Using VOSA to exploit Gaia data

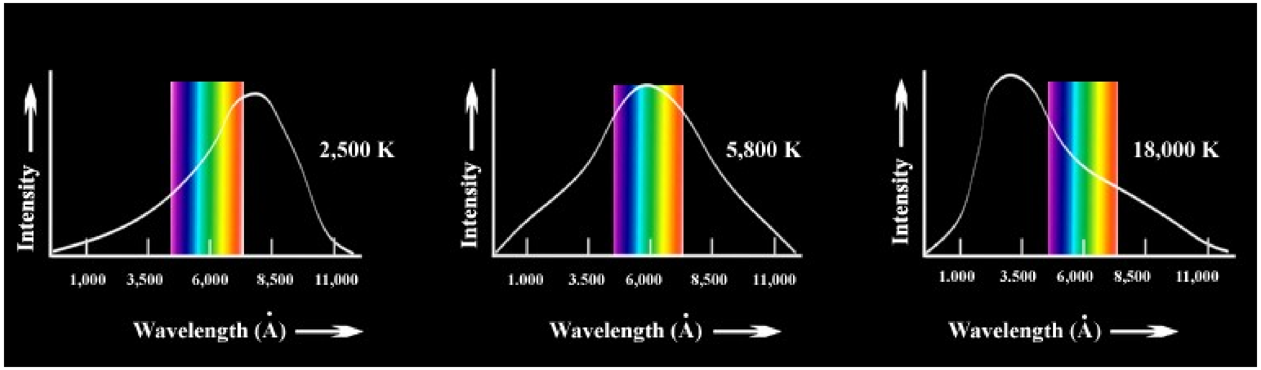
Enrique Solano

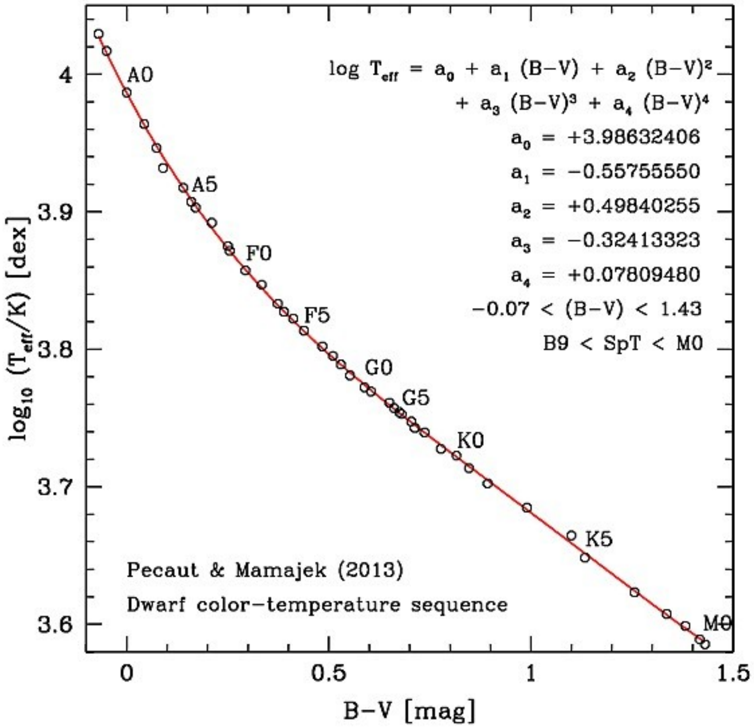
Carlos Rodrigo, Amelia Bayo, Francisco Jiménez

Outline

- Why use Spectral Energy Distributions (SEDs)?
- If you work with SEDs, why use VOSA?
- Example of science cases with Gaia and VOSA.

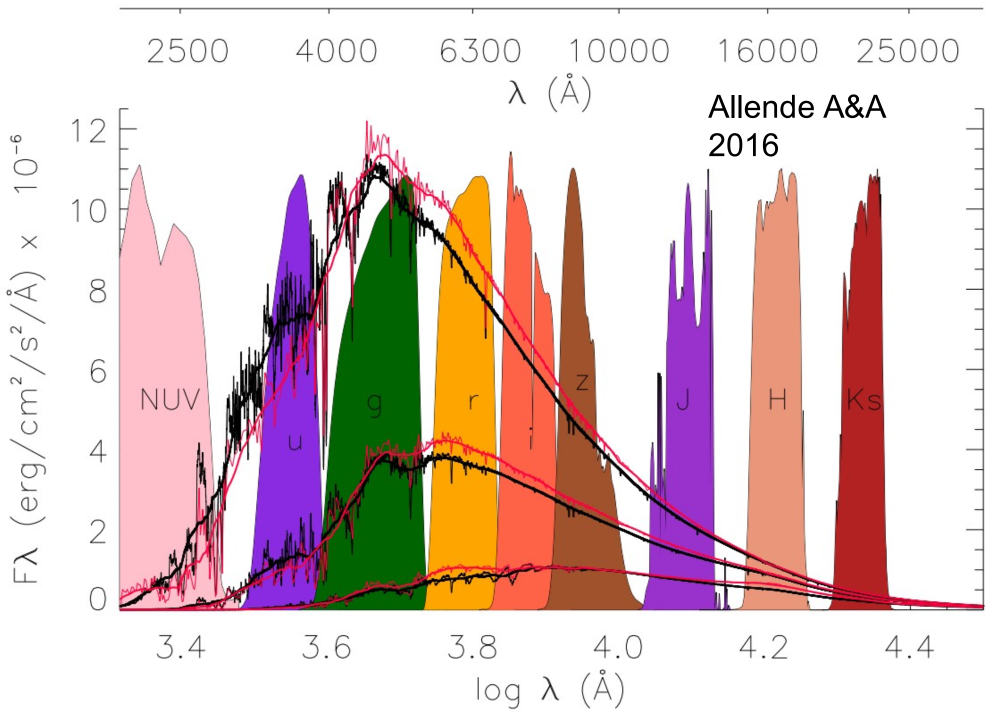
Why SEDs (Spectral Energy Distributions)?

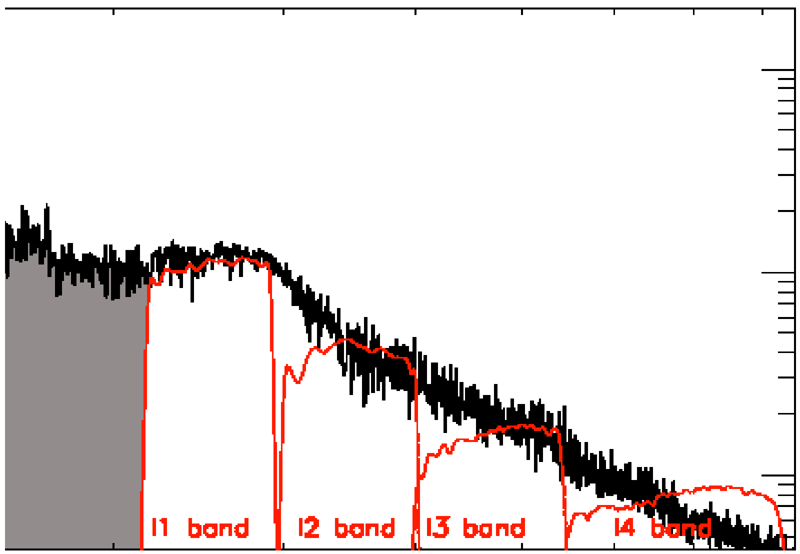




Why SEDs (Spectral Energy Distributions)?

Why SEDs (Spectral Energy Distributions)?





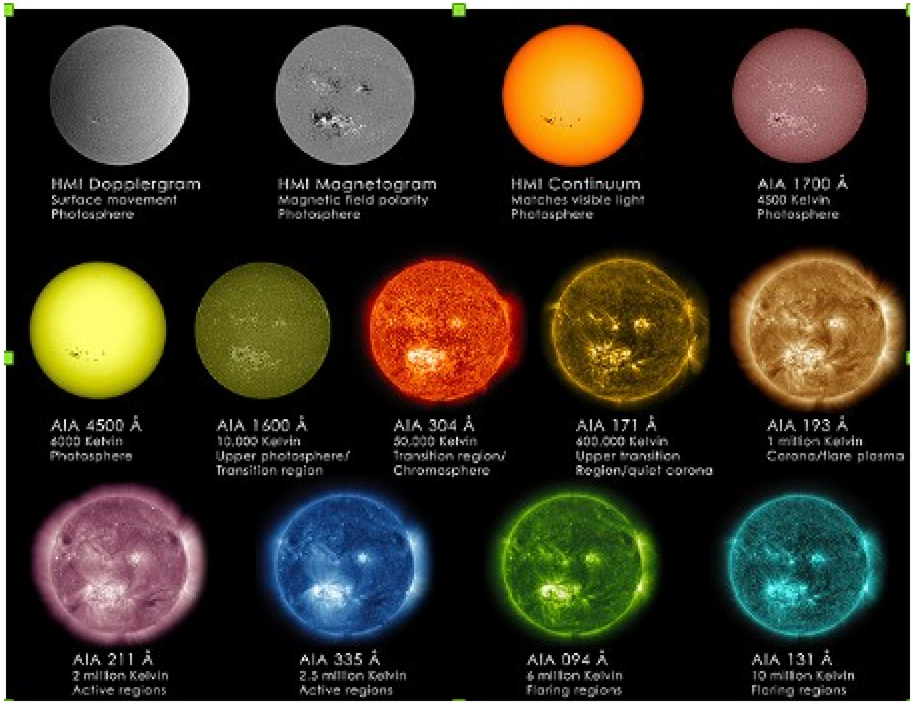
$$F_{Bol} = \int_0^\infty F_\nu d\nu$$

Building SEDs

How to build a Spectral Energy Distribution?

