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NICS, the Near Infrared Camera-Spectrometer of the TNG

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Abstract. This paper describes the current operational status of NICS, the infrared multimode instrument of the TNG telescope, and briefly discusses some of the most representative astrophysical results obtained with this instrument.

Key words. Infrared – Astronomical instrumentation

1. NICS at the TNG: current status

NICS (Near Infrared Camera Spectrometer) is the instrument developed by the Arcetri Observatory for the 3.58m Telescopio Nazionale Galileo (TNG). Its general concept and capabilities are summarized in Baffa et al. (2000) as well as in the dedicated web page at the TNG site (`http://www.tng.iac.es`) which is constantly updated.

NICS was delivered to the telescope in August 2000 and saw its first astronomical light a few weeks afterwards (Sep 16). Alike the other focal plane instruments of the TNG, NICS is permanently mounted, and ready for operations, on one of the two Nasmyth foci of the telescope. This flexibility, probably unique among 4m-class instruments, makes the TNG an ideal facility for flexible scheduling and service observing.

Unfortunately, NICS has suffered, and is still suffering by several problems which, besides producing a significant impact on the observational efficiency (NICS failures account to about one third of the total technical down-time of the TNG), also limit its astronomical capabilities.

The first problem is the optical quality of the optical system used for the large-field (0.25"/pixel, field of view of 4.2'x4.2') imaging. The 4 lenses in the camera loose their relative alignments during the cooling and, consequently, produce off-axis images with significant astigmatic and elongated by several pixels (see Fig. 1). This problem mainly limits the imaging capabilities of the instruments which, however, also includes a small field camera (2.2'x2.2') which delivers virtually perfect images with a 0.13"/pix scale adequate to sample the extremely good seeing (<0.4" at 2.2. μm) which often occurs at the TNG site. Therefore, any astronomer interested in high quality imaging data can obtain excellent data using NICS with its small field camera.

