Supercomputer 'Bura' as a computing facility for time-domain astrophysics

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Vera C. Rubin Observatory

→ conduct 10-year **Legacy Survey of Space and Time (LSST)**

- 8.4 m telescope (Cerro Pachon, Chile)
- 3.2 Gpx camera
- Survey: 10 000 deg^2 every 3 nights (in avg)
- 6 bands: ugrizy, 300 – 1050 nm
- r ~ 27.5
- Big Data: TB → PB

(Rubin Obs/NSF/AURA)

Synergy with other surveys

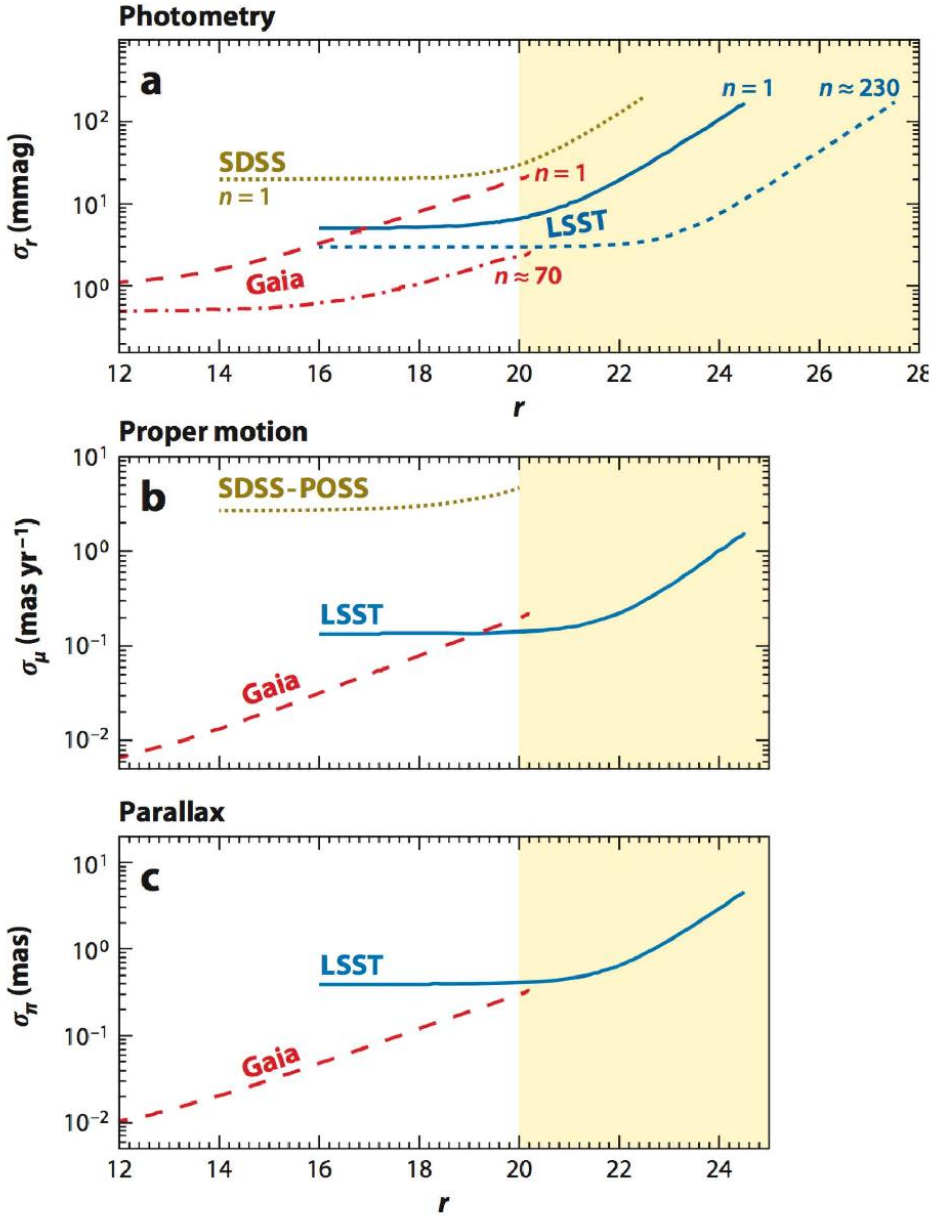
Gaia (parallax and proper motion)

