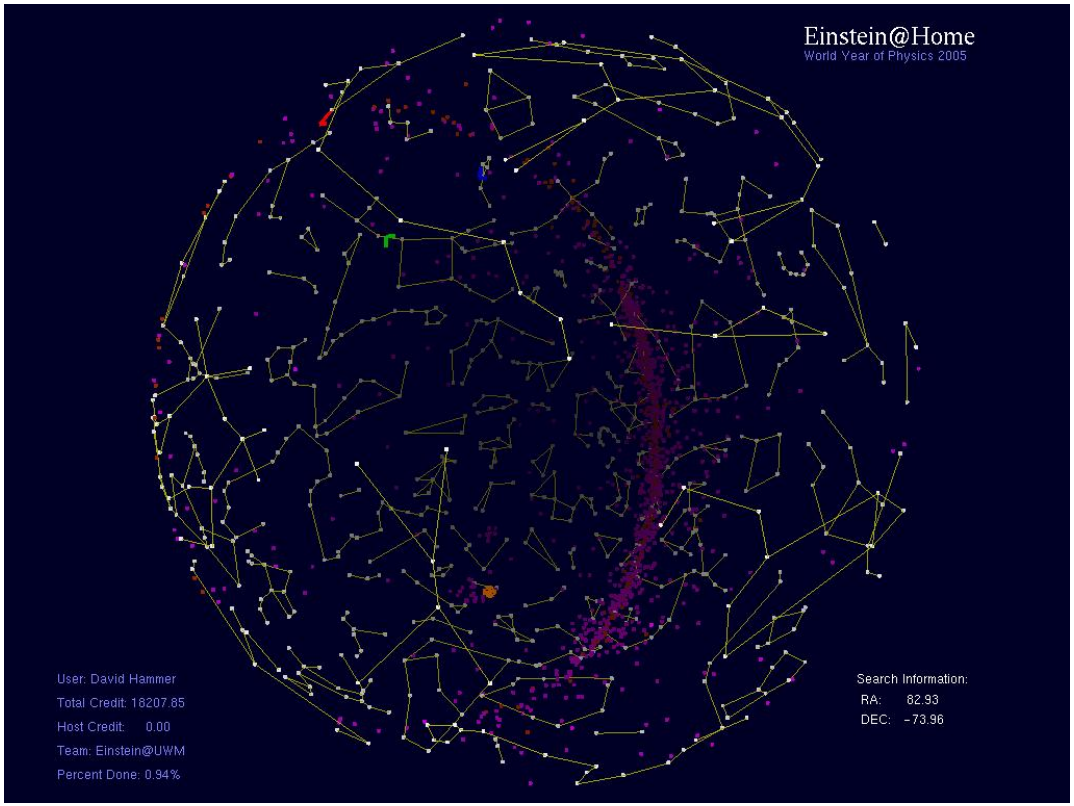
Managing scientific data in the Einstein@home volunteer computing project

Christian Beer & Avneet Singh
Albert Einstein Institute (AEI) Hannover

Einstein@Home in a nutshell

Volunteers contribute computing power to help search for
Pulsars and Gravitational Waves



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Einstein@Home GW searches

- 11 major GW searches performed on Einstein@Home
  - S3, S4, Early S5, S5 Hough, Full S5, S5 Galactic centre, S5GC1, S5GC1HF, S6Bucket, S6CasA, O1AS20-100* (*ongoing), looking for isolated compact objects (e.g. neutron stars etc)

- Why?
  - For e.g. S5GC1HF search:
    - without Einstein@Home = 5,000 years on standard laptop
    - with Einstein@Home = 6 months
  - For e.g. S6Bucket search:
    - without Einstein@Home = 10,000 years on standard laptop
    - with Einstein@Home = 1 year

Einstein@Home GW searches

- Trivia:
  - S5GC1HF searched for a whooping 10^{17} templates! This equates to 10^{17} comparisons performed over 6 months.

- Work division (S5GC1HF)
  - Searches usually search for frequency (1 parameter), spin-down (1 parameter) and locations (2 parameters) in sky
  - Divide the 4-parameter search ranges into very small tiles & compare all such tiles to the observed data.
  - Work-units sent to volunteers; each work-unit covers a certain range of the 4 parameters
  - Process 6.4 million work-units in parallel for 6 hours each!

