10^5-10^6) detections
  - **Rate** vs distance
  - **Mass distribution** vs distance

- Reach ~ peak SFR





~ x2

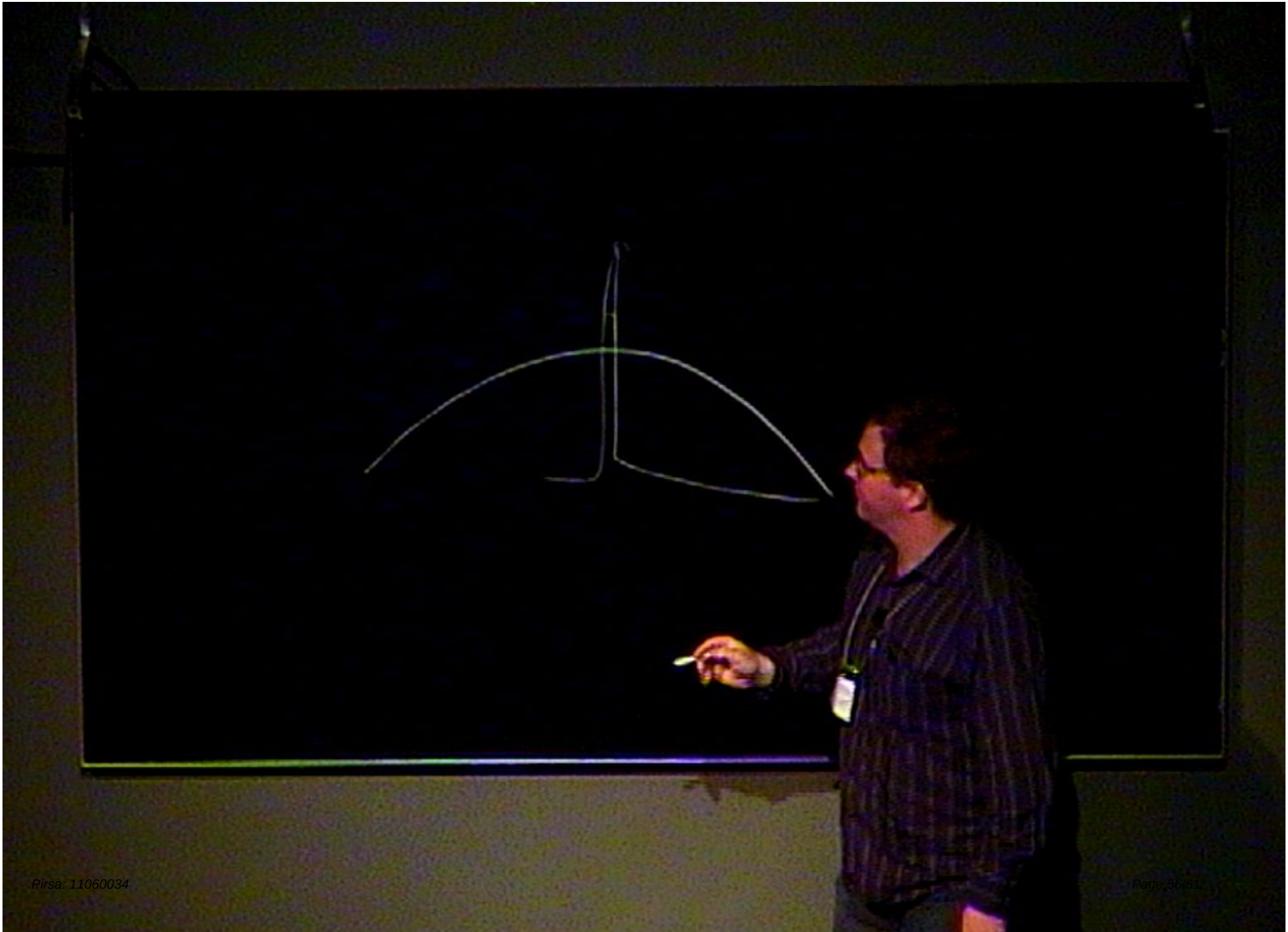
