The First Detection of a Strong Magnetic Field in a FS CMa Star

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Herbig Ae/Be stars *Allen & Swings 1976, A&A, 47, 293* supergiants

U N C L A S S I F I E D

FS CMa stars
Miroshnichenko 2007, ApJ, 667, 497

compact planetary nebulae

symbiotic stars

Lamers et al. 1998, A&A, 340, 117

Herbig Ae/Be stars

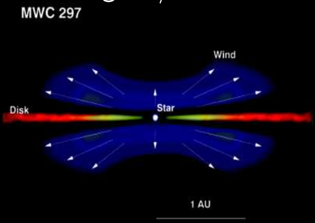


figure from Fabien Malbet

symbiotic stars

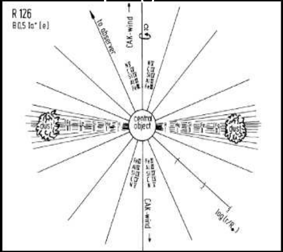
FS CMa stars

?

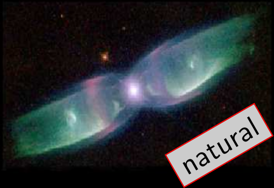
spectral properties
⇒ a pre-main sequence star

located far from the star-forming regions
⇒ can not be young

supergiants



Zickgraf et al. 1985, A&A, 143, 421



compact nebulae

planetary

Hen3-1398 Hen3-847
IRAS 01441+6026 StHa 145 MWC 17
GGR 8

what we know about FS CMa stars?

CPD-57 2874
SS 170 MWC 819
IRAS 06341+0159 Hen3-303
VES 723 He2-91
MWC 623 HD 50138 Hen3-140
HD 85567 Pe2-9
Hen3-938 AS 160
MWC 657
GGR 25 MWC 922
FS CMa
AS 174
IRAS 07080+0605 AS 116
AS 119 AS 222
AS 319 HDE 327083
MWC 349 3 Pup
V669 Cep
HD 87643
MWC 485 AS 446
IRAS 06071+2925
MWC 645 AS 386 AS 78
MWC 728
IRAS 07377-2523
FBS0022-021 IRAS 02103+7621
MWC 790
GG Car
AS 225 AS 381 AS 466
CPD-52 9243
MWC 137
MWC 1055 MWC 342
Hen3-298

infrared excess

Kurucz model

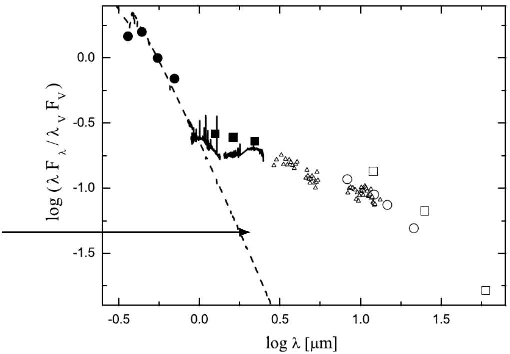


Figure 13. Spectral energy distributions of IRAS 00470+6429. Logarithm of the dereddened ($E(B-V) = 1.2$ mag) flux normalized to that in the V band (vertical axis) is plotted vs. logarithm of the wavelength in microns. The fluxes were dereddened using the interstellar extinction law from Savage & Mathis (1979). Symbols: circles, *UBVR* photometry; squares, near-IR photometry from 2MASS; the solid line, the 2003 NIRIS data; triangles, BASS data; large open circles, *MSX* data; and large open squares, IRAS data. The dashed line represents a Kurucz (1994) model atmosphere for $T_{\rm eff} = 20{,}000$ K.

Miroshnichenko et al. 2009, ApJ, 700, 209; IRAS 00470+6429

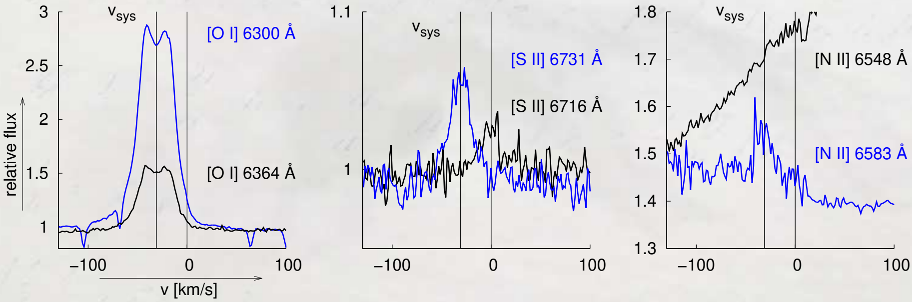
forbidden lines

- [O I] $\lambda\lambda$ 6300, 6364 Å almost always
- [S II] $\lambda\lambda$ 6716, 6731 Å usually
- [N II] $\lambda\lambda$ 6548, 6583 Å sometimes

