Considerations on IPv6 Scalability

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Geneva, Switzerland

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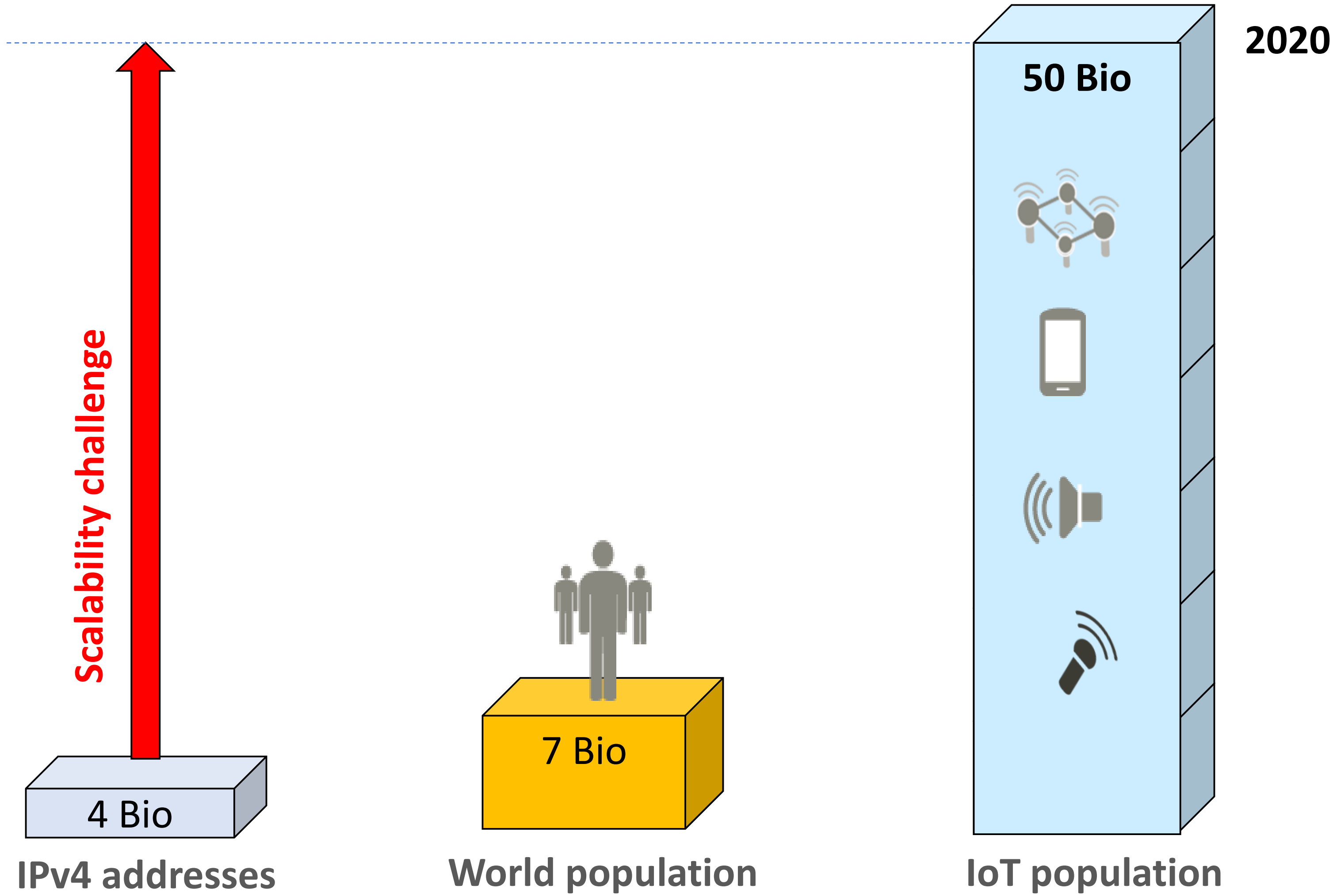
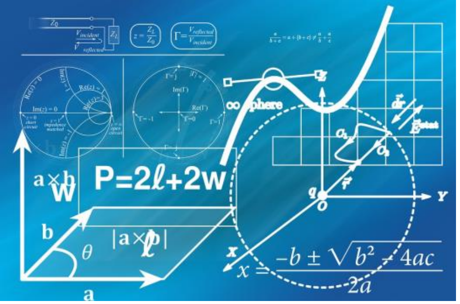
Why IPv6?