Pan-STARRS

DES

WISE (infrared observations)

ZTF (light curves of variable stars)



(Ivezic et al. 2014)

International participation

1. Institutional members (37 institutions from USA, Chile, France, Italy, Japan, Germany, Czech Republic, UK)
2. **International affiliates** → In-kind contribution and Data rights holder

Croatian Participation Group @ LSST (CRO-RBI in-kind contribution)

1. Institute Ruđer Bošković, Zagreb (group leader Lovro Palaversa)
2. University of Zagreb (Hvar observatory)
3. University of Rijeka (Faculty of Physics)

Scientific collaborations

CPG is active in (but not exclusively focused to):

1. **Transients and variable stars** (TVS)
2. Stars, Milky way and local volume (SMWLV)

Computer resources in-kind contribution

IDAC (International Data Access Centre)
SPC (Software processing centre)

- Dedicated computer resources for CPU(GPU)-intensive analysis & processing
- Demands for CPU(GPU) power, lower disk storage → HPC (high-performance computing) facility

Software processing centre

HPC 'Bura' at University of Rijeka as SPC:

1. Contribution with substantial amount of CPU-hours for (mainly) stellar astrophysics

2. Cooperation with Slovenian data access centre in Maribor

3. Astrophysicist domain support

4. Analysis of large amount of data + small-scale computing of individual groups

5. Not suited for development (no Jupyter notebooks)

"Bura" supercomputer

High performance computing facility → top 500

Rmax:	233.565 TFlop/s
Rpeak:	287.539 TFlop/s
Peak Power (kW):	108.48
Processor:	Xeon E5-2690v3
	(12 cores @ 2.6 GHz)
Cores per Node:	24
Nodes:	288

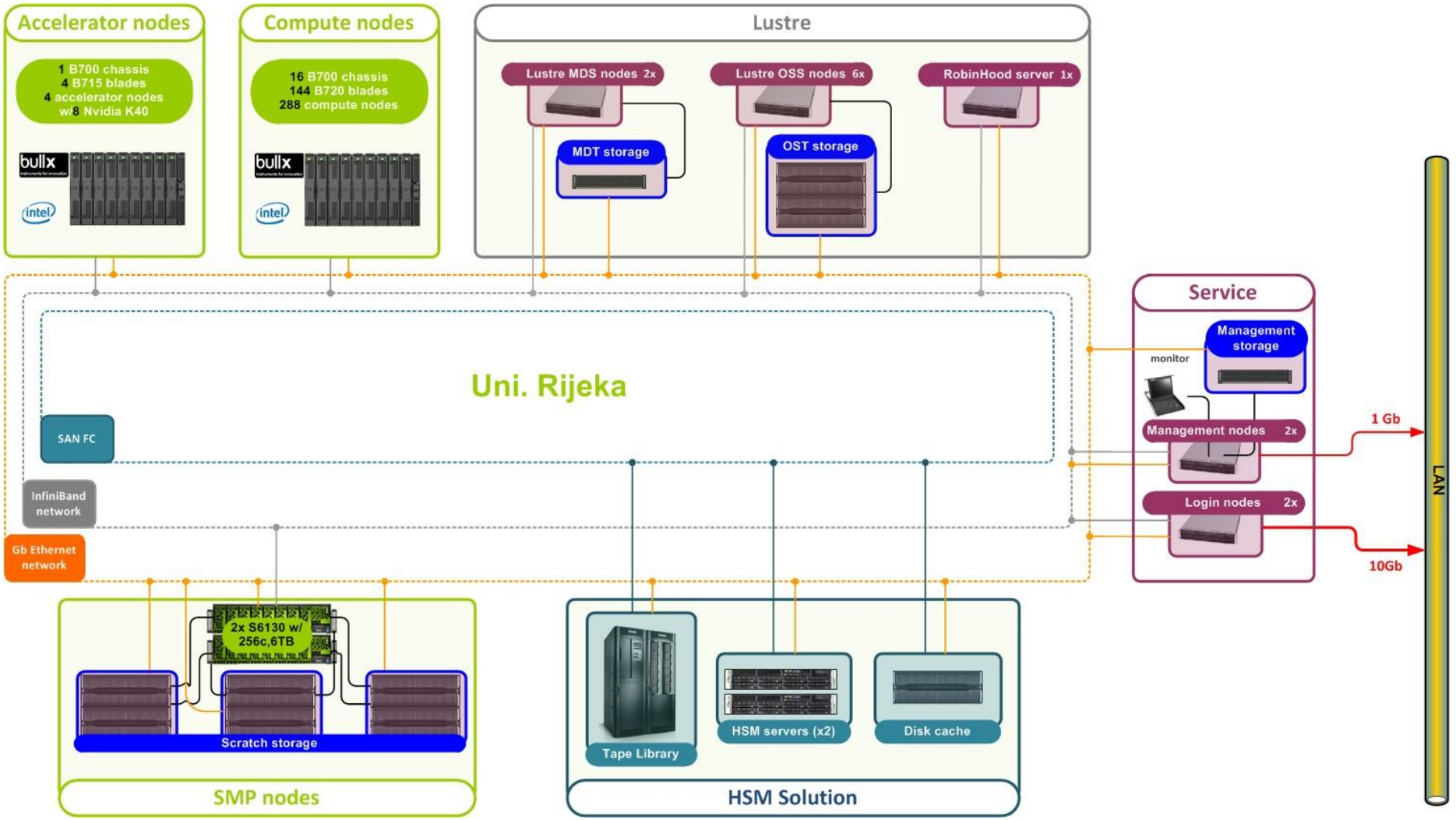
Center for Advanced Computing and Modelling

