The Computational Challenge of Microlensing in a new Perspective

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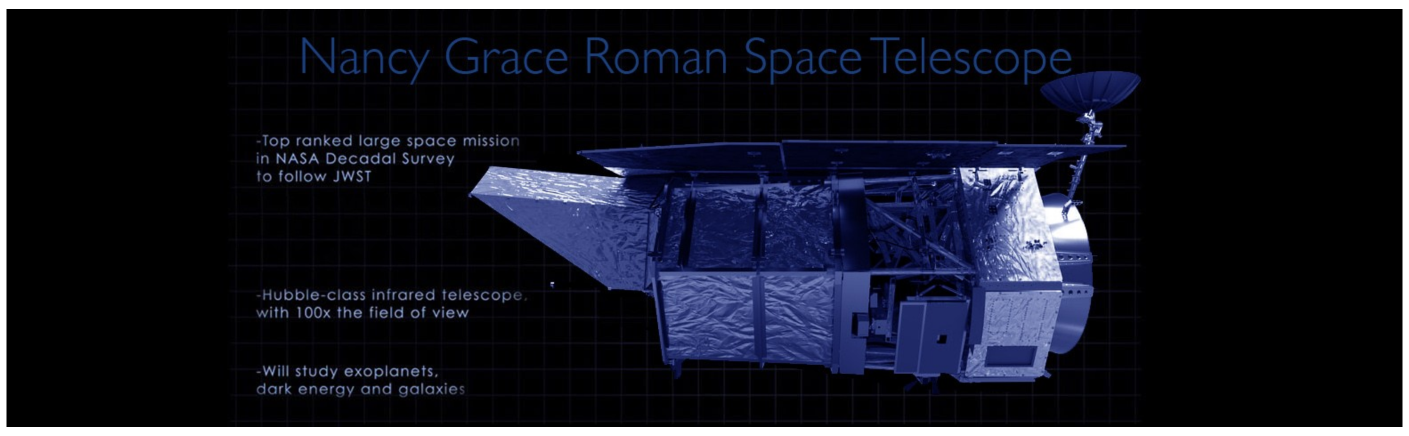
Abstract

The *Roman* space telescope will perform the deepest microlensing survey ever, with thousands of expected planets. Modeling planetary microlensing events requires the use of slow and cumbersome inverse methods to decipher the intricate web of gravitational lensing caustics from the observed light curve. VBBinaryLensing has imposed itself as the fastest public code for microlensing computation and it has been incorporated in all existing modeling platforms. The development of user-friendly analysis tools for microlensing is of primary importance to broaden the scientific impact of the results of the microlensing method throughout the exoplanetary community, and facilitate the approach of newcomers to the field.

