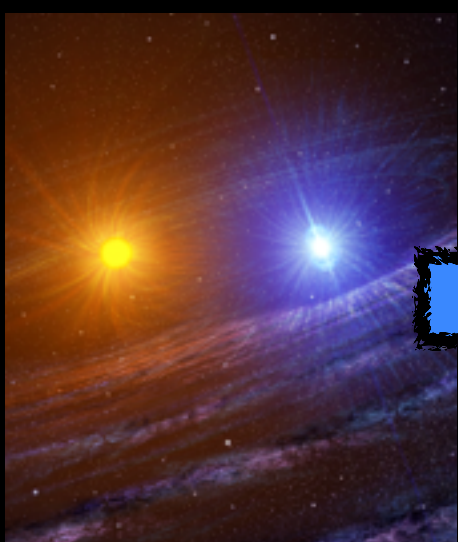
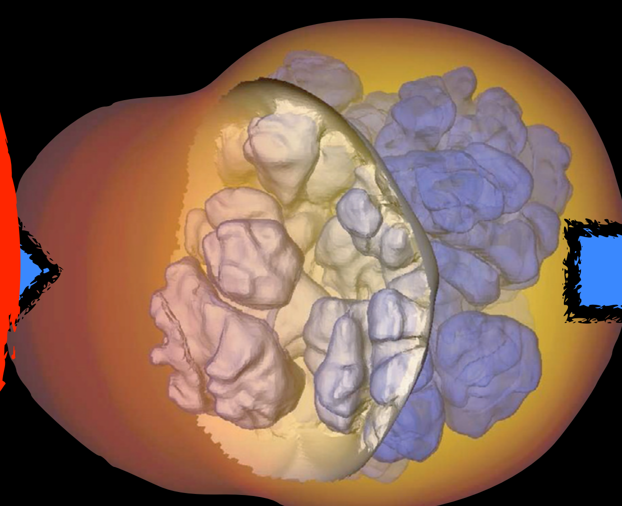
Supernova

