An X-ray view of hot subdwarfs

Sandro Mereghetti
INAF, IASF-Milano

N. La Palombara, P.Esposito, A. Tiengo
U.Heber, S.Geier, W.R.Hamann
G.L.Israel, L.Stella

Hot subwarfs can emit X-rays due to:

- Accretion onto a compact companion (in binaries)

$$L_X = \frac{GM}{R}\dot{M} = \frac{GM}{R}\left(\frac{R_a}{2a}\right)^2 \frac{V_R}{V_W}\dot{M}_{\rm W} \sim \frac{GM}{R}\left(\frac{R_a}{2a}\right)^2 \dot{M}_{\rm W}$$

$$\text{Bondi} - \text{Hoyle accretion radius}: \quad R_a = \frac{2GM}{V_R^2}$$

- "intrinsic" emission in the wind

(in single stars and in binaries)

$$L_X / L_{BOL} = 10^{-7\pm1}$$

X-ray observations of hsd: why ?

- Provide information on the (weak) winds from hot subdwarfs

- Allow us to discover and study interesting binaries → information on hsd formation/evolution

Hot sd are faint in X-ray → slow progress in the observations:

- 5 sdO detected:

1992: ROSAT → HD 49798

Israel+ 1997, Mereghetti+ 2009,2011, 2013

2012: XMM-Newton → BD +37° 442

La Palombara+ 2012, Heber+ 2014

2014: Chandra → BD +37° 1977, Feige 34, BD +28° 4211

