Spectroscopically resolving
the ‘inner‘ atmospheres
of elderly stars

= TIGvival =

Mira and her sisters

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Outline

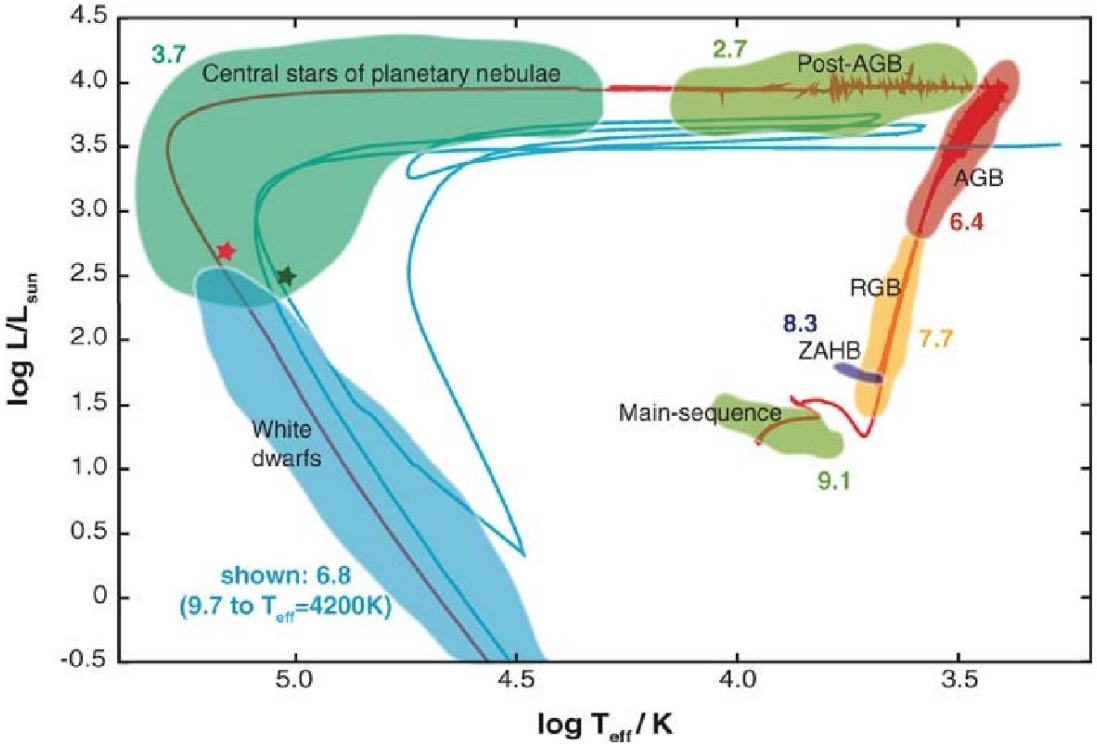
- AGB stars - Long-Period Variables (LPV) - ‘Miras‘
- TIG*vival*: Mira and other AGB stars – 2013 until today
- TIGRE/HEROS: ‘Heroes and villains’

Mass-loss mechanisms of

= AGB Stars =

AGB stars – *why worry*?

1. A one solar mass star loses on the order of 25% mass on the AGB



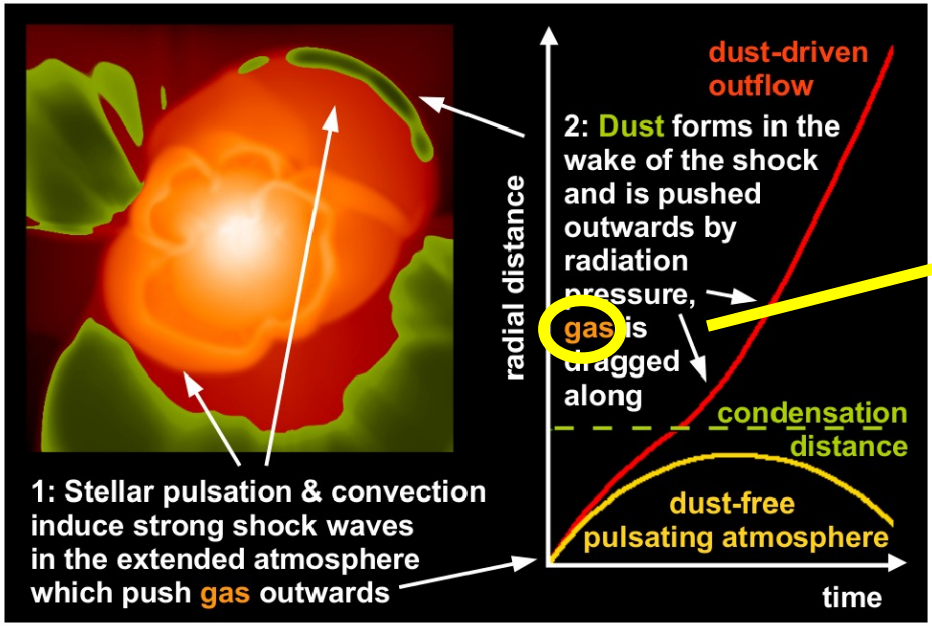
2. Snapshot of a 3D model:
1 solar mass with solar metallicity

3. AGB initial mass ~0.5 to ~8 solar masses
(2 solar masses with solar metallicity shown)

(Freytag & Höfner 2017, A&A 600)
http://www.astro.uu.se/~bf/movie/AGBmovie.html

(Herwig 2005, ARA&A 43 – log t [yr] given)