Ingredients

- Multiwavelength photometry

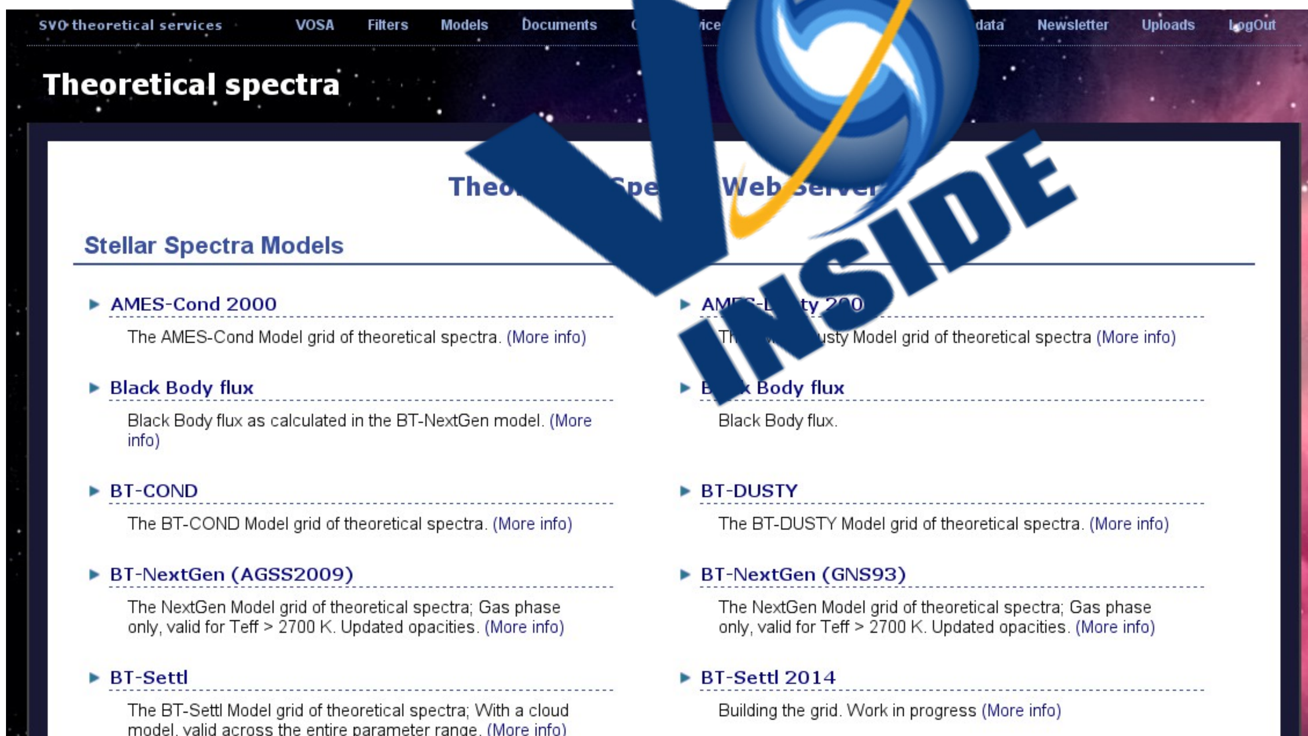


Data discovery, gathering and manipulation.

Building SEDs

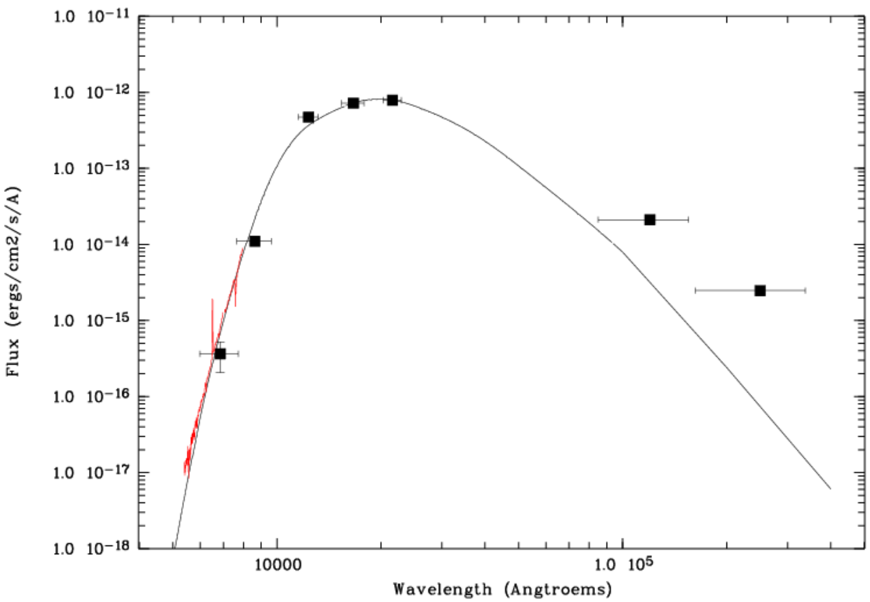
Data discovery gathering & manipulation

- Observational data
- Theoretical data



Building SEDs: Difficulties

- **Data Manipulation: From magnitudes to fluxes**



I/337/gaia — Post annotation — Gaia DR1 (Gaia Collaboration, 2016 — GaiaSource data (**Download** Gaia Sc

start AladinLite

Full	RA_ICRS deg	DE_ICRS deg	<Gmag> mag
1	063.4107528711	-89.9888879972	17.965
2	037.5117084305	-89.9858176527	16.664
3	084.7593492719	-89.9781776713	18.553
4	081.5942616579	-89.9832765720	20.472
5	070.9024070024	-89.9715663343	19.829
6	060.8702751299	-89.9781334323	19.492
7	073.1733654732	-89.9817426647	20.019
8	027.3236159503	-89.9767950251	17.006
9	029.9573489468	-89.9759664621	18.649
10	020.0044580076	-89.9836077196	19.202

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GAIA DATA RELEASE DOCUMENTATION — esa

Gaia Data Release 1 Documentation release D.0
[-] Gaia Data Release 1 Documentation release D.0
I Introduction to Gaia DR1
[-] II Gaia Data Processing

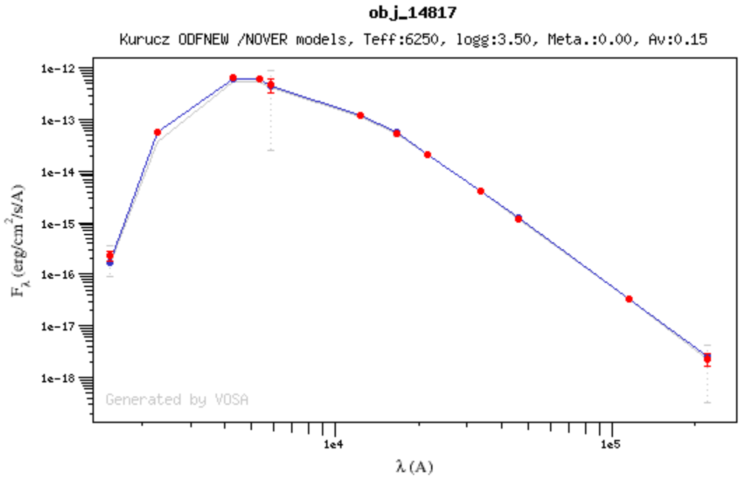
5 Photometry
5.2 Properties of the input data — 5.4 Processing steps

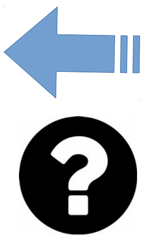
5.3 Calibration models

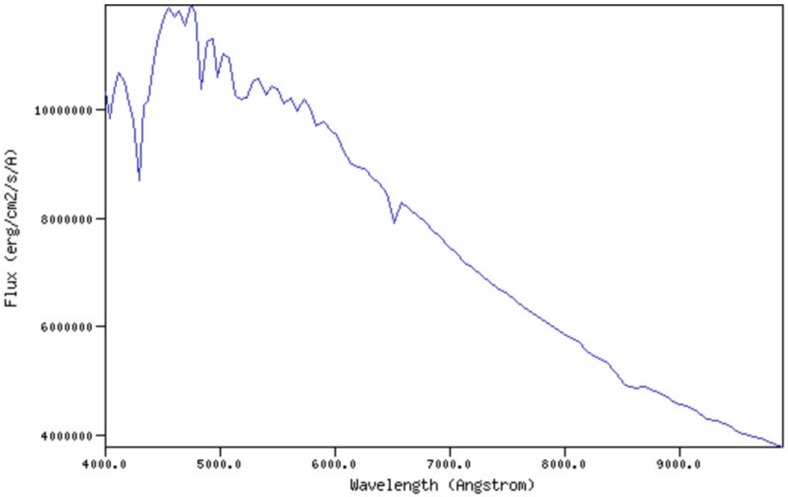
$$m_x = -2.5 \log_{10} \left(\frac{F_x}{F_{x,0}} \right)$$

