Detecting Neutrinos from Black Hole - Neutron Star Mergers

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Connecting Quarks with the Cosmos
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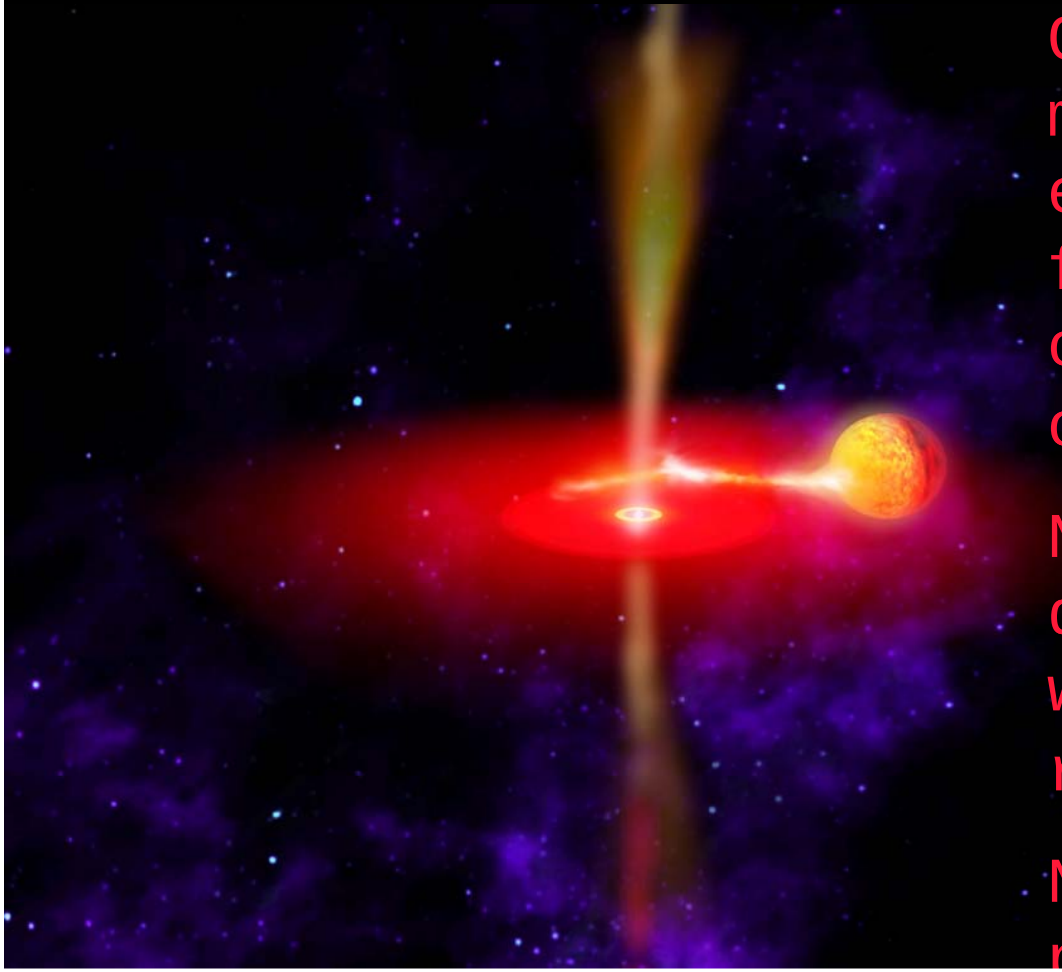
Accretion Disk around Black Hole-Neutron Star (BH-NS) mergers



GRBs : some of the most energetic explosions known, may follow from the collapse of compact objects

