The Whole Earth Telescope, Variable White Dwarf Stars, and Type Ia Supernovae

Harry Shipman, room 1205
University of Delaware

Talk for the Kavli Institute for Theoretical Physics

May 2007

Astrophysics Research Agenda

- Asteroseismology of white dwarfs (Provencal and Shipman, Communcations in Asteroseismology 2007, in press.)
- Basic Properties of WD (temperatures, masses, chemical compositions); ApJ 177, 723, 1972; ApJL 488, L43, 1997)

Publications are representative: there are more… I also occasionally omit co-authors to save space.

Astrophysics Agenda continued

- Investigating WD with new regions of the electromagnetic spectrum (uv: AJ 82,480, 1977; euv: ApJL 211, L103, 1977 and ApJ 392,L27,1992; x-ray: ApJ 206, L67,1976)
- Chromospheres in Brown and White Dwarfs (brown dwarfs: ApJ 630, L89-l01, 2005; highlighted in Nature 437, 4-5, 2005; and white dwarfs: ApJ 627, 418, 2005)

Science education research agenda

- Student learning of critical thinking and the nature of science (Brickhouse, Dagher, Letts, and Shipman, Journal of Research in Science Teaching 27, 340-362, 2000)
- Inquiry learning in large classes (The Physics Teacher, 38:541-542, 2000)
- Dealing with Student Misconceptions (Wells, Eslinger, and Shipman, presentation to National Association for Research in Science Teaching, 2007)

Science Education Agenda, more

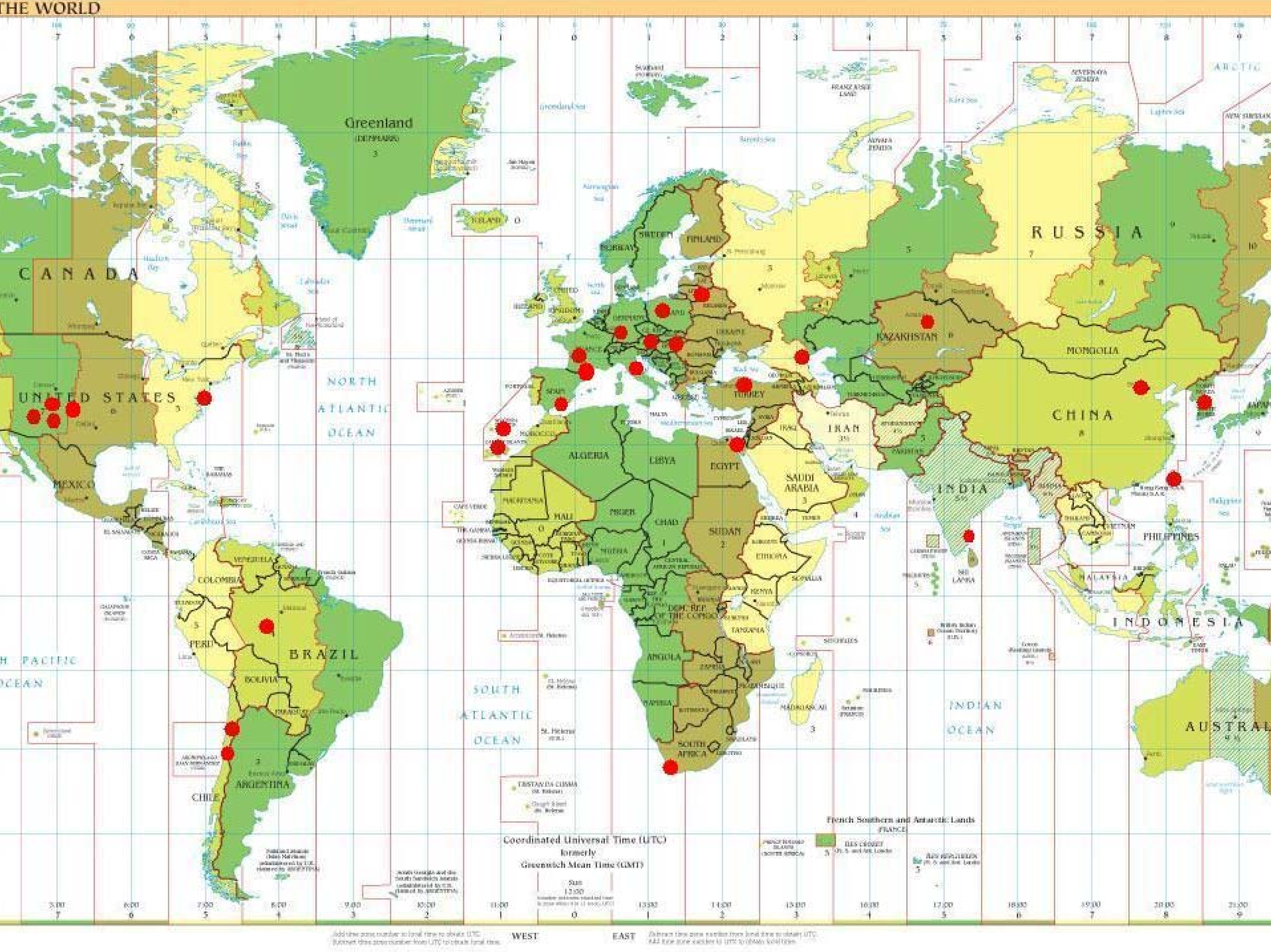
- Implementing astronomy curricula in grades K-12 (Densler and Shipman, Curriculum Handbook for Planetary Science, 2006)
- Teaching about the relationship between science and religion (Shipman, Brickhouse, Dagher, and Letts, Science Education 86: 526-547, 2002)

