

D. R. Gonçalves<sup>1</sup>, S. Akas<sup>1</sup> and G. Ramos-Larios<sup>2</sup>

(1) Valongo Observatory - Federal University of Rio de Janeiro, Brazil; (2) Instituto de Astronomía y Meteorología - Universidad de Guadalajara, Mexico

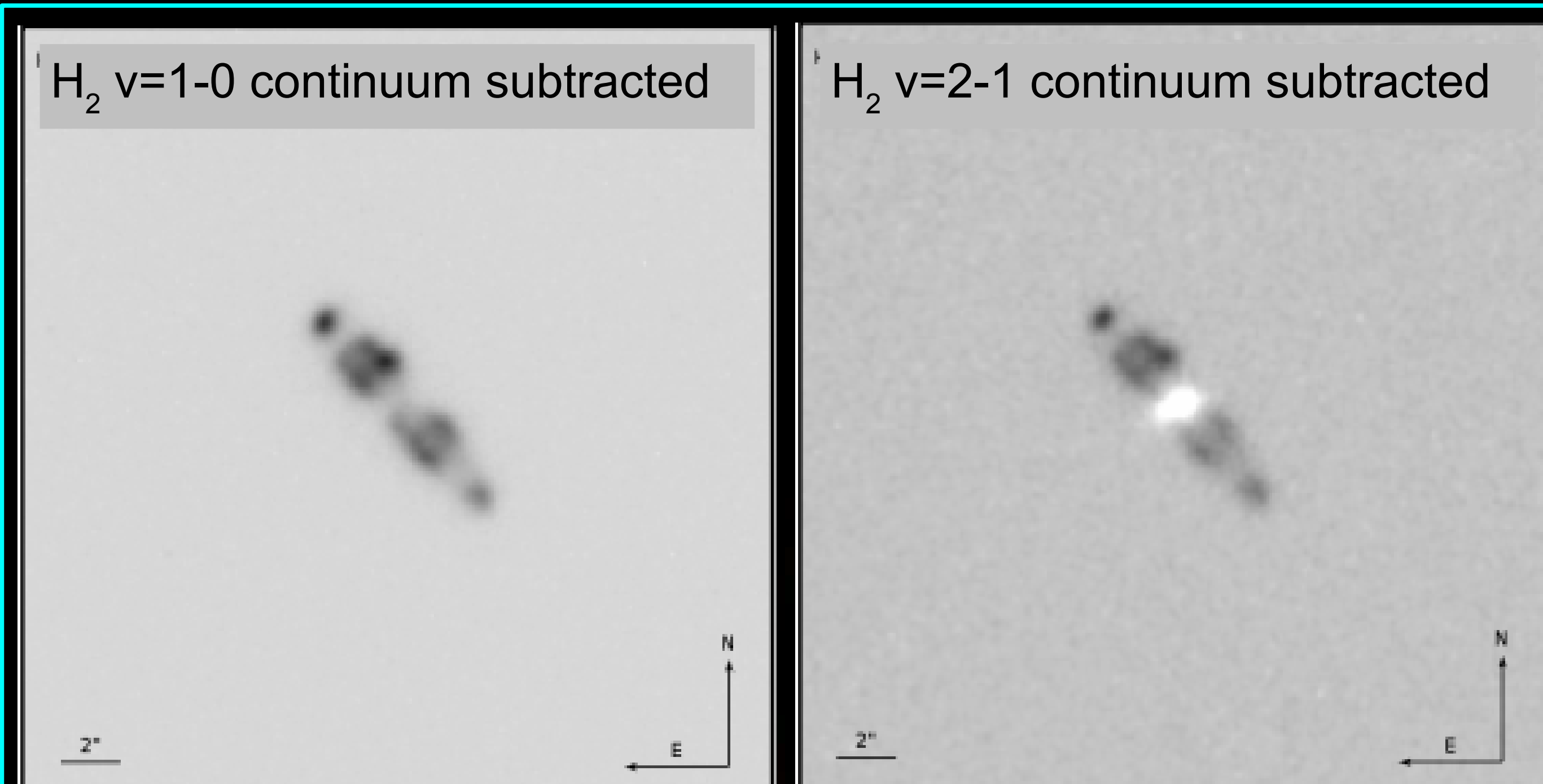
## Introduction

Optical imaging surveys of PNe have revealed that a fraction of them, spread in all the different morphological types, possess small-scale structures like jets, knots, filaments, etc. (Manchado et al. 1996; Corradi et al. 1996; Balick et al. 1998; Gonçalves et al. 2001). These structures are usually bright in the low-ionization lines (e.g. [N II], [O II]), therefore being grouped under the acronyms low-ionization structures – LIS). They cover a wide range in expansion velocities, from a few tens up to a few hundreds of km s<sup>-1</sup>.

Shock interactions should play an important role in the excitation of LIS, a natural guess that would explain their enhanced low-ionization emission-lines, given that it is known that they exhibit the same chemical abundances (of N and O, for instance) as the surrounding medium (Gonçalves et al. 2006; Akas & Gonçalves, 2015).