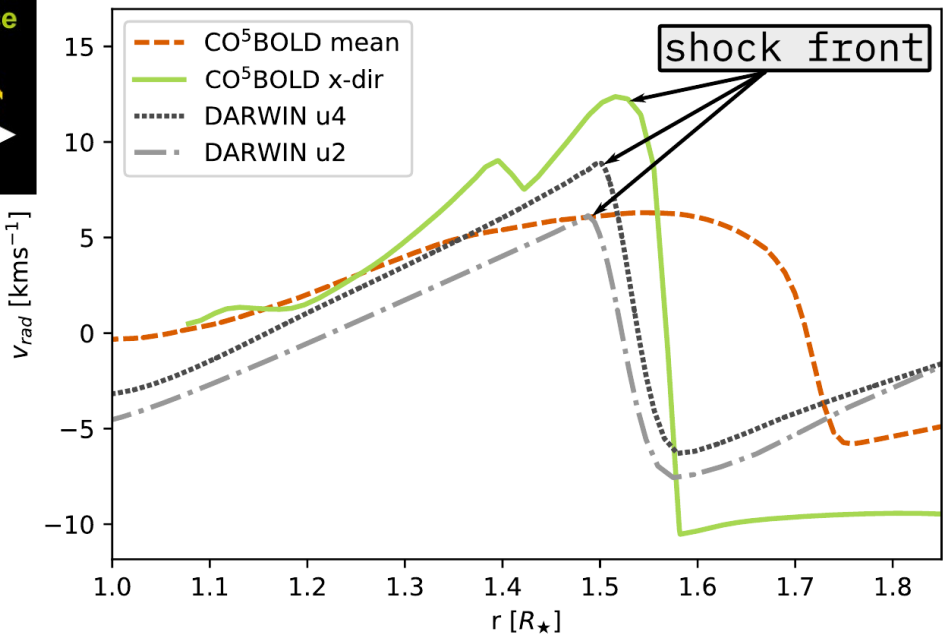
Mass loss of AGBs: PEDDRO



(Höfner 2016, CS 19)

(wikimedia)

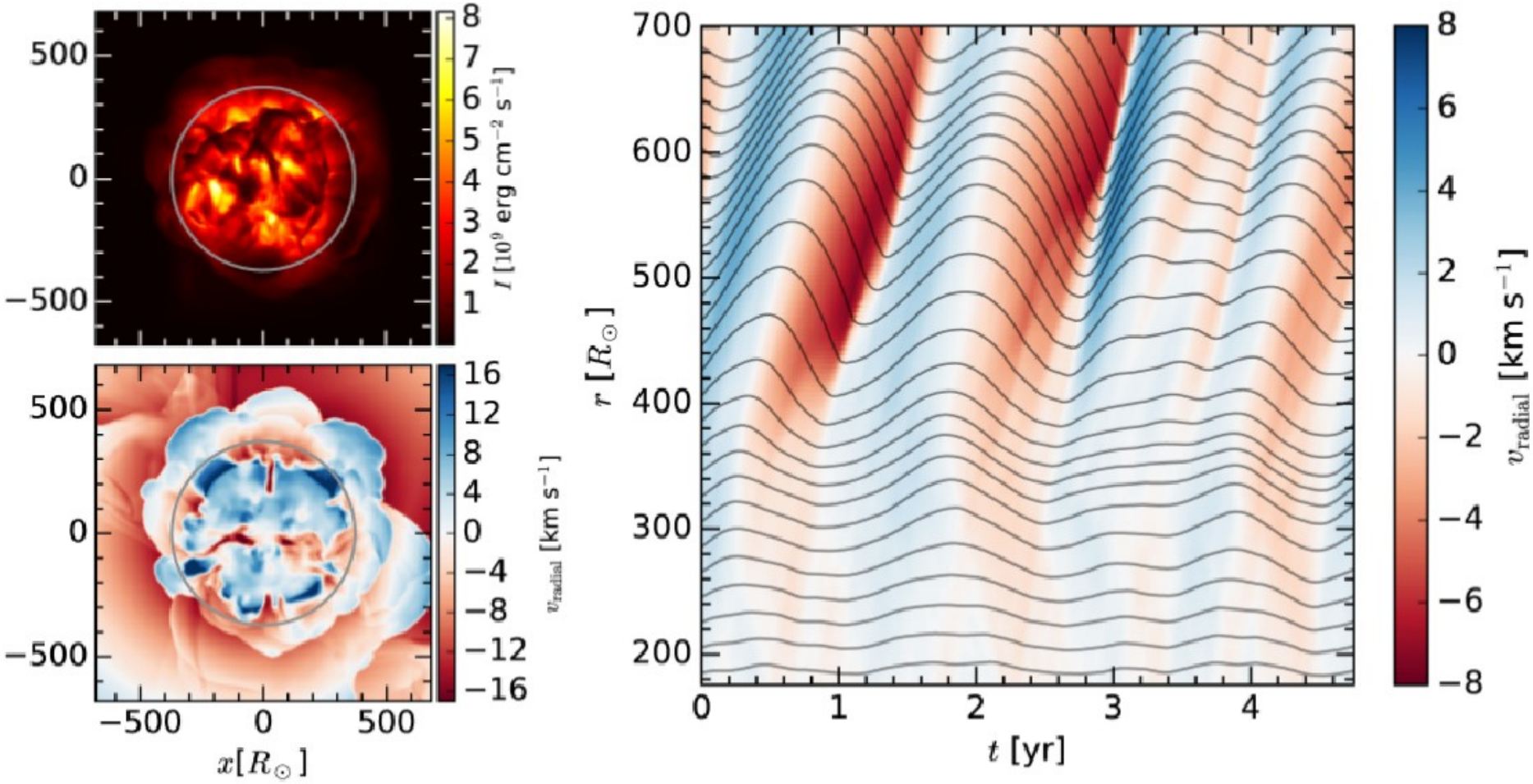
(Liljegren+ 2018, A&A 619)



