MAGNETIC FIELD IN C-RICH EVOLVED STARS

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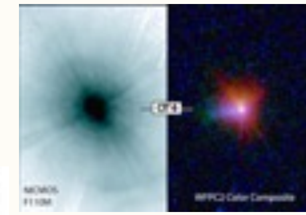
SOURCES

observations : IRAM 30M, EMIR/XPOL

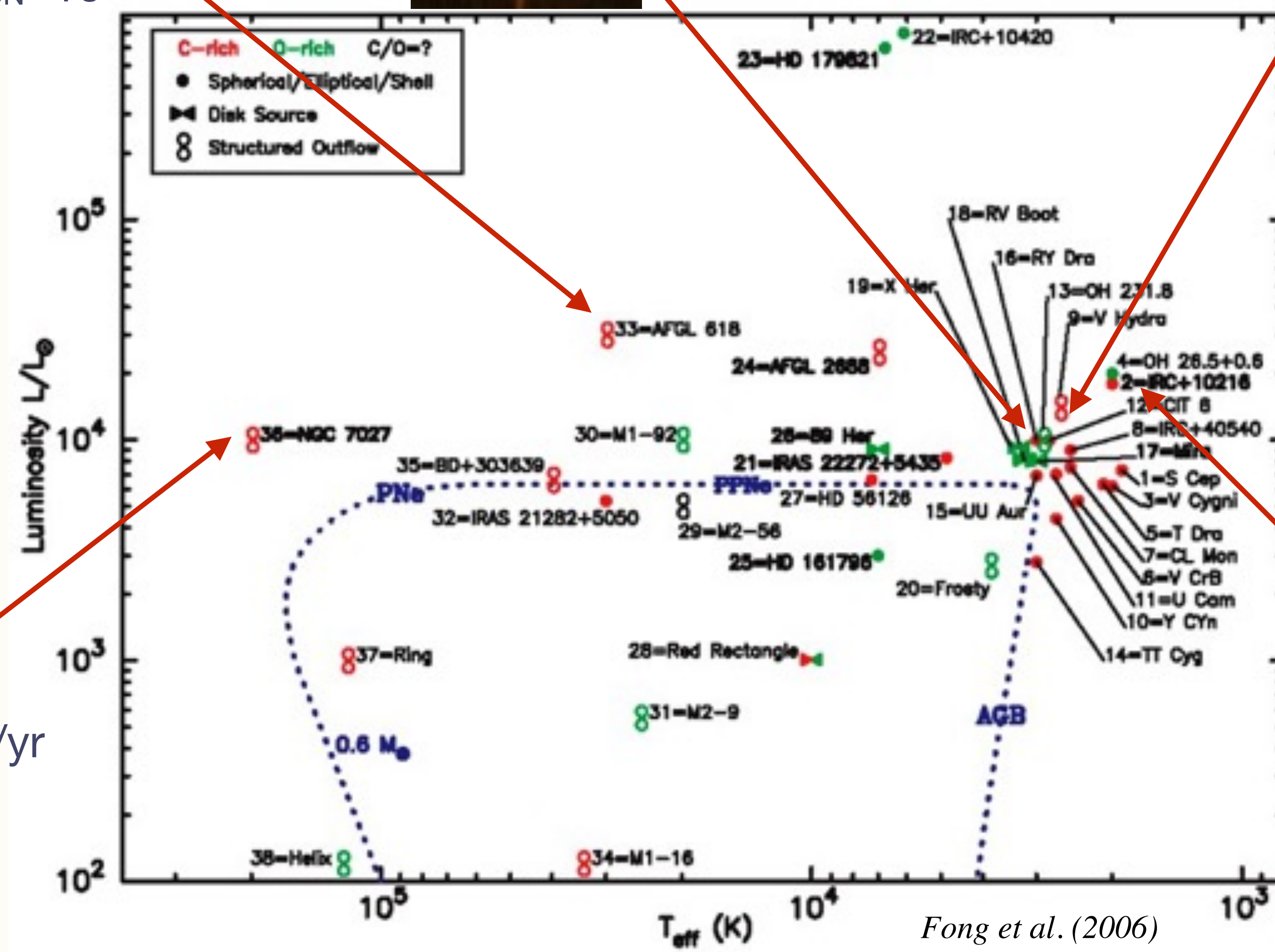
AFGL618
d=900 pc
dM/dT=2 $10^{-4} M_\odot$/yr
Θ_{CN}=10”

RY DRa
d= ?? pc
dM/dT= ??$M_\odot$/yr
Θ_{CN}= ??