Main Ideas of this talk

- The Whole Earth Telescope and what it can do
- Our most recent run: testing theories of convection and more
- White dwarf layer masses, magnetic fields, rotations, and masses

The Whole Earth Telescope

- A global network of 23 telescopes (latest run), mostly 1-m, a few 2-m
- Management and headquarters moved to the Mt. Cuba Observatory, a public, privately funded observatory associated with the University of Delaware, in 2006
- First run under new leadership is discussed here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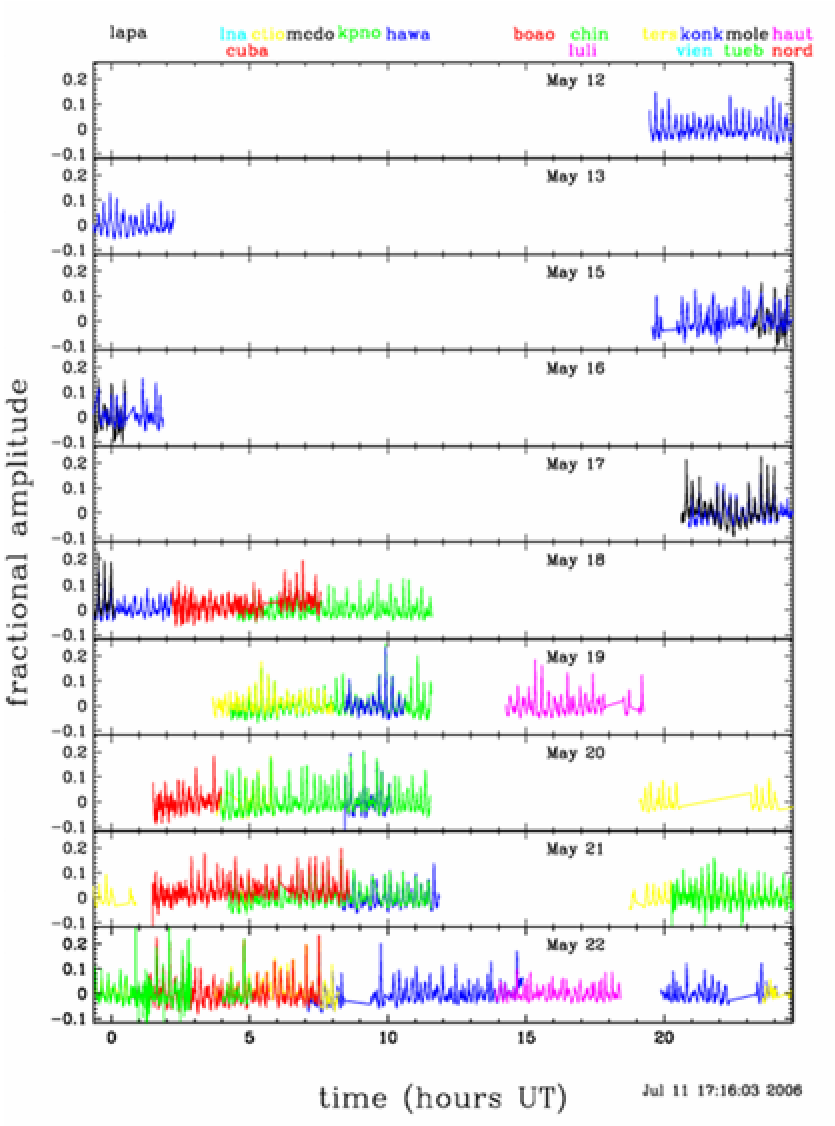
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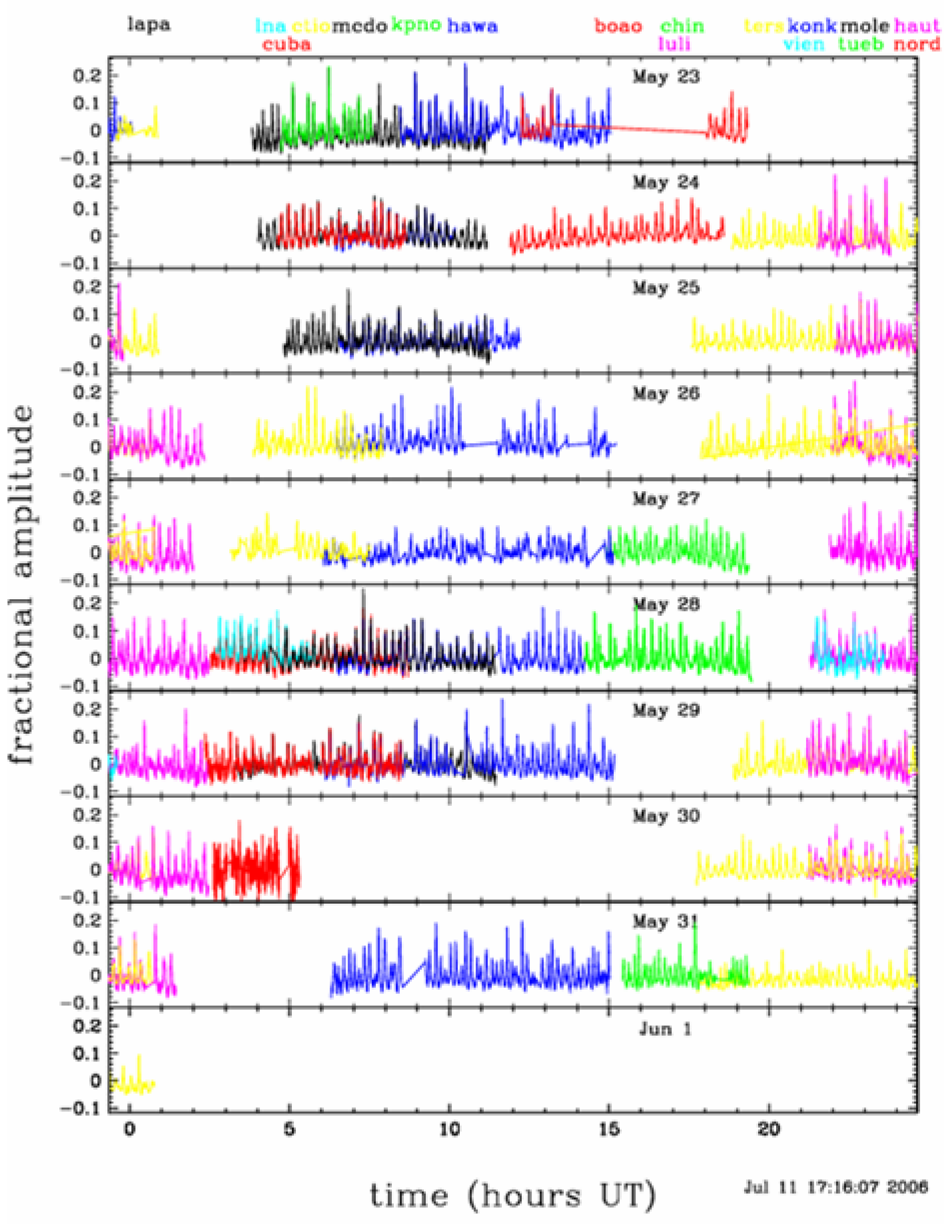