Observable



progenitor system

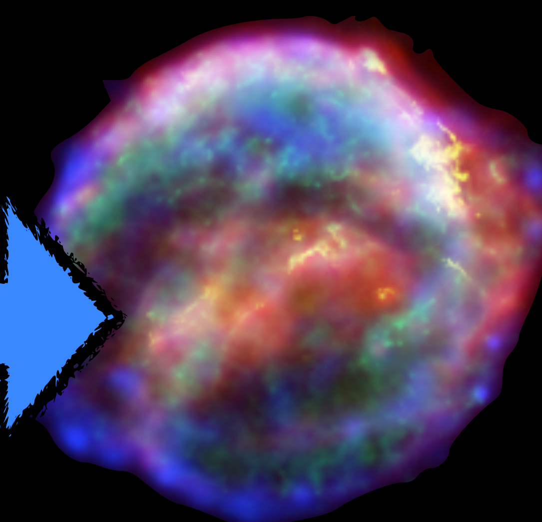


Explosion

Observable

Light Curve
Spectra
Neutrinos
GW Emission

Observable



Remnants

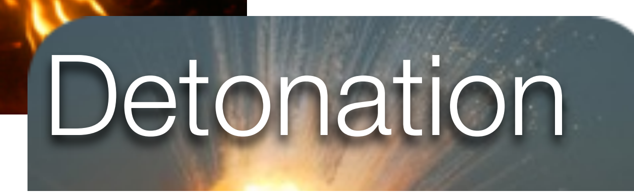
Some Questions

Type Ia supernovae

Progenitors

and/or

Explosions



White dwarf mass

Type Ibc supernovae

Progenitors

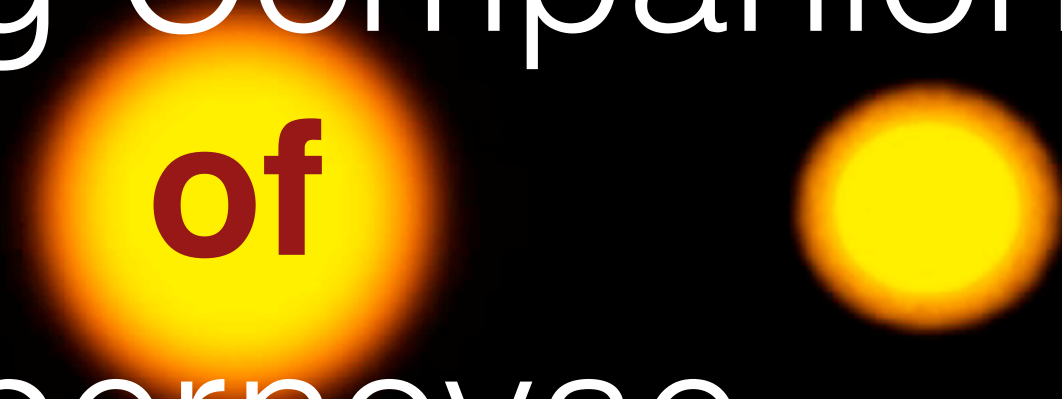
loss of envelope

and/or

Explosions

Core mass

Surviving Companions of Supernovae

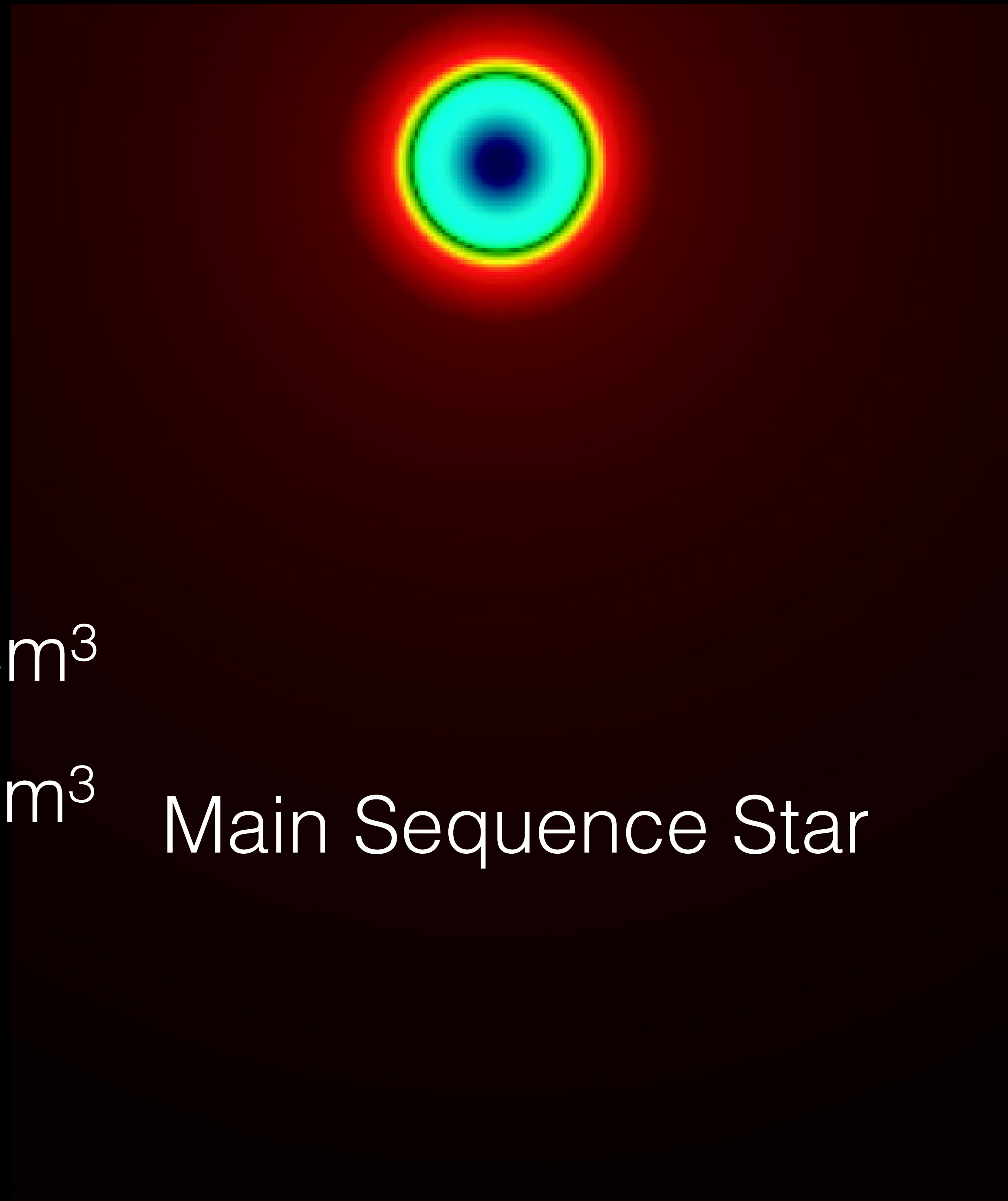


Wolfgang Kerzendorf
(ESO Fellow)
6th of June 2015
Chania - Greece

Pakmor et al. 2008

Impact Studies

http://goo.gl/snW5SL

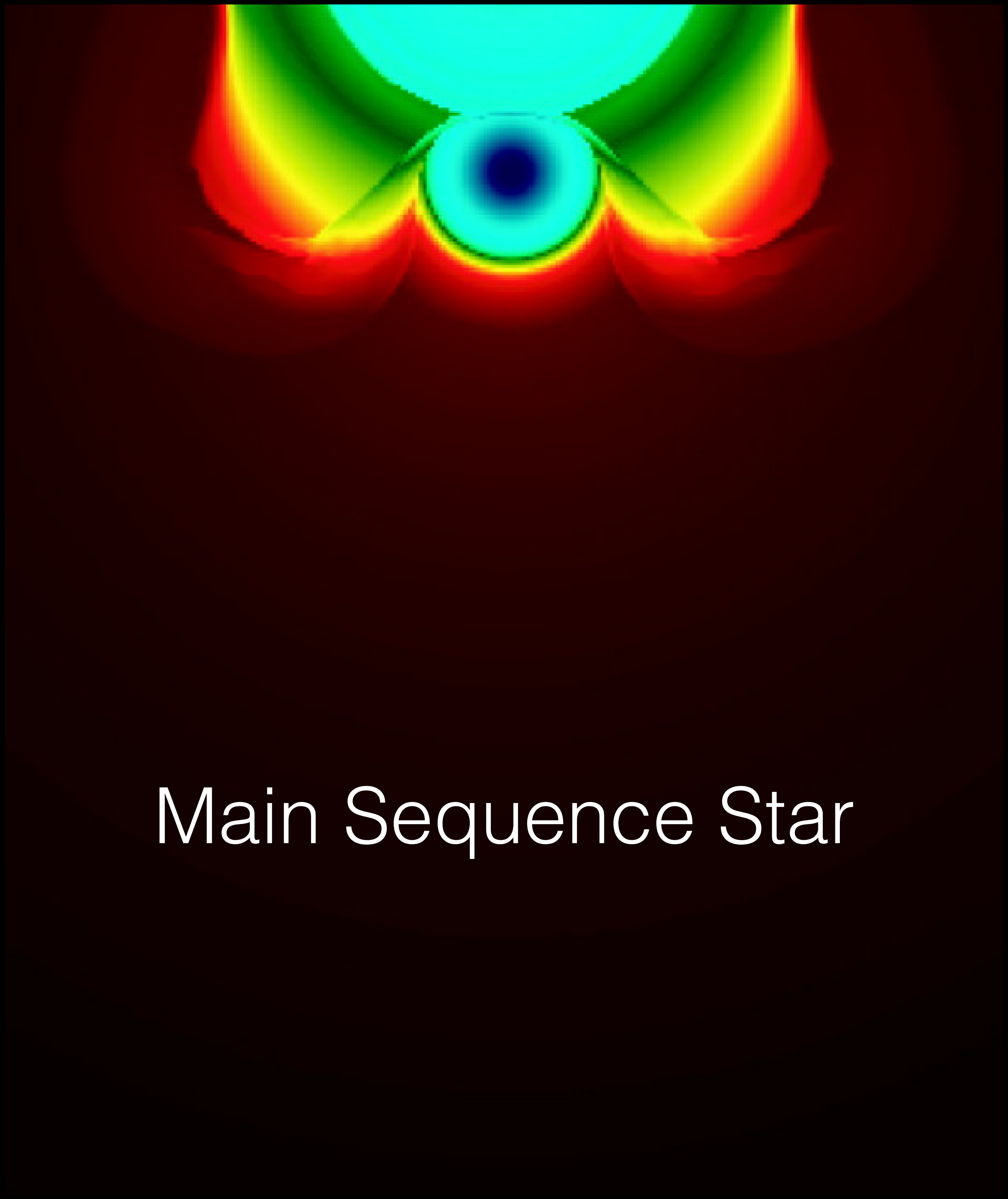


blue = 160 g / cm^3

red = 10^{-13} g / cm^3

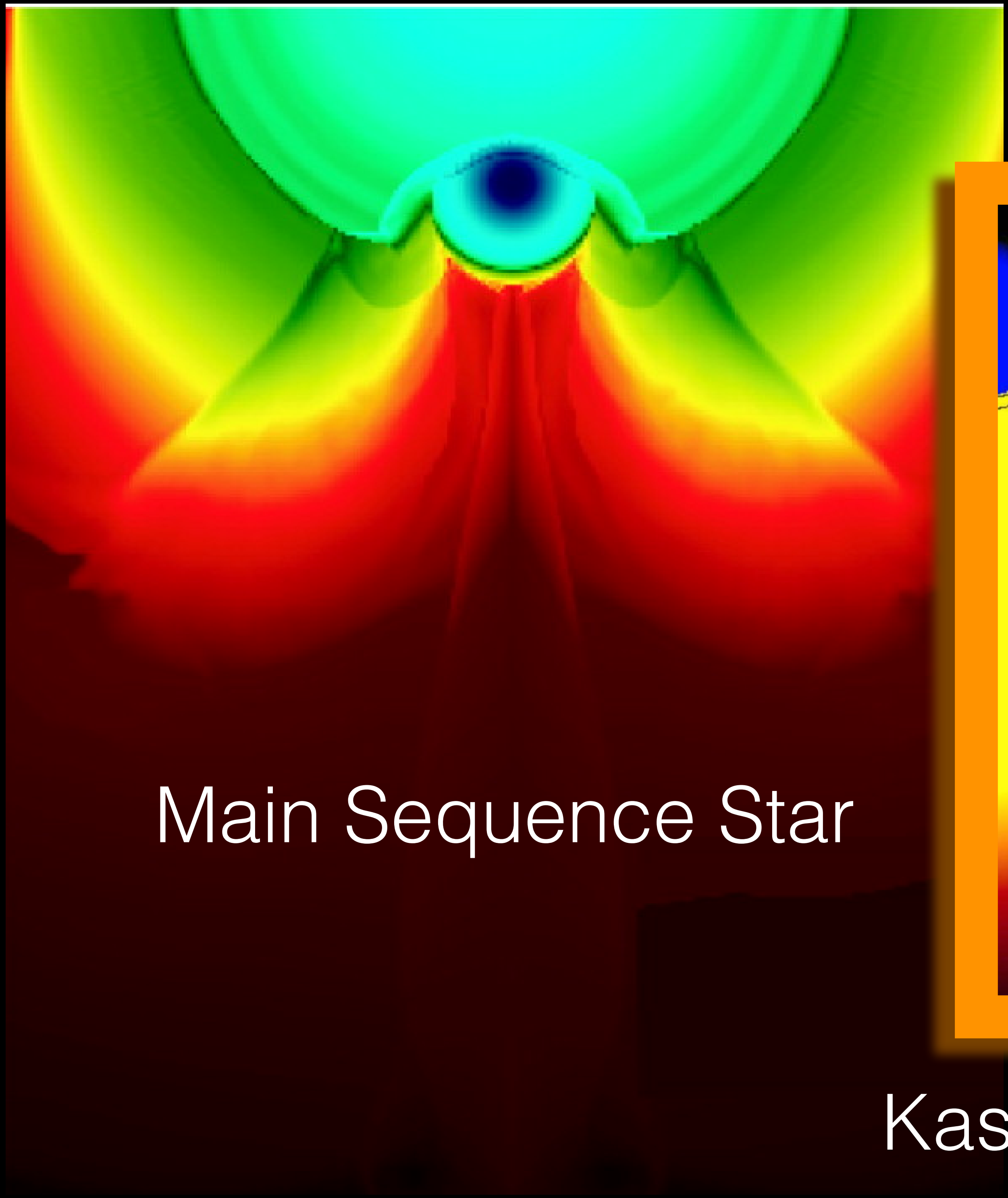
