DESIGNING FOR DISCOVERY IN THE ERA OF DATA-INTENSIVE ASTRONOMY

Sarah Hegarty

with A/Prof Christopher Fluke, Dr Aidan Hotan (CSIRO), & Dr Amr Hassan (Monash)

Melbourne University | August 29th, 2018

SWINBURNE UNIVERSITY OF TECHNOLOGY

CSIRO

Making Discoveries in Astronomy

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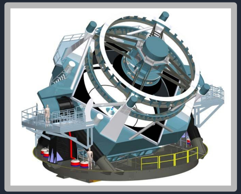

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(Norris, 2016)

Making Discoveries in **Data-Intensive** Astronomy

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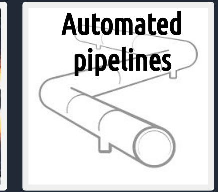

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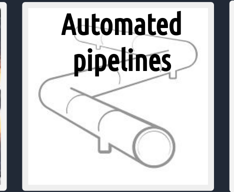

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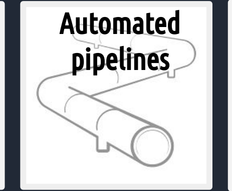

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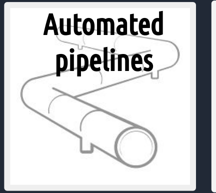

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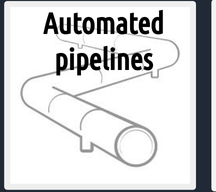

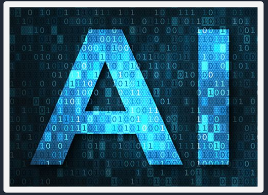

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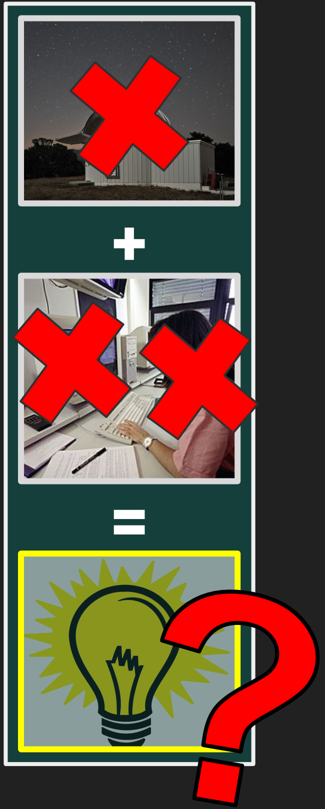

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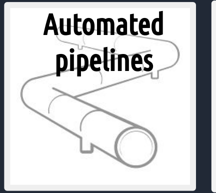

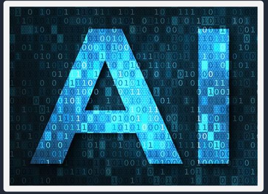

How can we capitalise on the discovery potential of data-intensive astronomy?

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→ Understand how we make discoveries

Technological Development

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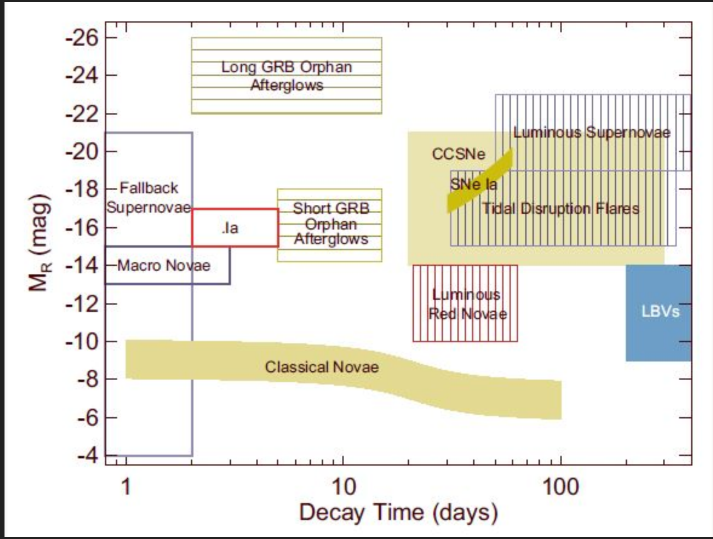
Harwit (1981)

Technological Development



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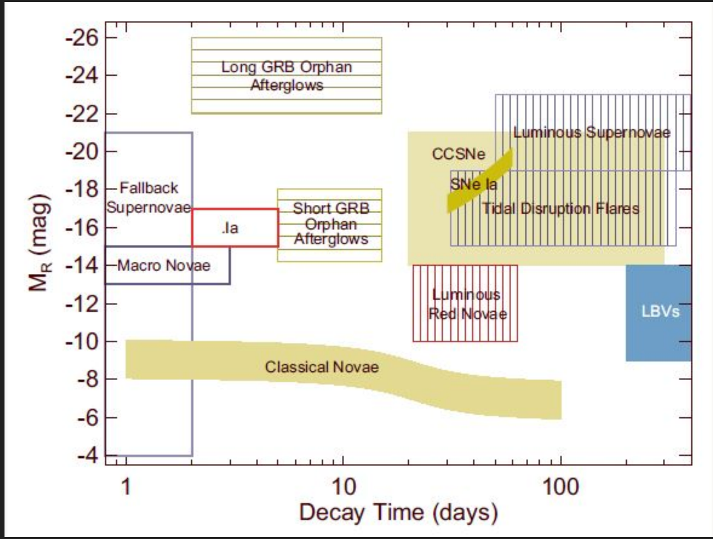

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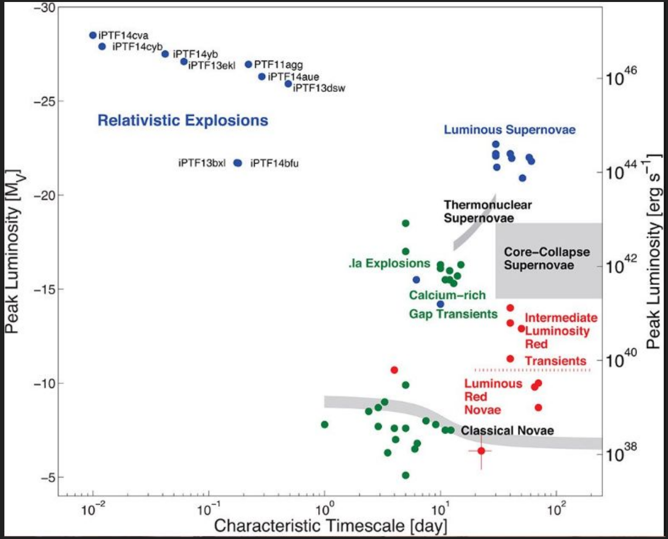

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Planning vs Serendipity

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Project
Use cepheids to improve value of H_0
UV spectroscopy of ig medium
Medium-deep survey
Image quasar host galaxies
Measure SMBH masses
Exoplanet atmospheres
Planetary Nebulae
Discover Dark Energy
Comet Shoemaker-Levy
Deep fields (HDF, HDFS, GOODS, FF, etc)
Proplyds in Orion
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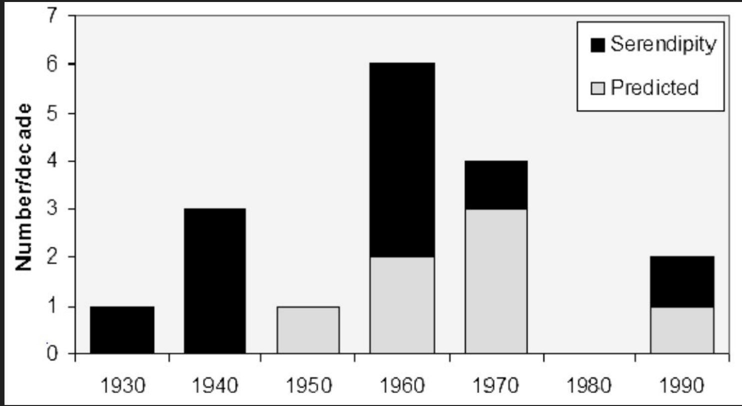

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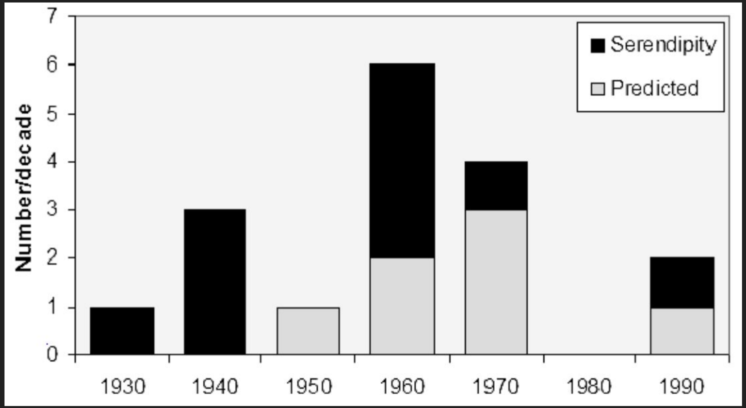

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“Astronomy is powered by serendipitous observations”

(Fabian, 2009)

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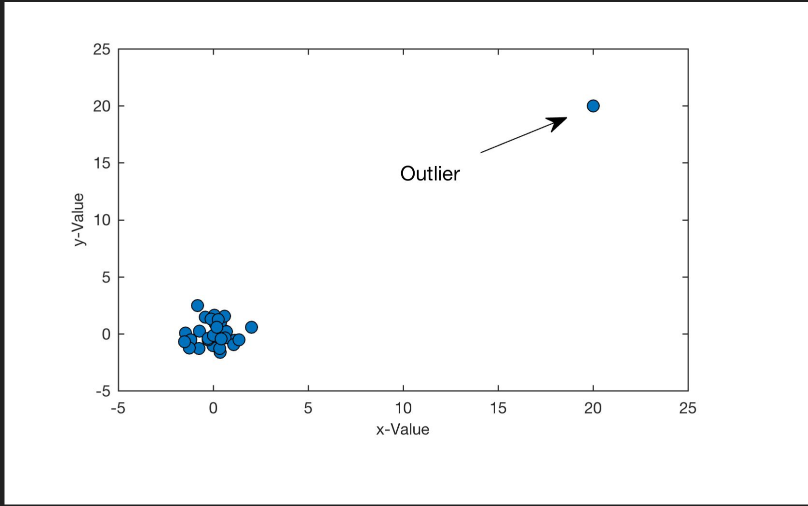

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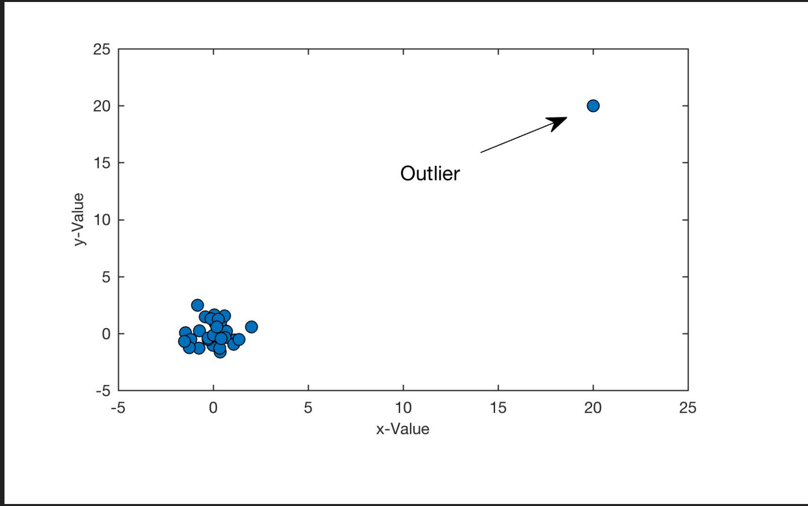

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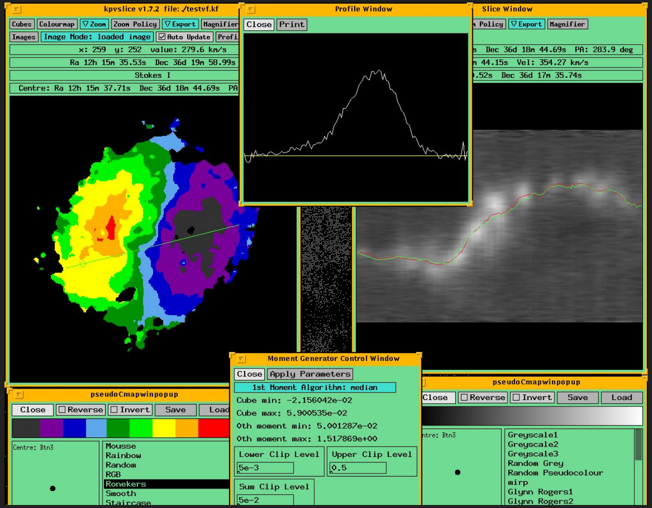

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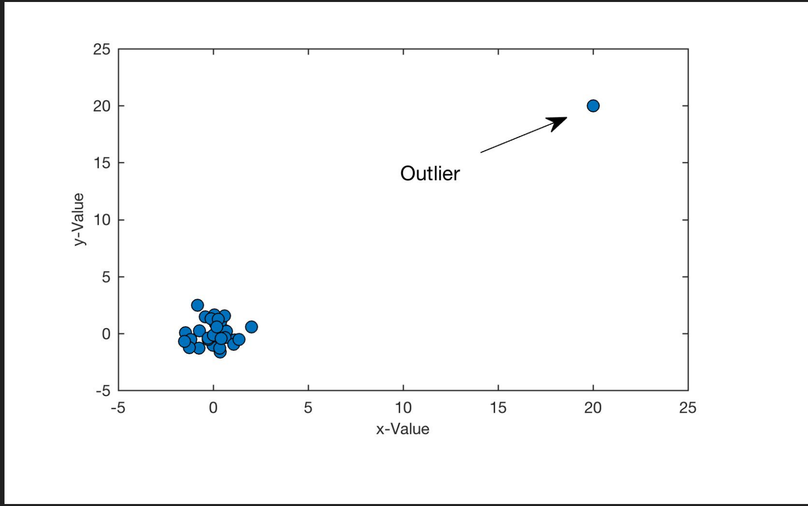

