Supplementary Information

RNA content in the nucleolus alters p53 acetylation *via* MYBBP1A

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Supplementary Methods

siRNAs

All siRNAs were purchased from Invitrogen. The siRNA duplexes siMYBBP (5'-UUCACCAGCCGACCUGACUGAAAGA-3'), siMYBBP-2 (5'-GGUCCGAGAUGAAAUAUGCCCUGAA-3'), siTIF-IA (5'-CGACACCGUGGUUUCUCAUGCCAAU-3'), siRPL5 (5'-CCUACUUUAAGAGAUACCAAGUGAA-3'), siRPL11 (5'-GCUAGAUACACUGUCAGAUCCUUUG-3'), siRPL23 (5'-CAGCAGUGGUCAUUCGACAACGAAA-3'), siRPL26 (5'-AAUCCCUUUGUGACUUCCGACCGAA-3'). Stealth^{TM} RNAi Luciferase reporter control duplex was used as a control.

RT-qPCR primers

5'-ATCGTCCACCGCAAATGCTTCTA-3' and 5'-AGCCATGCCAATCTCATCTTGTT-3' for β-Actin, 5'-CCATGAAAAAGGACATAGTG-3' and 5'-CGTGTCAAAGGAGCTTGGT-3' for TIF-IA, 5'-CCTGCAAACATGAGAAGCTG-3' and 5'-AGTGTGCCCCCTGCCTGTAG-3' for MYBBP1A, 5'-TGTTGCAGATTACATGCGCTACT-3' and 5'-CTCTCGTATAGCAGCATGAGCTT-3' for RPL5, 5'-CAGGTTTCAGCATCGCAGACAAG-3' and 5'-TTTGCCAGGAAGGATGATCCCA-3' for RPL11, 5'-AGTGGTCATTCGACAACGAAAG-3' and

5’-CTACTGGTCCTGTAATGGCAGAA-3’ for RPL23, 5’-CGGGAAAAGGCTAATGGCACAAC-3’ and 5’-CGAGATTTGGCTTTCCGTTCGAG-3’ for RPL26, 5’-GGAGACTCTCAGGGTCGAAA-3’ and 5’-TTAGGGCTTCCTCTTGGAGA-3’ for p21, 5’-CTCTCAGATGAAGATGATGAGG-3’ and 5’-CTGTTGCAATGTGATGGAAGG-3’ for HDM2, 5’-GGGCCCAGACTGTGAATCCT-3’ and 5’-ACGTGCTCTCTCTAAACCTATGCA-3’ for PUMA, 5’-AGTCGGGTTGCTTGGGAATGC -3’ and 5’- CCCTTACGGTACTTGTTGACT -3’ for 28S rRNA.

Antibodies

Rabbit anti-human MYBBP1A antibody was raised against a synthetic peptide corresponding to 1265–1328 amino acids of human MYBBP1A. Anti-Myc (MC045) antibody was purchased from Nacalai tesque; anti-FLAG M2 antibody, anti-FLAG M2-agarose and anti-β-Actin antibody were from Sigma; anti-HA (3F10) and anti-BrdU antibodies were purchased from Roche diagnostics; anti-p53 (DO-1 and FL393), anti-HDM2 (SMP-14), anti-UBF (F-9) and anti-p300 (N-15) antibodies were from Santa Cruz Biotechnology; anti-p53-K382Ac, anti-p53-S15P and anti-PUMA antibodies were from Cell Signaling Technology; anti-p53-K305Ac antibody was from BioLegend; anti-p53-K373Ac antibody was from Epitomics; anti-NPM antibody was from Zymed Laboratories.

RNA purification and RT-qPCR

Total RNA was isolated from cultured cells with Sepasol RNA I Super reagent (Nacalai tesque) and subjected to reverse transcription using random hexamers and SuperScript III reverse transcriptase (Invitrogen) according to the manufacturer's protocol. RT–qPCR was performed with the Thermal Cycler Dice Real Time System (TaKaRa). Data analysis was performed by using the comparative Ct method. Results were normalized to β-actin.

Immunofluorescence

Cells grown on chamber slides were rinsed twice with phosphate-buffered saline (PBS) (140 mM NaCl, 2.7 mM KCl, 1.5 mM KH_2PO_4, and 8.1 mM Na_2HPO_4) and fixed in 3.7% formaldehyde in PBS for 10 min. After rinsing twice with PBS, the cells were permeabilized in 0.1% Triton X-100 in PBS, blocked with TBS-T buffer containing 0.5% bovine serum albumin and 10% goat serum for 1 hour at room temperature. Then the cells were incubated with anti-MYBBP1A, anti-UBF, or anti-NPM antibodies for 1 hour, stained with AlexaFluor-conjugated secondary antibodies (Invitrogen) for 1 hour and mounted with Vectashield (Vector Laboratories). Immunofluorescence was performed using Biozero immunofluorescence microscopy (Keyence, Osaka, Japan).

Immunoblotting

Cell extracts were separated by SDS-polyacrylamide gel electrophoresis and transferred to PVDF membranes. After blocking with 3% skim milk in TBS-T buffer [20 mM Tris–HCl (pH 7.5), 150 mM NaCl, and 0.05% Tween20] for 1 hour, the membranes were incubated with the first antibody overnight at 4°C. After washing with TBS-T buffer, the membranes were incubated with horseradish peroxidase-conjugated

secondary antibody for 90 min. Bands were detected with Chemi-Lumi One (Nacalai tesque) or Immobilon Western blotting detection kit (Millipore). Stripping was performed using WB stripping solution (Nacalai tesque) according to the manufacturer's protocol. Total, phosphorylated, and acetylated forms of p53 were evaluated on the same membrane.

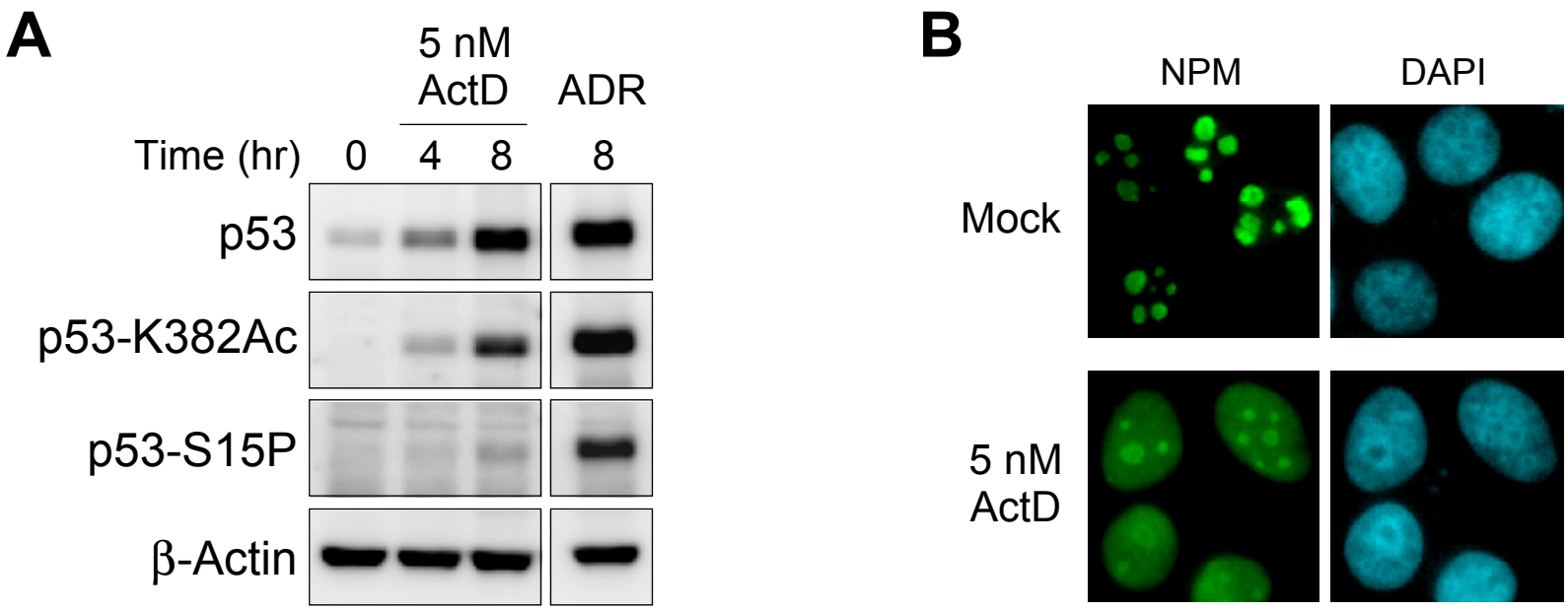
GST pull-down assay

cDNAs encoding full-length human p53 and its deletion mutant derivatives were cloned into pGEX-4T-1 (Amersham Biosciences). GST fusion proteins were expressed in BL-21 cells following induction with IPTG and purified with glutathione Sepharose 4B beads (Amersham). ^{35}S-labeled MYBBP1A was synthesized using in vitro transcription/translation-coupled reticulocyte lysate system (Promega). Binding was performed in TNE buffer [150 mM NaCl, 0.5% Nonidet P-40, 50 mM Tris-HCl (pH 8.0), 5 mM EDTA] for 30 min under rotation at 4°C, and the beads were washed 5 times with TNE buffer. Beads were boiled in SDS sample buffer for 5 min, and the supernatants were loaded to SDS-polyacrylamide gels followed by autoradiography.

