The shock chemistry of phosphorus in L1157 B1

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Abstract

We study the evolution of P-bearing species in a 1D C-shock model. Temporal variations of physical parameters (density, temperature) are adopted from Jiménez-Serra et al. (2008). We found that observed abundance of PN can be reproduced in C-shock models, only if the N atom abundance is high(10^{-6}) in the pre-shock gas.

1 Interstellar shock

In interstellar space , supersonic flow is driven

e.g.) Supernova explosion

Jet, outflow from protostar & protoplanetary disk

↓ collision with surrounding gas

Shock wave is driven !

{temperature, density, chemical composition} change drastically

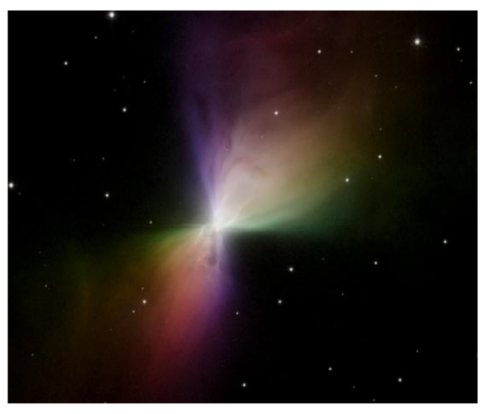


Fig1 : Outflow driven from central star

Shock wave is important to understand interstellar gases

2 Detection of PN towards L1157 B1

L1157

- a Class 0 protostar driving a well-collimated molecular outflow.
- B1 is a shocked region formed by an interaction between the outflow and ambient gas.
- Since B1 position is spatially apart from the protostar, the "pure" shock chemistry can be investigated

➔ Line surveys at NRO45m an IRAM30m (e.g. Arce et al. 2008, Sugimura et al. 2011)

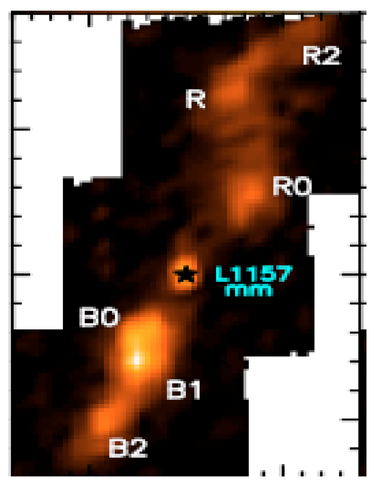


Fig2: H2O 179μm emission along L1157 outflow (Nisini et al. 2010)

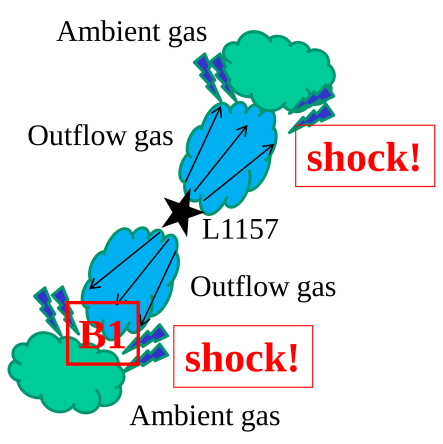


Fig3 : Schematic view of outflow gases Collision with ambient gases

Detection of PN

- previously , PN is detected only in high-mass start forming regions (Turner et al.1990)
- Yamaguchi et al. (2011) detected PN towards L1157 B1 shocked region.

3 Previous studies on phosphorus chemistry

Charnley & Millar (1994) investigated P-chemistry in the hot core model

Hot Core Model

- Hot core is a hot (~200K) dense gas clump observed in high-mass star forming regions.
- Heavy elements are initially frozen on dust grains, and evaporate at $t = 0$. … Phosphorus is initially in PH_3
- Calculate the gas-phase chemistry at **constant** temperature (ex. 100K) and density(n_H=2.0 × 10^7 cm^{-3})

result

- PN can be abundant enough to be observed in Hot Cores.