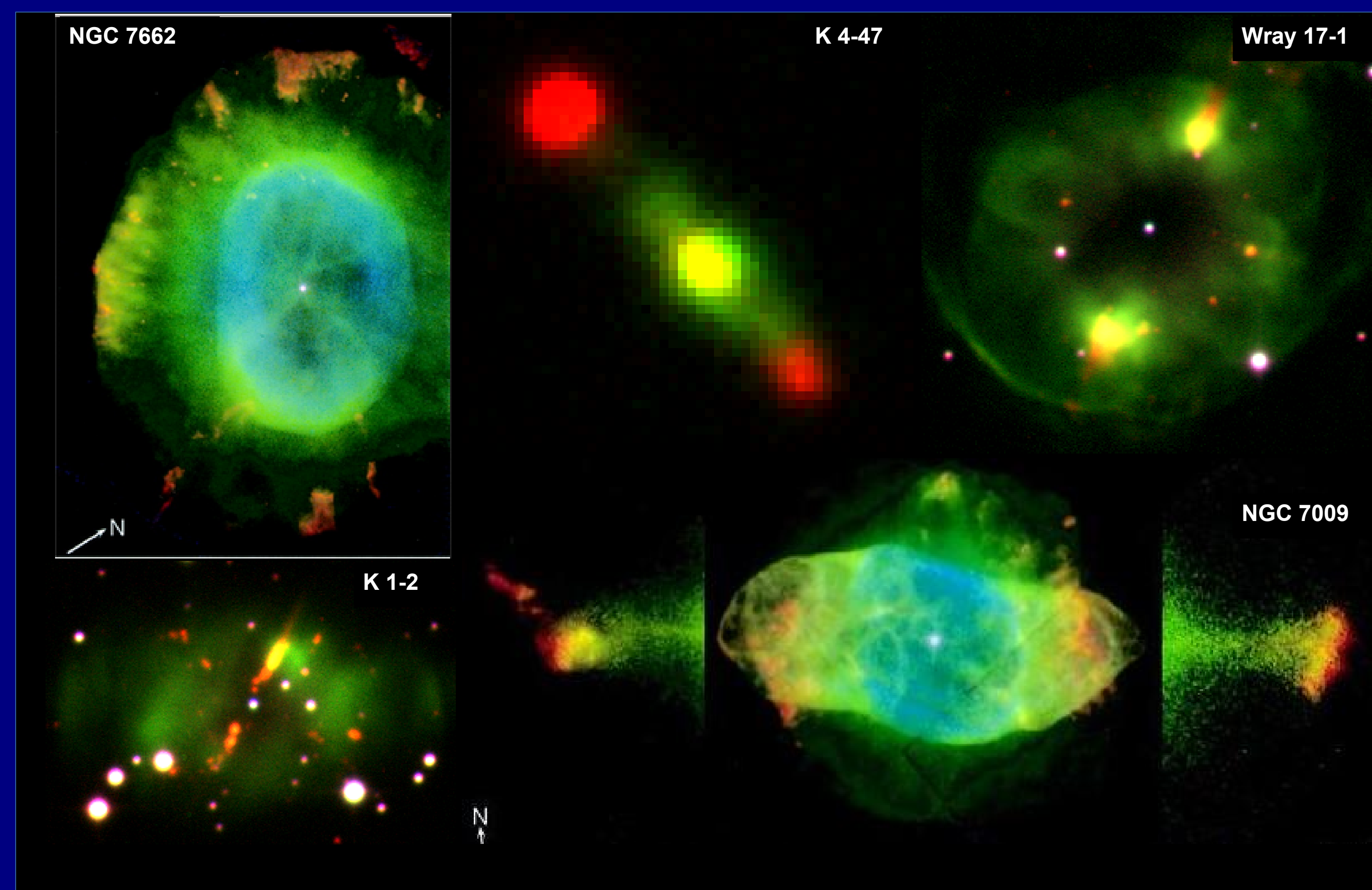
Electron temperatures of LIS do not differ from the PN large-scale structures (rims, shells and haloes). Nevertheless, their electron densities, Ne, were found to be lower than that of the other PN structures, and markedly inconsistent with the model predictions. Recently, Gonçalves et al. (2009) proposed that LIS are mainly made of non-ionized (molecular, atomic) gas.

## K 4-47



- K 4-47 is a compact PN with a pair of low-ionization structures very prominent in the optical emission-lines [N II], [SII], [O II], [O I]
- Near-IR H<sub>2</sub> (2.122μm and 2.248μm) is clearly detected associated with the pairs of knots (this work)
- This confirms that LIS are also made of molecular gas, apart from the ionized one (Gonçalves et al. 2009)
- The H<sub>2</sub> v=1-0/v=2-1 line ratio varies from 4 to 8, indicating shock-excitation, which is consistent with the high V<sub>exp</sub> of the knots ~250 km s<sup>-1</sup> (Corradi et al. 2000) and the shock models (Gonçalves et al. 2004; Akas & Gonçalves 2015; this work).