Nuclear run-on assay

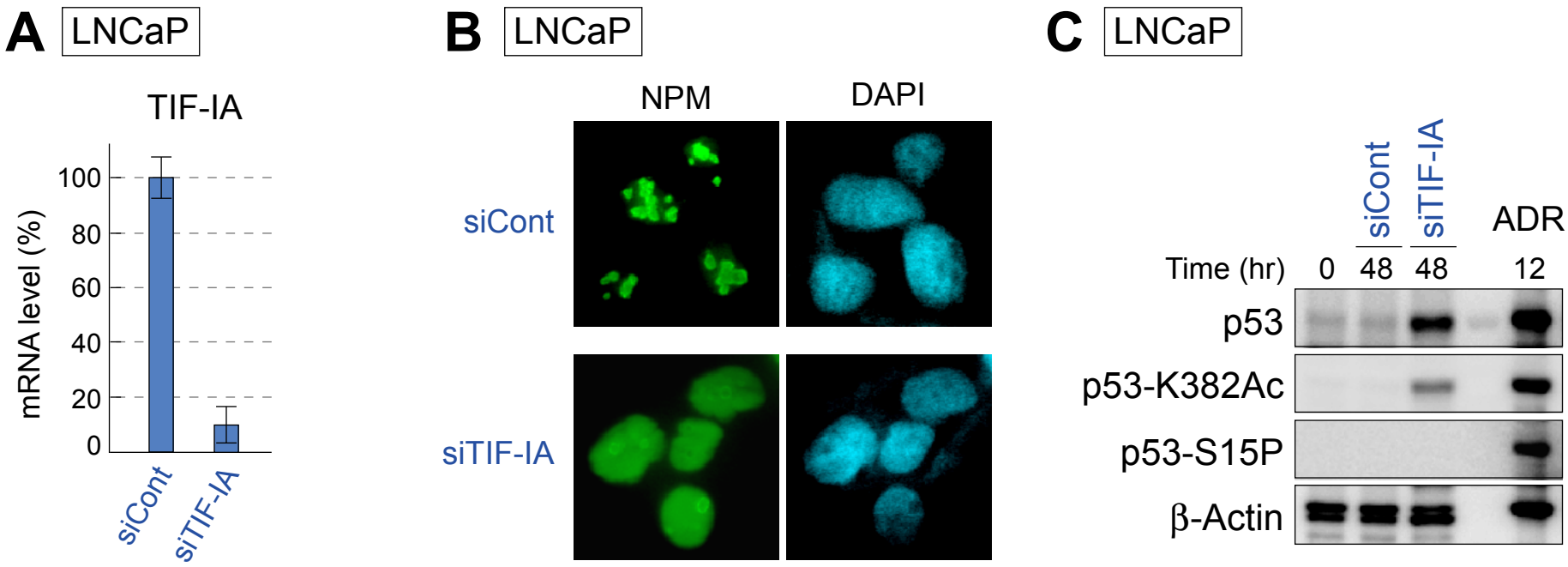
cDNAs probes corresponding to 28S rRNA was amplified by polymerase chain reaction, cloned into pGEM-T easy vector and spotted onto Hybond-N+ membrane (GE Healthcare). Run-on assay was performed on MCF-7 cells transfected with Control, MYBBP1A, RPL5, or RPL11 siRNA with or without TIF-IA siRNA. Approximately 1.0×10^7 cells were collected on ice and suspended in lysis buffer [10 mM Tris-HCl (pH 7.4), 10 mM NaCl, 3 mM $MgCl_2$ and 0.5% NP-40] for 10 min. Nuclei were collected

by centrifugation at 1,000 × g for 5 min, and washed twice with the same buffer. The nuclei were suspended in 50 mM Tris-HCl (pH 8.3), 40% glycerol, 5 mM $MgCl_2$ and 0.1 mM EDTA. The nuclei were mixed with an equal volume of reaction buffer [50 mM Tris-HCl (pH 8.0), 5 mM $MgCl_2$**,** 300 mM KCl, 0.5 mM of ATP, CTP, GTP and 100 μCi of α-^{32}P UTP] and incubated for 30 min at 30°C. Nuclear RNA was extracted and resuspended in RapidHyb hybridization buffer (GE Healthcare). Hybridization was carried out at 42°C for 24 hour. Membrane was washed twice at room temperature in 2× SSC containing 0.1% SDS and twice at 65°C in 0.2× SSC containing 0.1% SDS, and then exposed on BioMAX MS film.

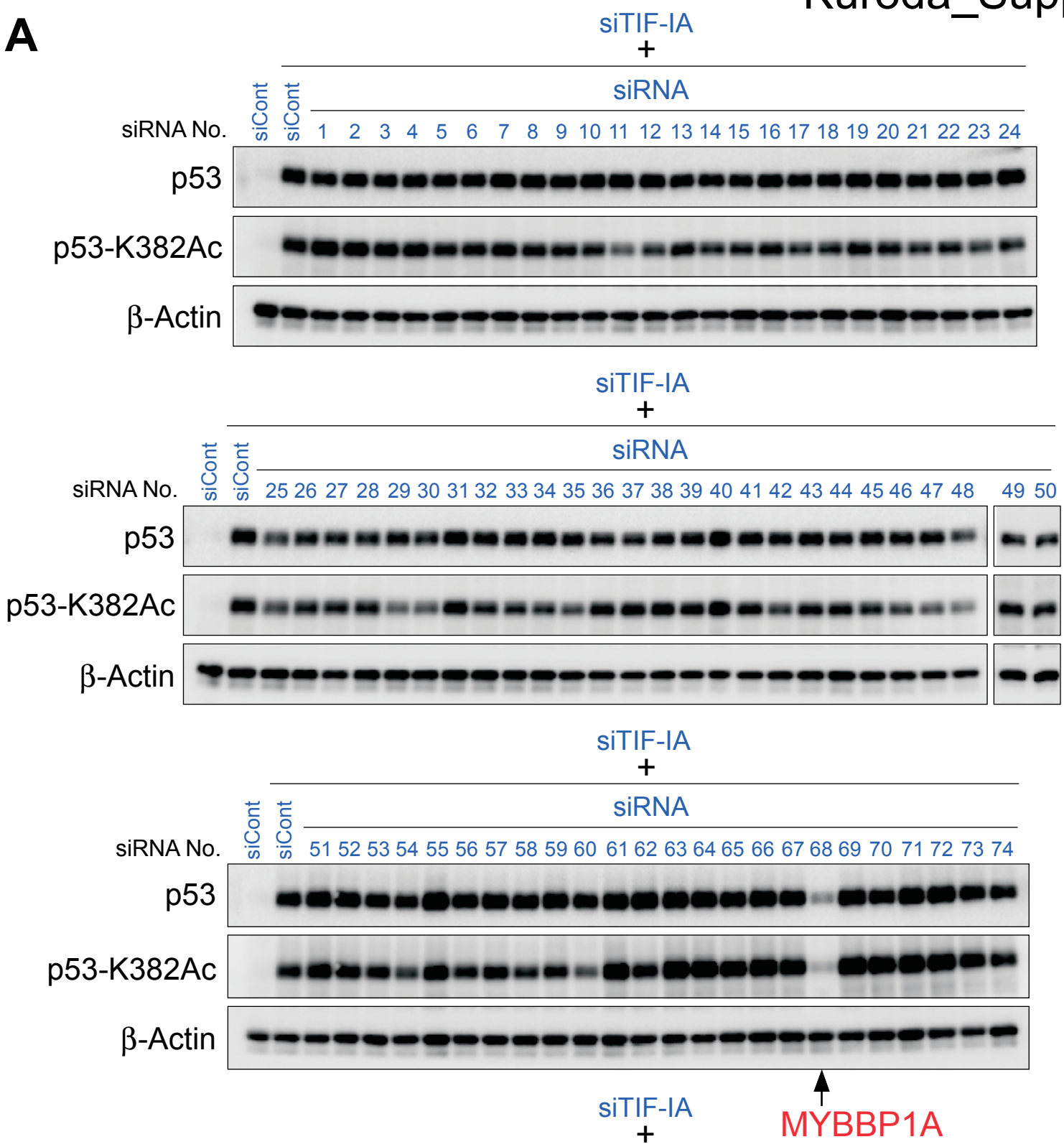


Supplementary Figure S1 Nucleolar disruption induced by low dose of ActD treatment causes acetylation of p53 protein without phosphorylation. (**A**) Low dose of ActD treatment induced accumulation and acetylation but not phosphorylation of p53 protein. MCF-7 cells were treated with a low concentration (5 nM) of ActD for indicated times, and the cell lysates were analyzed by immunoblot using the indicated antibodies. Lysates prepared from ADR (0.5 μg/ml)-treated cells were used as a positive control. (**B**) Nucleolar structure was disrupted by low dose of ActD treatment. MCF-7 cells were treated with 5 nM ActD for 8 hours, and the localization of NPM was visualized by immunofluorescence.

