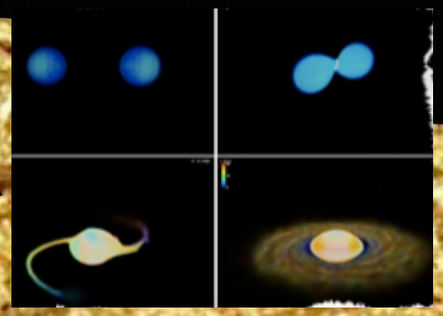


Binary Neutron Star Mergers as the Cosmic Furnaces of Gold

Tsvi Piran

The Hebrew University of Jerusalem

Copernicus Congress February 2023

erc

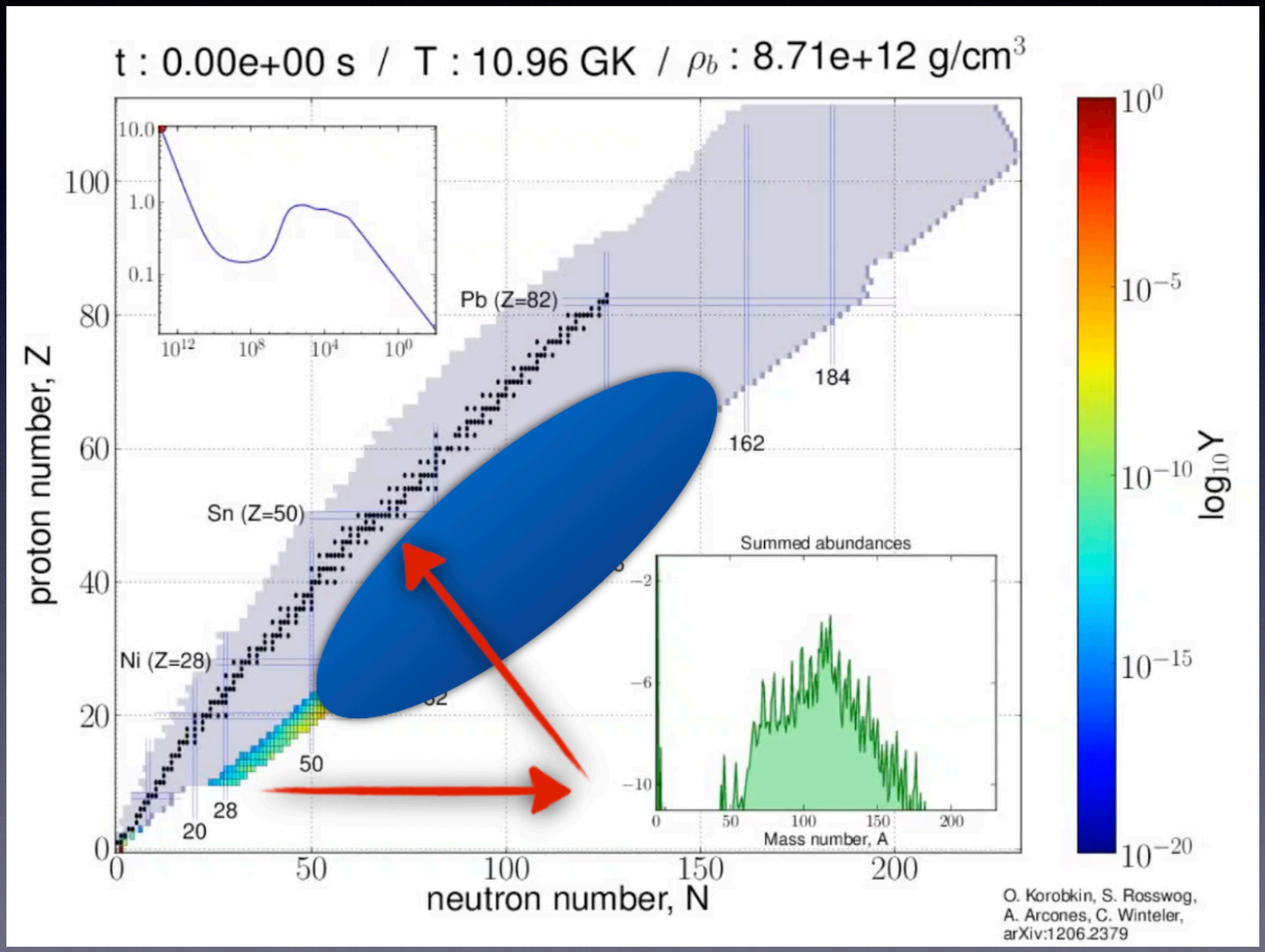
GRB

TReX

MultiJets

Decay of neutron star matter

Lattimer & Schramm 1974



Credit: Korobkin + 13

Two crazy ideas

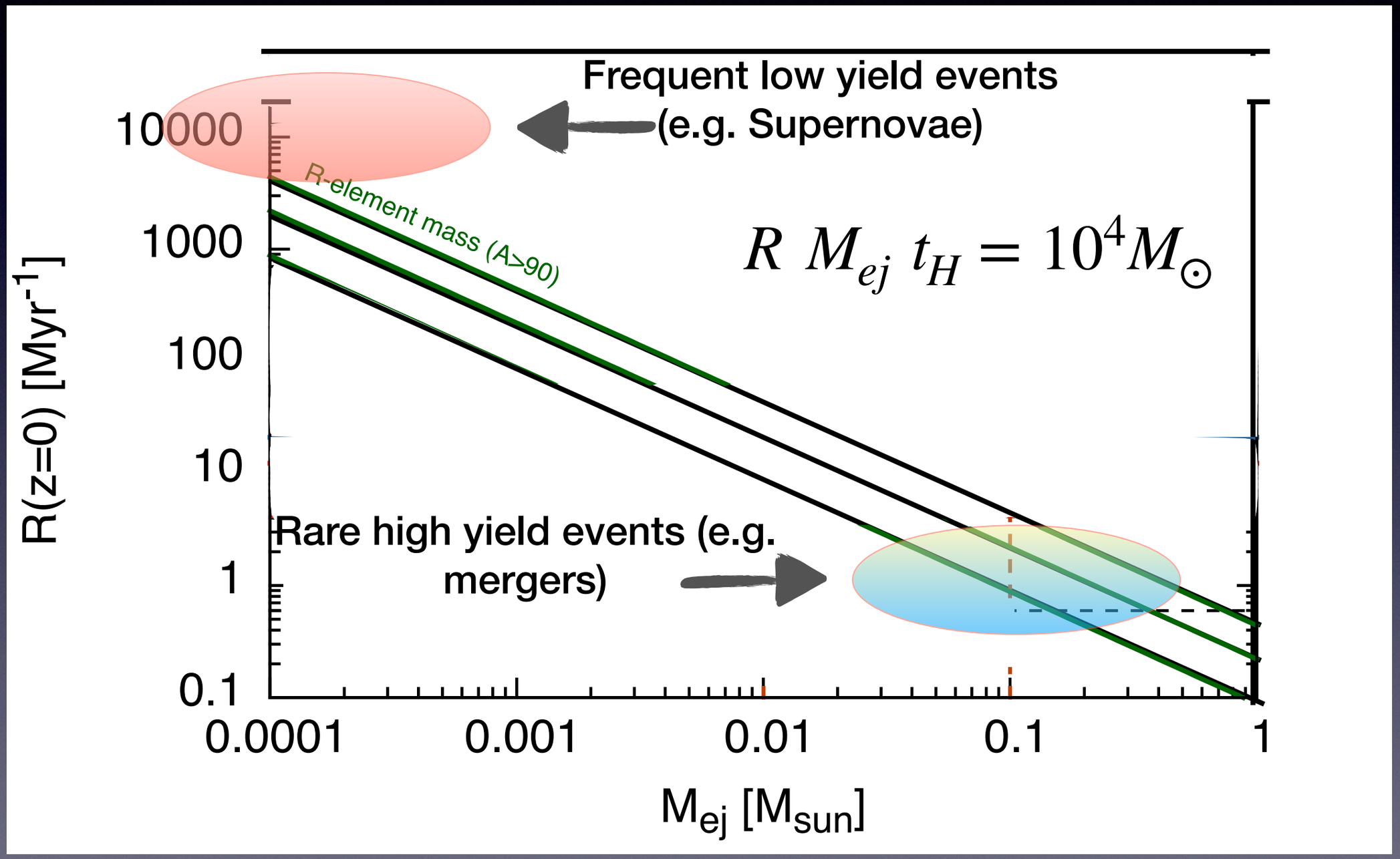
LETTERS TO NATURE

Nucleosynthesis, neutrino bursts and γ-rays from coalescing neutron stars

David Eichler*, Mario Livio†, Tsvi Piran‡ & David N. Schramm§

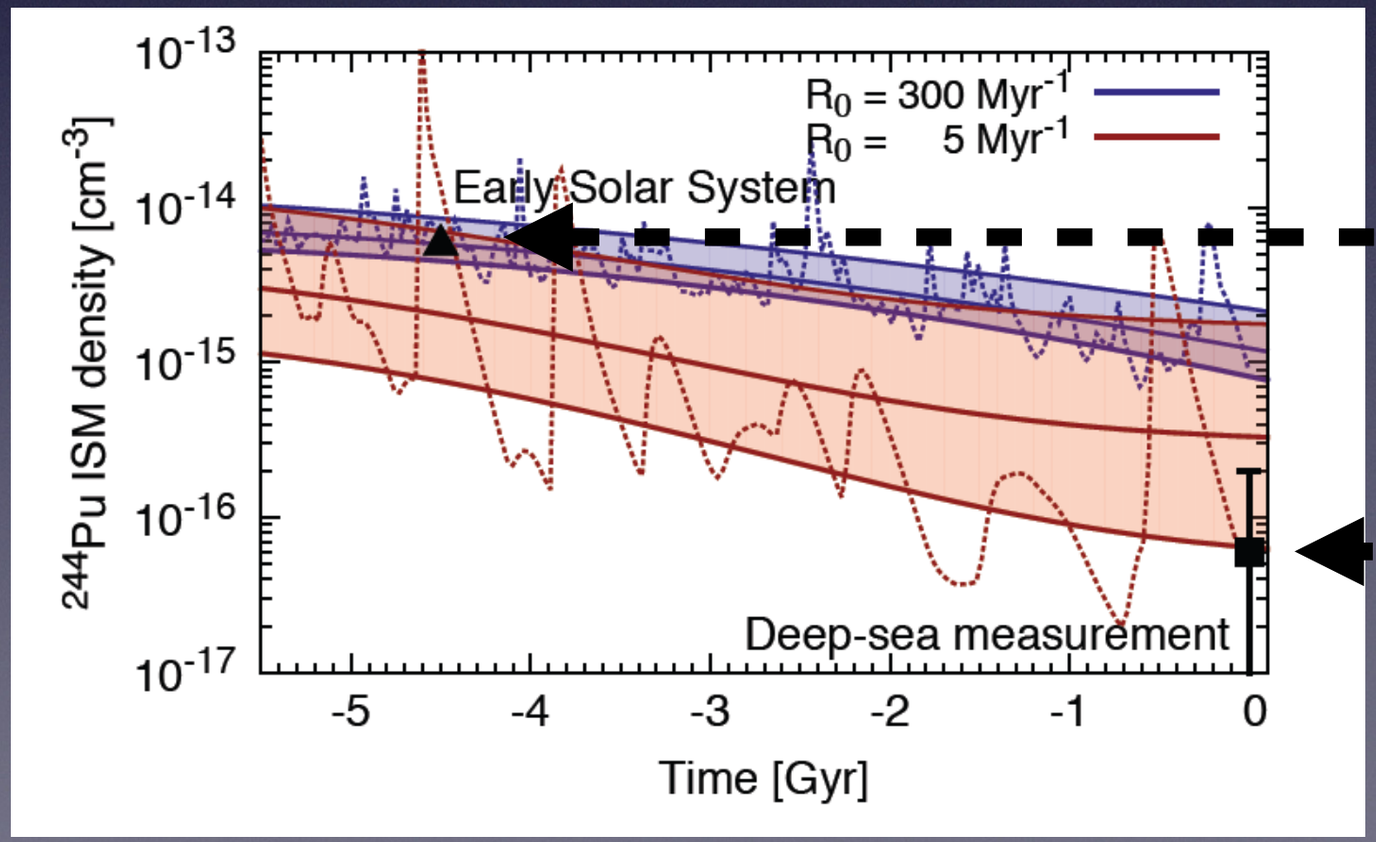
NEUTRON-STAR collisions occur inevitably when binary neutron stars spiral into each other as a result of damping of gravitational radiation. Such collisions will produce a characteristic burst of gravitational radiation, which may be the most promising source of a detectable signal for proposed gravity-wave detectors[1]. Such signals are sufficiently unique and robust for them to have been proposed as a means of determining the Hubble constant[2]. However, the rate of these neutron-star collisions is highly uncertain[3]. Here we note that such events should also synthesize neutron-rich heavy elements, thought to be formed by rapid neutron capture (the r-process)[4]. Furthermore, these collisions should produce neutrino bursts[5] and resultant bursts of γ-rays; the latter should comprise a subclass of observable γ-ray bursts. We argue that observed r-process abundances and γ-ray-burst rates predict rates for these collisions that are both significant and consistent with other estimates.