PEDDRO =
Pulsation-Enhanced Dust-Driven Outflow

(Höfner & Olofsson 2018, AARv 26)

PEDDRO – time evolution



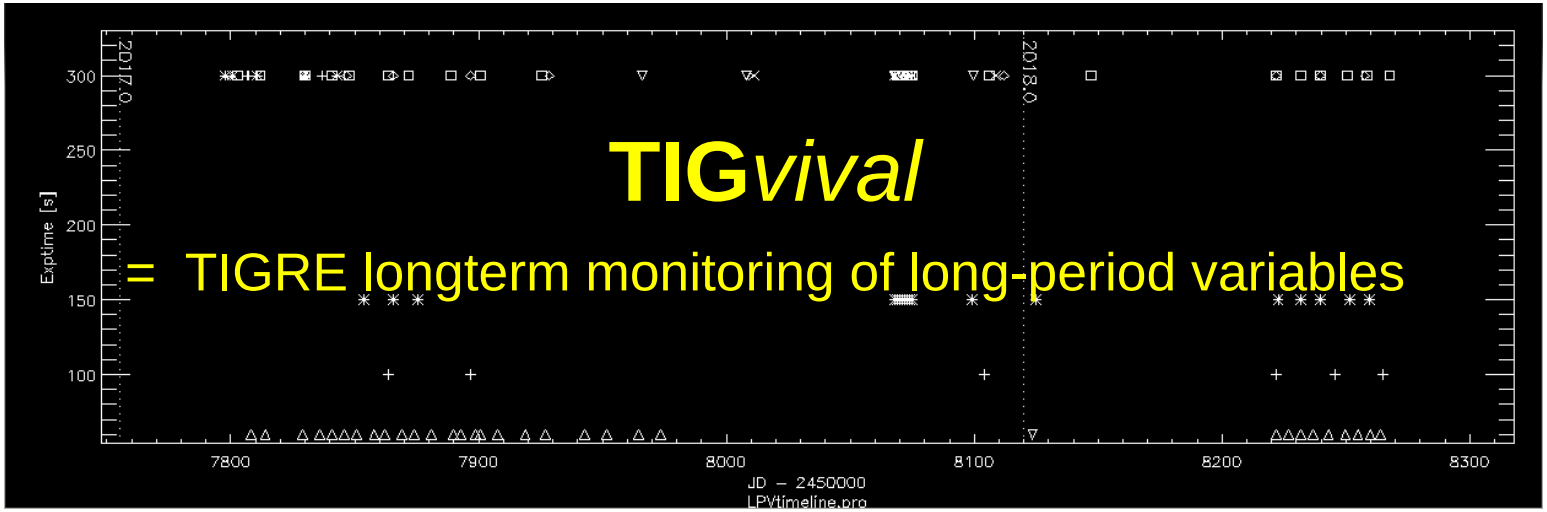
(Höfner 2016, CS 19; Freytag & Höfner 2017, A&A 600; Liljegren+ 2018, A&A 619)

(wikimedia)

= TIGvival =

Sleuthing Long-Period Variables (LPV)

TIGRE vigila variables de largo periodo a largo plazo



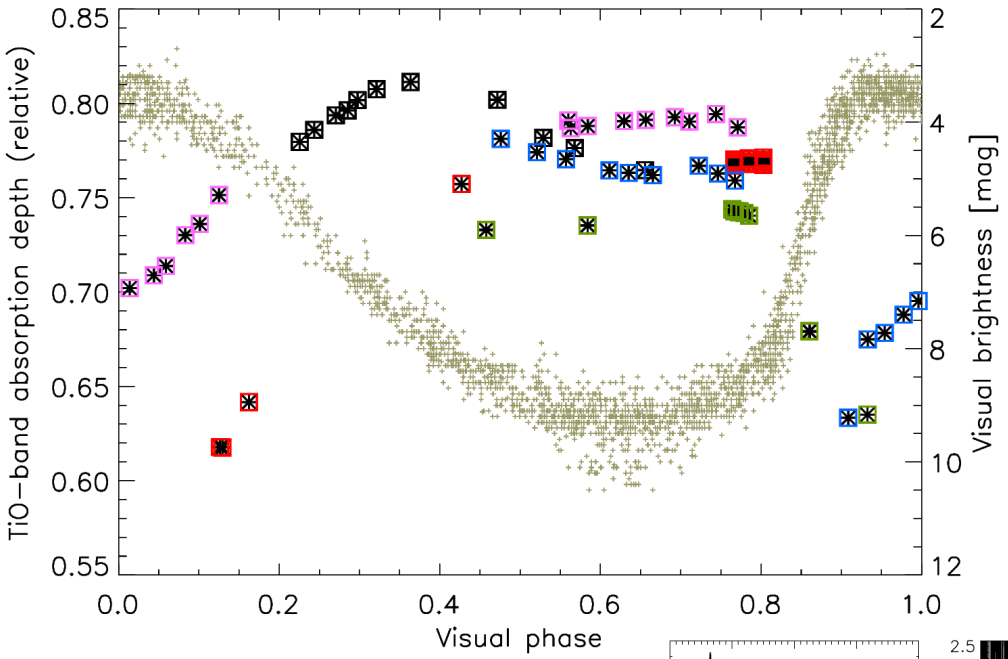
TIG*vival*

= TIGRE longterm monitoring of long-period variables

Object	m_V
U Hya	5.4 – 4.6 (Per= 183 d
G Her	5.5 – 4.3 (89 d, obs. 1
R Hya	8.5 – 5.5 (380 d, obs.
BK Vir	8.8 – 7.3 (150 , obs. 8
W Hya	10.0 – 5.8 (361 d, obs.
R Lep	10.0 – 5.5 (445 d, obs.
o Cet	10.2 – 2.0 (332 d, obs.
R Leo	11.0 – 4.5 (P= 310 d,
R Aql	11.0 – 5.5 (P= 271 d,
R Vir	11.5 – 6.0 (P= 146 d,