t=29s

Marietta et al. 2000



t=104s

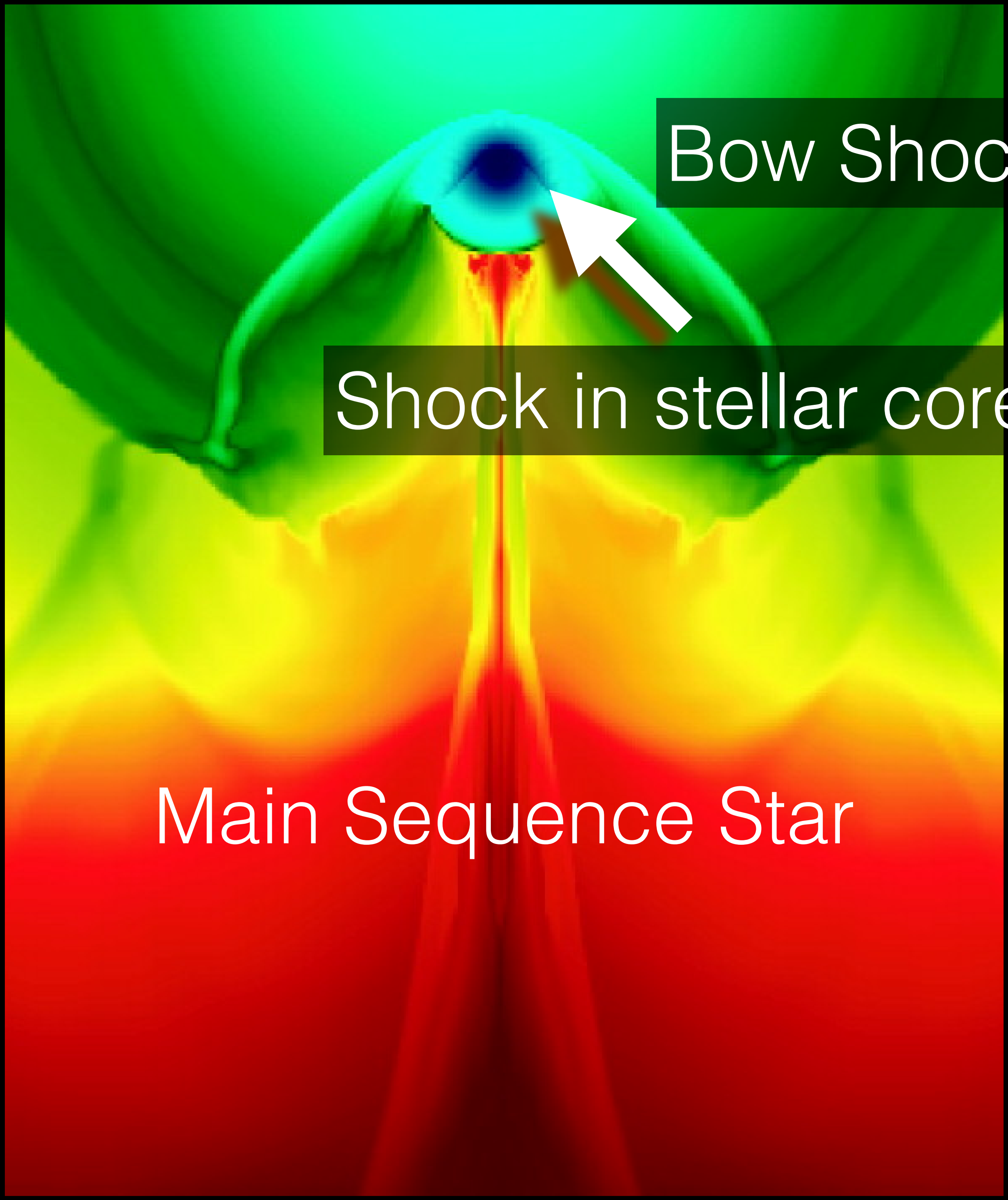
Marietta et al. 2000



Kasen et al. 2010

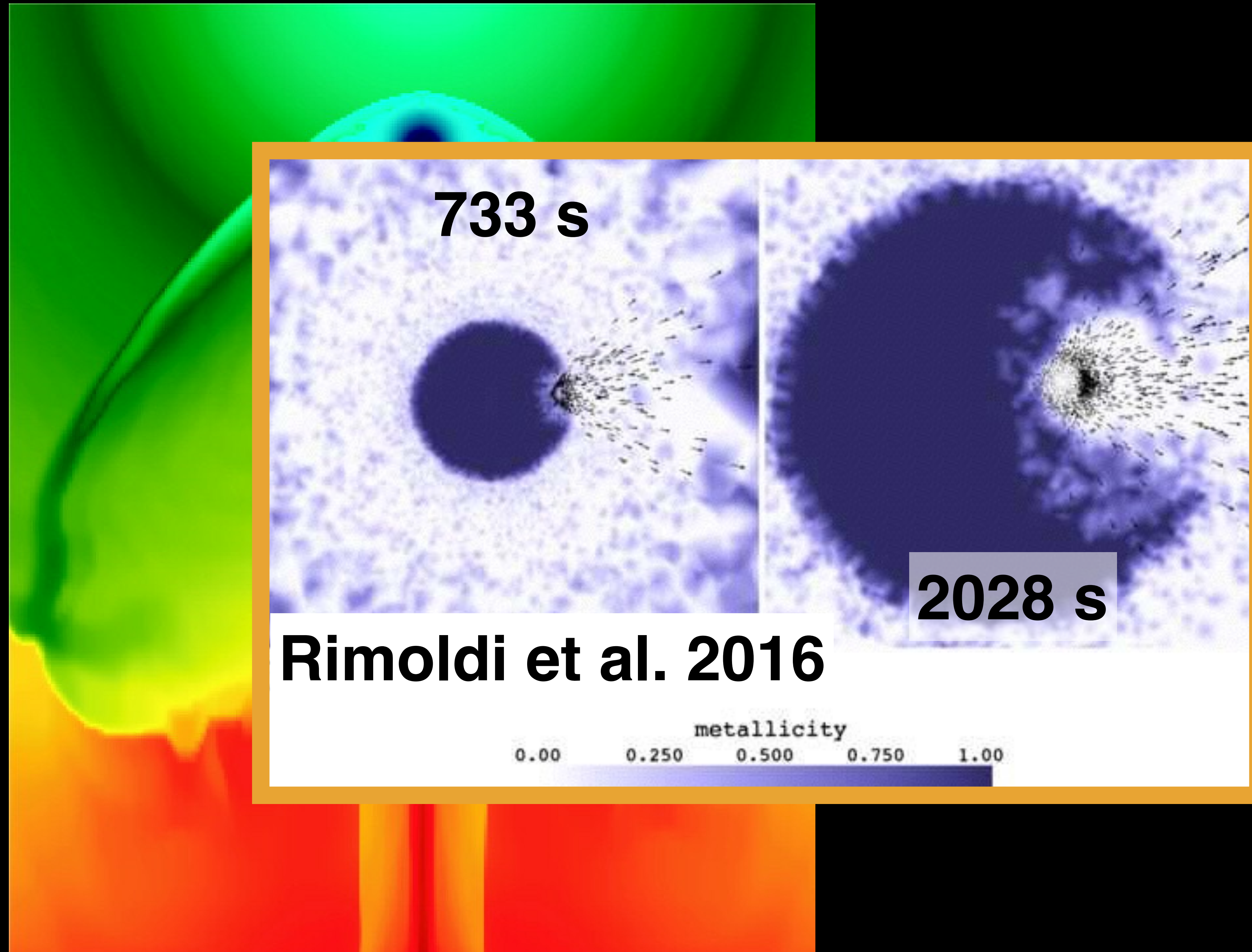
t=179s

Marietta et al. 2000



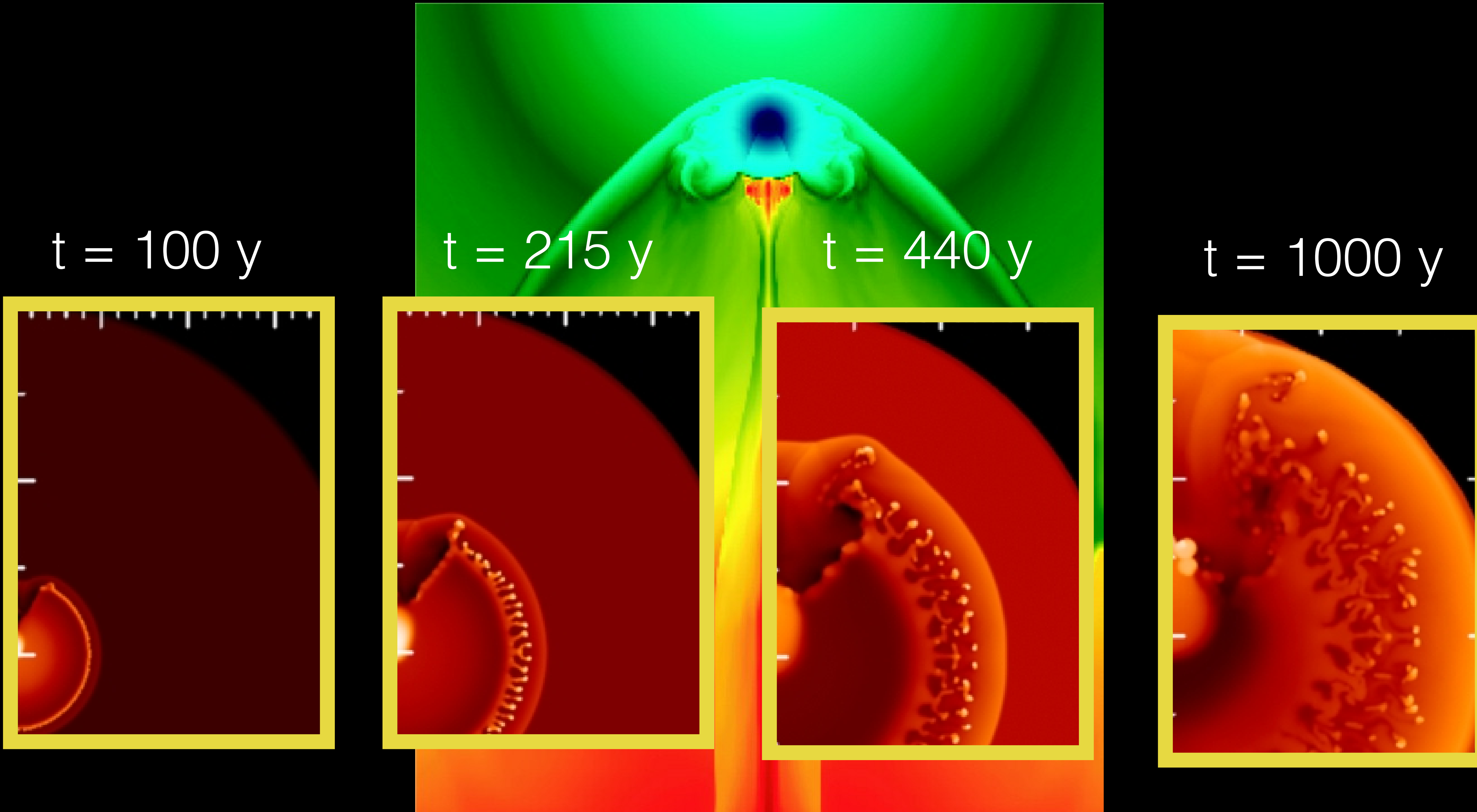
t=329s

Marietta et al. 2000



t=529s

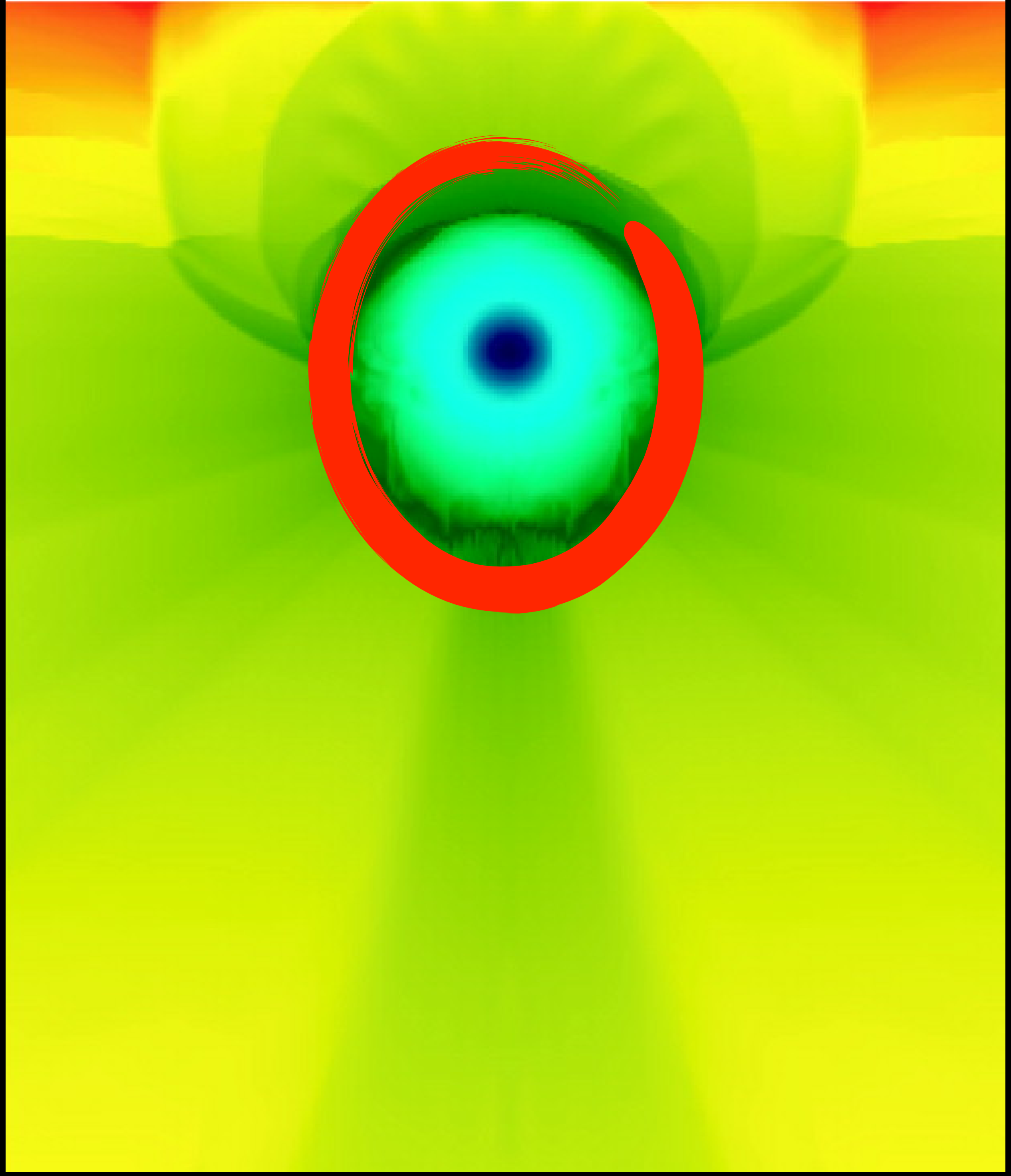
Marietta et al. 2000



Garcia-Senz et al. 2012

t=529s

Marietta et al. 2000



t=2033s

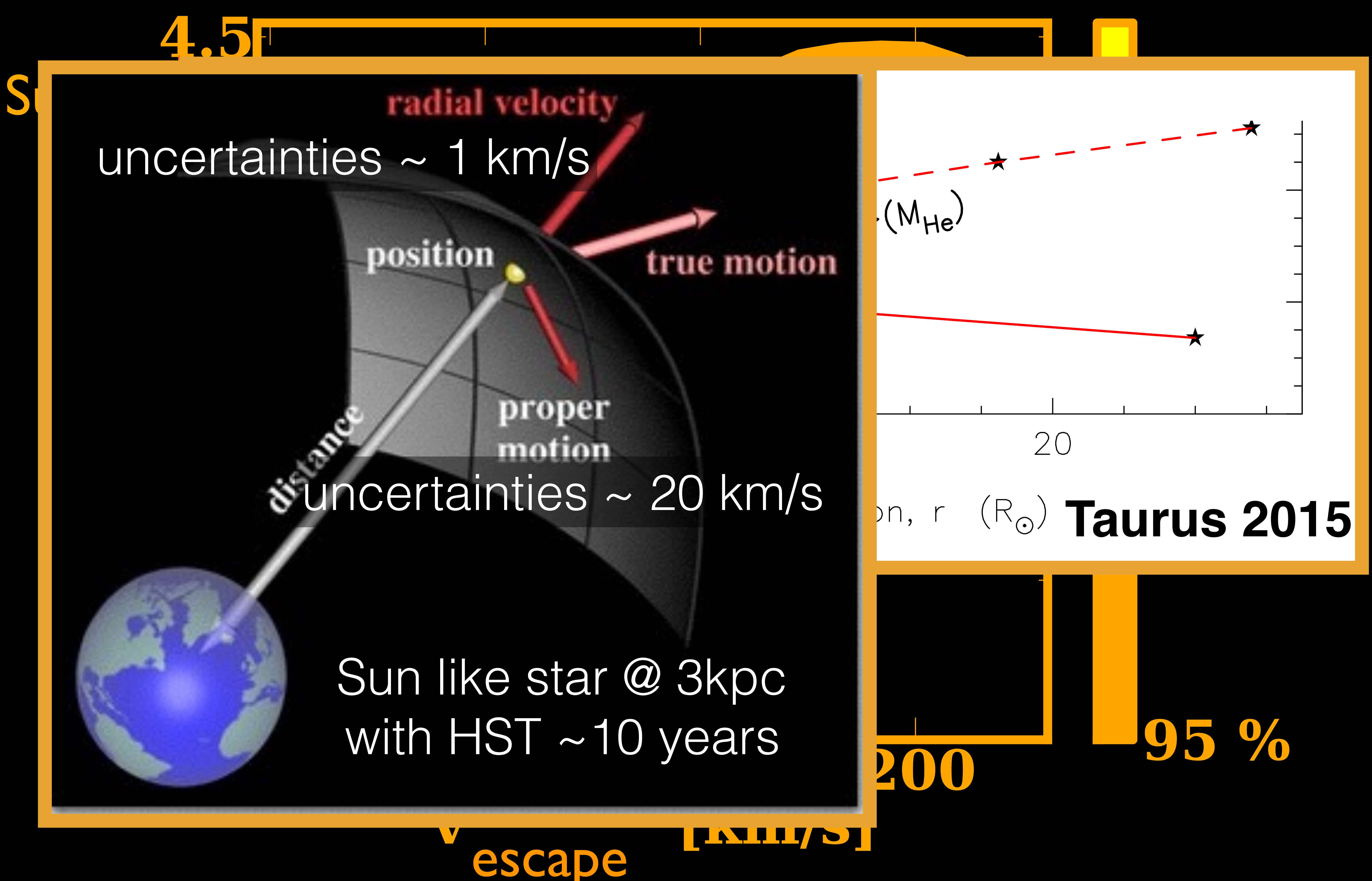
Marietta et al. 2000

Distinguishing Survivors

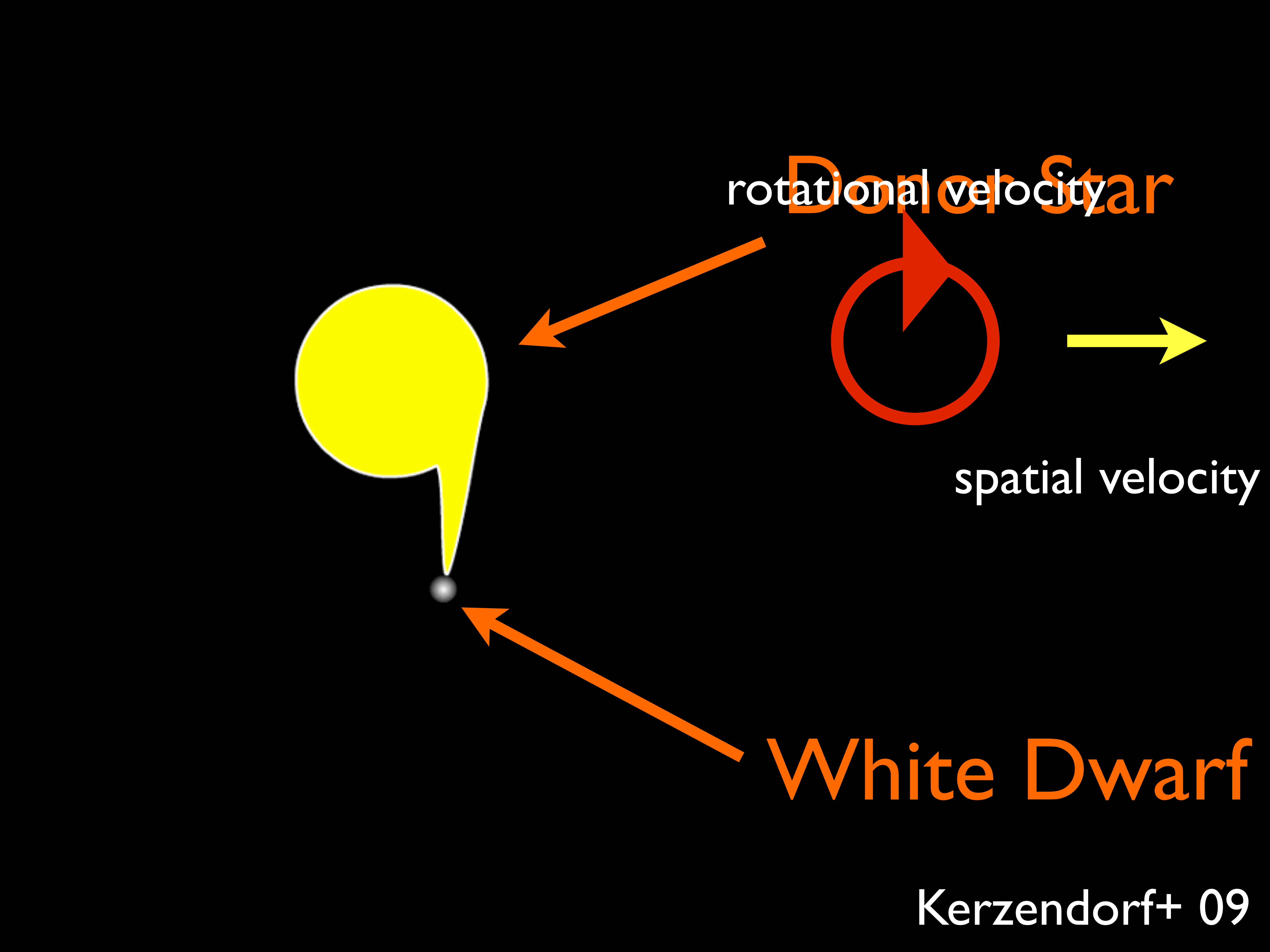
Unusual Velocity

Unusual Velocity

Han 2008

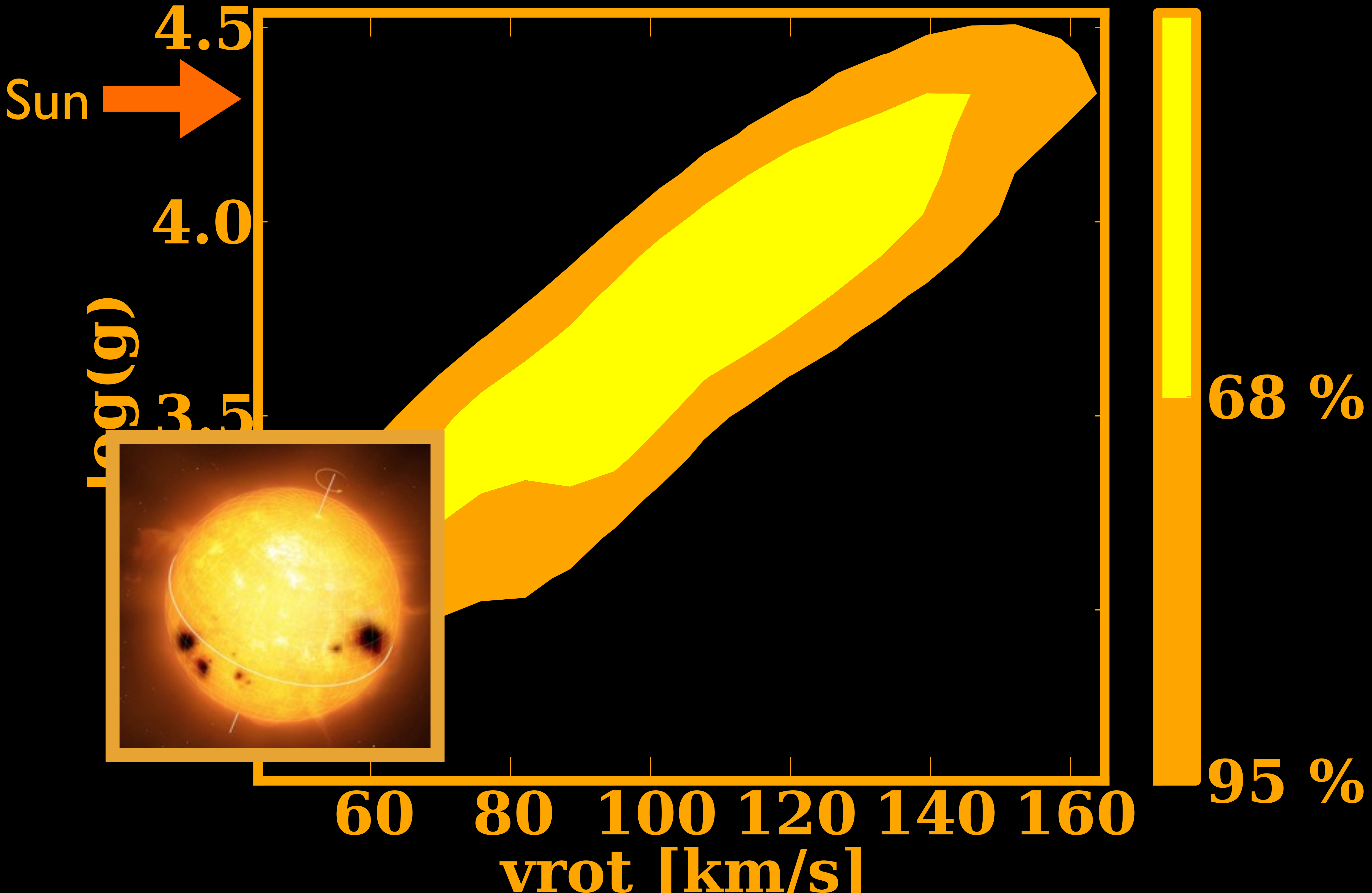


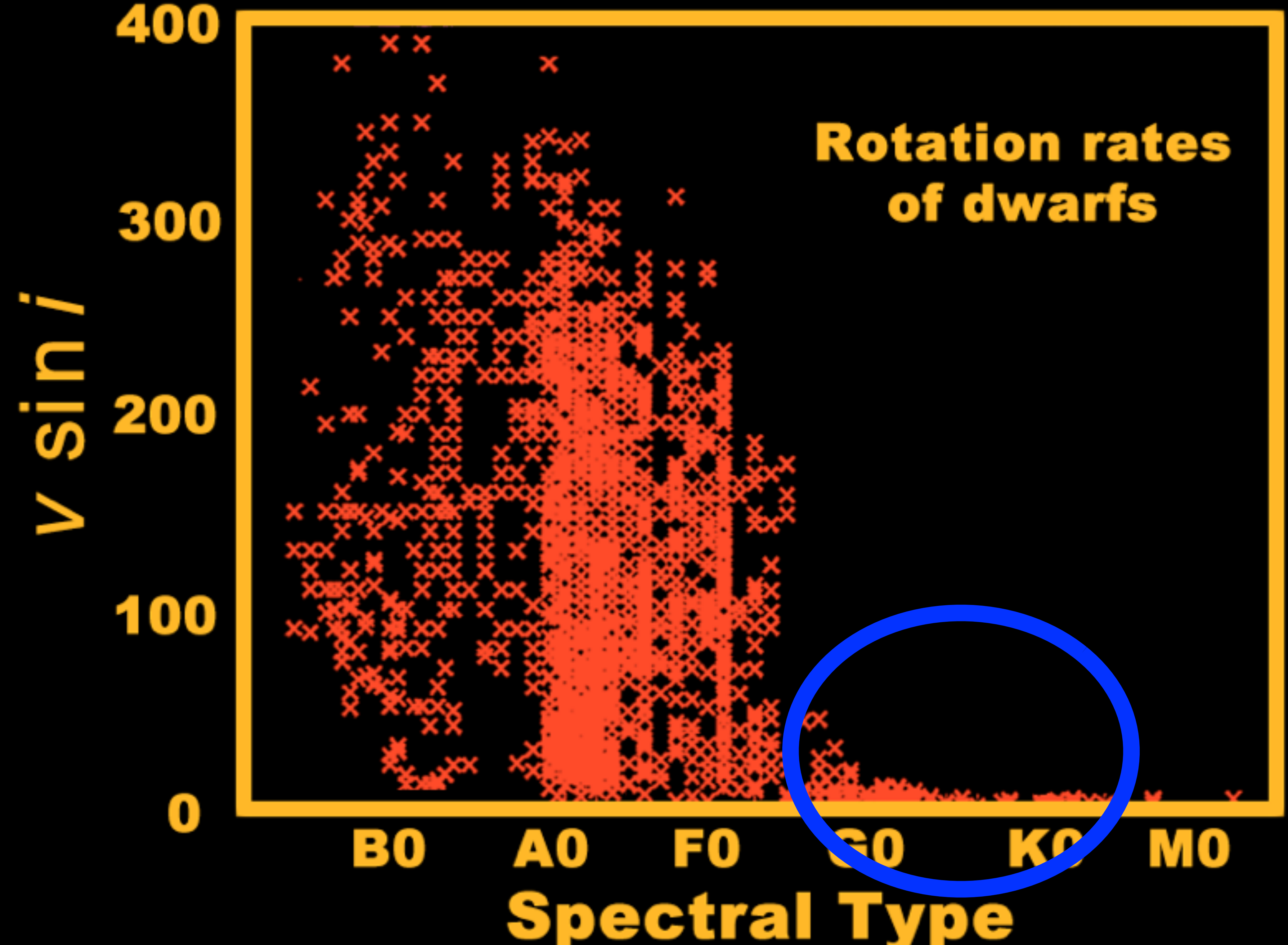
Unusual Rotation


Donor Star
rotational velocity
spatial velocity