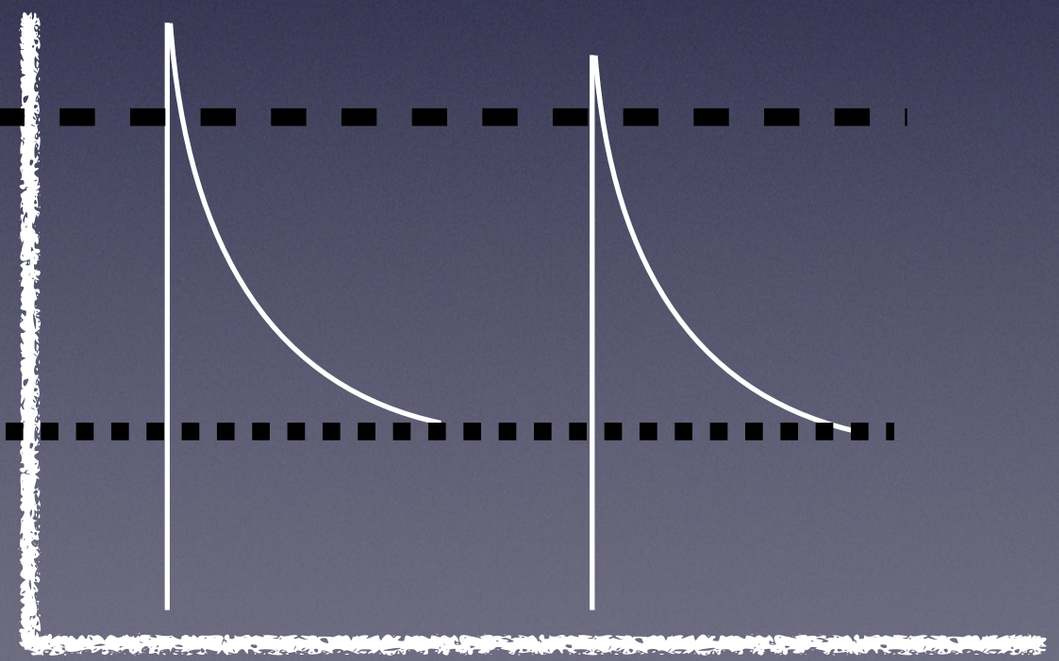
R-Process nucleosynthesis



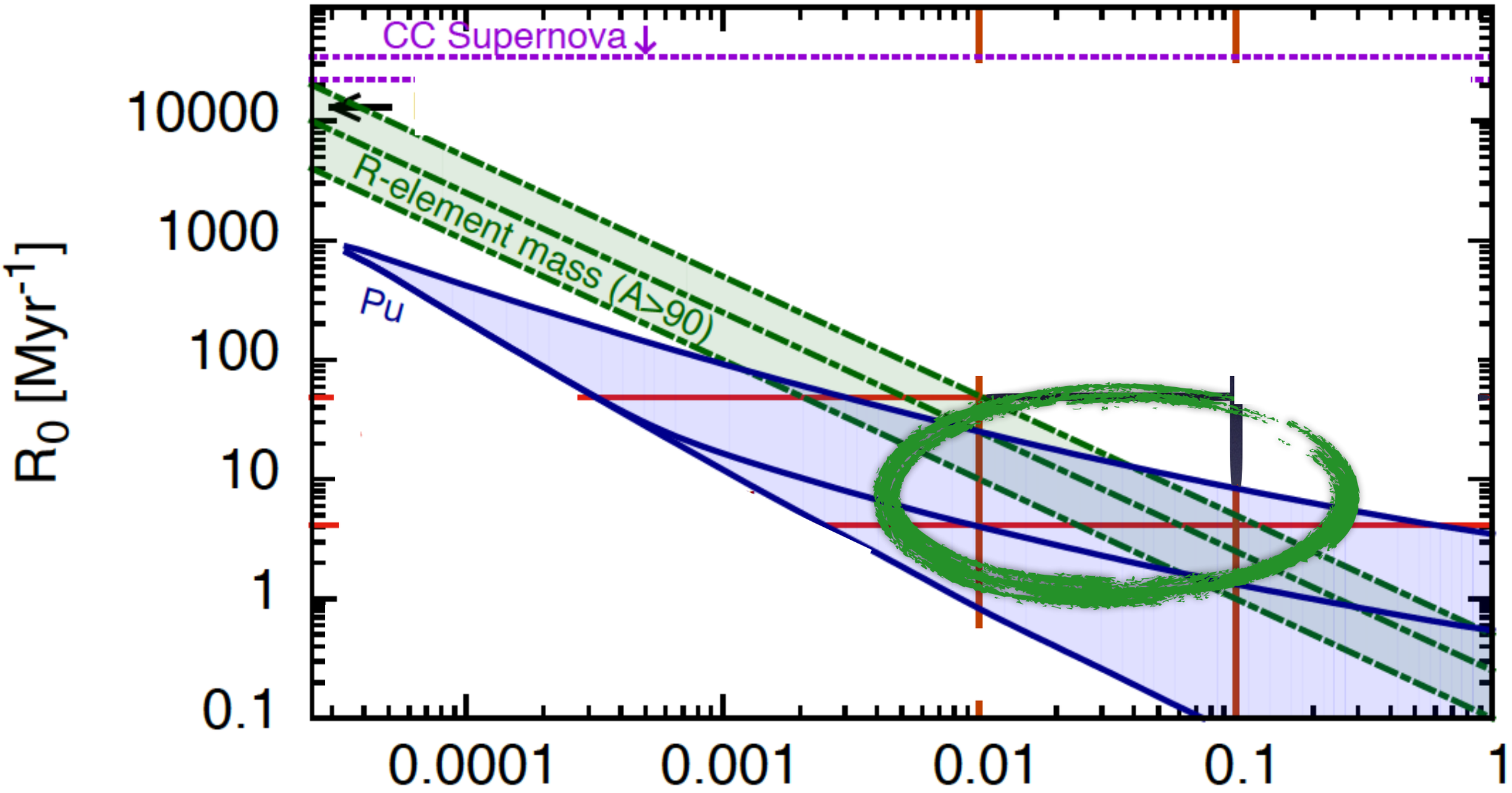
Radioactive ^{244}Pu deposition at early solar system and now vary by 50-5000