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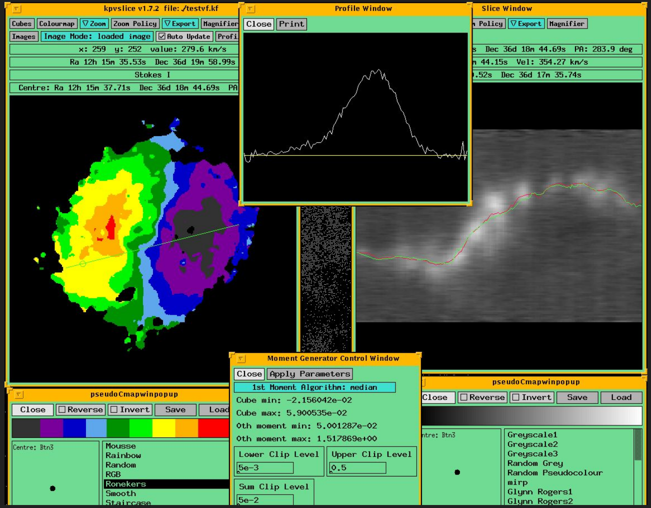

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‘Visualization is a crucial component of knowledge discovery in astronomy….at present, humans have pattern recognition and feature identification skills that exceed those of any existing automated approach.’
(Hassan & Fluke 2011)

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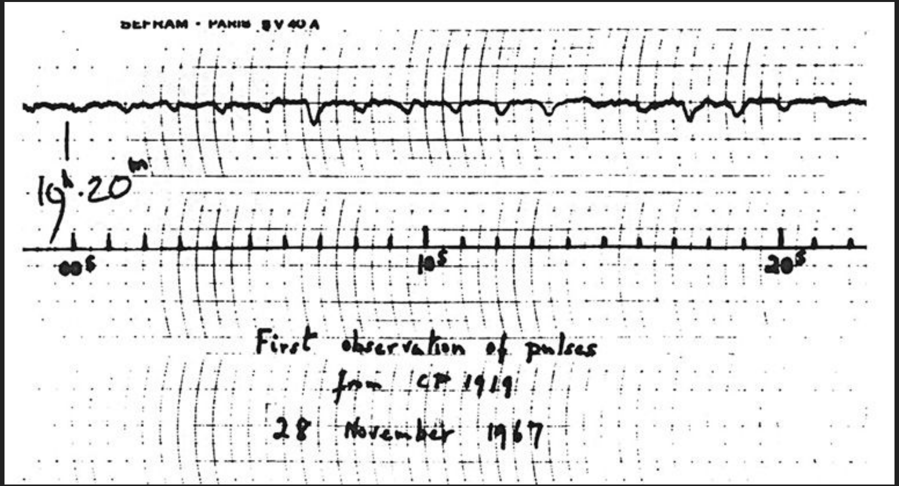

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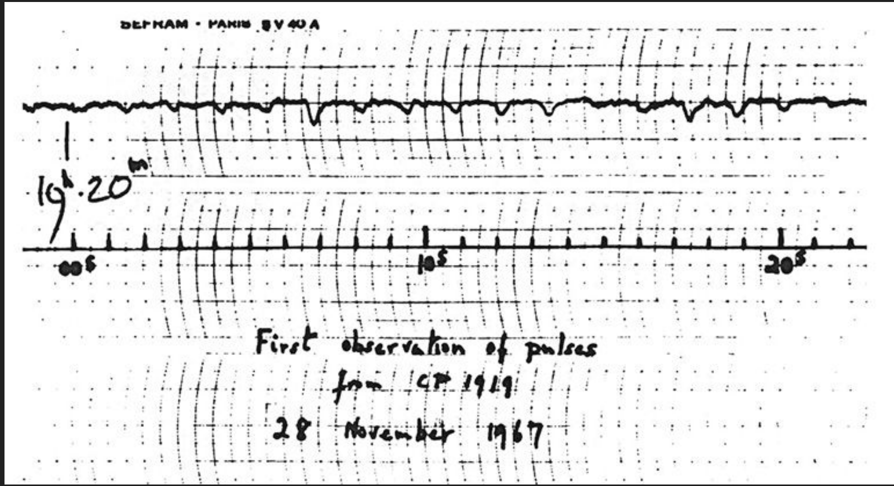

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'Discoveries invariably result from an individual becoming so familiar with the data, and hence the possible sources of error in them, that he/she can recognize an unexpected clue for what it is worth. '

(Wilkinson et al., 2004)

The Discovery Workflow

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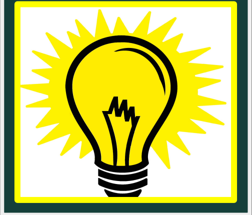

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Data Reduction

Data Analysis
(aka “thinking”)

Compare with models, other data, and publish

Contextualise, and debate with colleagues

Adapted from Norris (2010)

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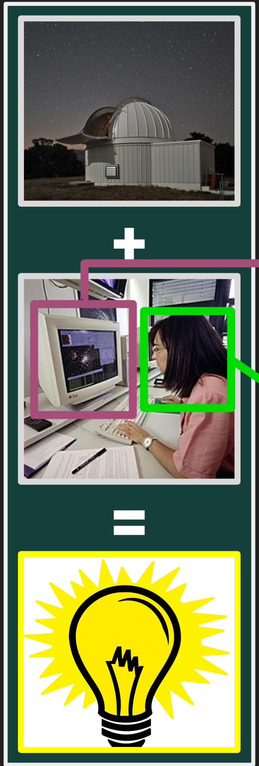

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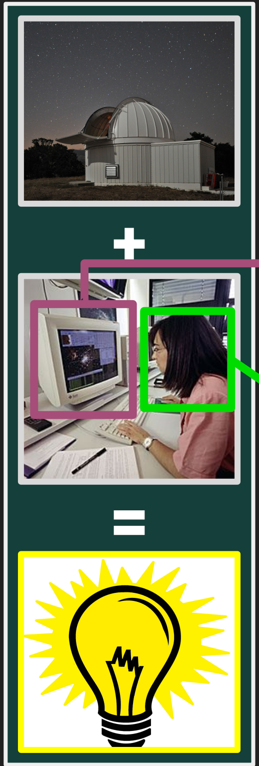

Telescopes	Data
Data Reduction	Information
Data Analysis (aka “thinking”)	Knowledge
Compare with models, other data, and publish	Understanding
Contextualise, and debate with colleagues	Wisdom

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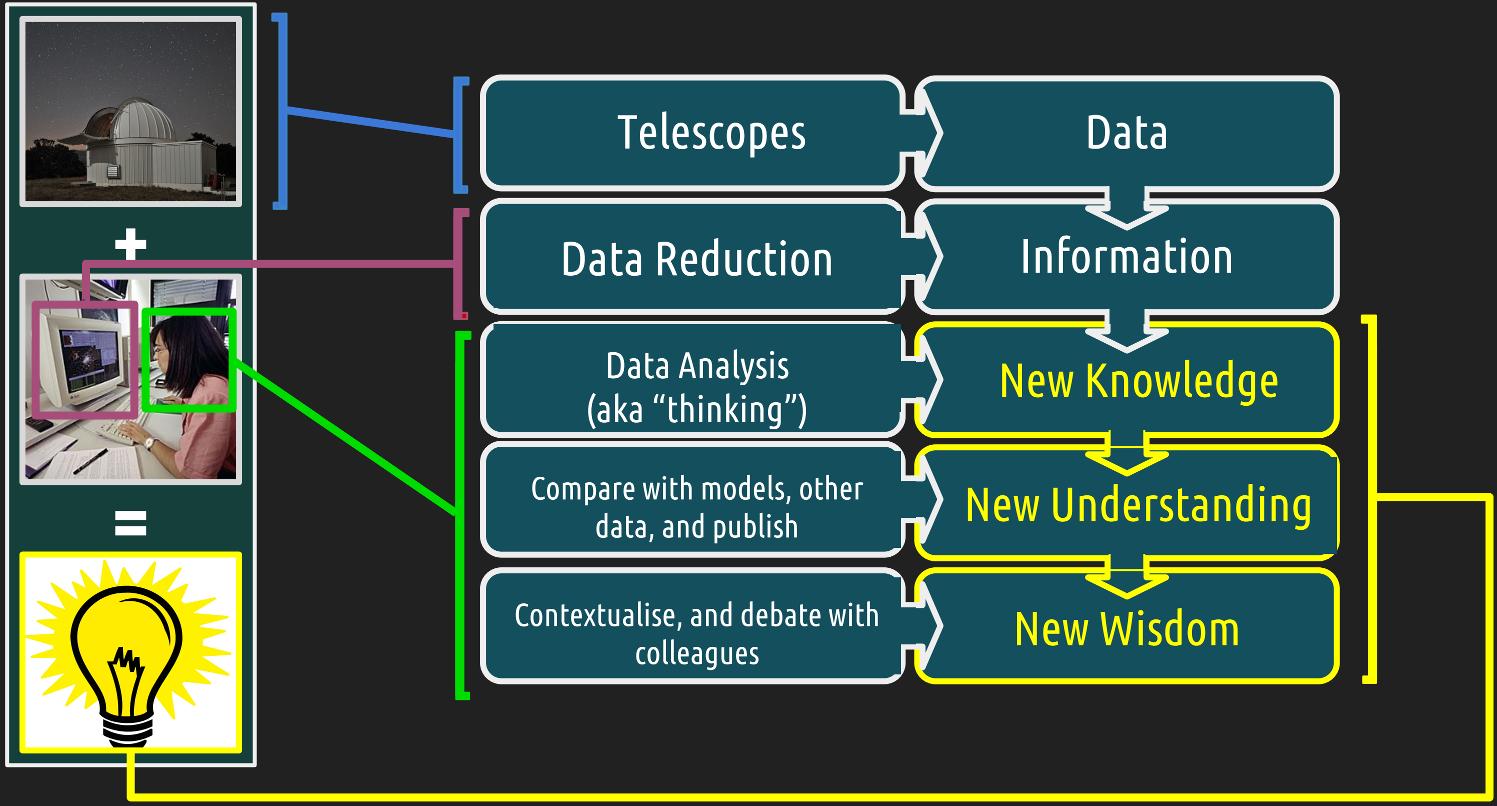

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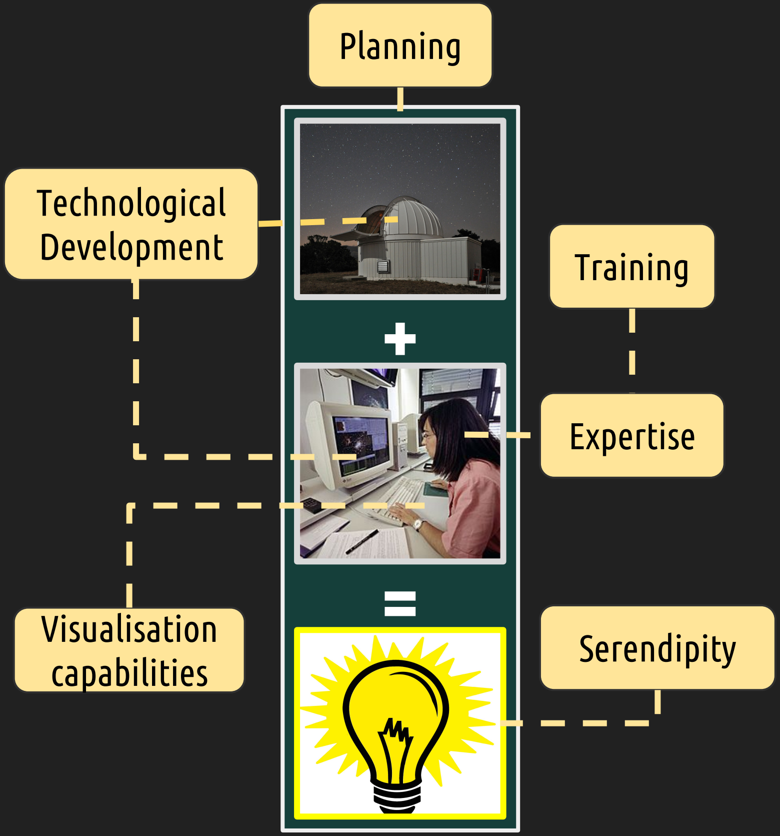

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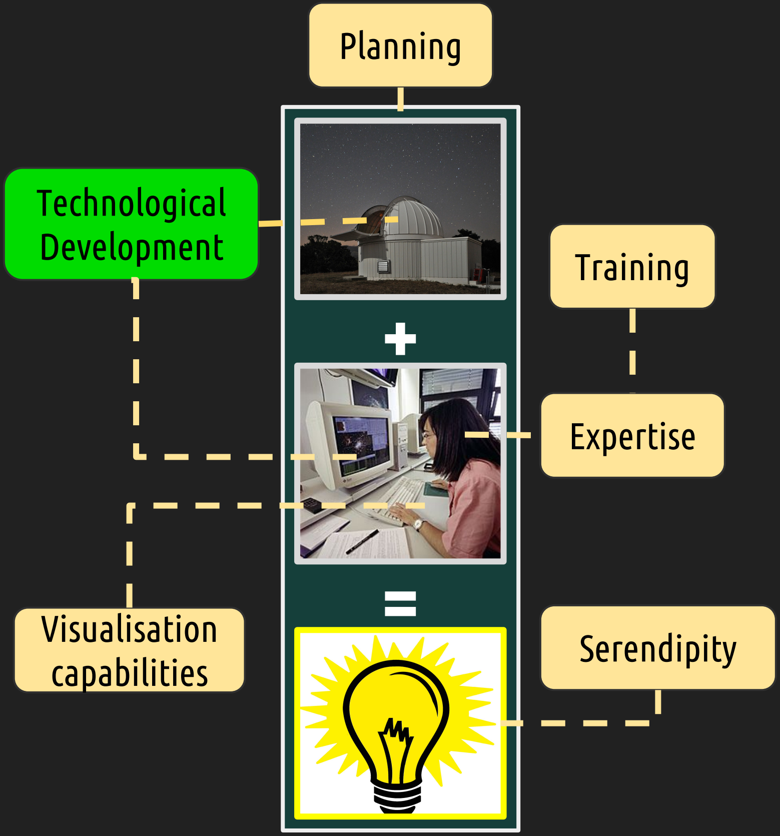