Eventually

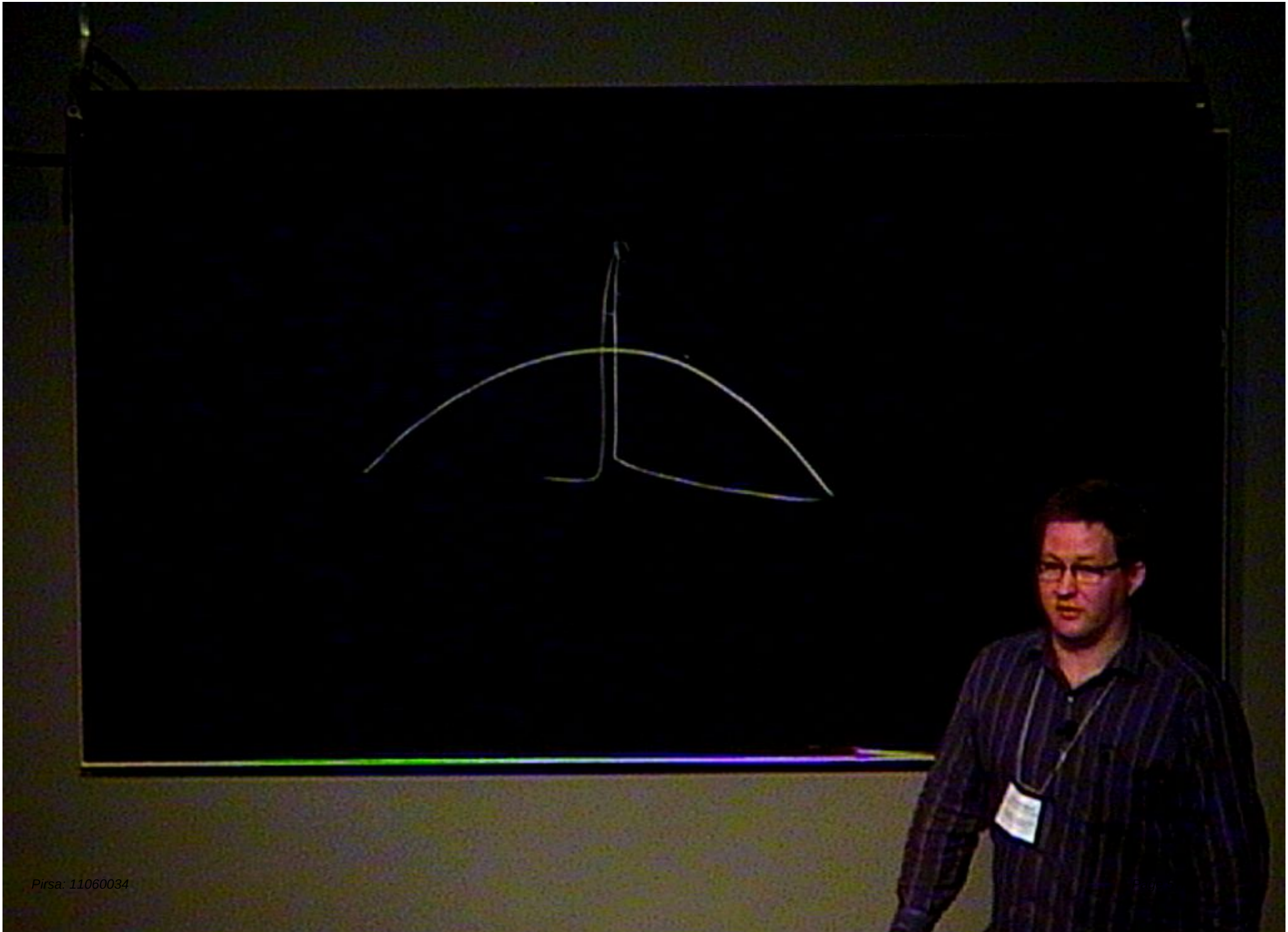
Distributions

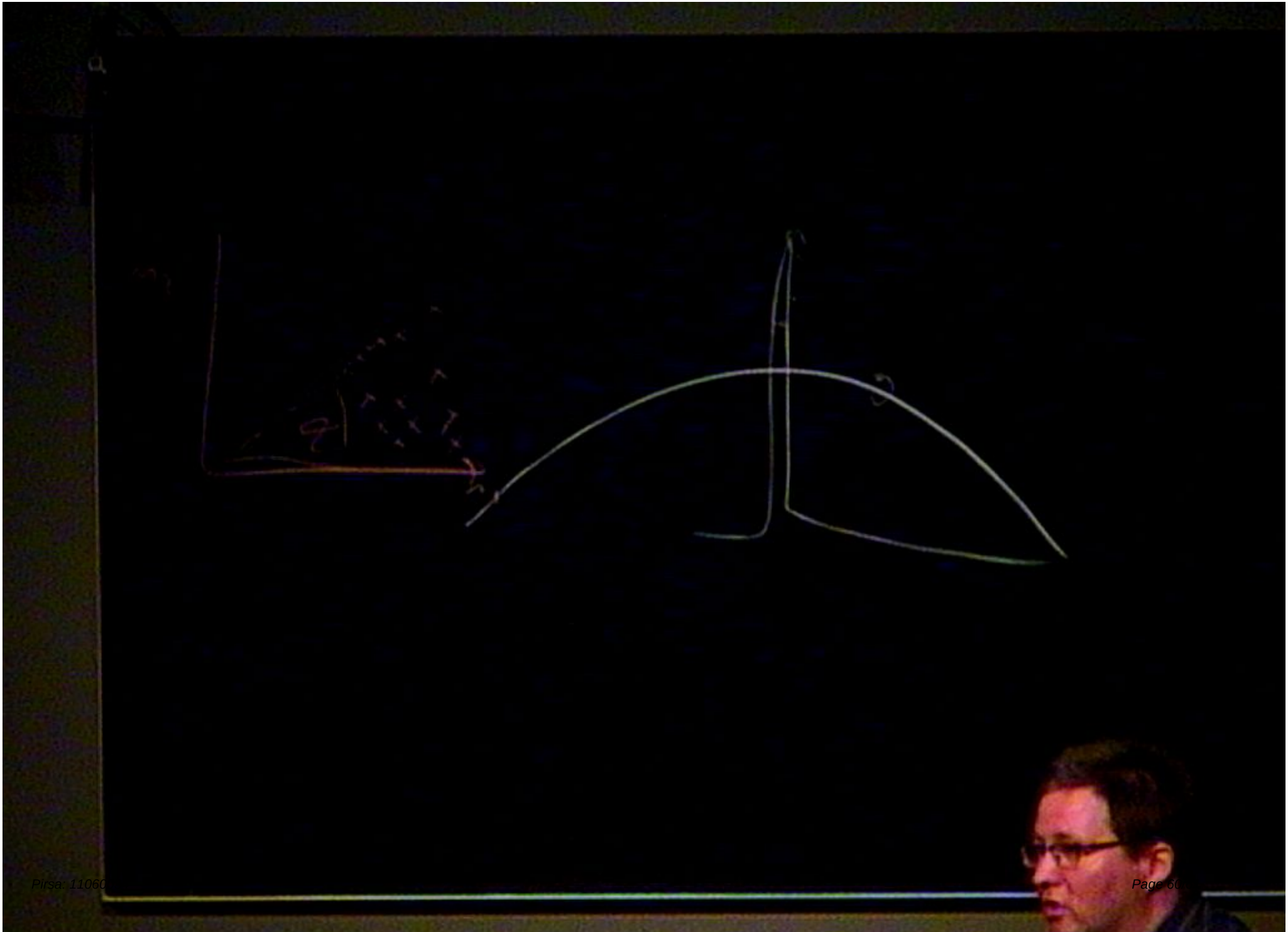
Distributions vs z (& Z)

Few sources **really** brig

Hopkins & Beacom ApJ 651 142 2006 (astro-ph/0601463): Fig. 4







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