La Palombara+ 2014, 2015

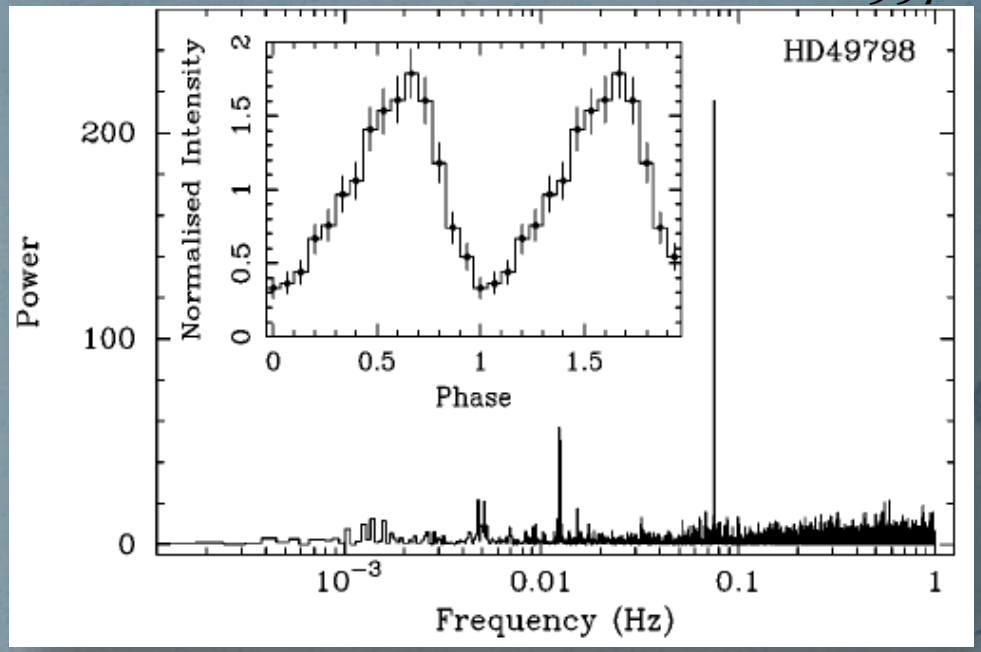
- only upper limits for sdB

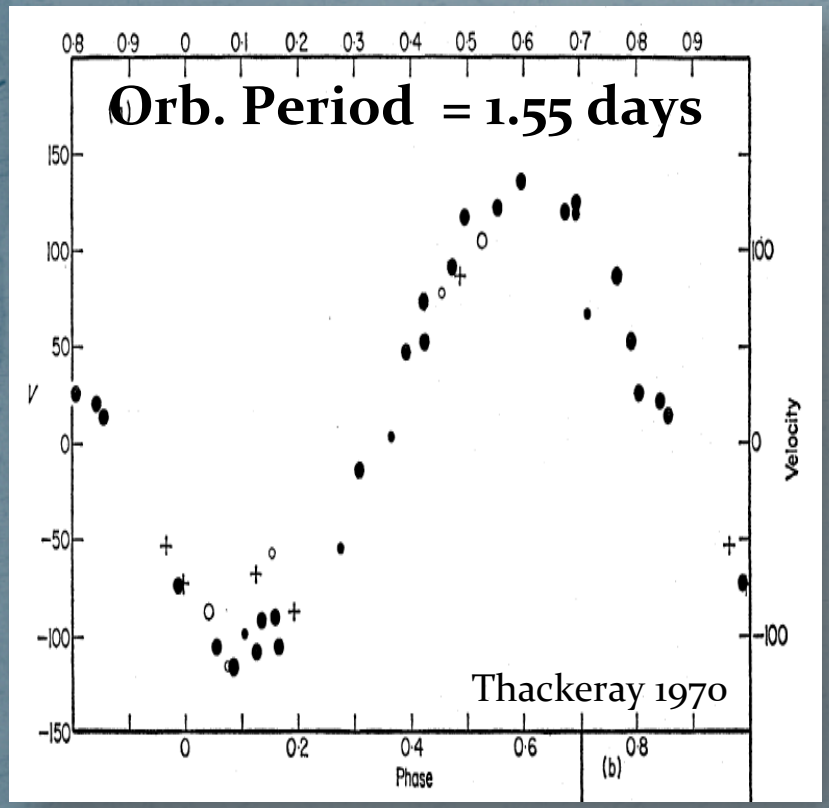
Mereghetti+ 2011, 2014

HD 49798: single-line spectrosc. binary

sdO6
T = 47,500 K
L ~ 10^4 $L_\odot$
Log g = 4.25

Israel+ 1997

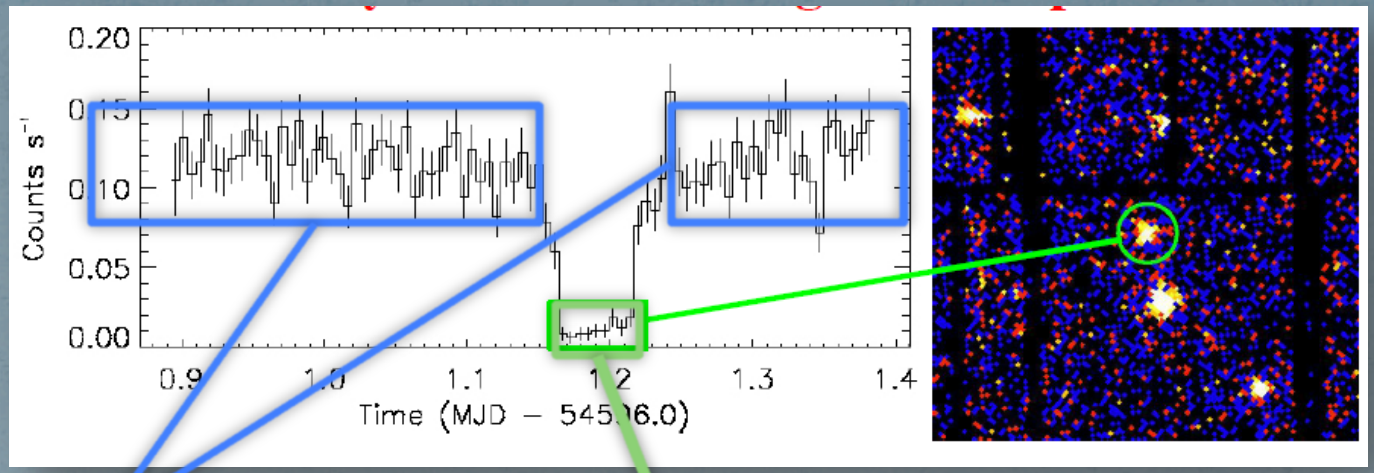


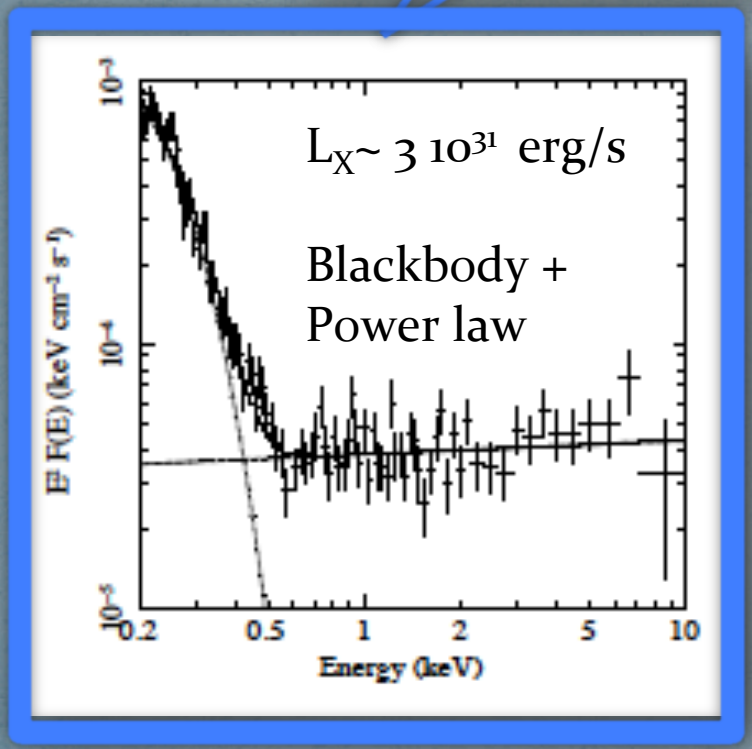


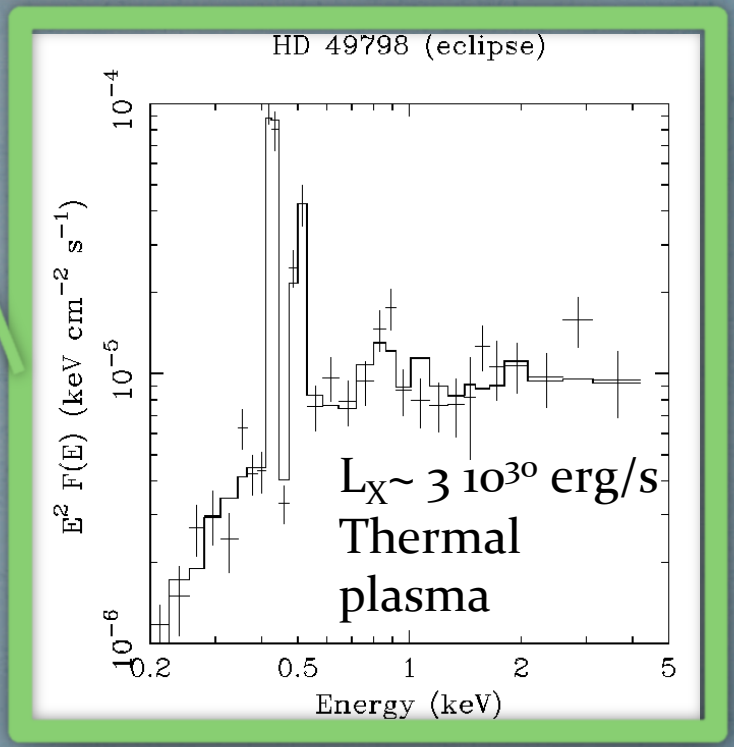
ROSAT: X-ray emission with 13.2 s periodicity

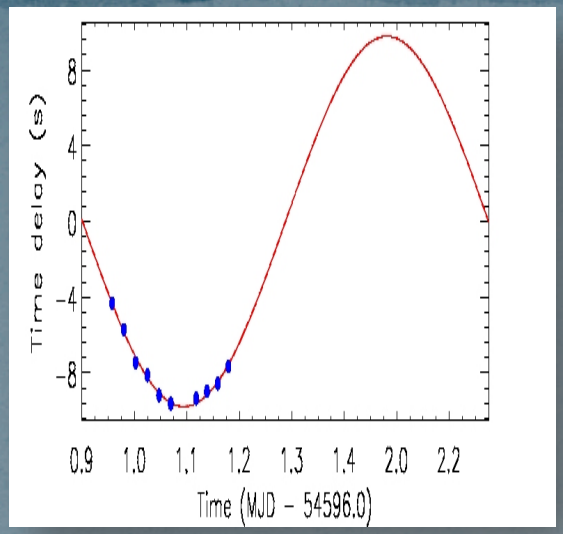
→ the companion is either a white dwarf or a neutron star