4 This Work

We investigate if PN can be produced in shocked regions

- Shock model : Jiménez-Serra et al. (2008) v=20km/s, n=2.0 × 10^4 cm^{-3} (Fig4)
- Solve the chemical reaction network along the flow 658 species , 11285 reaction …Combination of Garrod & Herbst (2006) , Harada et al.(2010), Willacy et al.(1998)

Fig4 : Time-evolution of temperature and number density of H nuclei

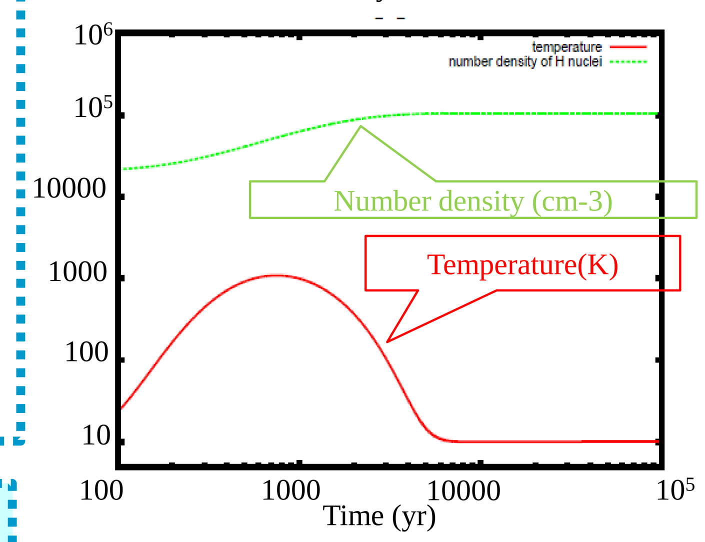


Table1 : Initial abundance

H+	1.0 × 10^{-11}	C2H2	5.0 × 10^{-7}	H2CO	2.0 × 10^{-6}	NH3	6.0 × 10^{-7}
He+	2.5 × 10^{-12}	CH4	2.0 × 10^{-7}	CH3OH	2.0 × 10^{-7}	H2S	1.0 × 10^{-7}
H3+	1.0 × 10^{-9}	C2H4	5.0 × 10^{-9}	C2H5OH	5.0 × 10^{-9}	OCS	5.0 × 10^{-8}
Fe+	2.4 × 10^{-8}	C2H6	5.0 × 10^{-9}	O2	1.0 × 10^{-6}	H2	5.0 × 10^{-1}
He	1.0 × 10^{-1}	CO	1.3 × 10^{-4}	H2O	2.8 × 10^{-4}	H	5.0 × 10^{-5}
Si	3.6 × 10^{-8}	CO2	3.0 × 10^{-6}	N2	3.7 × 10^{-5}	PH3	1.2 × 10^{-8}
HCOOCH3	2.0 × 10^{-9}	C2H4O	1.0 × 10^{-9}	CH2O2	5.0 × 10^{-10}		

Fig5 : Result1 time evolution of P-bearing species. Initial abundance is given in table1