Einstein@Home GW searches

- Results back: (S5GC1HF)
  - Bring back processed results from the volunteers.
  - Whooping quantity of data: 4 terabytes of data to be post-processed

- Post-processing (S5GC1HF)
  - Post-processing of 'candidates' required; roughly 10^{11} candidates released
  - We are looking for a few key candidates (1 or 2!) among the 10^{11} candidates
  - Several stages in 'post-processing'

Einstein@Home GW searches

- Did we find anything?
  - No? We are used to it! :-D
  - Yes?! Well, open the champagne! :-D

- Publish results in any case . . .
  - Publish signals, if any found. Let the chaos ensue!
  - Publish upper bounds, if nothing seen.
  - Estimate the loudness of the loudest candidate that we MOST LIKELY (with >90% confidence) would have detected, if it existed.
  - Current upper bounds put the GW strengths to be
  - $< 10^{-24}$ over 50-1500 Hz frequency range

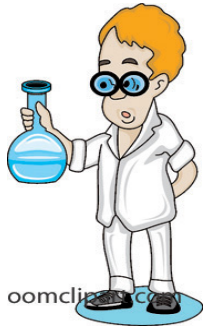
Einstein@Home GW searches

- Results till date . . .
  - No GW signals found!
  - We have searched all sky!
  - Frequencies searched between 50-1500 Hz
  - Spin-downs searched between 10^{-8} — 10^{-10}
  - Bounds of signal strengths < 10^{-24}

We keep searching . . .

The data problem

massive amount of data



High Performance Cluster takes **100 days** to process, **costs are high**

Internet-connected PCs take **100 days** to process, **costs are low**

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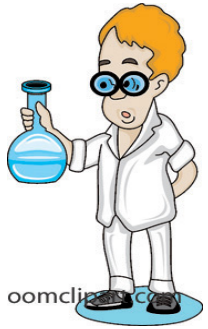
The data problem

massive amount of data



Splitting

S6CasA: 190 GB
O1-All-Sky: 75 GB
(projected)

data data data data data data data data data data data data data data data data data data data data data

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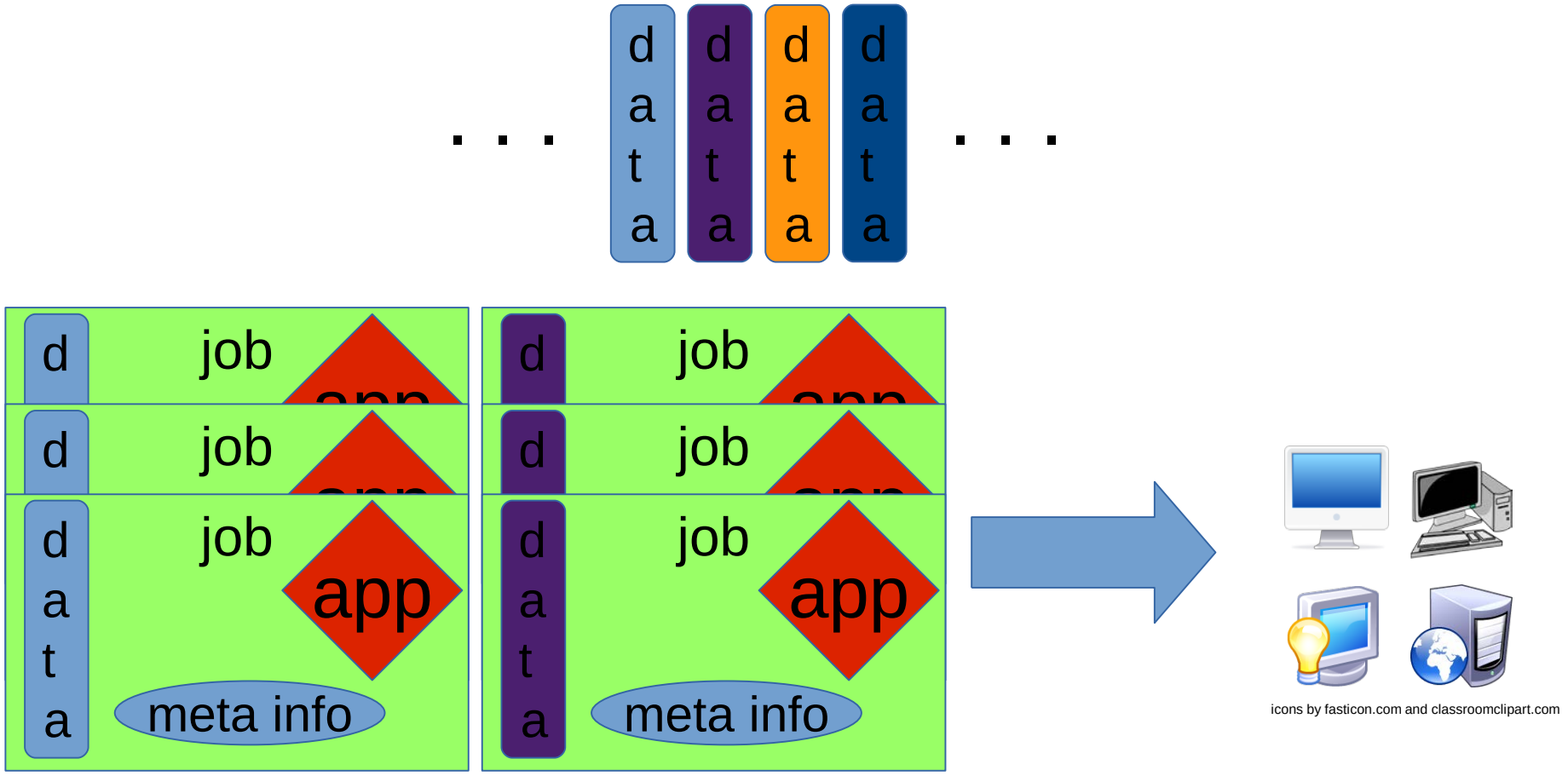
The data problem