TOP 500 The List. **440**

THE GREEN 500 **175**

HPCG **48**

Schematic Architecture



HPC resources @ Bura

Cluster (compute nodes)

- 288 nodes, 2 x Xeon E5-2690 (12c 2.6 GHz)/node, 24 cores/node → **6912 cores**
- **64 GB** memory/node, **320 GB** disk space/node → **18 TB total memory, 95 TB total disk space**

SMP (2 nodes)

16 x Xeon E7-8867 (16c 2.5 GHz)/node → **512 cores, 12 TB total memory, 245 TB total disk space**

GPGPU (4 accelerator nodes)

Each node: 2 x Xeon E5-2650 CPUs (8c 2.6 GHz) + 2 x Nvidia TeslaK40, 64 GB memory, 320 GB disk space

OS

Redhat Linux + Slurm Workload Manager

Data centre:

1 PB (Lustre scratch file system)

Archive: 2.5 PB (tape library)

Disk storage extension through **regional LSST cooperation grant** (Heising-Simons Foundation, 'Preparing for Astrophysics with LSST Program')

Science cases (possible and running)

Reported computational needs for LSST-related science (2023 survey, only active members of science collaborations):

- 100 M CPU-hours in total
- **35 M CPU-hours** for transients & variable stars
- 35 PB-years disk storage in total
- **12 PB-years disk storage** for transients & variable stars
- expected to rise by an order of magnitude