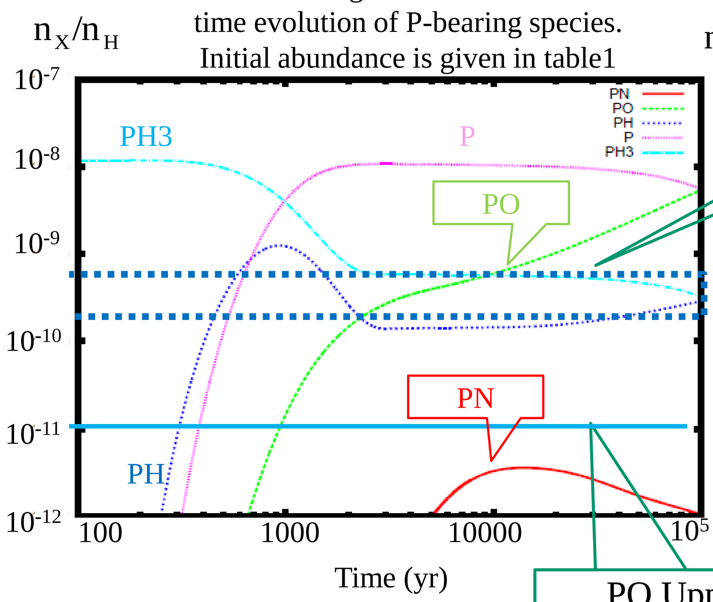


Fig6 : Result2 time evolution of P-bearing species. Initial abundance is from list1 + N=1.0^{-5}

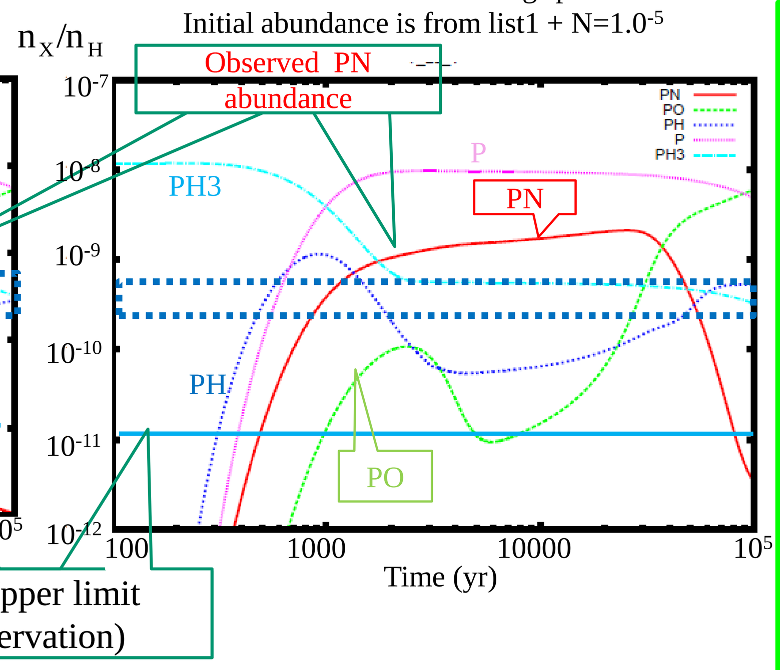
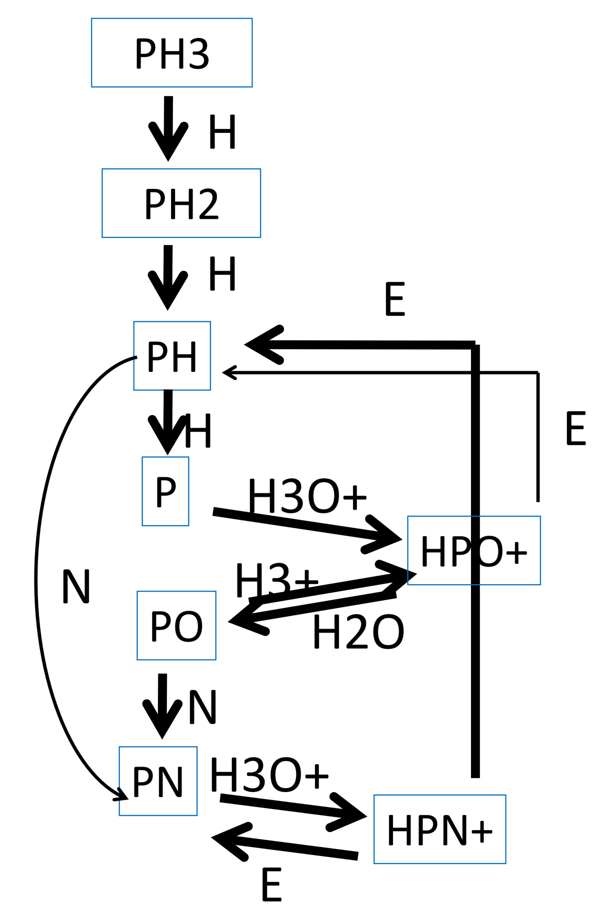