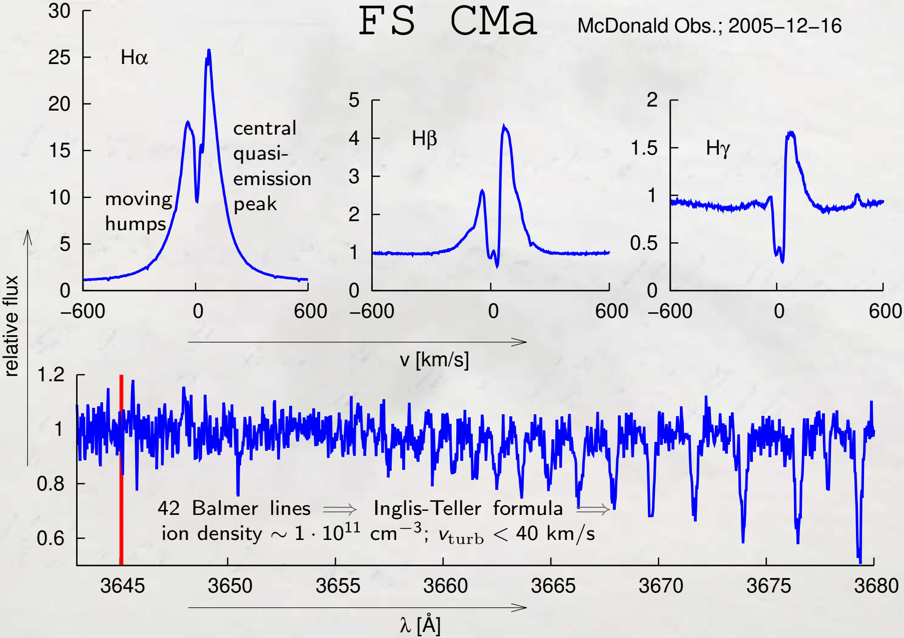
$\Longrightarrow$ nebular diagnostic

- narrow, symmetric, sometimes double peaked, relatively stable

MWC 342 CFHT; 2015-12-01



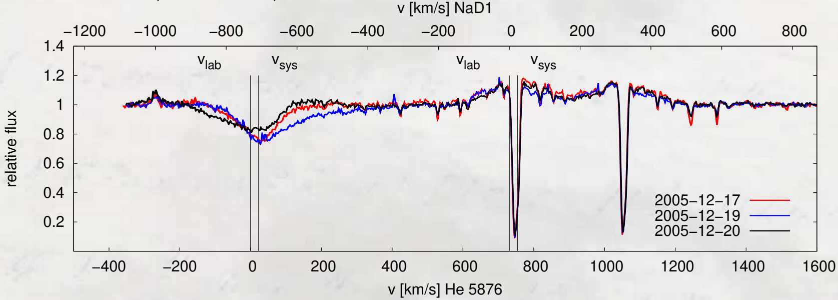
Balmer lines



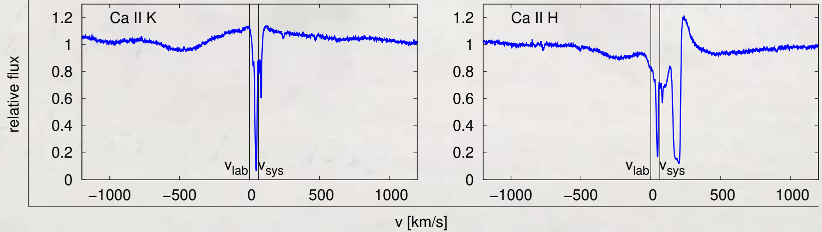
resonance lines

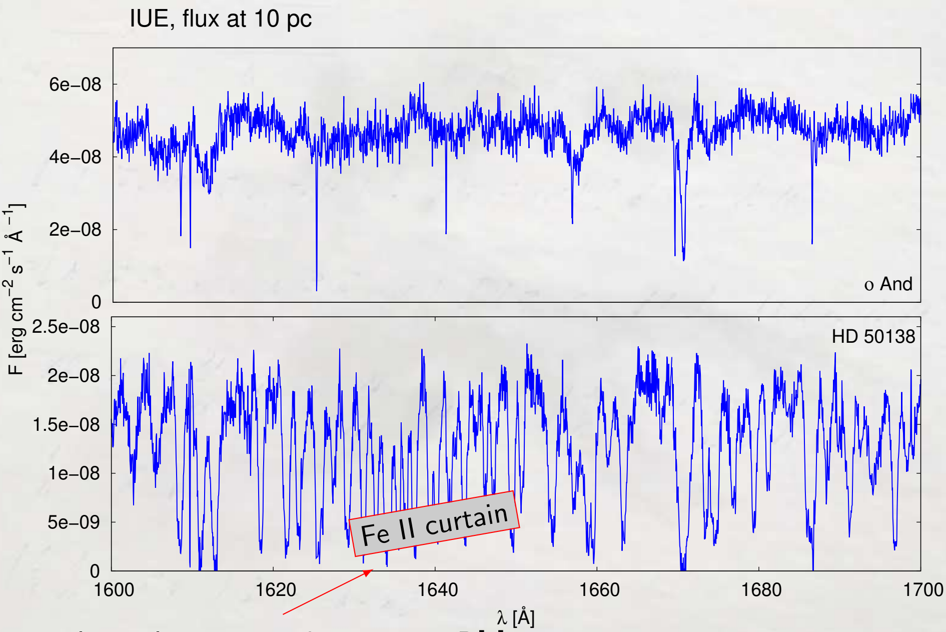
- broad, in emission, symmetric