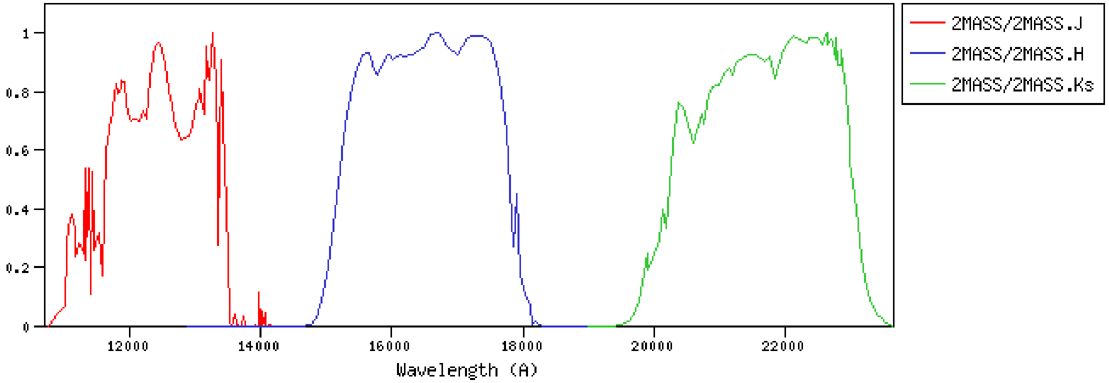
Building SEDs: Difficulties

- **Data Manipulation: From theoretical spectra to synthetic photometry**



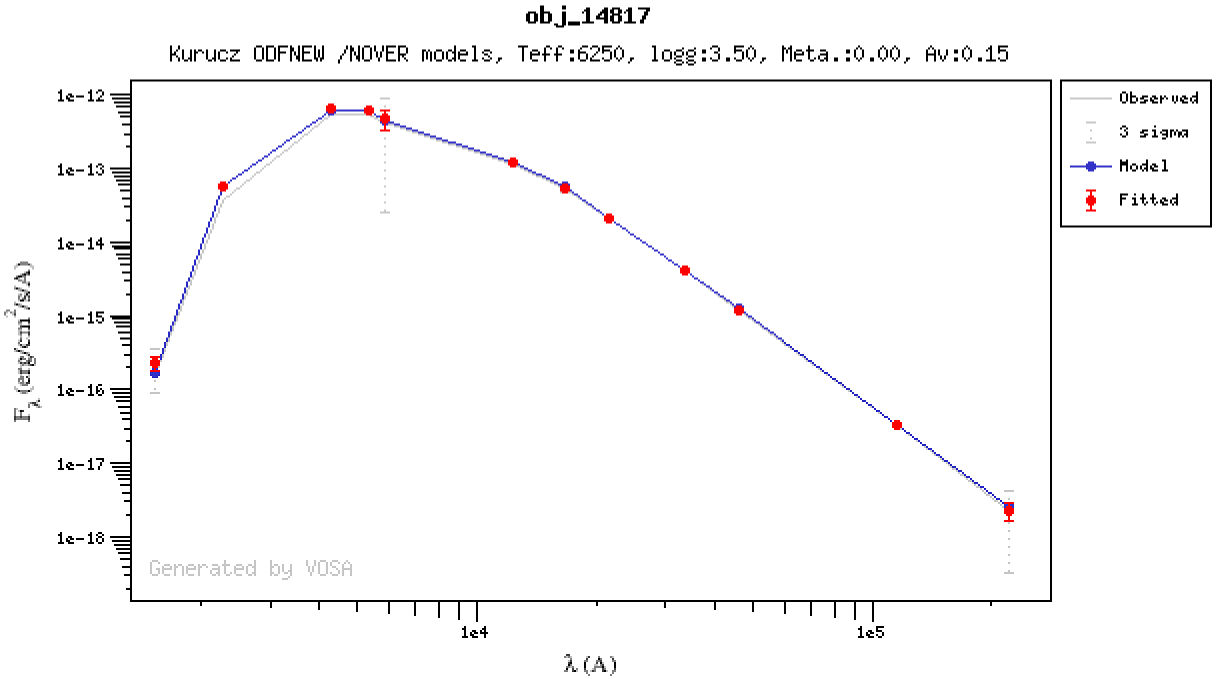






Building SEDs: Difficulties

- **Data Analysis: Model fitting**



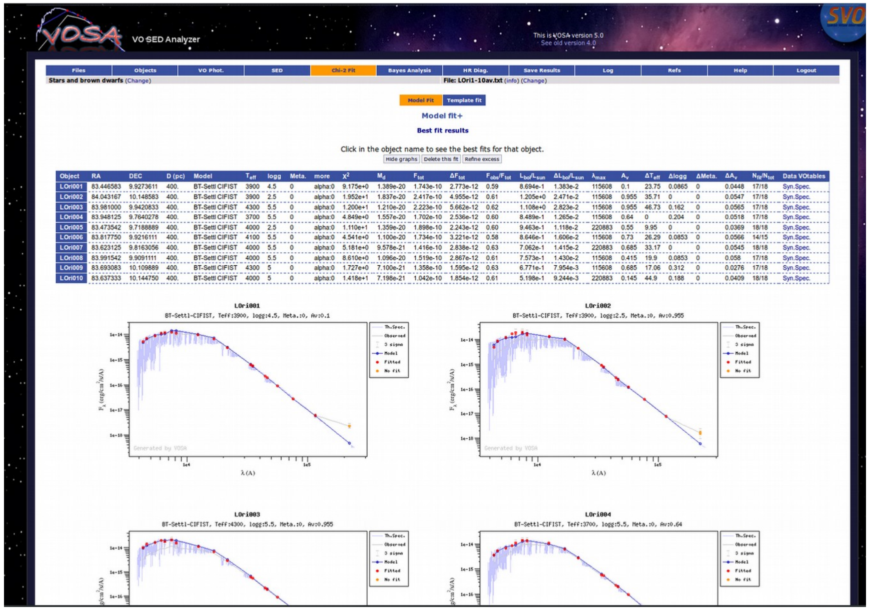
Which approach is best? Chi2? Bayes? Others?

Build your favourite SED by hand.

VOSA to the rescue

VO SED Analyzer

http://svo2.cab.inta-csic.es/theory/vosa/



- Available since 2008.
- More than 800 users.
- More than 1.000.000 objects.

VOSA to the rescue

- **More than 70 refereed papers**

A&A 492, 277-287 (2008)
DOI: 10.1051/0004-6361:200810395

VOSA: virtual observatory SED analyzer

An application to the Collinder 69 open cluster

A. Bayo[1, 2], C. Rodrigo ... nd F. Allard[3]

The first planet detected in the WTS: an inflated hot Jupiter in a 3.35 d orbit around a late F star*

M. Cappetta[1,†], R. P. Saglia[1,2], J. L. Birkby[3,4], J. Koppenhoefer[1,2], D. J. Pinfi... P. Cruz[6], G. Kovács[3], B. Sipőcz[5], D. Barrado[6,7], B. Nefs[4], Y. V. Pavlenko[8], L. ... C. del Burgo[10,11,12], E. L. Martín[13], I. Snellen[4], J. Barnes[5], A. Bayo[14], D. A. C... M. C. Gálvez-Ortiz[13], N. Goulding[5], C. Haswell[9], O. Ivanyuk[8], H. R. Jones[5], M... N. Lodieu[5], F. Marocco[5], D. Mislis[3], F. Murgas[15,16], R. Napiwotzki[5], E. Palle[15]... L. Sarro Baro[18], E. Solano[6,19], P. Steele[1], H. Stoev[6], R. Tata[15,16] and J. Zendejas...

Age determination of the HR8799 planetary system using asteroseismology

A. Moya[1,*], P. J. Amado[2], D. Barrado[1,3], A. García Hernández[2], M. Aberasturi[1], B. Montesinos[1] and F. Aceituno[2]

A&A 556, A144 (2013)

Proper motions of young stars in Chamaeleon
II. New kinematical candidate members of Chamaeleon I and II*

Belén López Martí[1], Francisco Jiménez-Esteban[1,2,3], Amelia Bayo[4,5], David Barrado[1,6], Enrique Solano[1,2], Hervé Bouy[1] and Carlos Rodrigo[1,2]

A&A 554, A20 (2013)

A Virtual Observatory Census to Address Dwarfs Origins (AVOCADO)
I. Science goals, sample selection, and analysis tools

R. Sánchez-Janssen[1], R. Amorín[2], M. García-Vargas[3], J. M. Gomes[4], M. Huertas-Company[5], F. Jiménez-Esteban[6,7,8], M. Mollá[9], P. Papaderos[4], E. Pérez-Montero[2], C. Rodrigo[6,7], J. Sánchez Almeida[10,11] and E. Solano[6,7]

A&A 560, A92 (2013)

Searching for transits in the Wide Field Camera Transit Survey with difference-imaging light curves

J. Zendejas Dominguez[1,2], J. Koppenhoefer[2,1], R. P. Saglia[2,1], J. L. Birkby[3], S. T. Hodgkin[4], G. Kovács[4], D. J. Pinfield[5], B. Sipőcz[5], D. Barrado[6,7], R. Bender[2,1], C. del Burgo[8], M. Cappetta[2], E. L. Martín[9], S. V. Nefs[3], A. Riffeser[1] and P. Steele[2]

The Seven Sisters DANCe
I. Empirical isochrones, luminosity, and mass functions of the Pleiades cluster*,,*****

H. Bouy[1], E. Bertin[2], L. M. Sarro[3], D. Barrado[1], E. Moraux[4], J. Bouvie... and Y. Beletsky[7]

The Astrophysical Journal Supplement Series > Volume 216 > Number 2

A GALEX-based Search for the Sparse Young ... Taurus-Aurigae Star Forming Region

Ana I. Gómez de Castro[1], Javier Lopez-Santiago[1], Fatima López-Martinez[1], Néstor Sánchez[1], Paol... Manuel Cornide[2], and Javier Yañez Gestoso[1]

