Supercomputer 'Bura' as a software processing centre for LSST Vera C. Rubin observatory

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Who am I?

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SVEUČILIŠTE U RIJECI

UNIVERSITAS STUDIORUM ZAGRABIENSIS MDCLXIX

Research interest

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...) (R. Jurdana-Šepić, I. Poljančić)

High energy astrophysics → MAGIC, CTA (D. Dominis-Prester, M. Manganaro, T. Terzić, S. Mićanović)

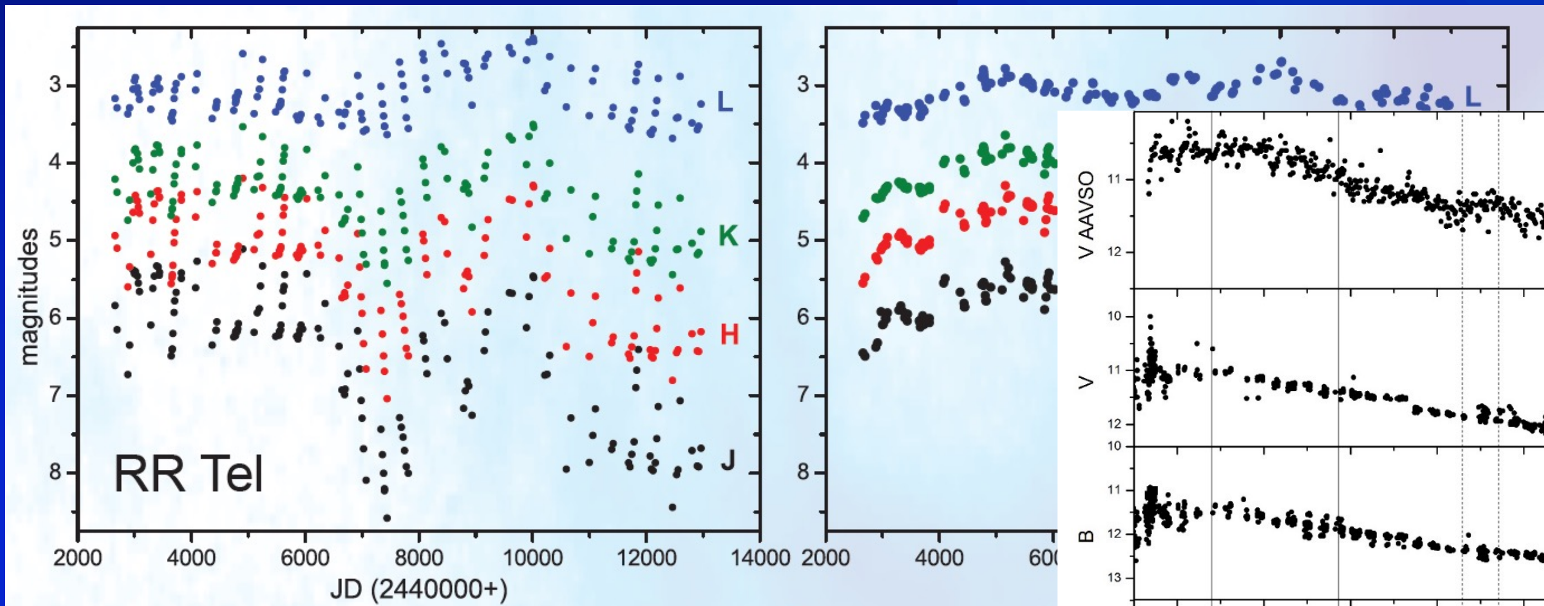
→ **synergy with LSST** (alerts, historic light curves...)