Object	Ra	Dec	m_V
U Ari	031103.0	+144800.3	8.0
S CMi	073243.1	+081905.2	8.0
X Hya	093530.3	−144128.6	8.5
R Leo	094733.5	+112543.8	5.5
R Tau	042818.0	+100944.8	9.0
U Ori	055549.2	+201030.7	10.0
R LMi	094534.3	+343042.8	7.5
X Oph	183821.1	+085002.8	7.0
ST Sgr	190129.2	−124534.1	9.0
S CrB	152124.0	+312202.6	7.5

TIGvival@Mira: TiO evolution in o Ceti



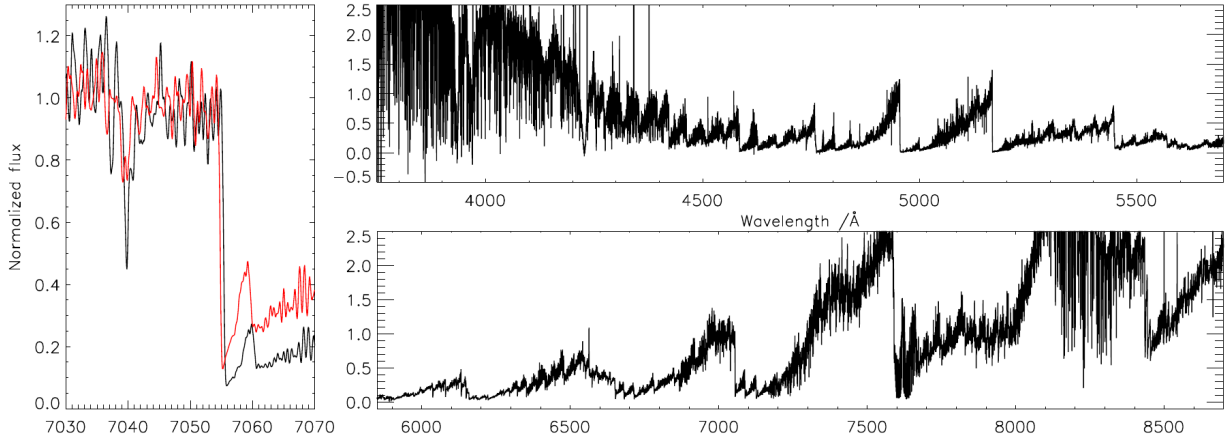
TIGvival: TiO 7055 Å in Mira

2013/14 (black) to 2018/19 (violet)
+ AAVSO visual photometry

(cf. also Castellaz+ 2000, AJ 120)