Nucleosynthesis = disk's conditions would favor r-process

Neutrino emission plays an important

Accretion Disk Model

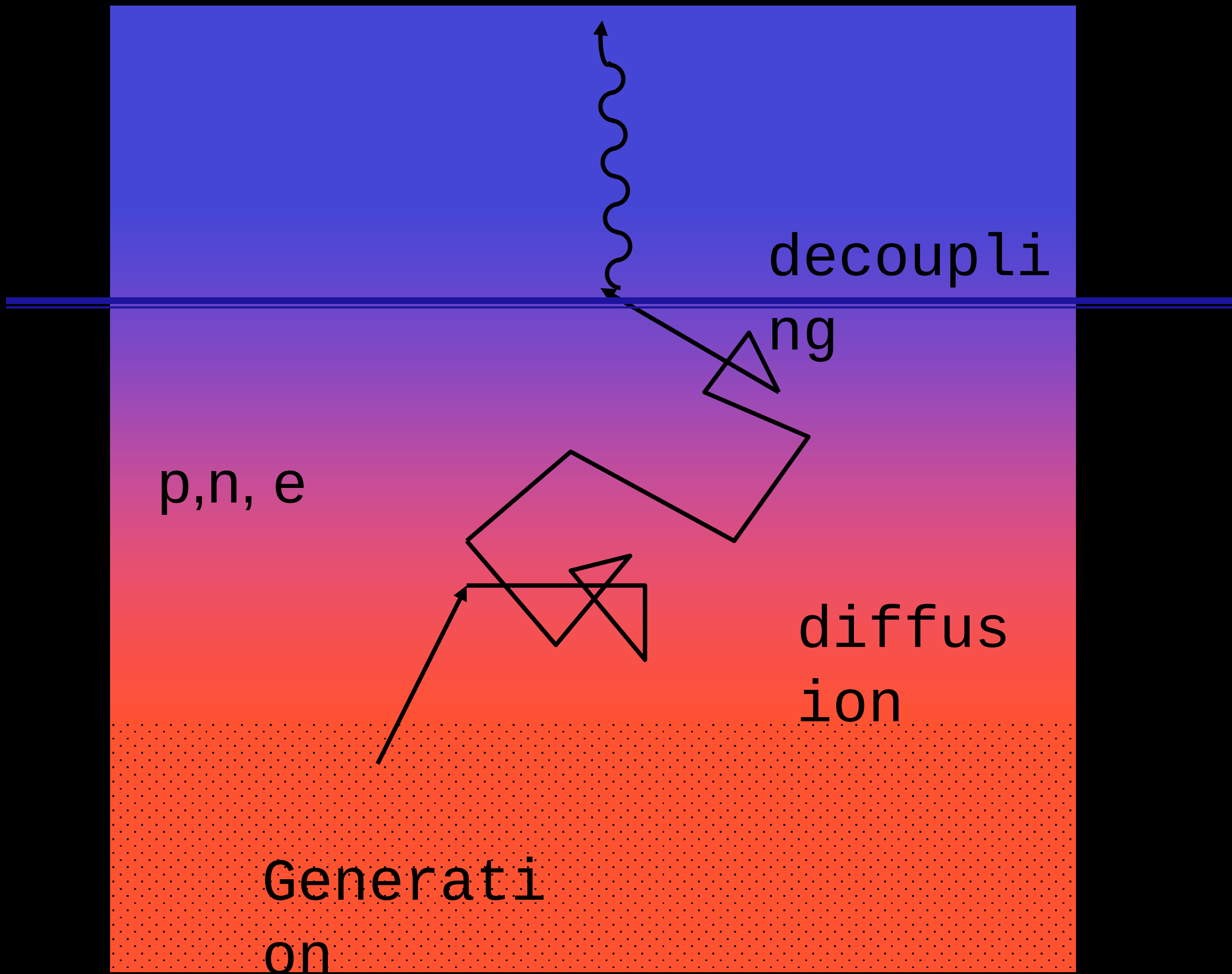
BH=2.5 solar masses, NS= 1.6. Hydrodynamics including GW and neutrino emission, M. Ruffert, H. Janka (2001)