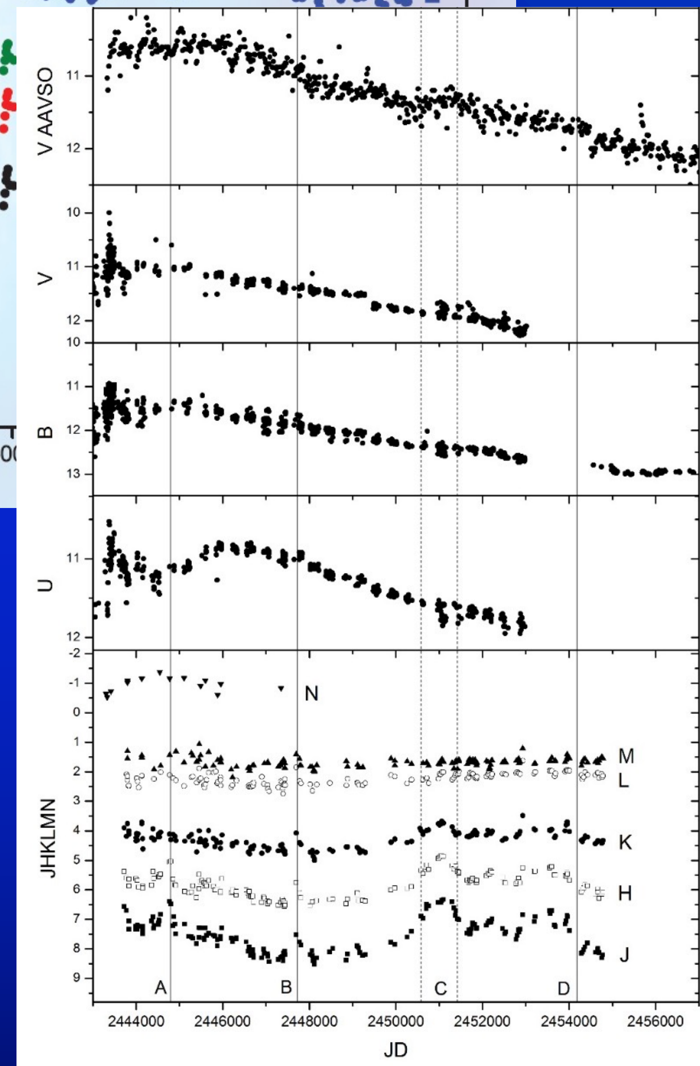
Solar physics (I. Poljančić)

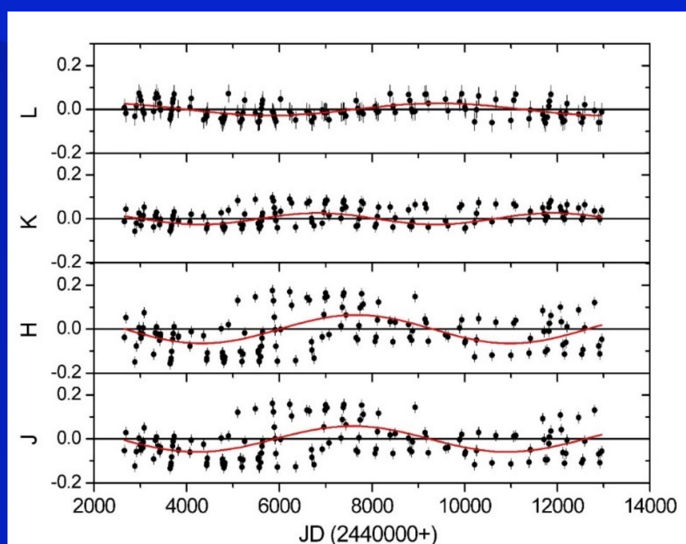
Symbiotic binaries as precursors of SN Ia

- single-degenerate scenario with massive WD, possibly in symbiotic system
- Total census and population properties are needed (are they members of old population as only SN Ia are present in elliptical galaxies?)
- Estimates ranges from 30 000 (Kenyon et al. 1993) to 300 000 (Munari et al. 1992), but only ~300 are known
- 2-4% of SyS are needed to explode as SN Ia in order to explain the observed SN Ia rate

Time-domain analysis of light curves (symbiotic Miras, LPV)