- very rarely emission almost disappears or asymmetry is detected

FS CMa NaD, He 5876 Å; McDonal Obs.



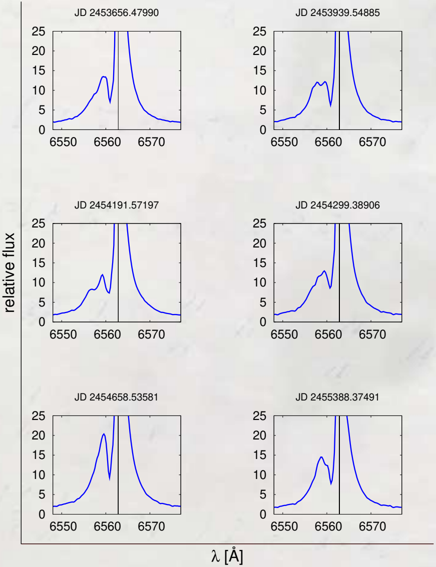
AS 160; UVES; 2013-09-27

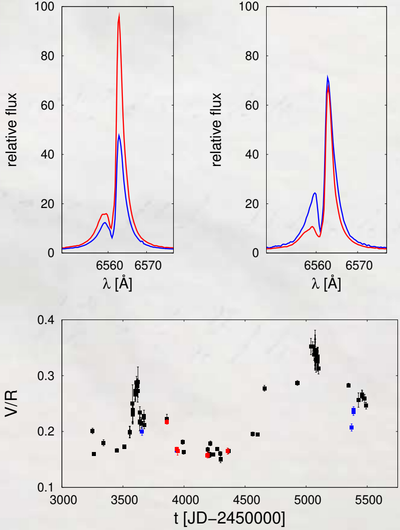




classical novae, symbiotic stars, B[e] supergiants

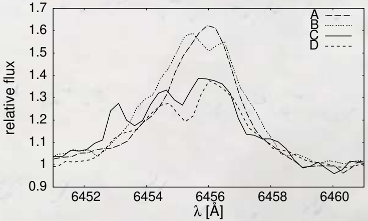
MWC 342 *(Kučerová et al. 2013, A&A, 554A, 143)*