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

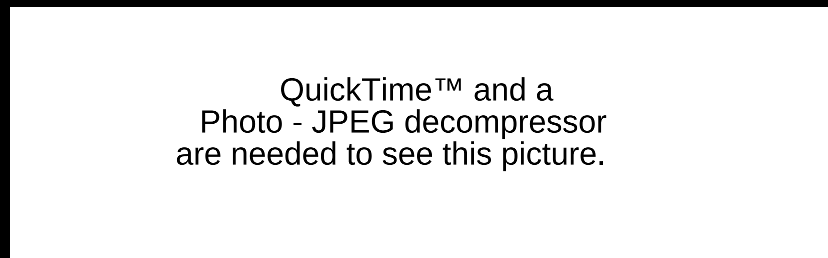
Neutrinos in Proto-Neutron Stars

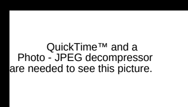
- Huge amounts of neutrinos are produced and emitted
- Most energy is lost by neutrino emission
- Neutrinos get trapped at high densities and temperatures
- Trapping defines the region where neutrino decouple = neutrino sphere

Neutrino Sphere

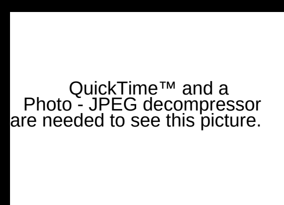


Neutrino Optical Depth

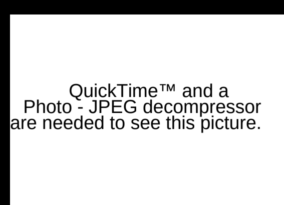




Neutrino mean free path



Optically Thin Region



Optically Thick Region

Neutrino Interactions in the Disk

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Charged Current

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Neutral Current

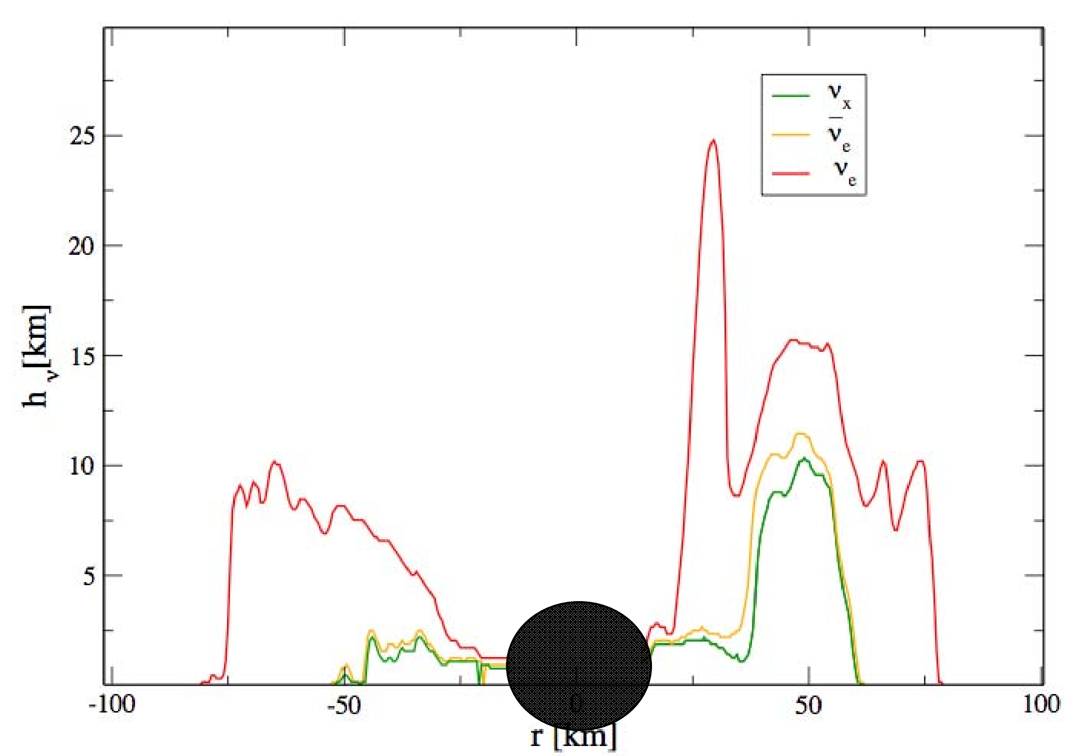
(All flavors)