A&A 574, A57 (2015)

The CoRoT chemical peculiar target star HD 49310*

...pil[1], W. W. Weiss[3] and T. Lüftinger[3]

A&A 558, A116 (2013)

HD 85567: A Herbig B[e] star or an interacting B[e] binary?
Resolving HD 85567's circumstellar environment with the VLTI and AMBER*,**

H. E. Wheelwright, G. Weigelt, A. ...

A&A 566, A103 (2014)

High-resolution imaging of *Kepler* planet host candidat...
A comprehensive comparison of different techniques*

J. Lillo-Box, D. Barrado and H. Bouy

A&A 541, A38 (2012)

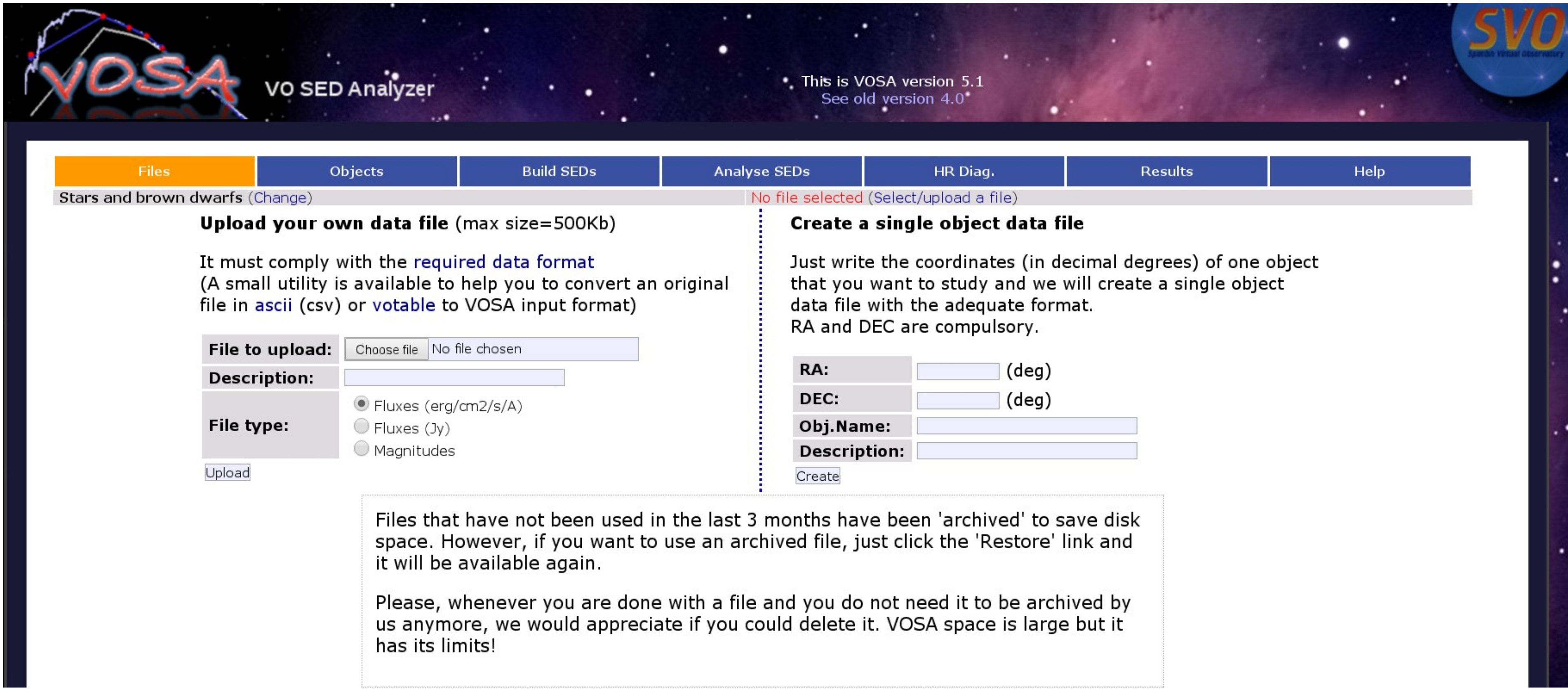
Warm debris disks candidates in transiting planets systems

Á. Ribas[1], B. Merín[1], D. R. Ardila[2] and H. Bouy[3]

Fundamental parameters of the close interacting binary HD 170582 and its luminous accretion disc

R. E. Mennickent[1,*], G. Djurašević[2], M. Cabezas[1], A. Cséki[2], J. G. Rosales[1], E. Niemczura[3], I. Araya[4] and M. Curé[4]

Why VOSA? Because...



Why VOSA? Because...

- **Multiwavelength photometry: observations**
  - Given a list of objects, VOSA gathers photometric information & metadata (identifiers, qflags, obs. dates,...) from archives & services using VO protocols (ConeSearch).

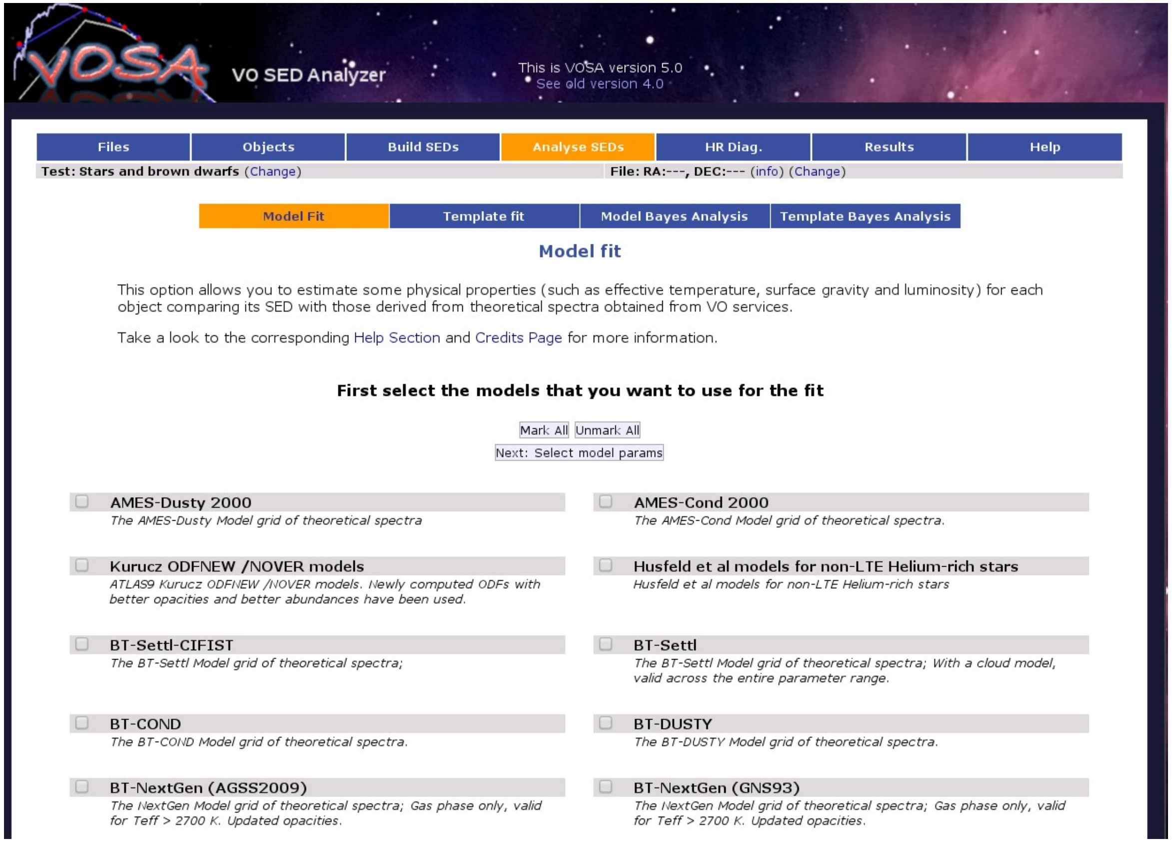
- 33 catalogues.
- From the UV to IR.

- Highly demanded.
- Large area.
- Information on quality.

Why VOSA? Because...

- **Multiwavelength photometry: models**

- 23 collections of theoretical spectra.
- VO protocols to handle theoretical models in a standard way.
- From O stars to brown dwarfs.
- From giants to white dwarfs.