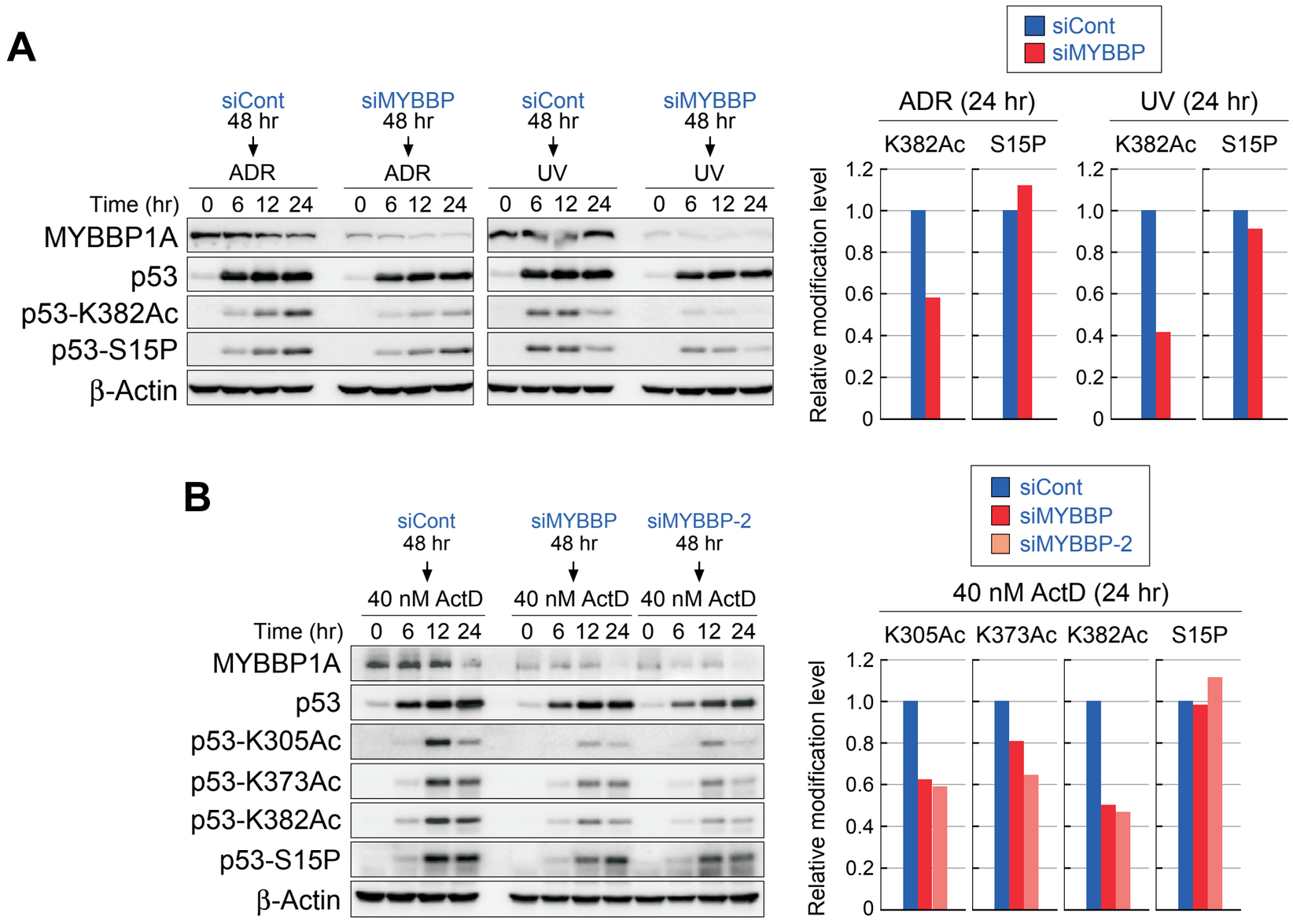
Supplementary Figure S2 Nucleolar disruption induced by TIF-IA knockdown causes acetylation of p53 protein without phosphorylation. (**A**) Knockdown efficiency of TIF-IA siRNA. MCF-7 cells were treated with siCont or siTIF-IA for 48 hours, and the mRNA levels were determined by RT-qPCR. The mRNA levels were normalized to β-Actin. Values are given as the mean ± SD for triplicate experiments. (**B**) Nucleolar structure was disrupted in TIF-IA siRNA treated cells. MCF-7 cells were treated with siCont or siTIF-IA for 48 hours, and the localization of NPM was visualized by immunofluorescence using an anti-NPM antibody. (**C**) Knockdown of TIF-IA induced accumulation and acetylation but not phosphorylation of p53 protein. MCF-7 cells were treated with siCont or siTIF-IA for the indicated times, and the cell lysates were analyzed by immunoblot using the indicated antibodies. Lysates prepared from ADR (0.5 μg/ml)-treated cells were used as a positive control. (**D**) Knockdown of TIF-IA induced acetylation of p53 protein. MCF-7 cells were treated with siCont or siTIF-IA for 48 hours. An equal amount of p53 was loaded, and acetylation levels were analyzed by immunoblot using an anti-acetylated p53 antibody.



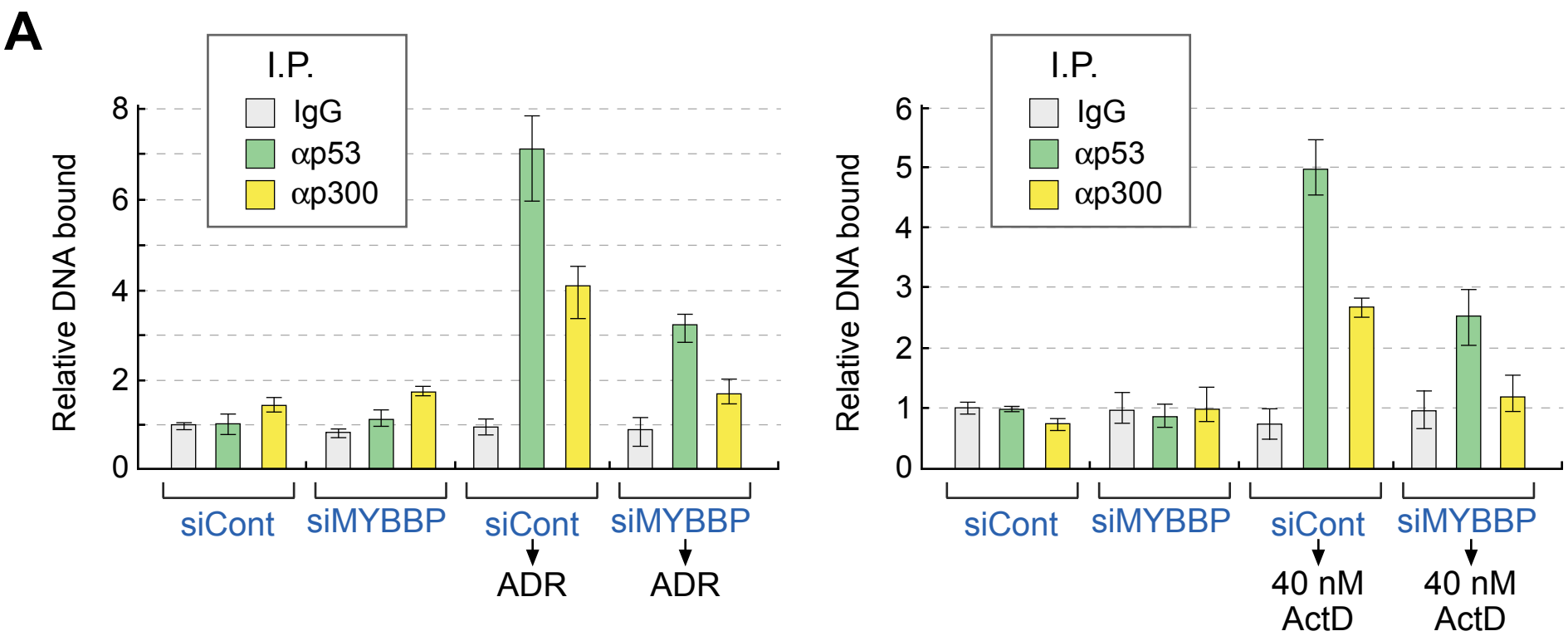
Supplementary Figure S3 MYBBP1A is necessary for the acetylation and transactivation of p53 and nucleolar stress-induced apoptosis in LNCaP cells. (**A**) Knockdown efficiency of TIF-IA siRNA in LNCaP cells. LNCaP cells were treated with siCont or siTIF-IA for 48 hours, and the mRNA levels were determined by RT-qPCR. (**B**) Immunofluorescence analysis showed translocation of NPM in LNCaP cells treated with siTIF-IA for 48 hours. (**C**) Knockdown of TIF-IA induced accumulation and acetylation but not phosphorylation of p53 protein in LNCaP cells. Lysates prepared from ADR (0.5 μg/ml)-treated cells were used as a positive control. (**D**) Knockdown of MYBBP1A decreased the acetylation levels at multiple lysine residues in p53 protein in LNCaP cells treated with siTIF-IA. (**E**) Knockdown of MYBBP1A reduced the elevation of p53 target gene products induced by siTIF-IA in LNCaP cells. (**F**) Knockdown of MYBBP1A decreased the level of apoptosis induced by siTIF-IA in LNCaP cells. Left: the phase-contrast images of LNCaP cells treated with the indicated siRNAs for 72 hours. Right: the percentage of dead cells was measured by trypan blue exclusion assay. Values are given as the mean ± SD for triplicate experiments.



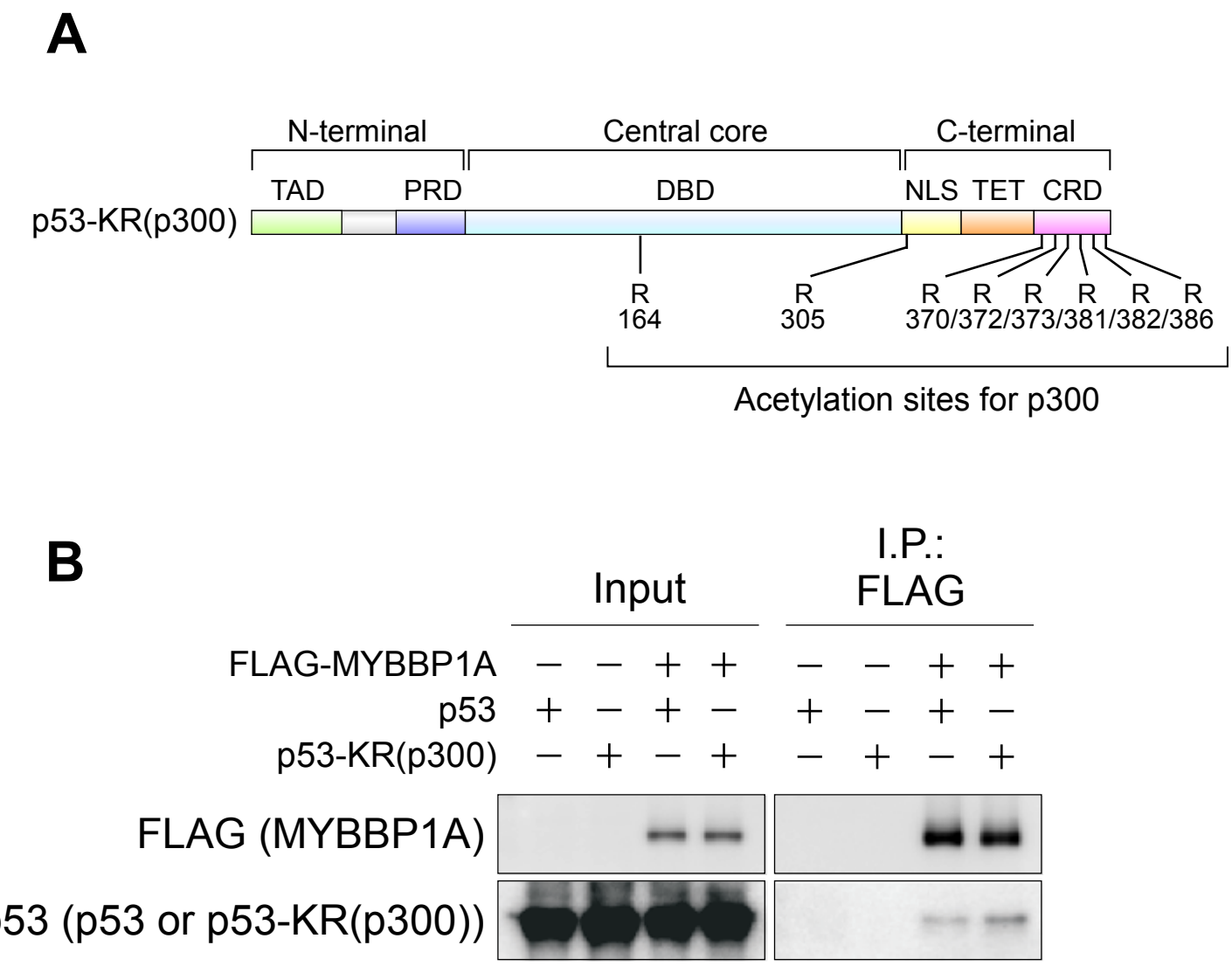
Supplementary Figure S4 Identification of nucleolar proteins that are involved in p53 acetylation and accumulation. (**A**) MCF-7 cells were treated with each siRNA and siTIF-IA for 48 hours, and the cell lysates were analyzed by immunoblot using anti-p53 and anti-acetylated p53 antibodies. #68 is siRNA against MYBBP1A. #101 and #102 are siRNAs against RPL5 and RPL11, respectively. (**B**) Knockdown efficiency of MYBBP1A, RPL5, RPL11, RPL23, or RPL26 siRNA, respectively. MCF-7 cells were treated with the indicated siRNAs for 48 hours, and the mRNA levels were determined by RT-qPCR. The mRNA levels were normalized to β-Actin. Values are given as the mean ± SD for triplicate experiments.