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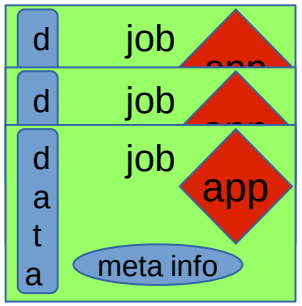
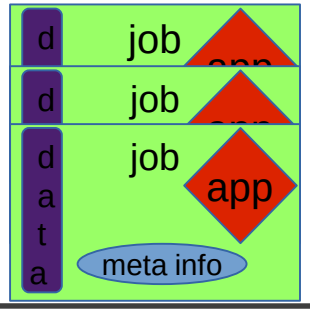
Sending data to volunteers

data

data

Einstein@home server





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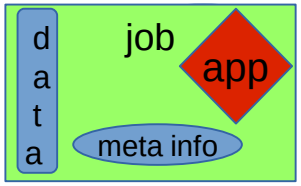

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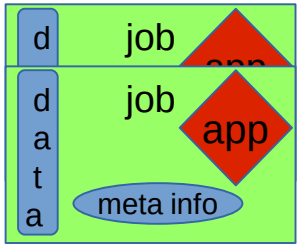

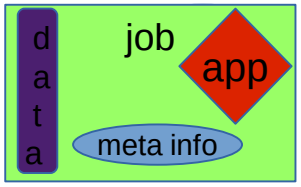

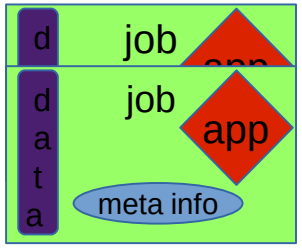

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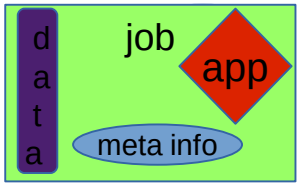

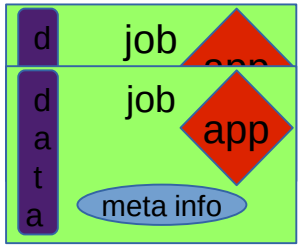

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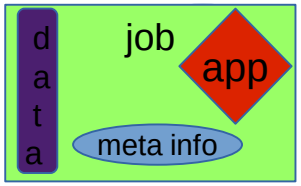

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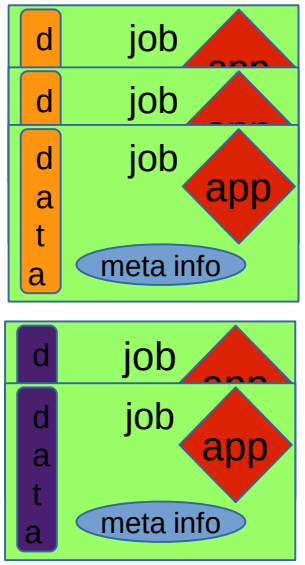

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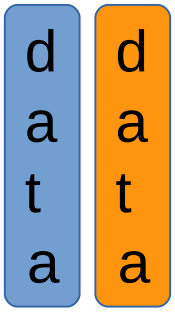

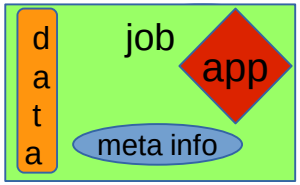

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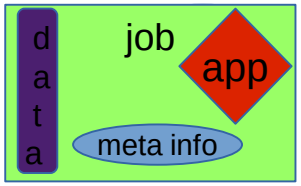

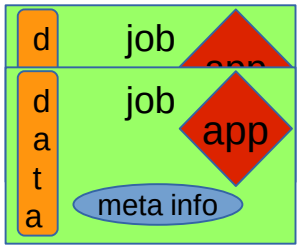

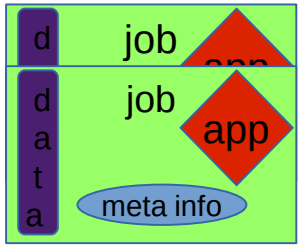

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Some Numbers

Data downloaded from AEI: 155 GB per day

Data uploaded to AEI: 16 GB per day

Metadata transfered: 94 GB per day

Storage Capacity at AEI: 50 TB (Einstein@home only)

Active Hosts: 60.000 (23.000 with a GPU)

Active Volunteers: 44.000

Detections:
55 Binary Pulsars, 18 Gamma-Ray Pulsars, 0 Gravitational Waves

Join Einstein@Home now

Go to:
https://**einsteinathome.org**
and sign-up

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