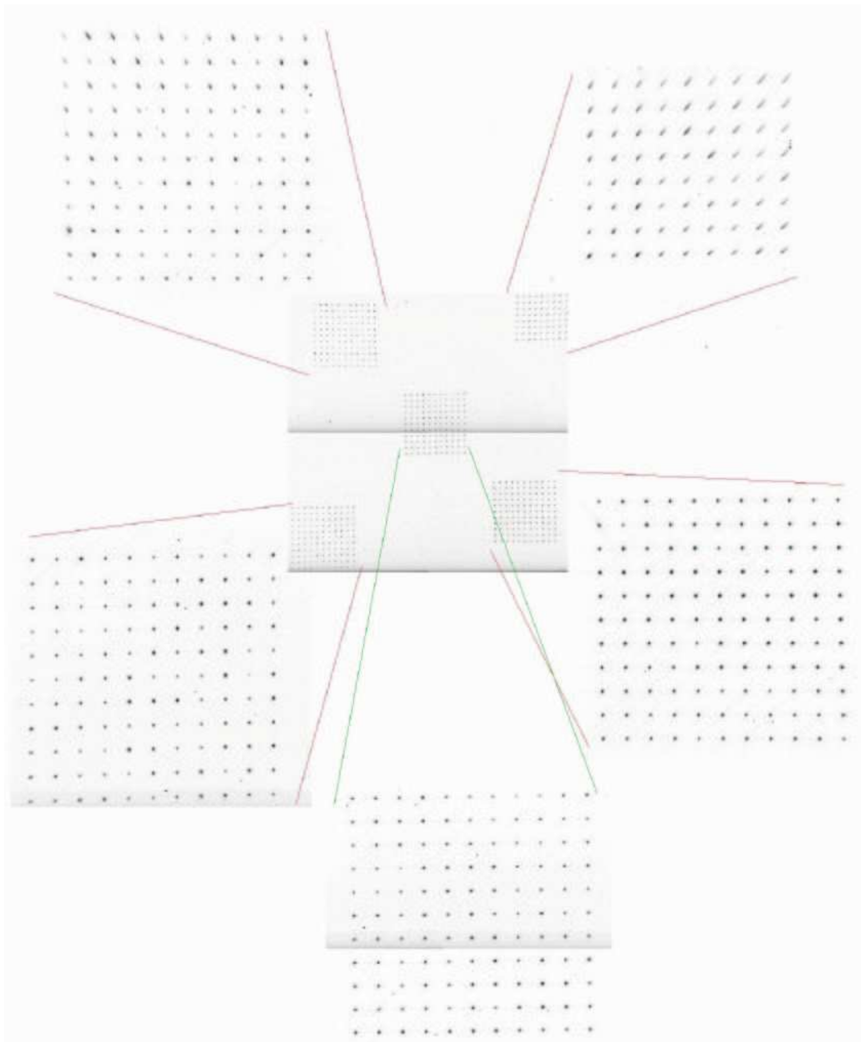

Fig. 1. NICS image of a pin-hole mask showing the optical abberations, particularly evident in the top corners. Similar images together with updated information on the status of the optics can be found at the TNG dedicated web page.

The second problem is related to the controller of the detector and low level electronics which, besides producing significant overheads for observations with short on–chip integration times (e.g. imaging observations in H and K), are sometimes unstable and force the observer to abort the exposure and manually reset the system several times during the night. This problem should be cured relatively soon, once the new low-level electronics and detector control system will be operative.

Always related to the detector and/or low levels electronics is the awkward behaviour of one of the four quadrants of the array which sometimes becomes unstable and produce virtually useless data (see

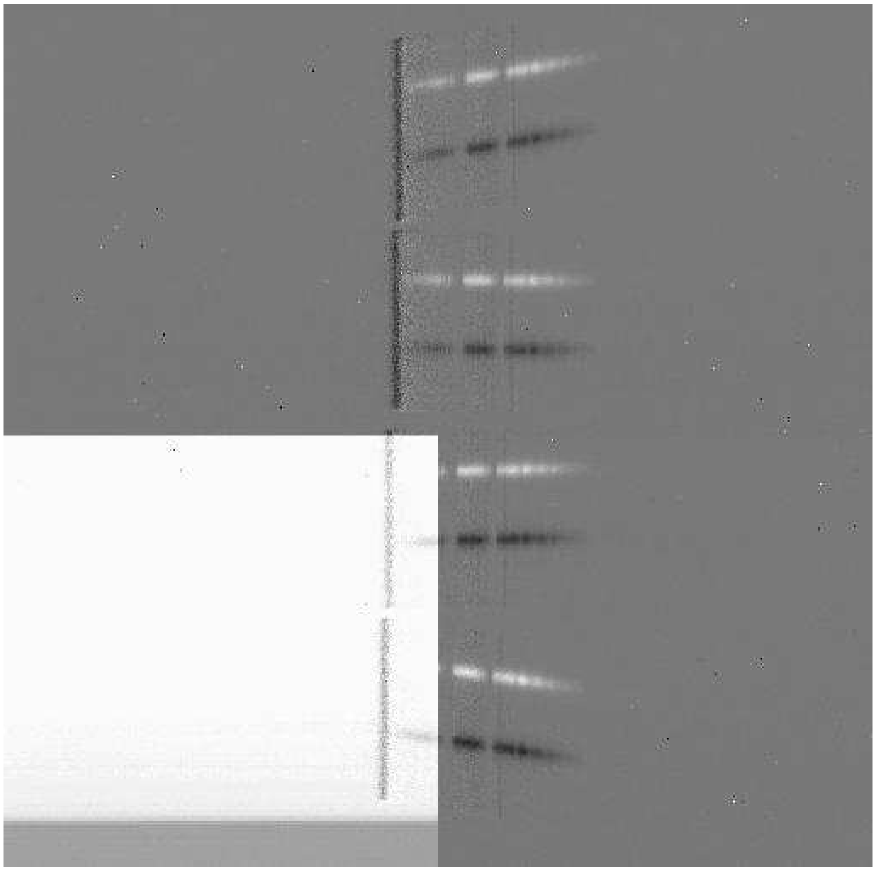

Fig. 2. Example of the effects produced by the instability of the first (bottom left) quadrant which produces a large offset and extra-noise in the images. This unpredictable, and so far not understood effect usually disappears after 10–30 minutes but, in some cases, may persist for several hours. The image displayed here is the difference between two 300 sec exposures with the instrument set in spectropolarimetric mode with the Amici disperser and the 0.5" slit. The four pairs of stellar traces correspond, from bottom to top, to measurements taken through a 90^o, 0^o, 45^o and 135^o ideal polarizer, respectively; wavelength increases from right to left. In this particular case the problem with the first quadrant limited the accuracy of the polarimetric measurements in the K band. The data were collected on Feb 6, 2002 and the targetted object was SN2002ap which was "dithered" along the slit to achieve an accurate sky-subtraction. The reduced spectra are publicly avalable at the TNG web site.