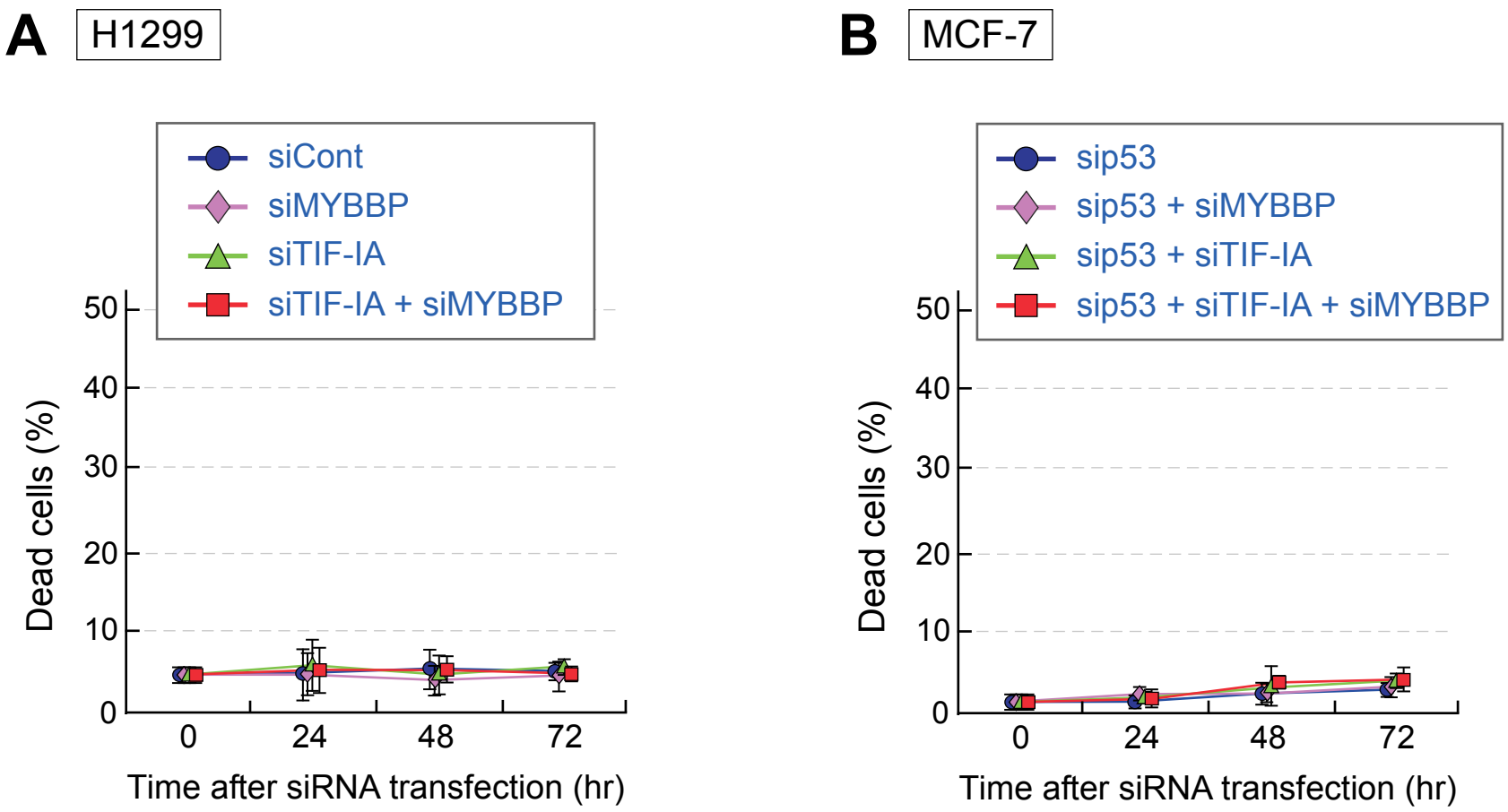
Supplementary Figure S5 MYBBP1A is necessary for the acetylation and accumulation of p53 induced by nucleolar stress. (**A**) Knockdown of MYBBP1A decreased p53 acetylation levels induced by ADR or UV treatment. Left: MCF-7 cells were treated with the siCont or siMYBBP for 48 hours. The cells were then treated with ADR (0.5 μg/ml) or UV (25 J/m^2) for the indicated times. The cell lysates were analyzed by immunoblot using the indicated antibodies. Right: relative quantification of acetylation and phosphorylation levels of p53 protein. Twenty-four hours after ADR or UV treatment, the intensity of the acetylated or phosphorylated p53 proteins were quantified by phosphoimager analysis and plotted. The intensities of the modified p53 proteins were corrected using p53 protein level. The intensity of the siCont-treated cells was normalized to 1.0. (**B**) Knockdown of MYBBP1A decreased the acetylation levels at multiple lysine residues in p53 protein by 40 nM ActD treatment. Left: MCF-7 cells were treated with siCont or two independent siMYBBP (siMYBBP and siMYBBP-2) for 48 hours, followed by 40 nM ActD treatment at the indicated times. The cell lysates were analyzed by immunoblot using the indicated antibodies. Right: relative quantification of acetylation and phosphorylation levels of p53 protein. Tenty-four hours after 40 nM ActD treatment, the intensity of the modified p53 proteins were quantified as (A).



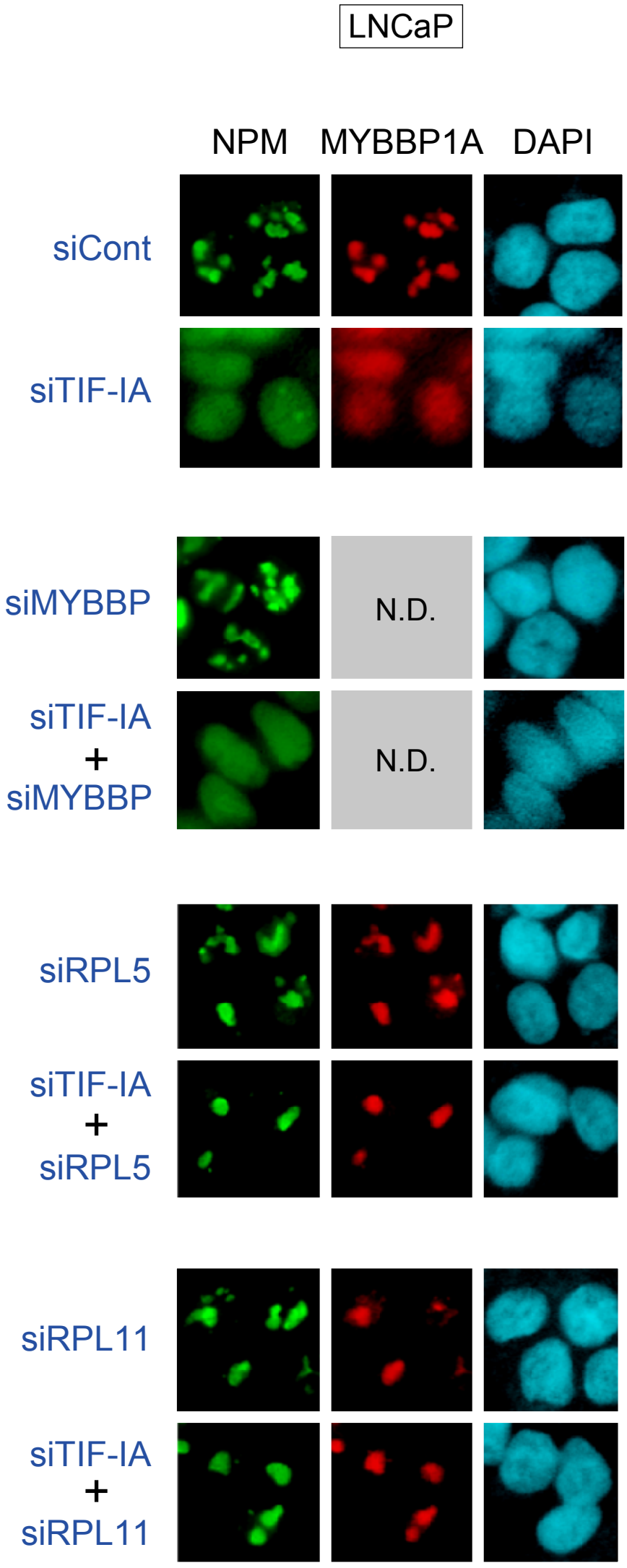
Supplementary Figure S6 MYBBP1A is necessary for the acetylation and transactivation of p53 and apoptosis induced by ADR or ActD. (**A**) Knockdown of MYBBP1A reduced the recruitment of p53 and p300 to the *p21* promoter in the ADR- or ActD-treated cells. MCF-7 cells were treated with siCont or siMYBBP for 48 hours prior to treatment with ADR (0.5 μg/ml) for 12 hours or ActD (40 nM) for 24 hours. A ChIP assay was performed using normal rabbit IgG, anti-p53, or anti-p300 antibodies. The p53-binding region of the *p21* promoter was amplified and analyzed by qPCR. Values are given as the means ± SD for triplicate experiments. (**B**) Knockdown of MYBBP1A reduced the elevation of p21 protein levels induced by ADR or ActD treatment. MCF-7 cells were treated with siCont or siMYBBP for 48 hours prior to treatment with ADR (0.5 μg/ml) or ActD (40 nM) for the indicated times. The cell lysates were prepared and analyzed by immunoblot using the indicated antibodies. (**C**) Knockdown of MYBBP1A decreased the level of apoptosis induced by ADR or ActD treatment. Left photos: the phase-contrast images of MCF-7 cells treated with the indicated siRNAs for 48 hours, and then treated with ADR (0.5 μg/ml) or ActD (40 nM) for 36 hours. Representative images are shown. Right graphs: percentage of dead cells. The percentage of dead cells was measured by trypan blue exclusion assay. Values are given as the mean ± SD for triplicate experiments.