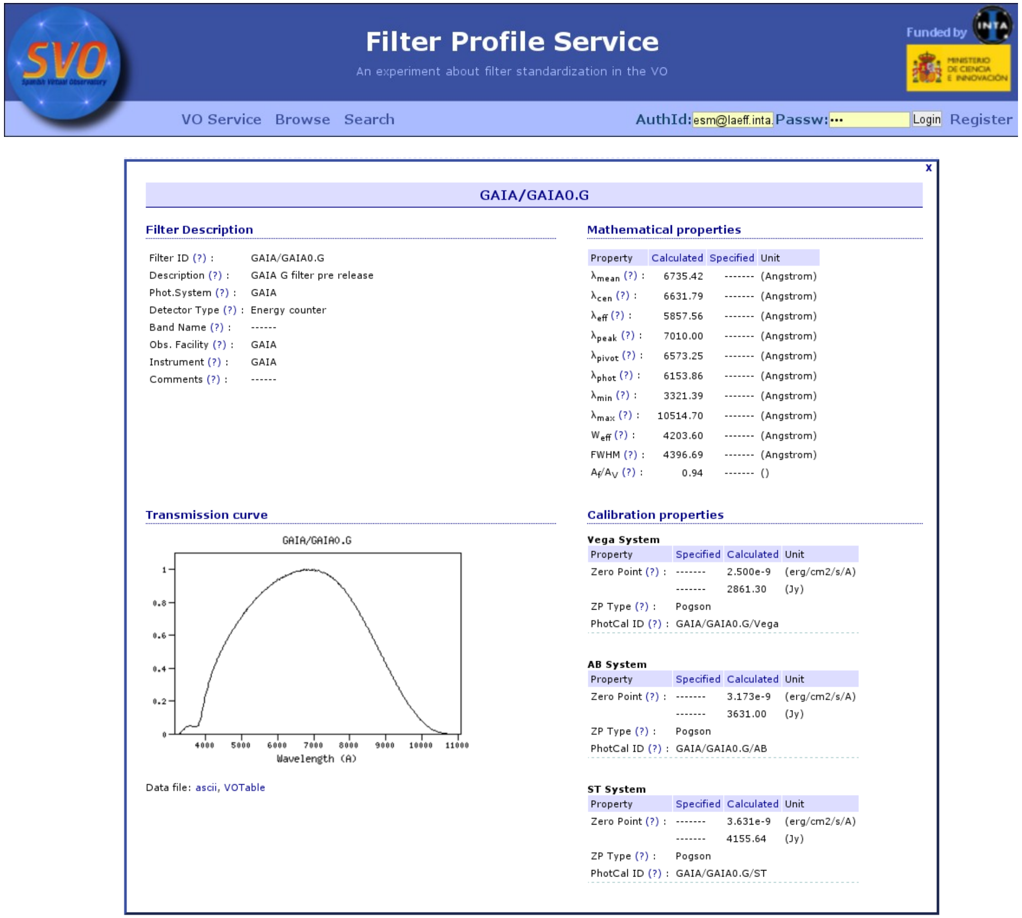


Why VOSA? Because...

- **From magnitudes to fluxes and from theoretical spectra to synthetic photometry.**

  - VOSA takes advantage of the Filter Profile Service to get the needed information (i.e. zeropoints and other filter properties to, for instance, estimate flux overlapping).

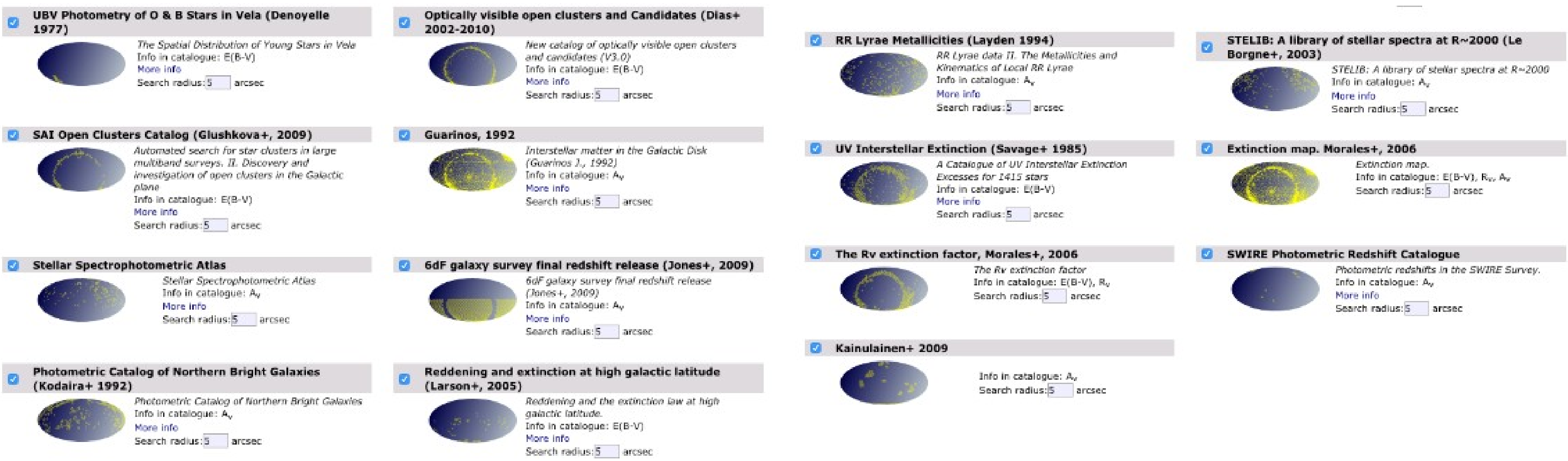
  - Photometric systems described following the VO Photometric Data Model.



Why VOSA? Because...

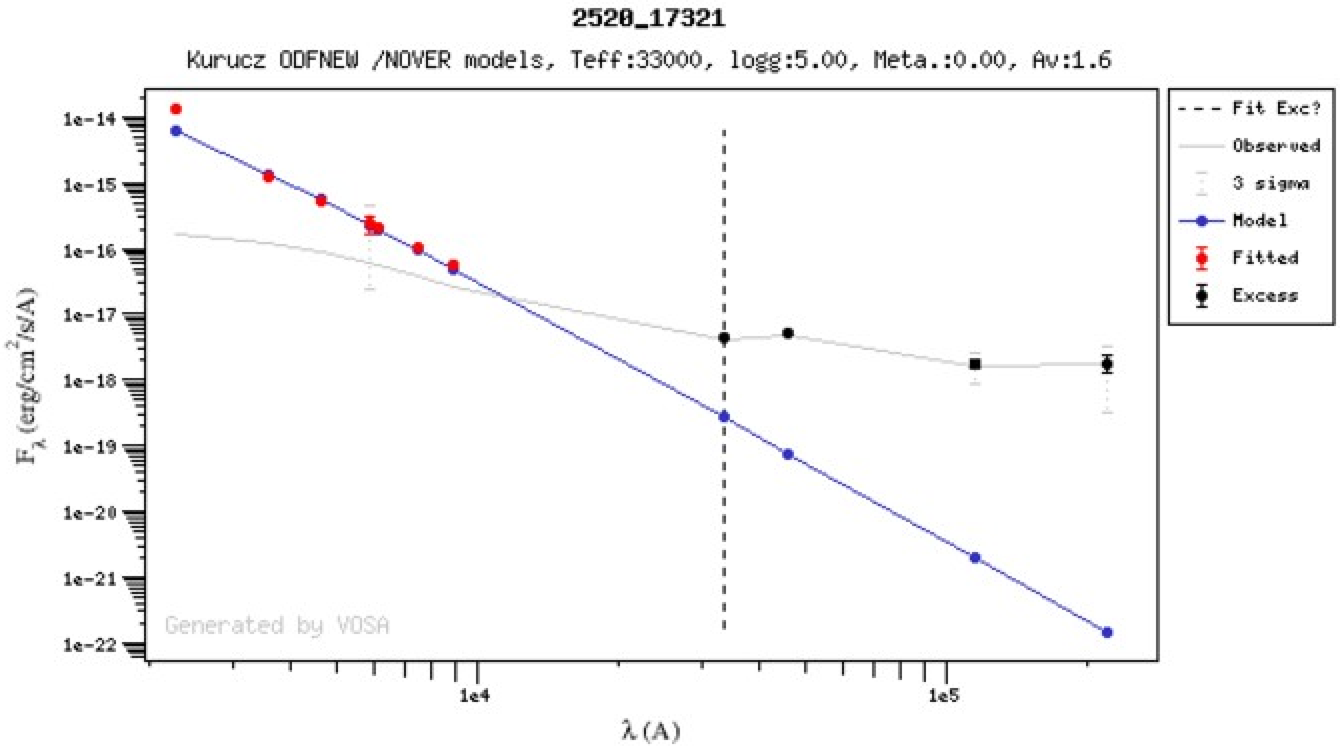
- **And many more things...**
  - **Parameters of interest (e.g. distances, extinction).**

Object			Final		User		Gaia TGAS						
Name	RA (deg)	DEC (deg)	Dis (pc)	ΔDis (pc)	D (pc)	ΔDis (pc)	Δ (arcsec)	RA (deg)	DEC (deg)	Plx (mas)	ΔPlx (mas)	D (pc)	ΔDis (pc)
AK_Pic	99.501523980	-61.533387245	21.295	0.367	21.295	0.367	---	---	---	---	---	---	---
BD-034778	301.205833	-2.655556	66.907	2.836	66.907	2.836	1.4874278531513	301.20577672353807	-2.6559653324222907	14.946160262675168	0.633445535189698	66.907	2.836
CP-681894	200.53125	-69.636667	98.892	3.477	98.892	3.477	0.62841099688041	200.53096654040246	-69.63681101855927	10.112062527326222	0.35555658147693964	98.892	3.477
EG_Cha	129.234167	-78.946111	102.264	6.427	102.26	6.427	0.86741015893762	129.23358291137242	-78.94589766116239	9.77865609415897	0.6145318505980452	102.264	6.427
HD_217379	345.116473141	-26.311887527	32.009	0.277	32.009	0.277	2.978832064554	345.1170290328832	-26.31254811756945	31.241380996286175	0.2701321530637279	32.009	0.277