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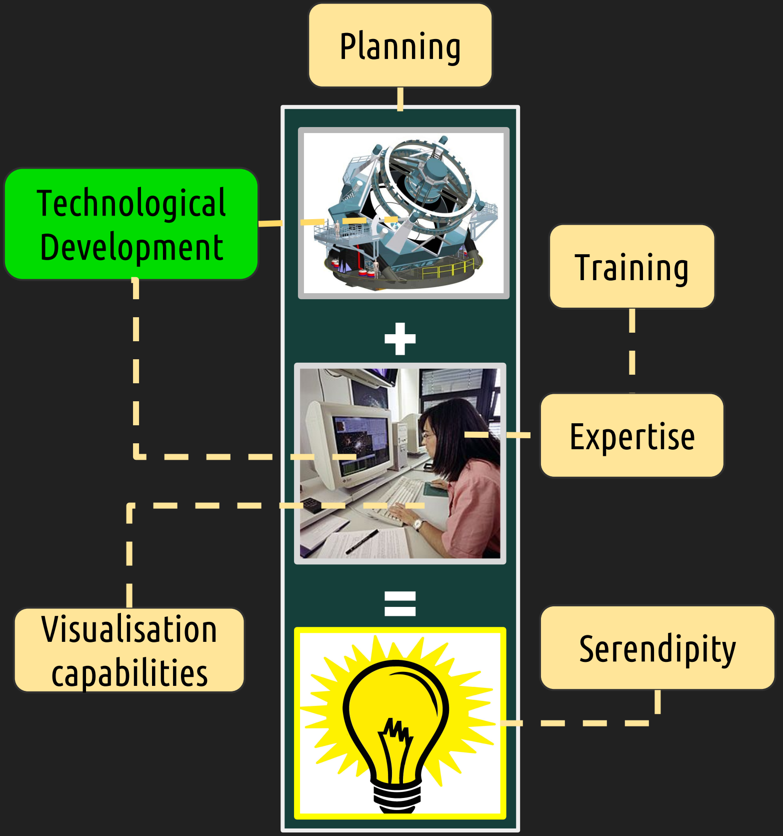

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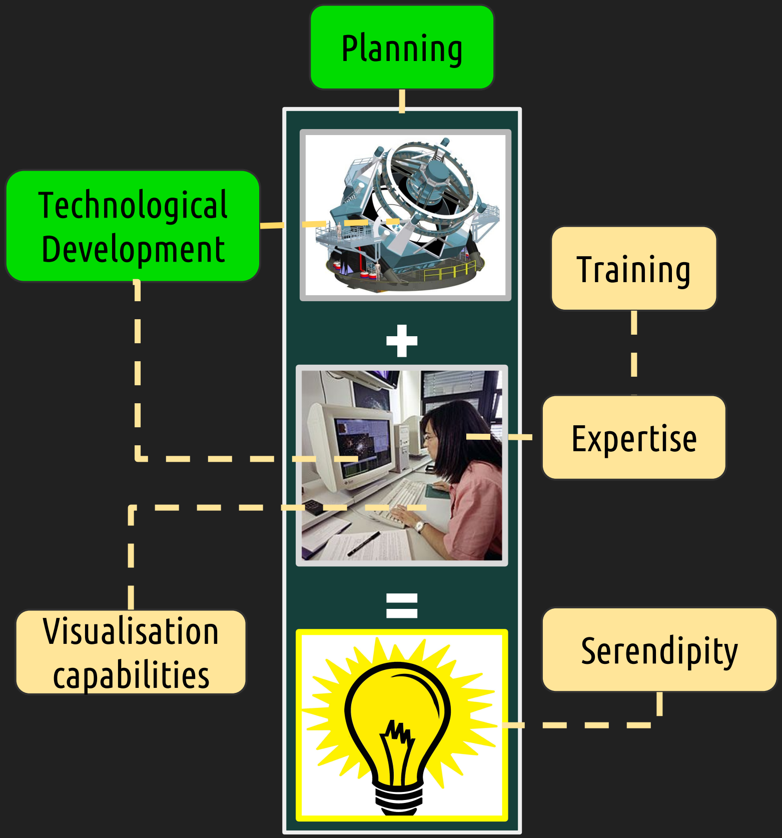

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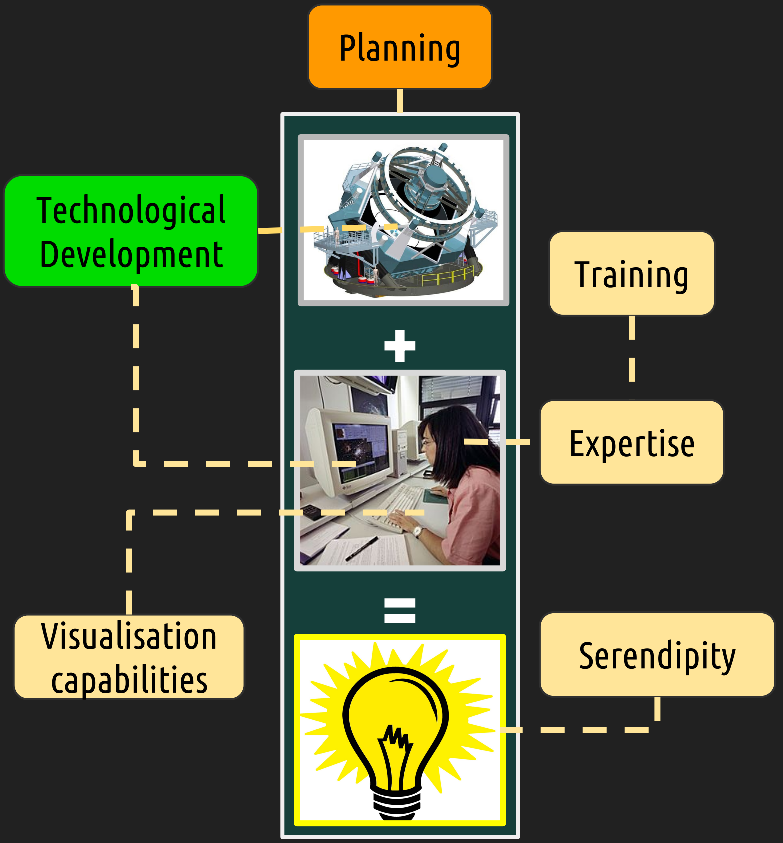

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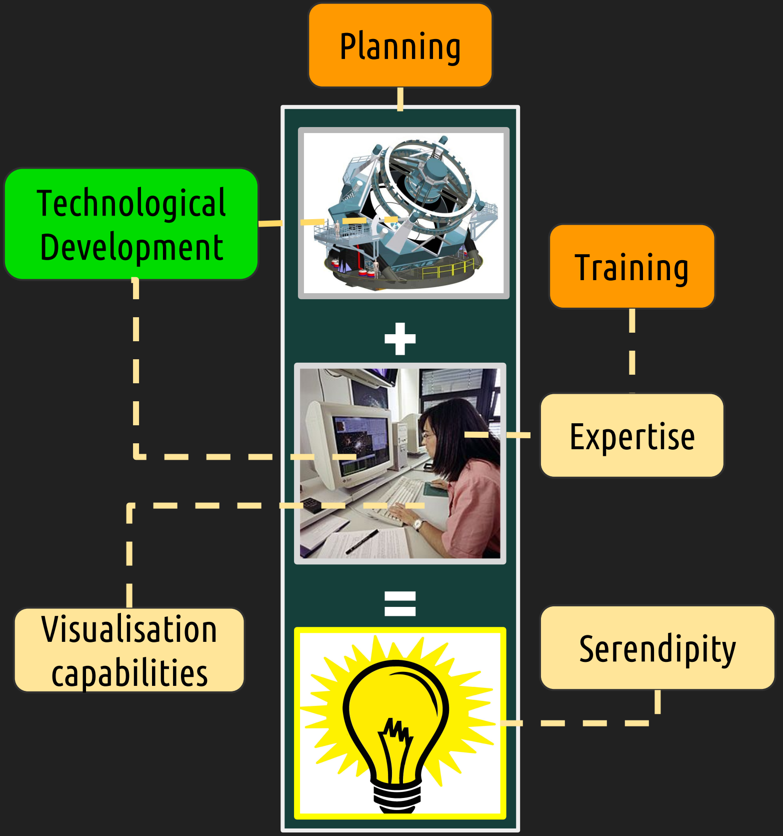

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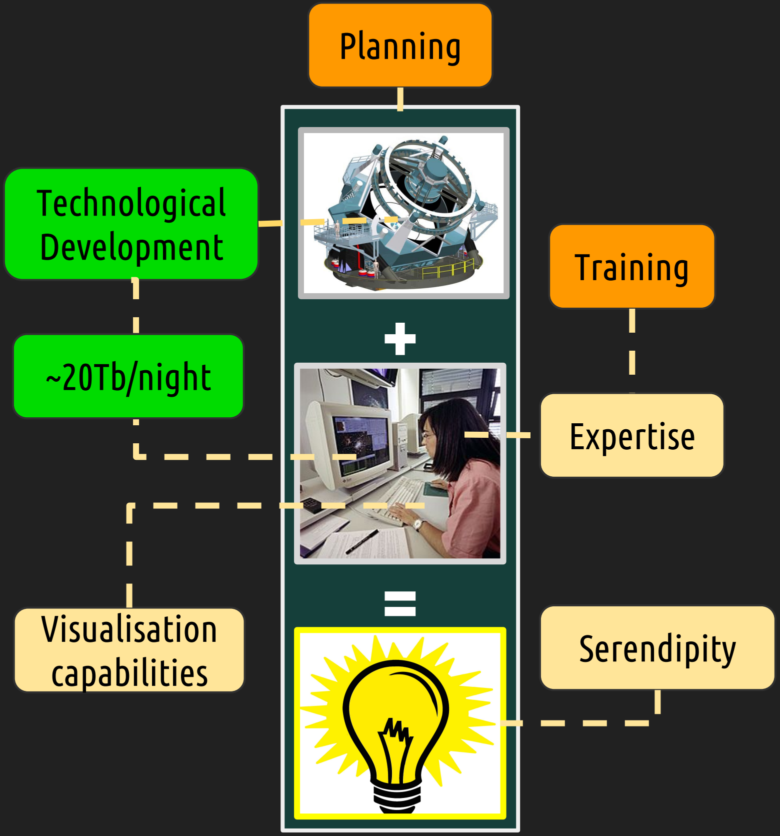

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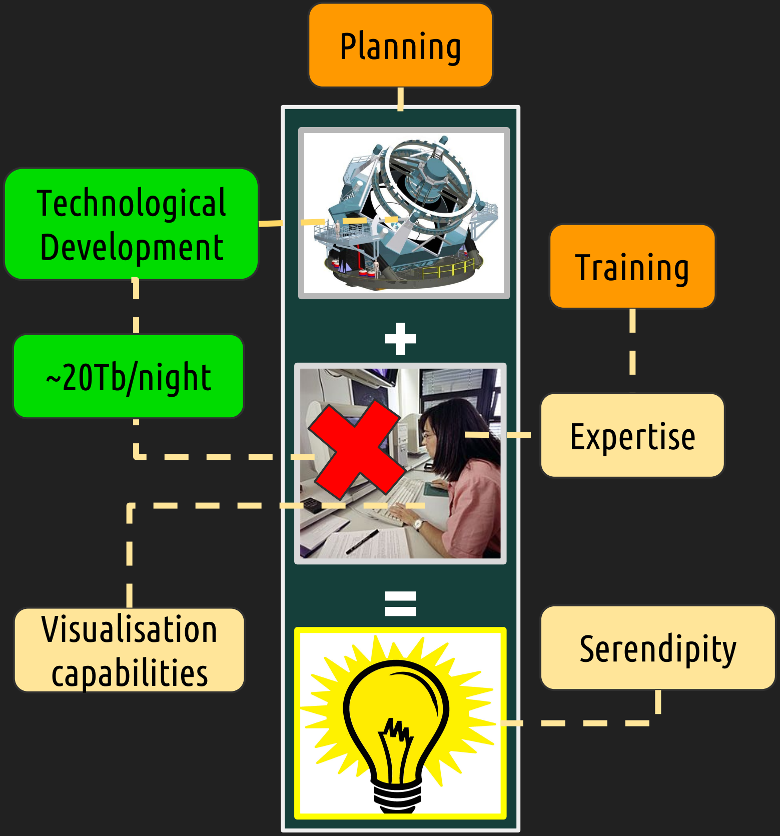