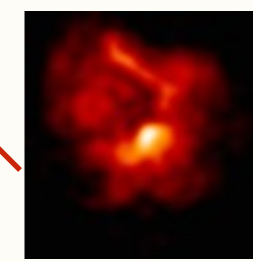


RW LMi
d=440 pc
dM/dT=1.5 10^{-6} $M_\odot$/yr
Θ_{CN}=10”

NGC7027
d=880 pc
dM/dT=2 $10^{-4} M_\odot$/yr
Θ_{CN}=11”?



Fong et al. (2006)



IRC+10216
d=120 pc
dM/dT=1.5 10^{-5} $M_\odot$/yr
Θ_{CN}=40”

CN = GOOD TRACER

- observed by Bachiller et al. (1997a,b) and Josselin & Bachiller (2003)
- CN paramagnetic species ⇒ Zeeman splitting when magnetic field is present
- **N=1-0 line=9 hyperfine components** split in two groups (around 113.17 and 113.49 GHz), with 7 main lines. Of those 7, **4 exhibit strong Zeeman effect**

Table 1: Zeeman Splittings for CN N=1→ 0 (Crutcher *et al.*1996). R.I. stands for *Relative Intensity* in LTE conditions.

(N', J', F')→(N, J, F)	ν_0 (GHz)	Z (Hz μG^{-1})	R.I.	Z × R.I.
1. (1, 1/2, 1/2) → (0, 1/2, 3/2)	113.14434	2.18	8	17.4
2. (1, 1/2, 3/2) → (0, 1/2, 1/2)	113.17087	-0.31	8	2.5
3. (1, 1/2, 3/2) → (0, 1/2, 3/2)	113.19133	0.62	10	6.2
4. (1, 3/2, 3/2) → (0, 1/2, 1/2)	113.48839	2.18	10	21.8
5. (1, 3/2, 5/2) → (0, 1/2, 3/2)	113.49115	0.56	27	15.1
6. (1, 3/2, 1/2) → (0, 1/2, 1/2)	113.49972	0.62	8	5.0
7. (1, 3/2, 3/2) → (0, 1/2, 3/2)	113.50906	1.62	8	13.0

CRUTCHER METHOD

Analysis method by Crutcher et al. (1996) : least-squares fit in frequency, simultaneously to all 7 hyperfines lines V spectra
⇒ Distinction between the Zeeman effect and instrumental effect