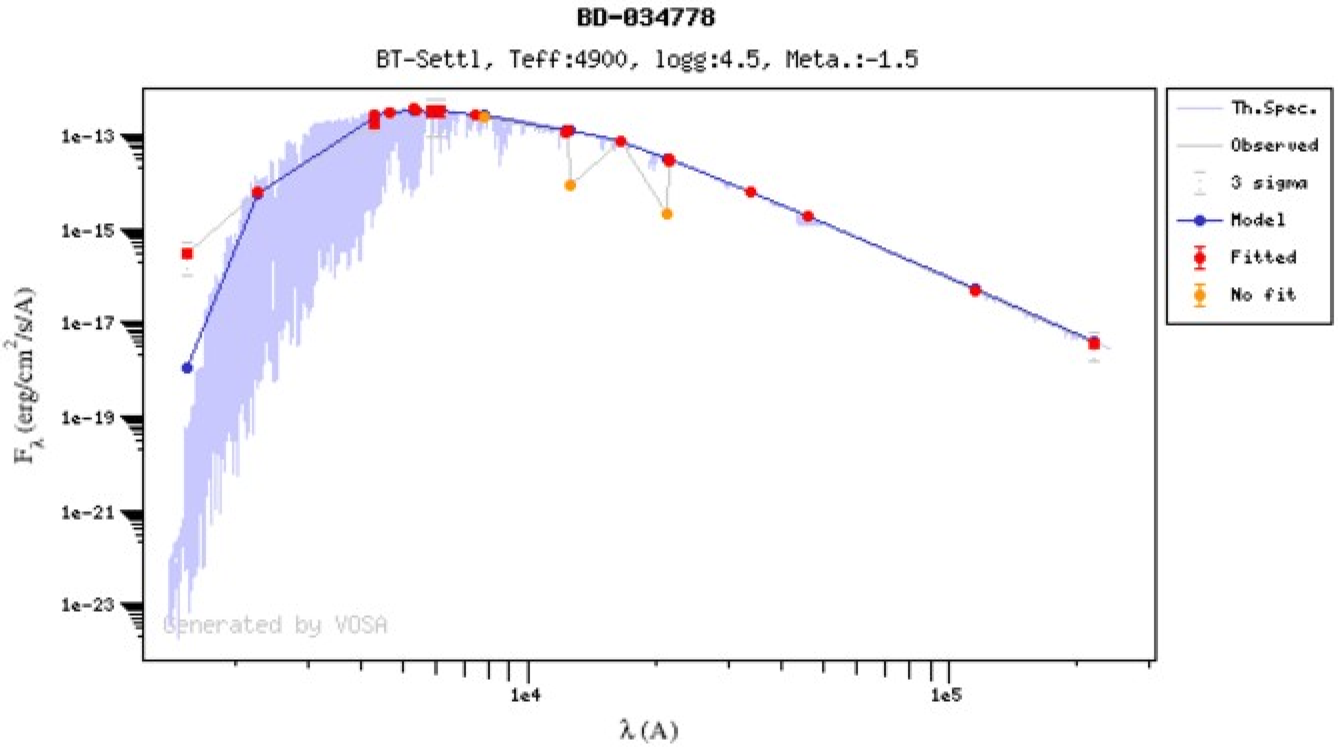
Why VOSA? Because...

- **And many more things...**
  - **Identification of IR excess**



Why VOSA? Because...

- **And many more things...**
  - **Identification of bad photometric points (not considered in the fit)**

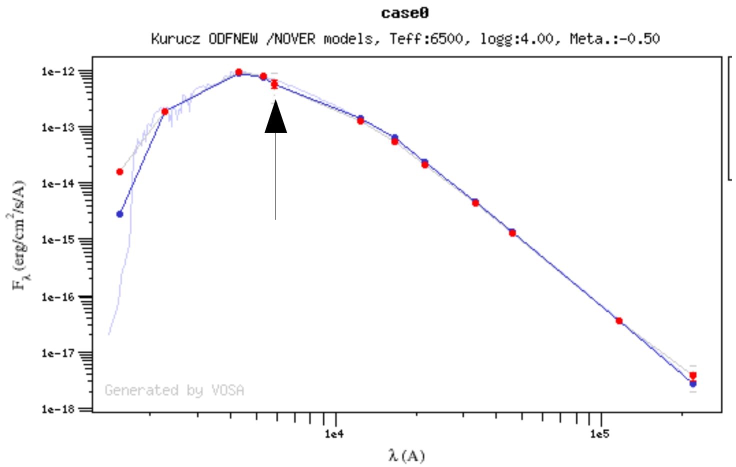


Science case #1: Determination of physical parameters

I/337/gaia Gaia DR1 (Gaia Collaboration, 2016
Post annotation GaiaSource data (**Download** Gaia Sc

start AladinLite

Full	RA_ICRS deg	DE_ICRS deg	<Gmag> mag
1	063.4107528711	-89.9888879972	17.965
2	037.5117084305	-89.9858176527	16.664
3	084.7593492719	-89.9781776713	18.553



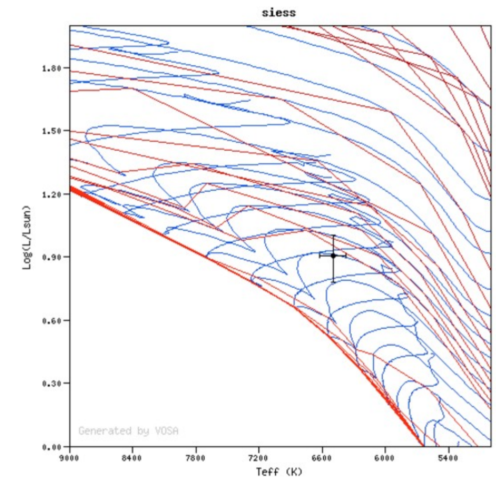
Objects

Object	Model	T_{eff}		LogL		Age		Mass	
case0	siess	6500	(6375,6625)	0.9087	(0.7817,1.0067)	0.0102	..(0.0090,2.0403) [1]	1.5997	(1.4995,1.7141)

[1] The distance to one of the closer curves has been estimated as the one to the closest point in the curve

Gaia TGAS

RA (deg)	DEC (deg)	Plx (mas)	ΔPlx (mas)
301.8466189871131	-42.070408408686404	4.367777320347275	0.3432906180577608



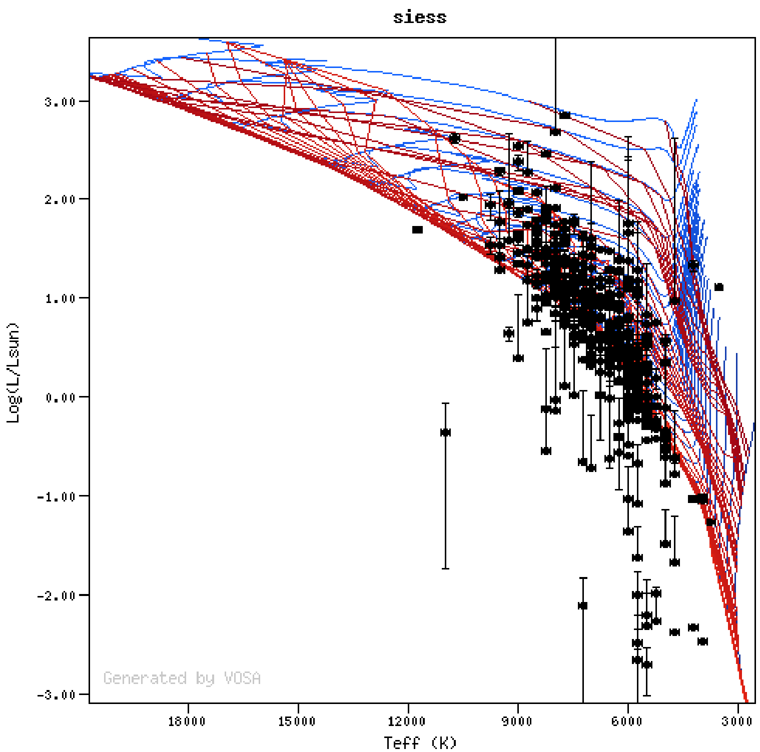
Science case #1: Disk characterization

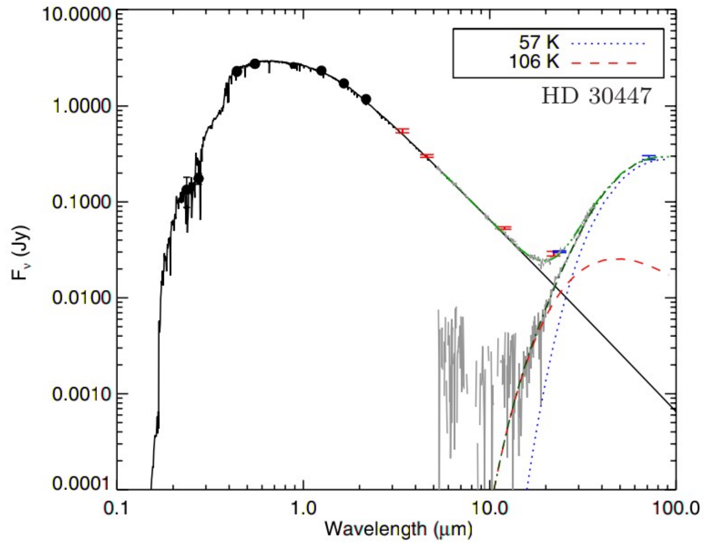
The Astrophysical Journal Supplement Series, 211:25 (22pp), 2014 April doi:10.1088/0067-0049/211/2/25