HD 49798: XMM-Newton discovery of X-ray eclipse



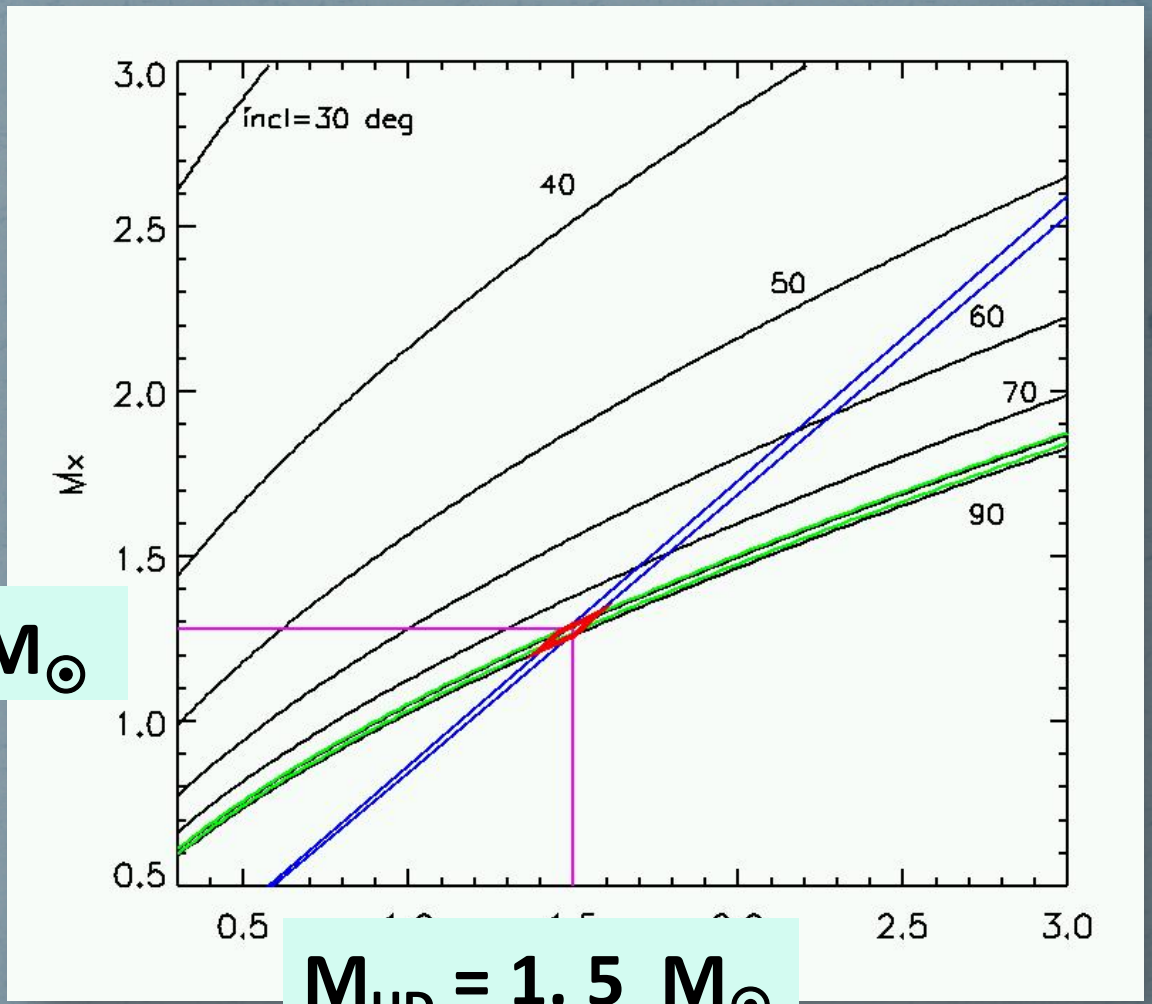






Radial velocity curve from X-ray pulsations

Optical and X-ray mass functions + inclination from eclipse duration

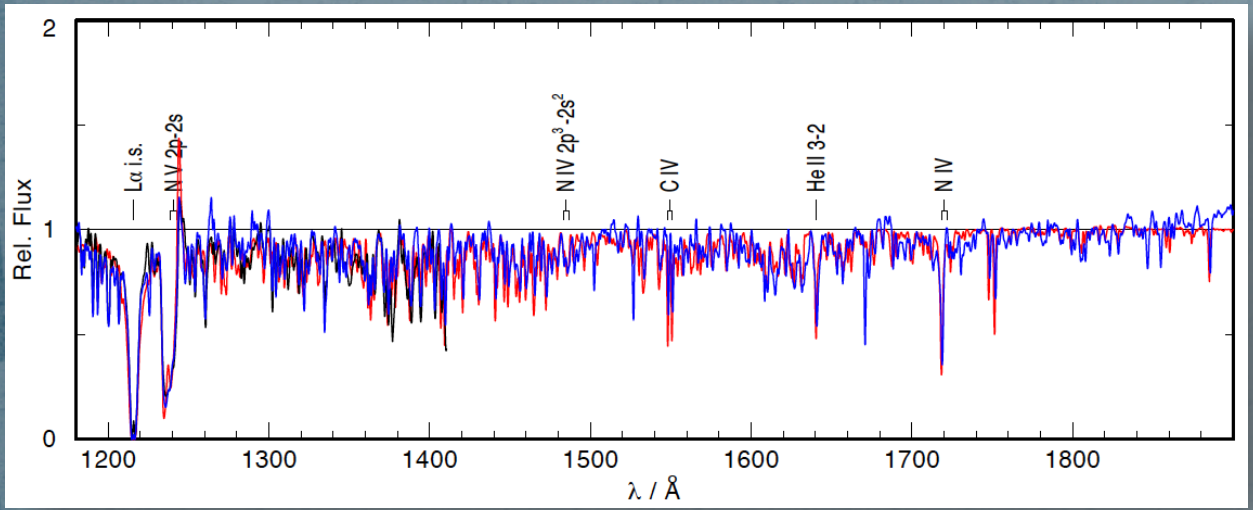


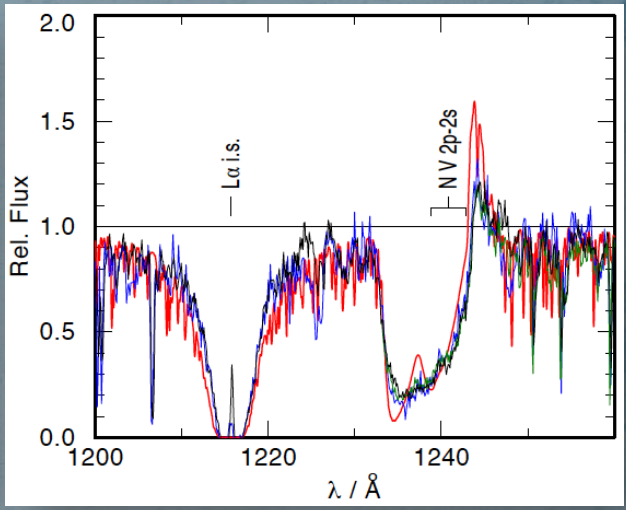
$M_X = 1.28\ M_\odot$

$M_{HD} = 1.5\ M_\odot$

HD 49798: evidence for stellar wind

New wind model fit to UV spectrum (Hamann private comm.) with d=0.6 kpc





Wind from the sdO :
V_W = 1200 km/s
$dM_W/dt = 6\ 10^{-10}\ M_\odot/yr$

Accretion luminosity:
~ $3\ 10^{33}$ erg/s for NS
~ 10^{31} erg/s for WD

Comparison with observed $L_X \sim 3\ 10^{31}$ erg/s favors a WD

HD 49798: a remarkable binary

- If the companion is a WD:
  - fastest-rotating WD (P=13.2 s) and very massive (1.28 +/- 0.05 $M_\odot$)