2020
50 Bio
Scalability challenge
7 Bio
4 Bio
IPv4 addresses
World population
IoT population



Mathematical Representations

Number of IPv6 unique addresses:

- 2^{128}
- 3.4×10^{38}
- 340 undecillions (340×10^{36})
- $2^{2^{7}}$
- Knuth’s up-arrow notation $2\uparrow 128$.
- Forth tetration of 2: $(2\uparrow\uparrow 4)^{8}$
- Maurer (or Rudy Rucker) presentation as $({}^{4}2)^{8}$

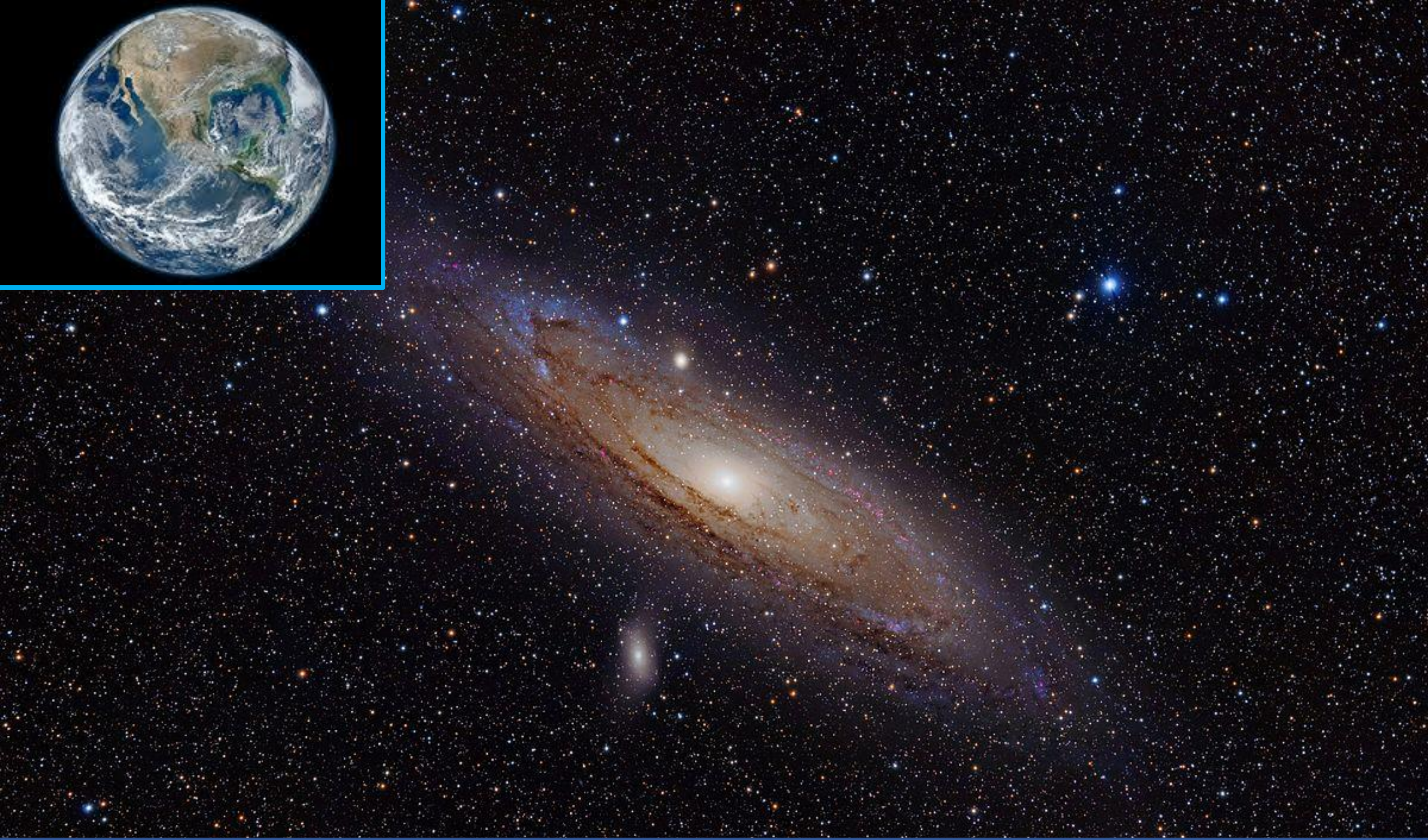
How Big

7.5 Billion Humans

7.5×10^9 < Pv6 ($3{,}4 \times 10^{38}$)

50 Billion IoT Devices

5×10^{10} < Pv6 ($3{,}4 \times 10^{38}$)