Fig. 2), the origin of this problem is still unclear.

The last problem is related to the mechanics, in particular to the fragility of the gears and to the positioning of the slit and grism wheels which often loose step and leave the selected slit/grism in an incorrect, tilted position thus forcing the observer to reset the wheel and repeat the operation. Considered that similar problems on the camera wheel have been solved during 2001, there are good reasons to expect that these defects will be eliminated.

Table 1. Imaging background[(1)] and sensitivities

Filter	Typical background (mag/sq. arcsec)	Limiting sensitivity (1h, 5σ, 1" seeing)
J	15.6	21.9
H	14.0	21.2
K'	13.4	20.7
K	12.8	20.3

[(1)] Please note that the values for J, H are somewhat conservative. The actual background in these bands is dominated by airglow emission and may vary by more than 1 magnitude during a single night, an instructive example is given in Fig. 3.

Going to the positive notes, it is important to note that the sky backgrounds measured with NICS in K' and K are among the lowest in the world (see Table 1 and Fig. 3), in spite of the fact that the TNG is not an IR optimized telescope. This remarkable result, which makes NICS $\simeq$0.5 mag more sensitive in K than e.g. its direct competitor on the WHT (INGRID), is the consequence of the careful optical design which foresees a very accurate re-imaging of the pupil which is blocked by a Lyot stop, see Oliva & Gennari (1995) for details.

Nevertheless, the strongest and most popular feature of NICS is represented by its spectroscopic modes which are summarized in Fig. 4. Besides the very wide choice of "classical" grisms, which allow medium resolution spectroscopic observations, NICS offers an Amici prism disperser which delivers complete 0.9-2.5 μm low resolution spectra with un-precedent efficiency (see also Oliva (2000)). This feature is unique among astronomical IR instruments and, most important, allows taking complete spectra of faint astronomical with integration times and sensitivities comparable to, or even better than those achievable with the IR instruments now available on 8m class telescopes.

2. Scientific highlights

So far, the most remarkable results were obtained with the very low resolution spectroscopic mode. These demonstrate that, by properly designing and optimizing an instrument, it is possible to fully exploit a medium size telescope like the TNG.

2.1. Spectroscopy of Trans-neptunian objects

Trans neptunian objects (TNOs) are large asteroids orbiting beyond Neptune which are believed to be the most pristine objects of the solar system. For this reason they have recently became very popular and, under a certain point of view, helped to revive the general interest in solar system astronomy.

Being so distant, TNOs are faint objects with, typically, J>18 and, therefore, difficult to study spectroscopically in the IR even with 10m-class instruments. The "status of art" in this field is well represented by the right-hand panel of Fig. 5 which displays a collection of IR spectra taken with the Keck (adapted from Brown et al. (2000)). The comparison with the NICS-Amici spectra of Licandro et al. ((2001)) shown in the left-hand panel of Fig. 5 is striking. Apart for covering a much broader wavelength range (which can only be achieved with a prism disperser), the NICS-TNG spectra have s/n ratios comparable to or even better than the Keck's data. Note in particular the case of 2000 EB173, which appeared flattish and featureless in the Keck spectrum. On the