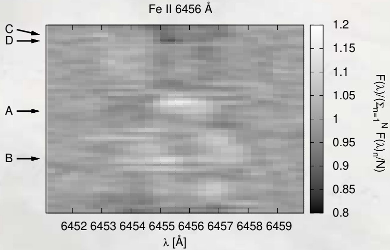




expanding layers

MWC 342 Fe II 6456 Å; Ondřejov data





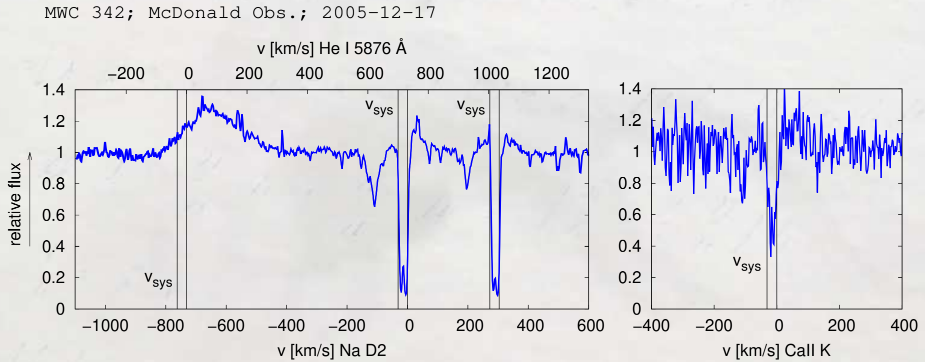
A = JD 2454240.39, B = JD 2453638.39, C = JD 2455388.37,
D = JD 2455346.49 – inverse P Cygni profile in He I 6678 Å

Kučerová et al. 2013, A&A, 554A, 143

material ejecta and infall

discrete components of resonance lines

- detected by MWC 342, AS 225, AS 174, HD 328990, HD 50138
- usually blue shifted, however the red-shift is also observed



- P Cygni, inverse P Cygni profile in absorption lines of He and metals

line-profile variability

absorption lines	✘	emission lines	✘ forbidden emission lines
night-to-night variability		$\sim$week $\wedge$ $\sim$months $\wedge$ $\sim$years	$\sim$months $\wedge$ $\sim$years

✘

photometry

- **multiperiodicity, found periods change from year to year**
- e.g. MWC 342

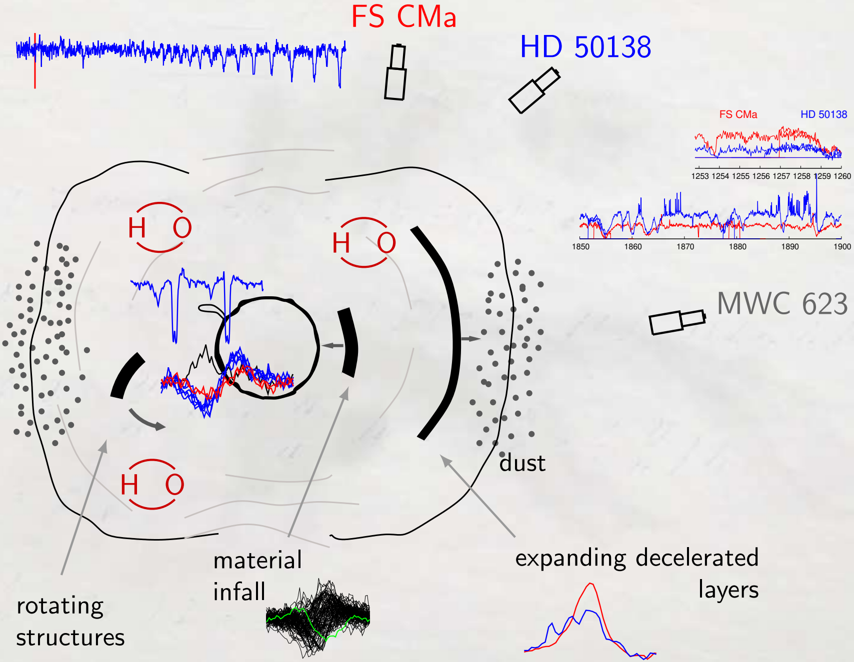
  a period from 14 to 16 days has been found in every observing run