  - Possible progenitor of over-luminous Type Ia SN

- If the companion is a NS:
  - Why the accretion-powered luminosity is so small ?

Outline

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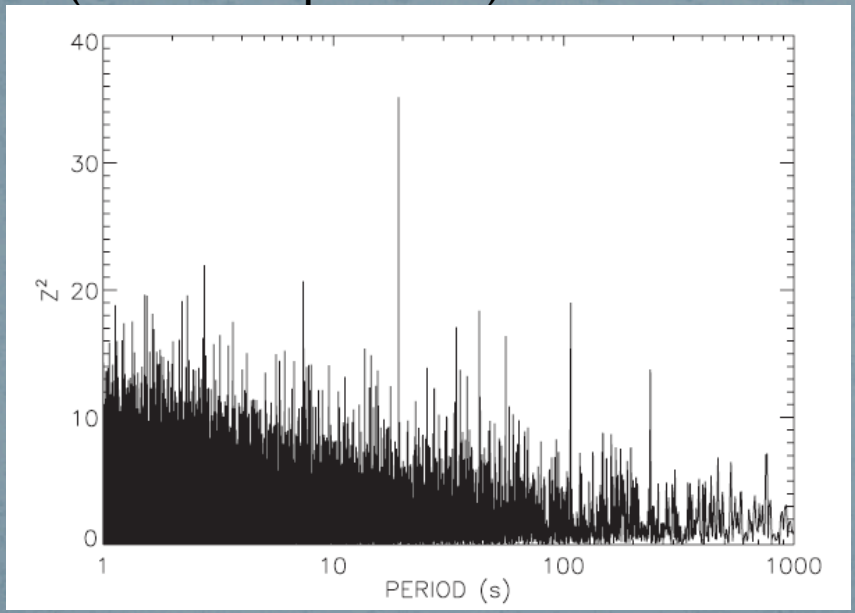
Mereghetti+ 2011, 2014

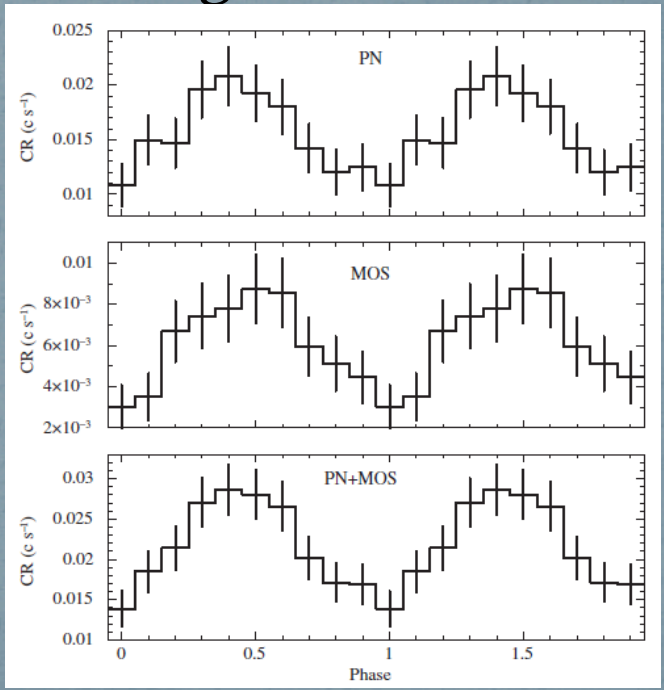
BD +37° 442 : the 2nd sdO detected in X-rays

Similar to HD49798 but apparently single

- XMM-Newton → soft X-rays detected
- X-ray periodicity at P=19 s suggests presence of WD or NS companion (3 σ significance, needs confirmation)
- large uncertainty on L_X = 10^{32}–10^{35} erg/s

(if PL+BB spectrum)





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No evidence of binarity from optical spectroscopy (Heber+ 2014)

→ face-on system ?