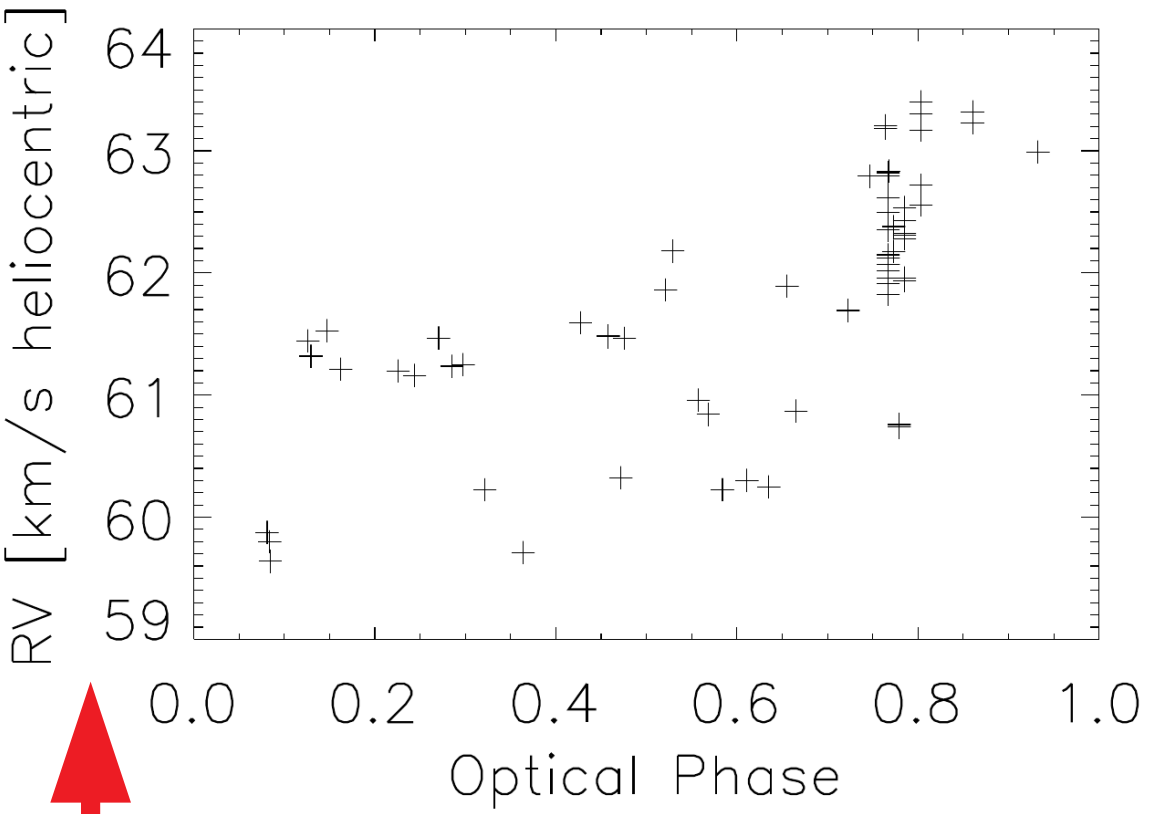
TIGRE spectra of Mira

Φ=0.16 (red) and 0.30 (black)
i.e. ~2 months apart



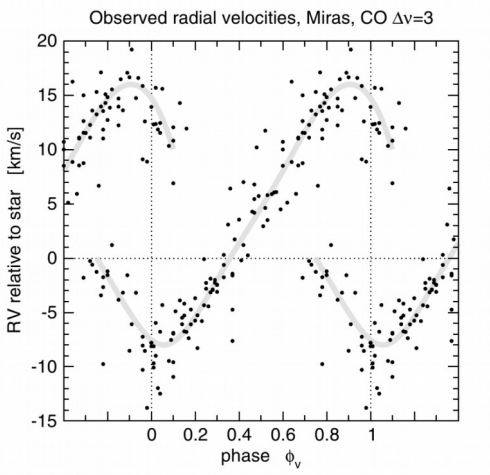
(Wolter+ 2019, IAUS 343,
cf. also Bladh+ 2015, A&A 575)

TIGvival@Mira: Photospheric velocities in o Ceti



TiO 7055 Å
Bandhead velocities in Mira
(TIGRE)

CO (17µm)
compiled for Mira variables

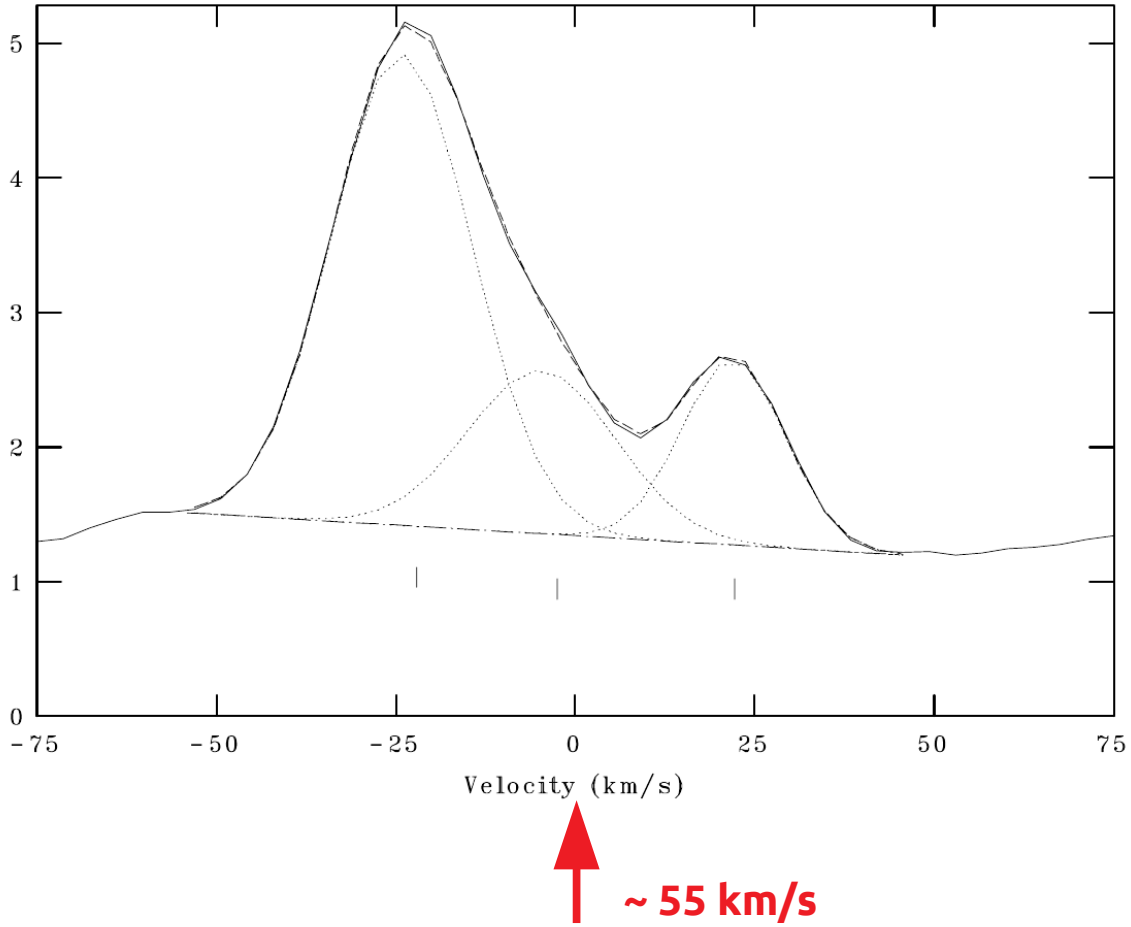


(Nowotny+ 2010, A&A 514)