Wallner et al., 2014



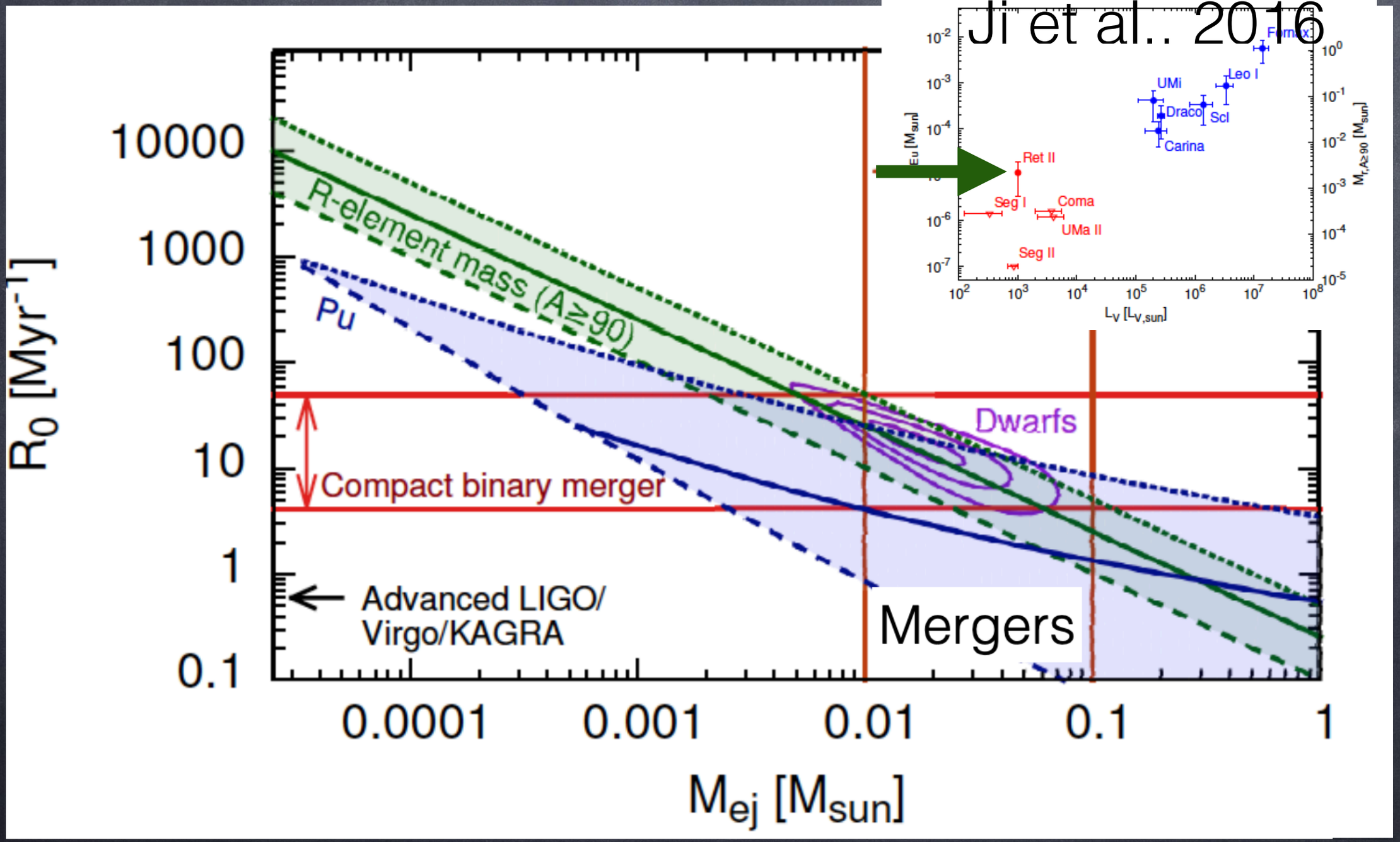


Breaking the degeneracy I: ^{244}Pu



Hotokezaka, TP & Paul, 2015

R-Process in dwarf Galaxies



Beniamini, Hotokezaka, &TP 2016

A Dwarf Galaxy **can** retain a binary Neutron Star

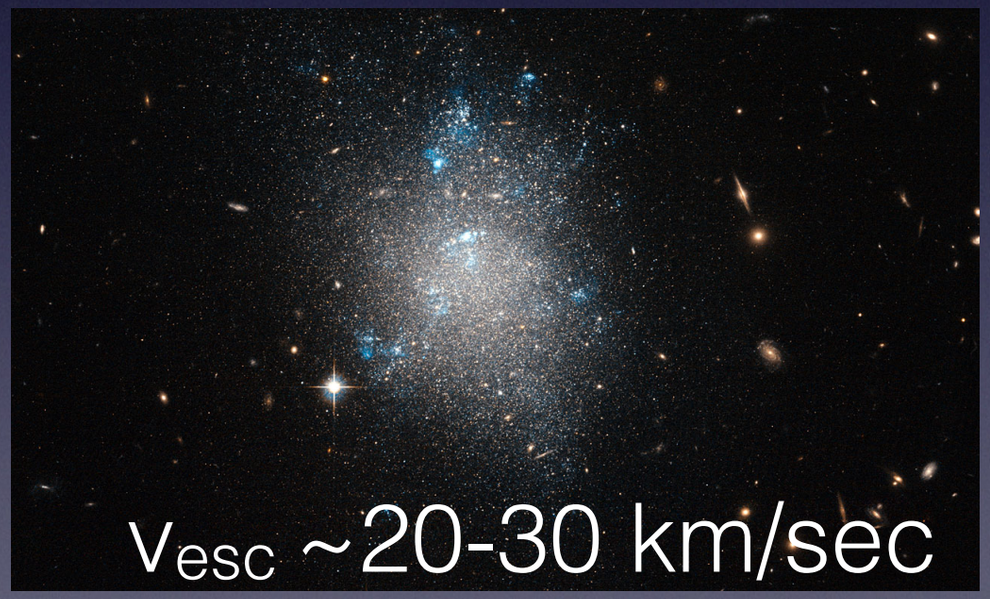
✳Most (2/3-3/4) observed Galactic binary neutron stars have almost circular orbits and a low proper motion

➡Very low mass ejection (<0.1 M_{sun})