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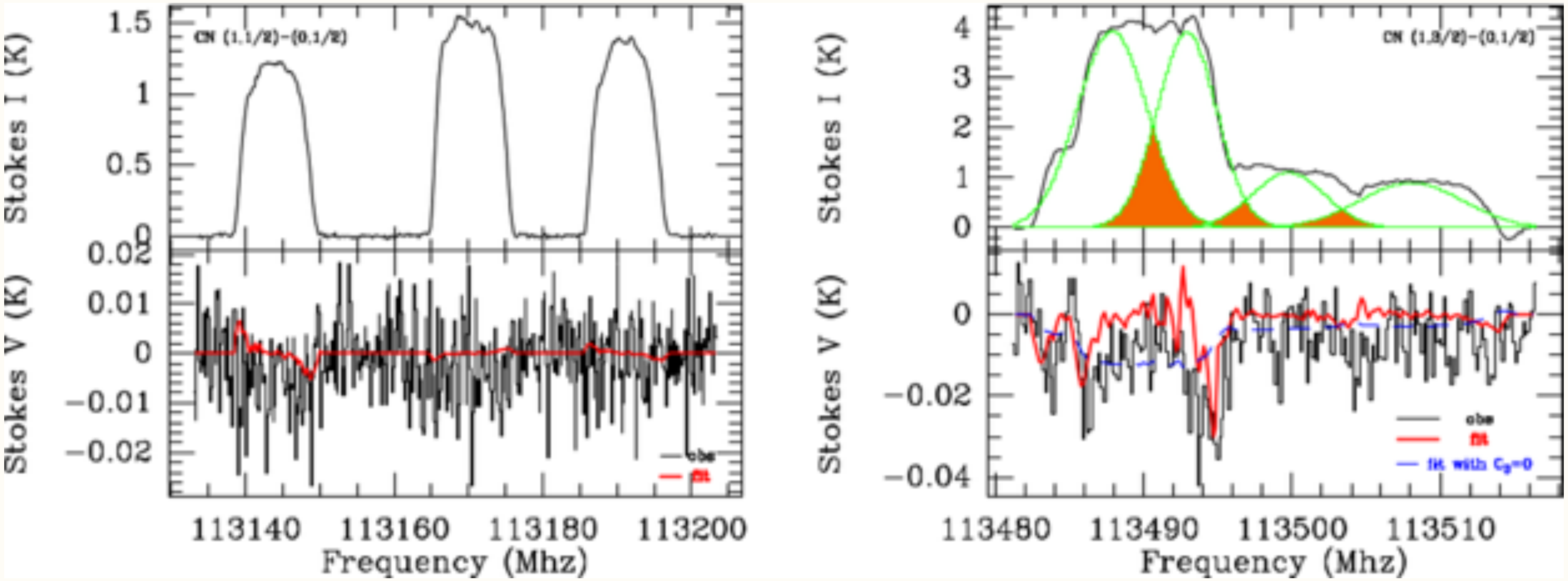
$$V_i(v) = C_1\, I_i(v) + C_2\, [dI_i(v)/dv] + C_3\, Z_i\, [dI_i(v)/dv] \qquad i=1, \ldots, 7$$

With

- C_1 : gain difference in the telescope between R and L circular polarization
- C_2 : Bean squint
- **C3 : $B_{los}/2$**
- Z: Zeeman factor