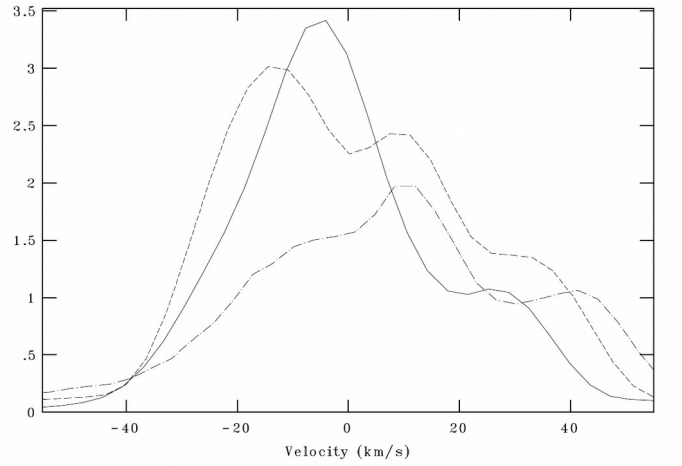
Mira's maser center velocity ($H_2$0, CO, SiO)

~ 55 km/s (heliocentric)

TIGvival@Mira: ‘Chromospheric’ velocities in o Ceti



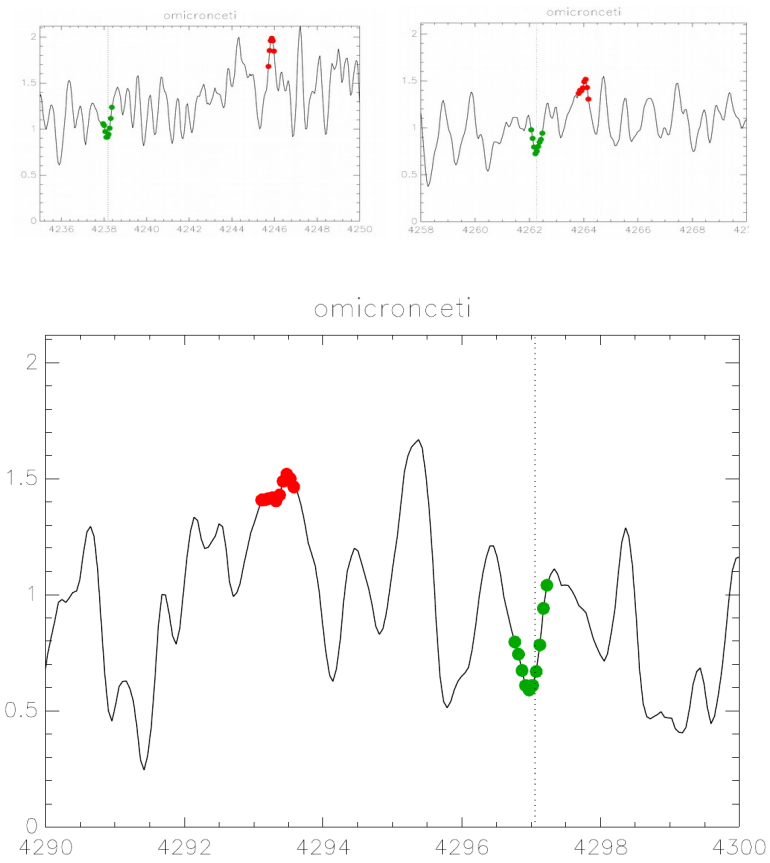
H alpha
velocities in Mira near phase 0
(TIGRE)



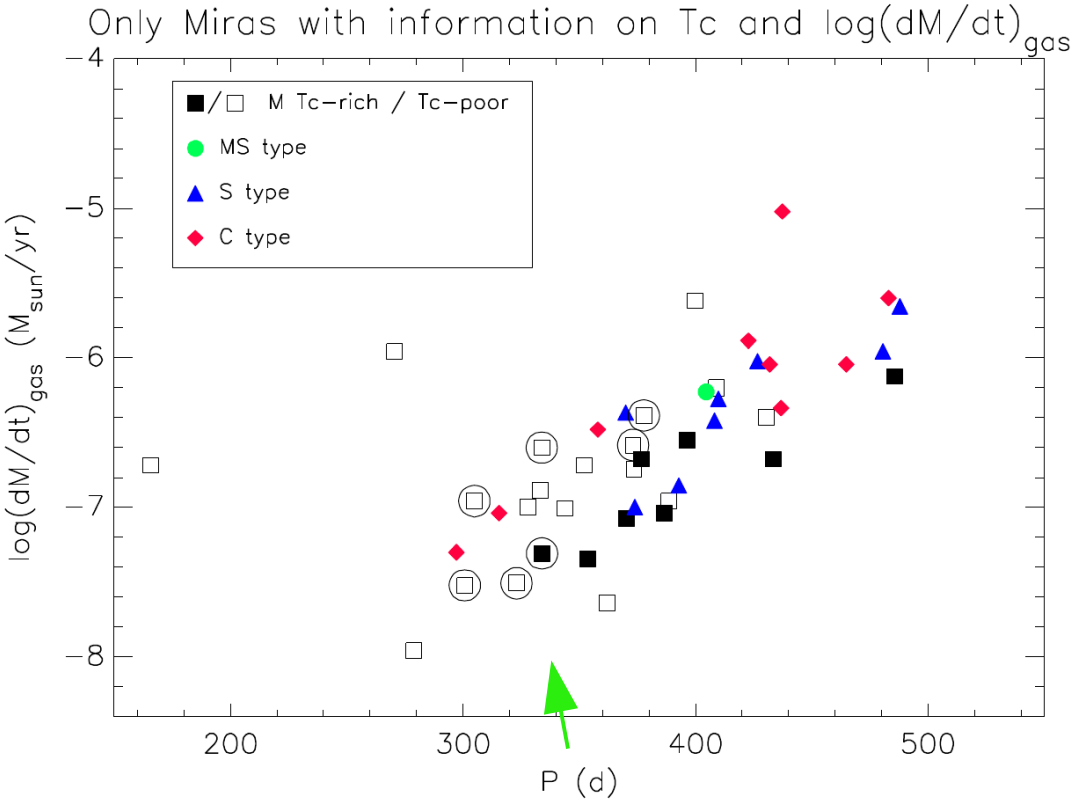
H delta, H gamma and H9
in Mira near phase 0.5