White Dwarf
Kerzendorf+ 09

Unusual Rotation

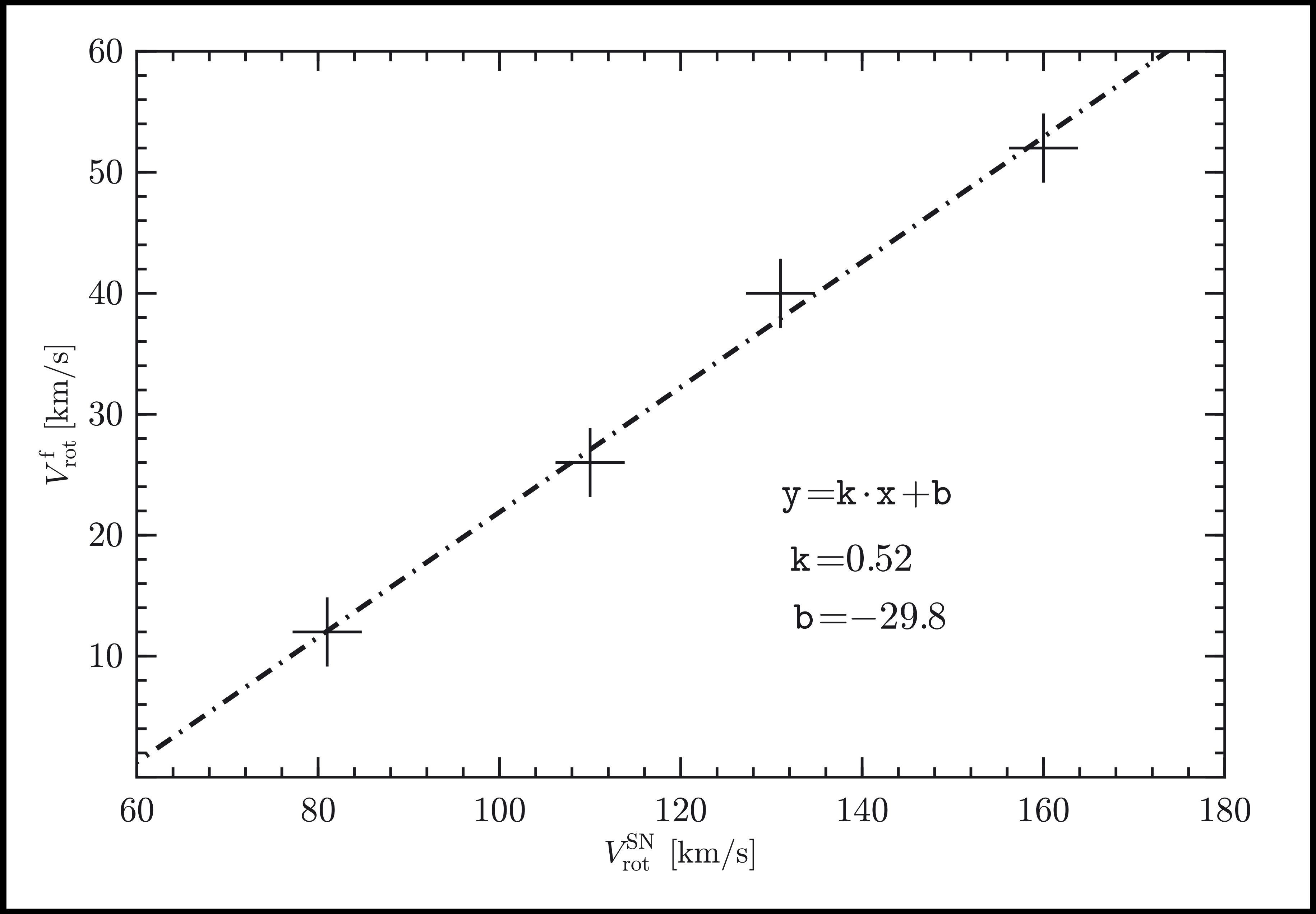
Han 2008





D. Gray - Analysis of Stellar Photospheres

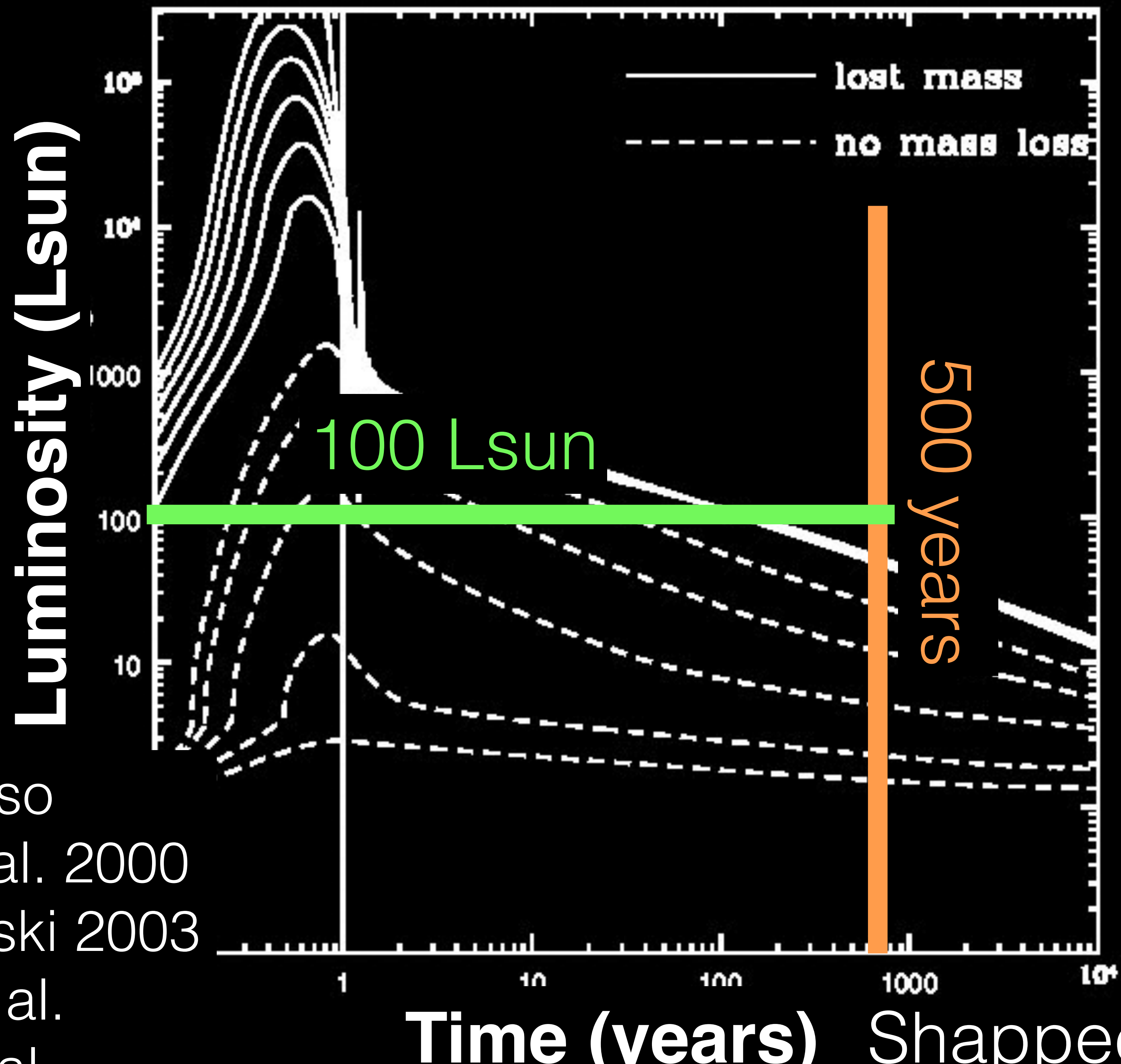
However ...



Z.W. Liu 2013

see also Pan+ 2012a

Unusual Brightness



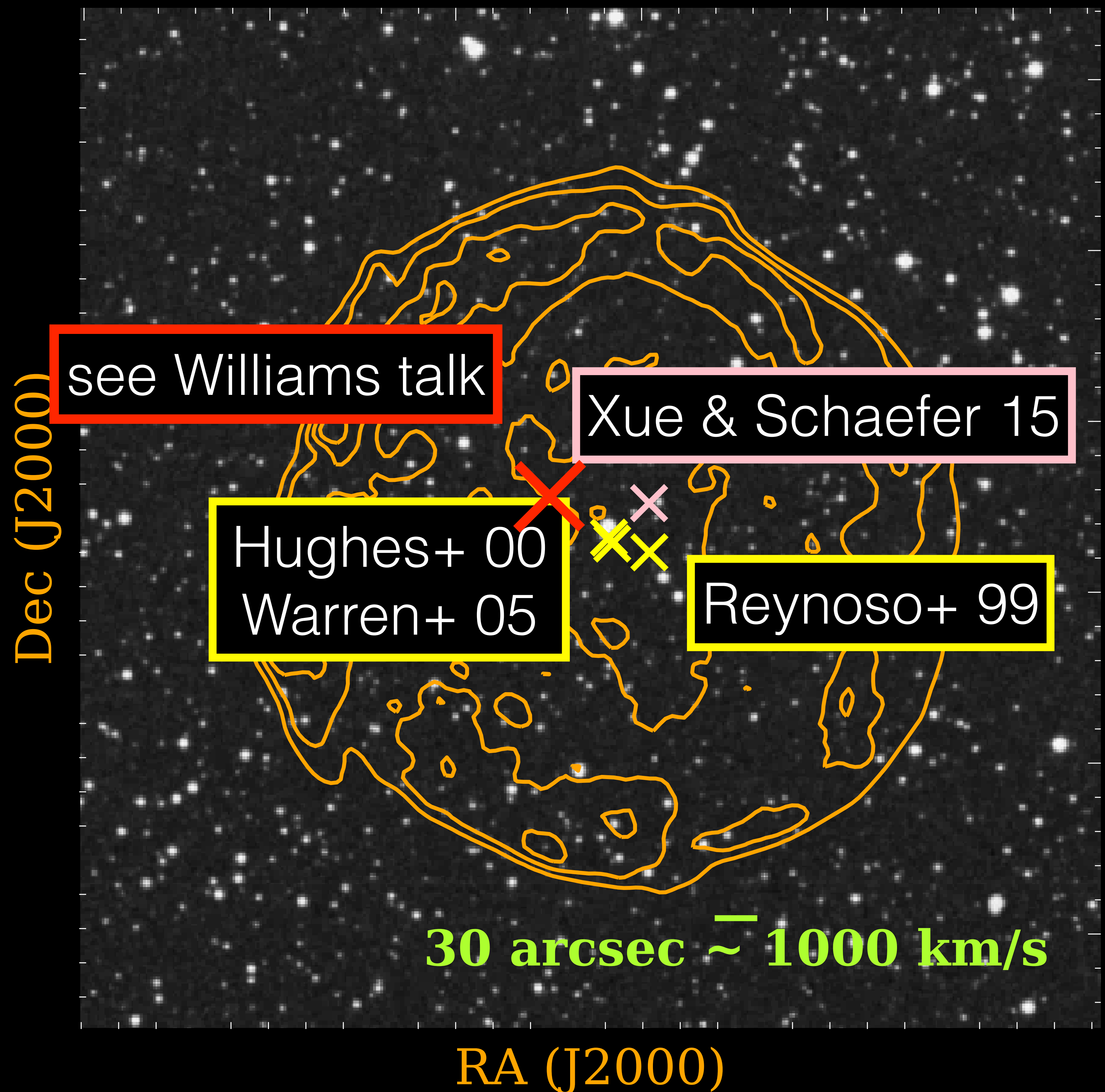
Shappee et al. 2013

see also
Marietta et al. 2000
Podsiadlowski 2003
Pan et al.
Liu et al.
and others

Searching for survivors

Tycho's remnant
A good example

Ruiz-Lapuente et al. 2004
Gonzalez-Hernandez et al. 2009
Kerzendorf et al. 2009
Kerzendorf et al. 2014
Bedin et al. 2014

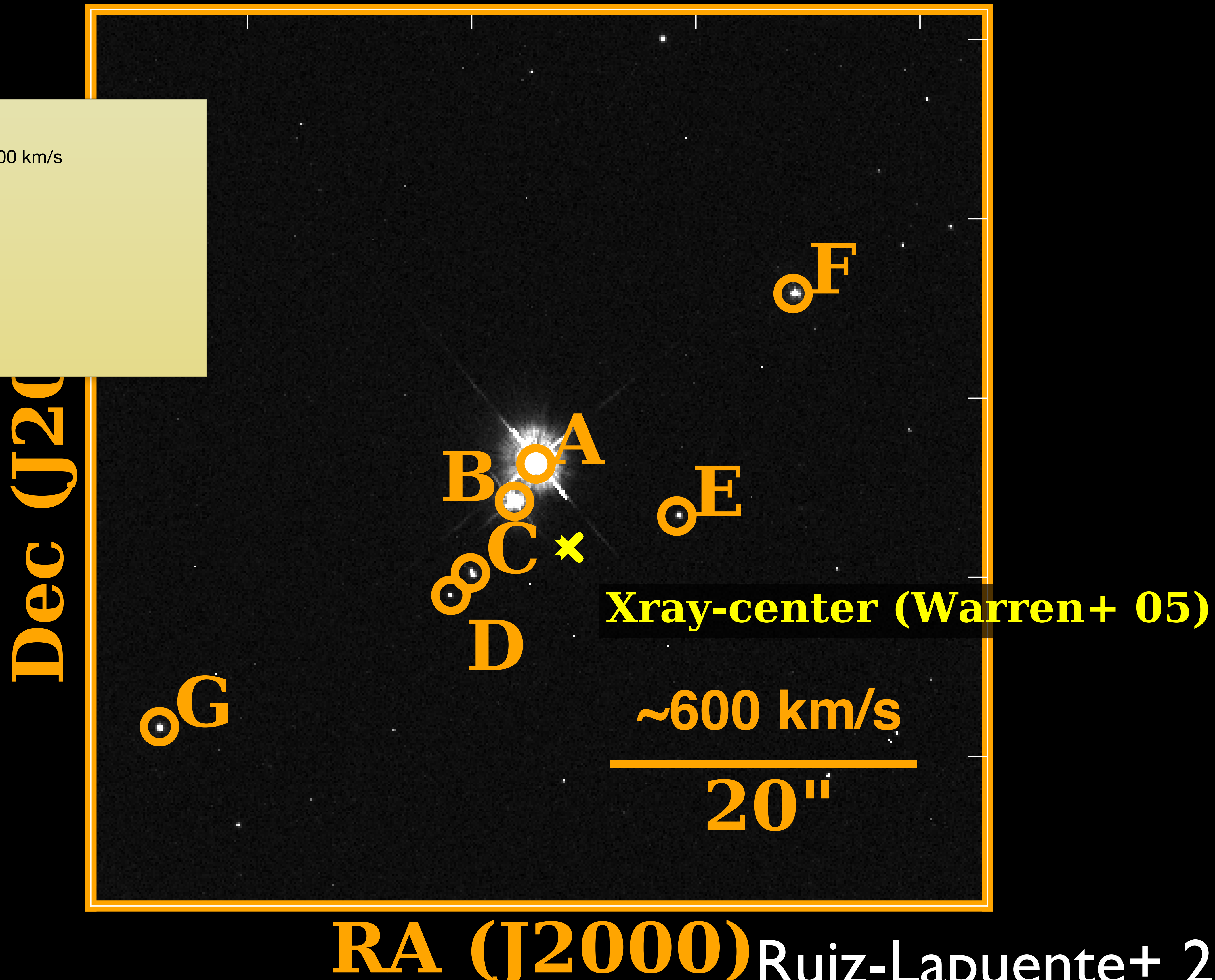


see Williams talk
Xue & Schaefer 15
Hughes+ 00
Warren+ 05
Reynoso+ 99
30 arcsec ~ 1000 km/s
Dec (J2000)
RA (J2000)