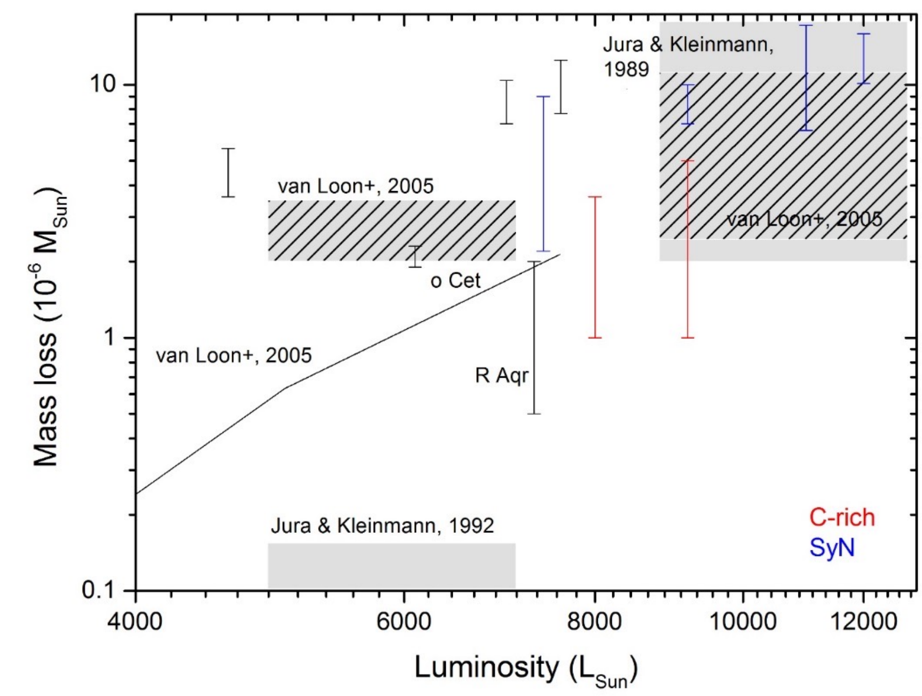


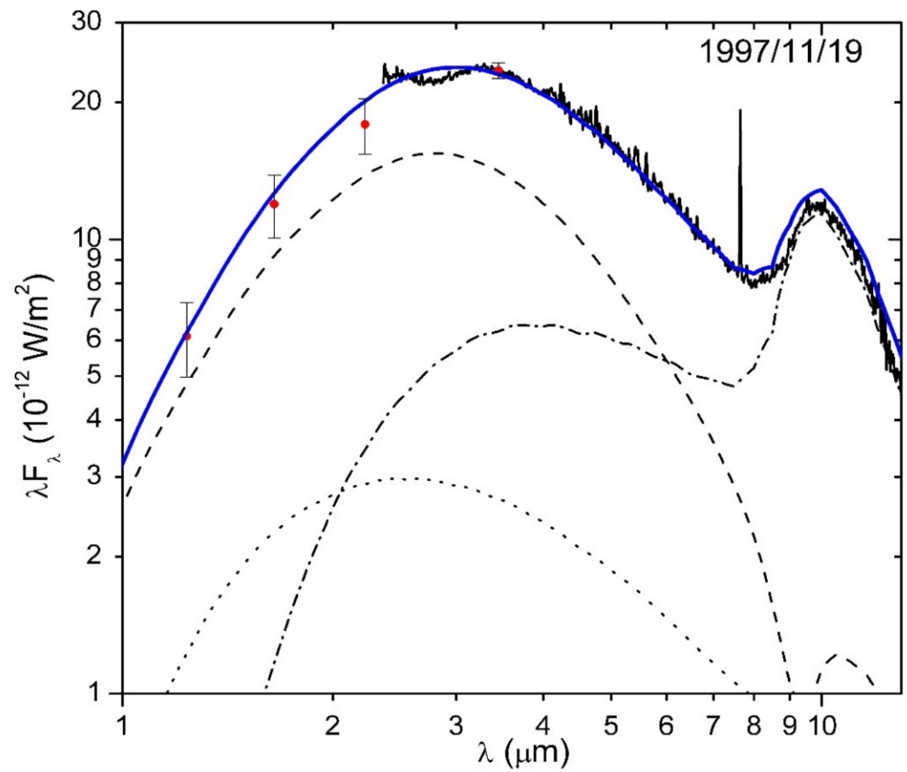


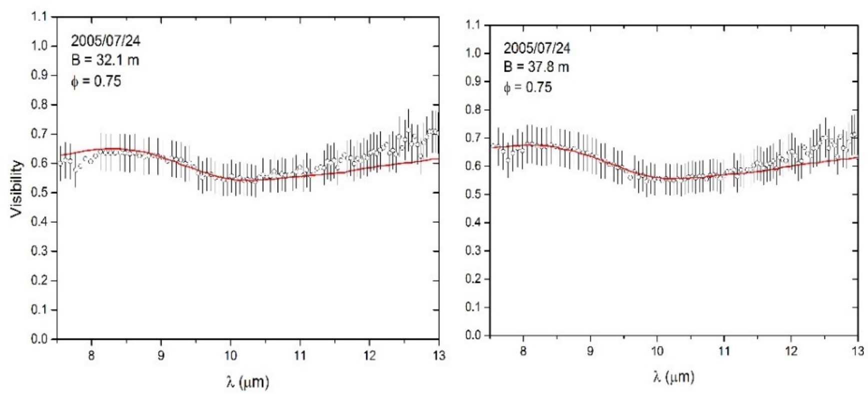
Jurkic & Kotnik-Karuza (2018)

Circumstellar dust: numerical modelling
(interacting binaries, LPVs/Miras)