Fig9: chemistry of the P-bearing species (shocked gas)



Model I

- initial abundances … Table1 Nomura & Millar (2004) PH3 abundance is from Charnley & Millar (1994)
- Vary the initial N atom abundance ($n(N)/n_H$ = 0 - 10^{-5})

result

- ***PN is created only if initial N abundance is above 10^{-6} (result3)***
- ***PO abundance is lower than upper limit (yamaguchi et al. in prep) only if N abundance is 10^{-5} (result4)***

cf. N is abundant (10^{-5}) in dense clouds (Maret et al. 2006).

Fig7: Result3 PN abundance with different initial N abundance

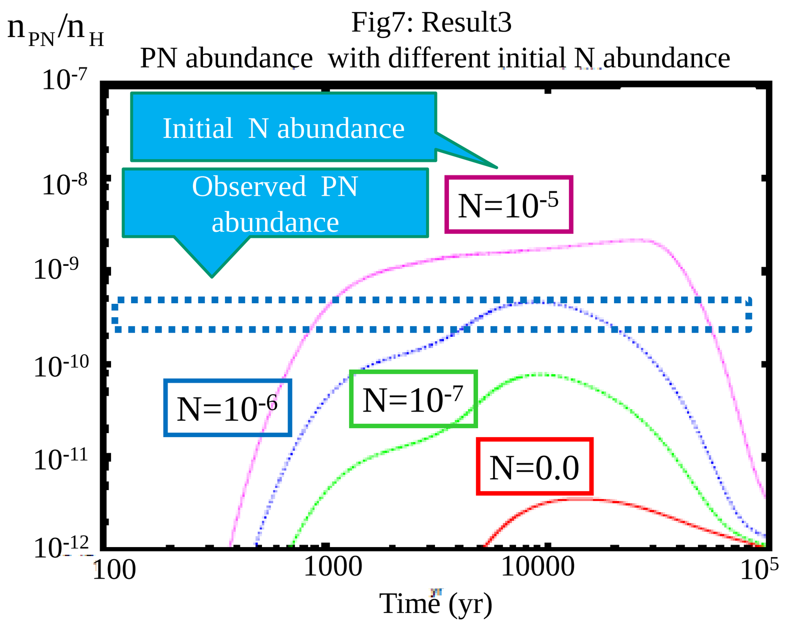
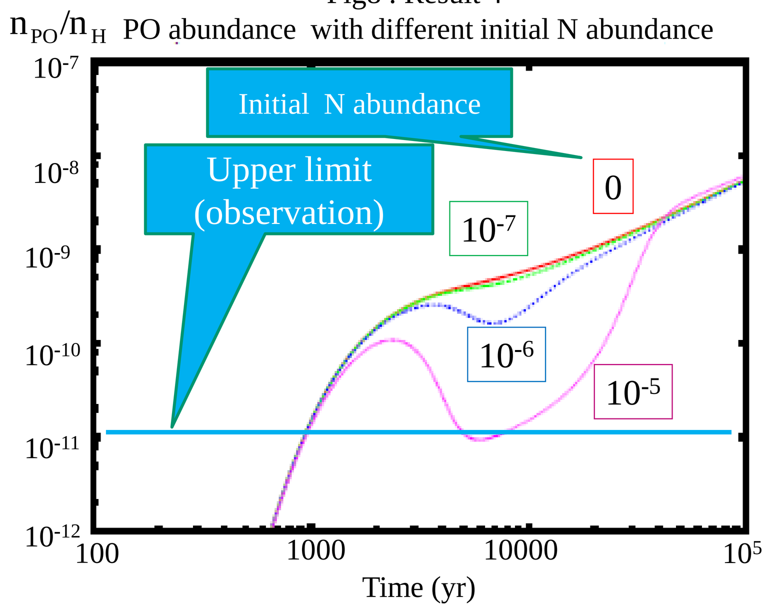