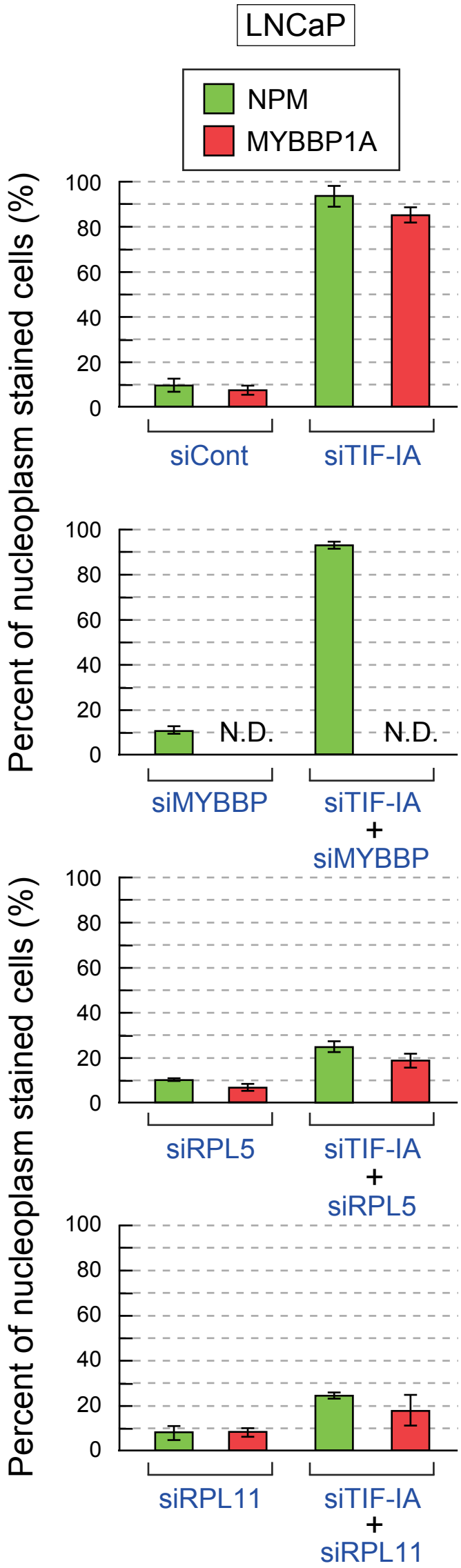


Supplementary Figure S7 MYBBP1A interacts with p53-KR(p300). (**A**) Schematic representation of the p53-KR(300) mutant. We generated p53 lysine-to-arginine mutant at eight acetylation sites for p300. (**B**) MYBBP1A interacted with p53-KR(p300). H1299 cells were transfected with combination of the expression vectors for FLAG-MYBBP1A, p53, and/or p53-KR(300), as indicated. Twenty-four hours after transfection, the cells were treated with ADR (0.5 μg/ml) for 12 hours. MYBBP1A was immunoprecipitated from the cell lysates using an anti-FLAG antibody and p53 association was detected by immunoblot using an anti-p53 antibody.

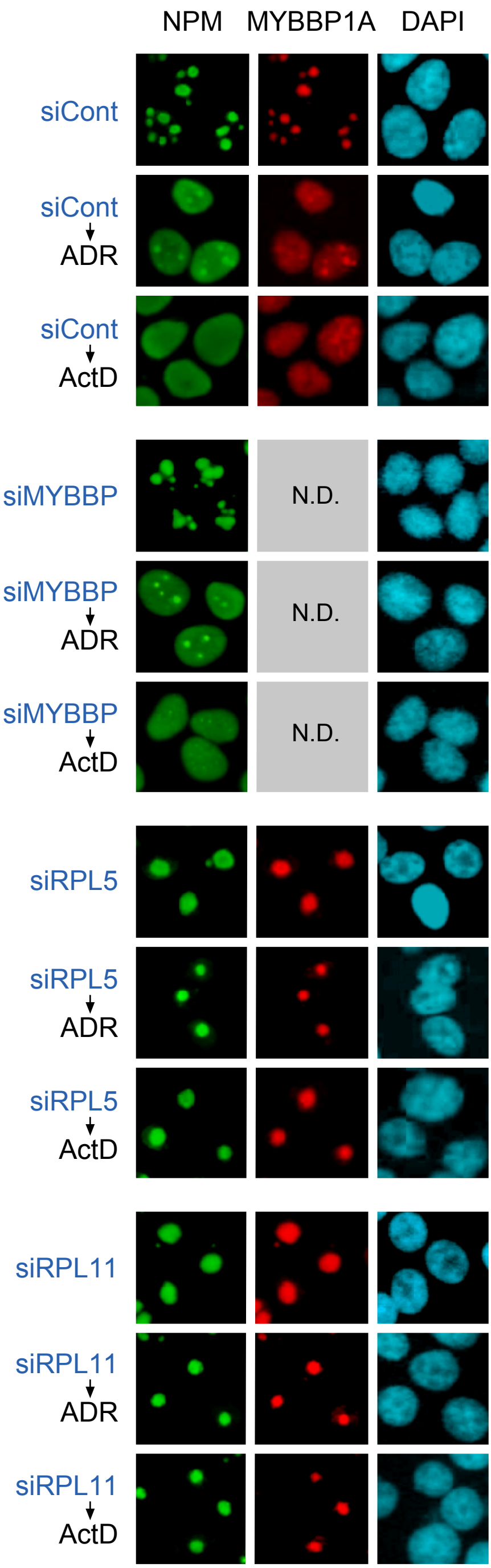


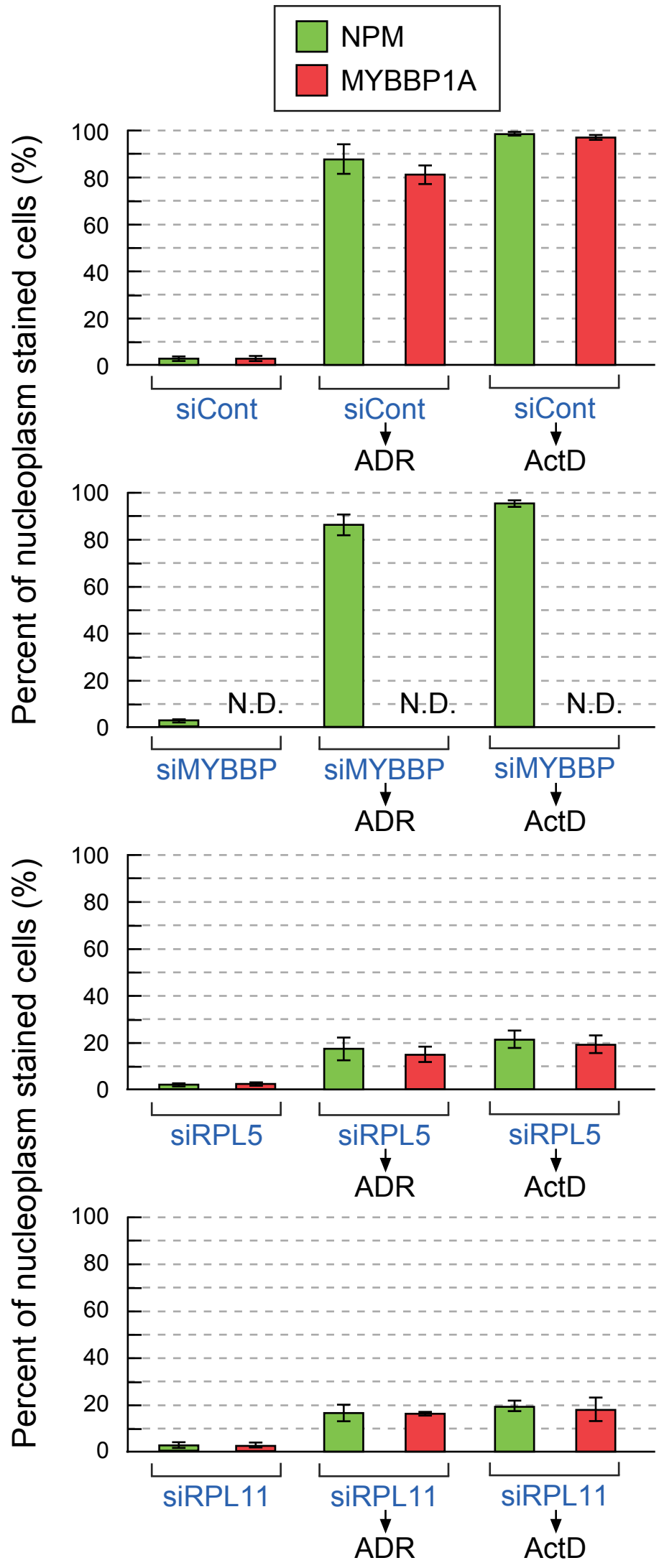
Supplementary Figure S8 Apoptosis induced by TIF-IA knockdown is dependent on the presence of p53. (**A**) The percentage of dead H1299 cells. H1299 cells were transfected with the indicated siRNAs for the indicated times, and the percentage of dead cells was measured by trypan blue exclusion assay. Values are given as the mean ± SD for triplicate experiments. (**B**) The percentage of dead p53-depleted MCF-7 cells. MCF-7 cells were treated with sip53 for 48 hours prior to treatment with the indicated siRNAs for the indicated times. The percentage of dead cells was measured as (A).