- photometry → SED fitting
- Phoenix/Kurucz stellar atmosphere models







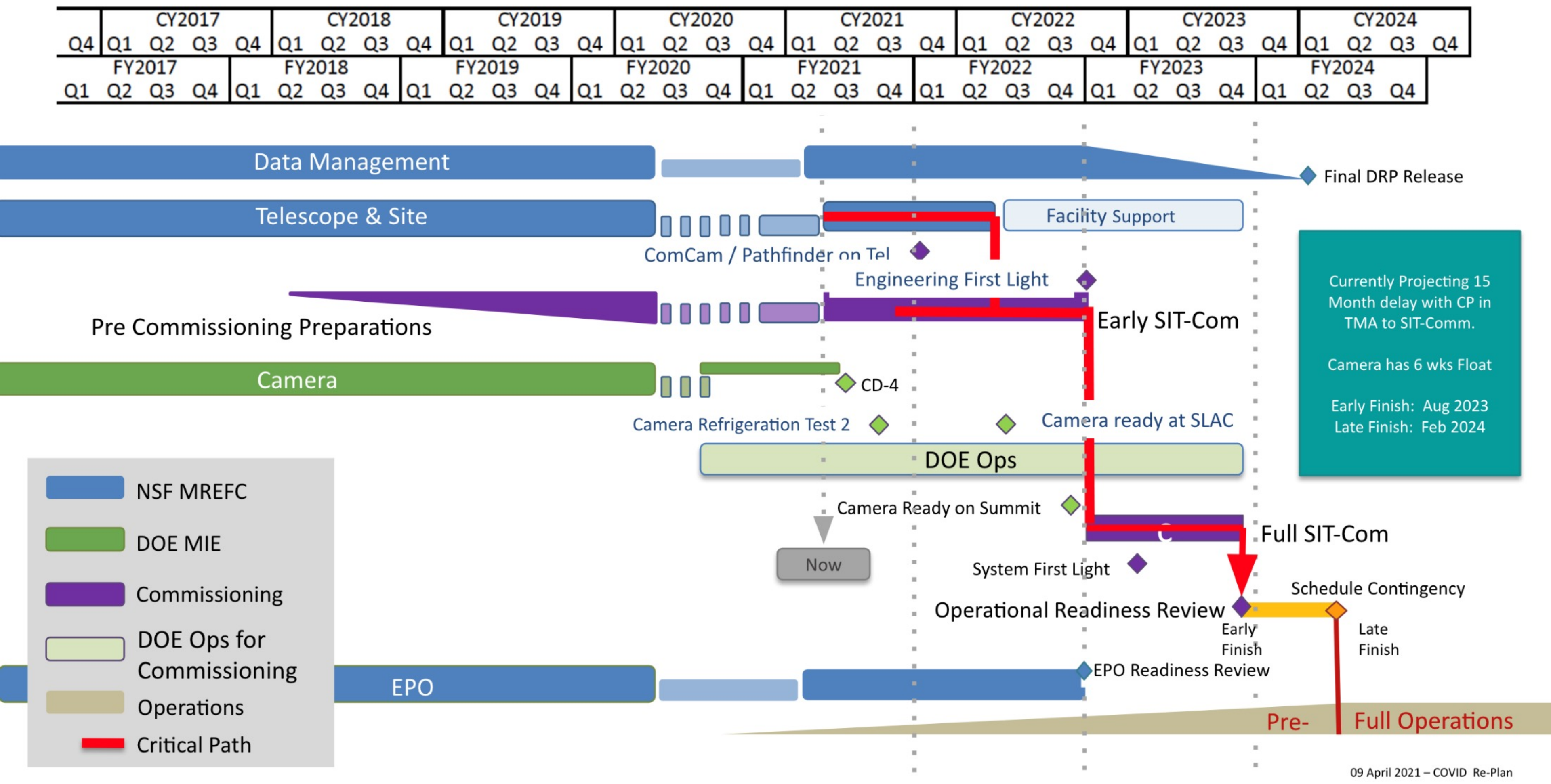
Vera C. Rubin Observatory

→ 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)

Rubin observatory project schedule



Synergy with other surveys

Gaia (parallax and proper motion)