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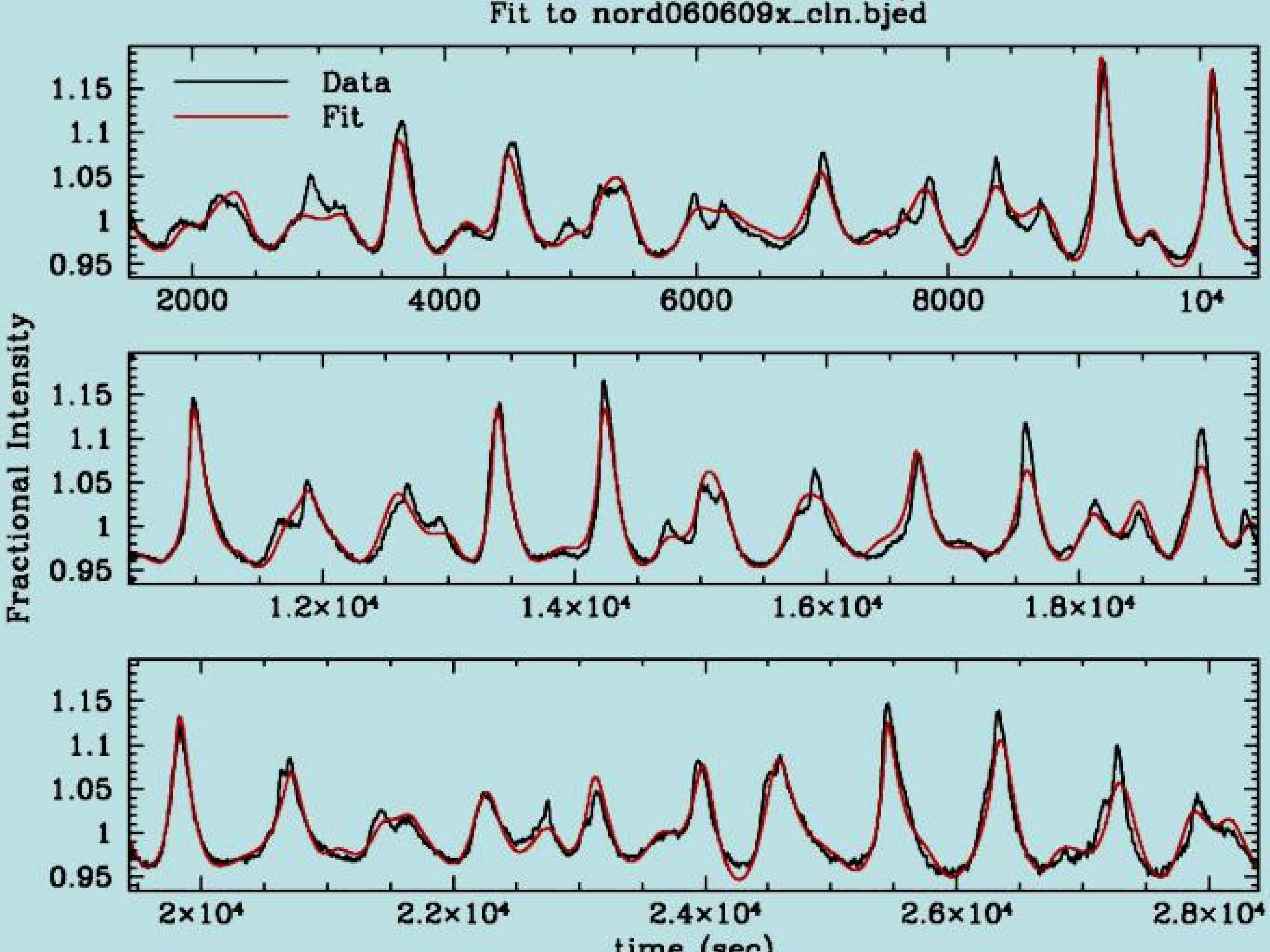
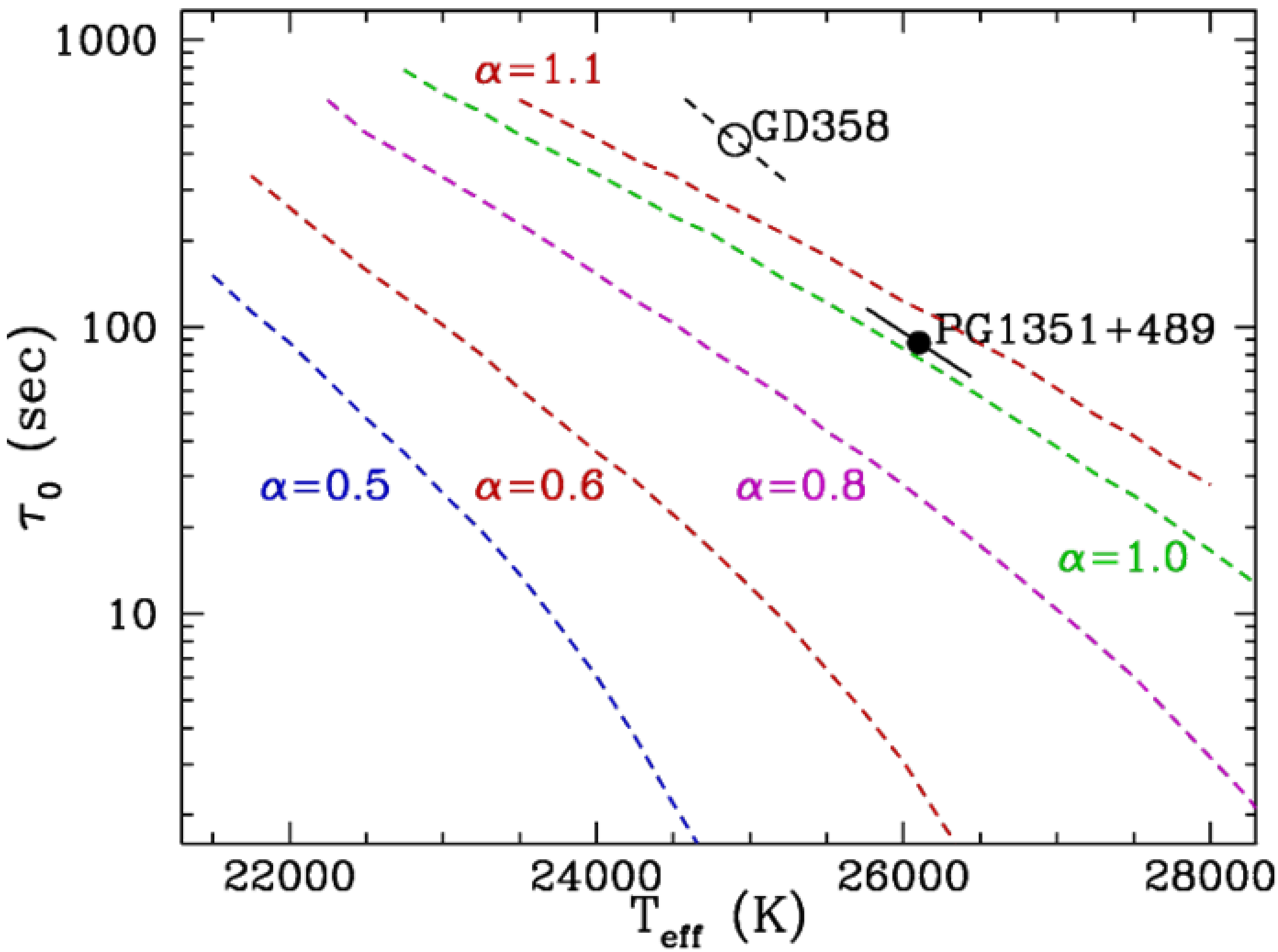
best-fit nonlinear solution (3 additional parameters)