Fig8 : Result 4 PO abundance with different initial N abundance



Model II

- Initial abundances are set by calculating molecular cloud chemistry (n_H=2 × 10^4 cm^{-3} , T=10K) with grain-surface reactions
- Molecular abundances at 0.1 Myr are adopted as initial abundances of the shock model (Fig 10).
- At t=0, all species on the grain surface is sputtered by shock wave

result

- ***we can reproduce observed PN and PO abundance (result7)***

Table2 : initial abundance of molecular cloud chemistry

He	1.0 × 10^{-1}	H2	5.0 × 10^{-1}	Si+	3.6 × 10^{-8}
N	7.46 × 10^{-1}	C+	1.36 × 10^{-4}	Fe+	2.4 × 10^{-8}
O	4.18 × 10^{-1}	S+	1.55 × 10^{-7}	P+	1.2 × 10^{-10}
H	5.0 × 10^{-5}	PH3	1.18 × 10^{-8}		

Fig10: Result6 Time evolution of P-bearing species (molecular cloud)

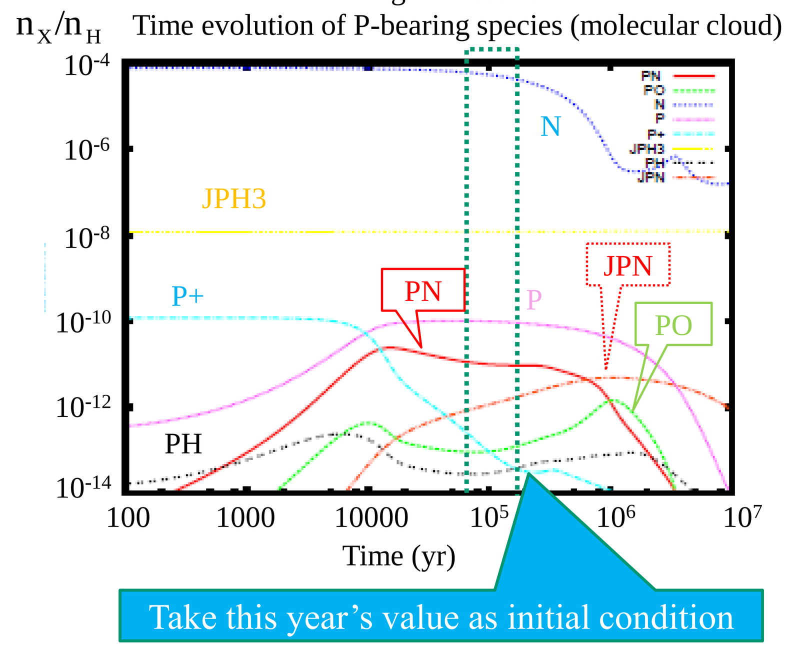
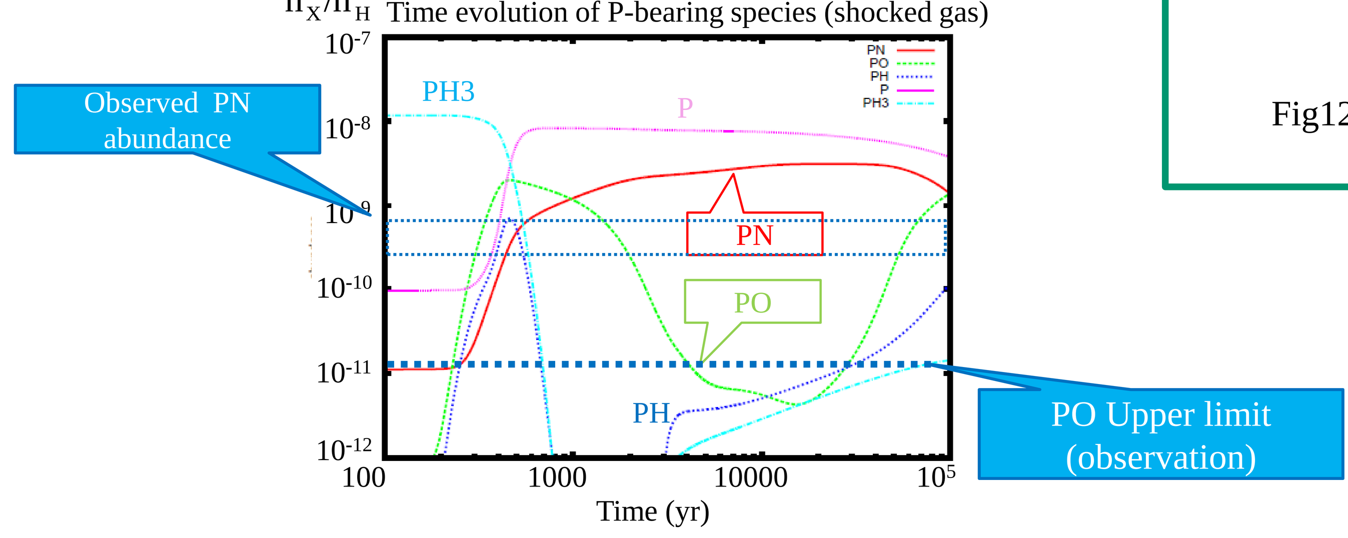