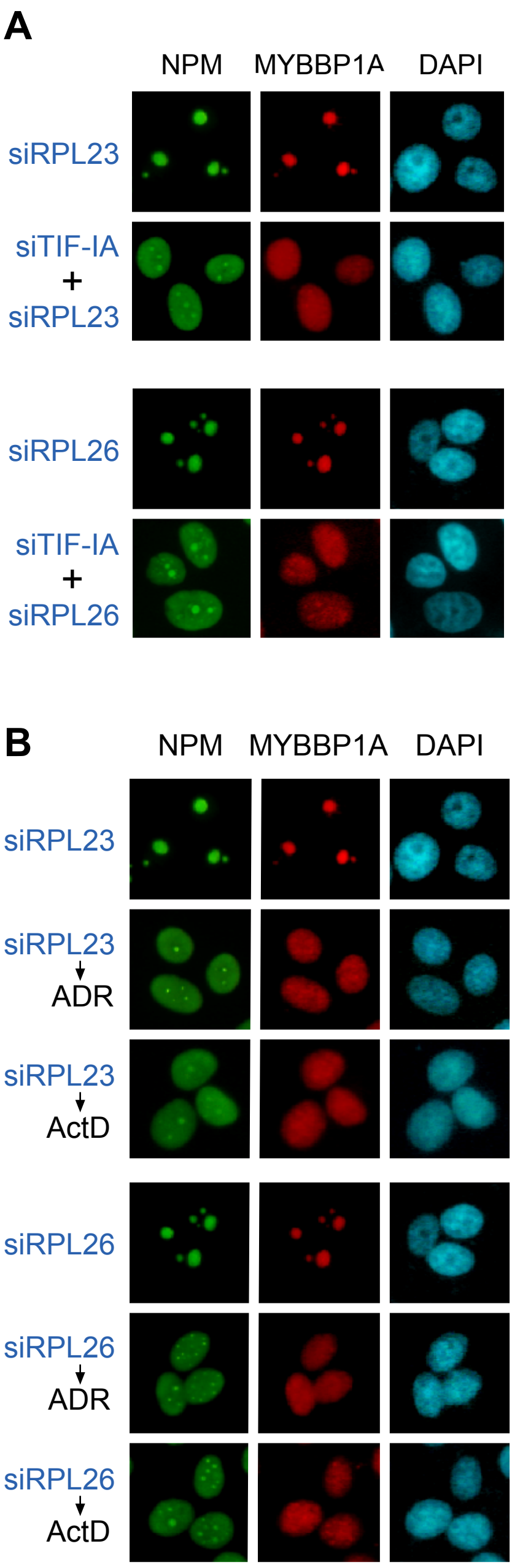


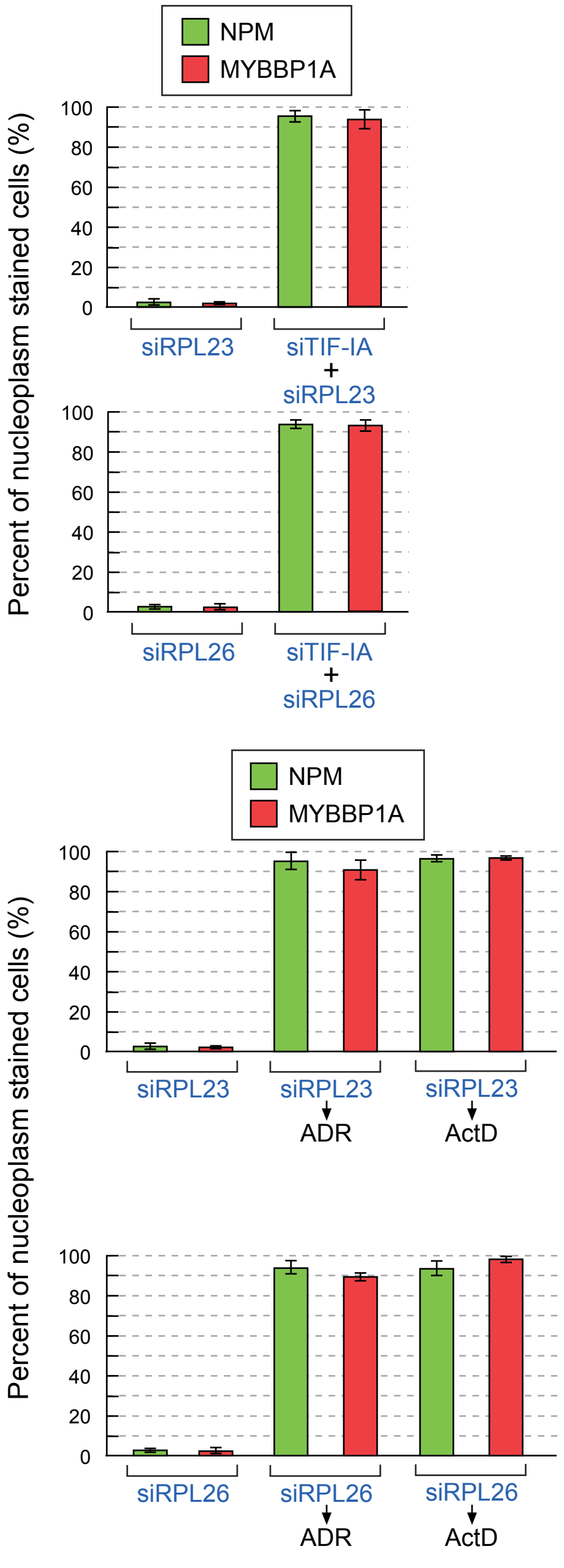
Supplementary Figure S9 RPL5 and RPL11 are required for the MYBBP1A translocation from the nucleolus in LNCaP cells. MYBBP1A translocation from the nucleolus to the nucleoplasm induced by TIF-IA knockdown was hampered by the knockdown of RPL5 or RPL11. Left: LNCaP cells were treated with the indicated siRNAs for 48 hours, and the cells were stained with the indicated antibodies or DAPI. N.D. means “not determined”. Right: The percentage of the cells that showed translocation of NPM or MYBBP1A from the nucleolus after treatment with the indicated siRNAs. Values are given as the mean ± SD for triplicate experiments.