(cf. also Pierce, Willson, Beavers 1979, PASP 91)

TIGvival@Tc: Technetium in AGB stars



Tc lines in Mira
(TIGRE, S. Uttenthaler)



Mass-loss and Tc in LPVs
(TIGRE measurements marked by O, S. Uttenthaler)

(cf. also Uttenthaler+ 2019, A&A 622)

Summary

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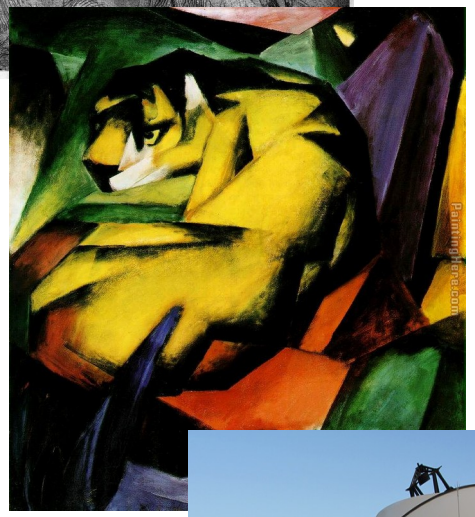


(wikimedia)

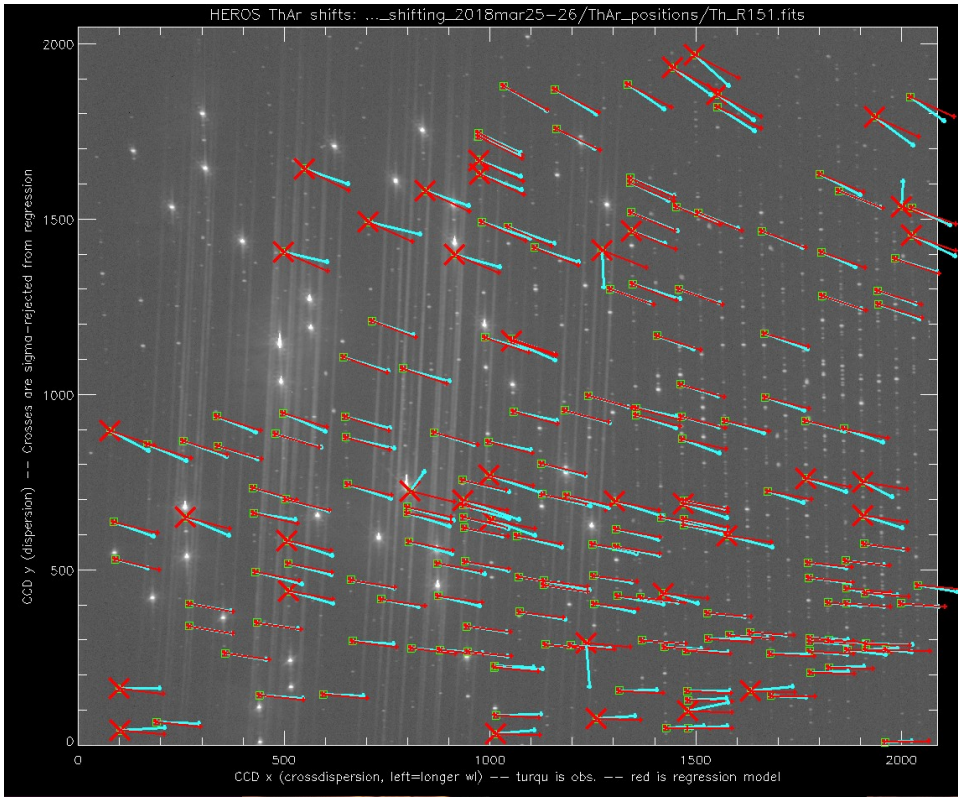
For >7 years, TIG*vival* will monitor ~10 long-period-variables to e.g. help gauge LPV-models

(wikimedia)

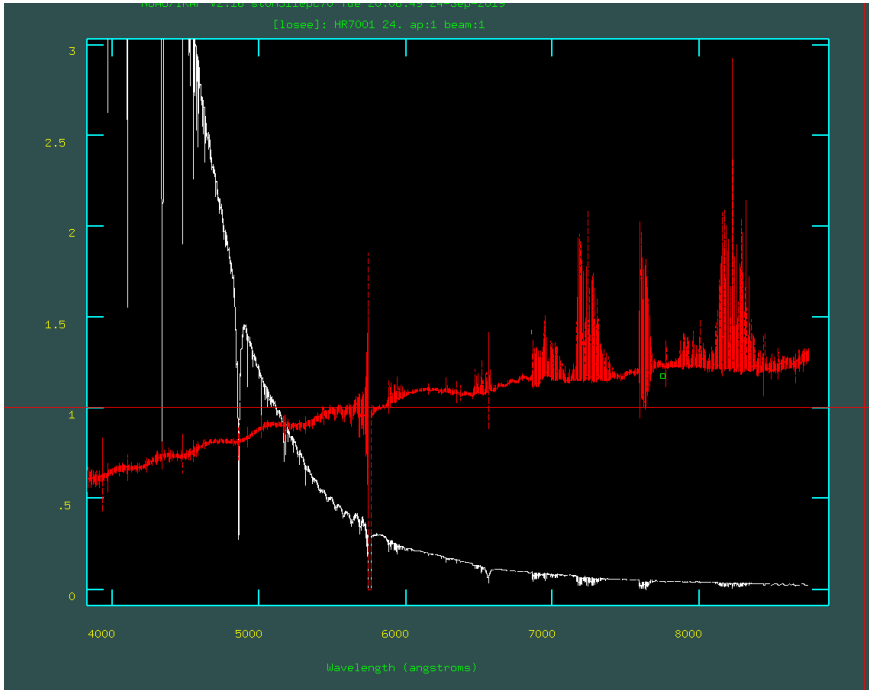
o Cet (Mira) @TIGRE exhibits quasi(?)-regular velocity and abundance variations – related to shocks in its photosphere and its 'chromosphere'