ESTIMATION B_{LOS} FOR ALL SOURCES



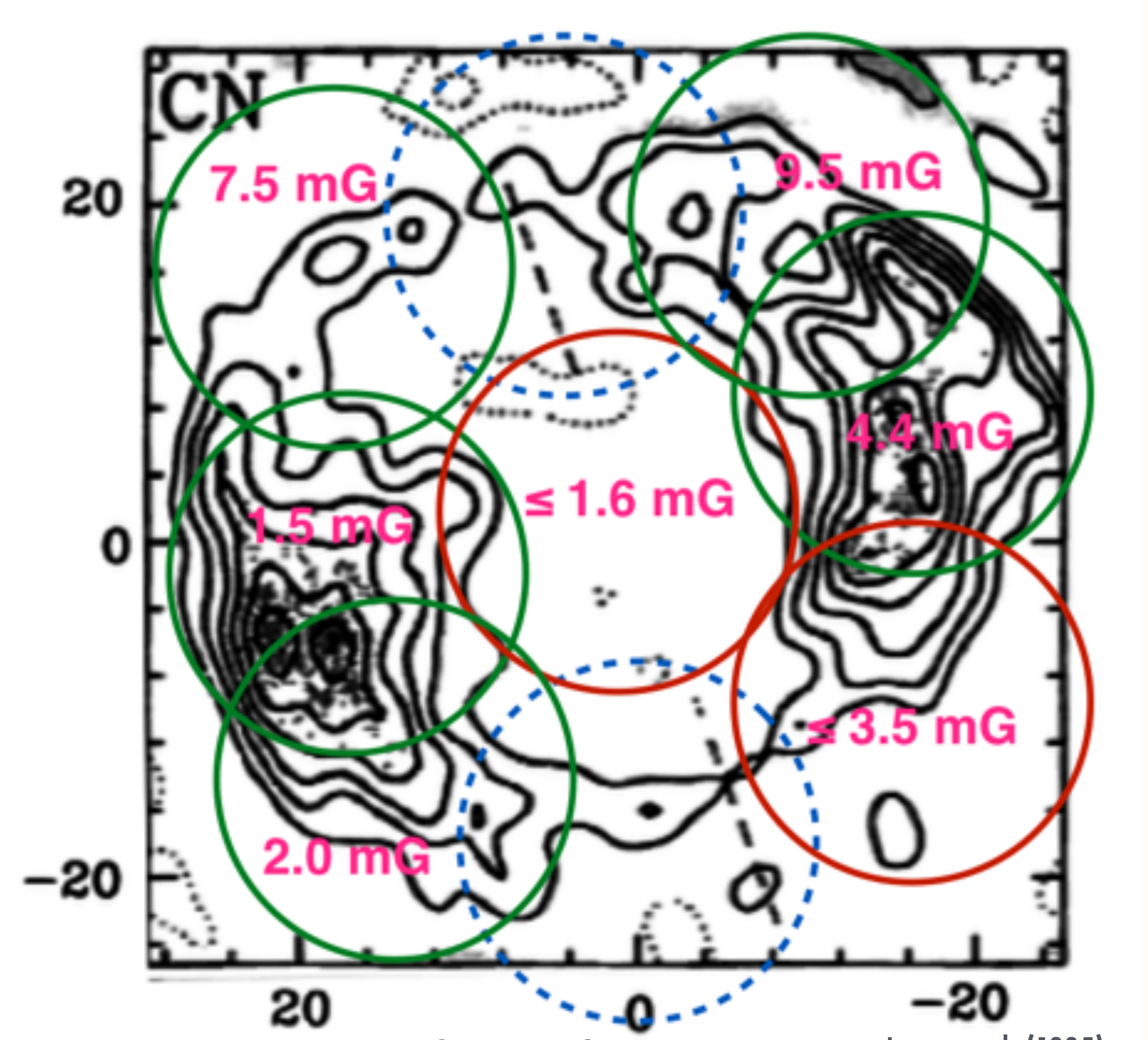
Object	$\chi(CN)$	d_{CN} AU	r_* AU	B_{los} mG	δB mG	B_{r_*} G	σ^a mK	S/N^b
RW LMi	$3.\ 10^{-5}$	2675-3340 (3-9")	2.6	≤ 3.8		≤ 4.4	7.1	2.6
RY DRa	$5.1\ 10^{-5}$	61-615 (0.14-1.5)"	1.0	≤ 14.2		≤ 4.8	30.3	2.5
IRC+10216 (-10",+20")	$6.2\ 10^{-7}$	2500 (21")	3.3	9.5	5.5	7.2	6.4	39.6
AFGL618	$2.1\ 10^{-6}$	2700 (3")	0.24	6.0	6.0	67.5	6.34	5.6
NGC7027	$2.3\ 10^{-7}$	10000 (11")	3.0×10^{-4}	≤ 8.0		$\leq 2.7\ 10^5$	7.80	1.54

$^{(a)}$smooth resolution 320kHz for 2016 observations and 160 kHz for 2006 observations. $^{(b)}$V integrated area devided by rms×δ

MAPPING THE MAGNETIC FIELD IN CW LEO

strong magnetic field detected on the northern part of the ring where the CN seems to be less dense