Fig11 : Result7 Time evolution of P-bearing species (shocked gas)



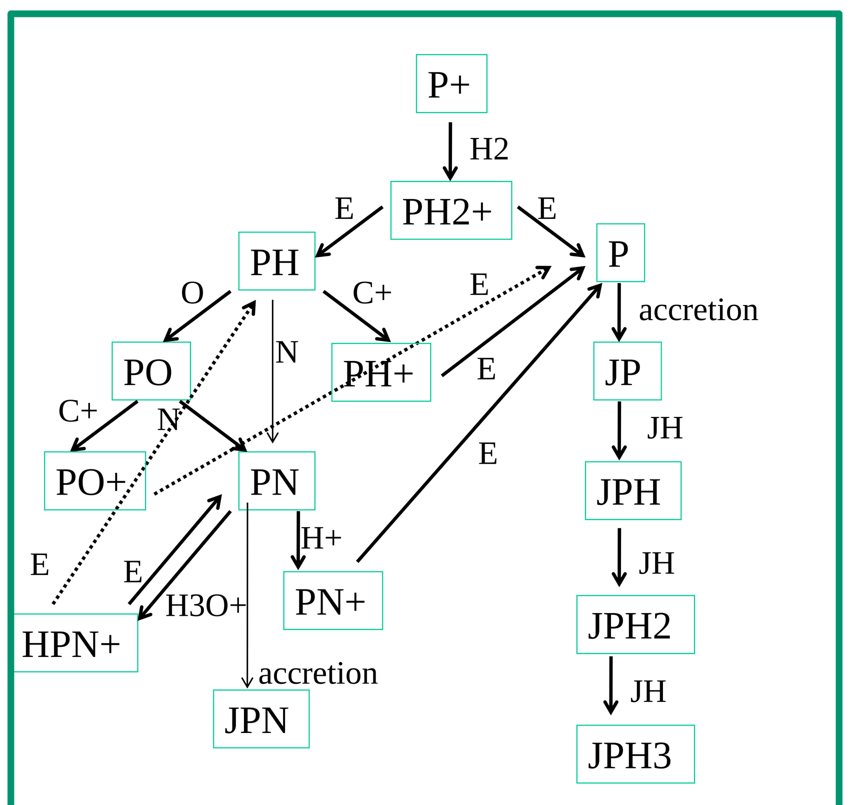


Fig12: chemistry of the P-bearing species (molecular cloud)