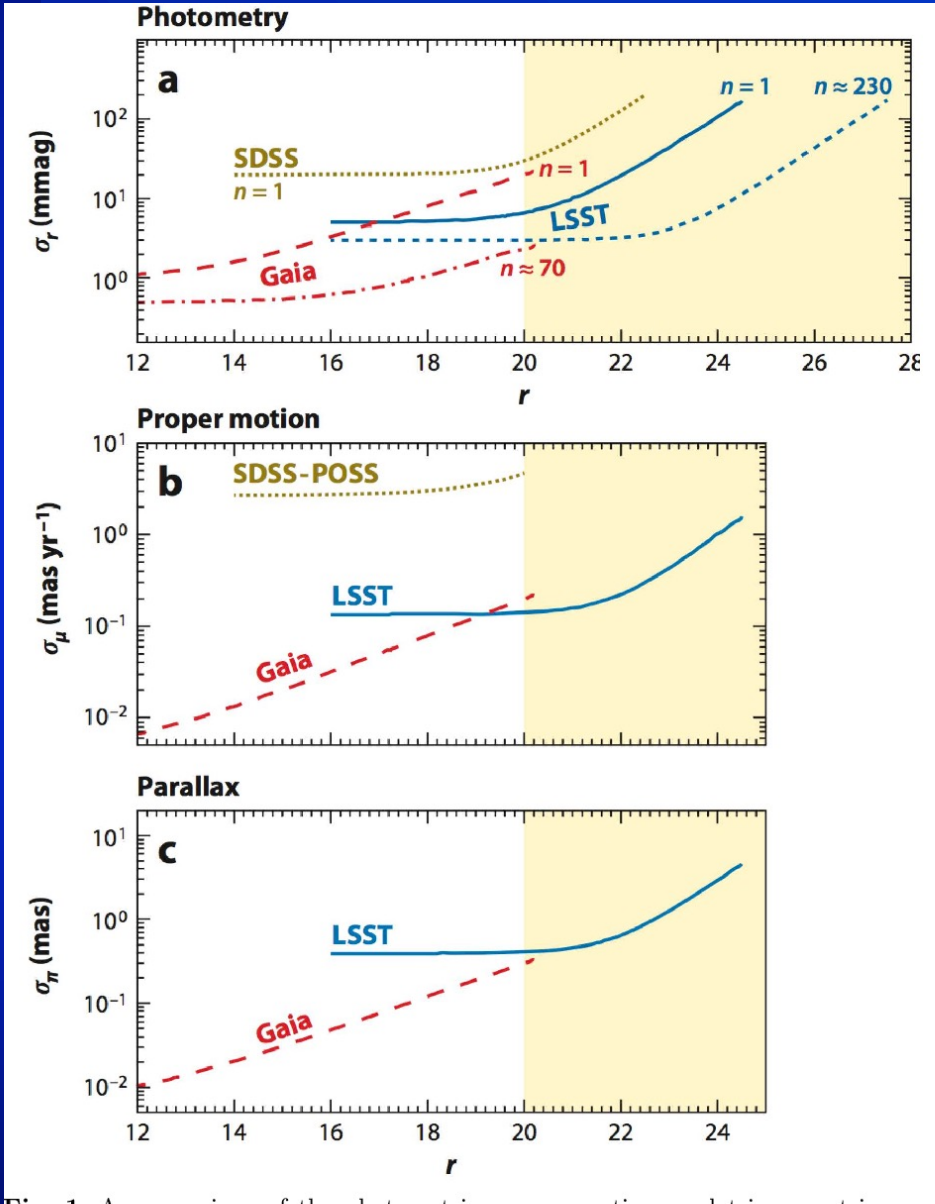
Pan-STARRS

DES

WISE (infrared observations)

ZTF (light curves of variable stars)

(Ivezic et al. 2014)



Participation

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

Croatian Participation Group @ LSST

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

In-kind contribution

- Software development (RBI, UniZg-HO)
- Software processing centre & IDACs (UniRi – HPC 'Bura')

Scientific collaborations

CPG is active in:

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

TVS science collaboration

Software development on regional level

- Dash: a data portal for preliminary investigation and analysis of LSST-based light curves (Lovro Palaversa & Alex Razim) + Observing Program Management (Yiannis Tsapras & Markus Hundertmark)
- Periodicity mining pipeline in time domain (Andjelka Kovačević, Dragana Ilić, Luka Popović)
- Variable star classifier based on machine learning (Robert Szabo et al.)
- Tidal Disruption Event Filtering (Andreja Gomboc)

Cadence optimization for variable stars

Krešimir Tisanić: "Simulations of multiband Lomb-Scargle-derived variable star periods"

TVS science collaboration

Computer resources in-kind contribution

IDAC (International Data Access Centre)

- (light) data access: light catalogues (stellar sources etc.)
- Limited data processing → e.g. basic periodicity analysis by multiband Lomb-Scargle periodogram (VanderPlas 2015)
- Rubin Science Platform (RSP) → not obligatory
- Demands for large disk storage

