Baade-Wesselink Method

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• Baade-Wesselink Method

Introduced by Baade (1926) as a test of the pulsating nature of Cepheids
• Baade-Wesselink Method

  Observed color ➔ Surface brightness ➔ Surface area ➔ Stellar radius in an arbitrary unit (as a function of phase)

  Spectrum ➔ Radial velocity-curve ➔ Radial displacement in kilometers (as a function of phase)
Light and radial velocity curve of δCephei (Schwarzchild, M. 1938)
• Baade-Wesselink Method
  First attempt:
  Unsuccessful (Bottlinger, 1928)
  - BB assumption is wrong!
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Becker’s assumption (Becker, 1940):

There is a one-to-one relation between color and surface brightness among Cepheids and throughout their variations.

Wesselink applied this assumption and got a reasonable radius of delta Cephei in 1946 (Wesselink, 1946)
Becker's assumption

Color (B-V)

Luminosity

Same surface-brightness

$R_2/R_1$!
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\[ R(t) \rightarrow \text{Mean radius} \rightarrow \text{Absolute L} \]

An independent calibration of P-L relation of Cepheids!!

Wesselink measured the size of delta Cephei: \( R = 38 \pm 3 \ R_\odot \) (Wesselink, 1946)
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\[ \rho \text{ (projection factor):} \]

Radial velocity \( \neq \) Surface velocity
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Limb darkening law:

\[ \sigma(\gamma) = \sigma(0) \times \left( 1 - \beta + \beta \cos \gamma \right) \]

And:

\[ \frac{\nu}{\bar{v}} = p = \frac{2(3 - \beta)}{(4 - \beta)} \]

\[ R_2 - R_1 = p \int \nu dt \]
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$p$ (projection factor):

No limb darkening ($\beta=0$) $\Rightarrow p=1$

Totally dark at limb ($\beta=1$) $\Rightarrow p=1.33$

Eddington Approximation $\Rightarrow p=1.41$

Recent $p=1.36$ (Merand 2006)

$p$ maybe close to 1 for stars with very extended atmosphere (Bohm-Vitense, 1986)
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  Brightness: measured at photosphere (optical depth = 2/3)

  Radial velocity: measured at line-forming layer (optical depth ~0.1)

  And also, line-forming layer is not always corresponding a same mass-layer during the expansion/contraction
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Surface flux (as a function of \( T \)) is dependent on \( g \) (gravitational acceleration) (Bohm-Vitense, 1989)

Color-index:

(V-I), (V-R): insensitive to \( g \) or metallicity (Cacciari, 1989)

(B-V): most accepted

Infrared: (V-K), (J-K), etc.
• Interferometric B-W Method

Variation in size can be observed directly! (Kervella et al, 2004)
• Interferometric B-W Method

Projection factor can be measured directly

\[ R_2 - R_1 = \int v \, dt \]

\[ p = 1.27 \pm 0.06 \text{ (Merand, 2006)} \]
References

Merand, A. 2006, Memorie della Societa Astronomica Italiana, v.77, p.231