ON THE POSSIBILITY FOR MEASURING THE HUBBLE CONSTANT FROM OPTICAL-TO-NIR VARIABILITY TIME DELAY IN AGNS

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ABSTRACT. The Optical-to-Near-infrared variability time delay have already been reported for a small number (~ 7) of AGNs and has been firmly established only for 5 of them. The time delay is probably increasing with the IR wavelengths. The most naturally this time delay can be interpreted by the model where IR emission is attributed to circumnuclear dust heated by the nuclear radiation. In given model a suggestion on narrowness of the near-infrared (NIR) emission region is quite natural, as far as the dust can be not saved on distances from the nucleus closer then some critical value, on which it is reached the sublimation temperature for graphite particles (Barvainis, 1987). For NGC 4151 case it has been shown that the NIR region has a form of thin ring or torus. The radius of this ring correlates with level of the nucleus activity (Oknyanskij et al. 1999). This dependency of radius of the NIR emission region from luminosity reveals itself as under object variability (as in the case of NGC4151), and also when objects with high and low luminosity are considered. We assume that the observed time delays allow us to derive a redshift independent luminosity distances to AGNs and estimate a Hubble constant.

Some problems of using this strategy for the Hubble constant determination are discussed.

Key words: AGNs: Sy1Gs, QSOs; individual: NGC4151, 7469, 3786, 3783, Fairal 9, GQ Comae; Cosmolgy: H_0 determination.

1. Introduction

H_0 - the Hubble constant is fundamental parameter in standard cosmology, measuring the rate at which the Universe is expanding. H_0 connected with many other significant values in cosmology and first of al age of Universe and distance scale. The value of the Hubble constant is still subject of intensive discussions in many publications.

There are 2 different groups of methods for the Hubble constant determinations can be noted:

1. Traditional or *"non direct"* methods, which use some directly measured distance in our Galaxy, for example till Hiades, then extrapolate it some way till other galaxies. In this group of methods are well known:

(i) using period-luminosity dependence for variable stars (a recent successful example of this is HST Key project (Freedman et al., 1994));

(ii) using the principle that a sample of nearby spirals of specific Hubble type represents a "fair" sample of intrinsic population (Sandage 1996; Goodwin, 1997); and some others.

Current estimates of H_0 using methods from this group are in range $\sim 60 - 90 \ kms^{-1} Mpc^{-1}$

2. *"Direct methods"*:

(i) Using Sunyaev-Zel'dovich effect (Syunyaev & Zeldovich 1980);

(ii) Using gravitationally lensed QSOs (Refsdal 1964);

(iii) Time delay between variability of AGN in different UV-Optical-NIR wavelengths (Collier et al., 1999);

(iv) and some others, for example, using motions and line-of-sight accelerations of water maser emission (Miyoshi et al. 1995).

Current estimates of H_0 using methods from this group are in range $\sim 30 - 80 \ km \ s^{-1} \ Mpc^{-1}$. "Direct" methods give systematically smaller values for H_0 than "non direct". Meanwhile these 'direct' methods are more model dependent.

We propose here a new method that utilizes the redshift-independent luminosities of AGNs obtained from observed optical-to-near IR time delay.

In chapter 2 we discuss the theory of the method. In chapter 3 we present our published and new results of the optical-to-NIR time delay determinations for several AGNs NGC4151 (Oknyanskij 1993, Oknyanskij et al. 1999), QSO PQ Comae and NGC7469 and combine them with other published results on the optical-to-NIR time delays in several other AGNs. Then we apply our method for determination of H_0 using the

observation results.

2. Theory

2.1. First step idea of the method
2.1.1. Basic assumptions

(i) NIR emission is attributed to circumnuclear dust heated by the nuclear radiation.

(ii) The dust is spherically symmetric and smoothly distributed.

(iii) NIR emission region has a form of a smooth spherical shell.

(iii) The dust (graphite grains) can be not survived on distances from the nucleus closer then some critical value, on which it is reached the sublimation temperature for graphite particles (Barvainis, 1987, next times here B1)

(iv) The time delay between UV (optical) and NIR variations caused by simple light travel time effects.

This critical distance, "evaporation radius" is given by (following to B1):

$$r_{evap} = 1.3 \ L_{UV,4}^{0.5} \ T_{1500}^{-2.8} pc \qquad (1)$$

where T is the grain evaporation temperature in units of 1500 K and L is ultraviolet luminosity in units $10^{46} ergs \ s^{-1}$ and r_{evap} is the radius in parsecs.

2.1.2. Core of the idea

From the observations we can get the time delay between UV (or optical) and near IR variations in some AGN, which give us r_{evap} and estimation of L_{UV}^*. Then we can use observed flux in UV to get independent from z distance to the object and estimate the H_0. If we have already got the estimation of the $L_{UV,H=50}$ for $H_0 = 50 \ km \ s^{-1} \ Mpc^{-1}$ then we can get estimation

$$H_0 = 50 \ (L_{UV,H=50}/L_{UV}^*)^{0.5} \ km \ s^{-1} \ Mpc^{-1} \qquad (2)$$

2.1.3 Problems

1. From the observations we have found that the NIR emission region should have form of thin ring or torus, but not spherical shell (Oknyanskij, 1999).

2. If the grains are depleted when the UV luminosity peaks, and cannot reform, then a dust-free hole surrounding the central source will be created with radius corresponding to the sublimation distance at the UV peak. This hole can be a problem in explanation of NIR variability.