Identify candidates

The Candidates

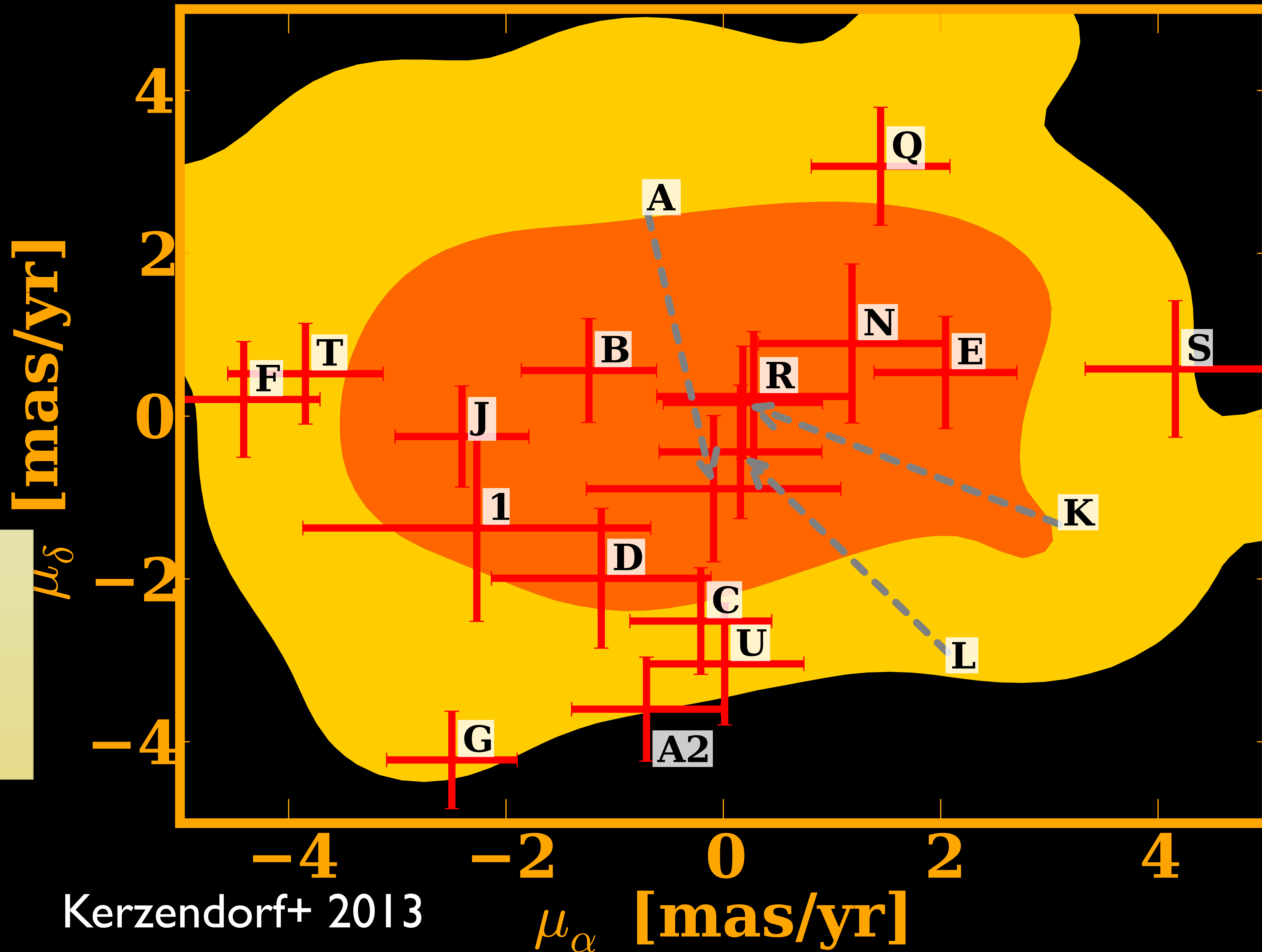
30 arcsecond roughly 1000 km/s



Ruiz-Lapuente+ 2004

Proper Motion

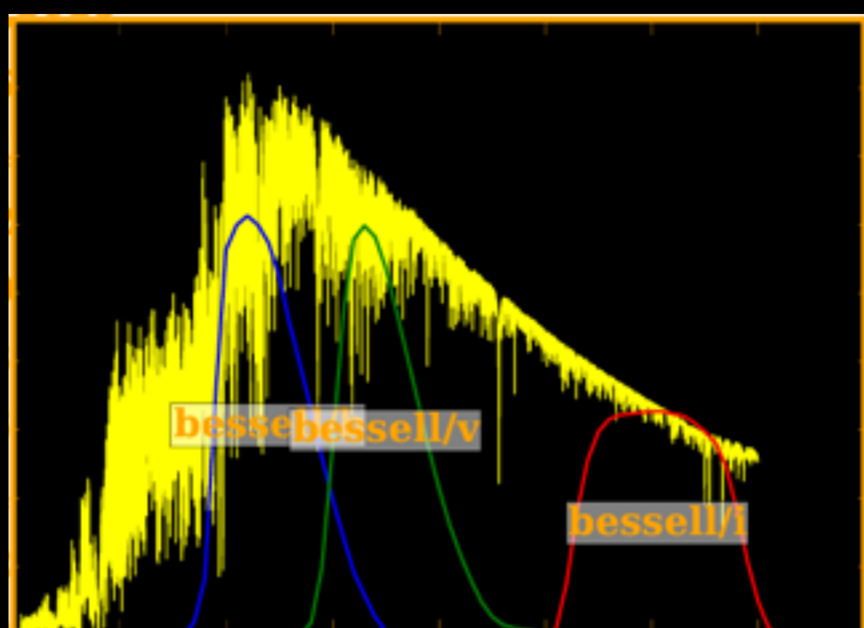
see also Bedin et al. 2014



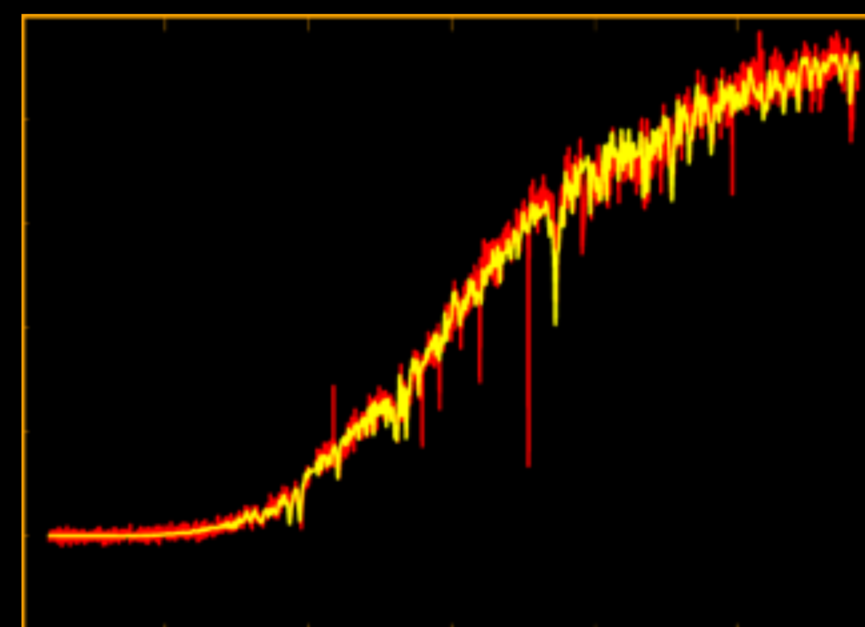
Kerzendorf+ 2013

Spectroscopic modeling

$$\mathrm{P}(\overbrace{T_{\mathrm{eff}}, \log g, [M/H]}^{\text{Munari Grid}}, v_{\mathrm{rot}}, v_{\mathrm{rad}}, A_V)$$



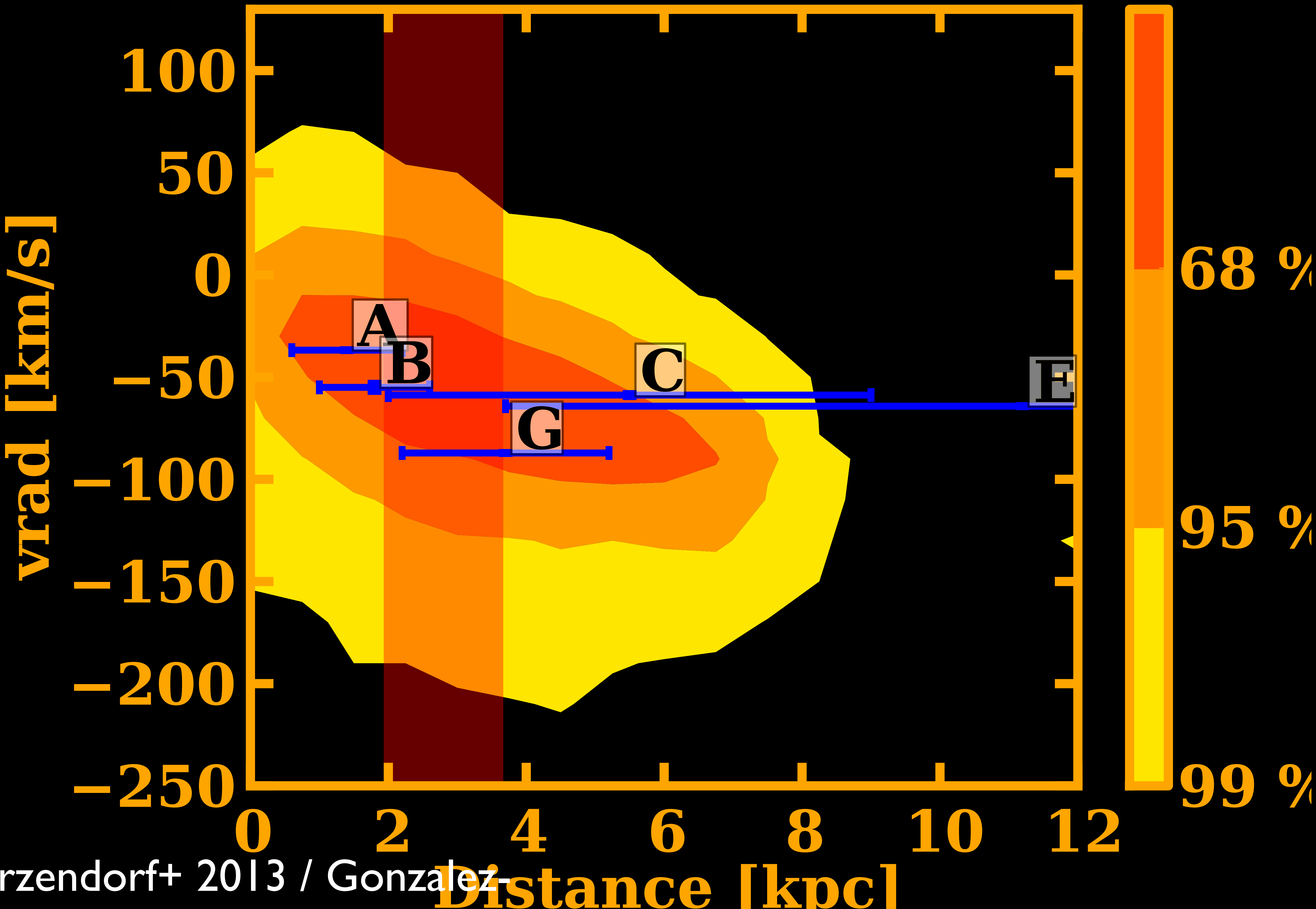
Photometry



Spectroscopy

StarKit - starkit.readthedocs.org

Radial Velocity

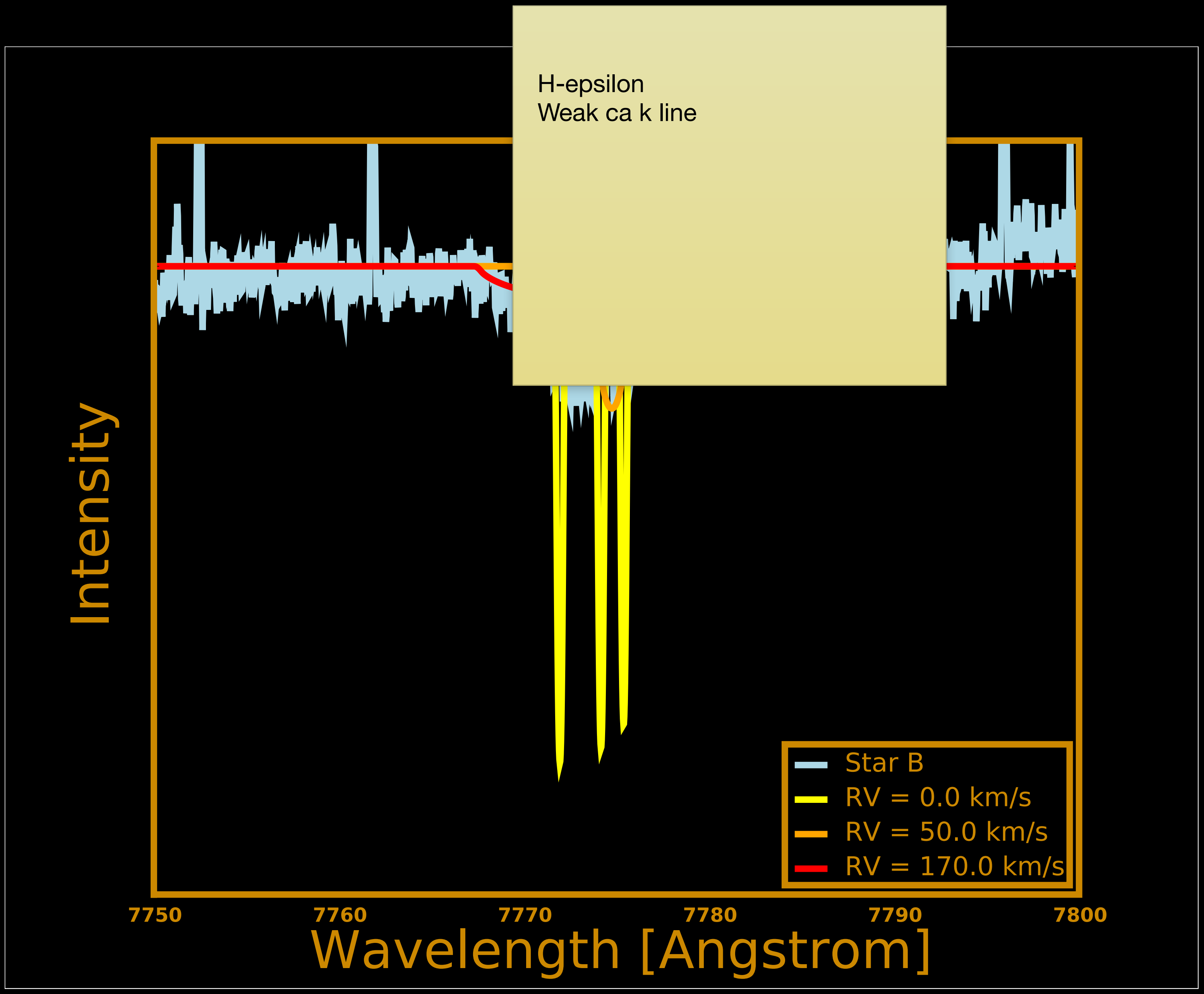


Kerzendorf+ 2013 / Gonzalez-Hernandez+ 2009

Tycho B

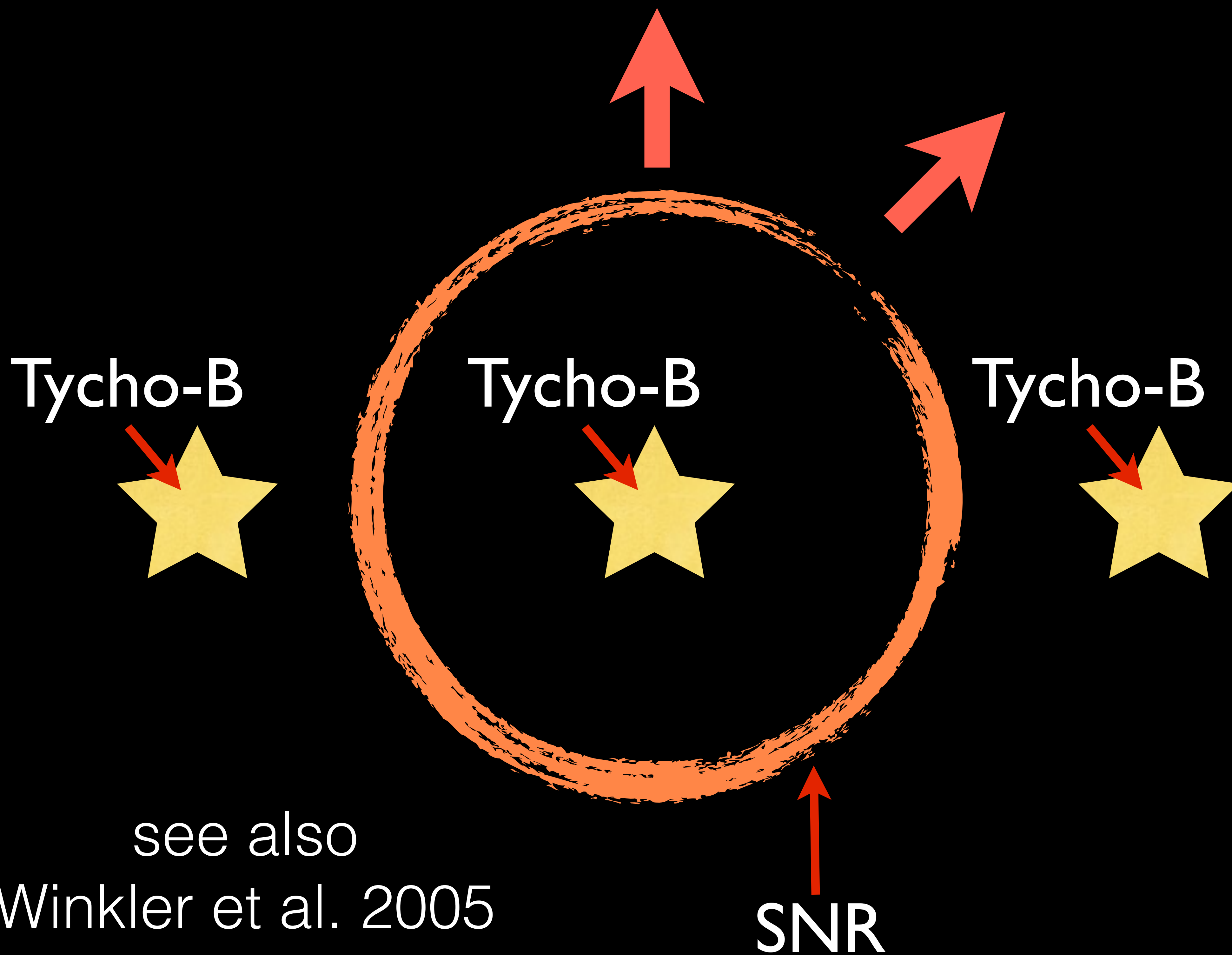
Tycho B

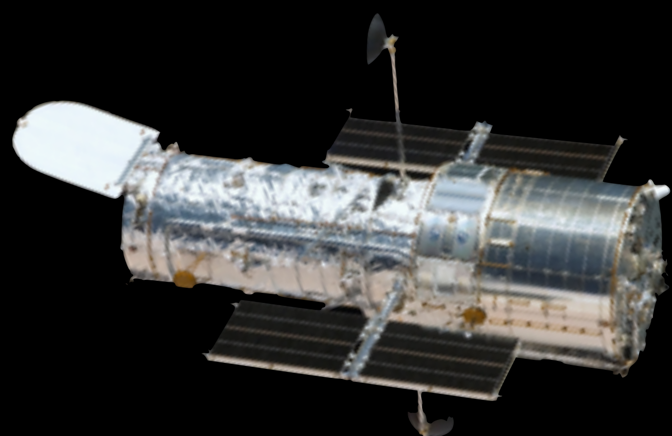
- A-Star 10,000K
- [Fe/H]~-1
- v rot=170 km/s
- low-res Observations
  - => log(g) = 4.1