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

TVS science collaboration

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 lite IDAC in Maribor

3. Astrophysicist domain support

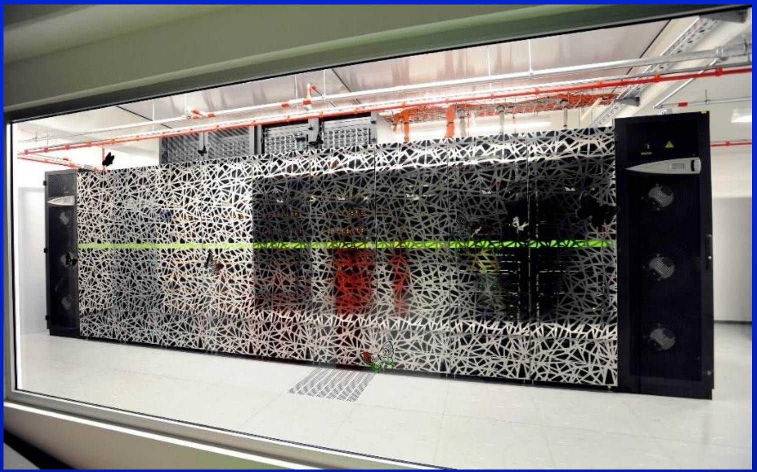
4. Analysis of large amount of data + small-scale computing of individual groups