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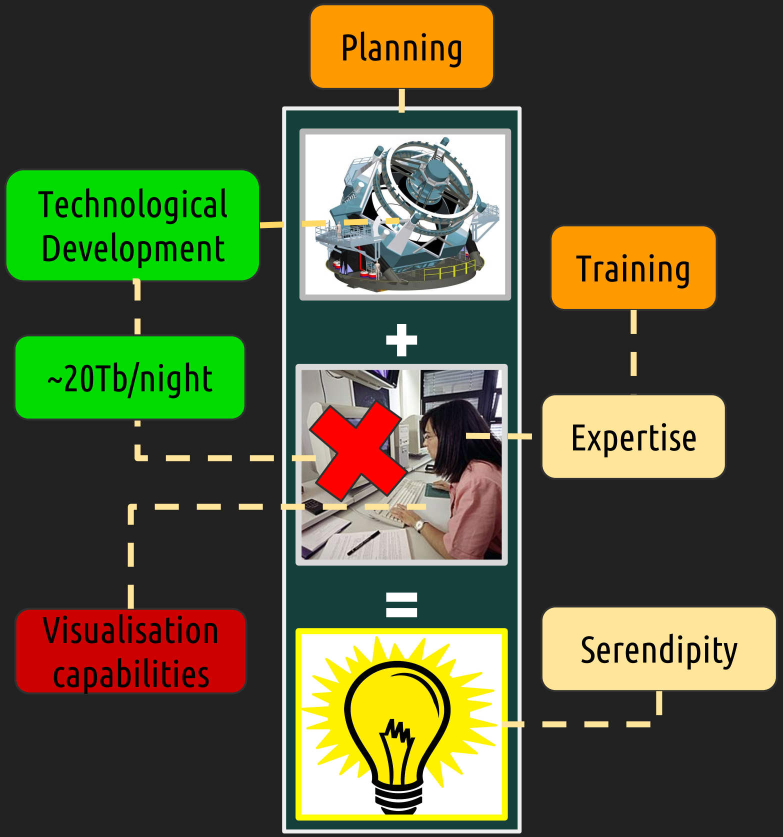

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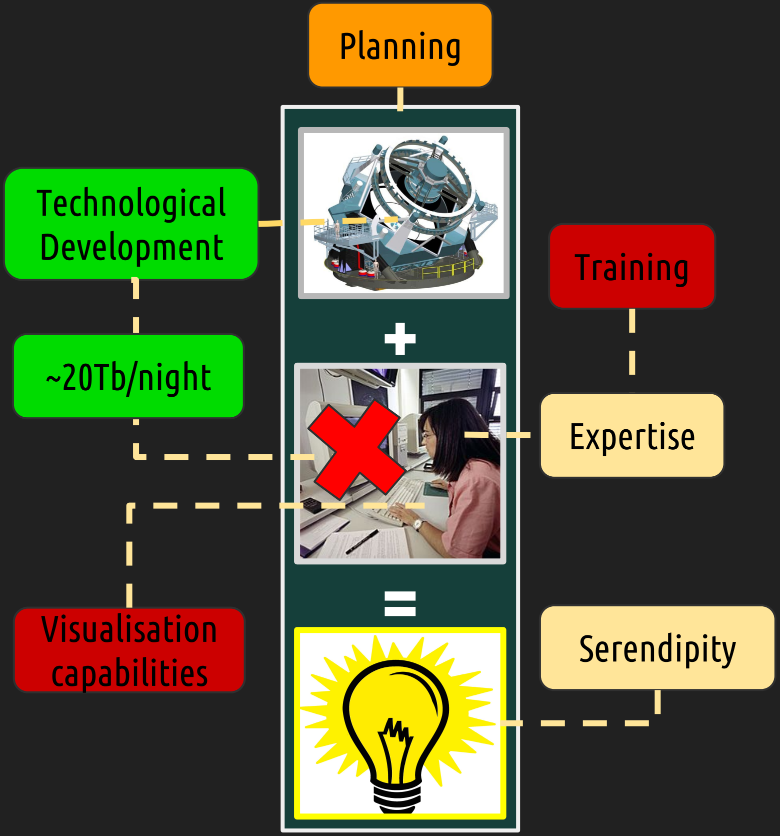

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- Discoveries strongly follow technological developments that open up new parameter space
- Many of the most exciting discoveries are serendipitous
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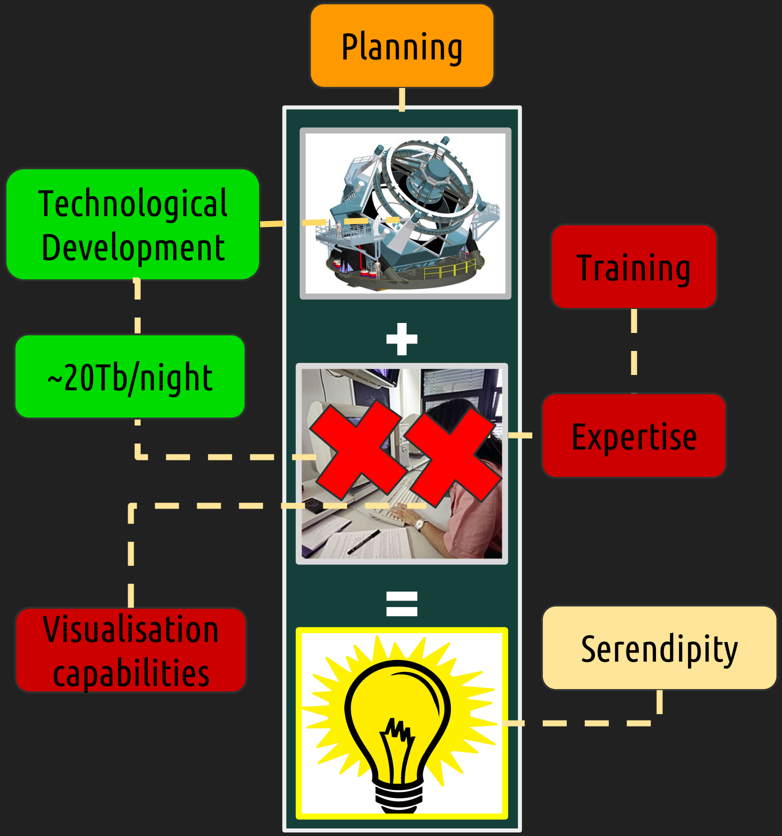
- Discoveries are the end result of effective workflows



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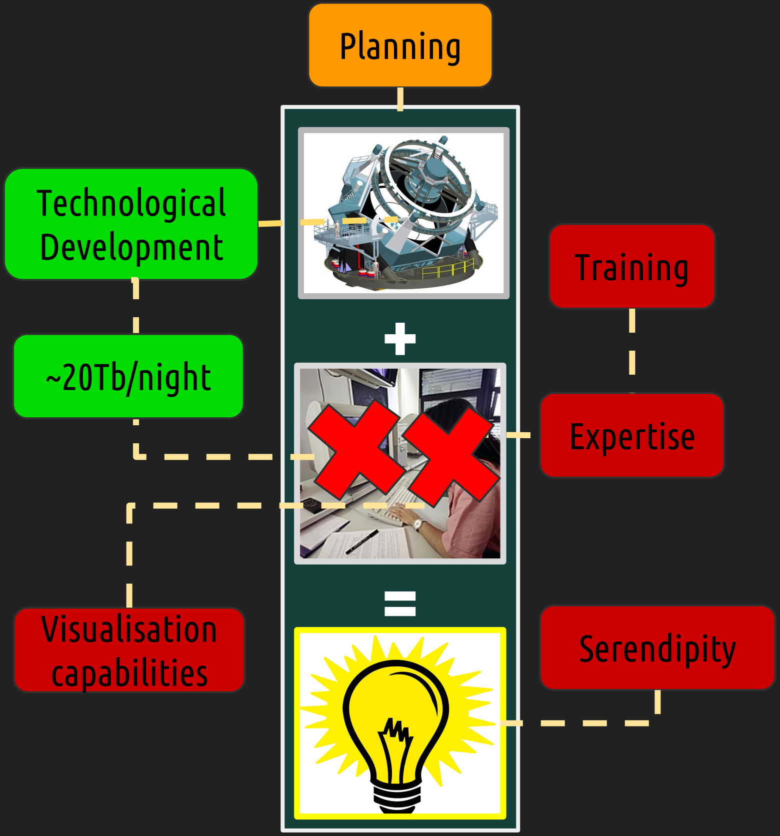

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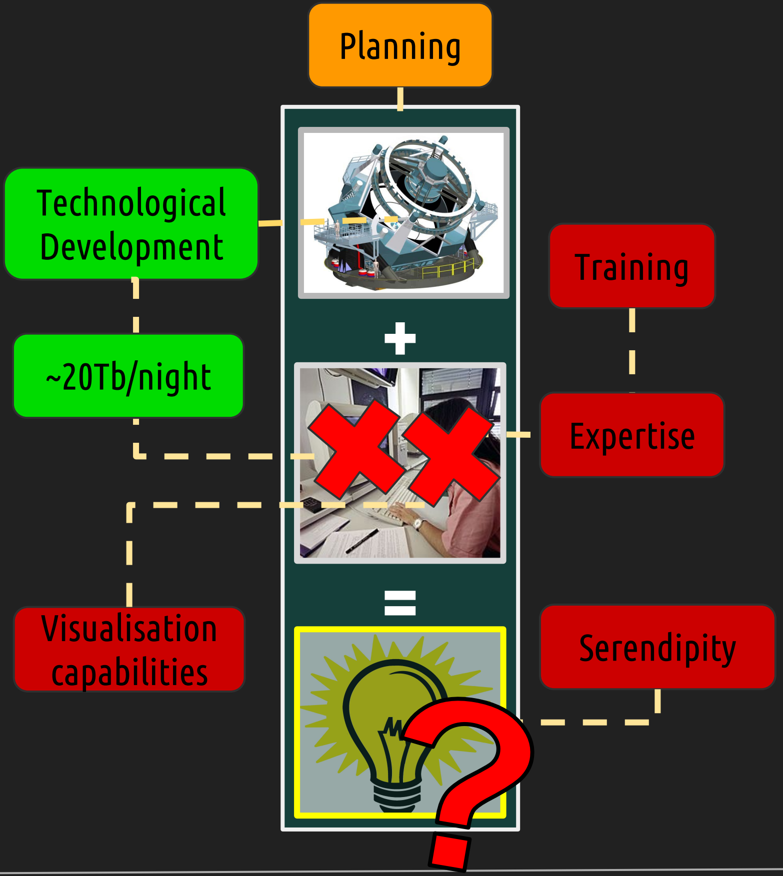


How can we capitalise on the discovery potential of data-intensive astronomy?

→ Understand how we make discoveries

How can we capitalise on the discovery potential of data-intensive astronomy?

→ Understand how we make discoveries

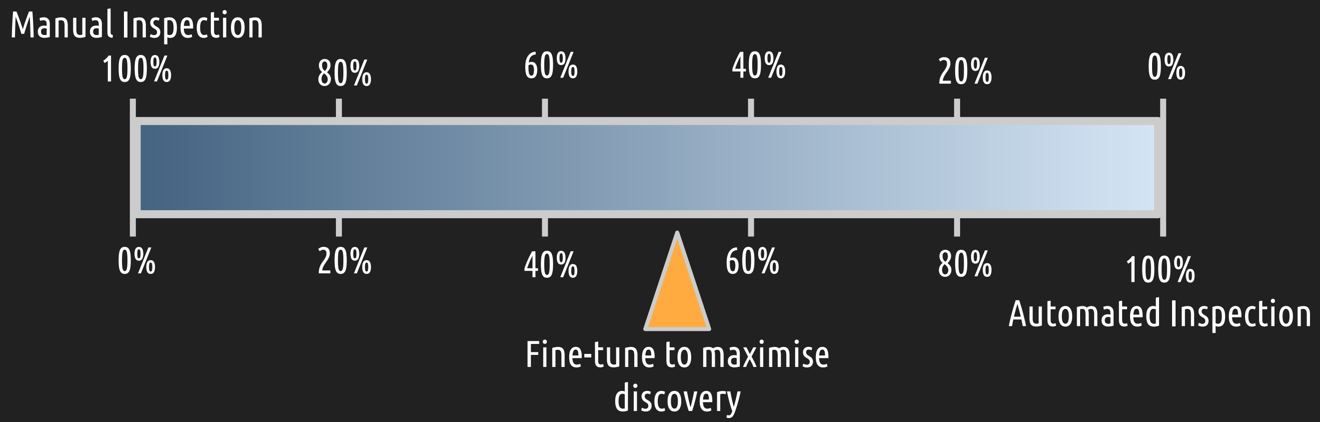
→ Use this understanding to “design in” discovery when we build data-intensive workflows

Designing Effective Discovery Workflows

Automated pipelines and machine-learning approaches are **essential** for data-intensive astronomy

but

We must **integrate** a role for the human astronomer **alongside** automated methods to maintain discovery mechanisms that we know to be important



Adapted from Fluke *et al.* (2016)

Responding to the Data-Intensive Discovery Challenge

Director:
A/Prof Christopher Fluke

Centre for Astrophysics & Supercomputing PhD Students

- **Dr Dany Vohl**
- Ms Sarah Hegarty
- **Dr Bernard Meade**

External Collaborators

- A/Prof David Barnes (Monash)
- **Dr Amr Hassan (Monash)**

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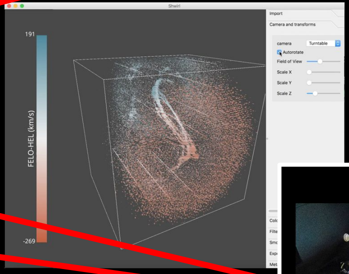
Shwirl

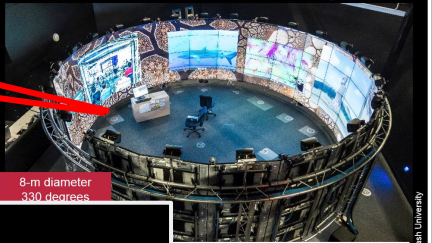
Dr Dany Vohl

Solution: Customised GPU-shaders for astronomy



Vohl, D., **Fluke, C.J.**, Barnes, D.G., Hassan, A.H., 2017, MNRAS, 471, ...

CAVE2@Monash University



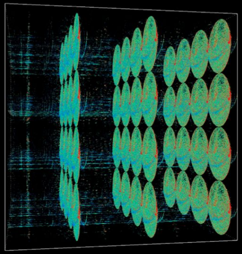
... we accelerate desktop-bound ...ation and analysis workflows?