Kerzendorf+ 2013

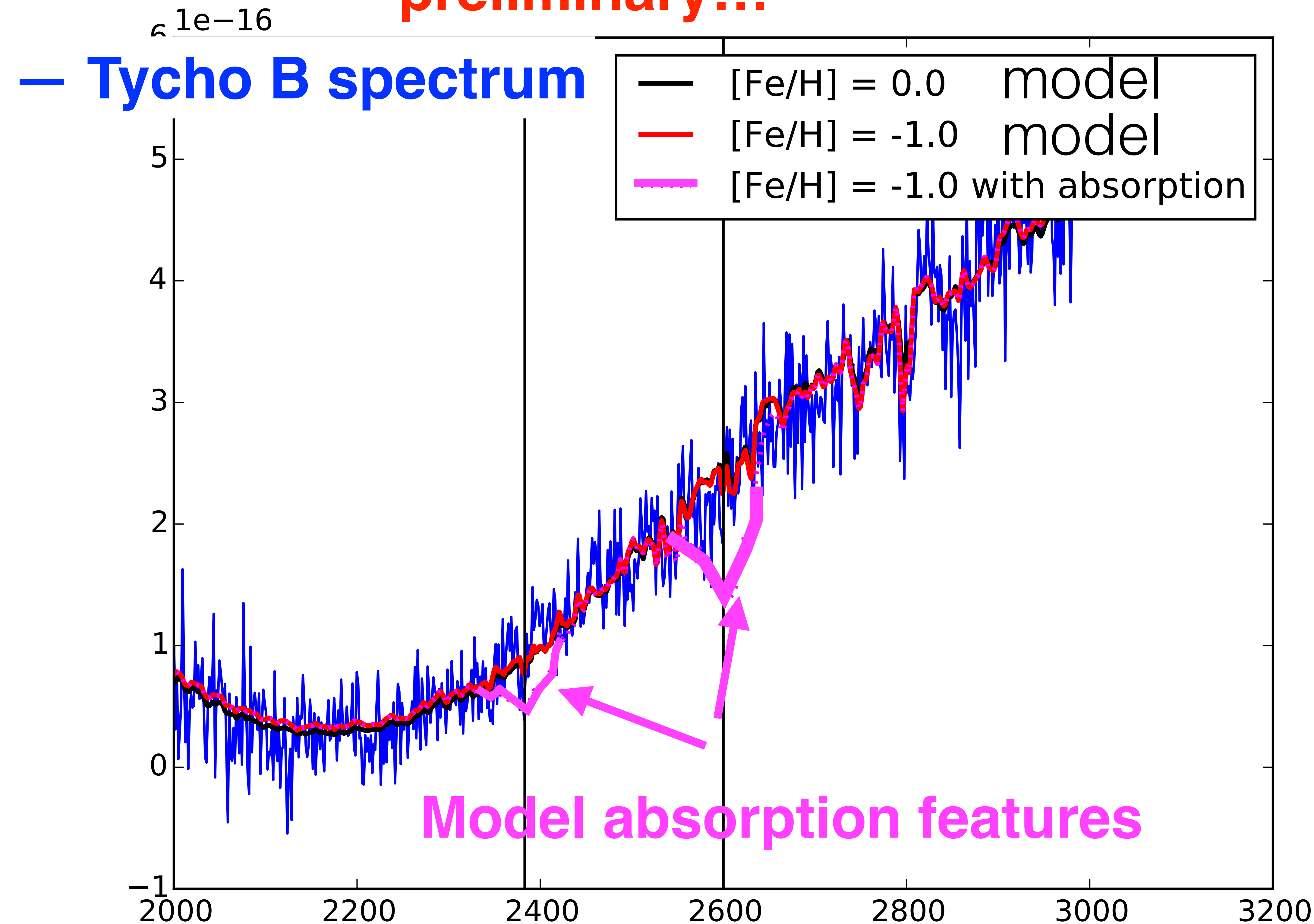
Where is it?





see also
Winkler et al. 2005
Ihara et al. 2007

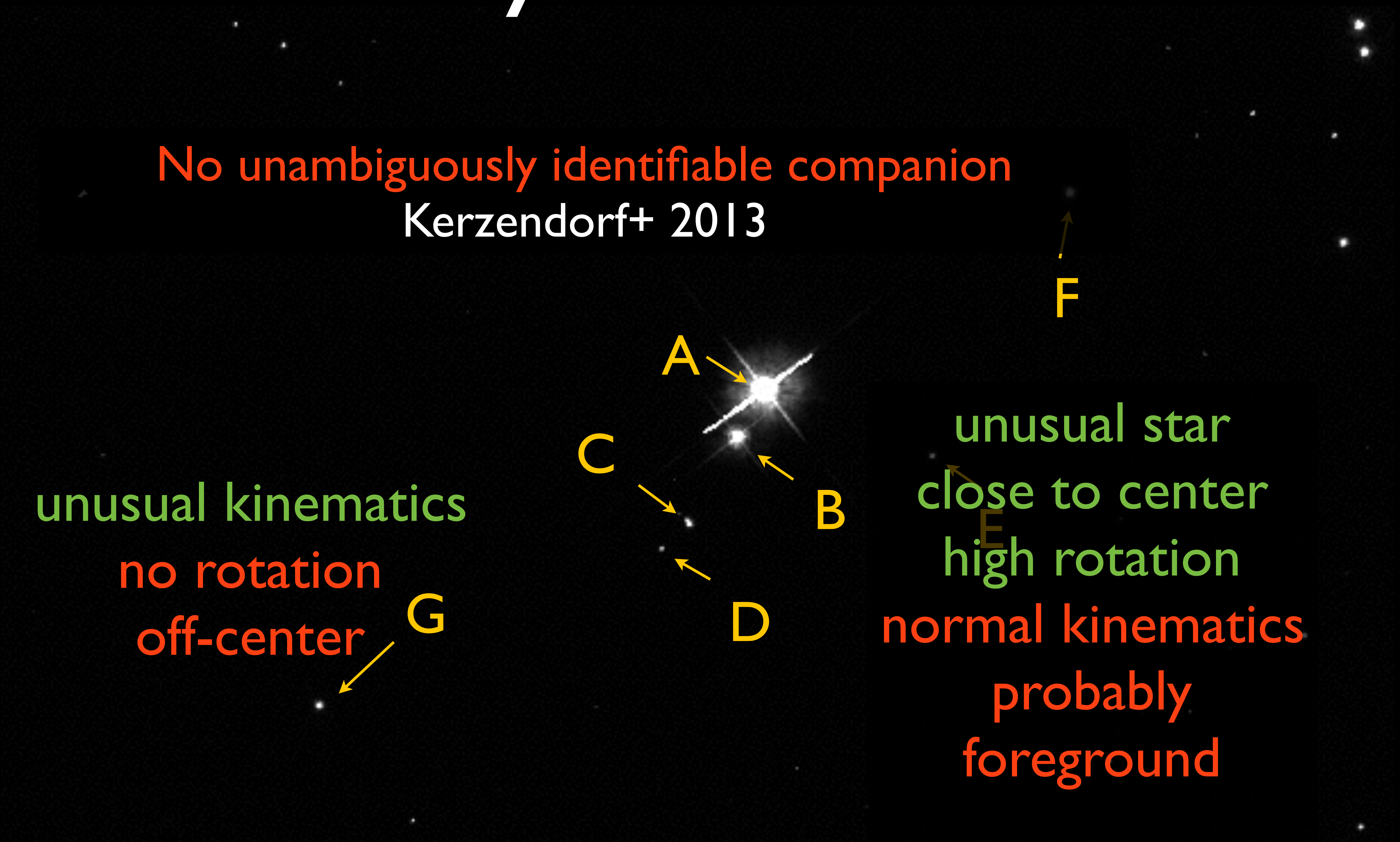
HST GO-13432
PI Kerzendorf



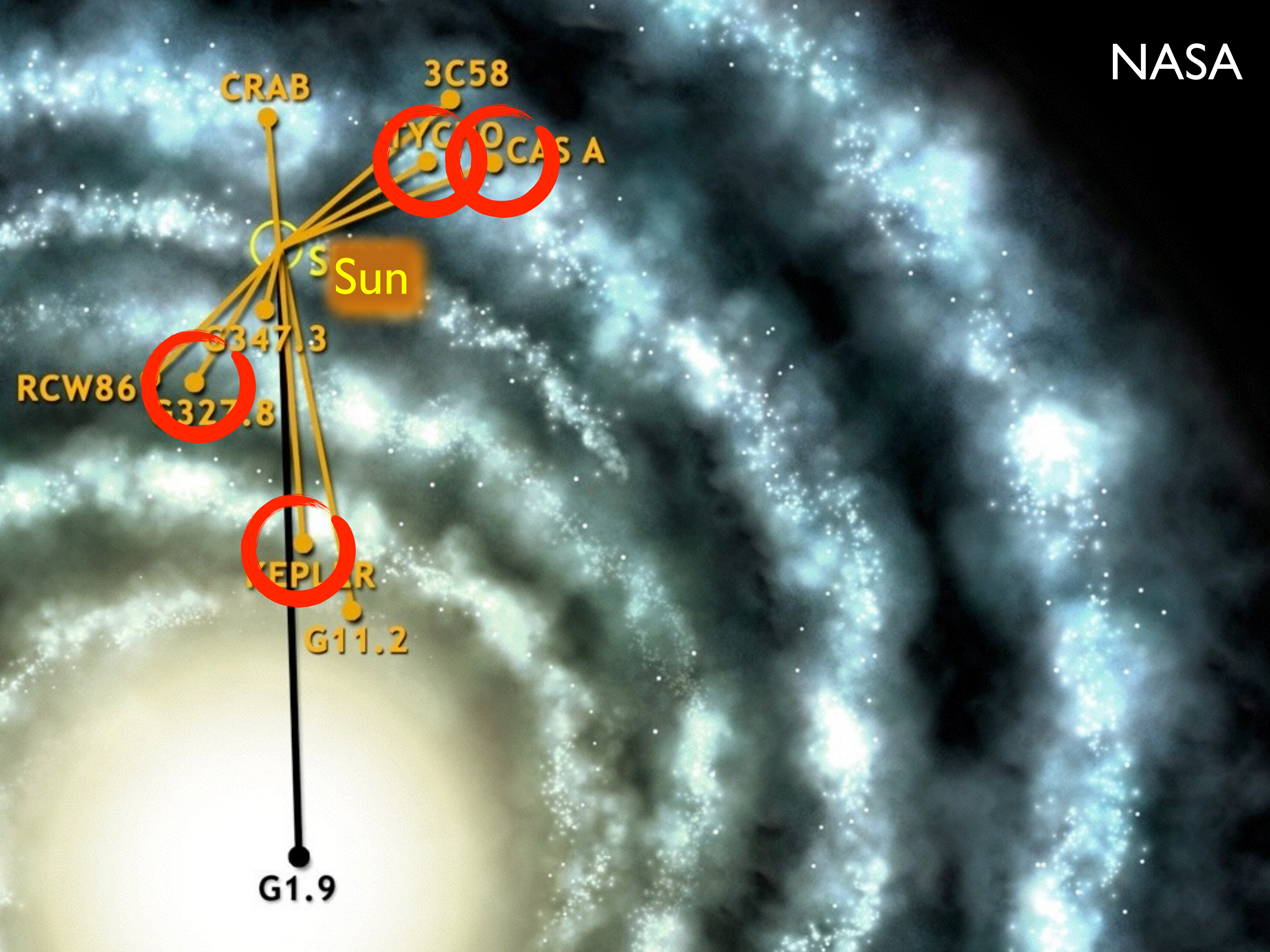
Kerzendorf et al. in prep.

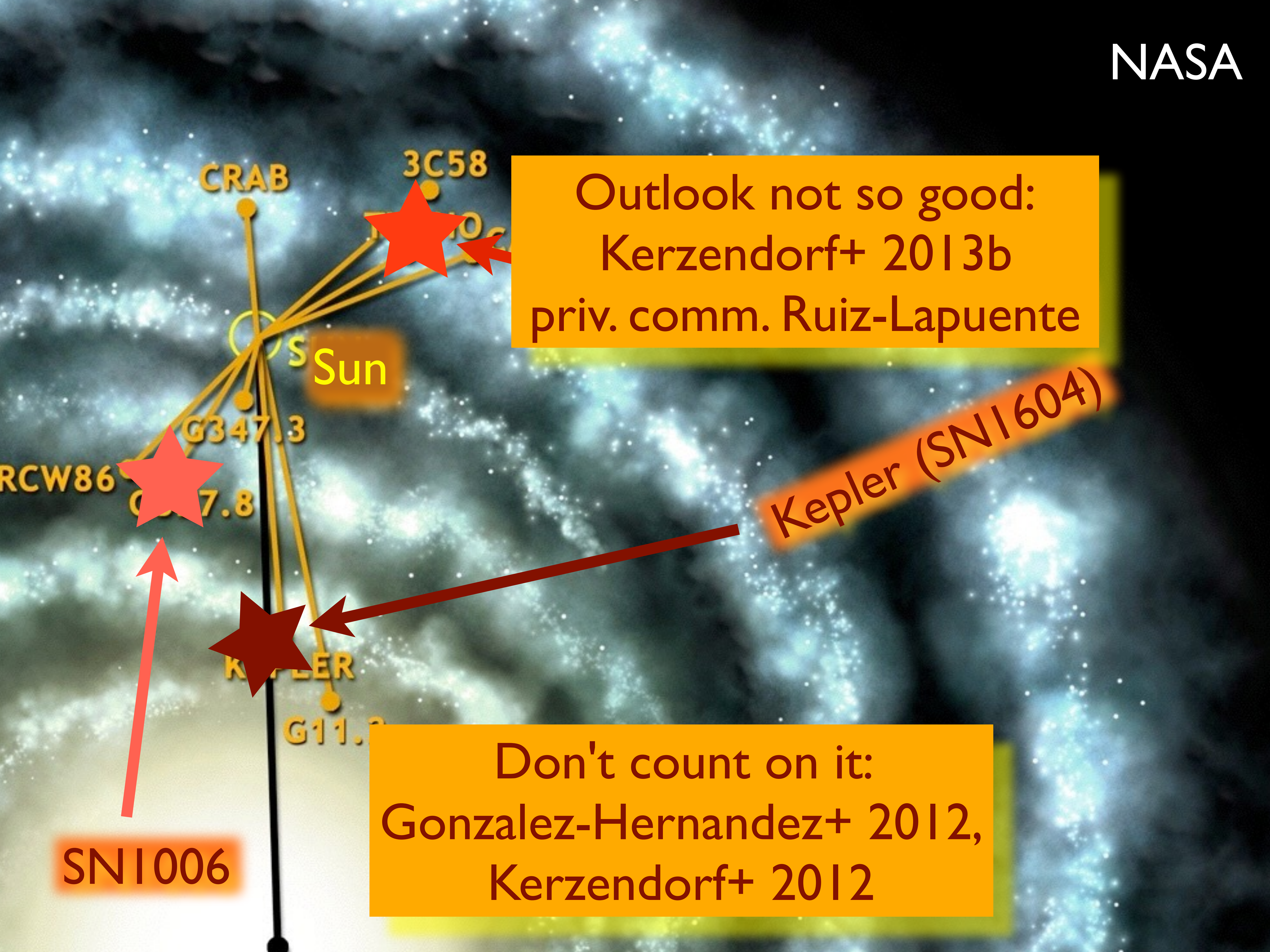
Conclusion

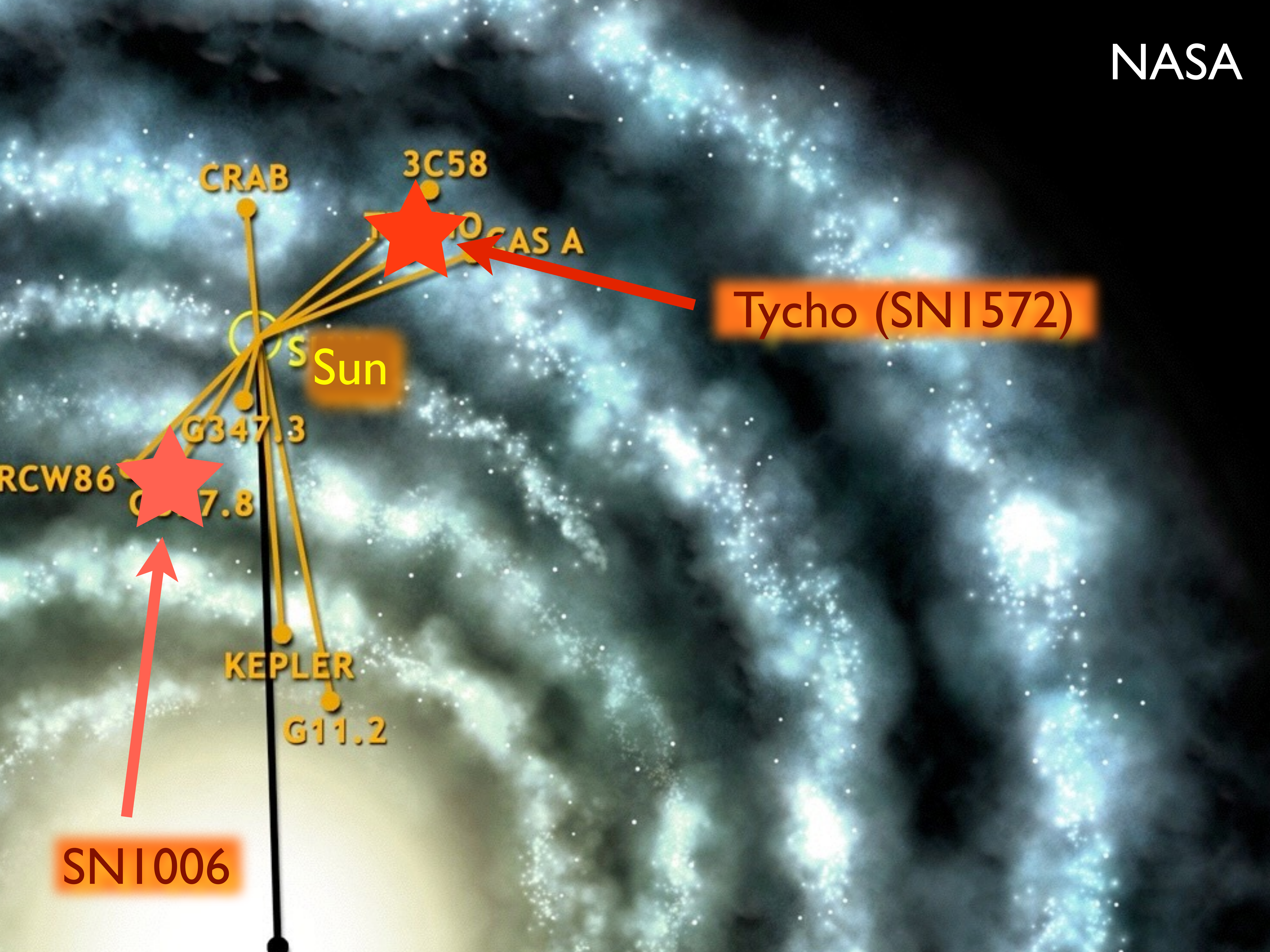
Tycho's Six


No unambiguously identifiable companion
Kerzendorf+ 2013
A
B
C
D
E
F
G
unusual kinematics
no rotation
off-center
unusual star
close to center
high rotation
normal kinematics
probably
foreground

Milky Way Remnants


NASA
CRAB
3C58
CAS A
Sun
RCW86
G11.2
G1.9


NASA
CRAB
3C58
Outlook not so good:
Kerzendorf+ 2013b
priv. comm. Ruiz-Lapuente
Sun
Kepler (SN1604)
RCW86
SN1006
Don't count on it:
Gonzalez-Hernandez+ 2012,
Kerzendorf+ 2012


NASA
CRAB
3C58
CAS A
Tycho (SN1572)
Sun
G347.3
RCW86
KEPLER
G11.2
SN1006

Magellanic Cloud Remnants

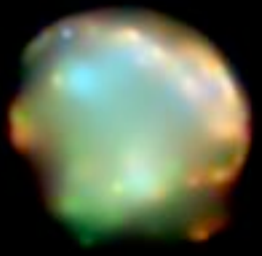
Magellanic clouds are perfect

- little extinction
- large distance
- known velocity & different from Milky Way
  - -> separate interlopers!