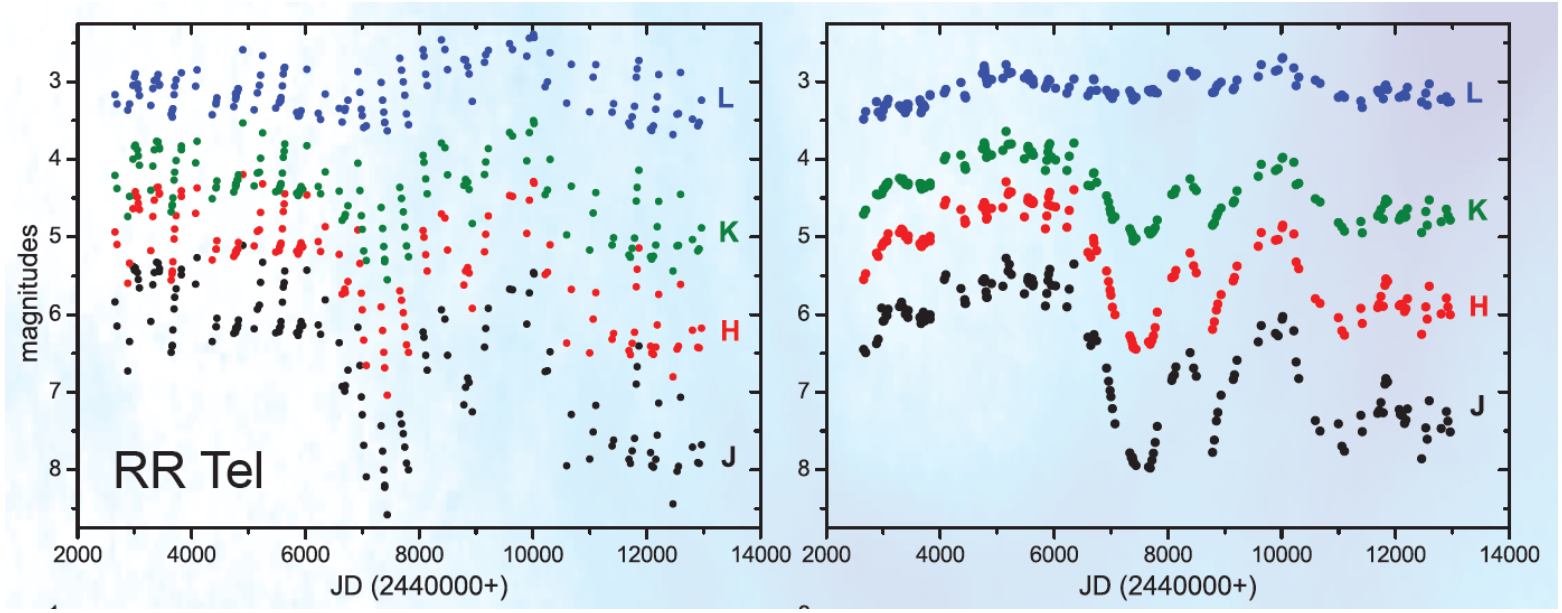
HPC 'Bura' is planned to host **object table** (50-75 TB) and offer **2 M CPU-hours/year** for LSST related computations

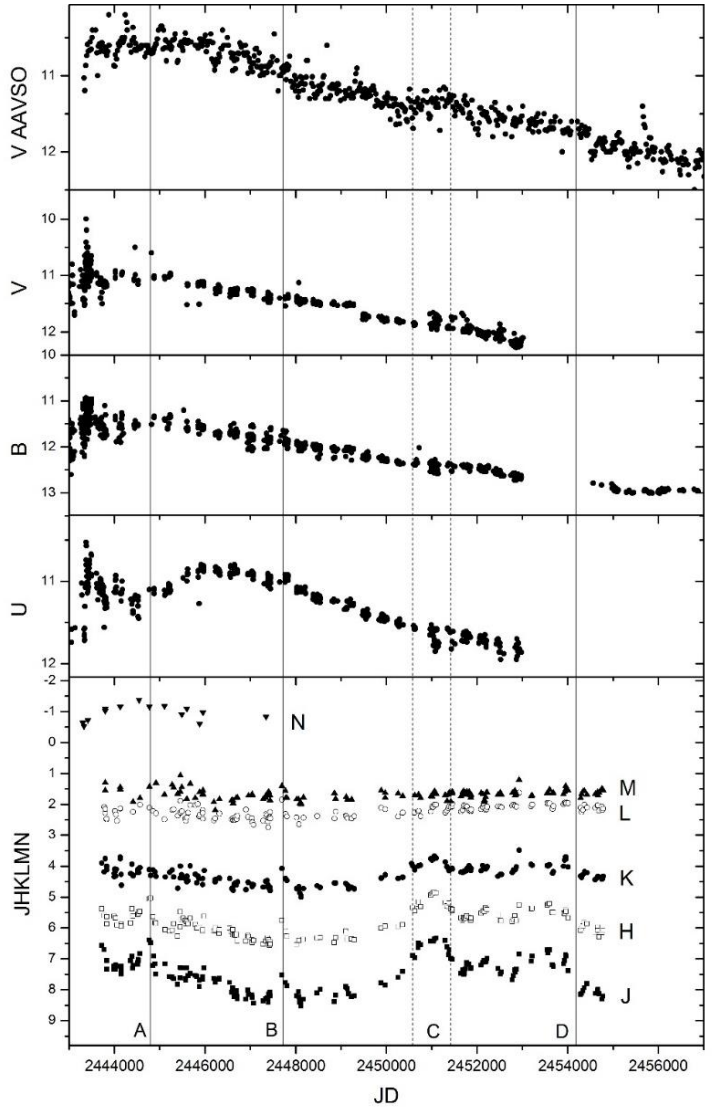
- reduced to stellar catalogue (around 35 TB)