Introduction

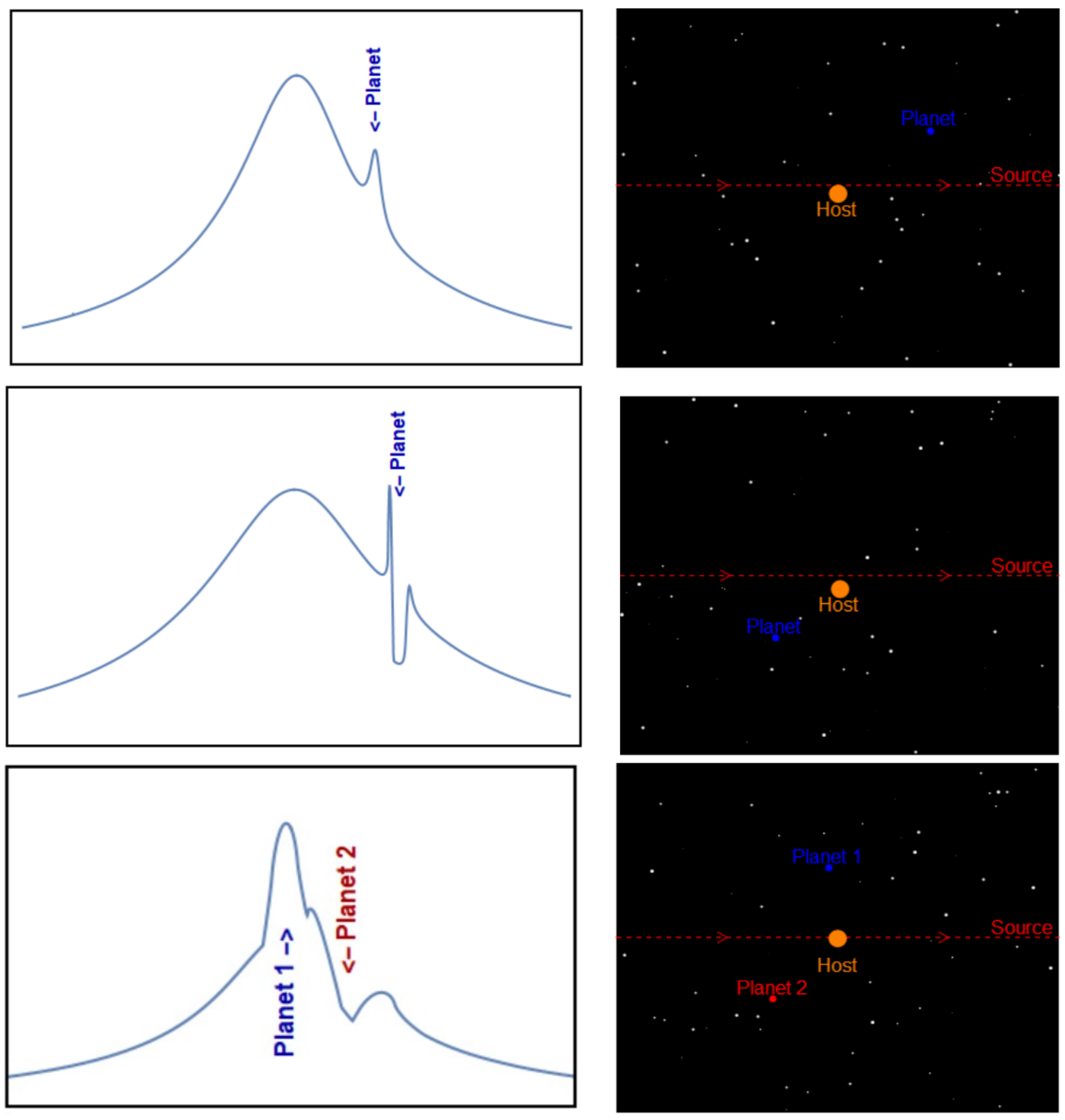
Microlensing occurs when the flux of a background star is amplified by the gravitational lensing caused by a foreground object. It is the only way to measure the masses of isolated objects, such as black holes, brown dwarfs or free-floating planets. It is the only method to effectively probe planetary abundances beyond the snow line and discover analogs of the Solar System. The *Roman Galactic Exoplanet Survey* is expected to discover thousands of planets down to Mars mass in the direction pointing toward the Galactic Bulge.



Interpreting Microlensing

There is a broad variety of possible microlensing light curves, depending on the planet-star separation and mass ratio, but also on the relative source-lens trajectory. Subtle higher order effects are very important to break degeneracies and improve our knowledge on the planetary system.

Figure 2: Some examples of planetary microlensing light curves



The calculation of the microlensing amplification for a given configuration is computationally expensive, since we need to invert the "lens map". In addition, in order to find the best model, we need to explore a multi-dimensional parameter space with many local χ^2 minima and degenerate valleys.

With the huge data flow from the *Roman* mission, it is imperative to speed up our computations and make microlensing modeling accessible to a broader community, so as to provide reliable and accessible results in a timely manner.

VBBinaryLensing

VBBinaryLensing is the fastest public code available for microlensing.

- Based on the contour integration technique
- Written in C++ and importable in Python
- Microlensing light curves including higher orders
- In the latest version, also includes astrometric shift of the images
- Represents the basic core of all existing modeling platforms (pyLIMA, MulensModel, muLAN)
- Available on GitHub and as a single zip file here.