THE *SPITZER* INFRARED SPECTROGRAPH DEBRIS DISK CATALOG. I. CONTINUUM ANALYSIS OF UNRESOLVED TARGETS

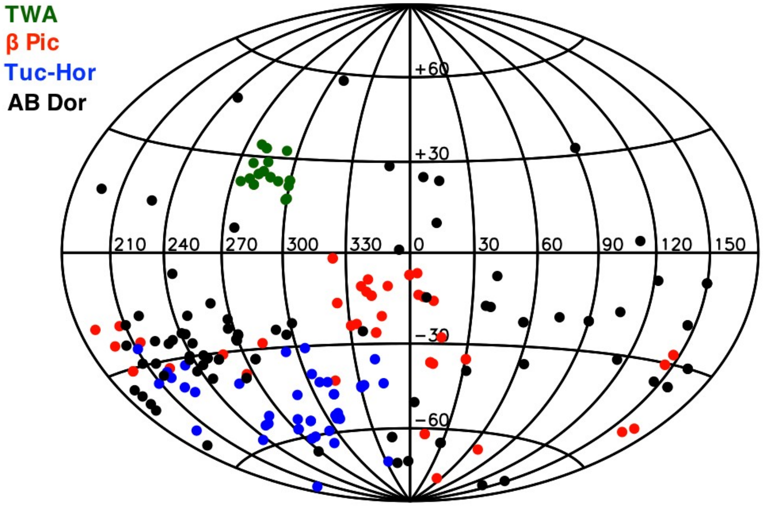
Christine H. Chen[1], Tushar Mittal[2], Marc Kuchner[3], William J. Forrest[4], Carey M. Lisse[5], P. Manoj[6], Benjamin A. Sargent[7], and Dan M. Watson[4]

- Detailed characterization of the photospheric component
- Disk evolution with age