GraphTIVA

Solution: GPU cluster

Benchmark:

- Swinburne Green II
- 500 GB file loaded on 96 GPUs (NVIDIA C2070) @ 5-7 fps



48 x 11.3GB = 540 GB

1. Hassan, A.H., **Fluke, C.J.**, Barnes, D.G., Kilborn, V.A., 2013, MNRAS, 429, 2442

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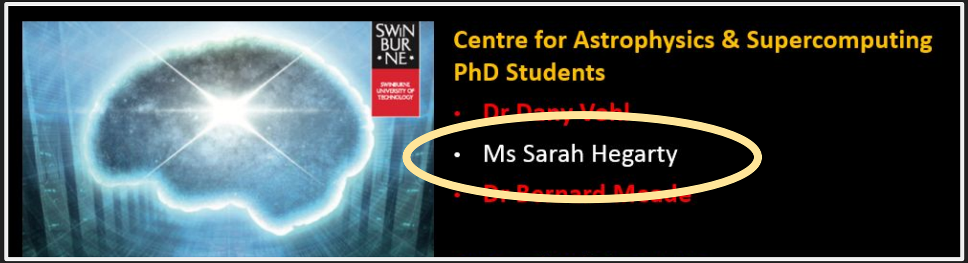

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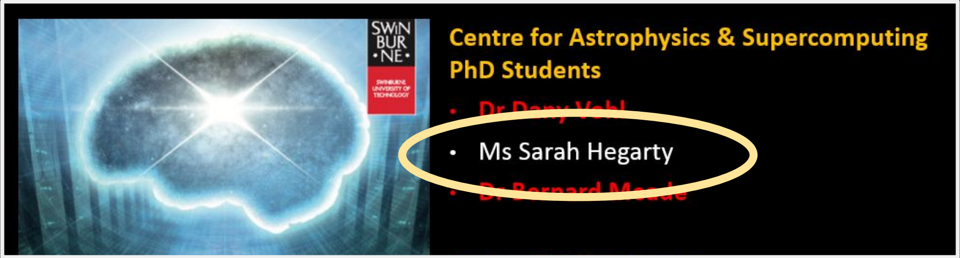
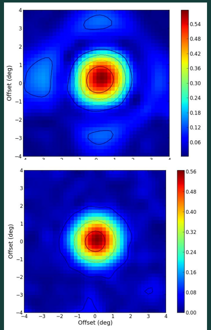


Designing Out Data Artefacts:

Better Beamforming for ASKAP



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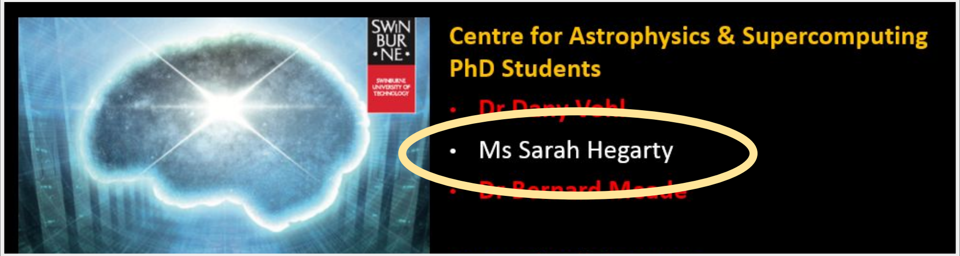

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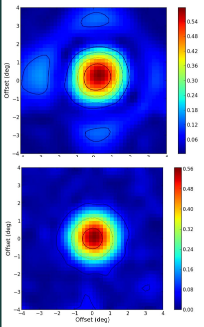

Building eResearch Workflows:

Theoretical Astrophysical Observatory

TAO | THEORETICAL ASTROPHYSICAL OBSERVATORY

and: Deeper, Wider, Faster

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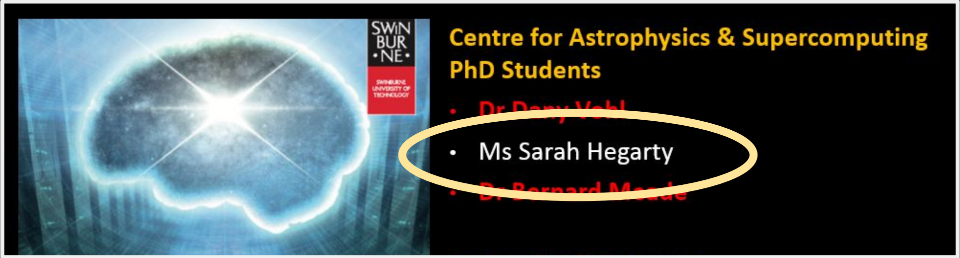

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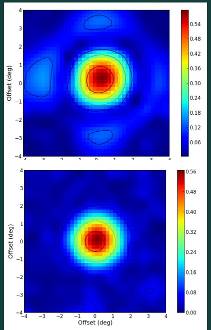

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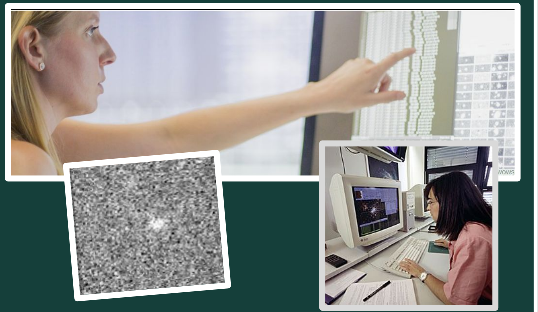
Understanding the Astronomer's Role:

PerSieve



A Case Study: *Deeper, Wider, Faster*

A detection and follow-up program for **fast** transients (Cooke+, in prep.)

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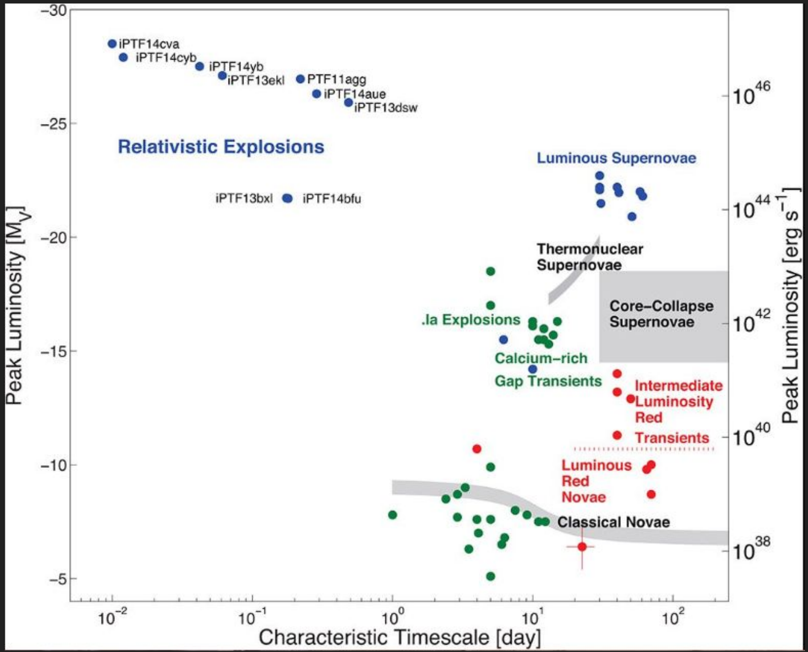

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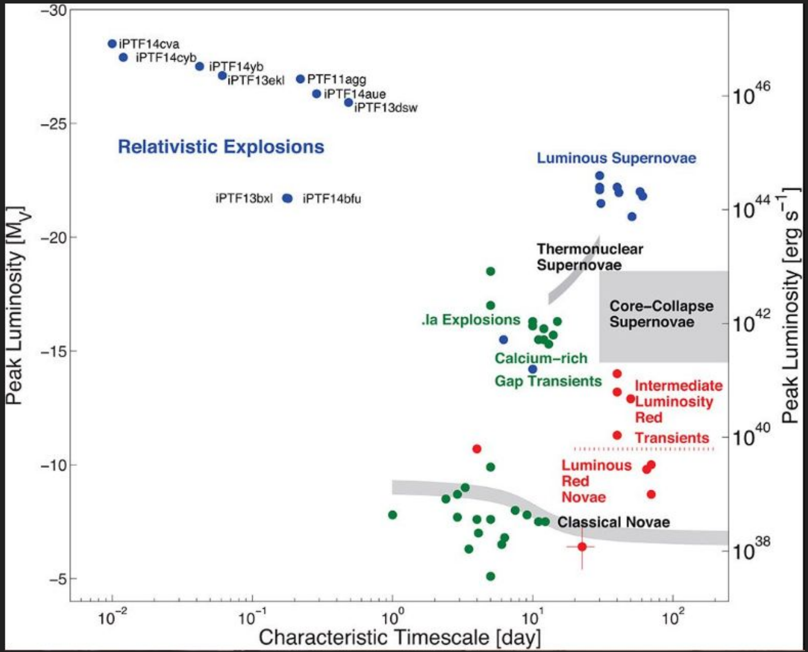

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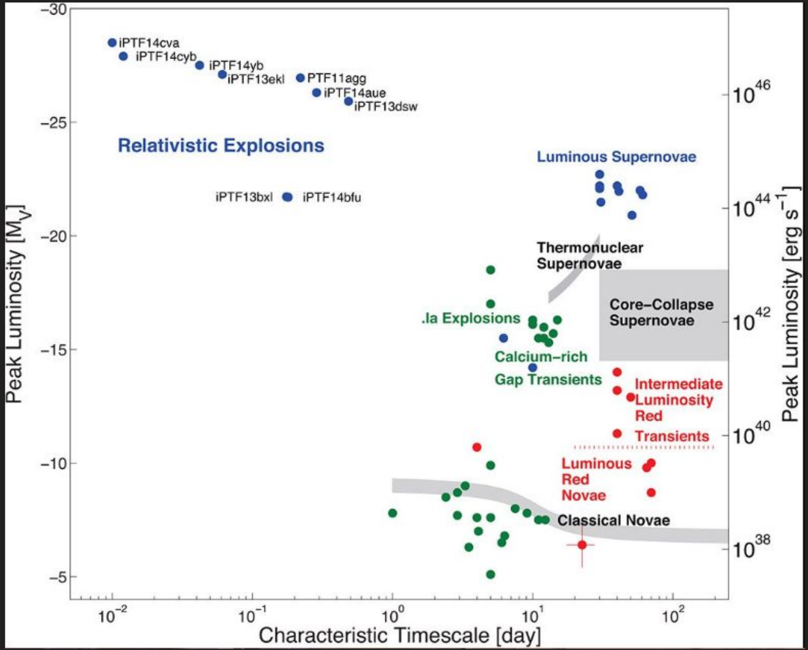

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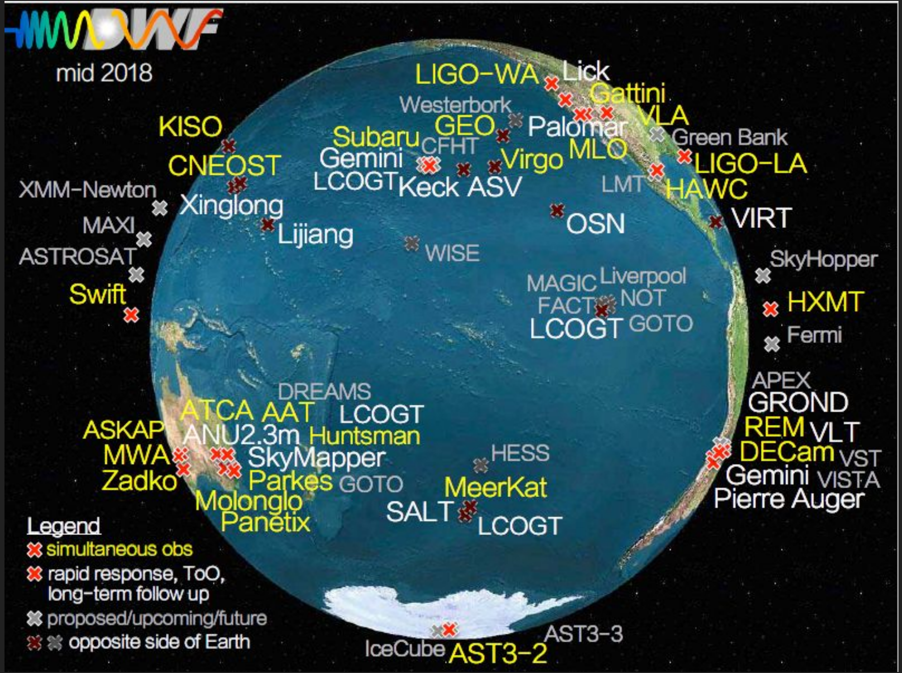