3. The nature of the grain is unknown. The evaporation temperature can be significantly higher then 1500 K considered in B1 and probably can reach 2000 K

(Sanders et al 1989). The size of the grains also can be bigger then 0.05 μ used for deriving (1) .

2.2. Next step model

Barvanis (1992) has considered the "survival" and "reformation" models. The reason for this is that clouds might serve to either protect the grain from sublimation, allowing them to serve when the UV flux high, or provide a medium in which grains can reform. So the model thus assumes that dust is located into clouds.

For next step we can use small improvements: we will assume that

(i) dust is clumped into clouds with UV optical depth $\tau_{UV} \geq 1$;

(ii) the dust region geometry has disklike form.

Thus model assumes clouds existing at radii well inside the sublimation radius for the peak UV flux given by (1).

In place of (1) we will use here improvement of it with 2 additional parameters given by Sitko et al. (1993):

$$r_{evap} = \ 9 \times 10^8 \ L_{UV,46}^{0.5} \ T^{-2.8} \ [0.05/A_\mu]^{0.5} \ e^{-\tau/2} pc \ \ (3)$$

where A_μ is graphite grain size in μ, τ - is optical depth of the clouds in UV. We will use following to Sitko et al. the same values of parameters: $T = 1700$ K, $A_\mu = 0.15$, $\tau = 1$.

3. Observational data on the Optical-to-NIR time delays in AGNs

By now, the time delay between optical (UV) and NIR variations has been detected in several AGNs. The data on these objects (including our results) are given in the Table 1. The data which are not quite reliable (for example, results for IIIZw2 (Lebofsky and Reike 1980) and NGC 1566 (Baribaud et al. 1992) were not included in the table. The objects where NIR radiation has nonthermal origin (BLACs) and objects with a peculiar orientation, presence of superluminal radio components (for example, 3C273) were not considered in the paper too.

4. Estimation of H_0

Observed data are very good following to the theoretical relation (3) for $H_0 = 50 \ km \ s^{-1} \ Mpc^{-1}$ (see Fig.1).

So using (2) we have got the estimation

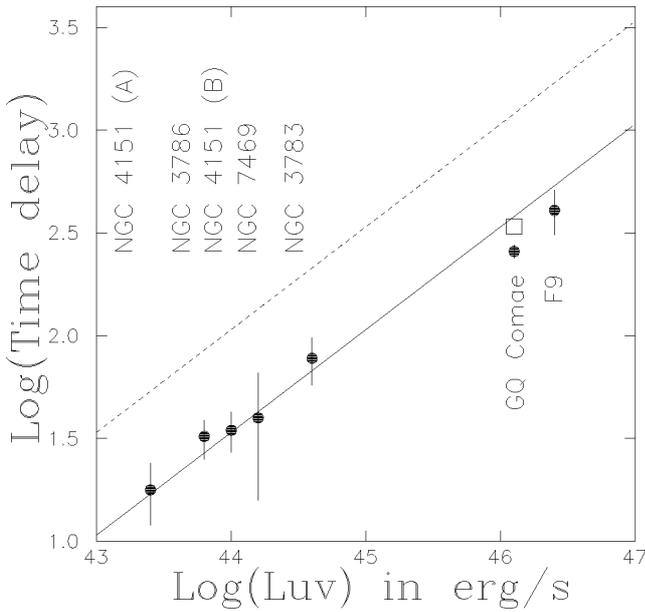$$H_0 \sim \ 50 \ km \ s^{-1} \ Mpc^{-1}. \qquad (4)$$

Figure 1: Dependence luminosity – time delay in logarithmic scale. Line corresponds to the theoretical dependence (3), dashed line - to the (1). Points correspond to the time delay data (for filter K) from Table 1 and UV luminosities estimated for $H_0 = 50$ km s^{-1} Mpc^{-1} from the observed fluxes. A box corresponds to the time delay for GQ Comae corrected for the red shift (z=0.165).

Table 1: AGNs with detected lag between the IR and optical or UV variations

Object	Δt, lag days (1 from 2)	Band (1 - 2)	References
NGC4151	$30 \div 60$	$L(UBV)$	Penston et al., 1994
	18 ± 6	$K(U)$	Oknyanskij 1993
	35 ± 8	$K(UBV)$	Oknyanskij
	97 ± 10	$L(UBV)$	et al.,1999
	8 ± 4	$H(UBV)$	
	~ 6	$J(UBV)$	
NGC3786	32 ± 7	$K(V)$	Nelson,1996)
NGC3783	~ 78	$K(U)$	Glass,1992
F9	410 ± 110	$L(UV)$	Clavel
	385 ± 100	$K(UV)$	et al.,1989
	250 ± 100	$H(UV)$	
	-20 ± 100	$J(UV)$	
NGC7469	–	JHLK	Glass,1998
	0 ± 25	$J(U)$	This paper
	41 ± 25	$K(U)$	
	≥ 65	$L(U)$	
	40 ± 20	$K(J)$	
	73 ± 15	$L(J)$	
	30 ± 20	$H(J)$	
GQ Comae	~ 250	$K(UV)$	Sitko
	~ 700	$L(UV)$	et al.,1993
	260 ± 20	$K(V)$	This paper
	750 ± 20	$L(V)$	

Summary

We have combined published data on the optical-to NIR time delay in AGNs. We have made cross-correlation analysis of published data using own code and have found the new values of time delays for NGC4151, 7469, GQ Comae.

We show that the observed time delays allow us to derive an estimate of the Hubble constant value, however it is model dependent.

The results presented here will be used as the groundwork for more detailed paper which is in preparation.

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