Science cases

Variable stars →

- Time-series analysis of light curves of variable stars (LPV, Miras)
- Circumstellar environment: dust in LPVs (Miras), giant stars, young stars; dust and gas in interacting binaries
- Interacting binaries (novae, symbiotic binaries...)

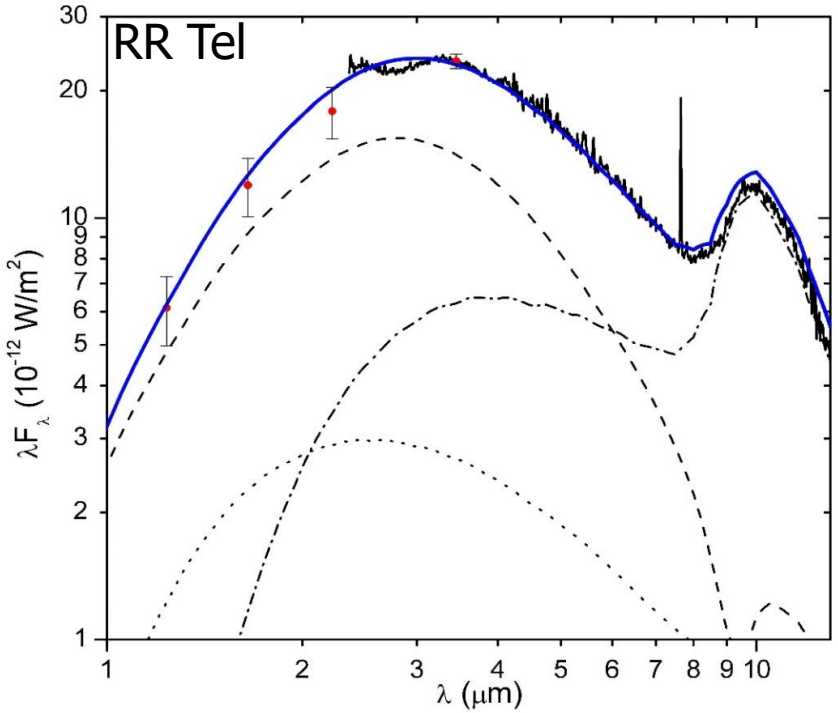