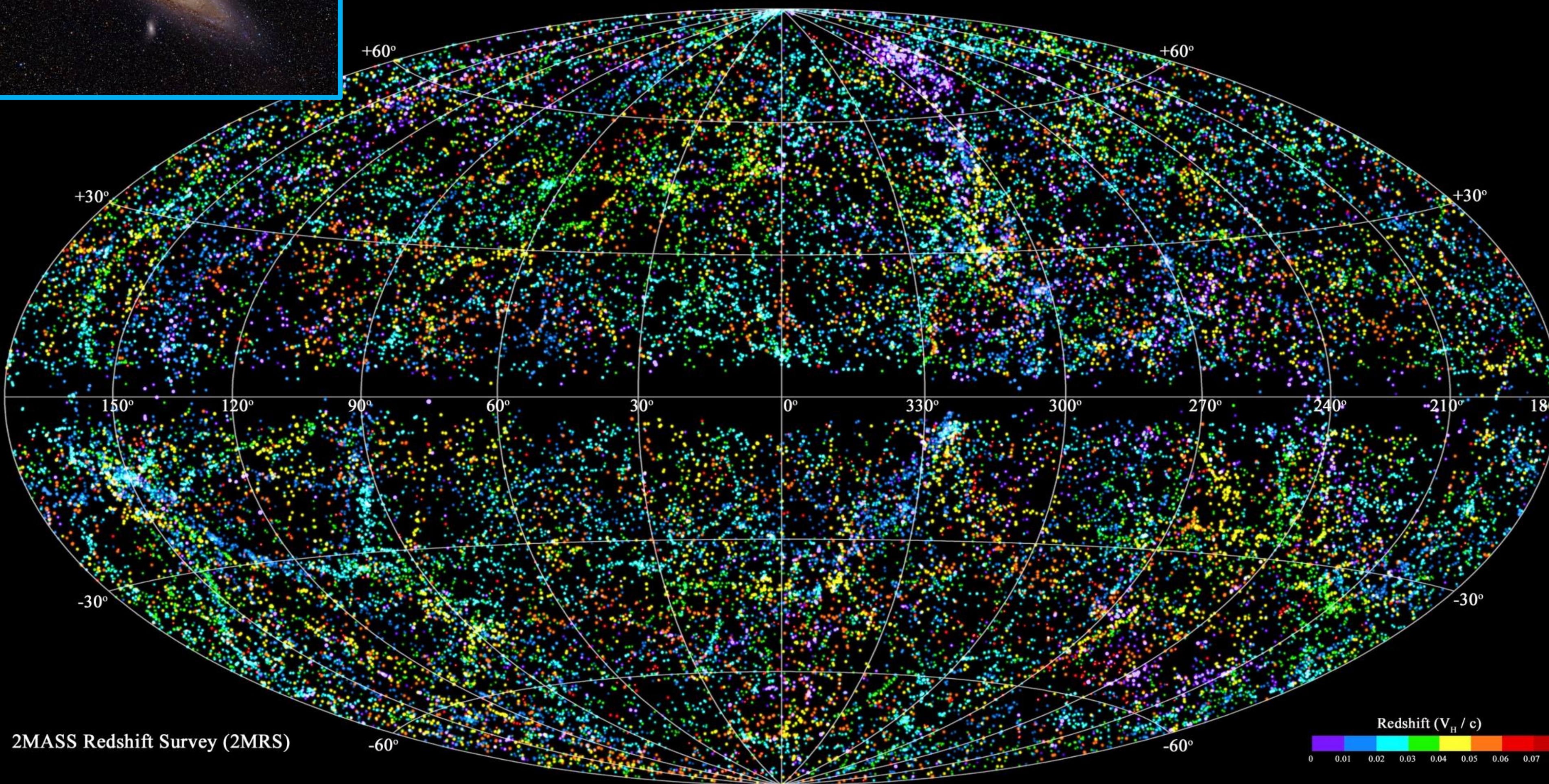


100 Billion Planets in our Galaxy

$1 \text{ x } 10^{11} < \text{Pv6 } (3{,}4 \text{ x } 10^{38})$

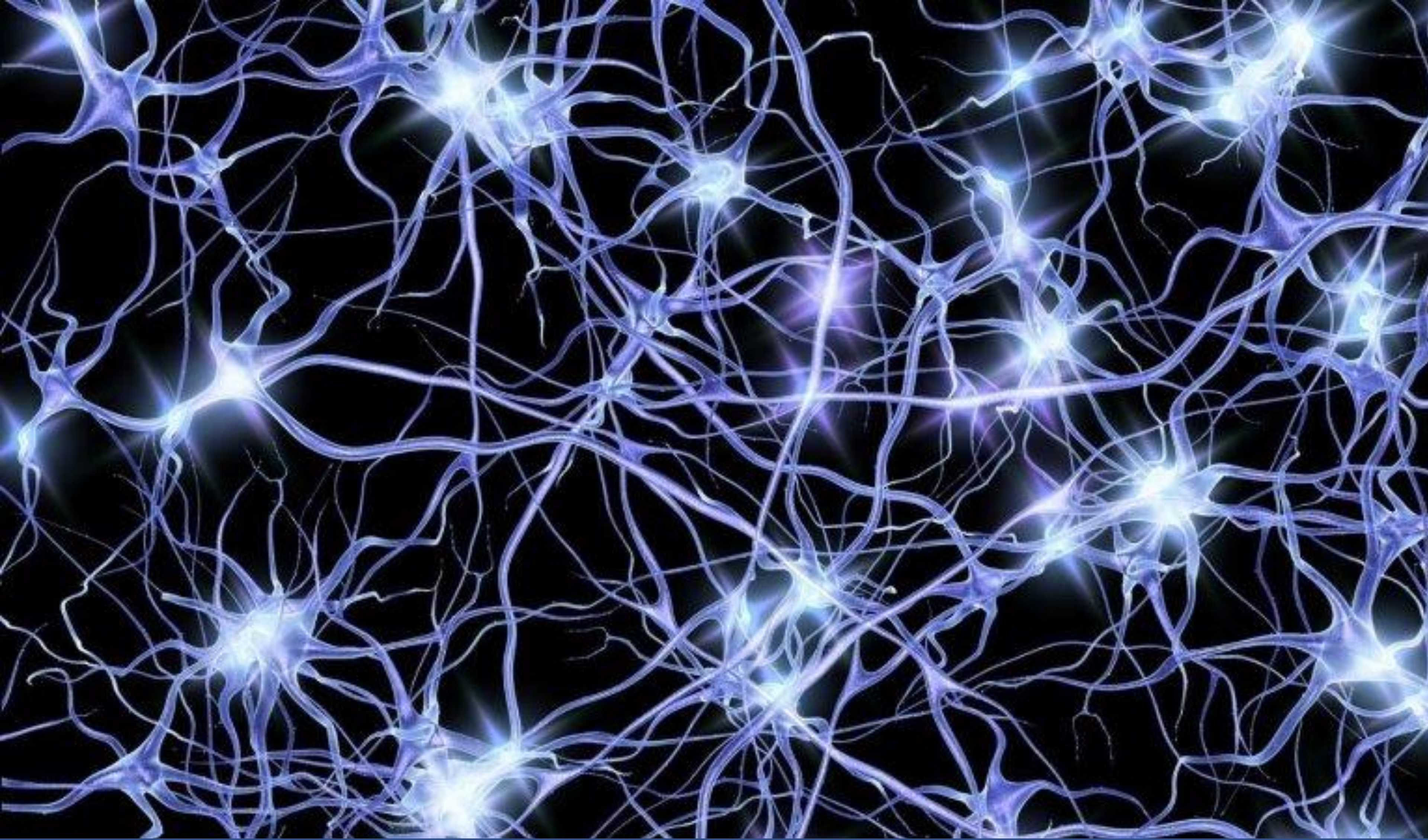
860 Billion Neurones in a Brain

$8.6 \times 10^{11} < $ Pv6 $(3{,}4 \times 10^{38})$



2 Trillion Galaxies in the Universe

2x 10^{12} $<$ Pv6 (3,4 x 10^{38})



1 Quadrillion Synapses in a Brain

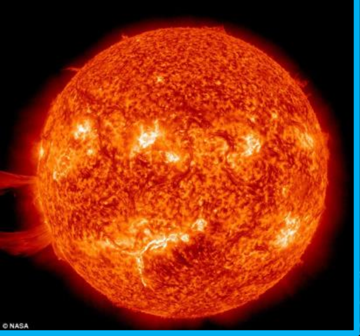
$1 \times 10^{15} < \text{Pv6}\ (3{,}4 \times 10^{38})$