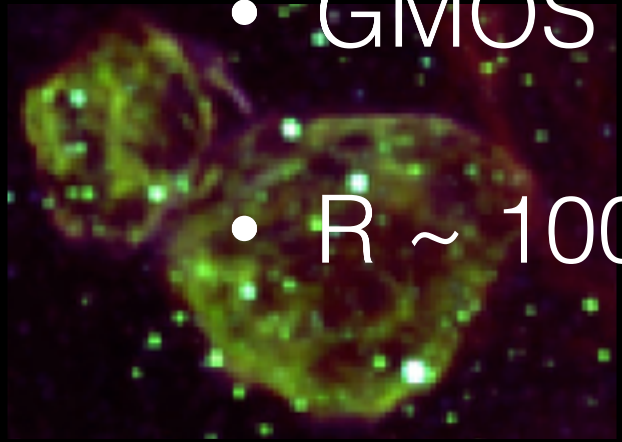

talk by L. Hovey
later today
Schaefer & Pagnotta 2012
Edwards, Pagnotta & Schaefer 2012

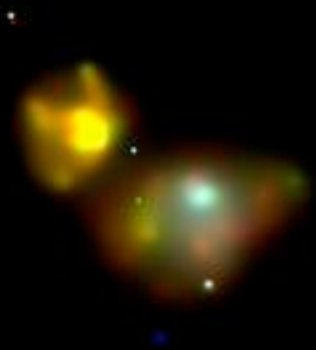

Magellanic Cloud Supernova Remnant Companion Survey
Kerzendorf, van Kerkwijk and Badenes in prep.

The survey



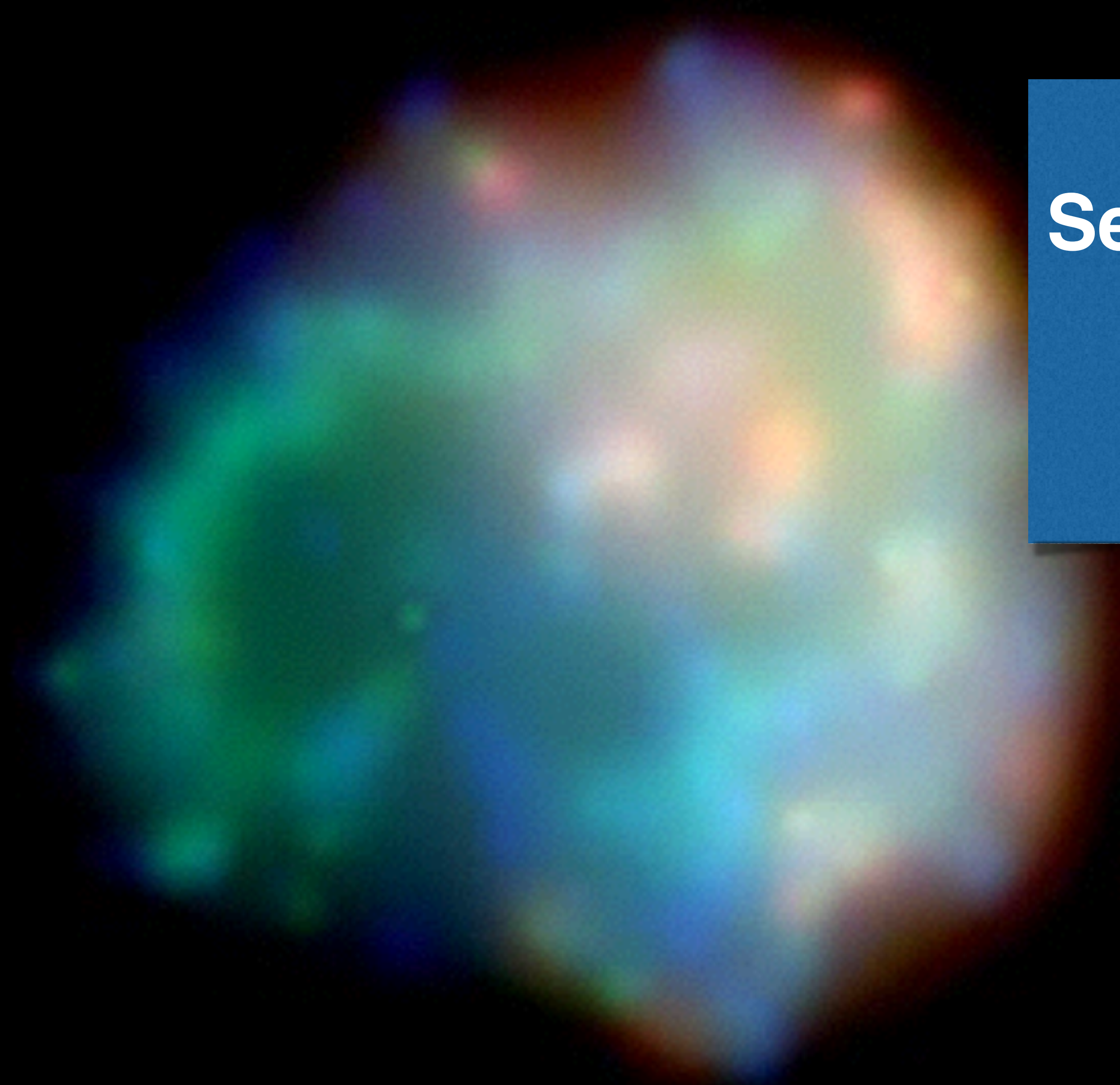
- 22 remnants (regardless of type)
- 153 Companion Candidates of all stars L>100 Lsun!
- 484 Calibration Stars!
- 4 spectra each:
  - GMOS B600 & R400 (3500 - 9000 A)
  - R ~ 1000





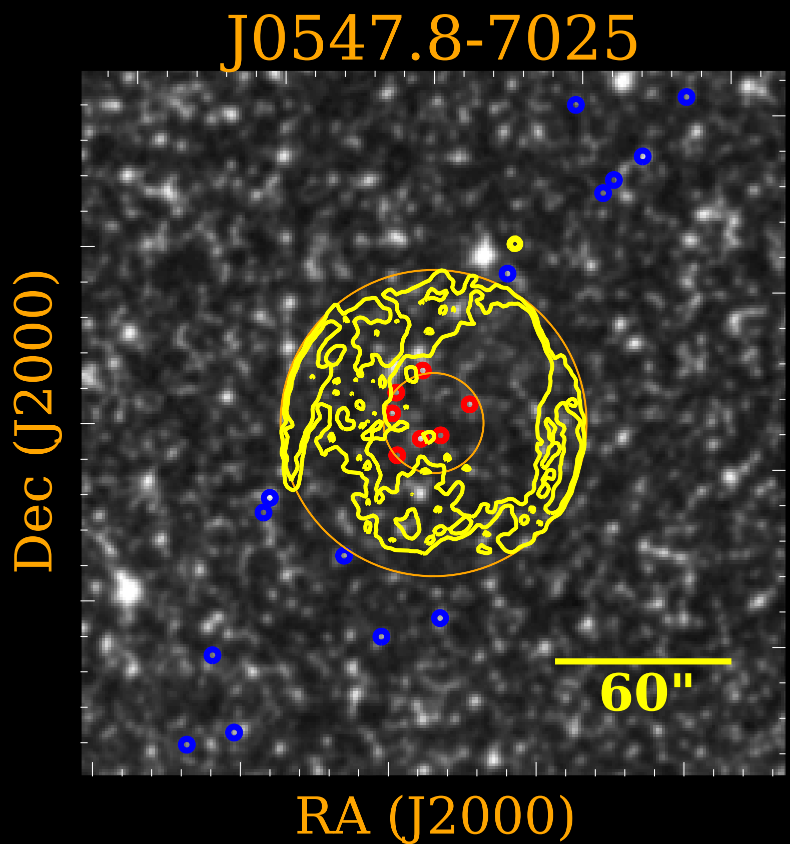
The Type las

J0509.0-6844
(N103B)

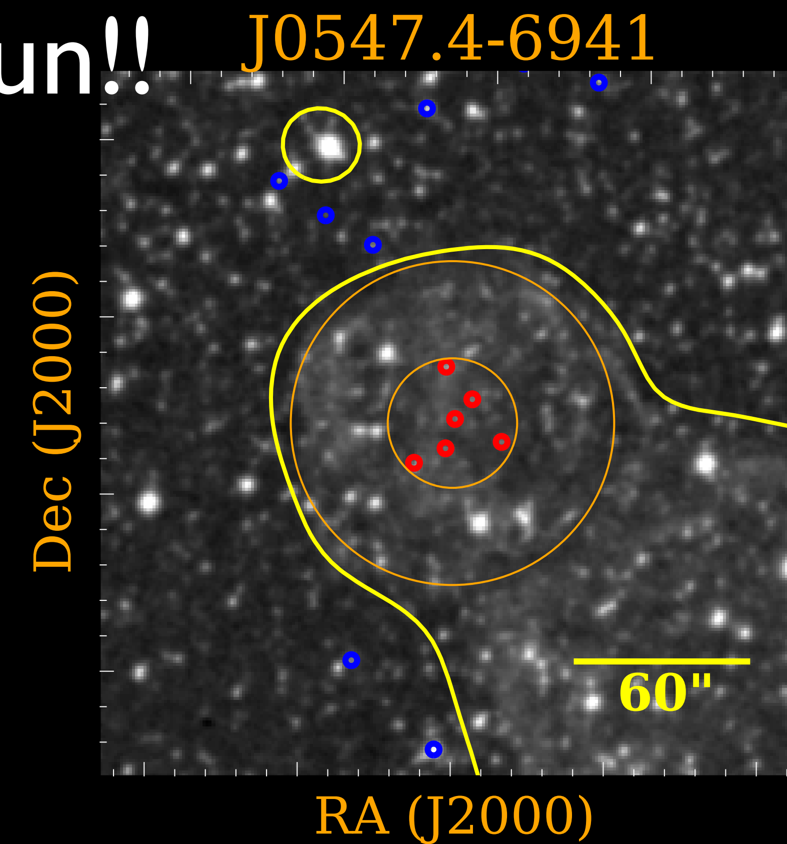


See talk by Williams
See talk by J. Li
later today

L>30 Lsun!!

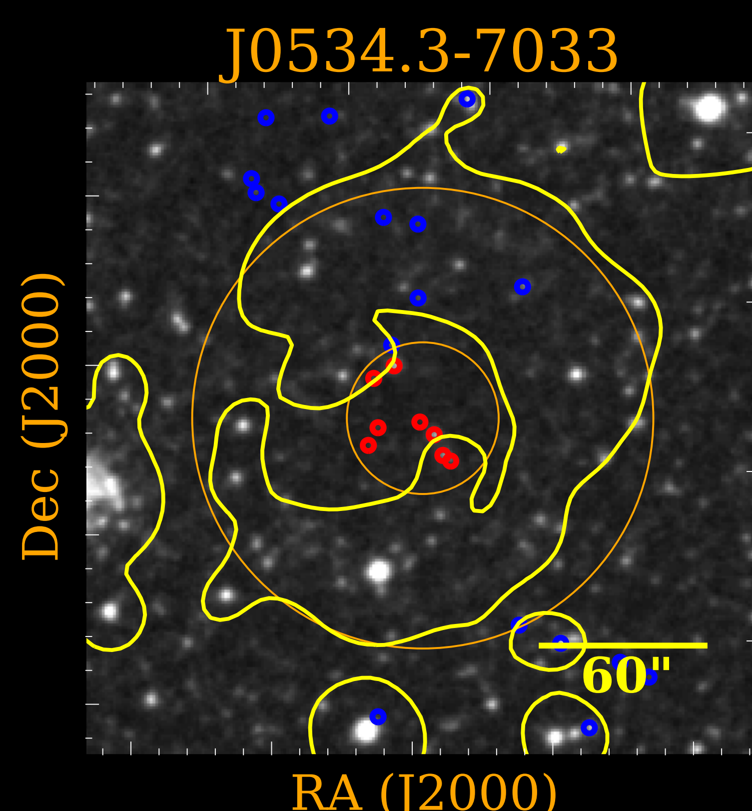


Hendrick et al. 2003



Williams & Chu 2005

Borkowski et al. 2006



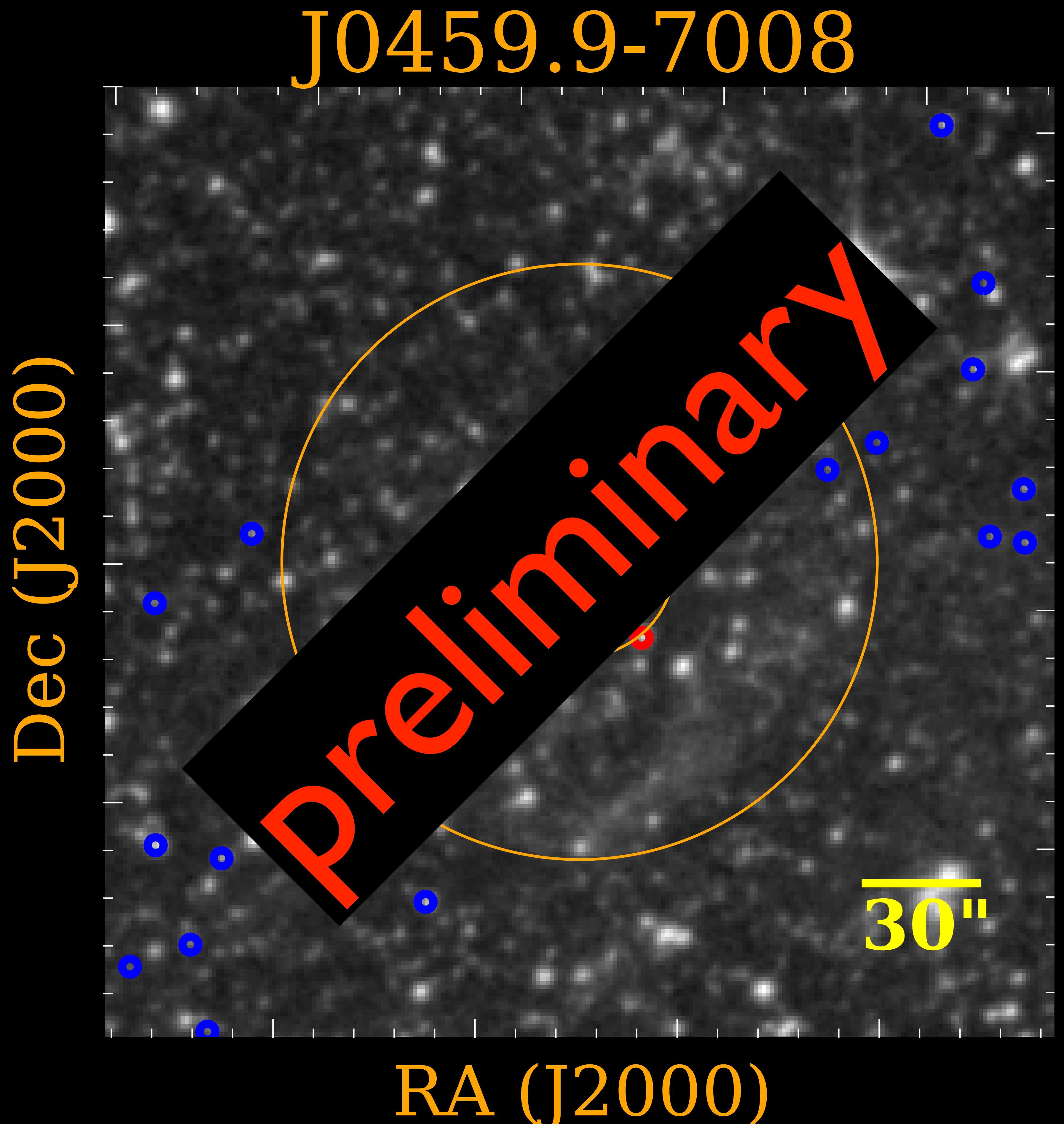
Kerzendorf et al. 2016 (in prep.)