→ long orbital period ?

→ fake detection of pulsations ?

Most likely intrinsic X-ray emission from sdO wind

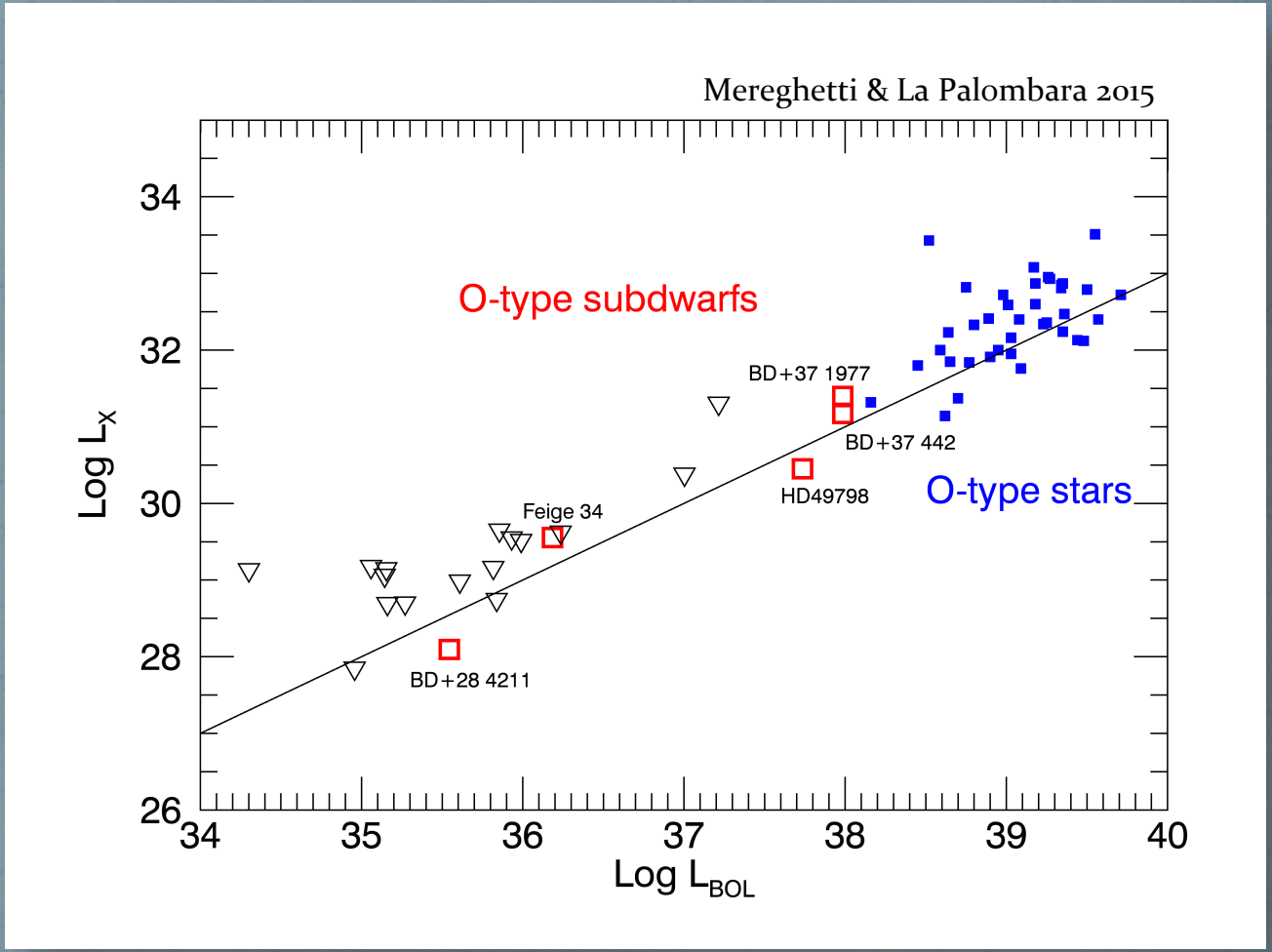
X-ray observation of other sdO stars

Chandra short observations (4 ks) of 19 sdOs with V< 12
Three new X-ray detections (La Palombara+ 2014):