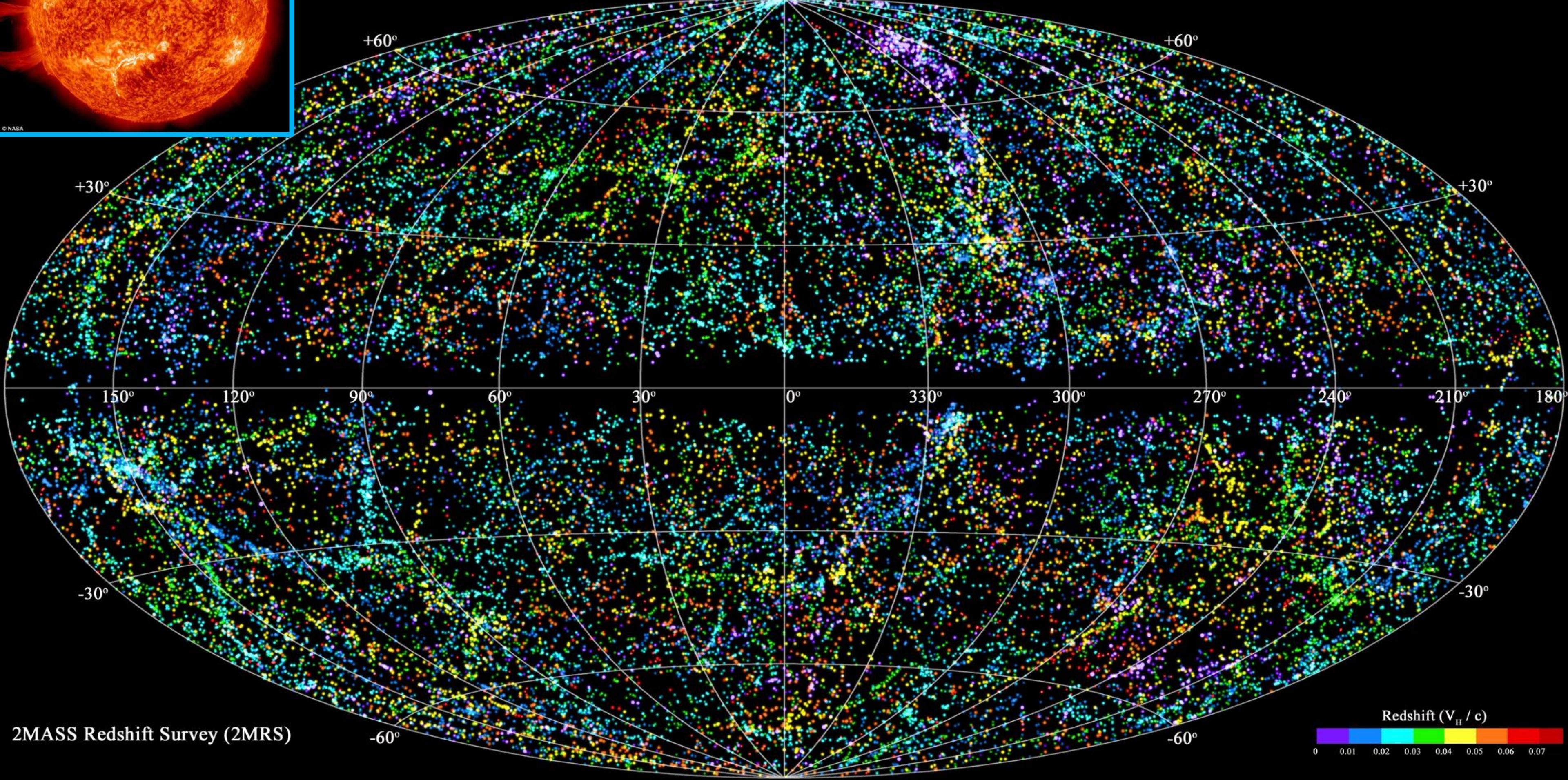
7.5 Quintillion Grains of Sand on Earth

7.5×10^{18} < Pv6 ($3{,}4 \times 10^{38}$)

