EROS 2
Proper Motion Search for Halo White Dwarfs

Bertrand Goldman

For the EROS collaboration,
CEA/DAPNIA, CNRS/IN2P3 & INSU, and others

XXth Moriond Astrophysics Meeting, Les Arcs, March 12, 2000

Scientific Context

Microlensing in 2000:

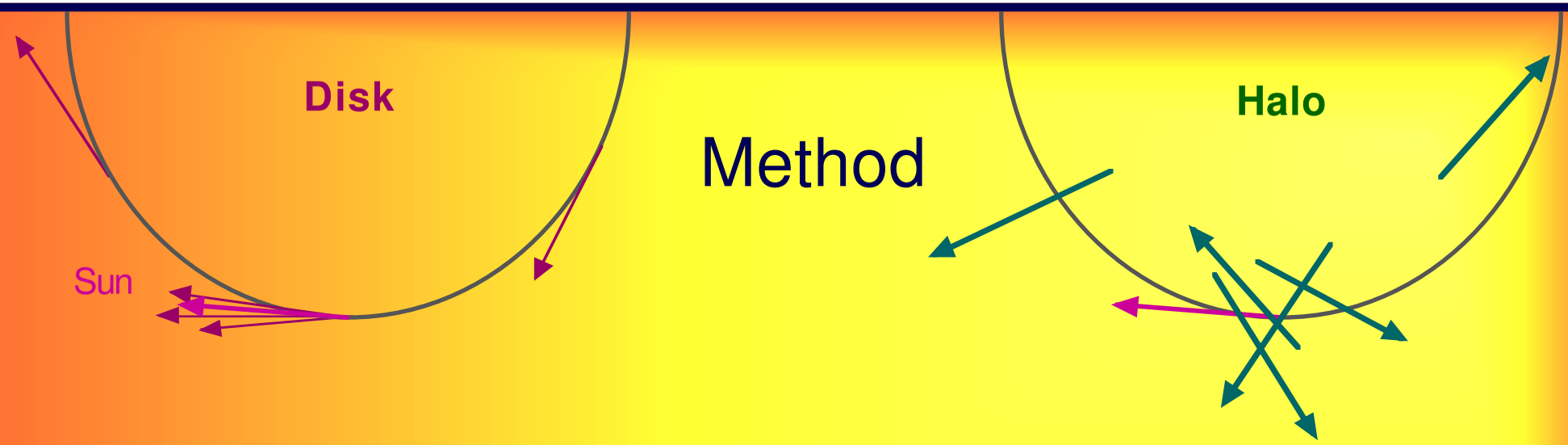
- positive results: MACHO: signal of 20% standard Halo, 0.4 M_o objects
- upper limits: EROS: upper limits at 20% on 10^{-6} to 1 M_o objects
- constraints from extragalactic and theoretical studies on the white dwarf mass budget

Possible confirmation of the WD hypothesis through proper motion survey

- 1999: detection by Ibata et al. of a few non-zero proper motion,
  blue objects in the HDF North
  identification by Mendez et al. of a blue stellar population high above the plan

EROS approach: wide solid angle; brighter objects than HDF's
in between pencil beams and plate surveys (volume larger than HDF)
possible spectroscopic confirmation of nearby candidates.

Method



expected different kinematics of the stars:

- velocity dispersion: 30—50 km/s ≈220 km/s (vs.)
- rotation: 220 km/s non-rotating (or slowly)

Local density: 0.0078 $M_\odot/pc^3$ or sixteen 0.5-$M_\odot$ WDs per 1,000 pc^3
for a spherical halo (higher densities for a flatter halo)

The Survey

- telescope: 1m Marly at La Silla
  cameras: 4k x 8k CCD mosaics in two broad bands, visible and near infrared
  pixel: 0.6 arcsec, 1 square degree field of view
- 1 Tb of images at high Galactic latitudes, shared with the supernova group
  exposures: 5—10 min , sensitivity down to V≈21.5 and I≈20
- Area: ≈400$^{\circ 2}$ with two epochs (3 to 8 images)
  200$^{\circ 2}$ with a two year baseline, with images every year

Precision

- astrometry on one single image: 25 mas = 0.04 pix for brighest stars
  0.18'' at 10-σ above sky background
- Proper motion: 20 mas/yr or 10 km/s at 100 pc
  0.1 ''/yr or 50 km/s at 100 pc
  typical maximum detection distance for faint objects
- Soft galaxy/star separation
  Contamination decreases with brighter magnitude limits.
  Multiple epochs also remove contamination.

Selection cuts

In each of the two bands:

- data: 1 measurement/yr for 3 years required
  minimum baseline: 550 days
- Fit: cut on χ^2 (no data cleansing) — removes ~1% of the data
- PM: signifance > 3.6σ — < 1% of simulated halo WDs
- high PM: μ < 6''/yr — < 5% of HWDs
- Cut to separate disk/halo population: μ_{halo} > 0.7''/yr — ~5—20% of HWDs

In this analysis in two colours:

- Compatility required between red and visible PM values:
  - direction < 40 degrees — ~1 % of HWDs
  - amplitude within 0.2 arcsec/yr — ~5 % of HWDs

Efficiency

- Efficiency measured by adding rescaled, real stars to our images
- Cosmetic defaults taken into account
- number of images per field
  image quality
  atmospheric conditions (seeing, absorption, sky background)

  | simulated

- Proper motion cuts applied
- Compatibility between motions measured in red and in visible bands

Disk and Halo expectations

Models used:

- disk: the Besançon model (Robin et al.)
  include LFs and kinematics for disk, thick disk and spheroid populations
- halo: “isothermal” standard halo
  excusively made of (DA) WDs of a various luminosities and colours of mass 0.5 $M_{\odot}$
  0.0078 $M_{\odot}/pc^3$ local density
- to each generated object:
  the observed error distribution
  the efficiency of detection are taken into account

→ catalogue of simulated HPM star candidates
to be compared with the actual candidates

Results on the WD composition of the Galactic Halo

- No halo candidate has been found
- Constraints can be put on the halo composition in WDs of M_V between 16 to 18.5, depending on WD colour
- No constraint can be put yet on fainter WDs or Helium WDs.

Prospects for the near future

- Analysis of each band separetly near completion
- Third epoch soon imaged for all fields (up to $400^{\circ 2}$)
- Fourth epoch forseen in 2001/02
  this will allow us to search deeper without an increased noise and galaxy contamination, and to lower the proper motion cuts
- Dedicated analysis for disk faint objects,
  → BDs in the infrared band
  → cool WDs in the visible band
  Several objects have already been confirmed by spectroscopy (L-4, BD, WD)
  (Goldman et al. 1999, Martín et al. 1999, Basri et al. 2000)