  $\wedge$

  a period from 40 to 120 days

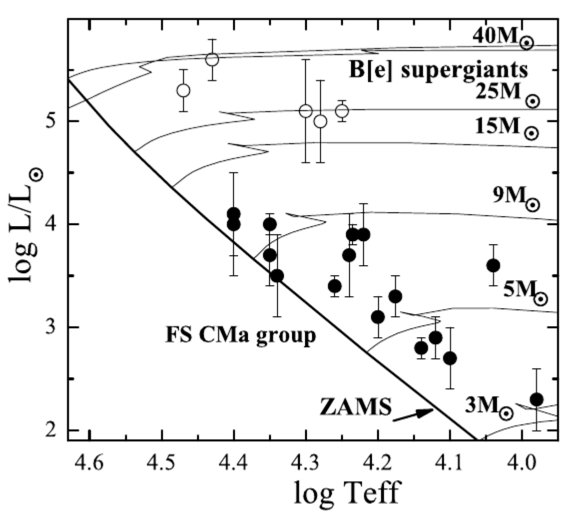
  this long period has not been detected every year

  Shevchenko et al. 1993, Ap&SS, 202, 121; Mel'nikov 1997, Astron. Lett. 23, 779; Chkhikvadze et al. 2002, Astrophys. 45, 8


FS CMa
HD 50138
FS CMa
HD 50138
1253 1254 1255 1256 1257 1258 1259 1260
1850 1860 1870 1880 1890 1900
MWC 623
H O
H O
H O
dust
rotating structures
material infall
expanding decelerated layers

HR diagram FS CMa stars

Miroshnichenko *(2017, ASPC, 508, 285)*



– full line – zero-age main-sequence

– single star evolutionary tracks *(Ekström at al. 2012)*

what could it be?

binaries *(Miroshnichenko 2007, ApJ, 667, 497, Miroshnichenko & Zharikov 2015, EAS Publications Series, 71, 181 ...)*

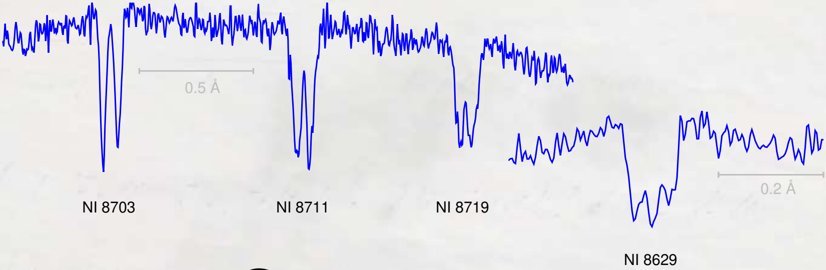
+ the simplest explanation
+ it naturally explains large mass-loss rate ($2.5 \cdot 10^{-7} - 1.5 \cdot 10^{-6} M_{\odot} yr^{-1}$)
  - $\dot{M}$ can be orders of magnitudes overestimated for FS CMa stars detailed models only for HD 87643, AS 78, and IRAS 00470+6429
    - β velocity law, or similar one $\Longrightarrow$ the **overestimation of $\dot{M}$** for not freely expanding medium
    - most massive FS CMa stars (radiative pressure larger) $\Longrightarrow$ not a representative stellar sample
+ Why the circumstellar matter do not freely expand?
+ most main-sequence B-type stars $(\sim 3 - 20 \mathrm{M}_{\odot})$ are born at least in pairs *(Preibisch et al. 2000, McSwain & Gies 2005)*

– not enough binaries have been confirmed

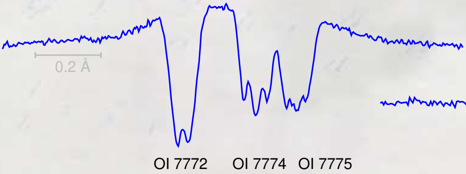
post-merger systems *(de la Fuente et al. 2015, A&A, 575, A10)*

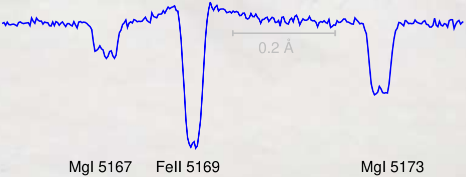
post-AGB stars

...



