

# Evolution and instability in Mira variables

- Miras, Semiregulars, and stellar evolution
- Slow period changes: [R Aql](#)
- Fast period changes: [T UMi](#)
- Fluctuating periods: [W Hya](#)
- The history of [R Hya](#)
- The future: planetary nebulae

## Miras and Semiregular variables

- Miras

- Periods of 200–600 days
- Visual amplitude  $A_V > 2.5$  mag
- Periods are stable but amplitude may vary
- Red giants with strong stellar winds

- Semi-regular variables

- Mira-like but shorter periods (50-150 days)
- SRb: irregular light curves
- Weaker winds

The matter lost by the star will later form a planetary nebula

## Slow period changes

Two Mira reported with slowly changing period: R Aql and R Hya

R Aql discovered 1850

1900: period was slowly decreasing

Decrease has continued at an almost constant rate

AD 1850:  $P = 360$ days

AD 2000:  $P = 275$ days

What is happening?

Star must be getting smaller

## Fast changes

A few Mira show a very sudden onset of period evolution

### Example [T UMi](#)

period 320 days between 1920 and 1980

since 1980: fast decline

AD 2000  $P = 240$  days

### Example [BH Cru](#)

Discovered as variable in 1965

Period rapidly increasing

Mira pulsations getting stronger

## Fluctuating periods

Most Mira periods vary by 1–2% over time  
but a few vary much more

Example *W Hya*

- period 400 days
- varying between 410 and 370 days
- fluctuations of 10% over 50 yr

*S Ori, R Nor, R Cen, ...*

## Instability

- 10%–50% of **brightest** and **longest-period** Miras show period instability
- $\Rightarrow$  occurs near the end of Mira evolution
- Period and amplitude strongly correlated

## Explanations?

1. Helium flash (**Thermal Pulse**)
2. Non-linear pulsation

## R Hya: a case study

- 3<sup>rd</sup> brightest Mira  $V = 5$
- $P = 400$  days
- Period evolution reported:  
Wood & Zarro (1981); Olbers (1841)

Post-1900 data: AAVSO, BAAVS, AFOEV,  
VSOLJ, RASNZ

Pre-1900 data: Müller (1918), Argelander  
(1869)

- Continuous decline since at least 1850
- Period constant since 1950 **385 days**
- Start of decline: needs historical data

## Evolution of R Hya

AD 1662–1770:  $P = 495$ days

AD 1770–1950: shortening

AD 1950–2000:  $P = 385$ days

R Hya evolved from one stable period to another

Easier explained as a non-linear pulsation

## Stellar evolution: the end

Miras consist of a small but heavy core and a very large envelope

Core: carbon ashes

hydrogen burning in a shell around the core  
alternated by helium flashes

Once remaining hydrogen used up:

Core will become a white dwarf

surrounding envelope becomes a planetary nebula

The evolution depends on the strength of the wind

## Winds of change

### Prediction

- wind depends on **luminosity and radius** of star (Bloeker, Reimers)
  - R Hya: wind change very small
- or wind depends on **period** of the star (Vassiliadis, Wood)
  - R Hya: wind decreased by a factor of 20

### Observation

The wind of R Hya **ceased** about 250 yr ago

Suggests **wind depends mainly on period**

## Rings

Miras with period changes will also change the strength of the wind

- Can cause rings of high and low density

R Hya type instability can explain the rings seen around planetary nebulae

Would require that period changes repeat every 200–400 yr

More observations requested!

## Summary

- Perhaps 10% of bright Miras have period variations larger than 5%.
- **Fluctuating** periods
- **Sudden** rapid changes: **decades**
- **Slow**, continuous changes: **centuries**
- AAVSO and other databases are revealing Miras to be intrinsically unstable
- Provides clues to the origin of the structures in planetary nebulae
  
- **Keep observing! A few more centuries please.**

Table 1: Pre-1850 observations of R Hya.

Year, month, date of maximum	observer
1662 04 18	Hevelius <sup>a</sup>
1670/2 <sup>b</sup> 04 15	Montanari <sup>a</sup>
1704 03 20	Maraldi
1705 09 01:	Maraldi
1708 05 20	Maraldi
1709 Nov 01:	Maraldi
1712 May 15:	Maraldi
1784 01 26	Pigott
1785 05 25	Pigott
1805 05 05	Piazzi
1809 04 04	Piazzi
1818 03 31:	Olbers
1823 04 18	Olbers
1827 01 30	Schwerd
1843 05 30	Argelander
1848 04 23	Argelander