residuals^2 = 1.3 ¢ 10^{-4}





1000
100
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24000
26000
28000
T eff (K)
τ 0 (sec)
α=1.1
GD358
PG1351+489
α=0.5
α=0.6
α=0.8
α=1.0

Results and future prospects

- Validate MLT and estimate α for DBV white dwarfs (done, preliminarily)
- Determine convection zone depth
- Test/calibrate models of convection in various parts of the HR diagram, including overshooting (needs additional stars)
- Identify more modes (what can this tell us?)

What else can WD variables tell us?

Nothing to do with type Ia supernovae, but…

Test the age of the Universe by measuring WD cooling over decades and find planets: two stars done (ZZ Ceti = R 548 and G 117-B15A). These stars have no planets yet; one other star does (Mullaly 2005). Cooling time scales okay. One DBV star in progress (Provencal, Shipman, and Sullivan).

See Mukadam et al. ApJ 594, 961, 2003.

Expected layer masses

- Current Conventional wisdom (CCW) suggests that white dwarfs have a carbon-oxygen core, with a thin layer of helium (10^{-2} solar masses) on top and, 80% of the time, a thinner layer of hydrogen (10^{-4} solar masses) on top of the He.
- Units for layer thicknesses in the table on the next page are M(observed)/M (CCW).

White Dwarf Properties from Seismology

Star	M(H)	M(He)	P_{rot}	B	M_{tot}	Ref.
L 19-2	1	0.9	13h			Bradley ApJ 552,326
G226-29	1		9h		0.8	Kepler et al. ApJ 447., 874
G 29-38	.005				0.75	Bradley & Kleinman 1997
GD154	10^{-6}		55h		0.7	Pfeiffer et al. A+A 214,182
R 548	1.5		21h		0.54	Bradley, ApJS 116, 307
G 117-B15A	1				0.55	Bradlley ApJS 116, 307
GD 165	2	2	55h		0.65	Bradley ApJ 552, 326
GD358	0	10^{-4} or 1	Diff.	1300	0.61	See next page
PG1159	0	30	33.1h	<6000	0.586	Winget et al. 1991

Some comments on layer masses:

- Uncertainty in He layer mass for GD 358 is from two different analyses (Winget et al., ApJ 430, 839; and Metcalfe et al. Ap.J. 545, 974) and should be cleared up by our data.

- H layer masses vary, in accordance with expectations from observations of cool WD

More observations, maybe relevant to SN Ia

- H layer masses are consistently small, always less than 10^{-4} solar masses. (Does this help H problem? I don’t think so.)

- How important is it to do more He layer masses? Could probably be done but requires more 2m telescopes (likely targets are faint)

Rotation rates:

- Asteroseismology is more sensitive than spectroscopy by factors of about 10, but is roughly consistent with it.

- If angular momentum per unit mass is conserved during late stellar evolution, we expect P_{rot} ~ 5 min, not the tens of hours that is observed

Rotation rates (more)

- If SN Ia progenitors are close binaries, much higher rotation than is the case in single stars would be expected

- Some magnetic WD's rotate EXTREMELY slowly (P_{rot} > 100 yr!)