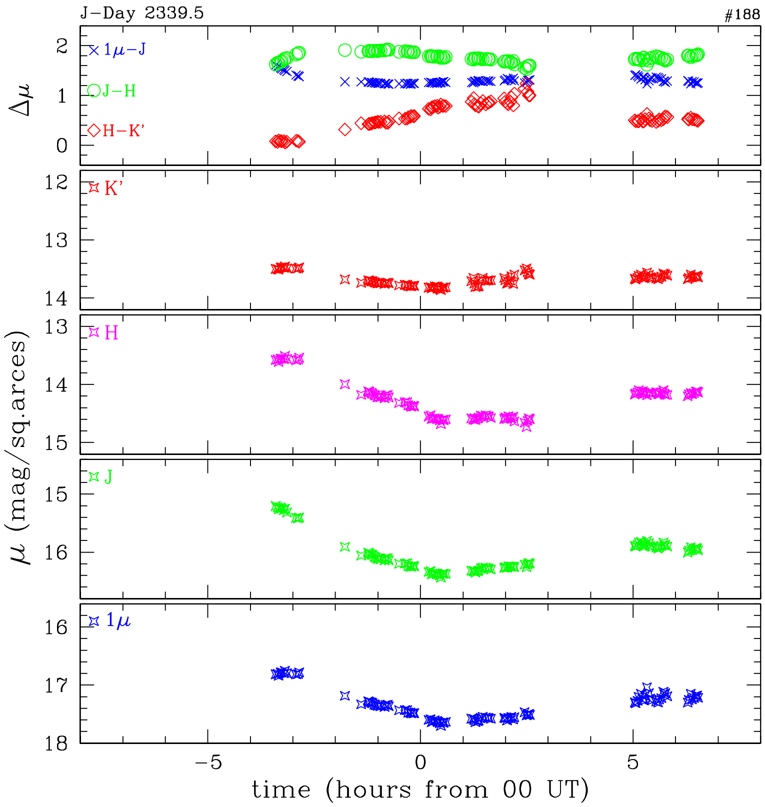

Fig. 3. Variation of the sky brightness during a typical observing night. The values in the various bands are **simultaneous** and are derived from 98 spectra taken with the Amici disperser on Mar 5/6, 2002, a night of half–moon which, noticeably, rised at 02 UT (i.e. the higher background values were measured when the sky was "dark").

contrary, the NICS spectrum demonstrated that this object is very red and with a deep and broad absorption feature in the K–band. This type of spectrum indicates that the surface of this object underwent considerable processing by particle irradiation.

2.2. Spectroscopy of brown dwarfs

The study of brown dwarfs, i.e. stars with very low mass and unable to start nuclear reactions in their cores, has been one of the most productive and popular field of stellar research in the last years. These objects are cold and extremely red and, in several cases, virtually invisible at optical wavelengths. Thanks to the large IR surveys (2mass and Denis), a considerable numbers of these stars have been discovered and classified using a variety of methods.

NICS-TNG gave a very important contribution to this field by making it possible to obtain, with quite short integration times, complete IR spectra with high accuracy on the overall spectral distribution. These data were used to define new indices for the classification of the stars (Testi et al. (2001)) as well as to study and classify candidates of young and low mass objects in star forming regions. Fig. 6 shows the spectrum of the most outstanding of such

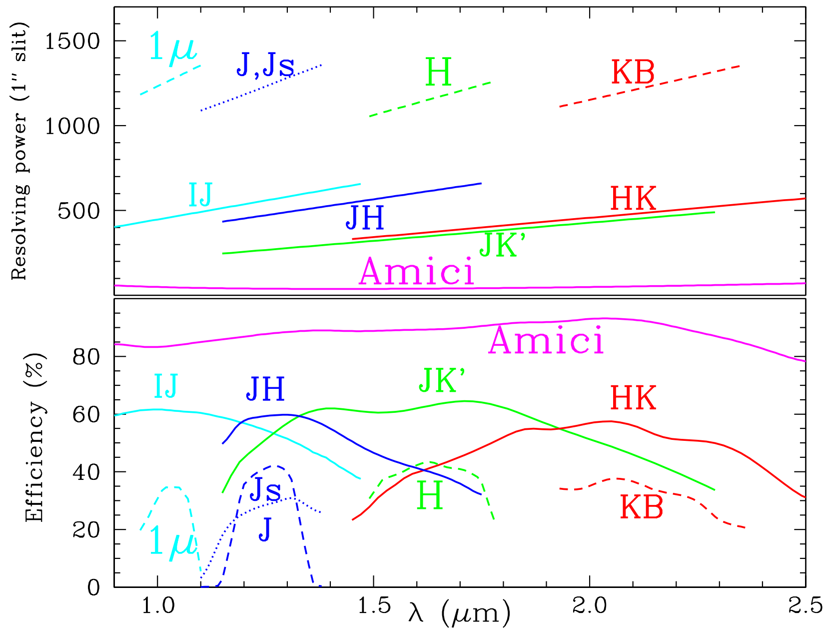

Fig. 4. Overview of the spectroscopic modes of NICS, the transmission curves include both the disperser and order-sorter efficiencies. Note the extremely high throughput of the Amici prism, a unique feature of NICS which allows collecting complete spectra of astronomical sources with unprecedent efficiency.

objects which, given its extremely low mass and young age, is probably the best existing example of genuine, isolated brown dwarf (Testi et al. (2002)).