Courtesy J. Cooke

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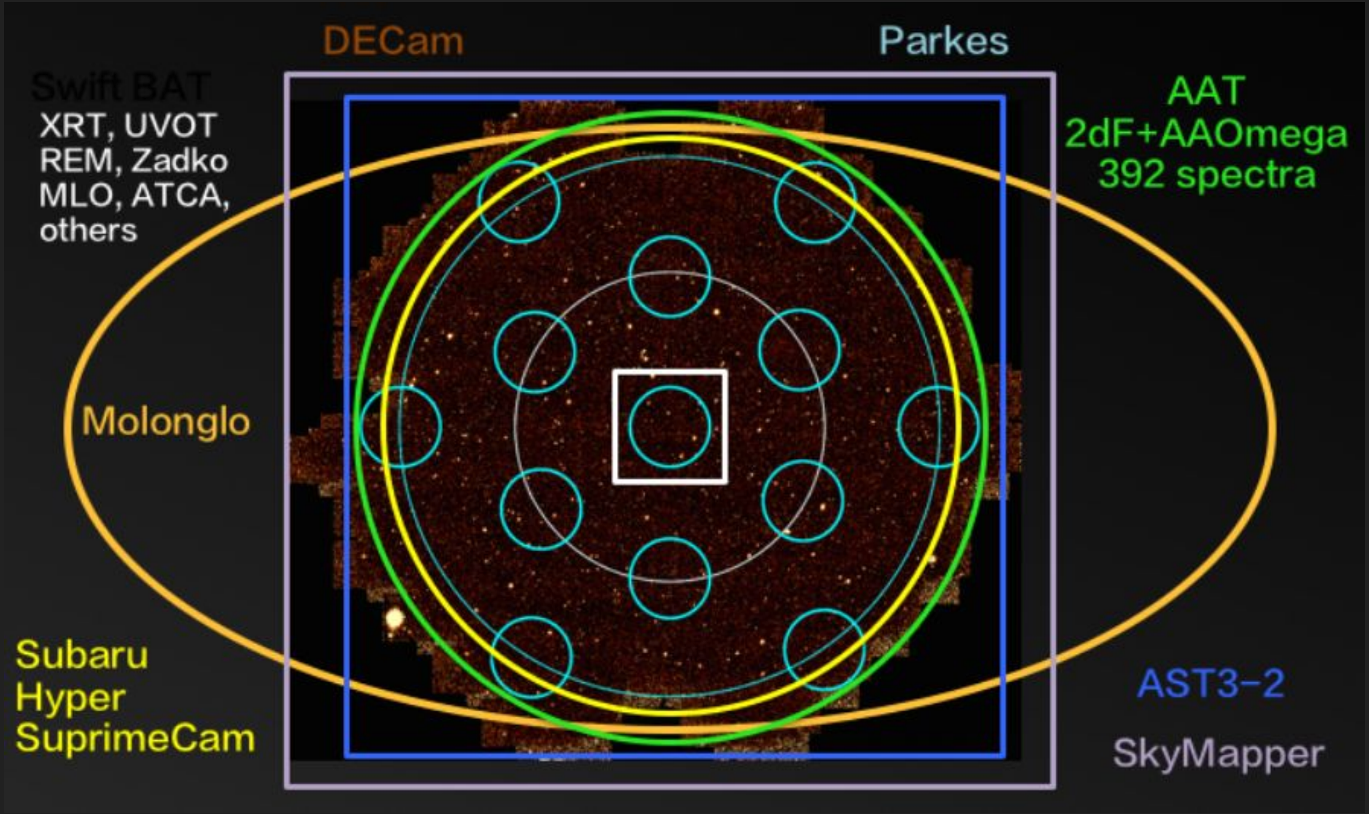

Andreoni & Cooke, 2018

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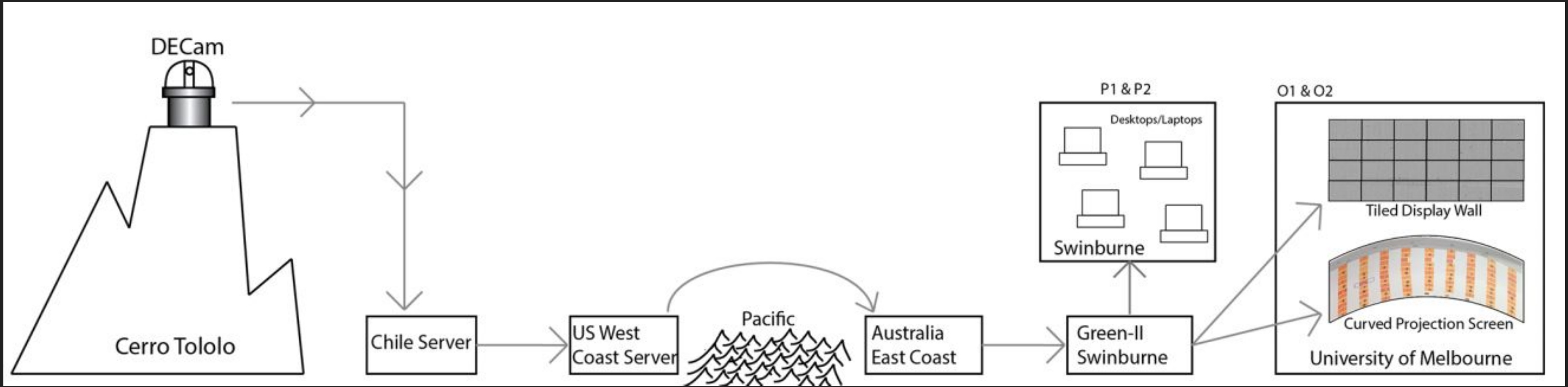
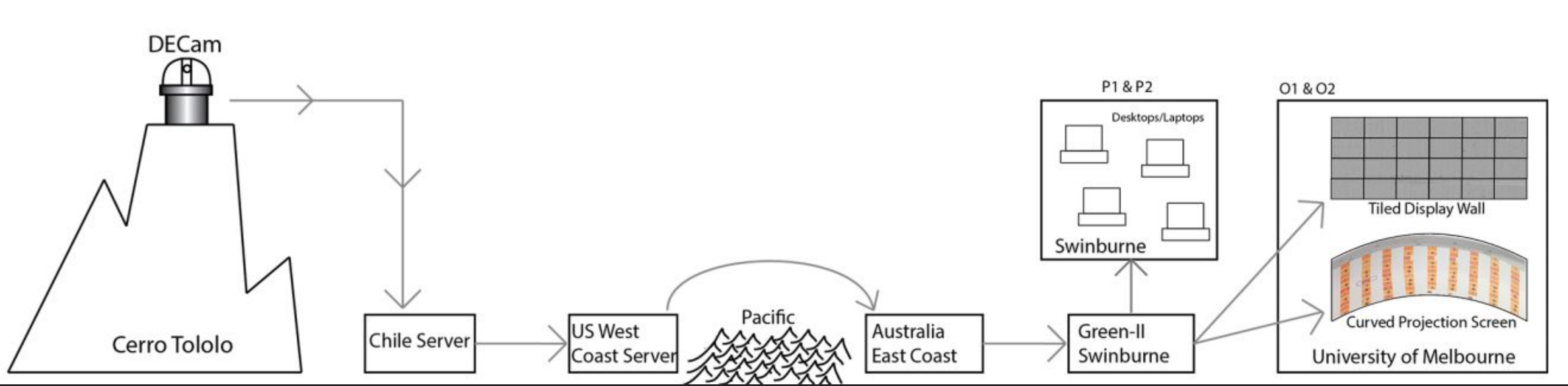


Figure: Meade+, 2017

A Case Study: *Deeper, Wider, Faster*

3 square degree FOV



~60 CCD images / 40 seconds
2048 x 4096 pixels each

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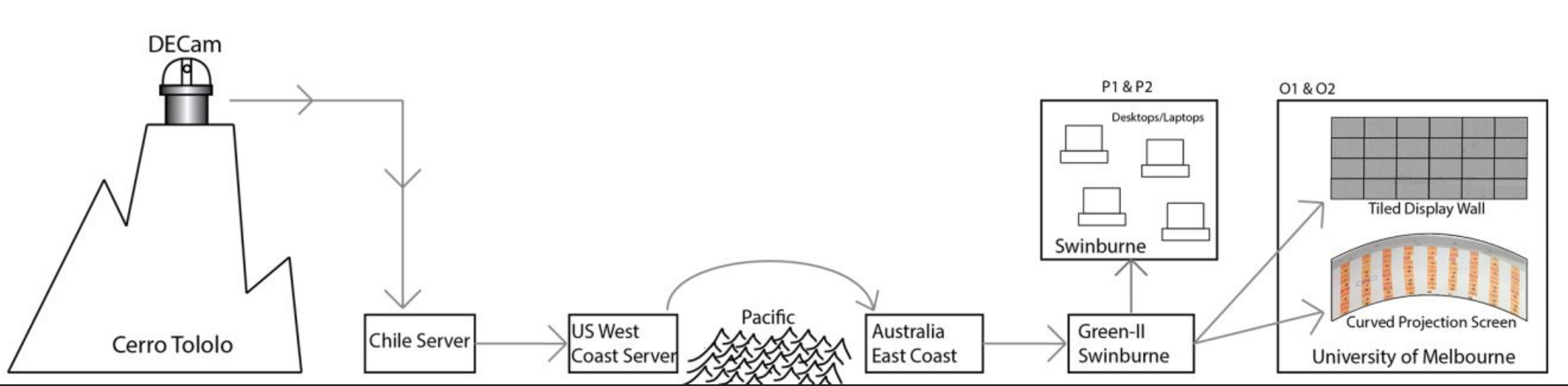

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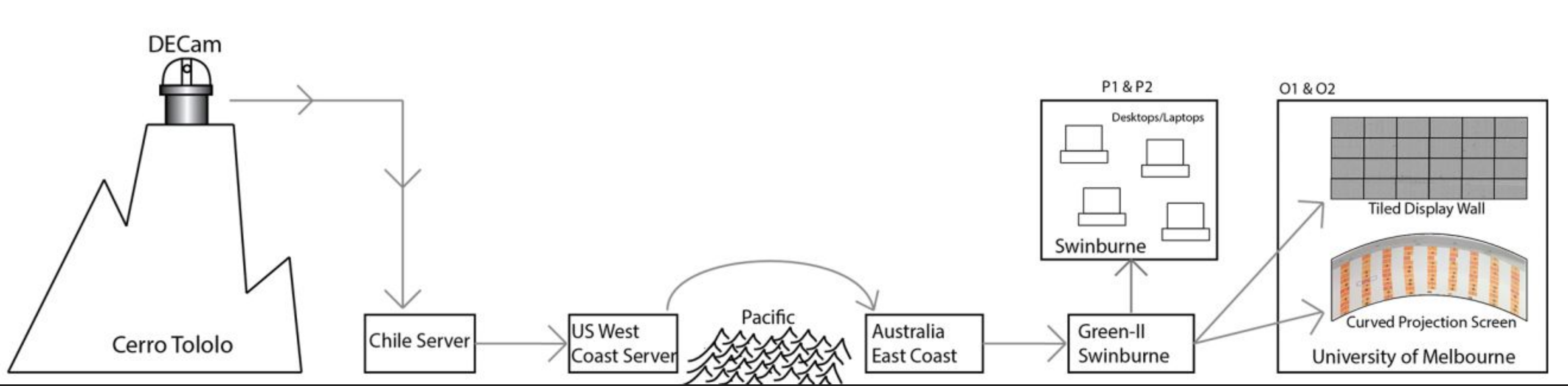

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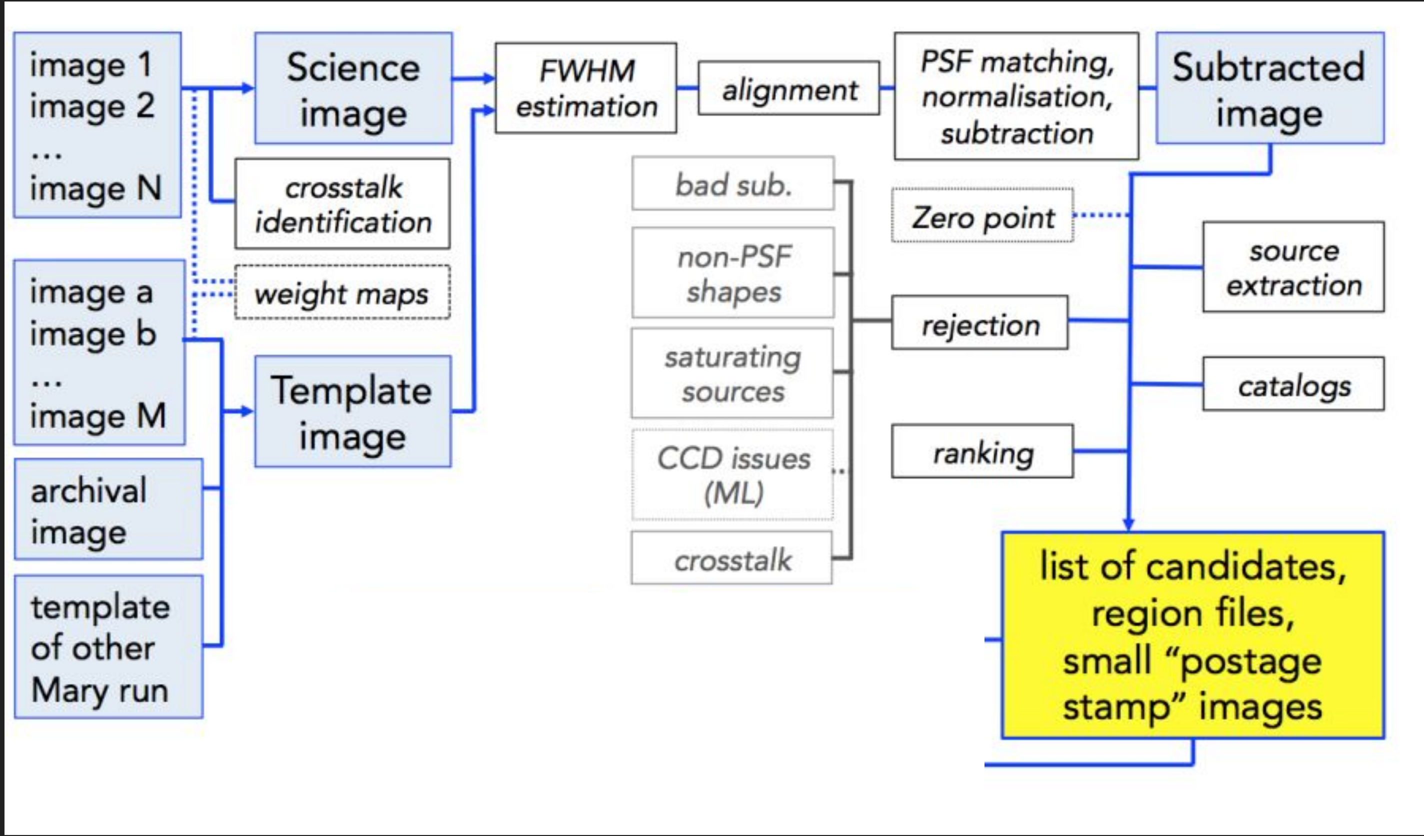