IRAS 17449+2320





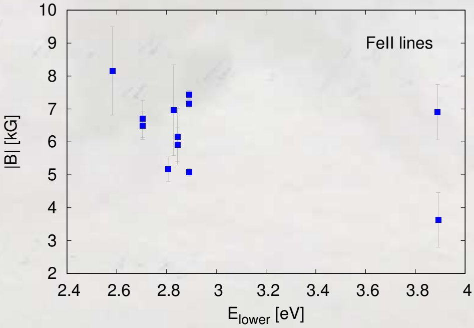
6.2 kG

IRAS 17449+2320

$\Longrightarrow$ Finally, the magnetic field must be taken into account for the study of FS CMa stars.
It naturally explains, why the circumstellar matter do not freely expand into the interstellar space.

mean magnetic field modulus:

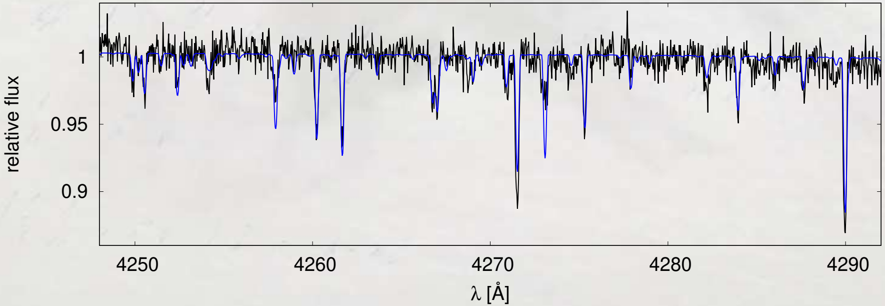
	2006-06-08	2012-02-09	2012-08-13
$\|\mathbf{B}\|$	6.0 ± 0.4 kG	5.8 ± 0.5 kG	6.2 ± 0.2 kG



results of the first analysis

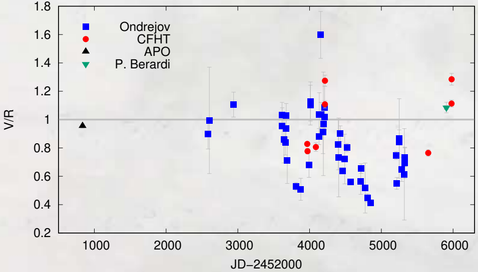
- discrete components of the resonance lines $\Longrightarrow$ material infall
- (36.1±0.2) d period of the ratio of intensity of the Hα emission edges (A. Miroshnichenko)
- radial velocities of SiII line 6 347 Å

  } stellar rotation
- variable continuum
- spectral fitting: upper limit of $T_{\mathrm{eff}} = 11\ 000$ K, $\log g = 4.1$, $v_{\mathrm{rot}} = 9.1\ \mathrm{km\,s^{-1}}$ + hot source ($T > 50\ 000$ K)



is IRAS 17449+2320 really a FS CMa star?

– V/R changes



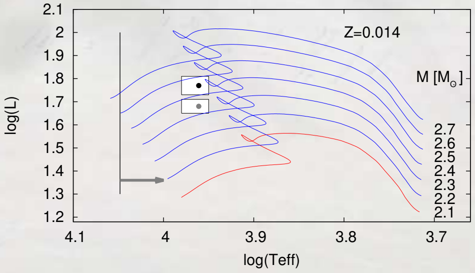
– night-to-night variability of Hα, OI, and two FeII lines
– HeI lines are remarkably stable, only 5 876 and 6 678 Å show small changes $\Longrightarrow$ stable photospheric regions
– HeI triplets are stronger than singlets (like in a nebular case)
– number of Paschen lines $\Longrightarrow$ lower density
– appearance of a red absorption in Hα and OI triplet $\lambda\lambda$ 7 772, 7 774, 7 775 Å, and 8 446 Å

new scenarios for FS CMa stars

- IRAS 17449+2320 space velocity $W = 8.470\ \mathrm{km\,s^{-1}} \Longrightarrow$ escaped from a cluster
- Boubert & Evans (2018) $\Longrightarrow$ escaped from a cluster
- binaries escaped from a cluster merge soon (angular momentum conservation)
- strong magnetic field
- *(de la Fuente et al. 2015, A&A, 575, A10)*

$\Big\}$ **mergers**

- **atypical Ap star?**



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Canada France Hawaii Telescope N. Manset

Observatorio Astronomico Nacional San Pedro Martir S.V. Zharikov

Bellavista Obs. L
P. Berardi

Himalayan Chandra Telescope
A. Raj, H.P. Singh

picture: https://www.nationsonline.org/oneworld/continents_map.htm