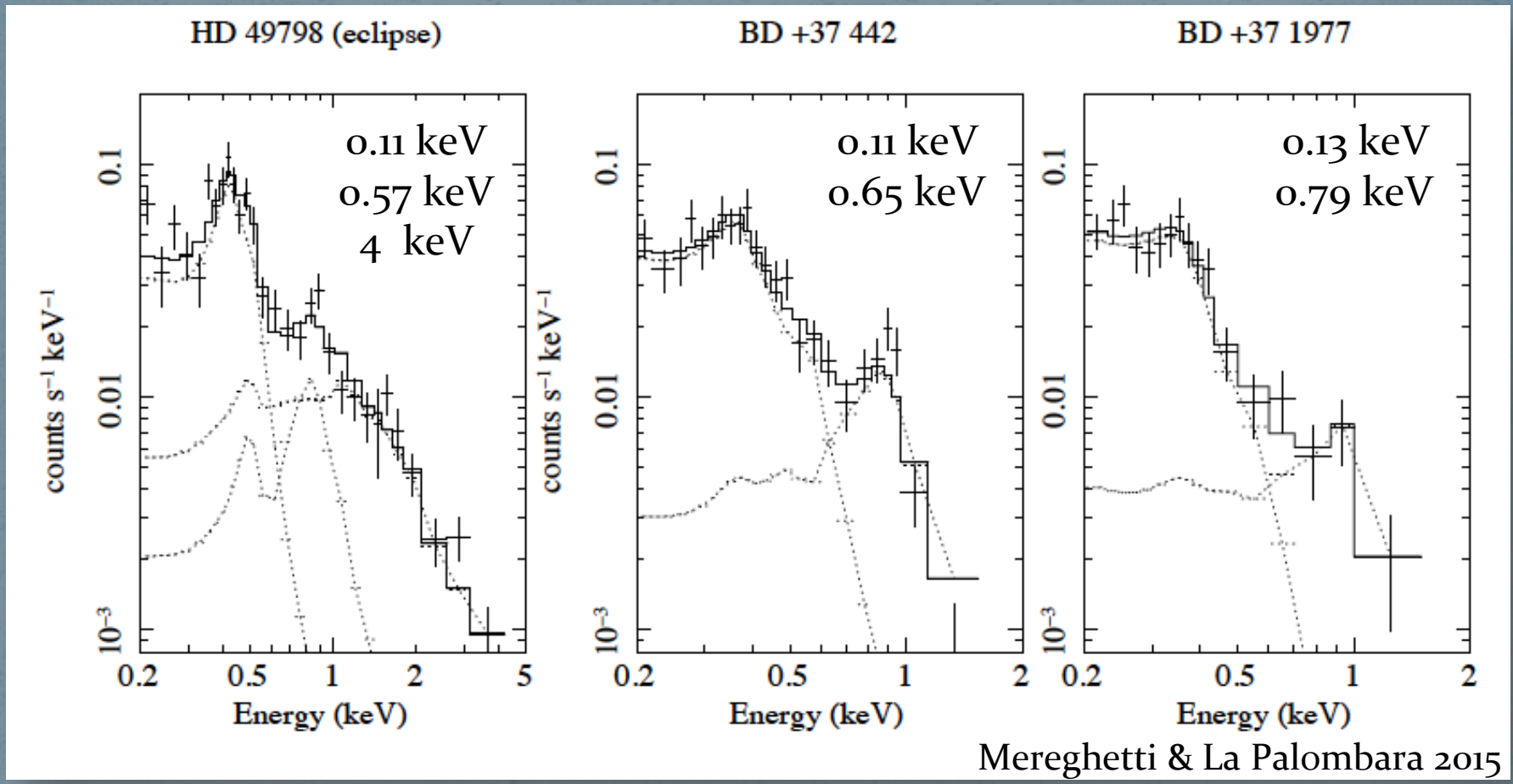
BD+37° 1977
BD+28° 4211
Feige 34

$L_x/L_{bol} \sim 10^{-7}$
as in normal O stars

→ X-rays could be emitted by shocks in the sdO winds...



X-ray spectra of sdO well fit by sum of 2 (or 3) thermal plasma models *(as nomal O-type stars)*



Mereghetti & La Palombara 2015

(Abundances fixed to values from optical/UV analysis)

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- **only upper limits for sdB**

Mereghetti+ 2011, 2014

X-ray upper limits for sdB binaries

CD -30 11223 : sdB + WD P_{ORB} = 1.2 hr

(Vennes et al. 2013, Geier et al. 2013)

Deep XMM-Newton observation → $L_x < 10^{29}$ erg/s

→ sdB mass loss rate $< 3\ 10^{-13}$ $M_\odot$/yr (Mereghetti+ 2014)