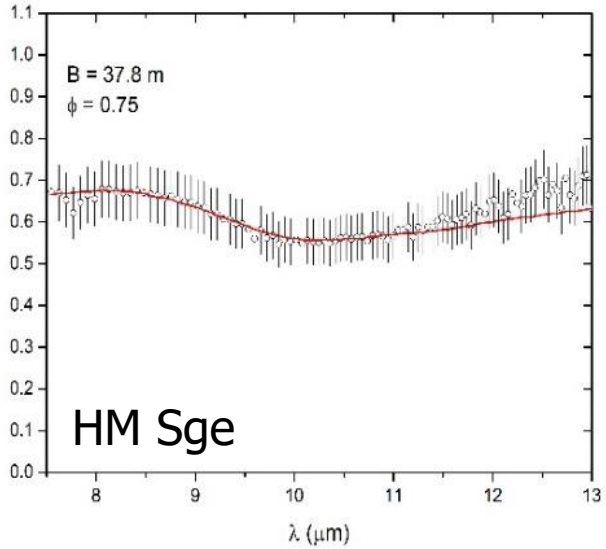


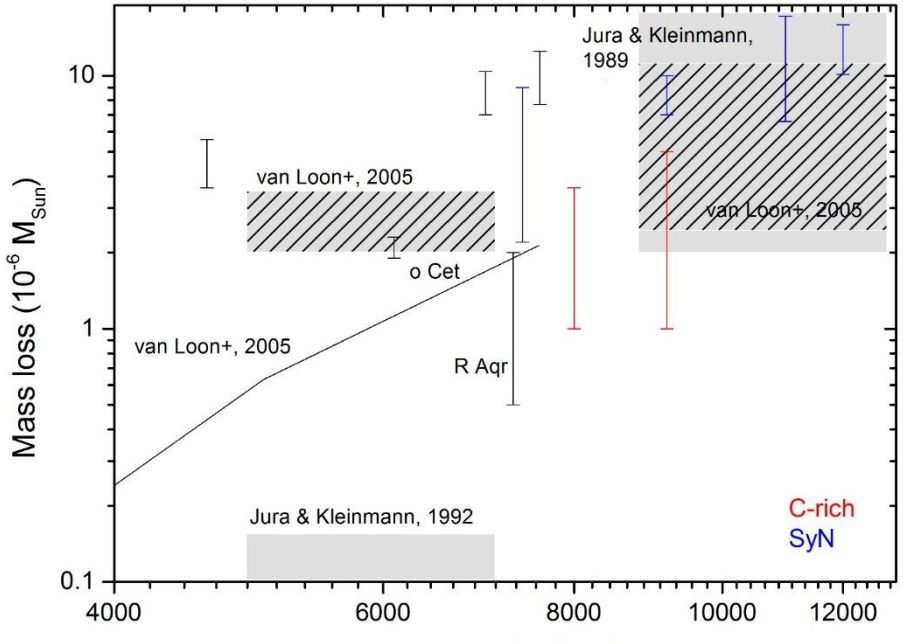
Science cases

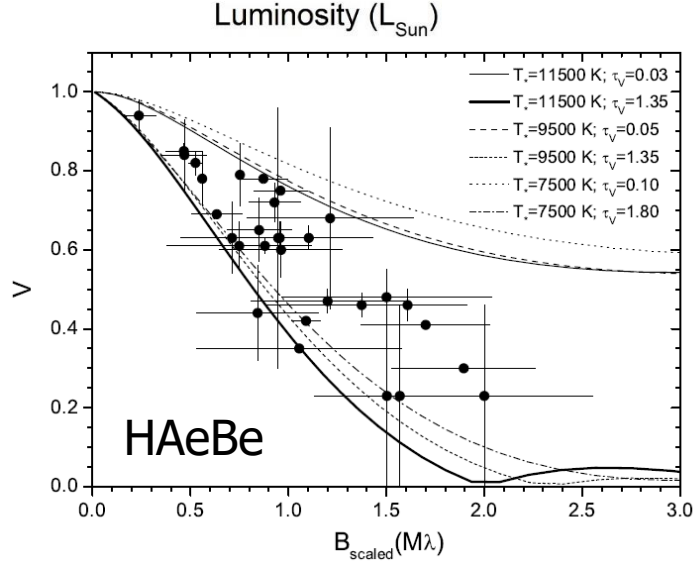
Circumstellar dust → interacting binaries, LPVs/Miras, YSO: TTau/HAeBe

- Photometry → SED fitting
- Phoenix/Kurucz stellar atmosphere models
- Radiative transfer → Leluya (Vinkovic, 2004)