"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

CNRM uniri
Center for Advanced Computing and Modelling

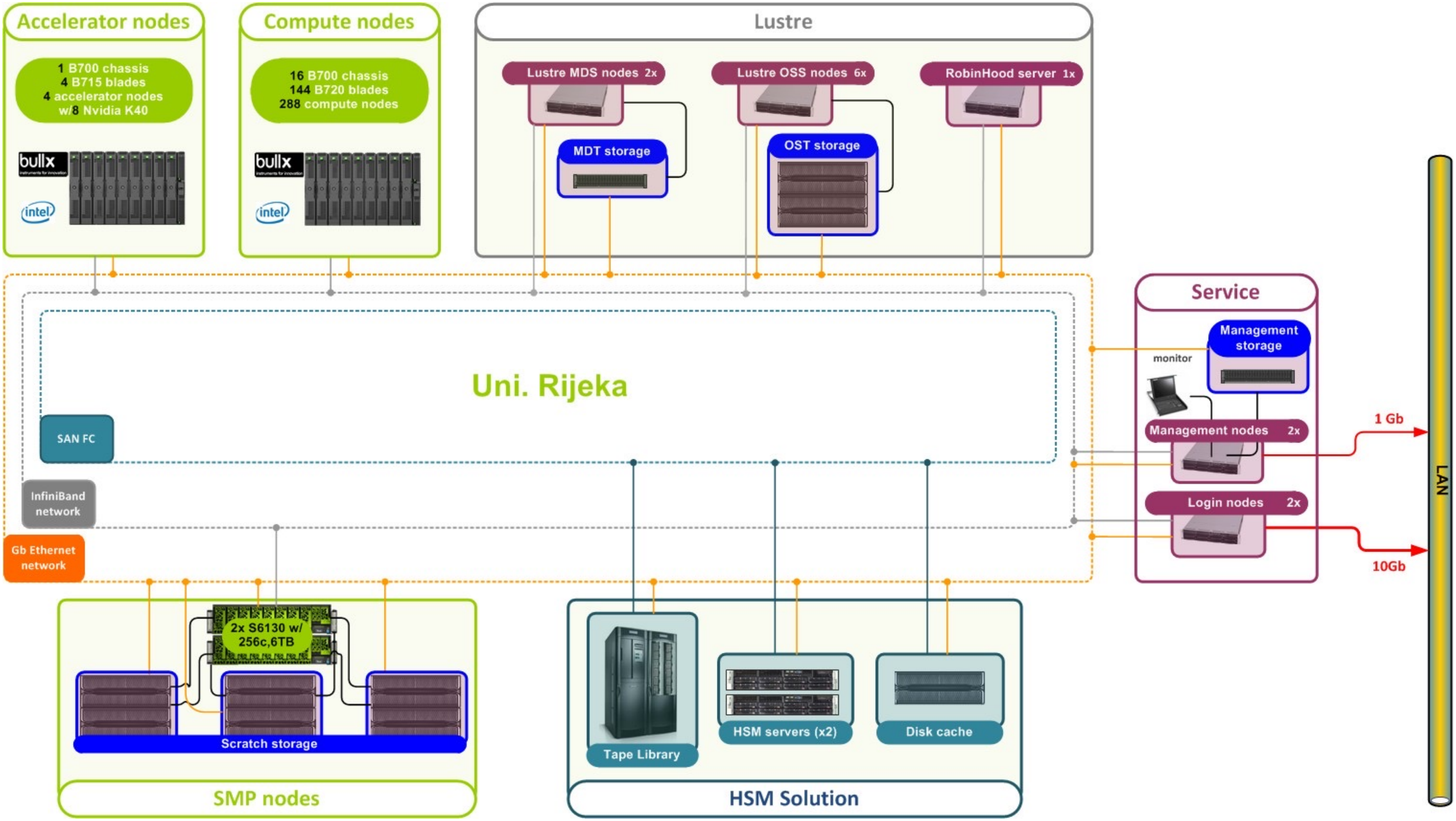


TOP500 The List. 44º

THE GREEN 500 175

HPCG 48

Schematic Architecture



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')

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

Possible science cases

Dashboard/TVS portal: a data portal for preliminary investigation and analysis of LSST-based light curves (Lovro Palaversa & Oleksandra Razim)

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

Possible science cases

Periodicity mining pipeline (SER-SAG in-kind contribution group: Andjelka Kovačević, Dragana Ilić, Luka Popović, Saša Simić et al.)

- SER-SAG in-kind contribution
- 2DHybrid: correlation of time series + wavelet transform + statistics (+ machine learning for gaps)
- Calculations on large amount of data
- Cross-correlation with other surveys (e.g. AXS)
- Different periodicity-finding techniques (?)

Possible science cases

Broad-band photometry and spectral energy distribution (Ivezic et al. 2017)

$$F_{band} = \int f_\lambda R_\lambda d\lambda$$

Bands: u, g, r, i, z, y (300 – 1050 nm)

- Determination of true SEDs from multiband LSST photometry
- **Photometric stellar parallaxes** to constrain temperature and luminosity with colors (Jurić et al 2008)
- **Photometric stellar metallicites** (trained by sources of known metallicity obtained from spectroscopy, e.g. from Gaia $\rightarrow$ Huang et al. 2019 (Gaia DR2 + LAMOST spectroscopy)

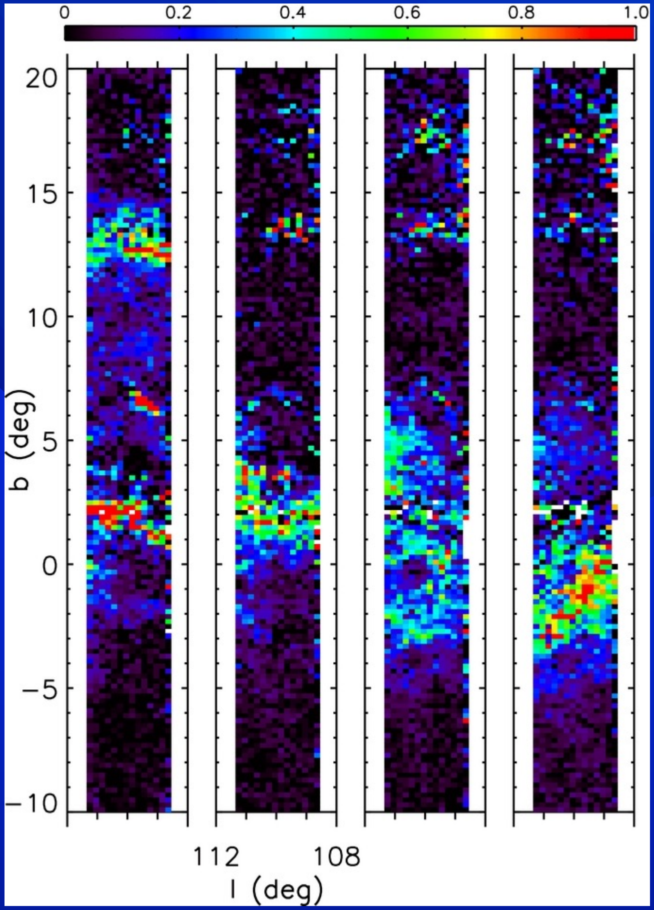
Possible science cases

- **Interstellar reddening**

'Simple' main-sequence fitting (SDSS) (Berry et al. 2012)
→ extinction at 1, 1.5, 2, 2.5 kpc

Gaia + Pan-STARRS + 2MASS (Green et al. 2019) → 799 000 000 objects

Advanced statistical approach:
- Maximum likelihood estimate
- Bayesian deconvolution of Gaia DR2 (Babusiaux et al. 2020, Lallement et al. 2019)



(Berry et al. 2012)

Possible science cases

Bayesian Extinction And Stellar Tool (BEAST)
(Gordon et al. 2019)