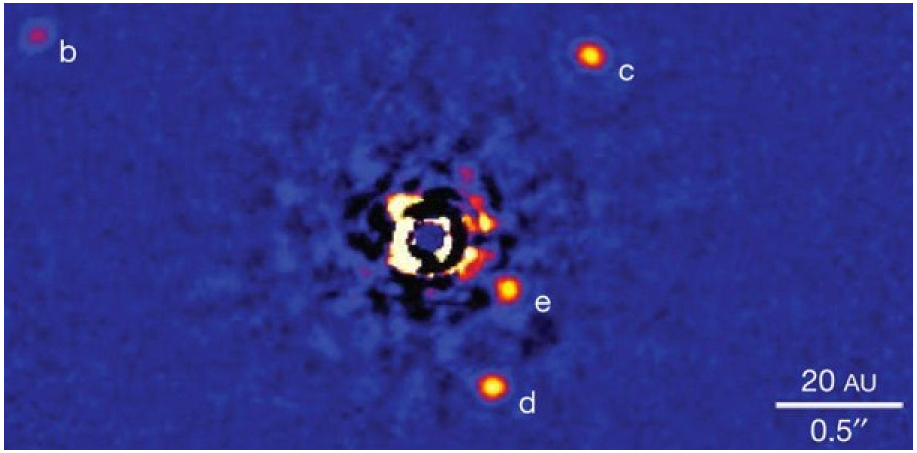


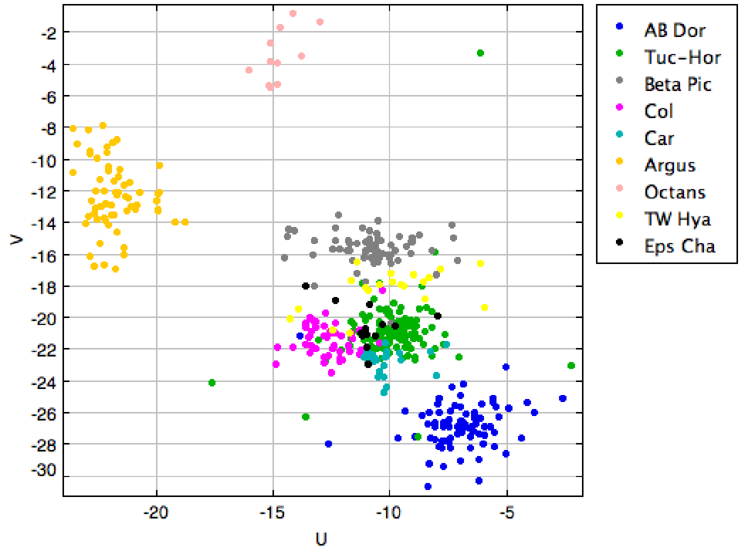


Science case #2: Stellar associations

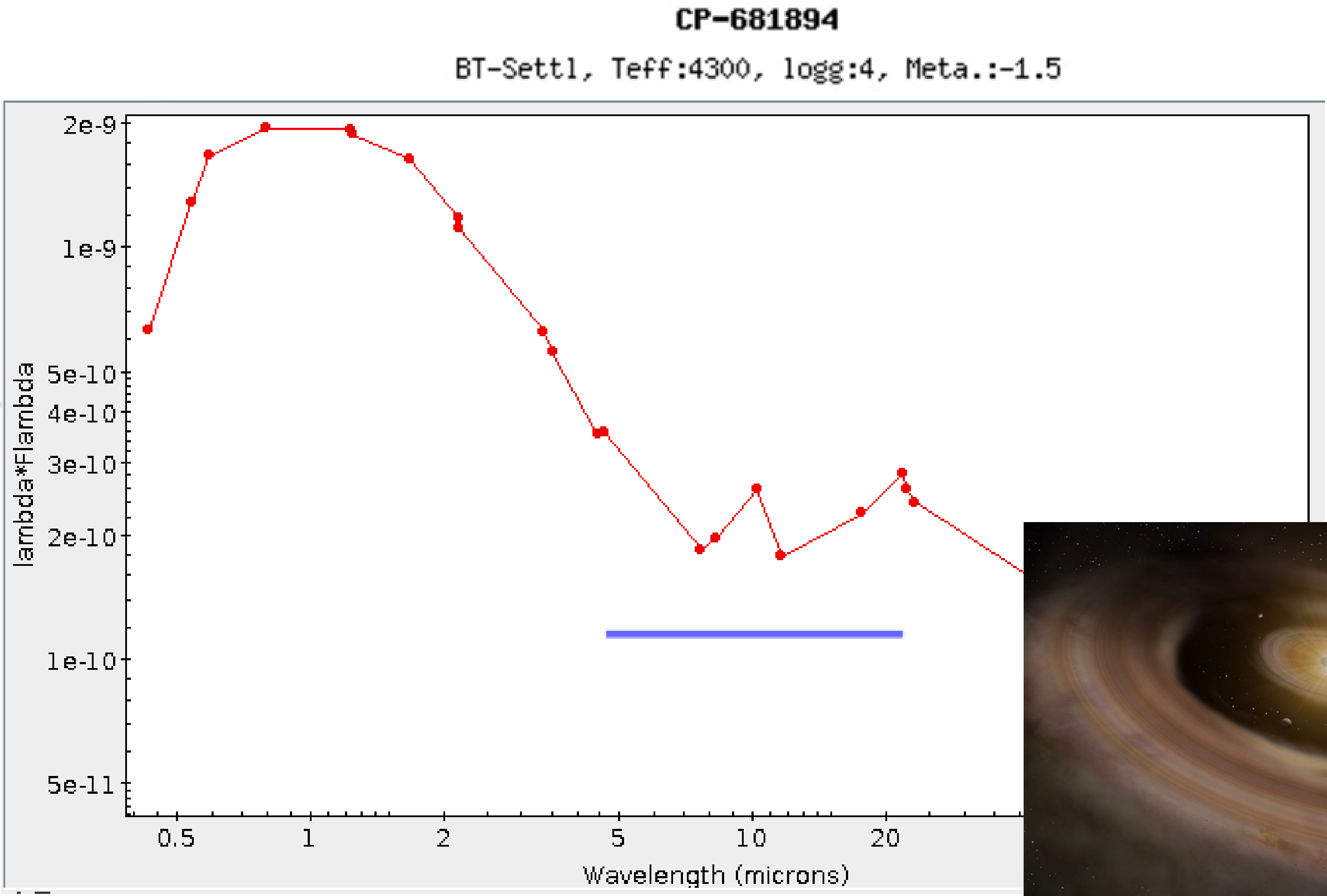


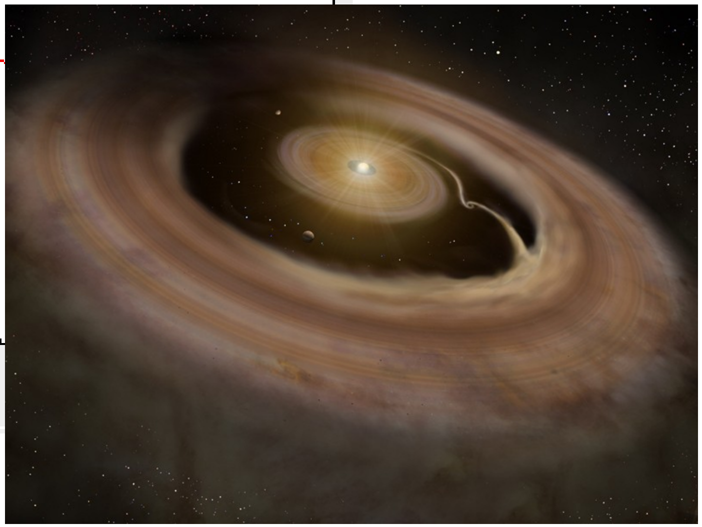
- < 150 pc
- 5 – 100 My



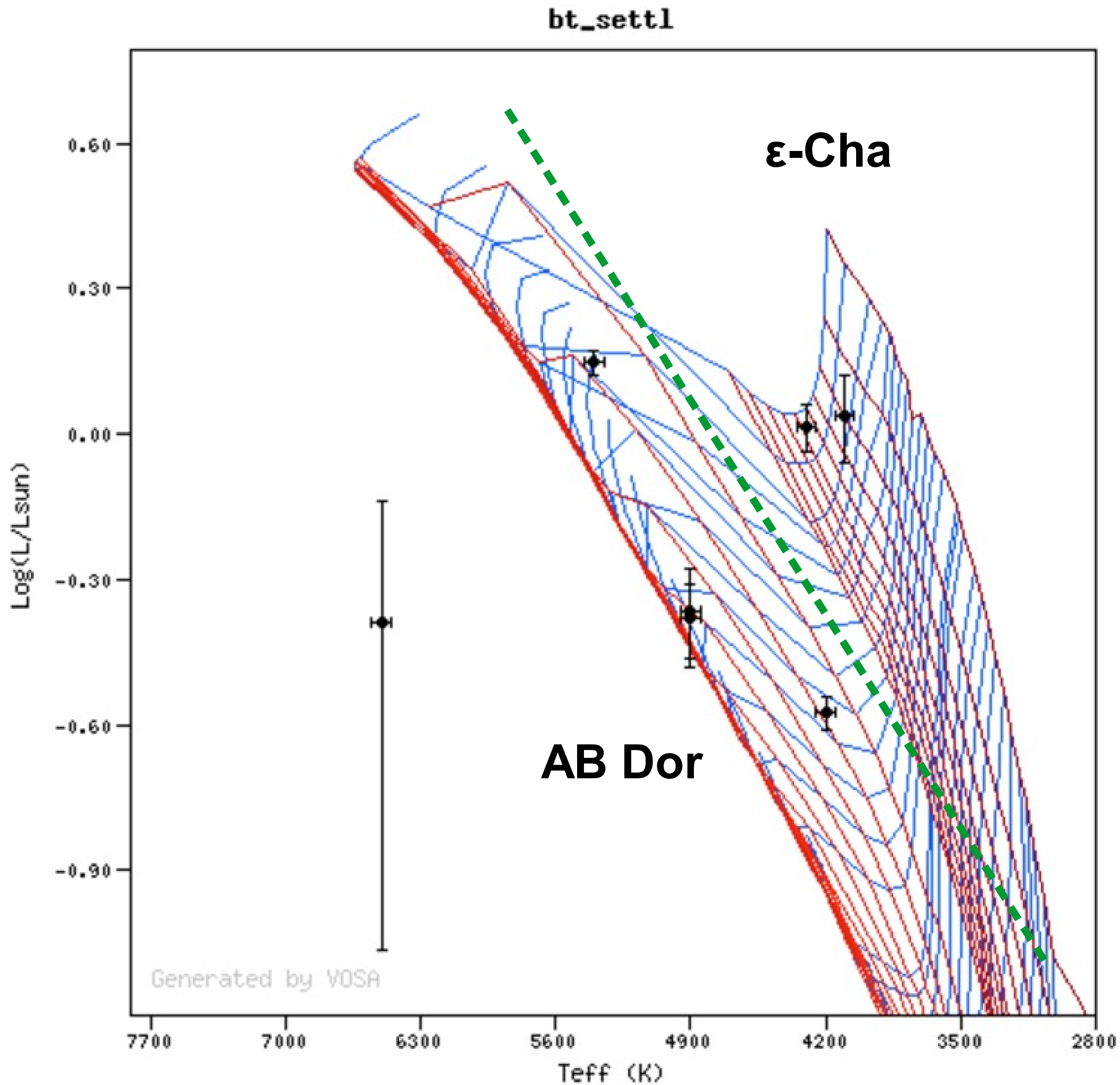


Science case #2: Identification of disks





Science case#2: Age estimation



Science case #3

arXiv.org > astro-ph > arXiv:1609.04389

Search or

Astrophysics > Earth and Planetary Astrophysics

Accurate, Empirical Radii and Masses of Planets with Gaia Parallaxes

Keivan G. Stassun (1,2), Karen A. Collins (1), B. Scott Gaudi (3) ((1) Vanderbilt University, (2) Fisk University, (3) Ohio State University)

(Submitted on 14 Sep 2016 (v1), last revised 15 Sep 2016 (this version, v2))

We present new, empirical measurements of the radii of 132 stars that host transiting planets. These stellar radii are determined using only direct observables---the bolometric flux at Earth, the stellar effective temperature, and the parallax newly provided by the Gaia first data release---and thus are virtually model independent, extinction being the only free parameter. We also determine each star's mass using our newly determined radius and the stellar density, itself a virtually model independent quantity from the previously published transit analysis. The newly determined stellar radii and masses are in turn used to re-determine the transiting planet radii and masses, once again using only direct observables. The uncertainties on the stellar radii and masses are typically 8% and 30%, respectively, and the resulting uncertainties on the planet radii and masses are 9% and 22%, respectively. These accuracies are generally larger than the previously published model-dependent precisions of 5% and 6% on the planet radii and masses, respectively, but the newly determined values are purely empirical. We additionally report stellar radii for 366 stars that host radial-velocity (non-transiting) planets, with a typical achieved accuracy in the radii of 2%. Most importantly, the stellar bolometric fluxes and angular radii reported here---with typical accuracies of 1.7% and 1.8%, respectively---will serve as a fundamental data set to permit the re-determination of the planet radii and masses with the {\it Gaia\} second data release to 3% and 5% accuracy, comparable to or better than currently published precisions, but in an entirely empirical fashion.

$$\Delta \mathrm{F} = \left(\frac{R_{planet}}{R_{star}} \right)^2$$

$$M_p = \frac{K_{\rm RV}\sqrt{1-e^2}}{\sin\, i} \left(\frac{P}{2\pi G} \right)^{1/3} M_\star^{2/3}$$

Science case #3

- Masses and radii of planets are necessary to:

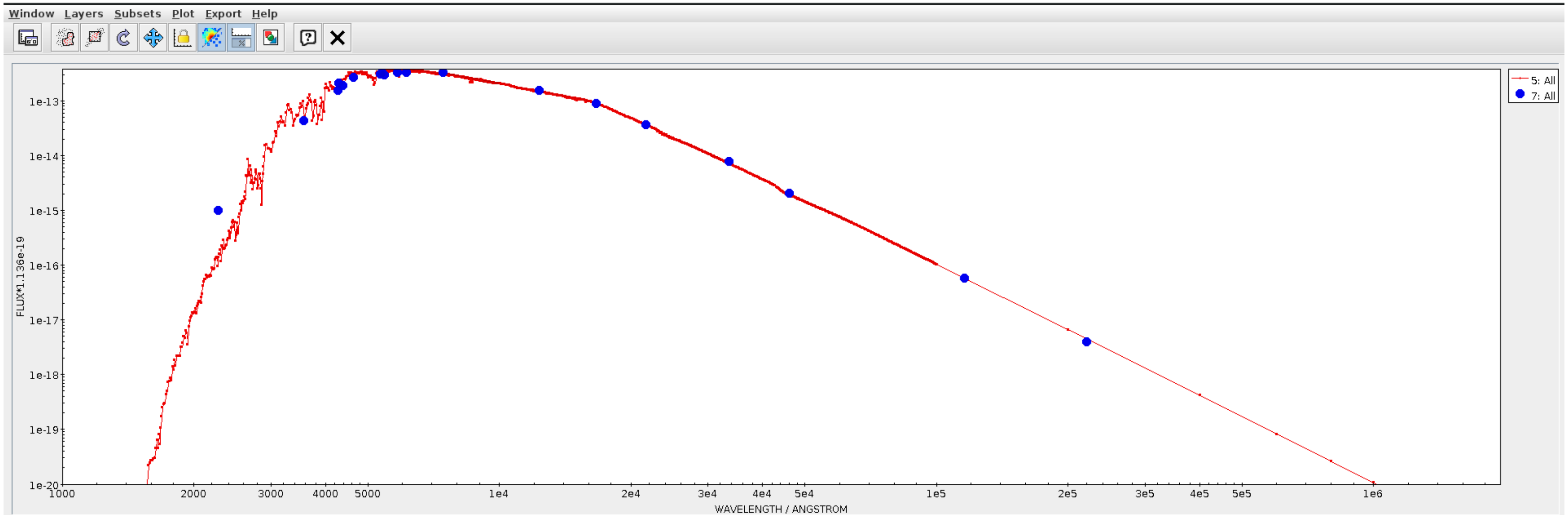
  - Shed light on inflated hot-Jupiters.
    - 0.2-2.1MJup. Radii larger than predicted by models.
    - Heat from the star and internal heating.

    → Planet radius as a function of irradiation, age, magnetic fields, winds,...

  - Infer the presence of rocky cores in hot-Jupiters.

    → Impact on formation theories (core accretion vs gravitational instability).

Science case #3



- Empirical determination (model independent) of the radii and masses of stars hosting planets.
- Fbol → empirical
- Lbol=4πD^{2}Fbol (D from TGAS parallaxes)
- R=sqrt(Lbol/(4πσTeff^4))
- g= G M / R^2

Do you want to know more?

- vosa-support@cab.inta-csic.es
- VOSA:
  http://svo2.cab.inta-csic.es/theory/vosa/
- VOSA workflow:

https://www.astron.nl/asterics/doku.php?id=open:wp4:view_vosa_tutorial