Figure 3: Example of basic use of VBBinaryLensing

```
#include <stdio.h>
#include "VBBinaryLensingLibrary.h"

int main()
{
   VBBinaryLensing VBBL;

   double Mag,s,q,y1,y2,rho,a1,accuracy;
   s=0.8; //separation
   q=0.1; // mass ratio
   y1=0.01; // source position
   y2=0.3;
   rho=0.01; // source radius

   VBBL.a1=0.51; // Linear limb darkening coefficient
   VBBL.Tol=1.e-2; // Accuracy goal
   Mag=VBBL.BinaryMag2(s,q,y1,y2,rho);

   printf("Magnification = %lf\n",Mag);

   return 0;
}
```

Expanding our knowledge on Exoplanetary Systems

The Roman Galactic Exoplanetary Survey will provide a large statistical sample of exoplanetary population in regions unexplored by other methods. Microlensing is sensitive to planets in intermediate (few AU) orbits down to very small masses. These planets will be distributed all along the line of sight to the Galactic Bulge, informing us on the planetary formation in different environments.

In order to exploit this Exoplanets mine, we are developing the necessary computational tools for a fast and efficient interpretation of microlensing events. These tools are also essential to disseminate the results to a broader community.

https://www.microlensing-source.org/

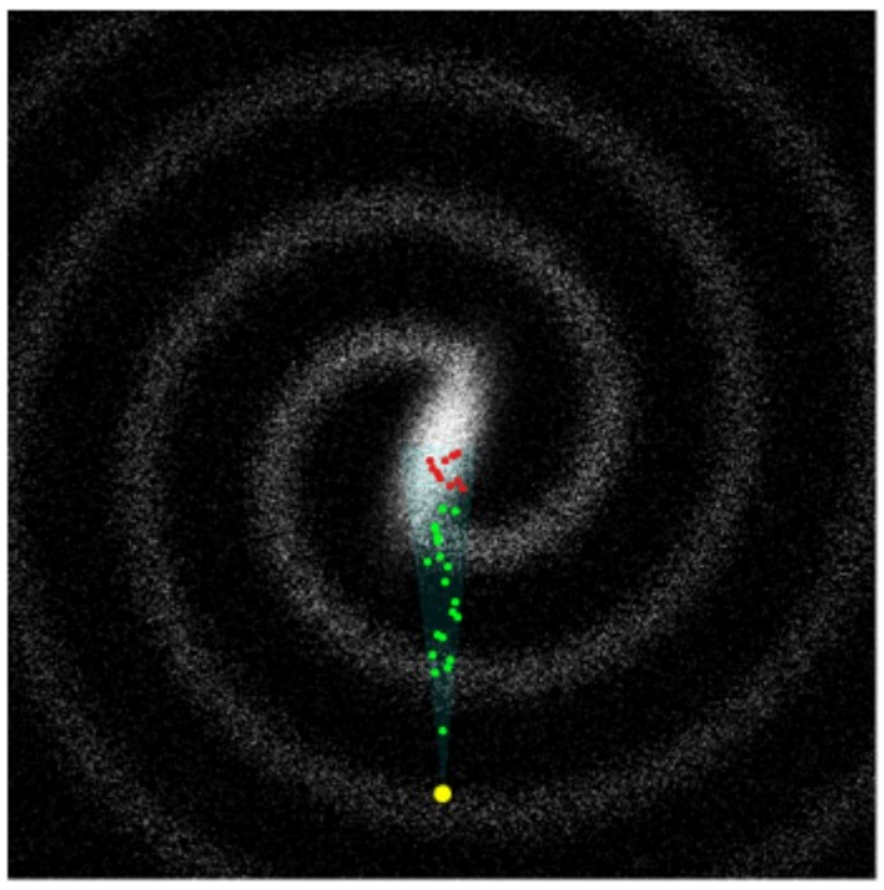


Figure 4: A possible distribution of planets in the Milky Way from microlensing statistics

References

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