7 Octillion Atoms in a Human Body

$7 \times 10^{27} < \text{Pv6}\ (3{,}4 \times 10^{38})$



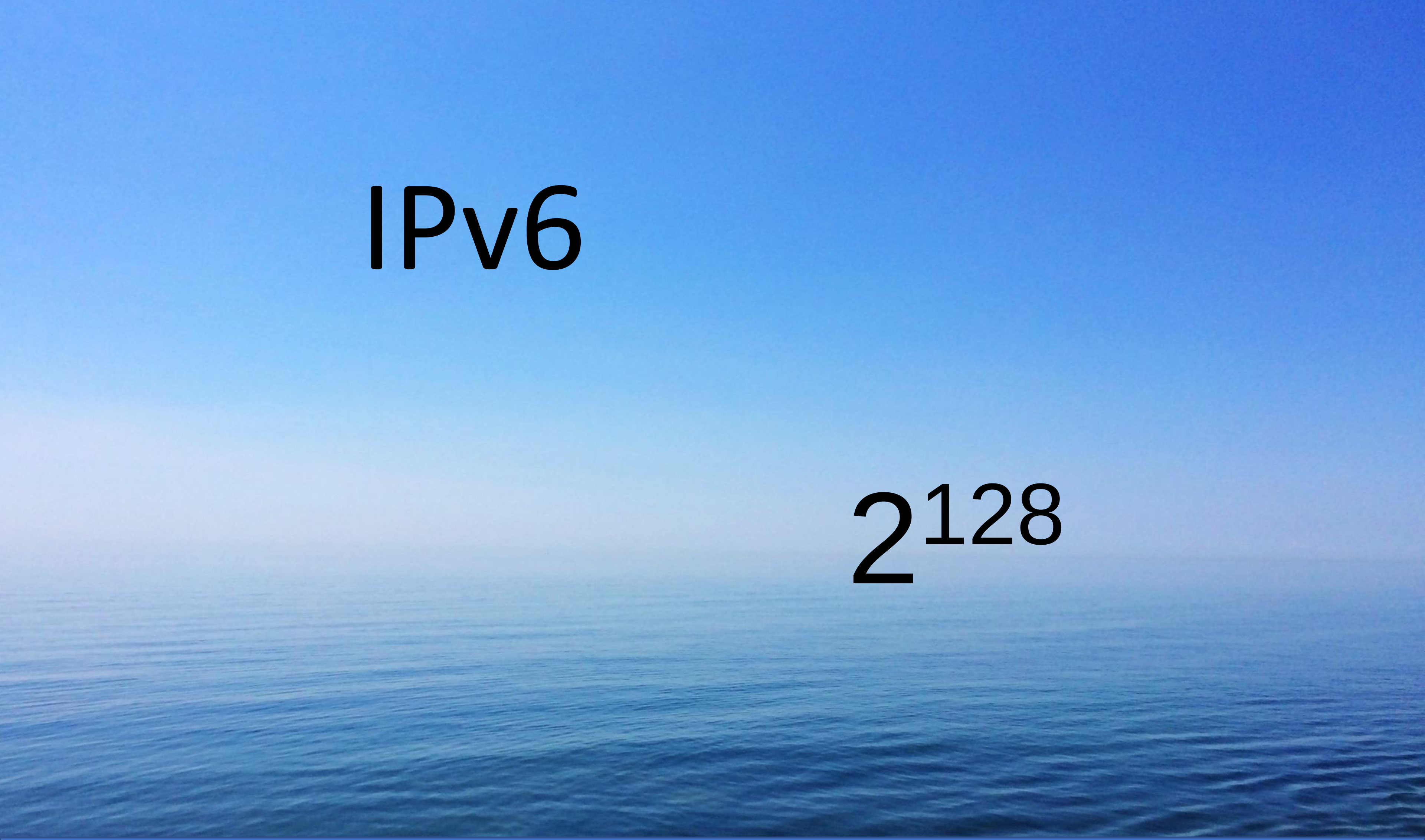


300 Sextillion Stars in the Universe

3×10^{23} < Pv6 ($3{,}4 \times 10^{38}$)

51 Undecillion Atoms in Humanity

5.1×10^{37} < Pv6 ($3{,}4 \times 10^{38}$)

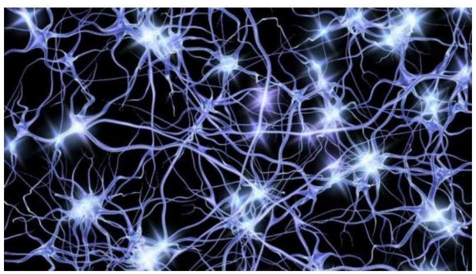
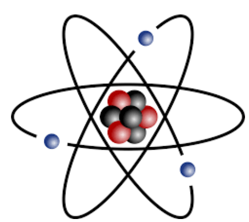