2.3. Spectroscopy of the most distant objects in the universe

Due to the cosmological redshift many of the most interesting features of the most distant quasars are shifted into the near-IR band, a spectral region where the reduced sensitivity of past instrumentation prevented a detailed study of many of their spectral features. The NICS-Amici combination made it possible studying the broad spectral features typical of quasars with unprecedented sensitivity.

Fig. 7 shows the near-IR spectrum of one of the most distant quasars known, SDSS J104433.04-012502.2, at z=5.80. The red line is a template obtained by the combination of a sample of quasars at z≃1. The most interesting results are the similarity of the spectral energy distributions, indicative of no reddening, and the blue-shifted absorption feature of the CIV. This feature classifies this object as a Broad Absorption Line quasar. The blue-shifted CIV absorption is ascribed to gas outflowing with velocities in excess of 10000 km/s.

This finding, combined with the observation of this quasar in the X-rays with the XMM-Newton satellite suggests that the outflowing gas obscures the quasar in the X-rays with a column of gas larger than $N_{\rm H} > 10^{24}$ cm^{-2}, i.e. a brick-wall made of a huge amount of gas. The implied outflow of mass ejected into the intergalactic medium is larger than 5 solar masses per year (see Maiolino et al. (2001) for details).

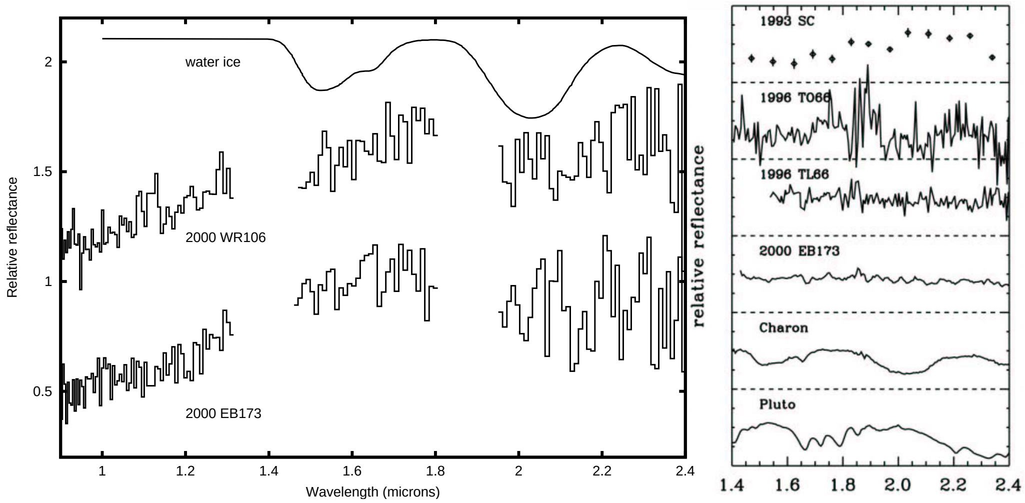

Fig. 5. Left panel: NICS-Amici spectra of two transneptunian objects of magnitudes J≃18.5, the y-scale ("reflectance") is the ratio between the object and the solar spectra. Both objects are very red between 0.9 and 1.8 μ and display a broad absorption deature in the K band. The spectrum of 2000 WR106 has quite deep water ice absorption features at 1.5 and 2.0 microns (see the comparison spectrum of 10 microns water ice particles at 90 K at the top of the figure).
Right hand panel: collection of Trans-neptunian spectra taken with the Keck telescope.