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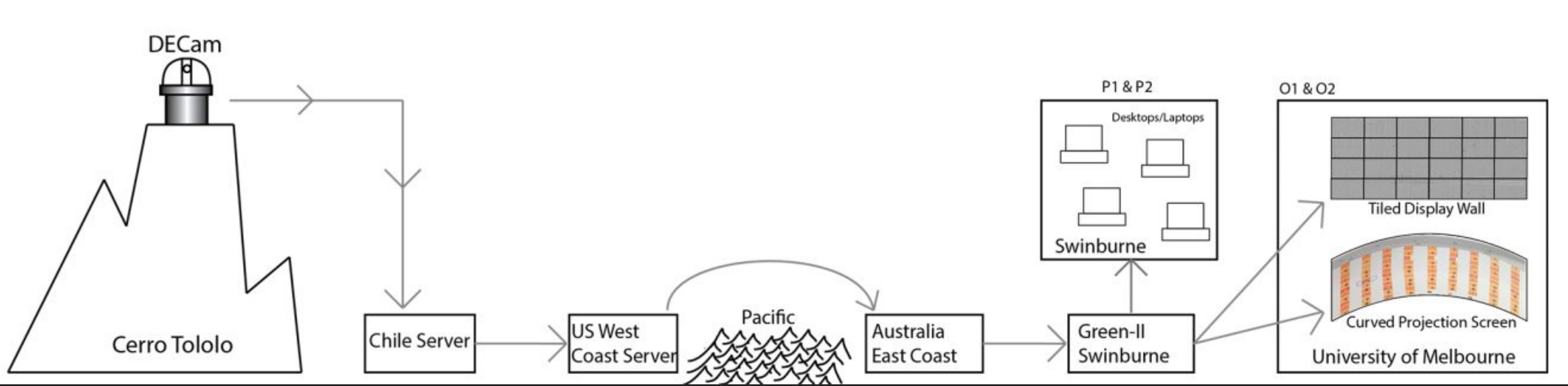
Visual inspection by volunteer astronomers



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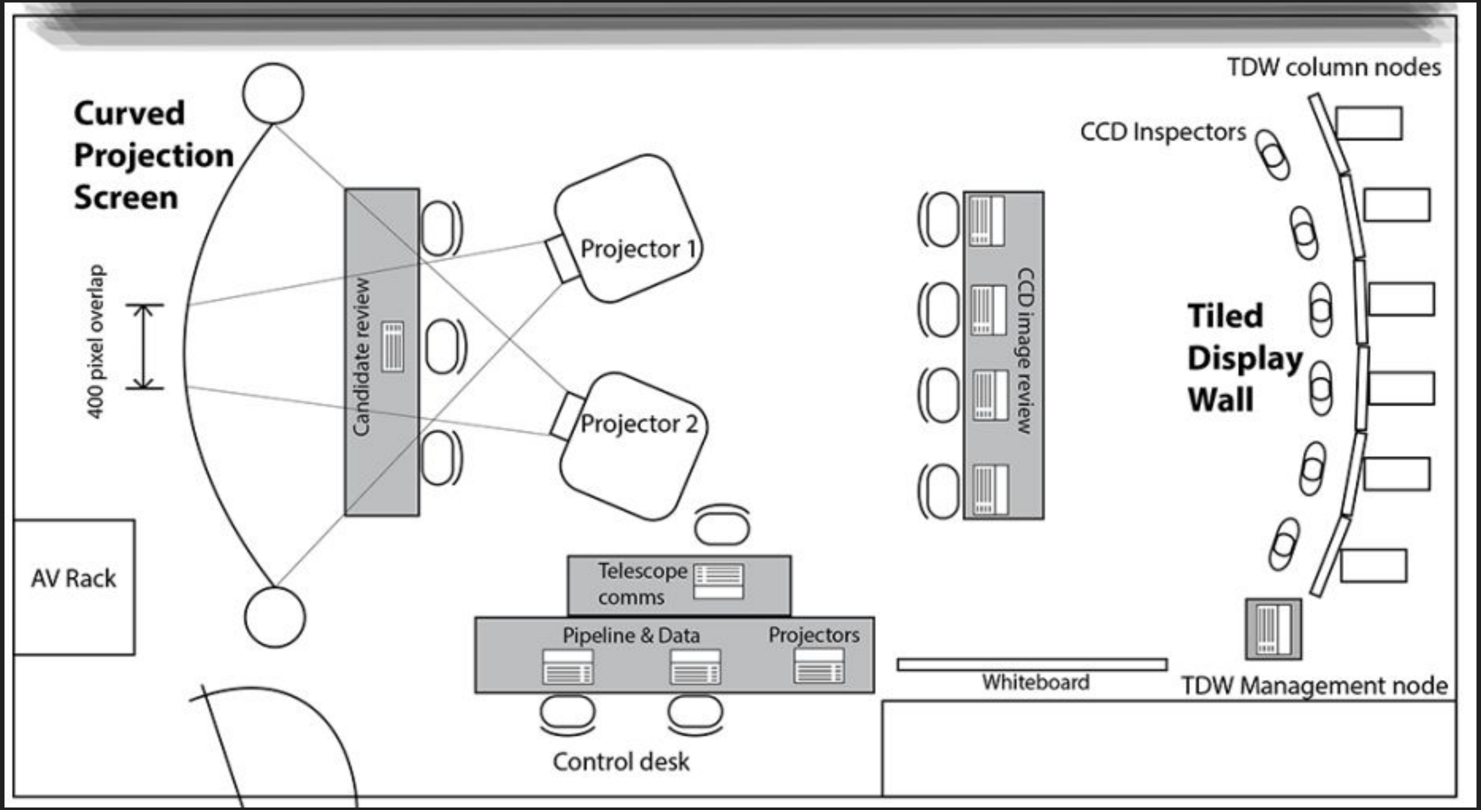

Meade+, 2017

A Case Study: *Deeper, Wider, Faster*

Photos courtesy B. Meade

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Photos courtesy B. Meade

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Photos courtesy B. Meade

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- ❏ Continue capitalising on the expertise and crucial discovery skills of these astronomers
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- ❏ Better understand the discovery process itself

Photos courtesy B. Meade

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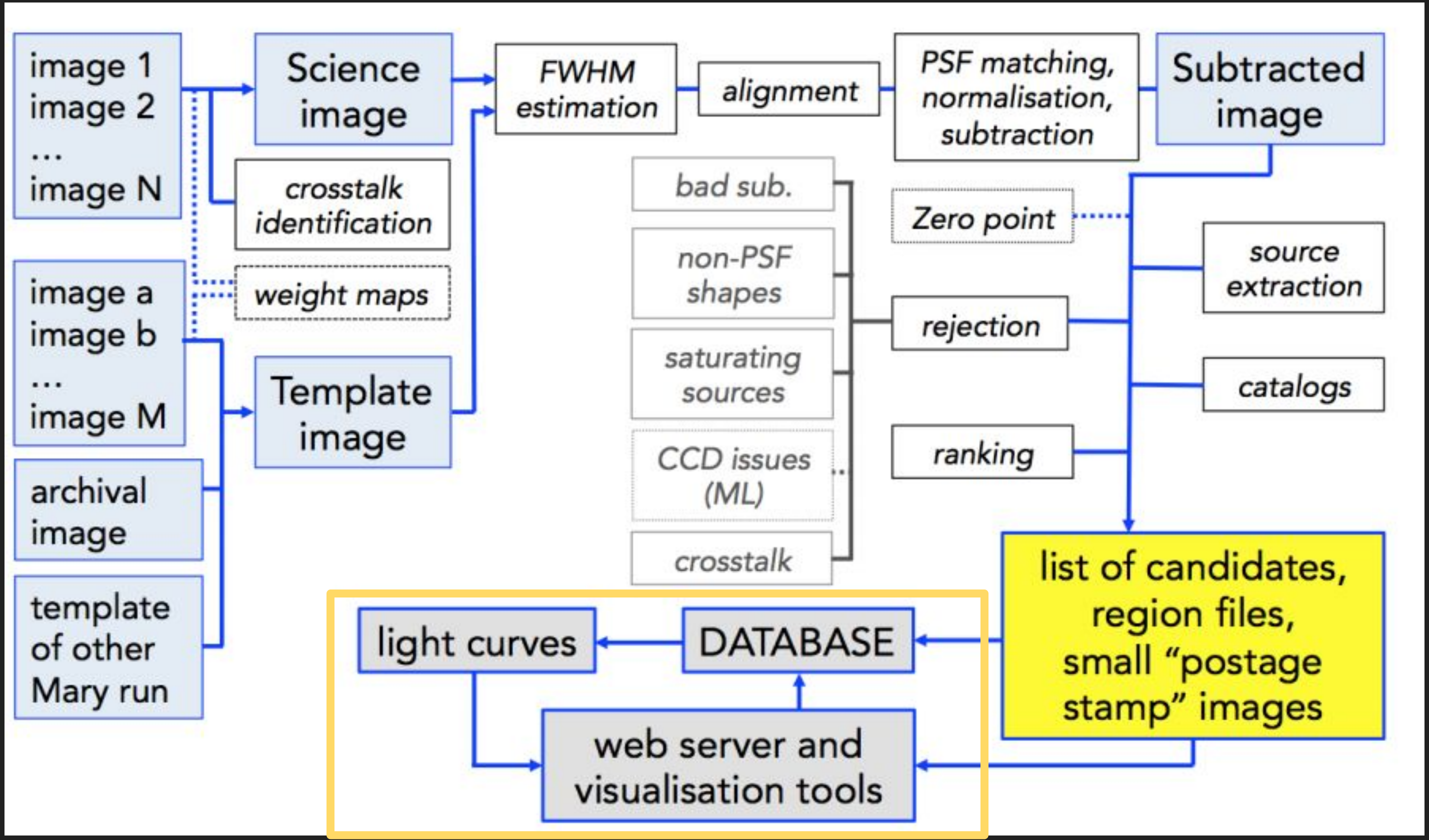

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PerSieve

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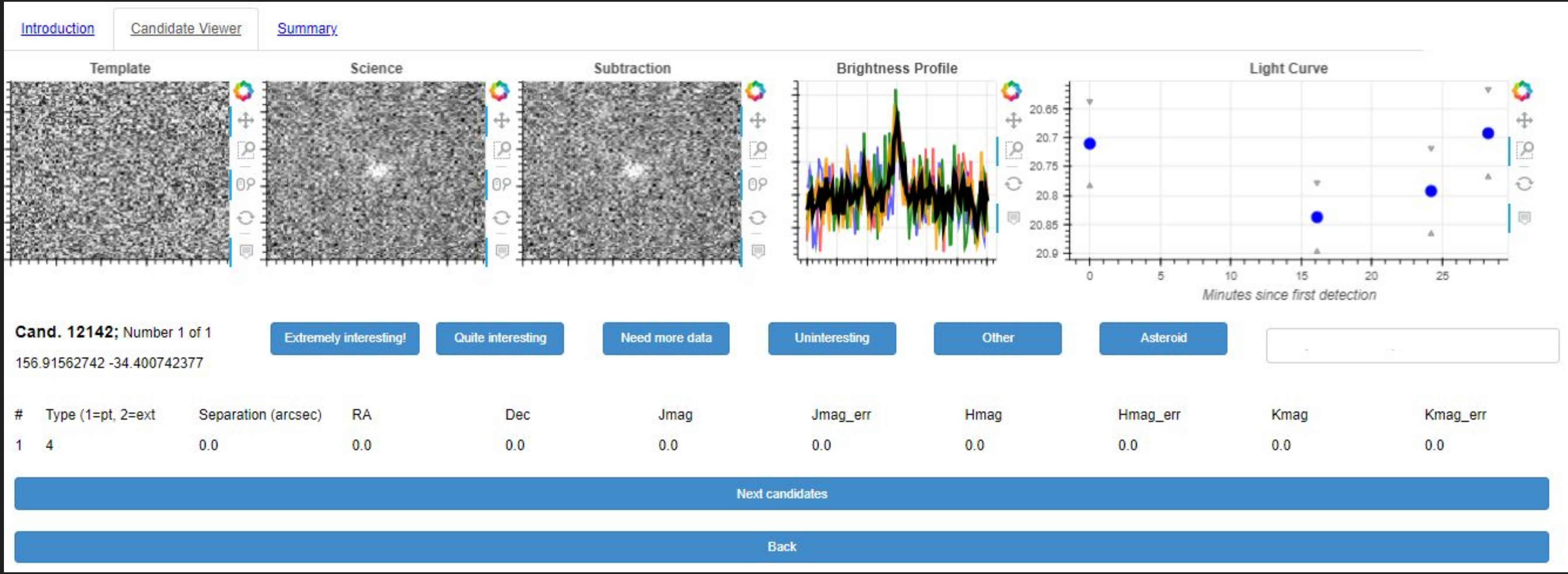