TIGRE/HEROS does measure at ~1 km/s precision and EW at a ~1% level – with careful calibration

HEROS ‘n villains



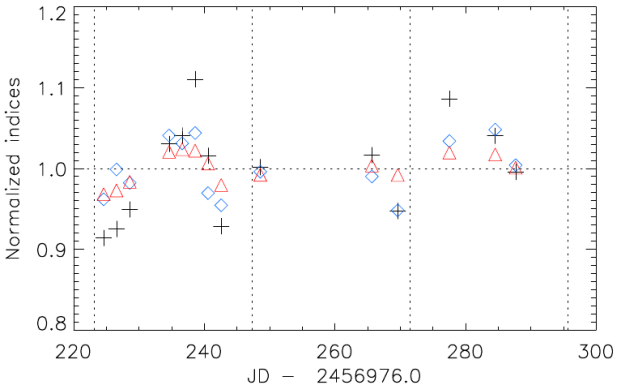
TIGRE/HEROS: ThAr at 15 vs. 20 °C (shifts x 100)



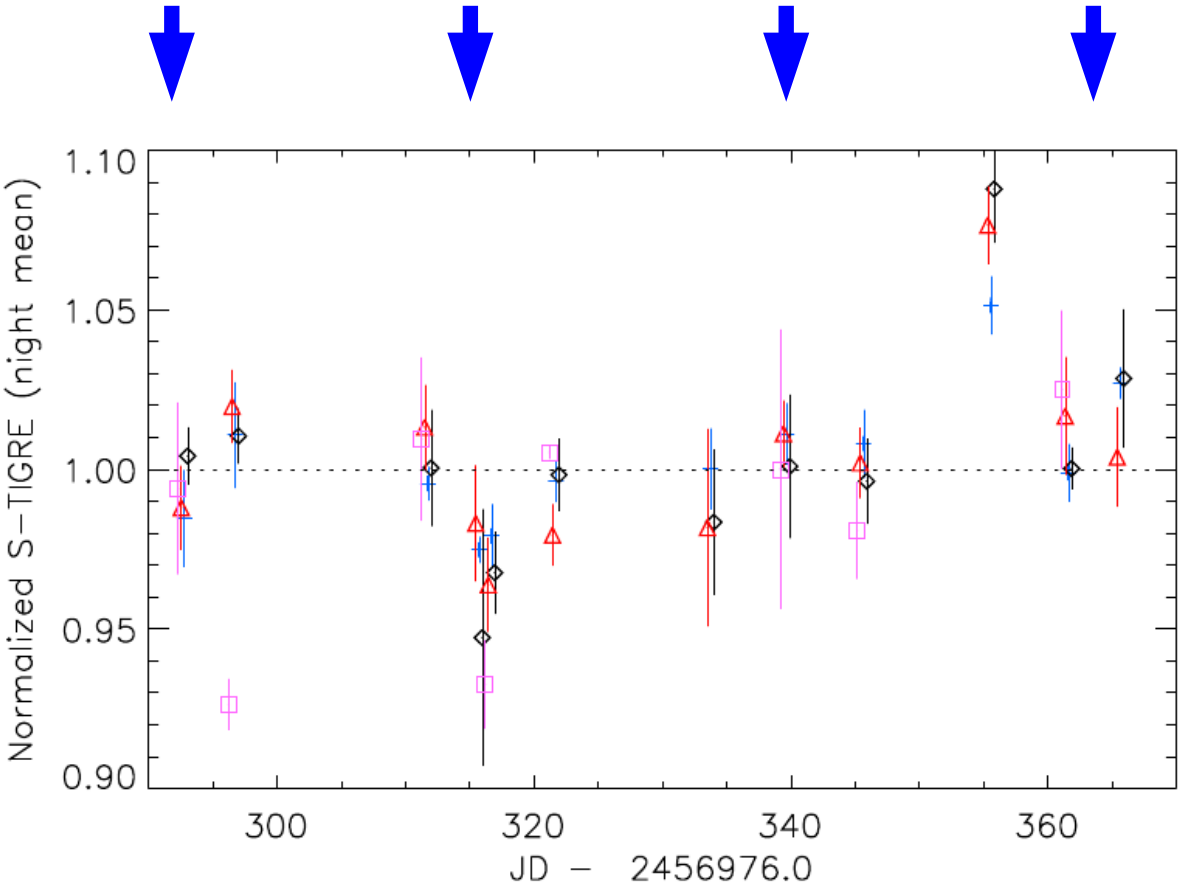
TIGRE/HEROS: Vega 1.2 vs. 3.0 arcsec

APPENDIX

OU And's chromospheric emission
(2015 TIGRE + NARVAL)



2015 NARVAL
(June-August)



(Borisova+ 2019, BlgAJ 31)

2015 TIGRE (v3)
(September-Nov.)

EMPTY