ASTP613 Final Exam Practice Problem

Nicolas McMahon - December 2025

EuropaCube:

The year is 2325 and human civilization has developed space-faring technology that greatly surpasses the rudimentary capabilities of previous centuries. Multimessenger astronomy has likewise advanced into a new era, yet ultra-high redshift supernovae remain elusive to astronomers. The international collaboration JANE-SNOW[1] has begun a new mission to build a "next generation IceCube" water cherenkov neutrino observatory on the surface of the galilean moon Europa. The extremely high salinity of Europa's surface ice contains 15% more ions than terrestrial ice, making it more efficient at detecting neutrinos!

Part A: Derive an expression for the minimum surface area required to detect an ultra-high redshift $z = 12$ core collapse supernova with EuropaCube.

Part B: Can EuropaCube detect the supernova in part A and comfortably fit on the surface of Europa? If so, what percentage of the surface of Europa would be covered by boreholes?

In answering the parts above you may make the following assumptions and any other simplifying assumption necessary to give a solution.

(1) $N_\nu = 3.0 \times 10^{58}$ neutrinos with energy $E_\nu = 10\ MeV$ are released in a single CCSN neutrino burst.

(2) $d_{SN} = 130,540\ Mpc$ is the luminosity distance of an ultra-high redshift supernova at $z = 12$.

(3) $y = 2.5\ km$ is the maximum depth our best borehole drilling robots can reach on into surface ice of Europa.

(4) $R_E = 1,560\ km$ is the equatorial radius of Europa.

(5) $\eta = 1.15$ is the salty ions coefficient, a necessary prefactor for the increased efficiency of neutrino detections from EuropaCube.

(6) $\rho_{ice} = 917\ kg \cdot m^{-3}$ is the mass density of ice.

(7) $\chi_p = 10/18$ is the mass fraction of protons in liquid water.

(8) $N_{int} = 4$ is the number of neutrino interactions required in a small amount of time to produce a positive detection of a CCSN neutrino event – just one neutrino is not enough!

[1] **JA**XA, **N**ASA, and **E**SA **S**uper**N**ova **O**bservatories on other **W**orlds