Neutrino "Surfaces" in Accretion Disk

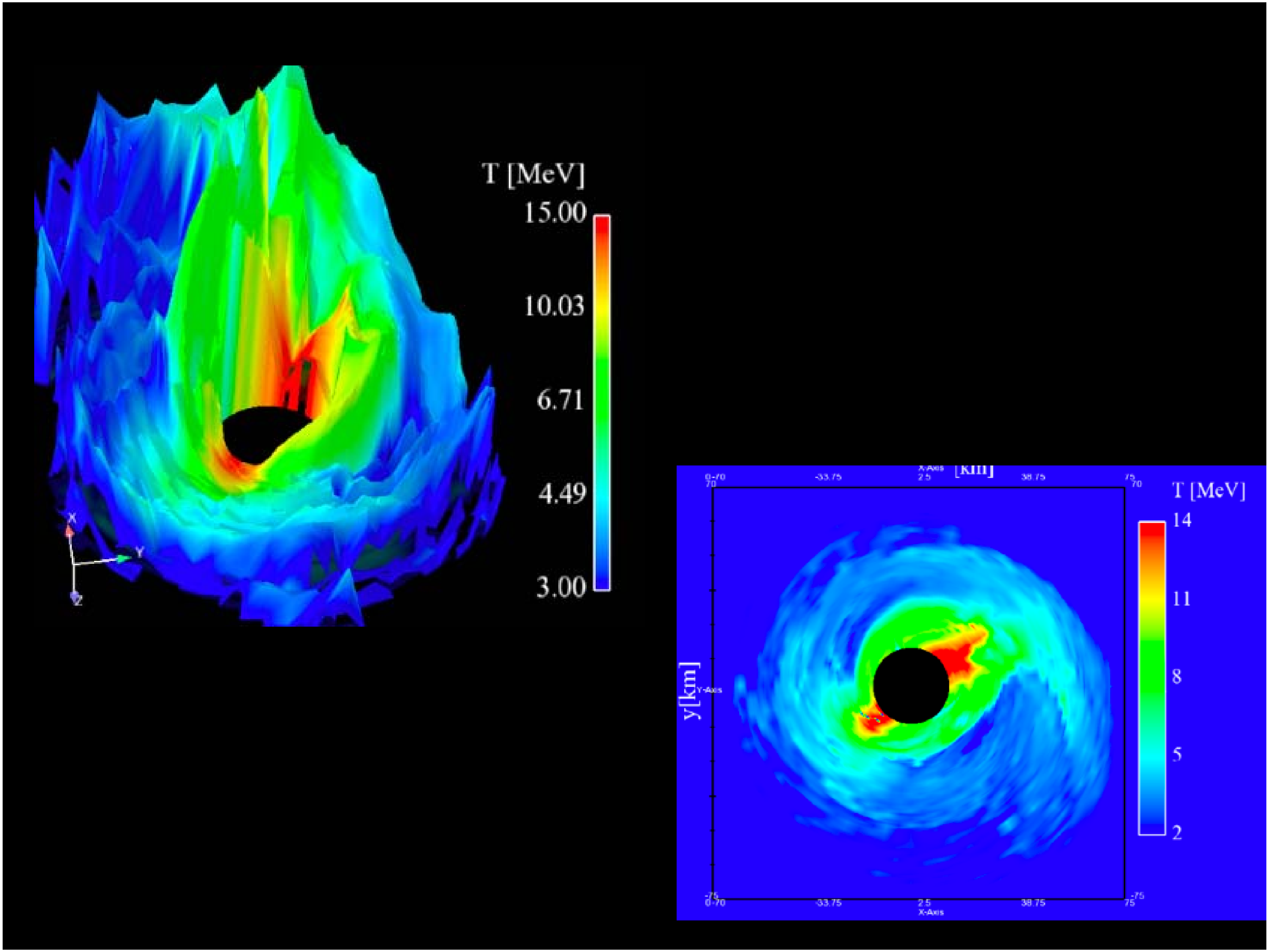
McLaughlin, Surman (2007)

Electron neutrinos decouple later at smaller T and densities

Neutrino surface defines the neutrino decoupling Temperature T_ν (Caballero et al 2009)