- Probabilistic modelling of photometric SEDs + interstellar reddening
- Stellar evolution & atmosphere models → fitting of photometric SEDs to derive:

Stellar properties: age, mass, metallicity, distance
Dust extinction properties: dust extinction, average grain size, extinction curve type

Possible science cases

- **Circumstellar dust & mass loss in giants**

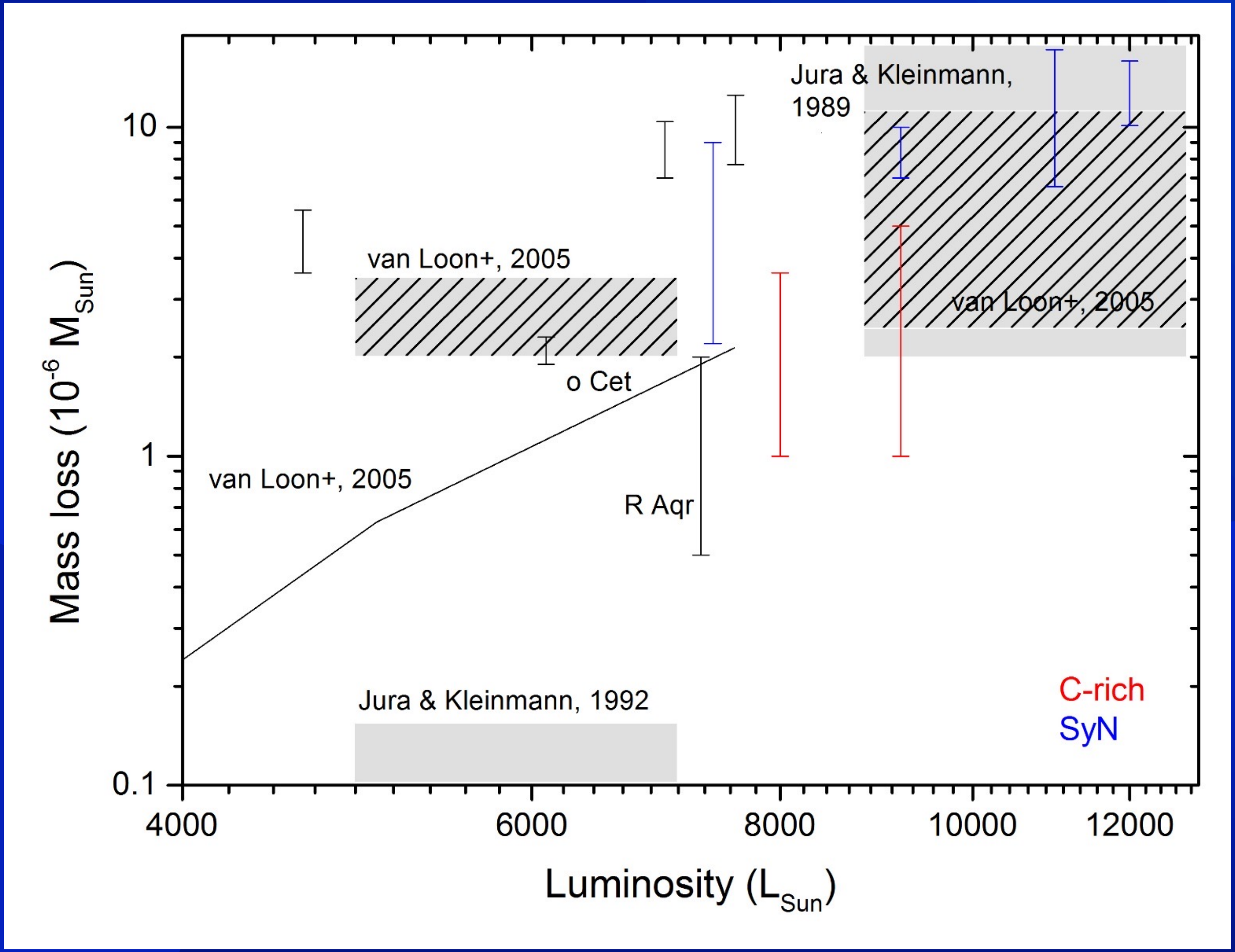
→ main source of dust in universe?

Gaia DR2 → 101 810 giants @ 700 pc (Goncharov & Mosenkov 2020)

Dust in C-rich giants from Gaia DR2 + 2MASS (Nanni 2019)

Radiative transfer models → SED → multiband LSST photometry + 2MASS, WISE

Mass loss rates from dust



AGBs & Symbiotic Miras (Jurkic, 2022, in prep.)

Thank you for your attention!

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