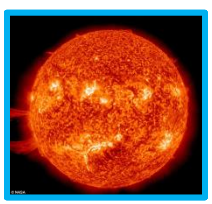
340 Undecillions IPv6 Addresses

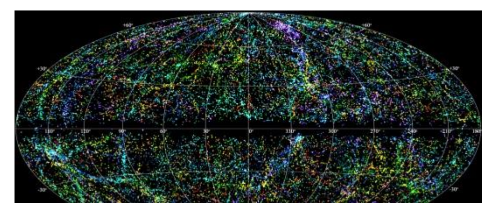
$3,4 \times 10^{38}$

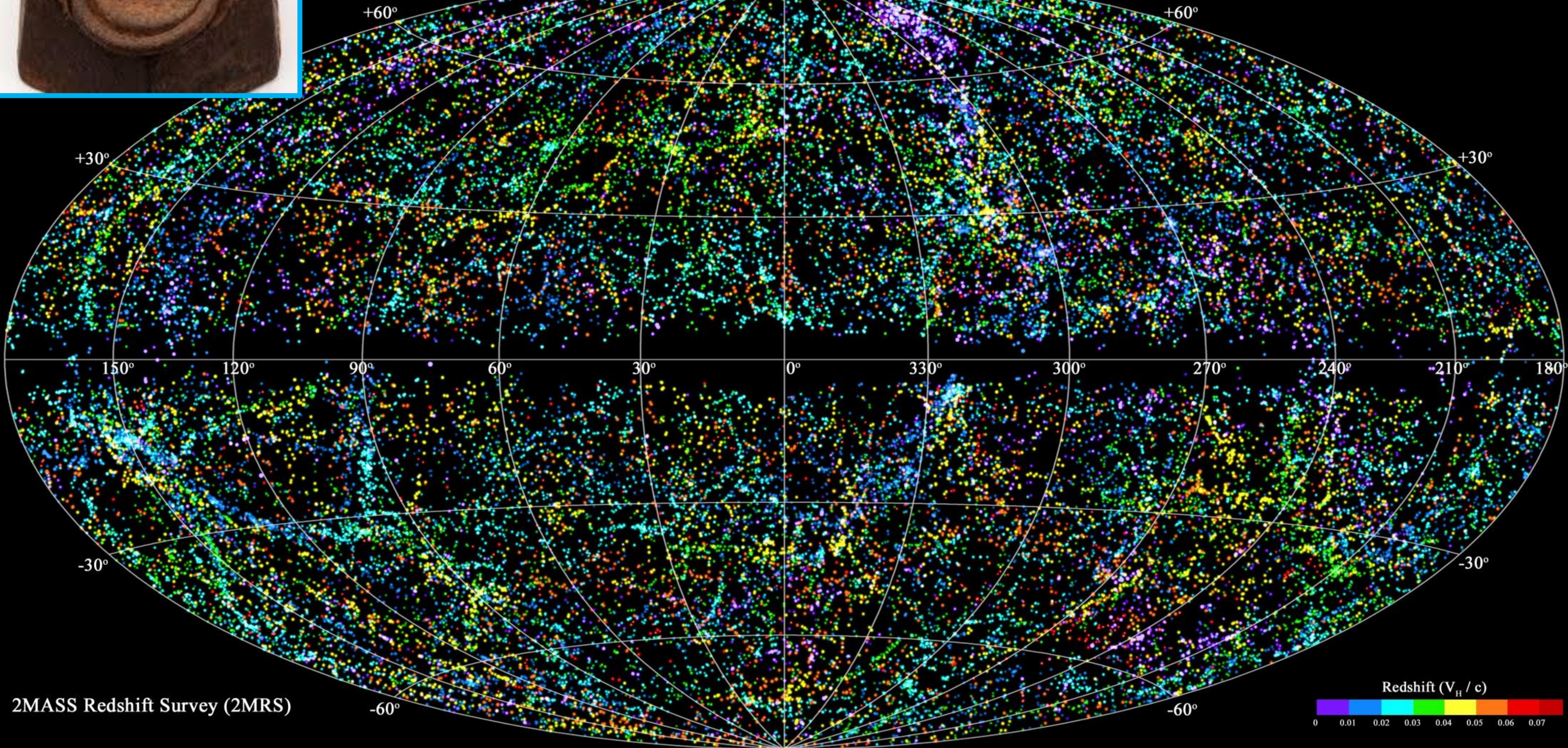
IPv6 >





Mass of the Universe

10^{50} to 10^{60} > Pv6 (3,4 x 10^{38})

Moving Beyond

Googol: 10^{100}

Googolplex: 10^{Googol} or $10^{10^{100}}$

$10\uparrow\uparrow 10$ (Guillion)

$100\uparrow\uparrow 100$ (Theillion)

$1000\uparrow\uparrow 1000$ (Vintillion)

$10\uparrow^{10}10$, or $10\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow 10$ (Zieglion)

$F^{10}(10)$, $F(F(F(F(F(F(F(F(F(F(10))))))))))$,

where $F(n) = n\uparrow^{n}n$. (Annilion)

Graham's number

Mathematical Big Numbers

Human Limitations

Human capacity

1 IP address allocation per second
80 years (days and nights)
$= 80 \times 365 \times 24 \times 60 \times 60$
= 2'522'880'000 addresses
$= \sim 2.5 \times 10^9$

1 IPv6 Subnet

$= 2^{64}$ unique public IP addresses
$= 1.8 \times 10^{19}$
= ~ Ten Billion larger (10^{10}) than human capacity
= ~ Humanity capacity

Conjectures

#1
IPv6 addressing capacity is sufficient to provide a unique 64 bits Host ID to each and every present and future IoT device on earth and in our solar system, as well as to each individual human and machine Internet user.

#2
Mankind will never be able to use and exhaust the complete potential of IPv6 addressing capacity, as long as the address block allocation is aligned with effective needs of end-users (i.e. limiting GRP allocation to /56 or /48).

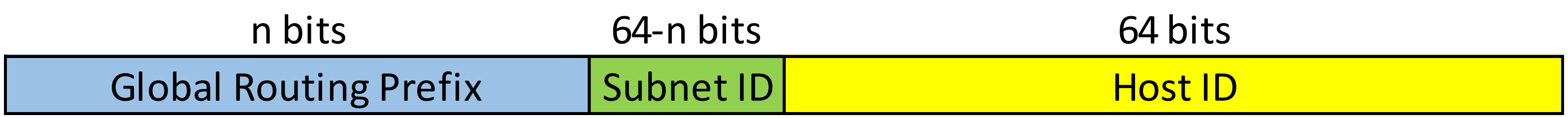
#3
IPv6 addressing capacity is sufficient to provide a unique complete 128 bits address to each and every star in the universe, but would either require an extended Network GRP or a NAT architecture to address large deployments of IoT in each stellar system.

Conjectures

#4
IPv6 addressing capacity is sufficient to address effective mankind requirements, but can be theoretically superseded by identifiers allocation in mathematical models based on hyperoperations tending towards very large results domains, such Googols, Googolplex, Guilions, Vintillions, Zieglions, Anilions and Graham number.

#5
A single IPv6 Subnet addressing capacity is superior to the whole humanity capacity to manually allocate an configure IPv6 addresses.