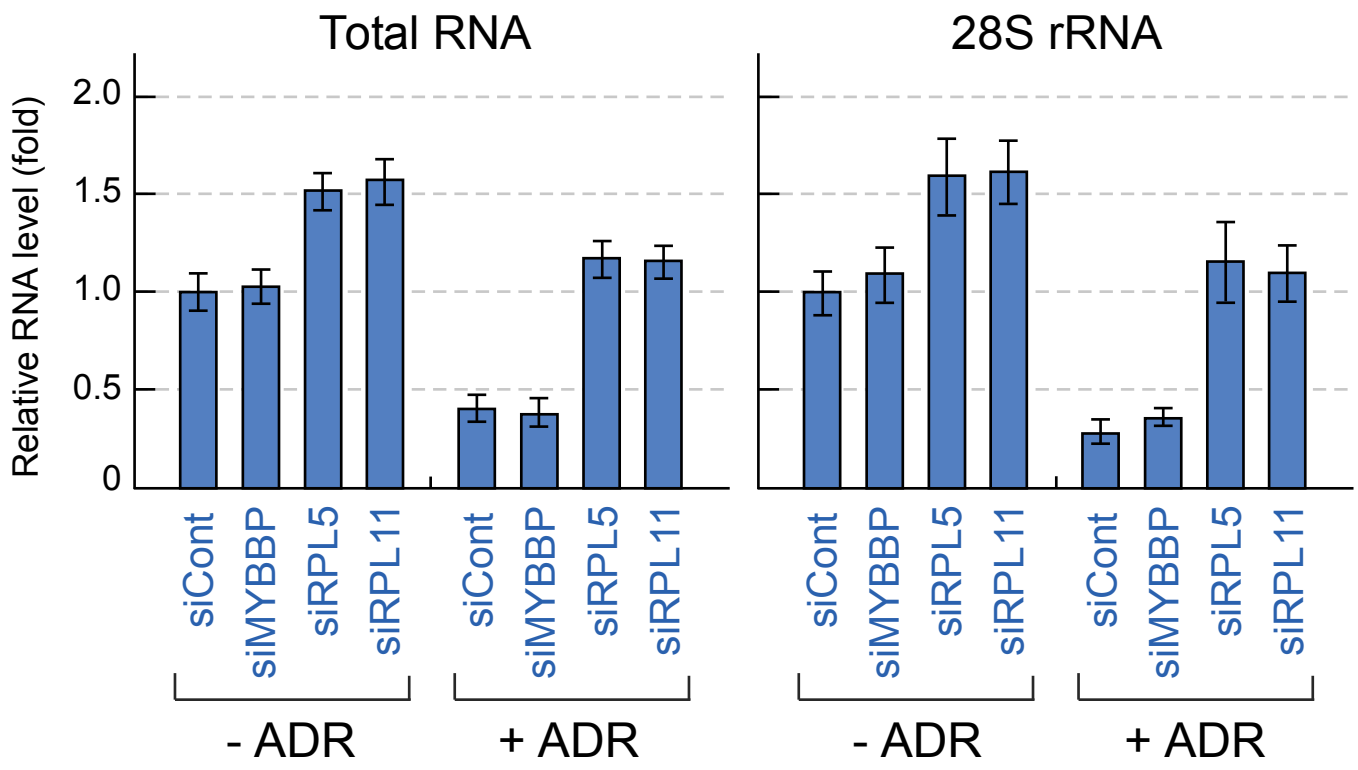


Supplementary Figure S10 RPL5 and RPL11 are required for the MYBBP1A translocation from the nucleolus in ADR or ActD treated cells. MYBBP1A translocation from the nucleolus to the nucleoplasm induced by ADR or ActD treatment was hindered by the knockdown of RPL5 or RPL11. Left: MCF-7 cells were treated with the indicated siRNAs for 48 hours, followed by the treatment with ADR (0.5 μg/ml) or ActD (40 nM) for 24 hours. The cells were stained with the indicated antibodies or DAPI. N.D. means “not determined”. Right: The percentage of the cells that showed translocation of NPM or MYBBP1A from the nucleolus after the treatment. Values are given as the mean ± SD for triplicate experiments.





Supplementary Figure S11 RPL23 and RPL26 are not required for the MYBBP1A translocation induced by nucleolar disruption. (**A**) Left: MCF-7 cells were treated with the indicated siRNAs for 48 hours, and the cells were stained with the indicated antibodies or DAPI. Right: The percentage of cells that showed translocation of NPM or MYBBP1A from the nucleolus after treatment with the indicated siRNAs. Values are given as the means ± SD for triplicate experiments. N.D. means "not determined". (**B**) Left: MCF-7 cells were treated with the indicated siRNAs for 48 hours, followed by the treatment with ADR (0.5 μg/ml) or ActD (40 nM) for 24 hours. The cells were stained with the indicated antibodies or DAPI. Right: The percentage of cells that showed translocation of NPM or MYBBP1A from the nucleolus after treatment with the indicated siRNAs. Values are given as the mean ± SD for triplicate experiments. N.D. means "not determined".



Supplementary Figure S12 Knockdown of RPL5 or RPL11 retains RNA content in the nucleolus in ADR treated cells. Total RNA was isolated from the isolated nucleoli of MCF-7 cells transfected with the indicated siRNAs for 48 hours and then treated with ADR (0.5 μg/ml) for 24 hours. The total RNA (Left) and 28S rRNA (Right) levels were quantified by spectrophotometry and RT-qPCR, respectively.

Kuroda_Supplementary Table S1

Supplementary Table S1 List of the nucleolar proteins that were knocked-down in the screen

siRNA No.	Name	Sequence	
1	DNTTIP2	GGAAGAACUGCUGGCUGAUUCUGAA	sense
		UUCAGAAUCAGCCAGCAGUUCUUCC	antisense
2	WDSOF1	AUAAGAGUCCUCUCGUUGGUCCCGG	sense
		CCGGGACCAACGAGAGGACUCUUAU	antisense
3	RPS19BP1	UACUCUGAGGUGGUCUCGACACUCU	sense
		AGAGUGUCGAGACCACCUCAGAGUA	antisense
4	RFC2	UCCUCACCAGGCUGAUGAAUGUUAU	sense
		AUAACAUUCAUCAGCCUGGUGAGGA	antisense
5	DIMT1L	CCCGUUCCAUGGACAUAGAUGACUU	sense
		AAGUCAUCUAUGUCCAUGGAACGGG	antisense
6	EXOSC3	UCACUAUGCCAAUCACAUGGUCUCC	sense
		GGAGACCAUGUGAUUGGCAUAGUGA	antisense
7	CDKN2AIP	AAUAGUGGCAAUUCUACCUCUGAGC	sense
		GCUCAGAGGUAGAAUUGCCACUAUU	antisense
8	RFC1	CCCAUCCCUGGAUUCGGAAUACAAU	sense
		AUUGUAUUCCGAAUCCAGGGAUGGG	antisense
9	TSPYL1	GGUGUCUCUUUCUACUCCAAUUAUA	sense
		UAUAAUUGGAGUAGAAAGAGACACC	antisense
10	PRKDC	UAAACACGGUCGUCACCAGUGUCUG	sense
		CAGACACUGGUGACGACCGUGUUUA	antisense
11	DDX56	UAACCGGGUUAUGUAAUAUCAGCUC	sense
		GAGCUGAUAUUACAUAACCCGGUUA	antisense
12	EXOSC4	CCCACGCUCCCAGAUUGAUAUCUAU	sense
		AUAGAUAUCAAUCUGGGAGCGUGGG	antisense
13	DIS3	CAGCAGACAACCAGCUGCAAGUUAU	sense
		AUAACUUGCAGCUGGUUGUCUGCUG	antisense
14	C6orf153	UUGGCUCUGCAAUUCCAACAGCUCC	sense
		GGAGCUGUUGGAAUUGCAGAGCCAA	antisense
15	SSB	AUACUCAUCAGUCACUUCAGGUAGG	sense
		CCUACCUGAAGUGACUGAUGAGUAU	antisense
16	CCDC59	GAGCCUUUAUUUGAAGAUCAGUGUA	sense
		UACACUGAUCUUCAAAUAAAGGCUC	antisense

17	REXO4	CAUAGGUCCAGAGGCGGCCAAGAUA	sense
		UAUCUUGGCCGCCUCUGGACCUAUG	antisense
18	PINX1	CCACAGGUAAAGAUGUGGAAAGUUA	sense
		UAACUUUCCACAUCUUUACCUGUGG	antisense
19	KIF2C	GGGCAGACAUUUGCCAACUCCAAUU	sense
		AAUUGGAGUUGGCAAAUGUCUGCCC	antisense
20	PTBP1	AGAAGGACCGCAAGAUGGCACUGAU	sense
		AUCAGUGCCAUCUUGCGGUCCUUCU	antisense
21	PARP1	AGAAGCUGCAGCUUGUAGUAGGAGU	sense
		ACUCCUACUACAAGCUGCAGCUUCU	antisense
22	XRCC1	UUAUCUCGCAGCUCGGAGCGGAAGG	sense
		CCUUCCGCUCCGAGCUGCGAGAUAA	antisense
23	EMG1	UUGAGUAGCUCAUAUGUCUUCCCUA	sense
		UAGGGAAGACAUAUGAGCUACUCAA	antisense
24	ABT1	UUUACGGGCCCUCAGUUCCUGCUCA	sense
		UGAGCAGGAACUGAGGGCCCGUAAA	antisense
25	SMC4	CAAGGACAUUCAGAGUUGUACAGUA	sense
		UACUGUACAACUCUGAAUGUCCUUG	antisense
26	SKIV2L2	GGGAAUUAACAUGCCAGCUAGAACU	sense
		AGUUCUAGCUGGCAUGUUAAUUCCC	antisense
27	PNO1	AAGAUUAGGUUGCAAAUGGCAGUUC	sense
		GAACUGCCAUUUGCAACCUAAUCUU	antisense
28	C14orf21	UGUUCGUGGACAAAGCUAGGGCCUG	sense
		CAGGCCCUAGCUUUGUCCACGAACA	antisense
29	NCL	UUCUGUUGCACUGUAGGAGAGGUUG	sense
		CAACCUCUCCUACAGUGCAACAGAA	antisense
30	PRPF19	UUUCAGGGUAGCCAGAGCUUCUCGG	sense
		CCGAGAAGCUCUGGCUACCCUGAAA	antisense
31	XRCC5	UUGGAAACAAGUCUUCAAGGGUGUC	sense
		GACACCCUUGAAGACUUGUUUCCAA	antisense
32	CDC2L5	GCCUCCCAUGCUGCCUGAAGAUAAA	sense
		UUUAUCUUCAGGCAGCAUGGGAGGC	antisense
33	FCF1	CAAGGAUCCAAGAUUUGAACGAUUA	sense
		UAAUCGUUCAAAUCUUGGAUCCUUG	antisense
34	BYSL	CAUUGUGGCAGCCUUCUCCAGGGUG	sense
		CACCCUGGAGAAGGCUGCCACAAUG	antisense

35	BLM	AACAGAAGGAAACUUCUGGCGAAGC	sense
		GCUUCGCCAGAAGUUUCCUUCUGUU	antisense
36	UTP18	GCUCAUAAAUGGCAUUGCUGGAUAU	sense
		AUAUCCAGCAAUGCCAUUUAUGAGC	antisense
37	ADAR	CAGAGAGGUGUUGAUUGCCUUUCCU	sense
		AGGAAAGGCAAUCAACACCUCUCUG	antisense
38	POP1	UGAAGUUCCAGGAUGAGGCUCUUGU	sense
		ACAAGAGCCUCAUCCUGGAACUUCA	antisense
39	RCL1	CAACAAGUUCAUACCUGAUAUCUAU	sense
		AUAGAUAUCAGGUAUGAACUUGUUG	antisense
40	CD3EAP	UAGAGGCUCAGUGUUAAUCUGUUCC	sense
		GGAACAGAUUAACACUGAGCCUCUA	antisense
41	NCAPD3	CGGAGUCAAGGAAAUGACAUCUUAU	sense
		AUAAGAUGUCAUUUCCUUGACUCCG	antisense
42	WDR3	GGGACAUAGCUUAUCUGCAAGAGAU	sense
		AUCUCUUGCAGAUAAGCUAUGUCCC	antisense
43	RFC5	CCAACAUCCUGGACUGGAUGUUGAA	sense
		UUCAACAUCCAGUCCAGGAUGUUGG	antisense
44	RBM39	CAAGAGCCCUGUGAGAGAACCUAUU	sense
		AAUAGGUUCUCUCACAGGGCUCUUG	antisense
45	AURKB	CCCGACAUCUUAACGCGGCACUUCA	sense
		UGAAGUGCCGCGUUAAGAUGUCGGG	antisense
46	PAI-RBP1	UAAACACACUGAUUUAGGAGUGCGU	sense
		ACGCACUCCUAAAUCAGUGUGUUUA	antisense
47	SMC2	AUUAGAAGCCCGAACCUGAGACAGG	sense
		CCUGUCUCAGGUUCGGGCUUCUAAU	antisense
48	MKI67IP	UUUAAAUCGCUCCUCCAUCCGUAGC	sense
		GCUACGGAUGGAGGAGCGAUUUAAA	antisense
49	ISG20L2	UUAUAUAGCUCCAUGGUGGCCUGGG	sense
		CCCAGGCCACCAUGGAGCUAUAUAA	antisense
50	TBL3	UCAGCUGAUGGCACCAUCAAGCUCU	sense
		AGAGCUUGAUGGUGCCAUCAGCUGA	antisense
51	ILF3	CCACUGAUGCUAUUGGGCAUCUAGA	sense
		UCUAGAUGCCCAAUAGCAUCAGUGG	antisense
52	ESF1	UUUGCAACCCGUCUAAACCGCUGGU	sense
		ACCAGCGGUUUAGACGGGUUGCAAA	antisense