➡NOT formed in a regular SNe

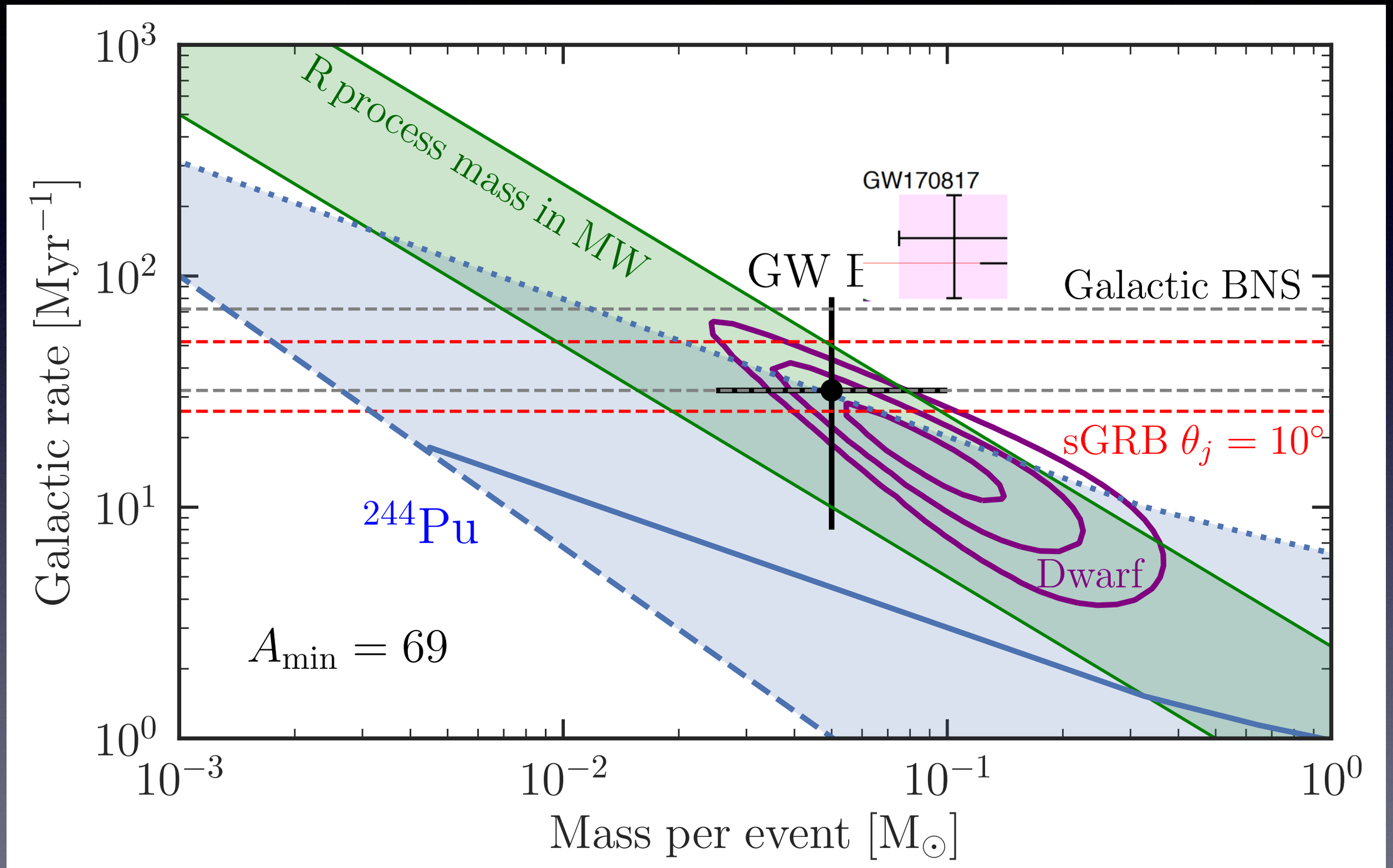
➡Very low kick velocity

➡<u>Won't be ejected from a Dwarf Galaxy</u>

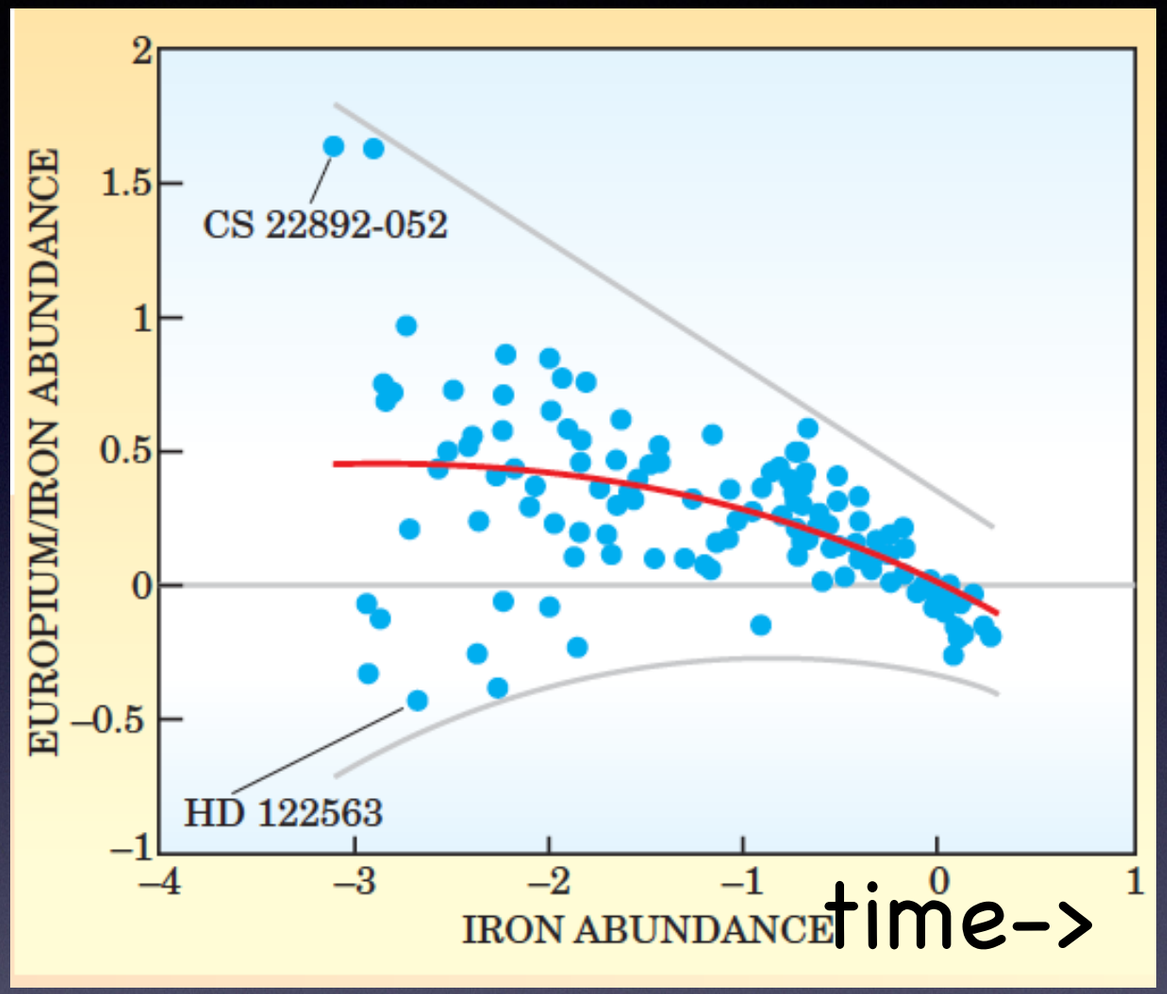


V_{esc} ~20-30 km/sec

After O3


R process mass in MW
GW170817
GW E
Galactic BNS
sGRB $\theta_j = 10°$
^{244}Pu
Dwarf
$A_{\rm min} = 69$
Galactic rate [Myr^{-1}]
Mass per event [M$_\odot$]
10^3
10^2
10^1
10^0
10^{-3}
10^{-2}
10^{-1}
10^0