[redacted]


T [MeV]
15.00
10.03
6.71
4.49
3.00
X
Y
Z
X-Axis
-33.75
2.5
38.75
75
70
-75
Y-Axis
y[km]
T [MeV]
14
11
8
5
2

Neutrino Spectrum

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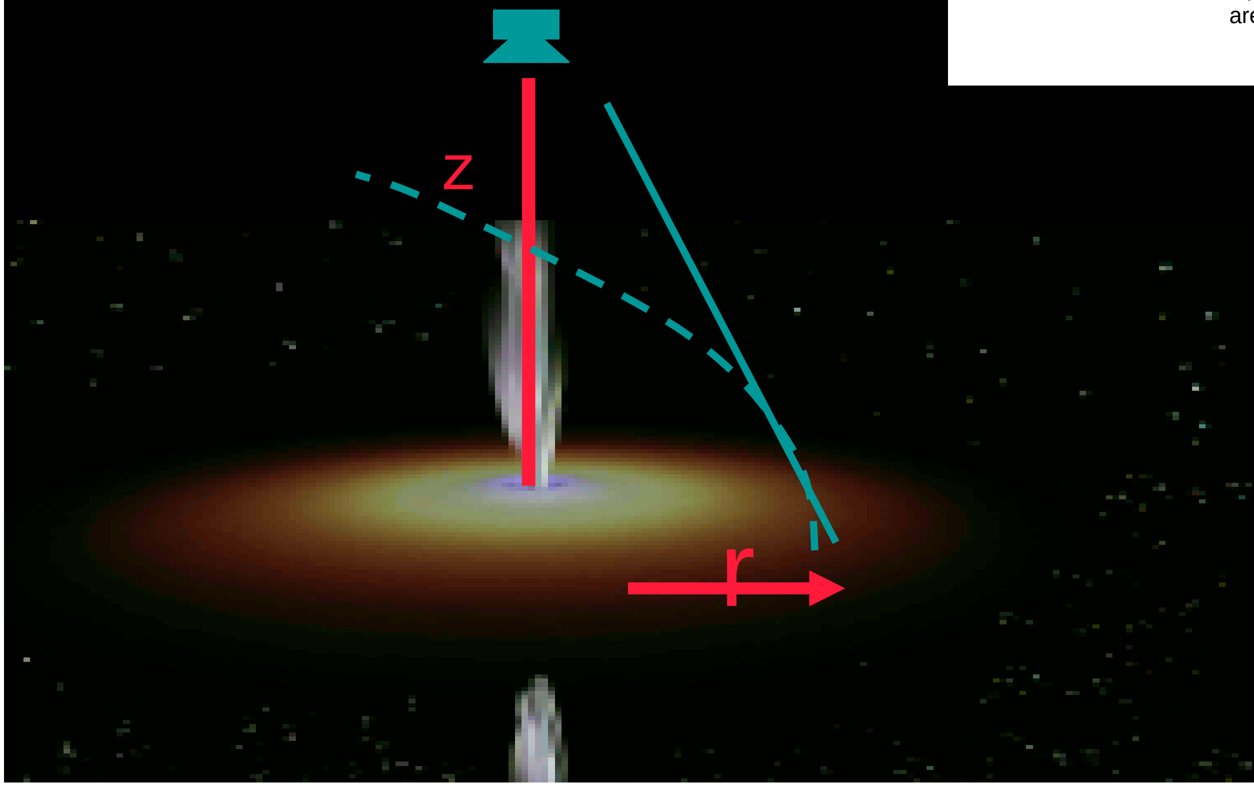
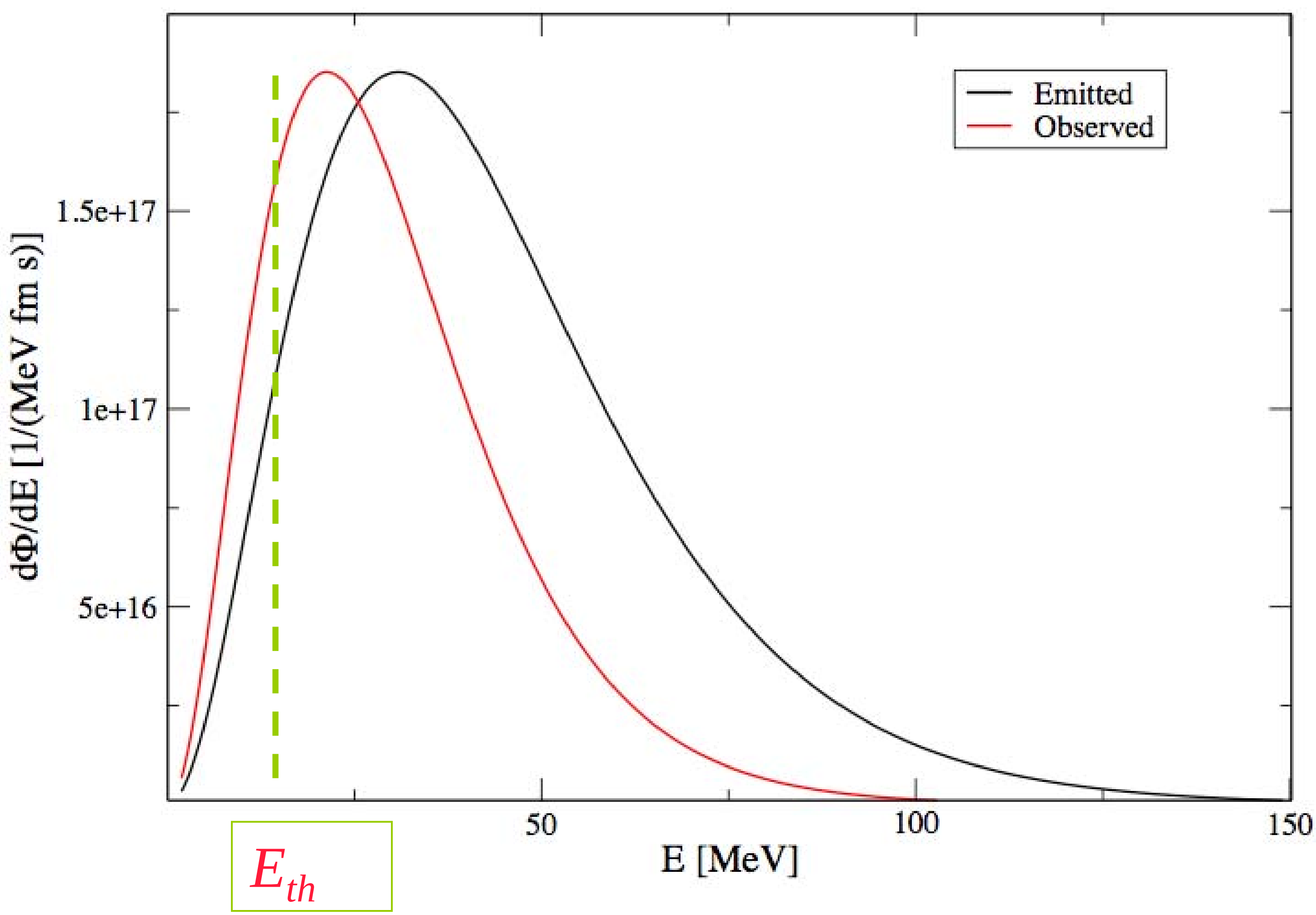