## LIS in PNe – [O III], He II, [N II]

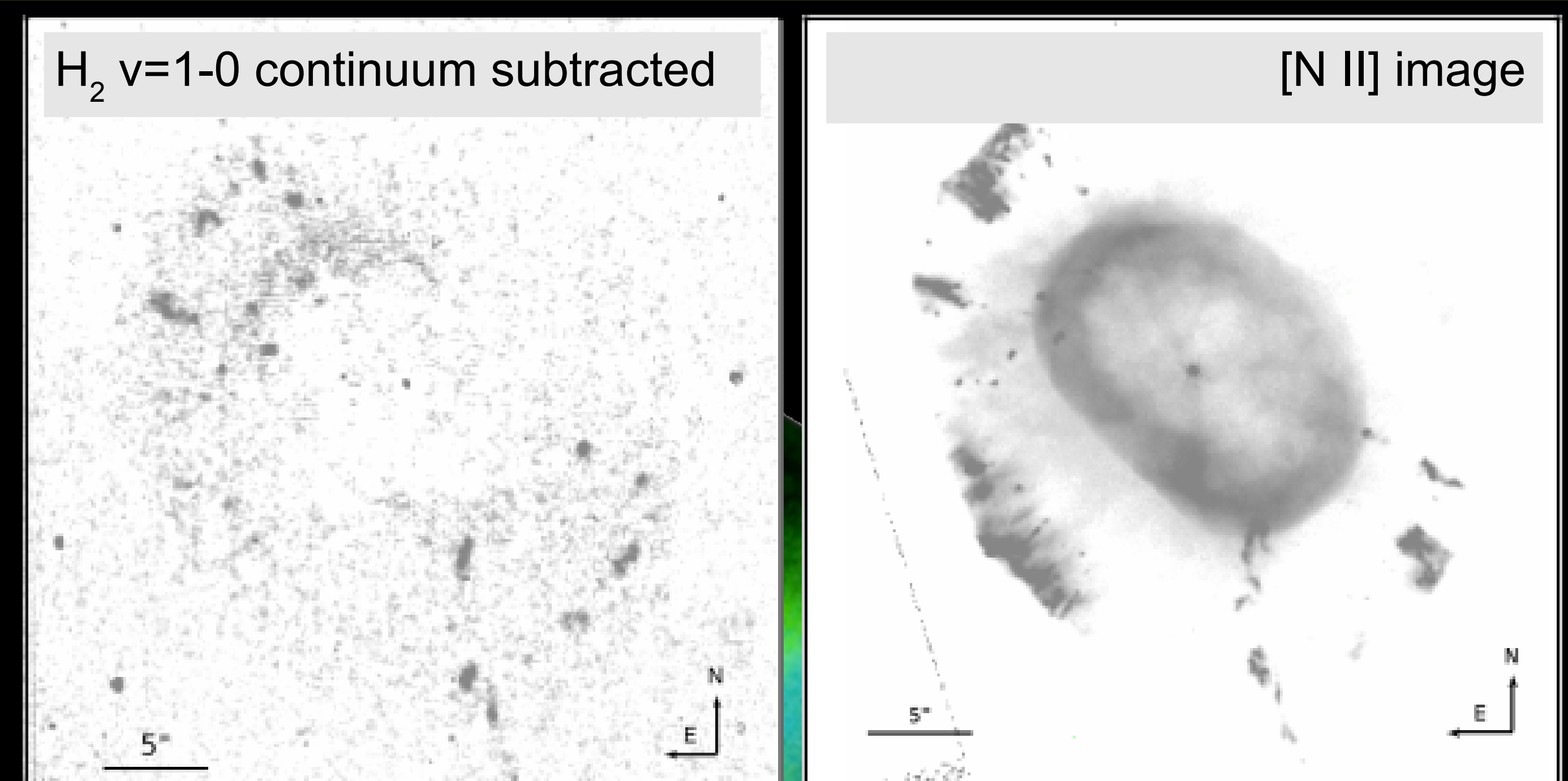


## NIRI@Gemini observations

High angular resolution H<sub>2</sub> near-IR images were obtained using NIRI@Gemini-N: pixel scale=0.117''; FoV of 120''; filters centered at 2.122μm (v=1-0) and 2.248μm (v=2-1). So far two PNe – K 4-47 and NGC 7662 were observed. Continuum images adjacent to the H<sub>2</sub> lines were also taken, at 2.0975μm and 2.2718μm, to isolate the intensity of the emission lines.

The data were taken in September and October of 2014, using 9 (v=1-0) and 21 (v=2-1) dithered positions of 90s and 155s, respectively. The latter increased the SNR, allowing to detect the faint H<sub>2</sub> lines associated to the small-scale LIS.

## NGC 7662



- NGC 7662 is an elliptical PN with a dozen of LIS in the periphery of the nebula
- H<sub>2</sub> emission at 2.122μm is detected in several LIS, but it is not detected in the main nebular components – rim and shell (this work)
- Very faint H<sub>2</sub> v=2-1 implies low v=1-0/v=2-1 ratio, similar to the typical values of shock-excited molecular H emission (this work).