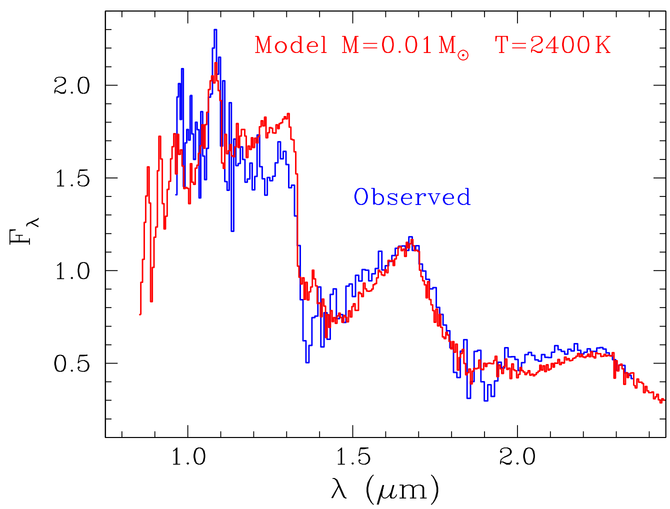

Fig. 6. NICS-Amici spectrum of a candidate brown dwarf in the ρ-Oph cloud compared with a theoretical spectrum (in red). The combination of extremely low mass (0.01 $M_\odot$) and very young age (<1 Myr) makes this object the most extreme case of recently formed, free–floating brown dwarf.

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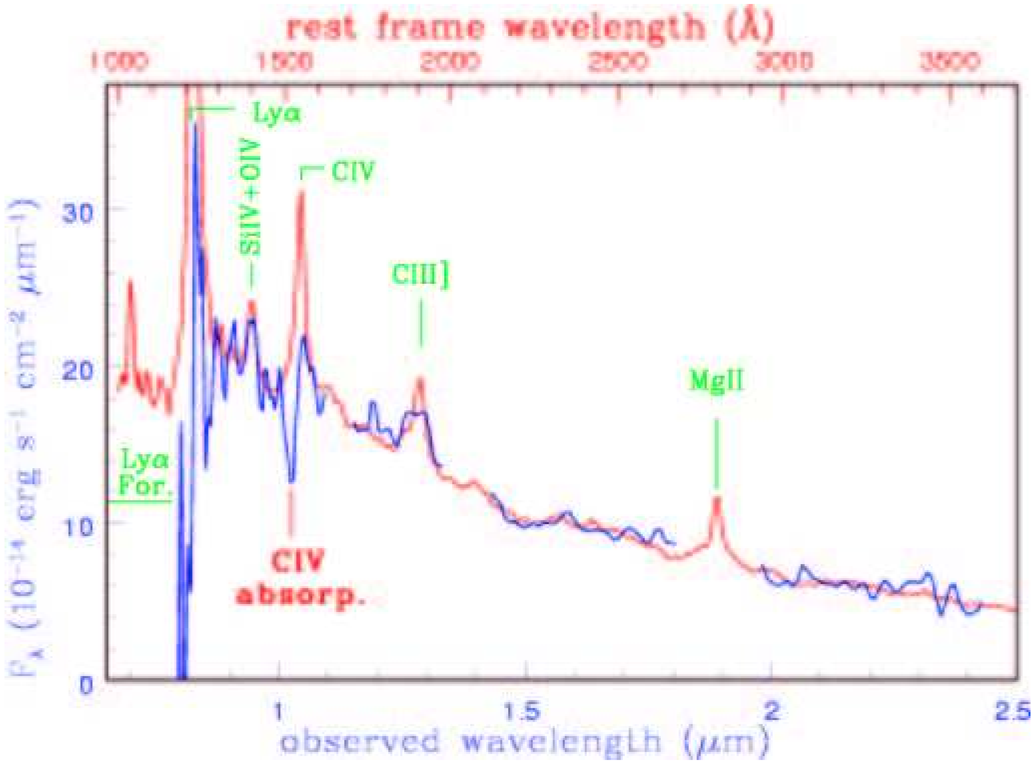

Fig. 7. NICS-Amici spectrum of one of the most distant (z=5.80) Quasar known. The object has a J$\simeq$18 and was observed with NICS-Amici with a total integration time of about 1 hour during the first months of instrument commisioning. The comparison between the observed spectrum (spectrum) and the average UV spectrum of nearby quasars (red) indicates that this objects in not reddened and has a prominent CIV absorption line.

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