Swift/XRT observations of 12 candidates from MUCHFUSS

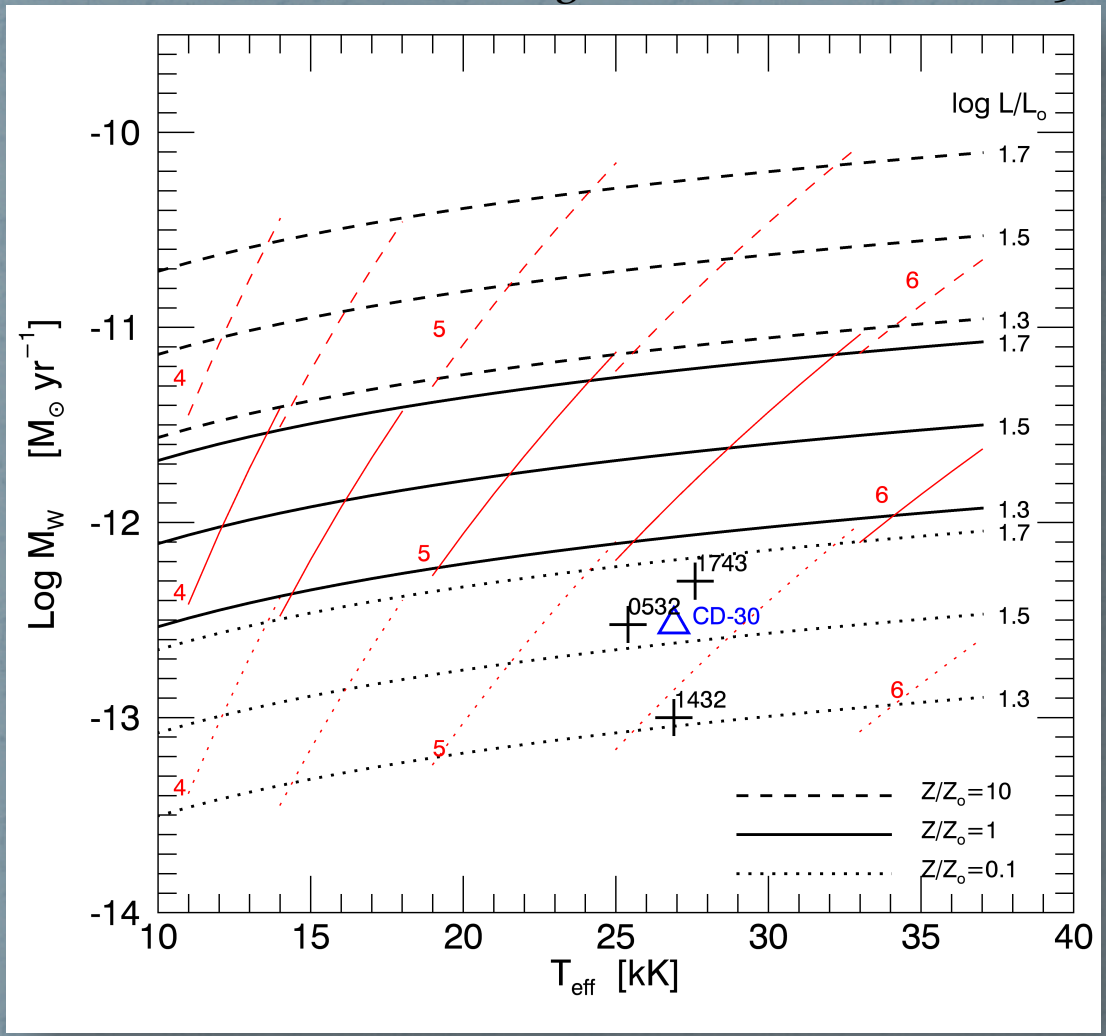
Mass loss rates < 10^{-13} - 10^{-12} $M_\odot$/yr if NS companions

< 10^{-13} - 10^{-12} $M_\odot$/yr if WD companions

(Mereghetti+ 2011)

Mass-loss rate upper limits for a few sdBs compared to predictions of Vink & Cassisi 2002

Mereghetti & La Palombara 2015



Inconsistent with predictions if metallicity is solar or higher

Summary

- Hot subdwarfs can be X-ray sources
  - Not only if they have compact companions, but also if single stars (wind emission)
- X-ray observations can
  - Provide information on the mass loss rate from hsd
  - lead to discovery of interesting sd binaries
- HD 49798: luminous sdO with massive WD companion
  - Dynamical mass measurement: M_{WD}=1.28 $M_{\odot}$
  - Fastest spinning WD: P = 13.2 s
  - Possible progenitor of
    - SN Ia with short delay time or
    - ``non-recycled'' millisecond pulsar

Open questions / points for discussion

- HD49798: CO or ONe WD companion? Could it be a NS?
  Origin and future evolution
  why such a fast rotating WD?
- X-ray emission in hsd
  - Can we use Bondi-Hoyle approximation ?
  - Can we use models of X-ray emission of normal OB stars?
  - Weak winds / decoupling / abundances / etc..
- sdBs with candidate compact companions
  Can we prove the presence of NS or WD ?
- best candidates for further X-ray observations ?
  Other luminous He rich sdO? Compact sdO? ... single sdB??
- more optical studies needed for the X-ray detected hsd?
  Better atmospheric parameters, abundances, ..? ...