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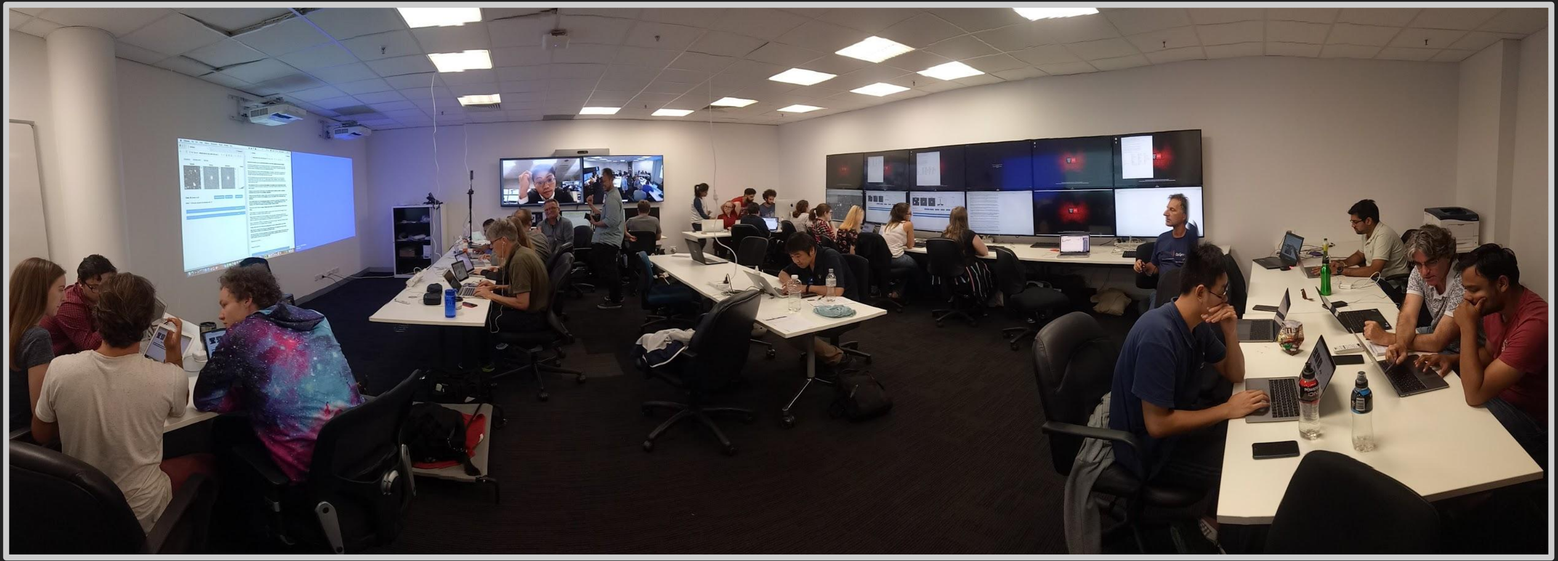

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>14,000 transient candidates assessed!

Studying the February 2018 DWF Observing Campaign

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I also captured detailed analytics of the volunteers’ work and decision making processes*

*With the approval of the Swinburne Human Research Ethics Committee, and the informed consent of all participants

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→ What do they look at?
→ How do they look at it?
→ What evaluations do they make?

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→ **What can we learn about expertise?**

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STUDYING THE FEBRUARY 2018 DWF OBSERVING CAMPAIGN

- Each interaction with the data, and the web framework, was tracked in detail
- Volunteers self-rated their astronomical expertise: Novice/Intermediate/Expert
    - Almost 19,000 total ‘decision workflows’ were captured
    - 21 ‘novices’ assessed ~3700 transient candidates between them
    - 8 ‘intermediates’ assessed ~630 transient candidates between them
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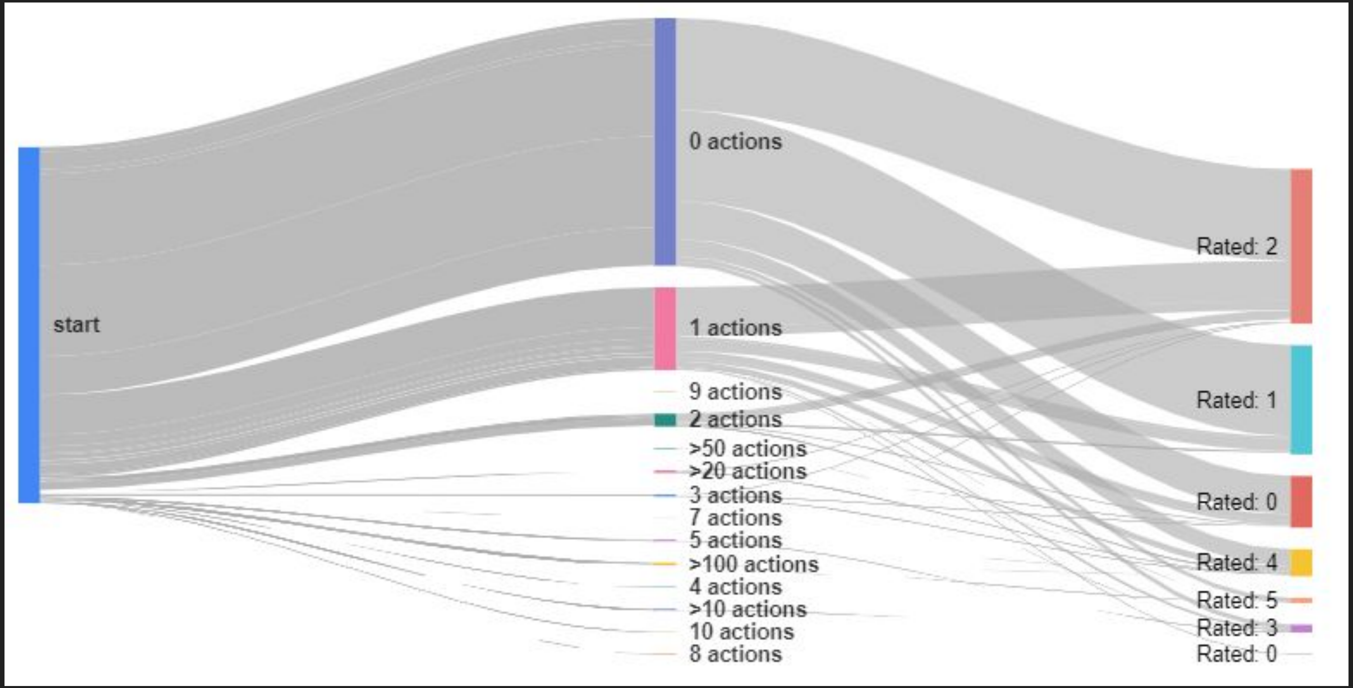
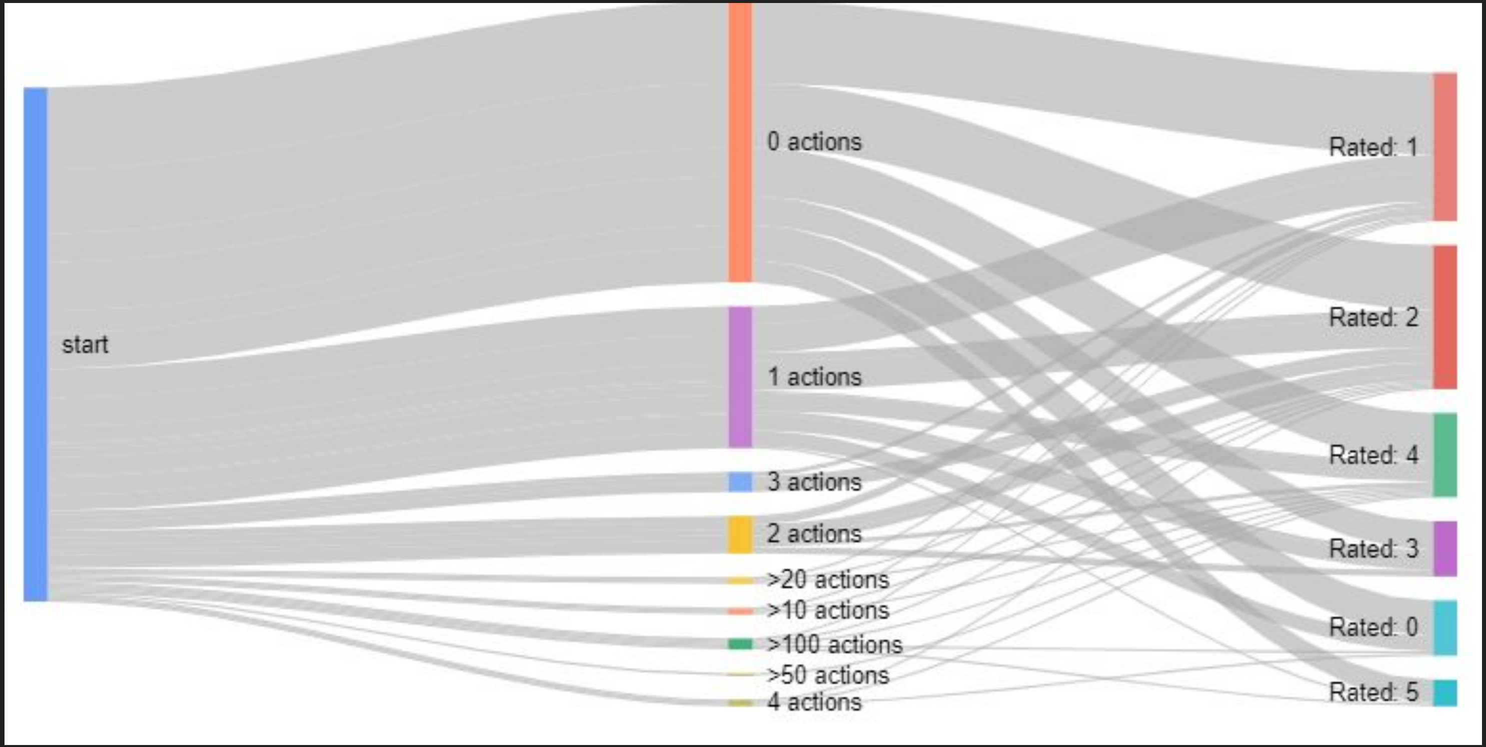


Flow diagram of ‘Novice’ workflows: interactions made with the data and final object ratings from 0 (least interesting) to 5 (most interesting)

Studying the February 2018 DWF Observing Campaign



Flow diagram of 'Intermediate' workflows: interactions made with the data and final object ratings from 0 (least interesting) to 5 (most interesting)

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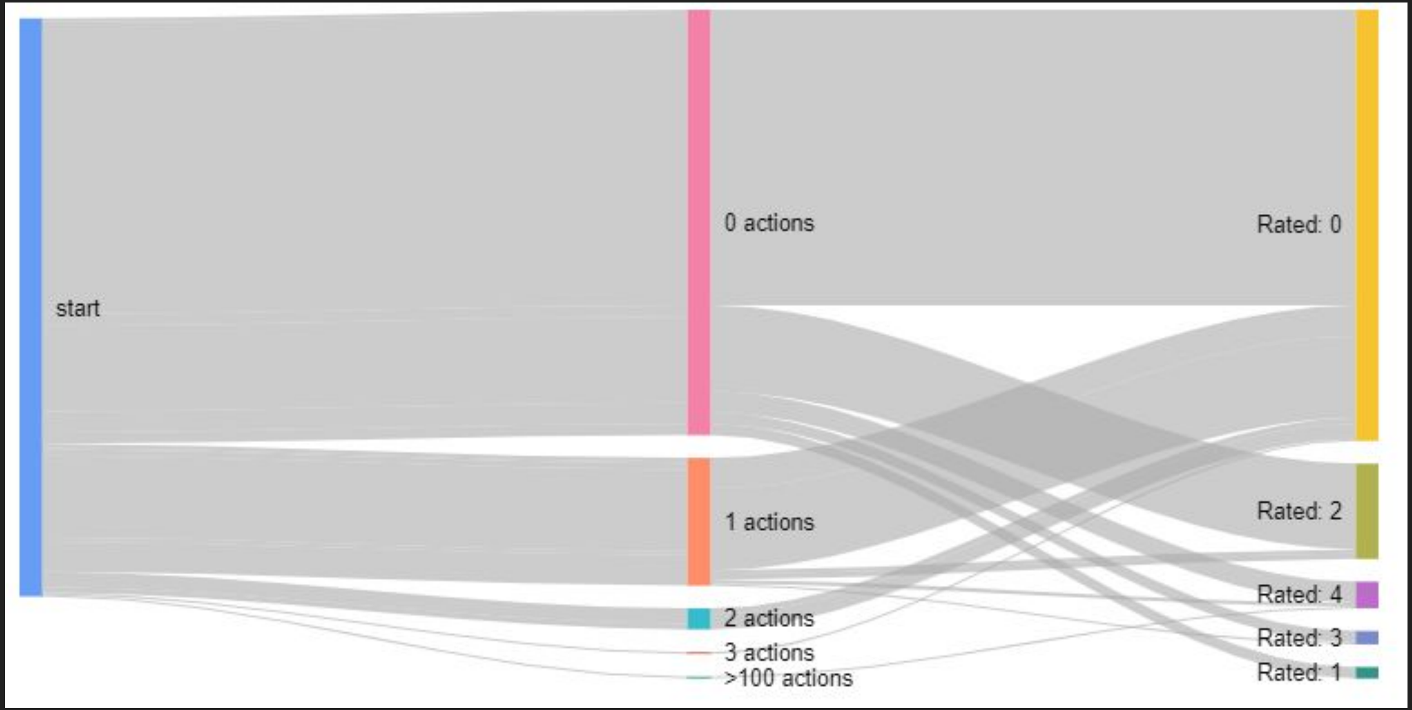

Flow diagram of Expert workflows: interactions made with the data and final object ratings from 0 (least interesting) to 5 (most interesting)

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- This data is enabling a range of different analyses of how human astronomers make discoveries
- We can use this knowledge to help build the human factor into other workflows
- Outside astronomy, this project is also guiding research into data-driven decision making (collaboration with Dr Clare MacMahon, Dr Lisa Wise, and teams)

Summary

- The data intensive era will offer us unprecedented discovery potential: but it will also challenge our existing ways of making discoveries
- We need to “design in” discovery capabilities as we develop our workflows for the era of data-intensive astronomy
- Keeping the astronomer “in the loop” is a valuable way to make this happen, as we have demonstrated using PerSieve within the *Deeper, Wider, Faster* project
- We are using this platform to study the astronomer *in situ*, and learn even more about how they work and make decisions
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