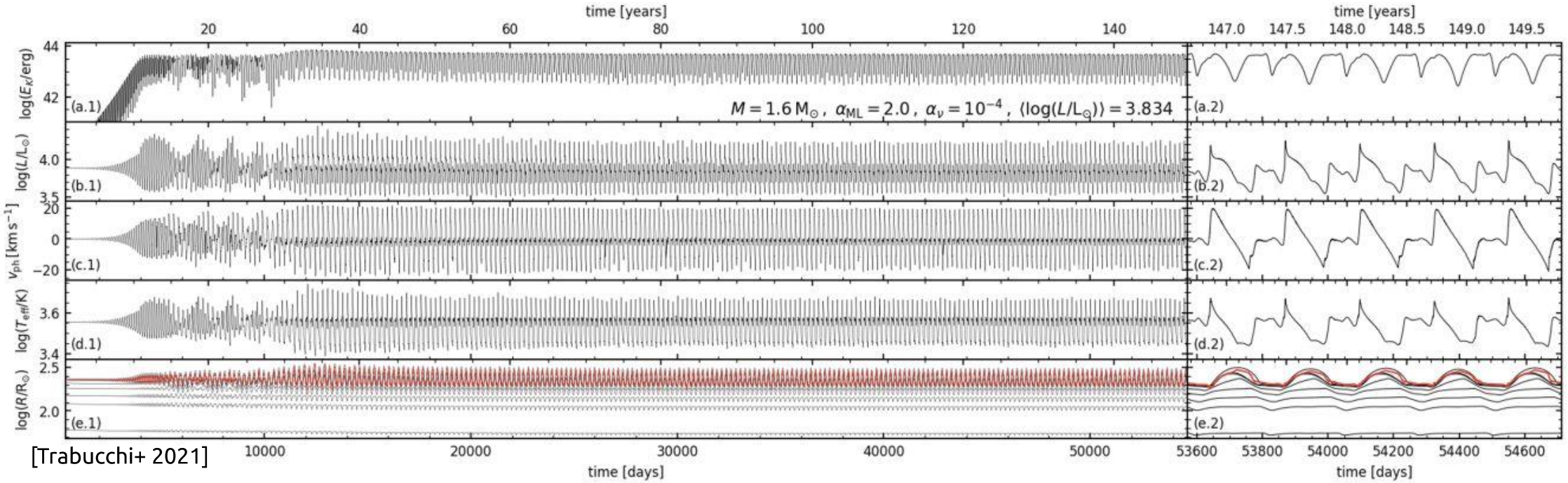
Science cases

Periodicity mining pipeline (running)
(A. Kovačević, D. Ilić, L. Popović, S. Simić, V. Radović et al.)

- Compiling short-period (<5yr) Supermassive Binary Black Hole (SMBBH) candidates
- Compiling stellar light curves catalogue
- Period determination, unsupervised clustering & classification
- 2DHybrid: (auto)correlation of time series (wavelet transform) + statistics and visualization (+ machine learning for gaps)
- Calculations on large amount of data
- Cross-correlation with other surveys (e.g. AXS)
- Different periodicity-finding techniques
- Testing on LSSTC AGN Data Challenge 2021 (Richards+21) and ZTF

Non-linear hydrodynamic pulsation models of LPVs (running) (Michele Trabucchi, Leo Girardi et al.)

- Grid of around 3 million simulations of AGB envelope models → time series describing the motion of envelope layers → extraction of pulsation periods and light curves in LSST filters
- Synthetic stellar population models used to simulate LSST stellar content



[Trabucchi+ 2021]

Science cases

Microlensing events (in preparation) (M. Hundertmark et al.)

- Detect and characterize microlensing events across the sky
- Find compact objects and microlensing exoplanets
- Simulation to estimate microlensing optical depth & expected event categories for shorter events
- Testing on DECam & ZTF

Science cases

TVS Dashboard/Portal: a data portal for preliminary investigation and analysis of LSST-based light curves (L. Palaversa & A. Razim)

- Front-end server for data access and visualisation
- HPC 'Bura' as back-end for more computer-intensive calculations (e.g. statistics, periodicity, classification ...)

Cross-matching (e.g. with AXS between LSST, Gaia, WISE, SDSS, 2MASS, etc.)
Interstellar reddening & stellar parameters

Takeaway

- Present and upcoming surveys such as LSST will require substantial amount of computing power for TB(PB)-scale of data

- HPC 'Bura' can be used for computer-intensive calculations and analysis that require large CPU power

Thank you for your attention!

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