IPv6 Address Structure



Two halves; three segments:

A. The Routing Address, which is split in two parts:
   I. The Global Routing Prefix (GRP)
   II. The Subnet Identifier (Subnet ID)

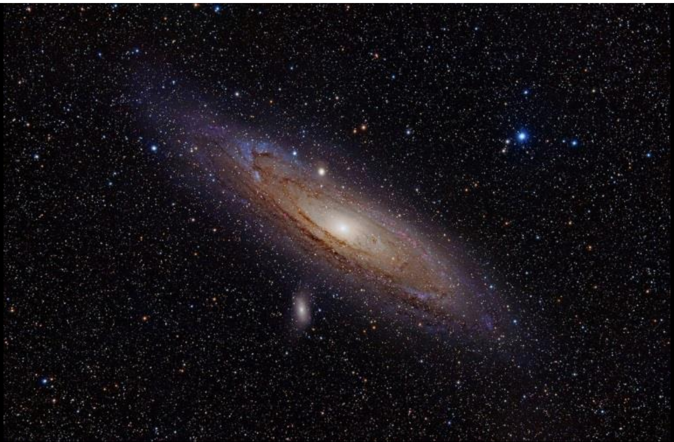
B. The Host ID

Galactic IPv6 Addressing Scheme

~ 100 Billion planets in our Galaxy (NASA)

- First block or 48 bits for a Global Routing Prefix for each planet
- Each planet can then allocate 16 bits for subnets
- 64 bits range for IPv6 Host ID fully available.

48 bits	16 bits	64 bits
Stellar Global Routing Prefix	Subnet ID	Interface ID



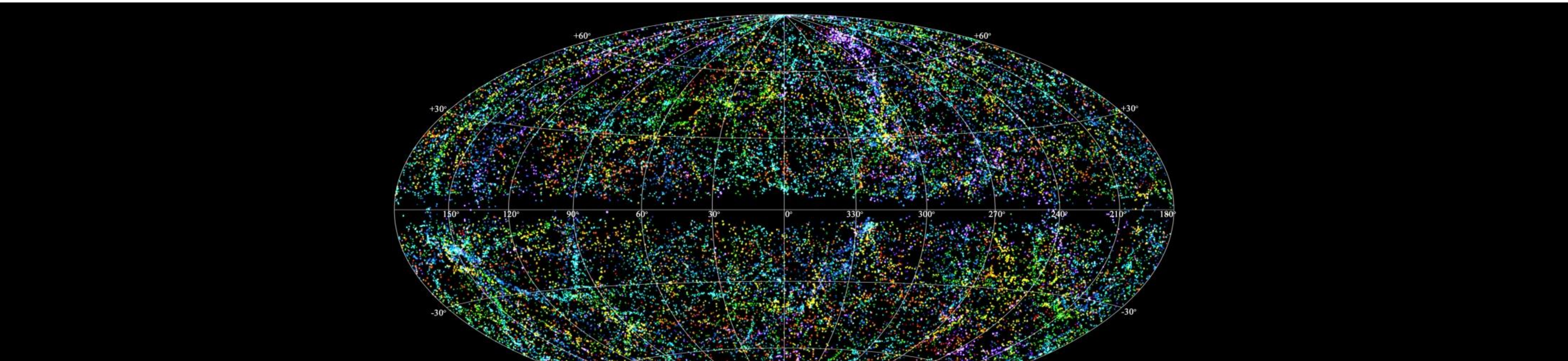
Intergalactic IPv6 Addressing Scheme

~2 x 10^{12} Galaxies in the universe (NASA)
~1.5 x 10^{11} stars per galaxy

- First segment of 48 bits for a galaxy routing prefix.
- Second segment of 48 bits for the star routing prefix.
- 32 bits for border routers identifiers (or single node identifiers).

This would enable to allocate to each star an addressing capacity equivalent to the current IPv4-based Internet.

48 bits	48 bits	32 bits
Galactic Globa Routing Prefix	Stellar Global Routing Prefix	Border Router ID



THANK YOU !

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IoT Requirements:

- **Scalability:**
  2^128 IP addresses
- **Self-configuration:**
  Stateless Address Auto-Configuration Mechanism (SLAAC)
- **Mobility**
- **Security:**
  IPSec, DTLS, etc.
- **Lightweight code:**
  6LoWPAN, CoAP, 6TiSCH , etc.
- **Global availability and interconnectivity:**
  Internet

Ideas of Scalability

~4,3	x 10^{9}	IPv4 addresses (2^{32})
~7,5	x 10^{9}	Human beings on earth
~5	x 10^{10}	IoT devices by 2020
~1	x 10^{11}	Planets in our galaxy
~8,6	x 10^{11}	Neurons in a brain
~2	x 10^{12}	Galaxies in the universe
~5,1	x 10^{14}	Square meters on the Earth surface
~1	x 10^{15}	Synapses in a brain
~7,5	x 10^{18}	Grains of sand on earth
~5,1	x 10^{20}	Square millimetres on the Earth
~3	x 10^{23}	Stars in the universe
~7	x 10^{27}	Atoms in one human body
~5,3	x 10^{37}	Atoms in all human bodies
~3,4	x 10^{38}	IPv6 addresses (2^{128})