Energy is Red-shifted

Deflection of trajectories

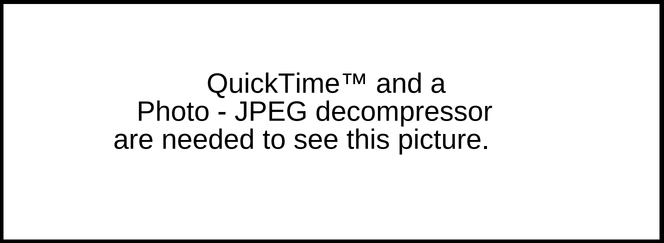
Oscillations

Energy Red Shift

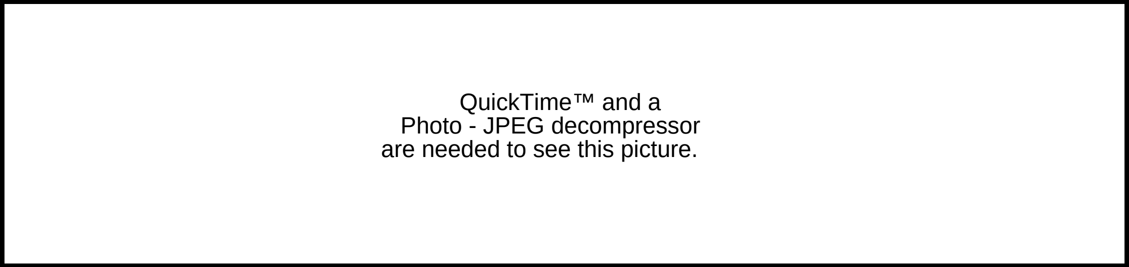


Neutrino Oscillations

Weak states ≠ Mass states



P = survival probability



Results

	E(MeV) Disk	E(MeV) PNS	L(erg/s) Disk	L(erg/s) PNS
	23.4	15	$2.4x10^{53}$	
ν_e	17.3	12	$1.6x10^{53}$	
	26	25	$3.0x10^{53}$	
ν_τ	26	25	$3.0x10^{53}$	
Total			$1.6x10^{[illegible]}$	10^{52}

Δt Disk = 0.15 s , Δt PNS = 10 s

How Many?

	$\bar{\nu}_e + p \rightarrow n + e^+$	$\nu + e \rightarrow \nu + e$	
SK(32 kton)	9100	390	
UNO(580 kton)	165000	7100	
Hyper-K(1Mton)	284000	12280	
Amanda(680 OM)	74000	2800	
IceCube(4800 OM)	522500	20200	
PNS(SK)	8300	320	
	$\nu + p \rightarrow \nu + p$		
KamLAND (1 kton)	470		
PNS	273		
	$\nu_e + {}^{208}\mathrm{Pb} \rightarrow {}^{207(6)}\mathrm{Bi} + e$	$\nu + {}^{208}\mathrm{Pb} \rightarrow {}^{207(6)}\mathrm{Pb}$	total
HALO (80 ton)	24	23	47
PNS			43
	$\nu_e(\bar{\nu}_e) + {}^{40}\mathrm{Ar} \rightarrow e(e^+)$	$\nu + e \rightarrow \nu + e$	
ICARUS (3 kton)	331	30	
LANNDD(70 kton)	7700	700	
PNS(ICARUS)	203	41	

Oscillat ions

	NOsc	S1	S2
(MeV)			
E_{ν_e}	17.3	20	26
$E_{\bar{\nu}_e}$	23.4	24	26
E_{ν_τ}	26	25	22
$E_{\bar{\nu}_\tau}$	26	25.6	25
$(\times 10^{57} \nu/s)$			
f_{ν_e}	6.0	6.4	7.1
$f_{\bar{\nu}_e}$	6.5	6.7	7.1
f_{ν_τ}	7.1	6.9	6.6
$f_{\bar{\nu}_\tau}$	7.1	7.0	6.8

	NOsc	S1	S2
$\bar{\nu}_e + p \rightarrow n + e^+$			
SK	9100	9800	11460
AMANDA	74000	79970	93200
$\nu + e \rightarrow \nu + e$			
SK	390	430	490
ICARUS (CC)	331	450	710
HALO	47	62	91
KamLAND	470	468	467

Conclusions and future work

- Neutrino temperatures, fluxes, luminosities and energies in the Disk are higher than in a PNS
- More luminous, signal is shorter (200 times) but more counts
- Using current detectors we can see as far as:
  - 983 kpc in SK

  In UNO we could see as far as:

  4 Mpc

  (Andromeda is at 780 kpc)

  LIGO can reach up to 20 Mpc for NS-NS

  40 Mpc BH-NS
- Diffusive background (NSNS event rate 10^{-6}-10^{-4}/yr)