Very Early nucleosynthesis

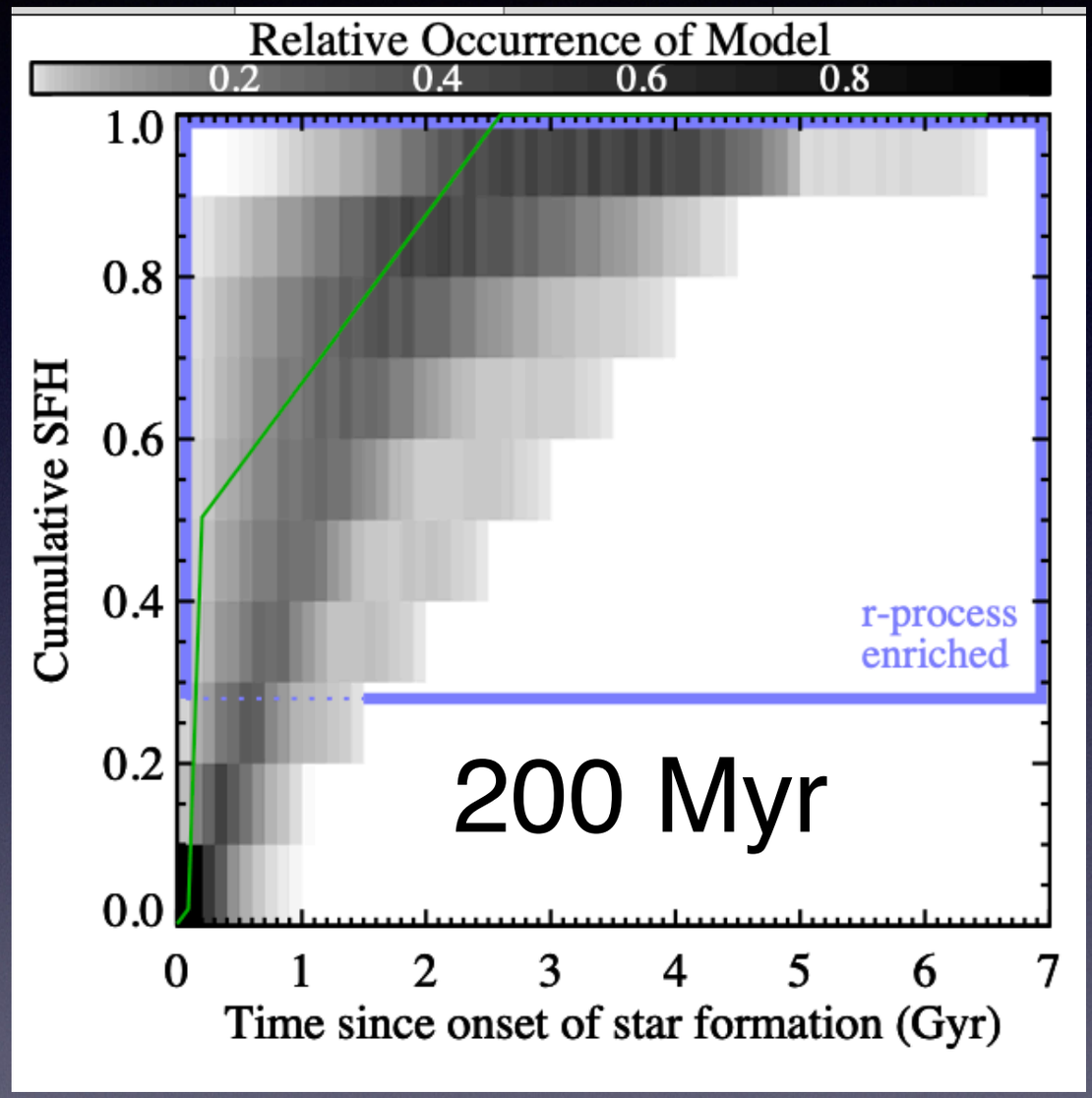


time->

Cowan & Thielemann

Milky Way

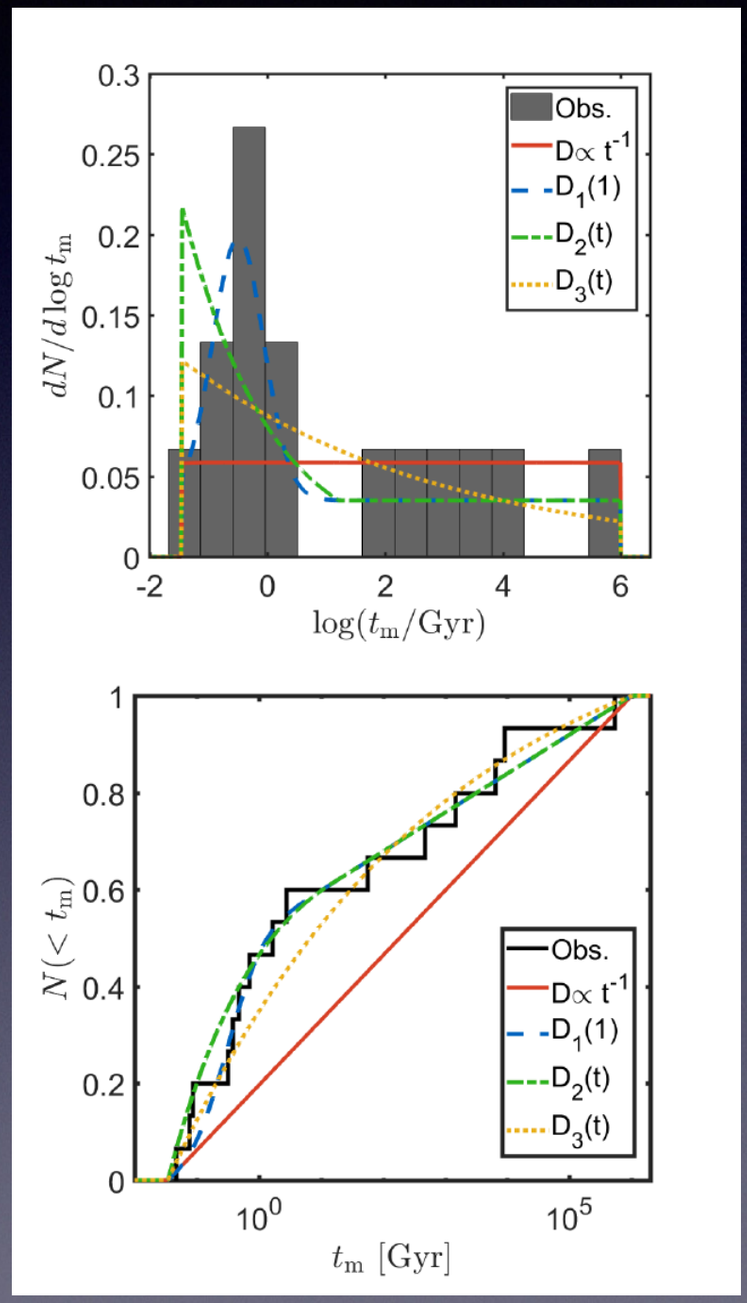
Ret II



Simon et al., 2023

Some like it short

- ✳The Galactic BNS have an excess of “short” merger times.
- ✳Expectation due to pulsar’s life time is a paucity of short mergers.
- ➡Excess at birth of BNS with short merger times.



Beniamini & TP 2019

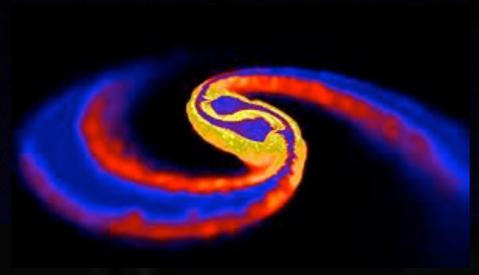
Why Gravitational Waves?

GW → Mergers → R-process

- Radioactive U and Th melt the Earth core → magnetic dynamo!
- Radioactive U and Th heat the mantle → plate tectonics - essential for evolution of intelligent terrestrial life as we know it.
- U and Pu may one day extinct life as we know it.

Our local merger

About 1000 Earth masses of Gold + Platimun + Uranium and other heavey metals. Less than 80 Million years before solar system formation at a distance of ~10 pc from the solar system!



Was this needed for life?