Summary

A futile search?

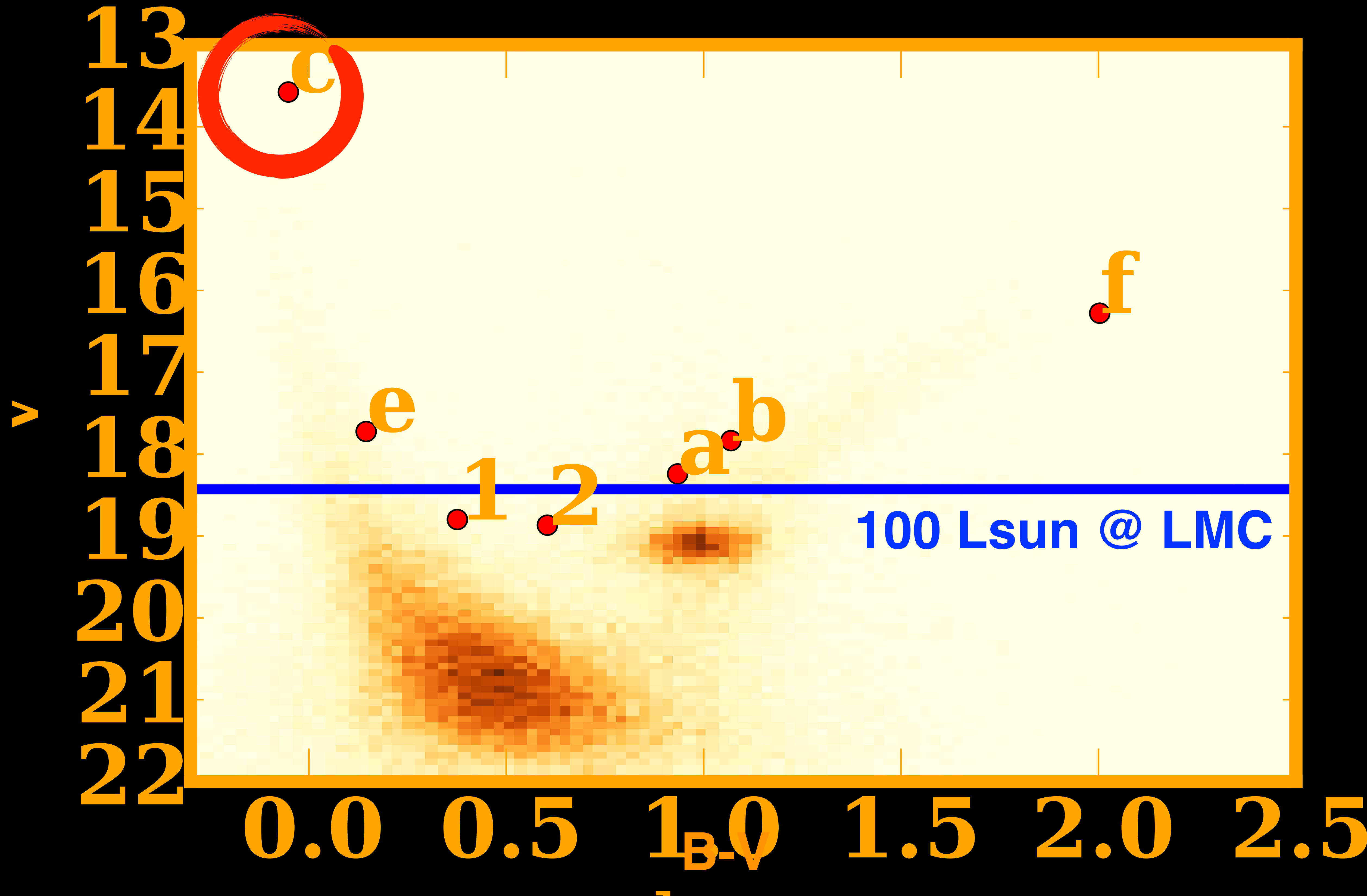
- Type Ia
  - don’t seem to have bright survivors (9 remnants)
  - or they hide well
  - double degenerate or alternate scenarios
- some unambiguous candidates
- just at the beginning

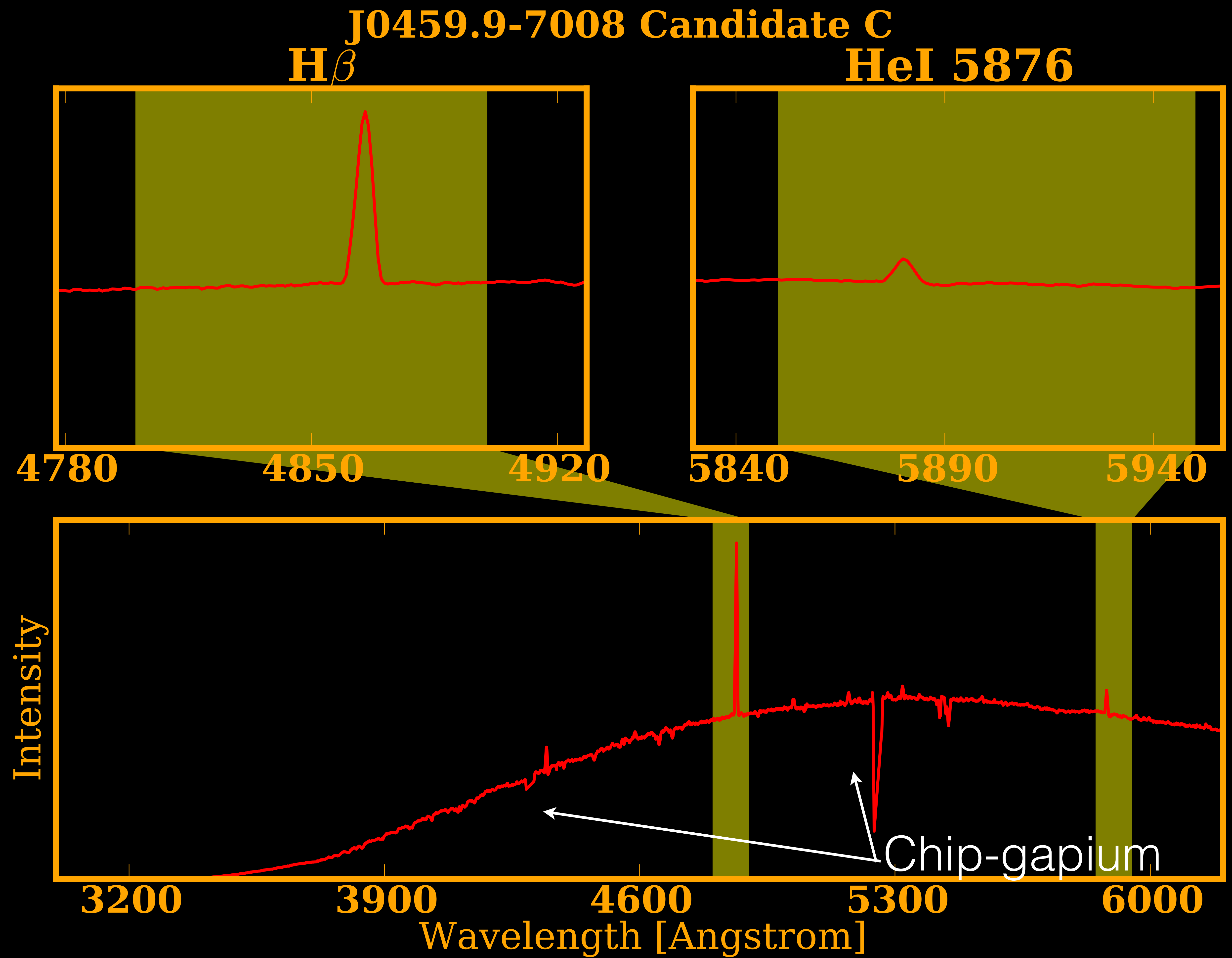
Some success



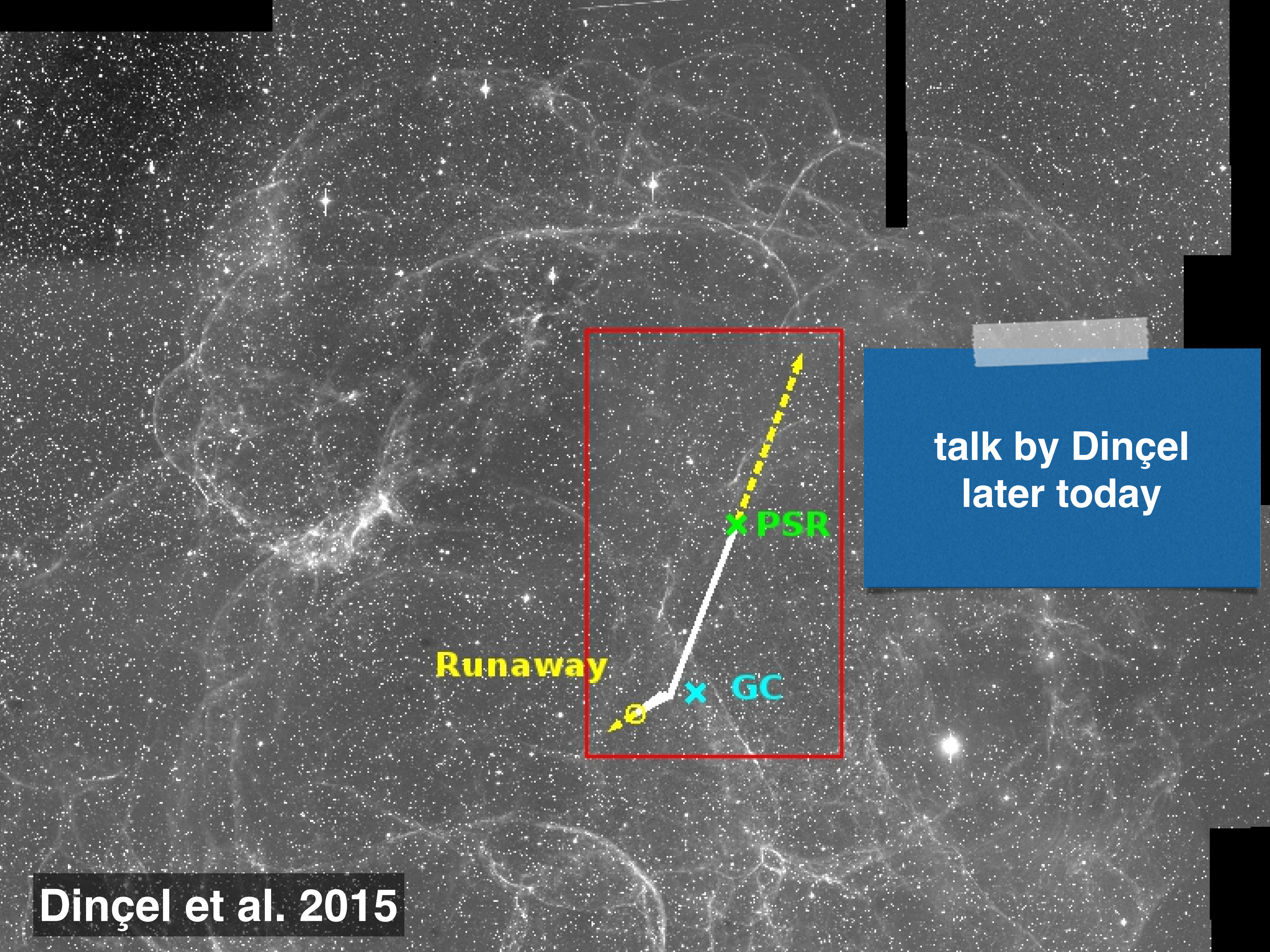
J0459.9-7008
Dec (J2000)
RA (J2000)
preliminary
30"

J0459.9-7008 Candidates





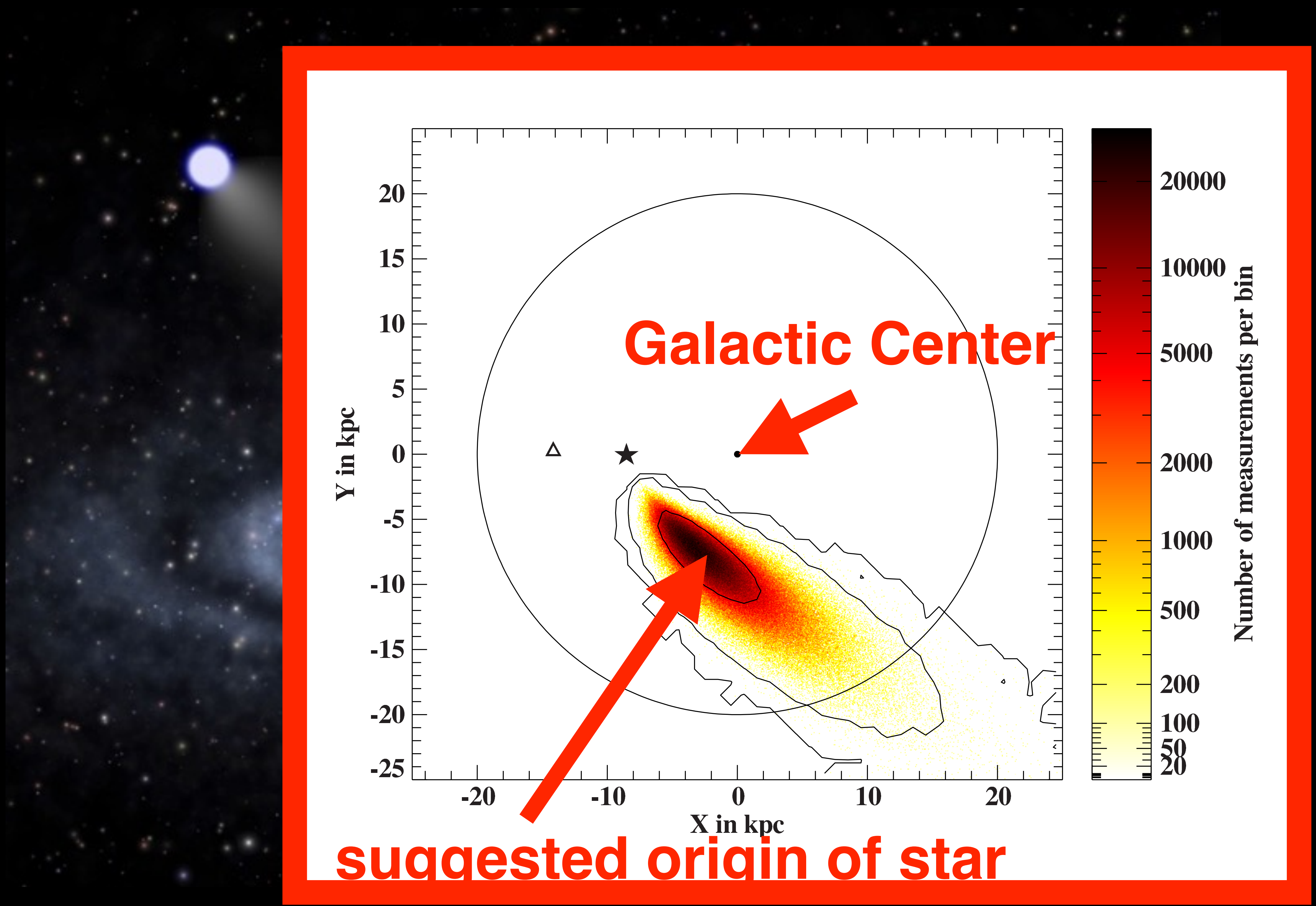
J0459.9-7008 Candidate C
Hβ
HeI 5876
4780
4850
4920
5840
5890
5940
Intensity
Chip-gapium
3200
3900
4600
5300
6000
Wavelength [Angstrom]



talk by Dinçel
later today

Dinçel et al. 2015

The fastest star in the Galaxy



Extragalactic success stories to come

… from Schulyer
… after the break

Thank you