53	TOP1	GGGAAGGACUCCAUCAGAUACUAUA	sense
		UAUAGUAUCUGAUGGAGUCCUUCCC	antisense
54	BMS1	CAGUGCAGAGGAAGAAGACUCAGAA	sense
		UUCUGAGUCUUCUUCCUCUGCACUG	antisense
55	SRP14	UUCAAGGUGAUAUAGACGCUGCCCG	sense
		CGGGCAGCGUCUAUAUCACCUUGAA	antisense
56	FBXL11	GAACCCGAAGAAGAAAGGAUUCGUU	sense
		AACGAAUCCUUUCUUCUUCGGGUUC	antisense
57	GPATCH4	AUAACGGGUGGUCUCCUUAGAAAGG	sense
		CCUUUCUAAGGAGACCACCCGUUAU	antisense
58	HIST1H1C	UUUCGUUUGCACCAGAGUGCCCUUG	sense
		CAAGGGCACUCUGGUGCAAACGAAA	antisense
59	SENP3	CCCUCAGCACUGAUGAGGUAGUAGA	sense
		UCUACUACCUCAUCAGUGCUGAGGG	antisense
60	H2AFZ	UGGGCCGUAUUCAUCGACACCUAAA	sense
		UUUAGGUGUCGAUGAAUACGGCCCA	antisense
61	RSL1D1	UUAUCCAGCUGCUUCCGUGCUGUCG	sense
		CGACAGCACGGAAGCAGCUGGAUAA	antisense
62	ZCCHC9	UUAUAUGUGGUACUAACUCGGGCCC	sense
		GGGCCCGAGUUAGUACCACAUAUAA	antisense
63	VRK1	AAGAGGUCCAUUGUCACUGGGUUCC	sense
		GGAACCCAGUGACAAUGGACCUCUU	antisense
64	CDK7	CCAAACUGUCCAGUGGAAACCUUAA	sense
		UUAAGGUUUCCACUGGACAGUUUGG	antisense
65	WDR36	CCGGACUGACAUUUCUCCAUAGAGA	sense
		UCUCUAUGGAGAAAUGUCAGUCCGG	antisense
66	CDK9	CAGAUGCUGCUUAACGGCCUCUACU	sense
		AGUAGAGGCCGUUAAGCAGCAUCUG	antisense
67	NOC4L	UGUCGUCGUAGUCCAGGUACUCCCG	sense
		CGGGAGUACCUGGACUACGACGACA	antisense
68	MYBBP1A	UUCACCAGCCGACCUGACUGAAAGA	sense
		UCUUUCAGUCAGGUCGGCUGGUGAA	antisense
69	WDR18	UGGACCUGGCUGAGCACCAUAUGUU	sense
		AACAUAUGGUGCUCAGCCAGGUCCA	antisense
70	WDR75	UUGCAAGCCAGUUACCAAAGCAGCC	sense
		GGCUGCUUUGGUAACUGGCUUGCAA	antisense

71	TOP2A	GCUCAGCUCUUUGGCUCGAUUGUUA	sense
		UAACAAUCGAGCCAAAGAGCUGAGC	antisense
72	CIRH1A	CAGGAAUCCGCUGUGUGGCUUACAA	sense
		UUGUAAGCCACACAGCGGAUUCCUG	antisense
73	NOL14	AUCAAUGACUGUGAGGUCUGGUGGG	sense
		CCCACCAGACCUCACAGUCAUUGAU	antisense
74	C1orf107	UUAGGGUGUUGAGUAGCUGGCUCUG	sense
		CAGAGCCAGCUACUCAACACCCUAA	antisense
75	TWISTNB	CCUUAACAGGAAACGCACCGGCAUU	sense
		AAUGCCGGUGCGUUUCCUGUUAAGG	antisense
76	KRR1	UUCUGAUUCAUCUUGGUUCUCCGGC	sense
		GCCGGAGAACCAAGAUGAAUCAGAA	antisense
77	TEX10	UUCAGUAGAUGACAGGCCUUCAUCC	sense
		GGAUGAAGGCCUGUCAUCUACUGAA	antisense
78	TTF1	GGAUGACUAAUGGUCGGCGUAUCUA	sense
		UAGAUACGCCGACCAUUAGUCAUCC	antisense
79	BOP1	UGUAGAUGCGCCUGCCAUCCAGGUC	sense
		GACCUGGAUGGCAGGCGCAUCUACA	antisense
80	POLR1A	CCAUCUCUCCCUGGUUGCUGAUUAU	sense
		AUAAUCAGCAACCAGGGAGAGAUGG	antisense
81	MINA	CGGCUCCCUGUAAGCAGAUGAAGUU	sense
		AACUUCAUCUGCUUACAGGGAGCCG	antisense
82	NPM3	UUACACUCGUCUUUGGCUCCCUCGG	sense
		CCGAGGGAGCCAAAGACGAGUGUAA	antisense
83	TINP1	CAGAGAGGGACAAUCUCGAGCUAAA	sense
		UUUAGCUCGAGAUUGUCCCUCUCUG	antisense
84	FRG1	UAGACUUCACGUAGGAGUACUCGGC	sense
		GCCGAGUACUCCUACGUGAAGUCUA	antisense
85	PELP1	CCUCAAUUCCUGGAGCAUCGGUAGA	sense
		UCUACCGAUGCUCCAGGAAUUGAGG	antisense
86	ZFP106	GGUGGCAUGGUUGCUCUCUGAUAUU	sense
		AAUAUCAGAGAGCAACCAUGCCACC	antisense
87	PWP1	CAGUGCAAUUUAGAGGUGCAUGUUU	sense
		AAACAUGCACCUCUAAAUUGCACUG	antisense
88	PPAN	AACUGUGGAACAUCACUUUGCCCUC	sense
		GAGGGCAAAGUGAUGUUCCACAGUU	antisense

89	LAS1L	CCUACAUCCUCAGAUGGACCGUUGA	sense
		UCAACGGUCCAUCUGAGGAUGUAGG	antisense
90	SRFBP1	GAGCAAUUGCCAGACUAGCAGUACA	sense
		UGUACUGCUAGUCUGGCAAUUGCUC	antisense
91	NAT10	GCGGUGGCAUUUGGGUACUCCAAUA	sense
		UAUUGGAGUACCCAAAUGCCACCGC	antisense
92	DUSP11	UACAGUGGACACCAAUAAGUUUAUC	sense
		GAUAAACUUAUUGGUGUCCACUGUA	antisense
93	EBNA1BP2	CCCUACGAAGCGACCCACUGAUUAU	sense
		AUAAUCAGUGGGUCGCUUCGUAGGG	antisense
94	RPL26	AAUCCCUUUGUGACUUCCGACCGAA	sense
		UUCGGUCGGAAGUCACAAAGGGAUU	antisense
95	GNL3	ACAACUUGCAUGCUCCUUGUAAGCC	sense
		GGCUUACAAGGAGCAUGCAAGUUGU	antisense
96	PES1	CCAUUGUCAACAAGUUCCGUGAAUA	sense
		UAUUCACGGAACUUGUUGACAAUGG	antisense
97	NOM1	GGAUCAGCAGGAGAGAGAAAUCAUU	sense
		AAUGAUUUCUCUCUCCUGCUGAUCC	antisense
98	NOL1	GGUCAAAGACUGGACUAGUGGUGUA	sense
		UACACCACUAGUCCAGUCUUUGACC	antisense
99	C14orf169	CAUGGAACUGUUGCUUGGUUCUUAU	sense
		AUAAGAACCAAGCAACAGUUCCAUG	antisense
100	RRP1B	CAGGAGGUUUCAGUCAGGAAGAACU	sense
		AGUUCUUCCUGACUGAAACCUCCUG	antisense
101	RPL5	UUCACUUGGUAUCUCUUAAAGUAGG	sense
		CCUACUUUAAGAGAUACCAAGUGAA	antisense
102	RPL11	GCUAGAUACACUGUCAGAUCCUUUG	sense
		CAAAGGAUCUGACAGUGUAUCUAGC	antisense
103	RPL23	CAGCAGUGGUCAUUCGACAACGAAA	sense
		UUUCGUUGUCGAAUGACCACUGCUG	antisense
104	NPM1	UAGUAGCGGUGGUCAGACAUGGAAA	sense
		UUUCCAUGUCUGACCACCGCUACUA	antisense
105	NCL	UUCUGUUGCACUGUAGGAGAGGUUG	sense
		CAACCUCUCCUACAGUGCAACAGAA	antisense
106	NS	ACAACUUGCAUGCUCCUUGUAAGCC	sense
		GGCUUACAAGGAGCAUGCAAGUUGU	antisense

107	ARF	GAAAGAACCAGAGAGGCUCUGAGAA UUCUCAGAGCCUCUCUGGUUCUUUC	sense antisense