⇒ CN distribution changed since 1995

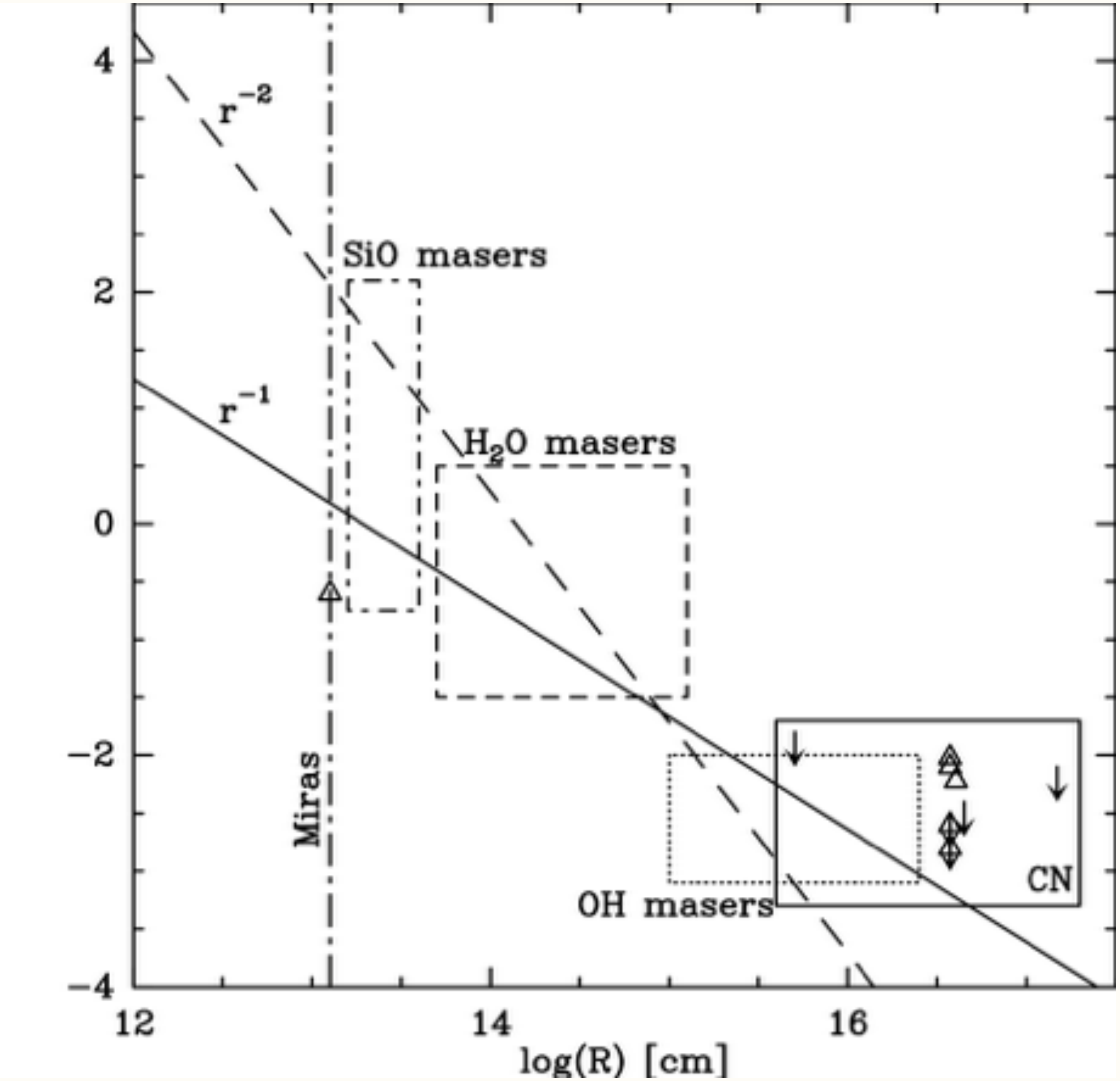


circle size = beam size 21,5′′ Lucas et al. (1995)

Green = detection, Red = non detection

Dash Blue = unobserved

observations made with the IRAM 30M



Triangles B values and Arrow upper values

most reliable scenario :
magnetic field decreased in
r^{-1} for AGB
⇒toroidal field

Not working for PPN/PN
stars :
Jordan et al (2012) find for PN
star B_{los} ∼ a few 100 G