Magnetic Fields

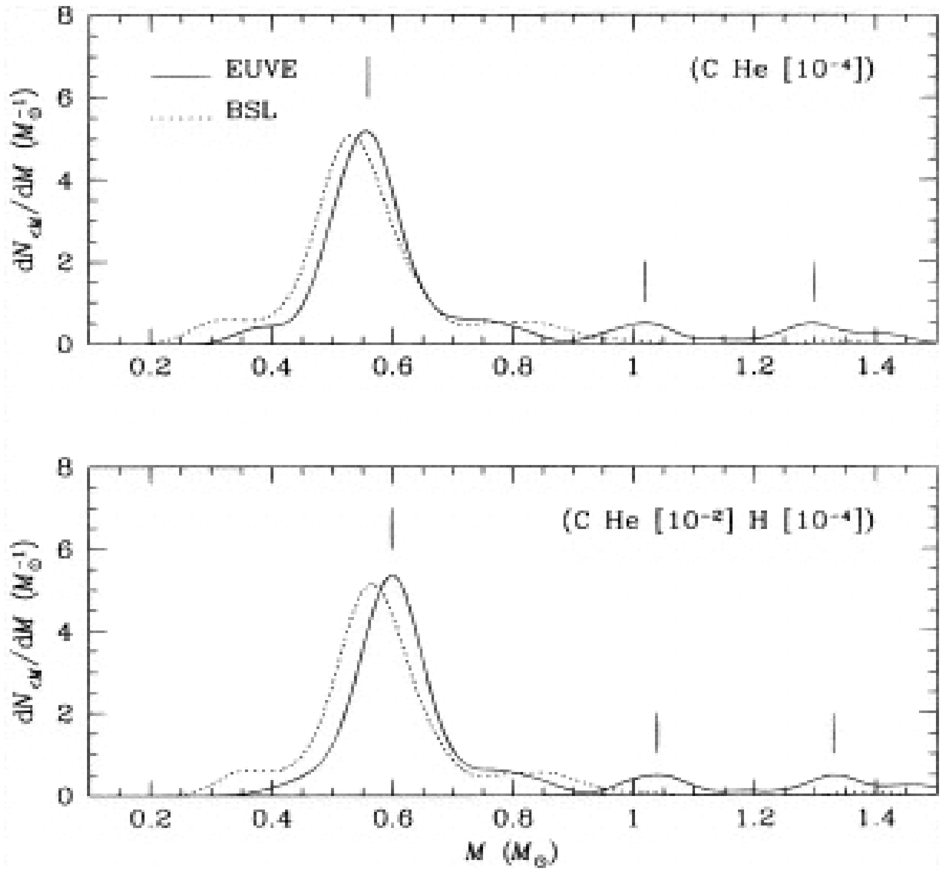
- Initially discovered by continuum circular polarization measured with an 0.6-m telescope (Kemp 1970) and interpreted by Shipman (1971, ApJ 167, 165). Current work is by Schmidt and Wickramasinghe.

- Most optical detections are at the level of 10^6 to 10^8 gauss; seismology can go as low as 10^3 gauss

White Dwarf Masses

- While asteroseismology can give very accurate individual masses, spectroscopy provides a much larger N, but is subject to selection effects
- Mass distributions have been published for a long time (for one of the earliest, see Shipman 1972, ApJ 177, 723, including a treatment of selection effects)

Vennes, Thejll, Galvan, and Dupuis, ApJ 480: 714-734, 1997



An odd idea

- Is it possible that some supernovae (maybe the 2002cx’s) come from the high-mass tail of the EUV selected white dwarfs?

- They are young, some in binaries (like Sirius B), maybe all in binaries, ???

Summary

- Asteroseismology of white dwarfs is a powerful tool, but it's not easy.
- Results for the most recent WET (=Whole Earth Telescope) run. Mt. Cuba Observatory in Delaware manages WET
- Layer masses can only be observationally measured with asteroseismology.
- We can also get magnetic fields, rotation rates, and masses.
- A suggestion (wild idea?) was made from mass distributions about one channel into the SN track.